Lenovo Network

Application Guide

for Lenovo Cloud Network Operating System 10.9

Lenovo™

Note: Before using this information and the product it supports, read the general information in the *Safety information and Environmental Notices* and *User Guide* documents on the Lenovo *Documentation* CD, and the *Warranty Information* document that comes with the product.

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Contents

Preface

This *Application Guide* describes how to configure and use the Lenovo Cloud Network Operating System 10.9 software on the following Lenovo RackSwitches:

- Lenovo RackSwitch G8272. For documentation on installing the switch physically, see the *Lenovo RackSwitch G8272 Installation Guide*.
- Lenovo RackSwitch G8296. For documentation on installing the switch physically, see the *Lenovo RackSwitch G8296 Installation Guide*.
- Lenovo RackSwitch G8332. For documentation on installing the switch physically, see the *Lenovo RackSwitch G8332 Installation Guide*.
- Lenovo ThinkSystem NE1032 RackSwitch. For documentation on installing the switch physically, see the *Lenovo ThinkSystem NE1032 RackSwitch Installation Guide*.
- Lenovo ThinkSystem NE1032T RackSwitch. For documentation on installing the switch physically, see the *Lenovo ThinkSystem NE1032T RackSwitch Installation Guide*.
- Lenovo ThinkSystem NE1072T RackSwitch. For documentation on installing the switch physically, see the *Lenovo ThinkSystem NE1072T RackSwitch Installation Guide*.
- Lenovo ThinkSystem NE10032 RackSwitch. For documentation on installing the switch physically, see the *Lenovo ThinkSystem NE10032 RackSwitch Installation Guide*.
- Lenovo ThinkSystem NE2572 RackSwitch. For documentation on installing the switch physically, see the *Lenovo ThinkSystem NE2572 RackSwitch Installation Guide*.

Who Should Use This Guide

This guide is intended for network installers and system administrators engaged in configuring and maintaining a network. The administrator should be familiar with Ethernet concepts, IP addressing, Spanning Tree Protocol, and SNMP configuration parameters.

Application Guide Overview

This guide will help you plan, implement, and administer the Cloud NOS (CNOS) software. Where possible, each section provides feature overviews, usage examples, and configuration instructions. The following material is included:

Part 1: Getting Started

This material is intended to help those new to CNOS products with the basics of switch management. This part includes the following chapters:

- Chapter 1, "Using the Command Line Interface", describes the CNOS command-line interface modes, commands, keyboard shortcuts, and aliases.
- Chapter 2, "Switch Administration", describes how to access the switch to configure the switch, and view switch information and statistics. This chapter discusses a variety of manual administration interfaces, including local management via the switch console, and remote administration via Telnet or Secure Shell.
- Chapter 3, "System License Keys", describes how to install additional features on the switch.
- Chapter 4, "Switch Software Management", describes how to update the CNOS software operating on the switch and how to convert from CNOS to ENOS.

Part 2: Securing the Switch

This material contains information about implementing security protocols on the switch. This part includes the following chapters:

- Chapter 5, "Securing Administration", describes methods for using Secure Shell for administration connections, and configuring end-user access control.
- Chapter 6, "AAA Protocols", describes different secure administration methods for remote administrators. This includes using RADIUS, Terminal Access Controller Access-Control System Plus (TACACS+) and Authentication, Authorization, and Accounting (AAA).
- Chapter 7, "Access Control Lists", describes how to use filters to permit or deny specific types of traffic, based on a variety of source, destination, and packet attributes.

Part 3: Switch Basics

This material contains information about setting up features on the switch. This part includes the following chapters:

- Chapter 8, "Interface Management", describes how to configure the switch interfaces, like the ethernet or management ports.
- Chapter 9, "Forwarding Database", describes how a Layer 2 device can be configured to learn and store MAC addresses and their corresponding ports.
- Chapter 10, "VLANs", describes how to configure Virtual Local Area Networks (VLANs) for creating separate network segments, including how to use VLAN tagging for devices that use multiple VLANs.

- Chapter 11, "Ports and Link Aggregation", describes how to group multiple physical ports together to aggregate the bandwidth between large-scale network devices.
- Chapter 12, "Spanning Tree Protocol", describes how to use the Rapid Per VLAN Spanning Tree Plus (Rapid PVST+) and Multiple Spanning Tree Protocol (MSTP) to build a loop-free network topology.
- Chapter 13, "Virtual Link Aggregation Groups", describes using Virtual Link Aggregation Groups (VLAGs) to form LAGs spanning multiple VLAG-capable aggregator switches.
- Chapter 14, "Quality of Service", discusses Quality of Service (QoS) features, including IP filtering using class maps, Differentiated Services, and IEEE 802.1p priority values.
- Chapter 15, "CEE", discusses using various Converged Enhanced Ethernet (CEE) features such as Priority-based Flow Control (PFC), Enhanced Transmission Selection (ETS) and Data Center Bridging Capability Exchange (DCBX).

Part 4: IP Routing

This part includes the following chapters:

- Chapter 16, "Basic IP Routing", describes how to configure the switch for IP routing using IP subnets, BFD, DHCP Relay and VRF.
- Chapter 17, "Routed Ports", describes how to configure a switch port to forward Layer 3 traffic.
- Chapter 18, "Address Resolution Protocol", describes how to use the Address Resolution Protocol (ARP) protocol to map an IPv4 address to a MAC address.
- Chapter 19, "Internet Protocol Version 6", describes how to configure the switch to use IPv6.
- Chapter 20, "Internet Group Management Protocol", describes how CNOS implements Internet Group Management Protocol (IGMP) Snooping to conserve bandwidth in a multicast-switching environment.
- Chapter 21, "Secure Mode", describes the difference between secure mode and legacy mode, what enabling secure mode means, and how to enable and disable it.
- Chapter 22, "Border Gateway Protocol", describes Border Gateway Protocol (BGP) concepts and features supported in CNOS.
- Chapter 23, "Open Shortest Path First", describes key Open Shortest Path First (OSPF) concepts, and how they are implemented in CNOS, and provides examples of how to configure your switch for OSPF support.
- Chapter 24, "Route Maps for Routing Protocols", describes route maps that are used to define route policy by permitting or denying certain routes based on a configured set of rules.
- Chapter 25, "Policy-Based Routing", describes policy-based routing that allows you to forward traffic based on defined policies rather than entries in the routing table.

Part 5: High Availability Fundamentals

This part includes the following chapters:

- Chapter 26, "Basic Redundancy", describes how the switch supports redundancy through LAGs and VLAGs.
- Chapter 27, "Virtual Router Redundancy Protocol", describes how the switch supports high-availability network topologies using Virtual Router Redundancy Protocol (VRRP).
- Chapter 28, "Layer 2 Failover", describes how to configure and use network adapter teaming for Layer 2 LAG failover.

Part 6: Network Management

This part includes the following chapters:

- Chapter 29, "Link Layer Discovery Protocol", describes how Link Layer Discovery Protocol (LLDP) helps neighboring network devices learn about each others' ports and capabilities.
- Chapter 30, "Service Location Protocol", describes the Service Location Protocol (SLP) that allows the switch to provide dynamic directory services.
- Chapter 31, "Simple Network Management Protocol", describes how to configure the switch for management through a Simple Network Management Protocol (SNMP) client.
- Chapter 32, "Telemetry", describes the CNOS Network Telemetry Agent and how to use the data it provides to fine-tune your network.

Part 7: Hyperconverged Infrastructure

This part includes the following chapters:

- Chapter 33, "Network Virtualization Gateway", describes how to integrate VMware NSX with your switch.
- Chapter 34, "Data Center Interconnection", describes how to interconnect data centers using MP-BGP EVPN or a static configuration.
- Chapter 35, "Network Policy Agent", explains how to use the CNOS network policy agent plug-in that works with Nutanix and VMware Virtual Domain Module.

Part 8: Monitoring

This part includes the following chapters:

- Chapter 36, "Port Mirroring", discusses tools to copy selected port traffic to a remote monitor port for network analysis.
- Chapter 37, "Sampled Flow", discusses using Sampled Flow (sFlow) for monitoring traffic.

Part 9: Appendices

This part includes the following appendices:

- Appendix A, “Getting help and technical assistance“, provides details on where to go for additional information about Lenovo and Lenovo products.
- Appendix B, “Notices“, contains safety and environmental notices.

Additional References

Additional information about installing and configuring your switch is available in the following guides:

- *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*
- *Lenovo Network Release Notes for Lenovo Cloud Network Operating System 10.9* for your switch
- *Lenovo Network Installation Guide* for your switch
- *Lenovo Network Python Programming Guide for Lenovo Cloud Network Operating System 10.9*
- *Lenovo Network REST API Programming Guide for Lenovo Cloud Network Operating System 10.9*

Typographic Conventions

The following table describes the typographic styles used in this book.

Table 1. *Typographic Conventions*

Typeface or Symbol	Meaning	Example
`ABC123`	This type is used for names of commands, files, and directories used within the text. It also depicts on-screen computer output and prompts.	View the `readme.txt` file. `Switch#`
`ABC123`	This bold type appears in command examples. It shows text that must be typed in exactly as shown.	`Switch#` **`ping`**
<ABC123>	This italicized type appears in command examples as a parameter placeholder. Replace the indicated text with the appropriate real name or value when using the command. Do not type the brackets. This also shows book titles, special terms, or words to be emphasized.	To establish a Telnet session, enter: `Switch#` **`telnet`** *<IP address>* Read your *User's Guide* thoroughly.
`{}`	Command items shown inside brackets are mandatory and cannot be excluded. Do not type the brackets.	`Switch#` **`copy {ftp|sftp}`**
`[]`	Command items shown inside brackets are optional and can be used or excluded as the situation demands. Do not type the brackets.	`Switch#` **`configure [terminal]`**
`|`	The vertical bar (**`|`**) is used in command examples to separate choices where multiple options exist. Select only one of the listed options. Do not type the vertical bar.	`Switch#` **`copy {ftp|sftp}`**
AaBb123	This block type depicts menus, buttons, and other controls that appear in graphical interfaces.	Click the **Save** button.

Part 1: Getting Started

This section discusses the following topics:

Chapter 1. Using the Command Line Interface

Lenovo Cloud Network Operating System uses an industry-standard command line interface (CLI). Like any switch CLI, there are subtle differences between the CNOS CLI and the CLI on switches from other vendors.

The following subjects are discussed in this chapter:

CLI Command Modes

The CLI has three major command modes listed in order of increasing privileges, as follows:

- User EXEC Mode: `Switch>`

  This is the initial mode of access. By default, on console sessions password checking is disabled for this mode.

- Privileged EXEC mode: `Switch#`

  This mode is accessed from User EXEC Mode. This mode can be accessed using the following command: **`enable`**

- Configuration Mode: `Switch(config)#`

  This mode allows you to make changes to the running configuration. If you save the configuration, the settings survive a reload of the switch. Several sub-modes can be accessed from the User EXEC Mode. This mode can be accessed using the following command: **`configure [terminal]`**

Each mode provides a specific set of commands. Most lower-privilege mode commands are accessible when using a higher-privilege mode.

Note: The word "`Switch`" is a generic term used throughout the *Application Guide* to indicate the hostname of the switch when issuing commands. Depending on the Lenovo RachSwitch or ThinkSystem, the word "`Switch`" will be replaced with one of the following:

Switch Type	Prompt
RackSwitch G8272	`G8272`
RackSwitch G8296	`G8296`
RackSwitch G8332	`G8332`
ThinkSystem NE1032 RackSwitch	`NE1032`
ThinkSystem NE1032T RackSwitch	`NE1032T`
ThinkSystem NE1072T RackSwitch	`NE1072T`
ThinkSystem NE10032 RackSwitch	`NE10032`
ThinkSystem NE2572 RackSwitch	`NE2572`

Command Line Interface Shortcuts

The following shortcuts allow you to enter commands quickly and easily.

CLI List and Range Inputs

For VLAN and port commands, you can specify lists and ranges of items can now be specified. For example, the `vlan` command permits the following options:

```
Switch(config)# vlan 1,3,1094                 (access VLANs 1, 3, and 1094)
Switch(config)# vlan 1-20                     (access VLANs 1 through 20)
Switch(config)# vlan 1-5,90-99,1090-1094      (access multiple ranges)
Switch(config)# vlan 1-5,19,20,1090-1094      (access a mix of lists and ranges)
```

The numbers in a range must be separated by a hyphen: <*start of range*>-<*end of range*>

Multiple ranges or items are permitted using a comma: <*range or item 1*>,<*range or item 2*>

Do not use spaces within list and range specifications.

Ranges can also be used to apply the same command option to multiple items. For example, to access multiple ports with one command:

```
Switch(config)# spanning-tree mst 1-4 cost 4096      (instances 1 through 4)
```

Command Abbreviation

Most commands can be abbreviated by entering the first characters which distinguish the command from the others in the same mode. For example, consider the following full command:

```
Switch(config)# show mac address-table interface ethernet 1/12
```

Any command can be abbreviated using the smallest unique strings. For example, the previous command can be abbreviated to:

```
Switch(config)# sh ma ad i e 1/12
```

Tab Completion

By entering the first letter of a command at any prompt and pressing **Tab**, the ISCLI displays all available commands or options that begin with that letter. Entering additional letters further refines the list of commands or options displayed. If only one command fits the input text when **Tab** is pressed, that command is supplied on the command line, waiting to be entered.

If multiple commands share the typed characters, when you press **Tab**, the ISCLI completes the common part of the shared syntax.

Line Editing

The following case-insensitive keystroke commands are available for editing command lines:

Command	Behavior
Ctrl + A	Moves the cursor to the beginning of the line.
Ctrl + B	Moves the cursor one character to the left.
Ctrl + D	Deletes the character at the cursor.
Ctrl + E	Moves the cursor to the end of the line.
Ctrl + F	Moves the cursor one character to the right.
Ctrl + K	"Kills" all text to the right of the cursor, putting it into a buffer.
Ctrl + L	Clears the screen, leaving the current line intact at the top.
Ctrl + N	Move to the next command in the command history.
Ctrl + P	Move to the previous command in the command history.
Ctrl + T	Swaps the character at the cursor with the character to the left of the cursor.
Ctrl + U	Clears all text from the command line.
Ctrl + W	Deletes from the cursor to the start of the "word."
Ctrl + Y	"Yanks" the text from the kill buffer.
Esc + B	Moves the cursor backwards one "word."
Esc + C	Capitalizes the first letter of the "word" or the character where the cursor is pointing.
Esc + D	Deletes to the end of the word to the right of the cursor.
Esc + F	Moves the cursor forwards one "word."
Esc + L	Changes the text to lowercase from the cursor to the end of the "word."
Esc + U	Changes the text to uppercase from the cursor to the end of the "word."

Command Aliases

Command aliasing enables you to change the names of commands in the CLI.

Defining Aliases

To define an alias, enter:

```
Switch(config)# alias <command alias> <current command>
```

For example, to use the alias **dis** to invoke the **show** command, enter:

```
Switch(config)# alias dis show
```

Removing Aliases

To remove an alias, enter:

```
Switch(config)# no alias <command alias>
```

To remove all aliases, enter:

```
Switch(config)# no alias all
```

Displaying Aliases

To see the list of aliases configured to your system, enter:

```
Switch(config)# show alias

CLI alias information:
======================
dis  : show
rem  : clear
```

Note: The alias command does not do validation checking. If you enter an invalid command for an alias to invoke, you will not get an error message when you create the alias, but you will get an error message when you actually invoke that alias.

Rules for Using Aliases

The following rules apply when you are defining an alias:

- An alias must be an alphanumeric string that starts with an alphabetic character. There can be no spaces or punctuation characters in an alias name. There *can* be dashes and spaces in the *command* being aliased. For example, the following command aliases the string **dis** to **show sys-info**:

```
Switch(config)# alias dis show sys-info
```

- You cannot "escape" non-alphanumeric characters with a backslash or with quotes. For example, you will get an error message if you enter:

```
Switch(config)# alias dis\sys-info show sys-info
```

- You can have multiple aliases for the same command, but you cannot have multiple commands mapped to the same alias. For example, if you enter:

```
Switch(config)# alias dis show
Switch(config)# alias rev show
```

  The aliases `dis` and `rev` will both invoke the `show` command. However, if you enter:

```
Switch(config)# alias dis show
Switch(config)# alias dis enable
```

  The **dis** alias will invoke the **enable** command, because the first command is overwritten by the second.

- You *can* use an alias to invoke a multiple word command. For example, you can enter:

```
Switch(config)# alias ssi show sys-info
```

  The **ssi** alias will now invoke the command **show sys-info**.

- You *cannot* nest aliases. For example, if you enter:

```
Switch(config)# alias dis show
Switch(config)# alias ssi show sys-info
```

  The **ssi** command will return an error message.

- The alias name must differ from the original CLI command. For example, you will get an error message if you enter:

```
Switch(config-if)# alias switchport switchport
```

- You cannot alias an argument of a command. For example, if you configure:

```
Switch(config)# alias dis show
Switch(config)# alias si sys-info
```

  When you try to execute the following command:

```
Switch(config)# dis si
```

  the command will return an error message because the switch is trying to parse it as **show si**, which is an invalid command.

- If you use the name of an existing command as an alias name, it will override the existing command. For example, if you enter:

```
Switch(config)# alias qos show
```

  The qos command will behave as if you had entered **show**. To fix this, enter:

```
Switch(config)# no alias <command>
```

  In the case of fixing the **qos** command to its original function, you would enter:

```
Switch(config)# no alias qos
```

- An alias does not support multiple command lines. For example, if you enter:

```
Switch(config)# alias svsu show version show user
```

  You will get an error message.

- You cannot concatenate aliases. For example, if you enter:

```
Switch(config)# alias dis show
Switch(config)# alias pc port-channel
Switch(config)# dis pc 1
```

  You will get an error message after you enter **show pc**.

- The maximum number of aliases that can be configured on a switch is 128.
- The following are reserved words that cannot be used as an alias name:
  - alias
  - all
  - bfd
  - configure
  - disable
  - show
  - enable
  - end
  - exit
  - logout
  - name
  - no
  - python
  - quit
  - reload
  - clear
  - restart
  - write

Chapter 2. Switch Administration

Your RackSwitch is ready to perform basic switching functions right out of the box. Some of the more advanced features, however, require some administrative configuration before they can be used effectively.

The extensive Lenovo Cloud Network Operating System for the switch provides a variety of options for accessing the switch to perform a variety of configurations and to view switch information and statistics.

This chapter discusses the various commands used to administer the switch:

Administration Interfaces

Cloud NOS provides a variety of user interfaces for administration. These interfaces vary in character and in the methods used to access them. Some are text-based and some are graphical; some are available by default, while others require configuration; some can be accessed by local connection to the switch, while others are accessed remotely using various client applications. For example, administration can be performed using any of the following:

- A built-in, text-based command-line interface (CLI) and menu system for switch access via a serial port connection or an optional Telnet or SSH session
- SNMP support for access through third party commercial and open source network management applications.

The specific interface chosen for an administrative session depends on your preferences, the switch configuration, and the available client tools.

In all cases, administration requires that the switch hardware is properly installed and turned on (see the *Lenovo Network Installation Guide* for your switch).

Industry Standard Command Line Interface

The Industry Standard Command Line Interface (ISCLI) provides a simple and direct method for switch administration. Using a basic terminal, you can issue commands that allow you to view detailed information and statistics about the switch, and to perform any necessary configuration and switch software maintenance.

You can establish a connection to the ISCLI in any of the following ways:

- Serial connection via the serial port on the switch (this option is always available)
- Telnet connection over the network
- SSH connection over the network

Establishing a Connection

The factory default settings permit initial switch administration through the built-in serial port. The switch can also be initially configured through the OOB management port that gets a default IP address (192.168.50.50/24); in this case, the user is able to log in via SSH into the port and perform initial configuration.

Remote access using the network requires the accessing terminal to have a valid, routable connection to the switch interface. The client IP address may be configured manually, or an IP address can be provided automatically to the switch using a service such as DHCP (see "DHCP IP Address Services" on page 58). An IPv6 address can also be obtained using IPv6 stateless address configuration.

Note: Throughout this manual, *IP address* is used in places where either an IPv4 or IPv6 address is allowed. IPv4 addresses are entered in dotted-decimal notation (for example, 10.10.10.1), while IPv6 addresses are entered in hexadecimal notation (for example, 2001:db8:85a3::8a2e:370:7334). In places where only one type of address is allowed, *IPv4 address* or *IPv6 address* is specified.

Using the Serial Console Port

You can access the switch CLI through the serial console port on the front panel of the switch. This port uses RS-232 serial communications.

1. Use the console cable kit to connect the serial console port to a terminal or a computer running a terminal emulation program.

   The console port terminal-emulation requirements are as follows:

   - Default Baud Rate
     - G8332, G8296, G8272, NE1032, NE1032T, NE1072T: 9,600 bps
     - NE10032, NE2572: 115,200 bps
   - Data Bits: 8
   - Stop Bits: 1
   - Parity: None
   - Flow Control: None

2. Log onto the switch. After the switch boots up, you are prompted to enter your login credentials (username and password). For details on the default switch login credentials, see "Switch Login Levels" on page 65.

Using the Switch Management Interface

To manage the switch through the management interface, you must configure it with an IP interface. Configure the IP address and network mask and default gateway address:

1. Log onto the switch.
2. Enter Global Configuration mode.

```
Switch> enable
Switch# configure [terminal]
Switch(config)#
```

3. Configure a management IP address and network mask:
   - IPv4 configuration:

```
Switch(config)# interface mgmt 0
Switch(config-if)# ip address <IPv4 address>/<IPv4 network mask length>
Switch(config-if)# exit
```

   - IPv6 configuration:

```
Switch(config)# interface mgmt 0
Switch(config-if)# ipv6 address <IPv6 address>/<IPv6 network mask length>
Switch(config-if)# exit
```

4. Configure the appropriate default gateway:
   - IPv4 configuration:

```
Switch(config)# vrf context management
Switch(config-vrf)# ip route 0.0.0.0 0.0.0.0 <default gateway IPv4 address>
Switch(config-vrf)# exit
```

   - IPv6 configuration:

```
Switch(config)# vrf context management
Switch(config-vrf)# ipv6 route ::/0 <default gateway IPv6 address>
Switch(config-vrf)# exit
```

Once you configure a management IP address for your switch, you can connect to the management port and use a Telnet or an SSH client from an external management station to access and control the switch. The management port provides out-of-band management.

Note: To use a telnet client, you must first enable telnet access with the command:

```
Switch(config)# feature telnet
```

Other Ways to Manage the Switch Using IP

Besides using the out-of-band management port to administer the switch, you can manage the switch using an in-band connection over the data ports. The following options are available for configuring in-band management:

- Switched Virtual Interface (SVI)
- L3 routed ports

"Switch Virtual Interfaces" on page 211 contains rules and more details about using an SVI, while "Configuring a Routed Port" on page 423 contains more details about configuring routed ports. The following section contains examples of each.

Configuring a Switched Virtual Interface for Management

A Switched Virtual Interface is a VLAN that has an IP address assigned directly on it via the command:

```
Switch(config)# interface vlan <VLAN number (1-4094)>
```

The VLAN must already exist before you configure the VLAN interface, and the VLAN must be allowed on any data ports you want to use to manage the switch. Along with configuring the VLAN interface, if you want to connect to the switch via a remote IP subnet, configure an in-band default gateway.

The following is an example of configuring an SVI and associated default gateway.

1. Log onto the switch.
2. Enter configuration mode and create the desired VLAN to be used by the SVI:

```
Switch> enable
Switch# configure [terminal]
Switch(config)# vlan <VLAN number (1-4093)>
Switch(config-vlan)# exit
```

3. Create the SVI and configure the IP address and network mask.

```
Switch(config)# interface vlan <VLAN number (1-4094)>
Switch(config-if)# ip address <IP address>/<prefix length>
Switch(config-if)# exit
```

4. Configure the in-band default gateway (optional).
   - IPv4 configuration:

```
Switch(config-if)# ip route 0.0.0.0/0 <default gateway IPv4 address>
```

   - IPv6 configuration:

```
Switch(config-if)# ipv6 route ::/0 <default gateway IPv6 address>
```

You must carry the VLAN being used for management on at least one of the in-band data ports, to permit management of the switch via this path.

Using the Switch Ethernet Ports in Routed Port Mode for Management

You also can configure in-band management directly on any of the switch Ethernet data ports by setting the physical interface to Routed Port mode. To allow in-band management via the Routed port feature use the following procedure:

1. Log onto the switch.
2. Enter interface mode and configure an ethernet interface as routed port.

```
Switch> enable
Switch# configure [terminal]
Switch(config)# interface ethernet <chassis number>/<port number>
Switch(config-if)# no switchport
```

3. Configure the interface IP address and network mask on this physical Ethernet interface.
   - IPv4 configuration:

```
Switch(config-if)# ip address <IPv4 address>/<IPv4 prefix length>
Switch(config-if)# exit
```

   - IPv6 configuration:

```
Switch(config-if)# ipv6 address <IPv6 address>/<IPv6 prefix length>
Switch(config-if)# exit
```

4. (Optional) Configure the in-band default gateway.
   - IPv4 configuration:

```
Switch(config)# ip route 0.0.0.0/0 <default gateway IPv4 address>
```

   - IPv6 configuration:

```
Switch(config)# ipv6 route ::/0 <default gateway IPv6 address>
```

Once you configure the IP address and have a network connection, you can use a Telnet or an SSH client from an external management station to access and control the switch. Once the default gateway is enabled, the management station and the switch do not need to be on the same IP subnet to communicate.

The switch supports an industry standard command-line interface (ISCLI) that you can use to configure and control the switch over the network using a Telnet or an SSH client. You can use the ISCLI to perform many basic network management functions. In addition, you can configure the switch for management using an SNMP-based network management system.

For more information, see the documents listed in "Additional References" on page 31.

Using Telnet

A Telnet connection offers the convenience of accessing the switch from a workstation connected to the network. Telnet access provides the same options for user and administrator access as those available through the console port.

By default, Telnet access is disabled. Use the following command to enable or disable Telnet access:

```
Switch(config)# [no] feature telnet
```

Once the switch is configured with an IP address and gateway, you can use Telnet to access switch administration from any workstation connected to the management network.

To establish a Telnet connection with the switch, run the Telnet client on your workstation, use Telnet as the protocol type and the switch's IP address as the hostname.

You will then be prompted to enter a password as explained in "Switch Login Levels" on page 65.

By default, Telnet uses TCP port 23 of the remote host to establish a connection from the switch. When initializing a Telnet session, you can specify the TCP port of the remote host by using the following command on the switch:

```
Switch# telnet <switch IPv4 address> port <1-65535>
```

Note: The specified port will be used only for the current Telnet session. Future sessions will not use the selected port.

By default, Telnet clients will connect to the local Telnet server using TCP port 23 on the switch. To configure the TCP port used by a Telnet client when establishing a connection to the switch, use the following command:

```
Switch(config)# telnet server port <1-65535>
```

Using Secure Shell

Although a remote network administrator can manage the configuration of a switch via Telnet, this method does not provide a secure connection. The Secure Shell (SSH) protocol enables you to securely log into another device over a network to execute commands remotely. As a secure alternative to using Telnet to manage switch configuration, SSH ensures that all data sent over the network is encrypted and secure.

By default, SSH access is enabled. Use the following command to enable or disable SSH access:

```
Switch(config)# [no] feature ssh
```

The switch can do only one session of key/cipher generation at a time. Thus, an SSH client will not be able to log in if the switch is doing key generation at that time. Similarly, the system will fail to do the key generation if an SSH client is logging in at that time.

The supported SSH encryption and authentication methods are:

- Server Host Authentication: Client RSA-authenticates the switch when starting each connection
- Key Exchange: ecdh-sha2-nistp256, ecdh-sha2-nistp384, ecdh-sha2-nistp521, diffie-hellman-group14-sha1
- Encryption: aes128-ctr, aes192-ctr, aes256-ctr, aes128-gcm@openssh.com, aes256-gcm@openssh.com
- MAC: hmac-sha1, hmac-sha2-256, hmac-sha2-512, hmac-sha1-etm@openssh.com, hmac-sha2-256-etm@openssh.com
- User Authentication: Local password authentication, TACACS+

Lenovo Cloud Network Operating System implements the SSH version 2.0 standard and is confirmed to work with SSH version 2.0 compliant clients such as the following:

- OpenSSH_6.7p1 for Linux
- Secure CRT Version 7.3.4(build 839)
- Putty SSH release 0.60

Using SSH with Password Authentication

Once the IP parameters are configured, you can access the command line interface using an SSH connection.

To establish an SSH connection with the switch, run the SSH client on your workstation, use SSH as the protocol type and the switch's IP address as the hostname.

You will then be prompted to enter a password as explained in "Switch Login Levels" on page 65.

Using SSH with Server Key Authentication

SSH can also be used for switch authentication based on asymmetric cryptography. Server encryption keys can be generated on the switch and used to authenticate incoming login attempts based on the client's private encryption key pairs. After a predefined number of failed server key authentication attempts, a login error will appear and the SSH session will be disconnected.

To set up server key authentication:

1. Disable SSH:

```
Switch(config)# no feature ssh
```

Note: SSH settings cannot be modified if SSH is enabled.

2. Generate an SSH key:

   - DSA:

```
Switch(config)# ssh key dsa [force]
```

   - RSA:

```
Switch(config)# ssh key rsa [force]
```

Note: You can also configure the length of the RSA key by using the following command:

```
Switch(config)# ssh key rsa length <768-2048>
```

3. Configure a maximum number of failed server key authentication attempts before the SSH session will be disconnected:

```
Switch(config)# ssh login-attempts <1-10>
```

Note: The default number of failed attempts is 3.

4. Re-enable SSH:

```
Switch(config)# feature ssh
```

Once the server key is configured on the switch, a client can use SSH to log in from a system where the private key pair is set up.

Using Simple Network Management Protocol

CNOS provides Simple Network Management Protocol (SNMP) version 1, 2, and 3 support for access through any network management software, such as Switch Center or Lenovo XClarity.

Note: The SNMP read function is enabled by default. For best security practices, if SNMP is not needed for your network, disable this function prior to connecting the switch to the network.

To access the SNMP agent on the switch, the read and write community strings on the SNMP manager must be configured to match those on the switch.

The read and write community strings on the switch can be configured using the following commands:

- read-only access community string:

```
Switch(config)# snmp-server community <community string (1-32 characters)> ro
```

- read-write access community string:

```
Switch(config)# snmp-server community <community string (1-32 characters)> rw
```

The SNMP manager must be able to reach any one of the IP interfaces on the switch.

For the SNMP manager to receive the SNMPv1 traps sent out by the SNMP agent on the switch, configure the trap host on the switch with the following command:

```
Switch(config)# snmp-server host <IP address> traps version 1 <trap host
community string>
```

For more information on SNMP usage and configuration, see Chapter 31, "Simple Network Management Protocol."

Zero Touch Provisioning

Zero Touch Provisioning (ZTP) enables a switch to automatically provision itself using the resources available on the network without manual intervention. When a switch with ZTP enabled starts up, it locates a DHCP server which provides the switch with an interface IPv4 address and a gateway IPv4 address. The switch then obtains the IP address of a TFTP server from which it downloads the necessary boot file. The next step is for the switch to run the boot file.

Note: The NE1032, NE1032T, and NE1072T can also download ZTP boot files from HTTP servers, not just TFTP servers.

On the switch, ZTP triggers when any of the following conditions are met:

- a switch boots with no startup configuration (only the default configuration)
- the startup configuration is erased and the switch is reloaded
- ZTP is forcedly enabled from the CLI

Note: ZTP will not be triggered if it is forcedly disabled from the CLI.

During the boot process, if the switch does not find a startup configuration and ZTP is enabled, the switch enters ZTP mode. When forcedly enabled from the CLI, the switch enters ZTP mode regardless of the presence of a startup configuration. The switch searches for available DHCP servers and requests them to acquire an interface address, a gateway address, the TFTP (or HTTP, in the case of NE1032, NE1032T, and NE1072T) server address, and the boot file name.

After the information from the DHCP server is obtained, ZTP downloads and runs the boot file, and then executes the ZTP process according to the boot file. ZTP automatically handles the process of upgrading the switch firmware image and installing configuration files.

Notes:

- During the boot process, a prompt appears asking if you want to abort or continue the ZTP process. If you choose to exit ZTP, the switch continues with its normal boot process, using the default configuration or any startup configuration, if one is present on the switch and ZTP was forcedly enabled from the CLI.
- If ZTP was forcedly enabled and no DHCP server was found during the ZTP process, the switch removes from the management interface any previously manually configured IPv4 address.
- If ZTP is canceled during its execution, the switch exits ZTP mode. If an interface IPv4 address was obtained, it is not released. If any files were downloaded, they are not deleted.
- Important ZTP events are logged by the switch and are available for display from a console session.

DHCP Discovery

After entering ZTP mode, the switch sends a DHCP discover message on its management interface requesting DHCP offers from the DHCP servers present on the network. The receiving DHCP server replies with a DHCP offer message.

When the DHCP client receives the DHCP offer message, it requests the DHCP server to send the following information:

- an interface IPv4 address
- a gateway IPv4 address
- the TFTP (or HTTP, in the case of NE1032, NE1032T, and NE1072T) server IP address (using option 66)
- the boot file name (using option 67)

The switch completes the DHCP negotiation process (request and acknowledgement) with the DHCP server, which assigns the switch an IPv4 address. The switch then uses the acquired TFTP (or HTTP, in the case of NE1032, NE1032T, and NE1072T) server IP address to contact that server. The boot file name contains the complete file path of the boot file on the remote server. The switch then downloads the boot file.

If no DHCP servers reply to the DHCP discover message or if no DHCP offer meets the ZTP requirements, the switch is unable to complete the DHCP negotiation and an IPv4 address is not assigned (except the default IPv4 address 192.168.50.50/24, but this cannot help the switch finalize the ZTP process). ZTP tries three times to successfully obtain the required information. If the DHCP negotiation fails three times, the switch exits ZTP mode and continues the normal boot process.

Notes:

- The interface IPv4 address obtained from the DHCP server is kept and used even after the ZTP process over.
- ZTP supports only DHCPv4 and not DHCPv6.
- ZTP supports the following transfer protocols:
  - for G8272, G8296, G8332, NE10032, NE2572: only TFTP
  - for NE1032, NE1032T, NE1072T: TFTP and HTTP
  - ZTP does not support FTP, SCP, or SFTP
- DHCP servers must be configured with options 66 and 67 to ensure that the switch always obtains the TFTP server hostname and the boot file name during the ZTP process.

DHCP options 66 and 67 are enabled by default on the switch. If either of them is disabled, the ZTP process results in a failure.

DHCP option 66 provides the IP address of a single TFTP (or HTTP, in the case of NE1032, NE1032T, and NE1072T) server. To enable or disable DHCP option 66, use the following command:

```
Switch(config)# interface mgmt 0
Switch(config-if)# [no] ip dhcp client request tftp-server-name
Switch(config)# exit
```

DHCP option 67 provides the file path of the boot file needed by ZTP. To enable or disable DHCP option 67, use the following command:

```
Switch(config)# interface mgmt 0
Switch(config-if)# [no] ip dhcp client request bootfile-name
Switch(config)# exit
```

ZTP Boot File

The boot file is written in YAML format and contains switch models, and under each switch model are several fields that instruct the ZTP process what to do.

The boot file may contain up to three fields under each switch model:

- `img_name` - this instructs ZTP to update the switch firmware image to the specified image version and configure it as the standby image on the switch
- `configuration` - this instructs ZTP to copy the specified configuration file from the TFTP (or HTTP, in the case of NE1032, NE1032T, and NE1072T) server and use it as the startup configuration file on the switch
- `script` - this instructs ZTP to copy the script file and execute it on the switch

ZTP checks the boot file for the switch model and executes the appropriate actions according to the fields under the correct switch model.

ZTP supports the execution of Python scripts. If there is a `script` field under the switch model in the boot file, that field has a higher priority than the other two fields (`img_name` and `configuration`), thus ZTP ignores them. ZTP downloads the Python script file to the switch and executes it. The script can also contain instructions to download and install a switch firmware image and a configuration file.

Note: The Python script file is stored in a temporary folder on the switch and it is deleted once the switch reloads.

Following is an example of a boot file:

```
G8272:
     img_name     : G8272-10.9.0.1.img
     configuration: netboot_config_file_G8272
     script       : netboot_G8272.py

G8296:
     img_name     : G8296-10.9.0.1.img
     configuration: netboot_config_file_G8296
     script       : netboot_G8296.py

G8332:
     img_name     : G8332-10.9.0.1.img
     configuration: netboot_config_file_G8332
     script       : netboot_G8332.py
```

Note: After the ZTP process is over, the switch is reloaded if the firmware image or the startup configuration are updated. If ZTP executes a Python script, the reloading of the switch is decided by the script instead.

Forcedly Enabling or Disabling ZTP

ZTP can be forcedly enabled on the switch even if there is a startup configuration present. It can also be forcedly disabled to not execute even if there is no startup configuration.

ZTP can have one of the following states:

- Default
- Forcedly Enabled
- Forcedly Disabled

To forcedly enable ZTP on the switch, use the following command:

```
Switch(config)# boot zerotouch force enable
```

To forcedly disable ZTP on the switch, use the following command:

```
Switch(config)# boot zerotouch force disable
```

To reset the ZTP to its default setting, use the following command:

```
Switch(config)# no boot zerotouch force
```

To view the current ZTP state, use the following command:

```
Switch# show boot

Current ZTP State: Enable
Current FLASH software:
 active image: version 10.9.0.1, downloaded 18:39:47 UTC Wed Sep 16 2015
 standby image: version 10.9.0.1, downloaded 18:44:40 UTC Wed Sep 16 2015
 Uboot: version 10.9.0.1, downloaded 17:49:51 UTC Thu Jul 30 2015
Currently set to boot software active image
Currently scheduled reboot time: none
Current port mode: default mode
```

To view the ZTP parameters obtained after the ZTP process has executed, use the following command:

```
Switch# show zerotouch

TFTP server: 10.122.3.69
Image: G8xxx-10.9.0.1.img
Configuration: netboot_config_file_G8xxx
Script: netboot_G8xxx.py
```

DHCP IP Address Services

For remote switch administration, the client terminal device must have a valid IP address on the same network as the switch interface. The IP address on the client device may be configured manually, or obtained automatically using IPv6 stateless address configuration, or an IP address may be obtained automatically via DHCP relay as discussed in the next section.

The switch can function as a relay agent for DHCP. This allows clients to be assigned an IP address for a finite lease period, reassigning freed addresses later to other clients. Acting as a relay agent, the switch can forward a client's IP address request to up to five DHCP servers. Additionally, up to five domain specific DHCP servers can be configured for each of up to 10 VLANs.

When a switch receives a DHCP request from a client seeking an IP address, the switch acts as a proxy for the client. The request is forwarded as a UDP unicast MAC layer message to the DHCP servers configured for the client's VLAN or to the global DHCP servers if no domain-specific DHCP servers are configured for the client's VLAN. The servers respond to the switch with a unicast reply that contains the IP default gateway and the IP address for the client. The switch then forwards this reply back to the client.

DHCP is described in RFC 2131 and the DHCP relay agent supported on the switch is described in RFC 1542. DHCP uses User Datagram Protocol (UDP) as its transport protocol. The client sends messages to the server on port 67 and receives messages from the server on port 68.

DHCP Client Configuration

DHCP is enabled by default on the management interface and disabled on all other interfaces. You can enable DHCP only on a maximum of 10 interfaces, including the management interface.

To enable or disable DHCP on an interface (for example ethernet interface 1/12), use the following command:

- for DHCPv4:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# no switchport
Switch(config-if)# ip address dhcp
```

- for DHCPv6:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# no switchport
Switch(config-if)# ipv6 address dhcp
```

Notes:

- DHCP cannot be enabled on an interface configured as a switch port, only on routing ports.
- Manually configuring an IP address on an interface will disable DHCP for that interface.

DHCPv4 Hostname Configuration (Option 12)

The switch supports DHCPv4 hostname configuration as described in RFC 2132, option 12. DHCPv4 hostname configuration is disabled by default.

The switch's hostname can be manually configured using the following command:

```
Switch(config)# hostname <system network name>
```

Note: If the hostname is manually configured, the switch does not replace it with the hostname received from the DHCPv4 server.

After DHCP configures the hostname on the switch, if the DHCPv4 configuration is disabled, the switch retains the hostname.

To enable or disable DHCP hostname configuration, use the following command on an interface (in this example, ethernet port 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# [no] ip dhcp client request host-name
```

To view the system hostname use the following command:

```
Switch> show hostname
```

Note: The switch prompt also displays the hostname.

DHCPv4 Syslog Server (Option 7)

The switch supports the requesting of the Syslog server IP address from the DHCP server as described in RFC 2132, option 7. The DHCPv4 Syslog server request option is disabled by default.

Note: Manually configured Syslog servers take priority over the DHCPv4 Syslog server.

Up to three Syslog server addresses received from the DHCPv4 server can be used. The Syslog server addresses can be learned over the management port or an ethernet port.

To enable or disable the DHCP Syslog server request, use the following command on an interface (in this example, ethernet port 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# [no] ip dhcp client request log-server
```

To view the Syslog server address, use the following command:

```
Switch> show logging server

Logging server:                 enabled
{*2.2.2.1}
        Server severity:      debugging
        Server facility:        local7
        Server vrf:             data
* - Values assigned by DHCP Client.
```

DHCPv4 NTP Server (Option 42)

This option request the DHCP server to provide a list of IP addresses indicating Network Time Protocol (NTP) servers available to the client. The NTP servers are listed in order of preference. The switch supports the requesting of NTP servers as described in RFC 2132, option 42.

By default, the switch does not include this request in DHCPv4 messages. To enable or disable this option on an interface, use the following command (in this example, ethernet port 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# [no] ip dhcp client request ntp-server
```

Note: Any manually configured NTP server will not be overwritten by the NTP servers received via DHCPv4.

To view the list of NTP servers, use the following command:

```
Switch> show ntp peers
```

DHCPv4 Vendor Class Identifier (Option 60)

This option is used by a DHCP client to identify itself to the DHCP server. It is used to define the vendor type and functionality of the DHCP client. The DHCP client can communicate to a server that it uses a specific type of hardware or software by specifying its Vendor Class Identifier (VCI).

The switch supports the identifying of a TFTP server as described in RFC 2132, option 60.

Each switch interface can be configured with a different VCI.

By default, the switch will include this option in DHCPv4 packets. To enable or disable the identification of TFTP servers use the following command (in this example, ethernet port 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# [no] ip dhcp client class-id
```

Note: Depending on the Lenovo RackSwitch, the default VCI is different.

- for the Lenovo RackSwitch G8272, the default VCI is 'LENOVO G8272'
- for the Lenovo RackSwitch G8296, the default VCI is 'LENOVO G8296'
- for the Lenovo RackSwitch G8332, the default VCI is 'LENOVO G8332'
- for the Lenovo RackSwitch NE1032, the default VCI is 'LENOVO NE1032'
- for the Lenovo RackSwitch NE1032T, the default VCI is 'LENOVO NE1032T'
- for the Lenovo RackSwitch NE1072T, the default VCI is 'LENOVO NE1072T'
- for the Lenovo RackSwitch NE10032, the default VCI is 'LENOVO NE10032'
- for the Lenovo RackSwitch NE2572, the default VCI is 'LENOVO NE2572'

DHCPv4 Snooping

DHCP snooping provides security by filtering untrusted DHCP packets and by building and maintaining a DHCP snooping binding table.

A trusted port is an interface connected to a legitimate DHCP server.By default, all ports are untrusted. To configure a port as trusted, enter the following Interface mode command:

```
Switch(config-if)# [no] ip dhcp snooping trust
```

By default, DHCP snooping is disabled globally and on all VLANs. You can enable DHCP snooping globally or on a specific VLAN. To enable this feature globally, enter the following command:

```
Switch(config)# [no] ip dhcp snooping
```

To enable DHCP snooping on a specific VLAN, use the following command:

```
Switch(config)# [no] ip dhcp snooping vlan <VLAN number (1-4093)>
```

Note: For DHCP snooping to work on a VLAN, you must enable DHCP snooping both globally and on that specific VLAN.

Configure the DHCPv4 Snooping Binding Table

The DHCPv4 snooping binding table contains the MAC address, the IP address, lease time, binding type, VLAN number, and port number that correspond to the local untrusted interface on the switch; it does not contain information regarding hosts interconnected with a trusted interface.

The binding table is saved to flash memory every ten minutes. When the system reboots, the binding table is recovered from the flash file. The maximum number of entries in the DHCPv4 snooping binding table is 2048.

Sometimes you may want to manually configure the binding table entries, such as when you need to use a static IP address. Use the following command to configure a binding table entry:

```
Switch(config)# ip dhcp snooping binding <MAC address> vlan <VLAN number
(1-4093> <IP address> interface ethernet <slot>/<port> expiry <lease time range>
```

Configure the DHCPv4 Snooping Syslog

The DHCP snooping daemon creates syslogs when some important events happen, such as a change to a dynamic entry or the timer.

There are two timers in DHCP snooping. One refreshes DHCP snooping binding entries every 60 seconds. The other one saves the binding table to flash every ten minutes. These syslogs are useful for monitoring and adjusting DHCP.

To set the DHCP snooping log level, enter:

```
Switch(config)# logging level dhcp-snp <logging level>
```

where:

Logging Level	Meaning
0	Emergency
1	Alert
2	Critical
3	Error
4	Warning
5	Notification
6	Information
7	Debug

DHCP Snooping Limitations

- DHCP snooping is not supported on a management port.
- DHCP is only supported on Ethernet ports. It is not supported on a Link Aggregation Group (LAG) or on a routed port.
- DHCP snooping does not support LACP or static LAGs.

DHCP Relay Agent

When DHCP clients and associated servers are not on the same physical subnet, a DHCP relay agent can transfer DHCP messages between them. When a DHCP request arrives on an interface, the relay agent forwards the packet to all DHCP server IP addresses configured on that interface. The relay agent forwards replies from all DHCP servers to the host that sent the request. If no DHCP servers are configured on that interface, the relay agent will not forward packets.

DHCP has two versions. DHCPv4 is used to configure hosts with IPv4 addresses, IPv4 prefixes, and other configuration data required to operate in an IPv4 network. DHCPv6 is used to configure hosts with IPv6 addresses, IPv6 prefixes, and other configuration data required to operate in an IPv6 network.

For DHCPv4, you can configure the relay agent to add the relay agent information (option 82) in the DHCPv4 message and then forward it to the DHCPv4 server. The reply from the server is forwarded back to the client after removing option 82.

The DHCP Relay Agent is globally enabled by default. To globally enable or disable DHCP use the following command:

- for DHCPv4:

```
Switch(config)# [no] ip dhcp relay
```

- for DHCPv6:

```
Switch(config)# [no] ipv6 dhcp relay
```

DHCP relay can be configured differently on each ethernet port or VLAN. The maximum number of DHCP servers configured on an interface is 32. To configure DHCP on an interface, use the following steps:

1. Enter the configuration menu for the desired interface (in this example, ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)#
```

2. Configure the DHCP server address:

   - for DHCPv4:

```
Switch(config-if)# ip dhcp relay address <IPv4 server address>
```

   - for DHCPv6:

```
Switch(config-if)# ipv6 dhcp relay address <IPv6 server address>
```

3. To view the current DHCP settings, use the following command:
   - for DHCPv4:

```
Switch> show ip dhcp relay
```

   - for DHCPv6:

```
Switch> show ipv6 dhcp relay
```

DHCPv4 Option 82

DHCPv4 option 82 provides a mechanism for generating IP addresses based on the location in the network of the client device. When you enable the DHCPv4 relay agent option on the switch, it inserts the relay agent information option 82 in the packet. The switch then sends a unicast DHCPv4 request packet to the DHCPv4 server. The DHCPv4 server uses the option 82 field to assign an IP address and sends the packet, with the original option 82 field included, back to the relay agent. The DHCPv4 relay agent strips off the option 82 field in the packet and sends the packet to the DHCPv4 client.

The configuration of this feature is optional. The feature helps resolve several issues where untrusted hosts access the network. See RFC 3046 for details.

To configure DHCPv4 option 82, use the following command:

```
Switch(config)# ip dhcp relay information option
```

Switch Login Levels

To enable better switch management and user accountability, two levels or *classes* of user access have been implemented on the switch. The levels of access to CLI management functions and screens increase as needed to perform various switch management tasks. Conceptually, access classes are defined as follows:

- *Network Operators* can only make temporary changes on the switch. These changes will be lost when the switch is reloaded or reset. Operators have access to the switch management features used for daily switch operations. Because any changes an operator makes are undone by a reload of the switch, operators cannot severely impact switch operation.
- *Network Administrators* are the only ones that may make permanent changes to the switch configuration—changes that are persistent across a reload or reset of the switch. Administrators can access switch functions to configure and troubleshoot problems on the device. Because administrators can also make temporary (operator-level) changes as well, they must be aware of the interactions between temporary and permanent changes.

Note: The default (predefined) access classes cannot be removed or their rules modified. Also, new access classes cannot be created.

Access to switch functions is controlled through the use of unique usernames and passwords. Once you are connected to the switch via console, Telnet, or SSH, you are prompted to enter a password. The default username and password combinations for each access level are listed in Table 2.

Note: It is mandatory that you change the default switch passwords after initial configuration. We recommend that you change the switch passwords as regularly as required under your network security policies.

Table 2. *Default Username and Password Combinations*

User Account	Password	Description and Tasks Performed	Status
`oper`	`oper`	The Operator manages all functions of the switch. The Operator can reset ports, except the management port.	Disabled
`admin`	`admin`	The Administrator has complete access to all menus, information, and configuration commands on the switch, including the ability to change both the operator and administrator passwords.	Enabled

The following characters are restricted in CNOS and cannot be used in passwords:

```
"?`&()<>|;'$
```

For more details, see “End-user Access Control” on page 134.

To display the current role configurations, use the following command:

```
Switch> show role

Role : network-admin
  Description: Predefined network admin role has access to all commands
  on the switch
------------------------------------------------------------------------
Rule    Perm    Type         Scope               Entity
------------------------------------------------------------------------
1       permit  read-write

Role : network-operator
  Description: Predefined network operator role has access to all read
  commands on the switch
------------------------------------------------------------------------
Rule    Perm    Type         Scope               Entity
------------------------------------------------------------------------
1       permit  read
```

While a network administrator has access to all of the CLI commands, a network operator has a more limited access, only being able to run commands such as:

- **show**
- **end**
- **exit**
- **logout**
- **quit**
- **terminal**
- **enable**
- **disable**
- **ping**
- **ping6**
- **traceroute**
- **traceroute6**
- **ssh**
- **ssh6**
- **telnet**
- **telnet6**
- **where**
- **configure [terminal]**

Changing the Default Network Administrator Password

After logging onto the switch for the first time or after updating the switch firmware to 10.8 or newer version, a screen prompt appears requesting you to change the default network administrator password.

```
You are required to change your default 'admin' user password immediately
Changing password for admin.

Current Administrator password:

Choose a strong password (Min 8 chars, at least 1 uppercase, 1 lowercase,
1 number. Consecutive characters (such as abcd), repeating characters
(such as aaabbb) and words that appear in the dictionary are disallowed.
New Administrator password:
Retype new Administrator password:
```

You must enter the current network administrator password, then set up a new password and then enter it a second time for confirmation.

Cloud NOS requires the use of strong passwords for users to access the switch. Strong passwords enhance security because they make password guessing more difficult.

The following rules must be followed when changing the network administrator password:

- Minimum length: 8 characters; maximum length: 80 characters
- Must contain at least one uppercase letter
- Must contain at least one lowercase letter
- Must contain at least one number
- Cannot be same as the username

Notes:

- After changing the default network administrator password, you must save the current running configuration. Otherwise, the new password is not saved. To save the current running configuration, use one of the following commands:

```
Switch# copy running-config startup-config
```

```
Switch# write
```

- If you do not configure a new network administrator password, your current session on the switch is terminated. You are not permitted to configure the switch until you change the default network administrator password.

Ping

Ping (Poll INternet Gateway) is an administration utility used to test the connectivity between two network IP devices. It also measures the length of time it takes for a packet to be sent to a remote host plus the length of time it takes for an acknowledgement of that packet to be received by the source host.

Ping functions by sending an Internet Control Message Protocol (ICMP) echo request to the specified remote host and waiting for an ICMP reply from that host.

Using this method, ping also determines the time interval between when the echo request is sent and when the echo reply is received. This interval is called round-trip time. At the end of the test, ping will display the minimum, maximum, and average round-trip times, and the standard deviation of the mean.

Besides the round-trip time, ping can also measure the rate of packet loss. This is determined by the number of received echo replies over the number of sent echo requests. It is displayed as a percentage.

The Switch also supports ping for IPv6 addressing.

To perform a standard ping test, use the following commands:

- IPv4:

```
Switch# ping <target IPv4 address> vrf management
```

- IPv6:

```
Switch# ping6 <target IPv6 address> vrf management
```

For example:

```
Switch# ping 10.10.10.1 vrf management

PING 10.10.10.1 (10.10.10.1) from 10.10.10.127: 56(84) bytes of data.
64 bytes from 10.10.10.1: icmp_seq=1 ttl=61 time=0.368 ms
64 bytes from 10.10.10.1: icmp_seq=2 ttl=61 time=0.280 ms
64 bytes from 10.10.10.1: icmp_seq=3 ttl=61 time=0.308 ms
64 bytes from 10.10.10.1: icmp_seq=4 ttl=61 time=0.291 ms
64 bytes from 10.10.10.1: icmp_seq=5 ttl=61 time=0.320 ms
--- 10.10.10.1 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 3996ms
rtt min/avg/max/mdev = 0.280/0.313/0.368/0.034 ms
```

Note: If no specific VRF instance is configured, the switch uses the default management VRF. In this case, the user can also use the following command:

- IPv4:

```
Switch# ping <target IPv4 address>
```

- IPv6:

```
Switch# ping6 <target IPv6 address>
```

Ping Configurable Parameters

Ping can be configured with various parameters, such as specifying the number or size of echo requests, the time interval between each transmission, or the nonresponsive timeout interval for sent packets.

Test Interruption

Ping tests can be manually stopped at any point in the process. When the interruption is detected, ping will stop sending echo requests and display the results based on the packets transmitted up to that point.

To manually terminate a ping test, press **Ctrl + C**.

Ping Count

By default, ping transmits a sequence of five echo requests. To configure the number of packets sent during the test, use the following command:

```
Switch# ping <target IPv4 address> count <1-655350>
```

Ping can also be configured to continuously send echo requests until the test is manually interrupted. To achieve this, use the following command:

```
Switch# ping <target IPv4 address> count unlimited
```

For IPv6 addressing, the commands are as follows:

```
Switch# ping6 <target IPv6 address> count <1-655350>
```

```
Switch# ping6 <target IPv6 address> count unlimited
```

Ping Packet Interval

By default, ping does not wait between consecutive echo requests. As soon as a echo reply has been received or the nonresponsive timer has expired, ping will send the next echo request.

To configure a time interval, in seconds, between the transmission of packets, use the following command:

```
Switch# ping <target IPv4 address> interval <1-60>
```

For IPv6 addressing, the command is as follows:

```
Switch# ping6 <target IPv6 address> interval <1-60>
```

Ping Packet Size

By default, ping sends echo requests with a packet size of 56 bytes. Specifying a larger size than the default can help in detecting the loss of big packets.

To configure the packet size, in bytes, use the following command:

```
Switch# ping <target IPv4 address> packet-size <1-65468>
```

For IPv6 addressing, the command is as follows:

```
Switch# ping6 <target IPv6 address> packet-size <1-65468>
```

Ping Source

By default, ping automatically chooses the outgoing interface for echo requests and sends the packets using the IP address of that interface. To check the connectivity of different paths through the network, you can specify the interface used for sending echo requests.

To use a specific interface during the ping test, use the following command:

```
Switch# ping <target IPv4 address> source <source IPv4 address>
```

Note: The *source IPv4 address* is the IP address of the desired switch interface.

You can also choose the interface used for the ping test by directly specifying the desired interface. To achieve this, use the following command (in this example, ethernet port 1/12 is used):

```
Switch# ping <target IPv4 address> interface ethernet 1/12
```

For IPv6 addressing, the commands are as follows:

```
Switch# ping6 <target IPv6 address> source <source IPv6 address>
```

```
Switch# ping6 <target IPv6 address> interface ethernet 1/12
```

Ping DF-Bit

By default, echo requests are fragmented when they are forwarded through the network. Configuring packets not to be fragmented when traversing the network can be help in determining the maximum transmission unit (MTU) of the path.

To enable the non-fragmentation of echo requests, use the following command:

```
Switch# ping <target IPv4 address> df-bit
```

Note: This parameter is configurable only for IPv4 addressing.

Ping Timeout

By default, after sending an echo request, ping waits up to a maximum of two seconds for an echo reply. If this time interval expires and an echo reply is not received, ping will declare that the remote host has timed out and that the sent packet is lost.

To configure the timeout interval, in seconds, use the following command:

```
Switch# ping <target IPv4 address> timeout <1-60>
```

For IPv6 addressing, the command is as follows:

```
Switch# ping6 <target IPv6 address> timeout <1-60>
```

Ping VRF

By default, ping uses the default Virtual Routing and Forwarding (VRF) instance. To configure ping to use a different VRF instance, use the following command:

```
Switch# ping <target IPv4 address> vrf {<custom VRF instance>|default|management}
```

Note: You can choose only between the default or management VRF instances.

For IPv6 addressing, the command is as follows:

```
Switch# ping6 <target IPv6 address> vrf {<custom VRF instance>|default|management}
```

Ping Interactive Mode

To configure a custom ping test, you can choose what parameters to change by combining the previously presented commands.

Besides this option, you can customize a ping test by using Ping Interactive Mode. In this mode, you can configure additional parameters: the type of service (ToS), the hop limit or time-to-live (TTL) and the data pattern.

Note: Ping Interactive Mode is only available for IPv4 addressing.

To enter Ping Interactive Mode, use the following command:

```
Switch# ping
```

You are prompted to specify the value of each configurable parameter. If you do not enter a value, the default is used.

```
Switch# ping

Vrf context to use [default]: management
Protocol [ip]:
Target IP address: 10.241.1.11
Repeat count [5]: 7
Datagram size [56]: 100
Timeout in seconds [2]: 1
Sending interval in seconds [1]:
Extended commands [n]: yes
Source address or interface:
Type of service [0]:
Set DF bit in IP header? [no]: yes
Data pattern [0xABCD]:
PATTERN: 0xabcd
PING 10.241.1.11 (10.241.1.11) 100(128) bytes of data.
108 bytes from 10.241.1.11: icmp_seq=1 ttl=61 time=0.337 ms
108 bytes from 10.241.1.11: icmp_seq=2 ttl=61 time=0.288 ms
108 bytes from 10.241.1.11: icmp_seq=3 ttl=61 time=0.311 ms
108 bytes from 10.241.1.11: icmp_seq=4 ttl=61 time=0.288 ms
108 bytes from 10.241.1.11: icmp_seq=5 ttl=61 time=0.317 ms
108 bytes from 10.241.1.11: icmp_seq=6 ttl=61 time=0.288 ms
108 bytes from 10.241.1.11: icmp_seq=7 ttl=61 time=0.315 ms

--- 10.241.1.11 ping statistics ---
7 packets transmitted, 7 received, 0% packet loss, time 5997ms
rtt min/avg/max/mdev = 0.288/0.306/0.337/0.022 ms
```

Interactions with Other Features

When Equal Cost Multiple Paths (ECMP) is enabled, if there are multiple ECMP routes between the switch and the Ping targeted host, then Ping packets travel equally across all ECMP paths.

Traceroute

Traceroute is a diagnostic tool used to determine the network route between the switch and a remote device. It displays the network nodes (routers or gateway devices) crossed by a packet until it arrives at the specified destination.

Traceroute sends a sequence of User Datagram Protocol (UDP) packets addressed to a remote device. To determine the intermediate routers between the source and the destination devices, traceroute adjusts the time-to-live (TTL) value, also known as hop limit, of each sequence of sent packets. When a packet crosses a router, its hop limit is decreased by one. If a router detects a hop limit of zero, it discards the packet and sends the source host an Internet Control Message Protocol (ICMP) error message - Time Exceeded.

Traceroute configures the starting sequence of packets with a hop limit of one. The packets reach the first router and their hop limit is reduced from one to zero. The router will not forward the packets, but will instead discard them. Then, it sends an ICMP error message to the source host.

Traceroute sends the next set of packets with a hop limit of two. This time, the first router forwards the packets, reducing their TTL value from two to one. The packets reach the second router, which updates their hop limit to zero and discards them. Then, the seconds router will send the source host an ICMP error message.

Traceroute continues to send packets with increasing hop limit until the targeted remote device receives the packets and returns an ICMP echo reply.

After receiving the echo reply, traceroute uses the returned ICMP messages to create a list of the routers crossed by the packets. It uses the time interval between transmission and reception of packets as the delay (or latency) value for each node.

The Switch also supports traceroute for IPv6 addressing.

To perform a traceroute test, use the following commands:

- IPv4:

```
Switch# traceroute <target IPv4 address>
```

- IPv6:

```
Switch# traceroute6 <target IPv6 address>
```

For example:

```
Switch# traceroute 10.241.1.11

traceroute to 10.241.1.11 (10.241.1.11), 30 hops max, 56 byte packets
 1  10.241.41.1 (10.241.41.1)  1.988 ms  2.117 ms  2.299 ms
 2  10.241.4.254 (10.241.4.254)  1.903 ms  1.914 ms  2.649 ms
 3  10.241.1.33 (10.241.1.33)  1.138 ms  1.195 ms  1.242 ms
 4  10.241.1.11 (10.241.1.11)  1.085 ms !X  1.079 ms !X  1.087 ms !X
```

Traceroute Configurable Parameters

Traceroute is less customizable than ping, providing options only for choosing the outgoing interface or Virtual Routing and Forwarding (VRF) instance.

Test Interruption

Traceroute tests can be manually stopped at any point in the process. When the interruption is detected, traceroute will stop sending UDP packets and display the results based on the packets transmitted up to that point.

To manually terminate a Traceroute test, press **Ctrl + C**.

Traceroute Source

By default, traceroute automatically chooses the outgoing interface for sending UDP packets and transmits the packets using the IP address of that interface. To check the connectivity of different paths through the network, you can specify the interface used for sending packets.

To use a certain interface during a traceroute test, use the following command:

```
Switch# traceroute <target IPv4 address> source <source IPv4 address>
```

Note: The *source IPv4 address* is the IP address of the desired switch interface.

For IPv6 addressing, the command is as follows:

```
Switch# traceroute6 <target IPv6 address> source <source IPv6 address>
```

In the case of IPv6 addressing, you can also choose the interface used for the traceroute test by directly specifying the desired interface. To achieve this, use the following command (in this example, ethernet port 1/12 is used):

```
Switch# traceroute6 <target IPv6 address> interface ethernet 1/12
```

Traceroute VRF

By default, traceroute uses the default Virtual Routing and Forwarding (VRF) instance. To configure traceroute to use a different VRF instance, use the following command:

```
Switch# traceroute <target IPv4 address> vrf {<custom VRF instance>|default|
|management}
```

Note: You can choose only between the default or management VRF instances.

For IPv6 addressing, the command is:

```
Switch# traceroute6 <target IPv6 address> vrf {<custom VRF instance>|default|
|management}
```

Traceroute Interactive Mode

To customize a traceroute test, you can also use Traceroute Interactive Mode. In this mode, you can configure additional parameters, such as the timeout interval, the hop limit or time-to-live (TTL), or the destination UDP port number.

Note: Traceroute Interactive Mode is only available for IPv4 addressing.

To enter Traceroute Interactive Mode, use the following command:

```
Switch# traceroute
```

You will be prompted to specify the value of each configurable parameter. If you do not enter a value, the default will be used.

```
Switch# traceroute

Vrf context to use [default]: management
Protocol [ip]:
Target IP address: 10.241.1.11
Source address: 10.241.41.27
Numeric display [n]: yes
Timeout in seconds [2]: 1
Probe count [3]: 5
Maximum time to live [30]: 20
Port Number [33434]: 15477
traceroute to 10.241.1.11 (10.241.1.11), 20 hops max, 56 byte packets
 1  10.241.41.1  0.665 ms  0.870 ms  1.102 ms  1.375 ms  1.611 ms
 2  10.241.4.254  1.459 ms  1.530 ms  1.568 ms  1.607 ms  1.646 ms
 3  10.241.1.33  0.790 ms  0.854 ms  1.654 ms  1.701 ms  1.755 ms
 4  10.241.1.11  0.287 ms !X  0.148 ms !X  0.096 ms !X  0.120 ms !X
0.130 ms !X
```

Network Time Protocol

The Network Time Protocol (NTP) is used to synchronize the internal clocks of network devices. This is helpful for troubleshooting network problems by correlating events on different network devices using, for example, syslog messages.

NTP provides the switch with a mechanism to accurately update its clock to be consistent with the clocks of other network devices within a precision of one millisecond.

NTP uses User Datagram Protocol (UDP) to communicate across the network.

By default, the NTP service is enabled on the switch. To enable or disable the NTP service, use the following command:

```
Switch(config)# [no] feature ntp
```

This can also be achieved by using the following command:

```
Switch(config)# [no] ntp enable
```

When NTP is enabled by using the **`ntp enable`** command, any configuration settings are saved in a file on the switch. If the protocol is disabled using the **`no ntp enable`** and then re-enabled, the switch will use that file to restore the NTP configuration. Any NTP commands issued while the protocol is disabled are ignored by the switch.

Note: If the NTP service is disabled by issuing the **`no ntp feature`** command, the NTP configuration is erased and it will not be restored after re-enabling the service.

By default, NTP will communicate across the interfaces configured in the management Virtual Routing and Forwarding (VRF) instance. To allow NTP to transmit and receive information using other VRF instances, use the following command:

```
Switch(config)# ntp use-vrf {default|management}
```

Note: Only the default or management VRF instances can be used.

NTP Synchronization Retry

An NTP synchronization can be manually triggered by using the following command:

```
Switch# ntp sync-retry
```

NTP Client and Peer

The switch can function as an NTP client and synchronize its internal clock with the clock of a remote NTP server. This synchronization is only one way, as the NTP server does not update its clock to match the one of the NTP client.

The switch supports both IPv4 or IPv6 address-based NTP.

To add or remove a remote NTP server, use the following command:

```
Switch(config)# [no] ntp server <IP address>
```

For the purpose of redundancy in scenarios where an NTP server is unreachable, NTP peers can be configured to communicate with each other. This mechanism is called symmetric-active mode and NTP peers associated in this manner can synchronize their internal clocks. The switch clock is updated using the clock of the remote NTP peer and vice-versa.

To add or remove a remote NTP peer, use the following command:

```
Switch(config)# [no] ntp peer <IP address>
```

Note: An NTP server and an NTP peer cannot share the same IP address. If you configure an NTP server using a specific IP address, you cannot use the same address to set up an NTP peer or vice-versa.

To view the list of currently configured NTP servers or peers, use the following command:

```
Switch> show ntp peers

------------------------------------------------------------
Peer IP Address                     Serv/Peer
------------------------------------------------------------
9.110.36.180                        Server (configured)
129.36.17.25                        Server (configured)
10.10.122.36                        Peer (configured)
10.10.122.59                        Peer (configured)
```

Note: The maximum number of NTP servers and peers statically or dynamically configured on the switch is 64.

To view the status of NTP servers and peers, use the following command:

```
Switch> show ntp peer-status

Total peers : 1
* - selected for sync, + - peer mode(active),
- - peer mode(passive), = - polled in client mode
remote              local             st    poll      reach    delay
-------------------------------------------------------------------------
=9.110.36.180       9.111.86.200      16    64        0        0.00000
```

NTP Authentication Field Encryption Key

Information (packets) exchanged between the switch and NTP servers or peers can be configured to include encrypted authentication fields. These fields are encoded using a key.

By default, no encrypted fields are included in NTP packets.

To configure encryption authentication fields for NTP servers, use the following command:

```
Switch(config)# ntp server <IP address> key <1-65534>
```

To configure encryption authentication fields for NTP peers, use the following command:

```
Switch(config)# ntp peer <IP address> key <1-65534>
```

NTP Polling Intervals

The switch will periodically poll configured NTP servers or peers, and synchronize its internal clock.

Each individual NTP server or peer can be configured with different poll intervals by specifying a minimum and maximum time limit. The polling interval limits are configured in seconds, using powers of 2.

Each limit can be configured with a minimum value of 4, meaning 2^4 or 16 seconds, and a maximum value of 16, meaning 2^{16} or 65536 seconds (18.2 hours).

To configure the minimum polling interval for NTP servers, use the following command:

```
Switch(config)# ntp server <IP address> minpoll <4-16>
```

To configure the minimum polling interval for NTP peers, use the following command:

```
Switch(config)# ntp peer <IP address> minpoll <4-16>
```

By default, the minimum polling limit has a value of 4 (16 seconds).

To configure the maximum polling interval for NTP servers, use the following command:

```
Switch(config)# ntp server <IP address> maxpoll <4-16>
```

To configure the maximum polling interval for NTP peers, use the following command:

```
Switch(config)# ntp peer <IP address> maxpoll <4-16>
```

By default, the maximum polling limit has a value of 6 (64 seconds).

NTP Preference

During configuration, some NTP servers or peers can be marked as preferred over other devices. Preferred NTP servers or peers take precedence when a clock update is required.

To configure an NTP server as preferred, use the following command:

```
Switch(config)# ntp server <IP address> prefer
```

To configure an NTP peer as preferred, use the following command:

```
Switch(config)# ntp peer <IP address> prefer
```

Dynamic and Static NTP Servers

Using the Dynamic Host Configuration Protocol (DHCP) client, the switch can dynamically learn the addresses of NTP servers.

The DHCP client will add a dynamic server to the list of NTP servers and peers only if the new server is not already statically configured on the switch, or the list has not reached its maximum size of 64 entries.

Static NTP servers take precedence over the ones dynamically learned through DHCP. Any dynamic NTP server entry is removed if a static entry for the same NTP server is configured on the switch.

If the list of NTP servers and peers is full, a statically configured NTP server will replace the oldest dynamic entry in the list. If there are no dynamic entries, the static server will not be added to the list.

The dynamic learning of NTP servers can only be enabled on individual switch interfaces. For more details, see "DHCPv4 NTP Server (Option 42)" on page 60.

NTP Authentication

The switch can be configured to use authentication keys when exchanging packets with an NTP server. NTP authentication ensures that the internal clock is synchronized only using information received from a trusted NTP server.

NTP authentication uses a digital signature that is added to a packet, and it does not encrypt the data contained inside the packet. The packet and the configured authentication key are used to generate a non-reversible magic number which is appended to the packet. The receiving device does the same computation and then compares the results. If authentication succeeds (the two magic numbers match), the packet is used to synchronize the time. If authentication fails (the two magic numbers do not match), the packet is discarded.

NTP uses two encryption algorithms: Message Digest 5 (MD5) and Secure Hash Algorithm I (SHA-I).

By default, NTP authentication is disabled.

To configure an authentication key, use the following command:

```
Switch(config)# ntp authentication-key <1-65534 (key ID)> {md5|sha1} <key string>
```

Note: You can configure up to 65534 NTP authentication keys. The maximum size of a *key string* is 8 characters. The *key string* is used together with the packet to generate the non-reversible magic number.

To remove an authentication key, use the following command:

```
Switch(config)# no ntp authentication-key <1-65534 (key ID)>
```

To view the configured NTP authentication keys, use the following command:

```
Switch> show ntp authentication-keys
```

Once an authentication key is created, the key can be configured as a trusted key and be used during the NTP authentication process. To enable or disable the use of a specific key in the authentication process, use the following command:

```
Switch(config)# [no] ntp trusted-key <1-65534 (key ID)>
```

To view the list of NTP trusted keys, use the following command:

```
Switch> show ntp trusted-keys
```

To enable or disable NTP authentication, use the following command:

```
Switch(config)# [no] ntp authenticate
```

To check the status of NTP authentication, use the following command:

```
Switch> show ntp authentication-status
```

NTP Authentication Configuration Example

To enable NTP authentication on the switch, use the following steps.

1. Configure an NTP authentication key:

```
Switch(config)# ntp authentication-key 10 sha1 MyString
```

2. Configure the authentication key as a trusted key:

```
Switch(config)# ntp trusted-key 10
```

3. Enable NTP authentication:

```
Switch(config)# ntp authenticate
```

Domain Name Server Client

CNOS offers a Domain Name Server (DNS) client. A DNS is a hierarchical, decentralized naming system for computers and services connected in a network. Mainly, it translates easy-to-remember domain names (such as www.example.com) to numerical IP addresses (92.175.123.87 or 2001::ba5) needed to identify and locate the devices and services. This allows the DNS to be rapidly updated when a service or host location is changed in the network, with no direct impact on its users, who go on using the known host name

To enable or disable the DNS service, enter:

```
Switch(config)# [no] ip domain-lookup
```

To configure a system as a DNS server, enter:

```
Switch(config)# [no] ip name-server <IP address> vrf {default|management}
```

where *IP address* is a valid IPv4 or IPv6 address.

To set the default domain name, enter:

```
Switch(config)# [no] ip domain-name <default domain name> vrf {default|
|management}
```

where *default-domain-name* is a valid domain name.

To add a domain to the list of domain names used by the DNS client, enter:

```
Switch(config)# [no] ip domain-list <domain name> vrf {default|management}
```

where *domain-name* is a valid domain name.

To add or remove a local mapping service between a specific hostname and IP address, enter:

```
Switch(config)# [no] ip host <hostname> <IP address> vrf {default|
|management}
```

where:

Argument	Description
hostname	The host name
IP address	a valid IPv4 or IPv6 address

To see the DNS server running configuration, enter:

```
Switch> show running-config dns
```

To see the DNS server options, such as whether it is enabled or disabled, the default domain, additional domains, name servers ,and IP address to hostname pairs, enter:

```
Switch> show hosts vrf {all|default|management}
```

Notes:

- The maximum number of domain name servers allowed per VRF instance is three.
- The maximum number of domain names allowed in the domain names list per VRF instance is six.
- The maximum number of hostname to IP address mappings allowed per VRF instance is 100.

System Logging

System logging (syslog) is the mechanism through which messages generated by different software components, such as BGP, NTP, or Telnet, are reported by the switch applications. These messages are reported using several types of outputs including the console terminal, virtual teletype (VTY) sessions (Telnet or SSH), log files, or they are sent to remote syslog servers. Logging messages provide operational information about software components, including the status of the application, error reports, and detailed debugging data.

The switch uses the following format when outputting syslog messages:

<Timestamp> <IP/Hostname>`(`*<OS string>*`:`*<VRF name>*`%`*<Syslog ID>*`:[`*<Process Name>*`] <Message>`

Note: The angle brackets (< and >) are not present in the syslog message format, but they are used here to differentiate the individual components of the message.

The following parameters are used:

- *Timestamp*

  The time of the message is displayed in the following format:

  <year>`-`*<month>*`-`*<day>*`T`*<hour(1-24)>*`:`*<minutes>*`:`*<seconds>*`+`*<timezone>*

  For example: `2015-08-01T18:39:59+00:00`

- *IP/Hostname*

  The IP address or hostname is displayed when configured.

  For example: `1.1.1.1` or `Switch`

- *OS string*

  A text string denoting the name of the switch operating system (in this case, `cnos`)

- *VRF name*

  The name of the VRF involved.

- *Syslog ID*

  The syslog ID consists of three components that identify the syslog message:

  <facility>`-`*<severity level>*`-`*<mnemonic>*

  - *facility* - the application to which the message refers (such as `BGP` or `NTP`)
  - *severity level* - the severity level of the message (a integer from 0 to 7)
  - *mnemonic* - a text string that uniquely describes a syslog message

- *Process Name*

  The process name is only used when the syslog message is generated by a shared library facility. In this case, the facility parameter within the Syslog ID field identifies the shared library facility, whereas the application process facility identifies the client process, which is using the shared library.

- *Message*

  The syslog message containing detailed event information.

Following are examples of syslog messages logged by process:

```
2017-05-17T04:50:33+00:00 G8272(cnos:default) %NSM-6-INIT: syslog service
initialized
```

```
2017-05-17T04:51:37+00:00 G8272(cnos:management)
%BGP-6-RIB_SCAN_REMAIN_TIME: RIB-SCAN timer is stopped with
remaining-time: 10 seconds
```

Following is an example of a syslog message logged by a shared library (SECUREIMG) executed in the context of the IMISH process:

```
2017-05-17T21:19:17+00:00 G8272(cnos:default)
%SECUREIMG-6-VALID_IMAGE_DETECTED: [IMISH] Valid image detected
```

Following is an example of a message logged by a sub-application facility (COPP thread of the QoS process):

```
2017-05-17T04:50:33.345+00:00 switch(cnos:default) %COPP-5-PACKET_LIMIT:
Maximum bandwidth utilization reached (port=eth0, limit=1 Gbps)
```

Syslog Output

Syslog messages are stored in two types of log files: the customer log file and the platform log file.

The customer log file stores messages generated by the switch applications. This includes logs that record normal daily operations of the protocols, as well as error conditions detected. These events are primarily used for troubleshooting and auditing. The customer log file is persistent across switch reloads and can be modified or removed. It can be configured to log messages of a certain severity. Its maximum size can also be configured to a value between 4 kilobytes (KB) and 10 megabytes (MB). The log file consists of 8 individual parts, each with a maximum size of 1.25 MB. By default, the switch is configured with a log file that has a maximum size of 10 MB and it stores messages with a severity level of 6 or higher.

The platform log file is used to store system messages generated by the switch operating system. These messages are mostly used for internal and debugging purposes, and are typically not of interest to the end users. These messages are stored in a set of files which are persistent across switch reloads. However, the log file is permanent and it cannot be removed or modified. It logs any system messages regardless of their severity and it consists of four individual parts, each with a maximum size of 1 MB, adding to a maximum total of 4 MB.

To configure the storing of syslog messages in a customer log file on the switch, use the command:

```
Switch(config)# logging logfile <log name> <0-7 (severity level)> size <4,096-10485760
(bytes)>
```

To delete all customer log file entries, use the following command:

```
Switch# clear logging logfile
```

To disable the logging of messages to the log file, use the following command:

```
Switch(config)# no logging logfile
```

Syslog messages can also be enabled to be sent to devices connected via console or virtual teletype (VTY) sessions (Telnet, SSH), or to remote dedicated syslog servers. By default, the logging of messages is enabled on console sessions for messages with a severity level of 2 or higher, and on VTY sessions for messages with a severity level of 5 or higher.

To enable or disable message logging on console sessions, use the command:

```
Switch(config)# [no] logging console
```

To enable or disable message logging on VTY sessions, use the command:

```
Switch(config)# [no] logging monitor
```

To enable or disable message logging to the current terminal, use the command:

```
Switch(config)# [no] logging terminal
```

Syslog Severity Levels

System Logging has eight severity levels that are attributed with a syslog message. They are commonly associated with an integer from 0 to 7, where 0 is the highest severity level and 7 the lowest.

Following are the different types of syslog severity levels:

- Emergency (0) - the system is unstable
- Alert (1) - a major error has occurred, that requires immediate action
- Critical (2) - an urgent error occurred, that requires immediate action
- Error (3) - a non-urgent error occurred
- Warning (4) - indication that an error might occur if not remedied
- Notice (5) - unusual events, but not error conditions
- Informational (6) - normal operation messages
- Debug (7) - information useful for debugging

When a severity level is configured, the switch will only log messages that have a severity equal or greater than the configured value. For example, when setting a severity level of 4, the switch will log messages that have a severity of 0, 1, 2, 3, or 4. Messages with a severity level of 5, 6, or 7 are not logged.

Each software component (such as OSPF or Telnet) or facility on the switch can be configured with a different severity level. While message logging for a component cannot be disabled, the severity level can be set to emergency (0), logging only the most severe messages for the specified component.

To configure the severity level of a facility, use the following command:

```
Switch(config)# logging level <facility> <0-7 (severity level)>
```

You can configure the severity level of all facilities by using the following command:

```
Switch(config)# logging level all <0-7 (severity level)>
```

Note: Each facility has its own default syslog severity level, which is usually different among facilities.

To view the severity level of a facility, use the following command:

```
Switch(config)# show logging level <facility>
```

To reset the severity level to its default value, use the following command:

```
Switch(config)# [no] logging level <facility>
```

For more details on syslog severity level commands, consult the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

Syslog Time Stamping

Each syslog message is generated with a timestamp that specifies the moment in time when the event of the message occurred.

The timestamp of a syslog message has the following syntax:

<*year*>-<*month*>-<*day*>-T<*hour*>:<*minutes*>:<*seconds*>+<*timezone*>

Note: The angle brackets (< and >) are not present in the timestamp syntax, but they are used here to differentiate the individual components of the message.

For example: `2015-08-01T18:39:59+00:00`

By default, syslog uses seconds as its base unit for timestamps. System logging can be configured to add fractions of a second (milliseconds or microseconds) to the timestamp of a message. To achieve this, use the following command:

```
Switch(config)# logging timestamp {microseconds|milliseconds|seconds}
```

To reset syslog to use seconds in timestamps, use the following command:

```
Switch(config)# no logging timestamp {microseconds|milliseconds|seconds}
```

Syslog Rate Limit

By default, the switch has a limit of how many messages it can log during a specific time interval. Any messages received above the maximum limit are not logged.

For system messages, the default rate limit is 512 messages every 5 seconds.

For every severity level, the default rate limit is 1024 messages every 10 seconds. Regardless of the software component that generated them, only 1024 messages with a certain severity can be logged during 10 seconds.

For every software component, the default rate limit is 512 messages every 10 seconds.

To configure the rate limit of a specific type of syslog message, use the following command:

```
Switch(config)# logging rate-limit num {<number of messages (1-4096)>|default}
interval {<1-600>|default} {facility <facility>|level <severity level (0-7)>|system}
```

To display the current syslog rate limit configuration, use the following command:

```
Switch(config)# show logging rate-limit
```

To disable syslog rate limiting, use the following command:

```
Switch(config)# no logging rate-limit {facility <facility>|level <severity level
(0-7)>|system}
```

For more details on syslog rate limit commands, consult the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

User Action Logging

By default, user action logs are saved to a file without displaying them on the console, or Telnet and SSH terminals.

User action logging has a severity level of informational (6).

You can configure whether user actions are logged to the console or to terminals (SSH or Telnet). To enable or disable user action logging on the console or on terminals, use the following command:

```
Switch(config)# [no] event-log {console|terminal} enable
```

You can also enable user action logging when using the CLI, REpresentational State Transfer (REST), or Simple Network Management Protocol (SNMP). To enable or disable user action logging for CLI, REST, or SNMP, use the following command:

```
Switch(config)# [no] event-log {cli|rest|snmp} enable
```

Note: For CLI, REST, or SNMP user action logging, their respective result (success or fail) is also logged.

Syslog Servers

You can configure the logging of messages to a remote dedicated syslog server. This can be statically configured, or dynamically learned via the Dynamic Host Configuration Protocol (DHCP).

By default, the logging of messages to a dedicated syslog server is disabled.

To add a static remote syslog server, use the following command:

```
Switch(config)# logging server <IP address> [<severity level (0-7)>] [vrf {data|
|management}] [facility <facility>] [protocol {tcp|udp}] [port <1-65535>]
```

To remove a static remote syslog server, use the following command:

```
Switch(config)# no logging server <IP address> [vrf {data|management}]
```

The severity level of a static syslog server can be configured by specifying its value when running the above command. If the severity level is not explicitly configured, the default value, debug (7), is used.

Static syslog servers take precedence over dynamically learned ones. If a syslog server is added using DHCP and then a static server is configured on the switch, the dynamic entry may be removed if one of the following conditions is met:

- the static server being added has the same IP address as the currently configured dynamic server
- the maximum number of servers allowed for a given type of IP addressing or address family (IPv4 or IPv6) has been reached

If a syslog server is already statically configured on the switch, it will not be dynamically added to the list.

Each Virtual Routing and Forwarding (VRF) instance on the switch has a limit on the number of configured syslog servers (static or dynamic). The limit is three servers for each type of IP address family, meaning that the switch can have up to three configured IPv4 syslog servers and up to three configured IPv6 syslog servers on each VRF instance.

Note: Only DHCPv4 can be configured to request syslog server addresses from a DHCP server. Thus, only IPv4 syslog servers can be dynamically learned. IPv6 syslog servers can only be added statically.

The dynamic learning of syslog servers can be achieved only on individual switch interfaces. For more details, see "DHCPv4 Syslog Server (Option 7)" on page 59.

Note: The severity level of dynamic syslog servers is debug (7).

As soon as a valid static or dynamic syslog server address is known by the switch, it immediately starts forwarding syslog messages to the remote server.

Note: The switch does not send syslog messages to syslog servers defined using DNS that are accessible through the default Virtual Routing and Forwarding (VRF) instance. DNS defined syslog servers using the management VRF instance are able to receive syslog messages from the switch.

Console Logging Flood Control

Syslog flooding occurs when one or more software components fail to function correctly and start to continuously generate a large number of syslog messages over a long time interval. Depending on the switch configuration, such syslog messages can be sent to devices connected through console or virtual teletype (VTY) sessions (Telnet, SSH).

Note: By default, the switch sends syslog messages to devices connected through a terminal connection (console, Telnet, or SSH).

Because terminal connections have a limited number of lines that can be displayed on the screen during a session, syslog flooding can cause the loss of control of the switch. The syslog messages appear on the screen faster than commands can be issued and processed correctly by the switch.

In the case where other connection options (for example SNMP or Python scripting) are not available, to regain control over the switch you must power down the device by disconnecting it from the power source. Syslog flooding can also happen during the switch startup process, before the configuration can be modified or other connection option can be set up.

Console Logging Flood Control enables you to regain control over the terminal during syslog flooding. During a storm of syslog messages press **Ctrl + C** three times during a three second time interval. A confirmation message is displayed indicating that syslog messages will not be sent to the console. The message will also inform you that the sending of syslog messages to the console cannot be re-enabled for the following 60 seconds. After this one minute time period has expired, the sending of syslog messages to the console can be re-enabled by pressing **Ctrl + C** three times during a three second time interval.

From the moment the confirmation message is displayed, you can access the switch and resolve the problem by correcting the configuration issue. For example, disabling the logging of messages to the console, modifying the severity level of the software component that generated the syslog flood, or modify the configuration of that application.

Duplicate Syslog Message Suppression

Duplicate Syslog Message Suppression prevents the switch from logging more than one copy of a repetitive syslog message. When a sequence of identical syslog messages is detected, the first message is logged and its timestamp is recorded. The following repetitive syslog messages are suppressed for a certain time interval and they are not logged by the switch.

The first occurrence of the repetitive syslog message is always logged at the moment it happens. The following duplicate messages are suppressed during three different time intervals (suppression intervals). After a suppression interval, a summary message is displayed informing about the number of times the syslog message repeated.

Initially, duplicate messages are suppressed for 30 seconds after the first occurrence. If this time interval expires and the syslog message still repeats, it will be suppressed for another 120 seconds (2 minutes). The third time, the suppression interval is increased to 600 seconds (10 minutes). At the end of each suppression interval, the next duplicate syslog message will trigger the summary message. The expiration of a suppression interval does not generate the summary message. If the time interval expires and no duplicate syslog messages are logged, the summary message can be delayed well beyond the suppression interval.

By default, duplicate syslog message suppression is disabled on the switch. To enable or disable it, use the following command:

```
Switch(config)# [no] logging throttle
```

The following is an example of duplicate syslog message suppression and the summary message after the first suppression interval:

```
2016-07-2T7:39:10+00:00 switch(data) %TELNET-3-ERR_CONNECT: Failed to
obtain a VTY for a session: ''tty-server' detected the 'resource not
available' condition' There are no TTYs available

2016-07-2T7:39:45+00:00 switch(data) %TELNET-3-ERR_CONNECT: last message
repeated 2 times
```

The suppression of duplicate syslog messages is interrupted if a new syslog message is detected. The new syslog message is logged immediately, thus canceling the current suppression interval. Other syslog messages from the previous sequence are considered as new and the suppression process starts over.

Core Dump Information

When a core dump occurs, a core dump file is created, and the following notice is added to the system banner after login:

```
=========================================================================
+ NOTE: Core dump files exist in FLASH.                                  +
+       Use 'show cores' to see a list of all existing core dumps.      +
+       Use 'system cores' to upload the core dumps for analysis.       +
+       Use 'clear cores' to erase the dumps from FLASH.                +
+-----------------------------------------------------------------------+
+ Core file                   | Date / time                             +
+-----------------------------------------------------------------------+
+ core.hsl                    | 2018-06-15 12:54:37                     +
+ .core_url_info              | 2018-06-15 14:43:34                     +
+ core.hsl.gz                 | 2018-06-15 14:49:59                     +
=========================================================================
```

To list all the core dump files currently stored on the switch, use the following command:

```
Switch# show cores
```

To delete all the core dump files stored on the switch, use the following command:

```
Switch(config)# clear cores
```

Login Banners

The switch allows the configuration of the message-of-the-day (MOTD) banner that is displayed after a successful login, and the pre-login banner that is displayed before logging onto the switch.

The login banners have the following limitations:

- the maximum length of the banner message is 2 kilobytes
- the maximum length of each banner line is 512 bytes
- the maximum number of lines is 1,024

To configure the MOTD banner, use the following command:

```
Switch(config)# banner motd <message>
```

To disable the displaying of the MOTD banner, use the following command:

```
Switch(config)# no banner motd
```

To reset the MOTD banner to its default value, use the following command:

```
Switch(config)# banner motd default
```

The default MOTD banner value has the following format:

NOS <*System Firmware Version*> Lenovo <*System name*>, <*System build time*>

For example:

```
NOS 10.8.1.0 Lenovo RackSwitch G8272, July 31 19:42:56 EDT 2018
```

To display the currently configured MOTD banner, use the following command:

```
Switch> show banner motd
```

To configure the pre-login banner, which is displayed before logging onto the switch, use the following message:

```
Switch(config)# banner login <message>
```

To disable the displaying of the pre-login banner, use the following command:

```
Switch(config)# no banner login
```

To display the currently configured pre-login banner, use the following command:

```
Switch> show banner login
```

You can configure login banners with multiple screen lines. Each banner line can be set using a single command. Each consecutive command does not overwrite the previous banner message, but instead adds a new line to the message.

```
Switch(config)# banner motd message_line_1
Switch(config)# banner motd message_line_2
Switch(config)# show banner motd

message_line_1
message_line_2
```

You can also delete specific lines from the banner message instead of deleting the whole message. To delete a specific banner line, use the following command:

```
Switch(config)# no banner motd <1-1024>
```

For example:

```
Switch(config)# show banner motd

message_line_1
message_line_2

Switch(config)# no banner motd 1
Switch(config)# show banner motd

message_line_2
```

Idle Disconnect

By default, the switch will disconnect your Telnet session after 10 minutes of inactivity. This function is controlled by the idle timeout parameter, which can be set from 0 to 35791 minutes, where 0 means the session will never timeout.

Use the following command to set the idle timeout value:

```
Switch# terminal session-timeout <0-35791>
```

Note: This command only applies to the current terminal session.

Python Scripting

You can create and execute local Python scripts on switches to make small programs that allow a switch to automatically provision itself, perform fault monitoring, upgrade the image files, or auto-generate configuration files. You can use local scripts as a key part of your auto-provisioning solutions. You can also manage scripts on the switch.

You can implement version control systems, automatically generate alerts, create custom logging tools, and automate the management of network devices. Using Python scripts, you can perform many functions that can be performed through the CLI. In addition to configuration, you can notify users by sending e-mails or updating the syslog.

To enter the Python Programming Shell, use the following command:

```
Switch# python

>>>
```

To exit the Python Programming Shell, use the following command:

```
>>> quit()

Switch#
```

Note: You can also press **Ctrl + D** to exit the Python Programming Shell.

See the *Lenovo Network Python Programming Guide for Lenovo Cloud Network Operating System 10.9* for details on how to create and execute Python scripts.

REST API Programming

The Lenovo REpresentational State Transfer (REST) Application Program Interface (API) enables you to remotely configure and manage a Lenovo switch using REST and HyperText Transfer Protocol (HTTP).

The REST API is a JavaScript Object Notation-based (JSON) wrapper around Lenovo's Python Programming interface. It is a component of Configuration, Management, and Reporting (CMR) on CNOS.

To enable and disable REST API on the switch, use the following command:

```
Switch(config)# [no] feature restApi
```

The default settings for REST API is enabled. HTTPS is also enabled by default.

To view the current state of REST API, use the following command:

```
Switch> show restApi server

rest server enabled port: 443
restApi pki rest_mgmt vrf management
restApi pki rest_default vrf default
```

See the *Lenovo REST API Programming Guide for Lenovo Cloud Network Operating System 10.9* for details on how to use the Lenovo REST API.

Chapter 3. System License Keys

License keys determine the number of available features on the switch. Each switch comes with a basic license that provides the use of a limited number of functions. On top of the basic license, optional upgrade licenses can be installed to expand the number of available features.

License keys will be installed only once per feature on a specific switch, regardless of the Lenovo Network OS used. When a new Lenovo NOS is installed on the switch, the license keys will need to be reinstalled.

For G8272, a switch supporting dual boot, meaning it can run both Lenovo Enterprise Network OS (ENOS) and Lenovo Cloud Network Operating System (CNOS), a license key installed using CNOS will be also available in ENOS and vice-versa.

This section discusses the following topics:

Obtaining License Keys

License keys or activation keys can be acquired using the *Lenovo System x Features on Demand* (FoD) website:

https://fod.lenovo.com/lkms/angular/app/pages/index.htm#/welcome

You can also use the website to review and manage licenses, and to obtain additional help if required.

Note: If you have a Lenovo ID, you can register at the website.

License keys are provided as files that must be uploaded to the switch. To acquire an activation key, use the FoD website to obtain an Authorization Code. You will need to provide the unique ID (UID) of the specific switch where the key will be installed. The UID is the last 12 characters of the switch serial number. This serial number is located on the Part Number (PN) label and is also displayed during successful login to the device.

You can view the UID of a switch using the following command:

```
Switch> show license host-id

System serial number: Y052MV4CR026
```

When available, download the activation key file from the FoD site.

Installing License Keys

Once an FoD license key file have been acquired, it must be installed on the switch.

To install activation keys using the switch CLI:

1. Log into the switch.
2. Enter Global Configuration command mode:

```
Switch> enable
Switch# configure [terminal]
Switch(config)#
```

3. Install the license key by copying it from a remote server or a USB device:
   - Remote FTP, SCP, SFTP, or TFTP server:

```
Switch(config)# license install {ftp|scp|sftp|tftp} <server address and file path> vrf management
```

   For example, using a TFTP server:

```
Switch(config)# license install tftp
tftp://10.120.33.12/fod-keys/fodEE3 vrf management
```

   - USB device:

```
Switch(config)# license install usb1 <file path>
```

   For example:

```
Switch(config)# license install usb1 fod-keys/fodEE3
```

   Note: Repeat this step when installing multiple license keys.

   The license key has now been successfully installed on the switch.

4. If using a USB device, dismount it:

```
Switch(config)# system eject-usb
```

5. To view installed license keys, use the following command:

```
Switch> show license brief
```

Uninstalling License Keys

If you wish to remove or disable a feature that is available only through the use of a license key, you can achieve this by using the following command:

```
Switch(config)# no license install <license file>
```

For example:

```
Switch(config)# no license install fodEE3
```

Note: When removing the ONIE license key from the switch, the ONIE software image is also removed.

Transferring License Keys

Licenses keys are based on the unique switch device serial number and are non-transferable.

In the event that the switch must be replaced, a new activation key must be acquired and installed. When the replacement is handled through IBM Service and Support, your original license will be transferred to the serial number of the replacement unit and you will be provided with a new license key.

ONIE License Key

The Open Network Install Environment (ONIE) is a small Linux-based operating system that provides an open install environment for networking devices without operating systems.

ONIE is pre-installed on the NE10032 and the NE2572 switches; it is not pre-installed on other switches, and it can be activated only using an FoD license key. The process of obtaining and installing an activation key is described in "Obtaining License Keys" on page 98.

After you have successfully installed the appropriate FoD license key, you will be able to install ONIE on the switch. For more details on ONIE and how to install and use it, see the *Lenovo Network ONIE User Guide*.

Note: ONIE is not supported on the G8332.

Chapter 4. Switch Software Management

The switch software image is the executable code running on the device. A version of the image comes pre-installed on the device. As new versions of the image are released, you can upgrade the software running on your switch. To get the latest version of software supported for your switch, go to the following website:

http://support.lenovo.com

To determine the software version currently used on the switch, use the following switch command in Privileged EXEC mode:

```
Switch# show boot

Current FLASH software:
  active image: version 10.9.2.0, downloaded 02:05:34 UTC Sun May 15 2016
  standby image: empty
  Uboot: version 10.9.2.0, downloaded 02:05:36 UTC Sun May 15 2016
  ONIE: empty
Currently set to boot software active image
Currently scheduled reboot time: none
Current port mode: default mode
```

The typical upgrade process for the software image consists of the following steps:

1. Load a new firmware image and boot image onto an FTP, SFTP, HTTP, SCP, or TFTP server on your network.
2. Transfer the new images to your switch.
3. Specify the new software image as the one which will be loaded into switch memory the next time a switch reload occurs.
4. Reload the switch.

For instructions on the typical upgrade process using the CNOS ISCLI, see "Installing New Software to Your Switch" on page 104.

CAUTION:
Although the typical upgrade process is all that is necessary in most cases, upgrading from (or reverting to) some versions of Lenovo Cloud Network Operating System requires special steps prior to or after the software installation process. Please be sure to follow all applicable instructions in the release notes document for the specific software release to ensure that your switch continues to operate as expected after installing new software.

Installing New Software to Your Switch

The switch can store up to two different CNOS images (called `active` and `standby`) and a special boot software named U-boot. U-Boot is an open source, primary boot loader used to package the instructions needed to boot the switch operating system kernel.

When you install a new CNOS image, it will be placed in the standby image on the switch. When you reload the switch using the standby image, it is swapped with the active image. After the switch reloads, the current active image will become the new standby image, and the current standby image will become the new active image.

Note: U-boot is included in the CNOS image.

To load a new software image to your switch, you will need the following:

- The new software image loaded on a FTP, SCP, HTTP, SFTP, or TFTP server on your network.
- The IP address of the FTP, SCP, HTTP, SFTP, or TFTP server.
- The name of the new system image or ONIE image.

Note: Before installing an ONIE image on the switch, you need to install the appropriate license key. For more details, see "System License Keys" on page 97.

When the software requirements are met, use the following procedures to download the new software to your switch using the ISCLI.

Installing System Images from a Remote Server

1. In Privileged EXEC mode, enter the following command:

```
Switch# copy {ftp|http|scp|sftp|tftp} <server address and file path> system-image
os vrf management
```

For example, using the TFTP protocol:

```
Switch# copy tftp tftp://10.120.33.12/nos-images/G8xxx-CNOS-10.9.1.0.imgs
system-image os vrf management
```

The exact form of the server address and the file path of the CNOS image will vary by server. However, the file location is normally relative to the FTP, SCP, SFTP, or TFTP directory (for example, `tftpboot`).

Note: If you use the parameter **`all`** instead of **`os`** you will also install the U-boot file included in the CNOS image. You will also get updates and fixes made to the boot and OS images, as well as error messages you can ignore.

2. If required by the FTP, SCP, or SFTP server, enter the appropriate username and password.

3. You will be prompted to confirm the download of the CNOS image:

```
Confirm download operation? (y/n) [n]
```

Once confirmed, the software will begin loading into the switch.

```
Confirm download operation? (y/n) [n] y
Download in progress
.....................................................................
Copy Success

Install image...This takes about 90 seconds. Please wait
Valid image detected.
Check image signature succeeded
Extracting image: 100%
Installing system image to slot 2:
Installing image: 100%
Extracting image: 100%
OS image installation succeeded.

Standby image now contains Software Version 10.9.2.0
```

4. The new CNOS version is installed as the standby image. Once the installation is successful, you are asked if you want the switch to boot next time using the new image.

```
Switch is currently set to boot active image.
Do you want to change that to the standby image? (y/n) [n] y
Switch is to be booted with standby image.
```

5. Reboot the switch to run the new CNOS version:

```
Switch# reload
```

The system prompts you to confirm your request. Once confirmed, the switch will reboot to use the new CNOS image.

Note: Any unsaved configuration changes will be lost once the switch starts reloading.

Installing System Images from a USB Device

1. Use the following command to copy a CNOS image from a USB drive to the switch:

```
Switch# copy usb1 <file path> system-image os
```

In this example, a CNOS image is copied from a directory on a USB drive:

```
Switch# copy usb1 nos-images/G8xxx-CNOS-10.9.1.0.imgs system-image os
```

Note: If you use the parameter **all** instead of **os** you will also install the U-boot file included in the CNOS image. You will also get updates and fixes made to the boot and OS images, as well as error messages you can ignore.

2. You will be prompted to confirm the download of the CNOS image:

```
Confirm download operation? (y/n) [n]
```

Once confirmed, the software will begin loading into the switch.

```
Confirm download operation? (y/n) [n] y
Download in progress
.....................................................................
Copy Success

Install image...This takes about 90 seconds. Please wait
Valid image detected.
Check image signature succeeded
Extracting image: 100%
Installing system image to slot 2:
Installing image: 100%
Extracting image: 100%
OS image installation succeeded.
Standby image now contains Software Version 10.9.2.0
```

3. The new CNOS version is installed as the standby image. Once the installation is successful, you are asked if you want the switch to boot next time using the new image.

```
Switch is currently set to boot active image.
Do you want to change that to the standby image? (y/n) [n] y
Switch is to be booted with standby image.
```

4. Dismount the USB drive:

```
Switch(config)# system eject-usb
```

5. Reboot the switch to run the new software:

```
Switch# reload
```

The system prompts you to confirm your request. Once confirmed, the switch will reboot to use the new software.

Note: Any unsaved configuration changes are lost once the switch starts reloading.

Installing U-boot from a Remote Server

1. In Privileged EXEC mode, enter the following command:

```
Switch# copy {ftp|http|scp|sftp|tftp} <server address and file path> system-image
boot vrf management
```

For example, using the TFTP protocol:

```
Switch# copy tftp tftp://10.120.33.12/nos-images/G8xxx-CNOS-10.9.1.0.imgs
system-image boot vrf management
```

Note: If you use the parameter **`all`** instead of **`boot`** you will also install the CNOS image. You will also get updates and fixes made to the boot and OS images, as well as error messages you can ignore.

The exact form of the server address and the file path of the U-boot file will vary by server. However, the file location is normally relative to the FTP, SCP, HTTP, SFTP, or TFTP directory (for example, `tftpboot`).

2. If required by the FTP, SCP, HTTP, or SFTP server, enter the appropriate username and password.

3. You will be prompted to confirm the download of the U-boot file:

```
Confirm download operation? (y/n) [n]
```

Once confirmed, the software will begin loading into the switch.

```
Confirm download operation? (y/n) [n] y
Download in progress
.....................................................................
Copy Success

Install image...This takes about 90 seconds. Please wait
Valid image detected.
Check image signature succeeded
Extracting image: 100%
Installing Boot Loader:
Updating flash: 100%
Boot image installation succeeded.
Boot loader now contains Software Version 10.9.2.0
```

On the next reload, the switch will use the new U-boot file.

Installing U-boot from a USB Device

1. Use the following command to copy a U-boot file from a USB drive to the switch:

```
Switch# copy usb1 <file path> system-image boot
```

In this example, a U-boot file is copied from a directory on the USB drive:

```
Switch# copy usb1 nos-images/G8xxx-CNOS-10.9.1.0.imgs system-image boot
```

Note: If you use the parameter **all** instead of **boot** you will also install the CNOS image.

2. You will be prompted to confirm the download of the software image:

```
Confirm download operation? (y/n) [n]
```

Once confirmed, the software will begin loading into the switch.

```
Confirm download operation? (y/n) [n] y
Download in progress
.....................................................................
Copy Success

Install image...This takes about 90 seconds. Please wait
Valid image detected.
Check image signature succeeded
Extracting image: 100%
Installing Boot Loader:
Updating flash: 100%
Boot image installation succeeded.
Boot loader now contains Software Version 10.9.2.0
```

On the next reload, the switch will use the new U-boot file.

Selecting a Software Image to Run

The switch can store up to two CNOS images. These images are referred to as the active and standby images. The active image is the image that the switch is currently using when rebooting. The standby image is the image that the switch keeps as backup, in case of a failure when booting the active image.

To see what CNOS versions are stored in each image and what image is configured to be used on the next reload, use the following command:

```
Switch# show boot

Current FLASH software:
  active image: version 10.9.2.0, downloaded 11:45:39 UTC Mon Feb 15 2016
  standby image: version 10.9.2.0, downloaded 14:44:26 UTC Tue Feb 9 2016
  Uboot: version 10.9.2.0, downloaded 11:17:04 UTC Wed Nov  4 2015
Currently set to boot software active image
Currently scheduled reboot time: none
Current port mode: default mode
```

You can choose which CNOS image the switch will use on the next reload by running the following command:

```
Switch(config)# boot image {active|standby}
```

For example:

```
Switch(config)# boot image standby

Switch# show boot

Current FLASH software:
  active image: version 10.9.1.0, downloaded 11:45:39 UTC Mon Feb 15 2016
  standby image: version 10.9.1.0, downloaded 14:44:26 UTC Tue Feb 9 2016
  Uboot: version 10.9.1.0, downloaded 11:17:04 UTC Wed Nov  4 2015
Currently set to boot software standby image
Currently scheduled reboot time: none
Current port mode: default mode
```

The switch will now reload using the standby image. After reloading, the switch interchanges the CNOS images. The standby image before the reload becomes the new active image and vice-versa.

Reloading the Switch

You can reboot the switch to make your CNOS image files changes occur.

Normal Reboot

To reboot the switch, use the following command:

```
Switch# reload
```

You are prompted for confirmation:

```
Switch# reload

reboot system? (y/n):
```

After confirming, the switch will halt and perform a reboot. Any opened sessions will be closed. After the reload is complete, you'll have to log in the switch.

```
Switch# reload
reboot system? (y/n): y

Broadcast message from root@switch (Mon Feb 15 15:47:06 2016):

The system ireboot: Restarting system
...
G8xxx login:
```

Note: Any unsaved configurations will be lost once the reboot process starts.

Scheduled Boot

The scheduled boot feature lets you schedule a switch reload in a future time, enabling you to perform switch upgrades during off-peak hours. To set up a scheduled reboot, enter:

```
Switch# reload schedule {monday|tuesday|wednesday|thursday|friday|
|saturday|sunday} HH:MM [reason <reason>]
```

where:

Parameter	Description
monday	Reboot on Monday.
tuesday	Reboot on Tuesday.
wednesday	Reboot on Wednesday.
thursday	Reboot on Thursday.
friday	Reboot on Friday.
saturday	Reboot on Saturday.
sunday	Reboot on Sunday.
HH:*MM*	Hours and minutes in 24-hour format
reason	(Optional) The reason for the reboot

If there is unsaved information, an error message occurs. To confirm the reboot, enter **y**. Note that any unsaved information will be lost once the reboot starts.

```
WARNING: There is unsaved configuration!!!
Confirm scheduled reboot ? (y/n): y
```

To cancel a scheduled reboot, enter:

```
Switch# reload schedule cancel
```

To display the boot schedule state, enter:

```
Switch# show boot
```

Note: If the switch is rebooted prior to the scheduled reboot time, the previously scheduled reboot will be removed from the configuration, effectively cancelling the scheduled reboot.

Copying Configuration Files

You can also copy running and startup configuration files to or from the switch. This can be done via a remote server or a USB device.

Note: You cannot copy to the switch configuration files that exceed 4 MB in size or that have a line count larger than 100,000 lines.

Copy Configuration Files via a Remote Server

You can use the ISCLI to copy configurations files from or to a remote FTP, SCP, SFTP, HTTP, or TFTP server.

Use the following command to copy the startup configuration file from a remote server:

```
Switch# copy {ftp|http|scp|sftp|tftp} [<server URL and file path>] startup-config
```

For example, using the TFTP protocol:

```
Switch# copy tftp tftp://10.120.33.12/conf/mystartup.cfg startup-config
```

Use the following command to copy the running configuration file from a remote server:

```
Switch# copy {ftp|scp|sftp|tftp} [<server URL and file path>] running-config
```

For example, using the TFTP protocol:

```
Switch# copy tftp tftp://10.120.33.12/conf/mystartup.cfg running-config
```

Use the following command to copy the startup configuration file to a remote server:

```
Switch# copy startup-config {ftp|scp|sftp|tftp} <server URL and file path>
```

For example, using the TFTP protocol:

```
Switch# copy startup-config tftp tftp://10.120.33.12/conf/mystartup.cfg
```

Use the following command to copy the running configuration file to a remote server:

```
Switch# copy running-config {ftp|scp|sftp|tftp} <server URL and file path>
```

For example, using the TFTP protocol:

```
Switch# copy running-config tftp tftp://10.120.33.12/conf/myrunning.cfg
```

Copy Configuration Files to a USB Device

You can insert a USB drive into the USB port on the switch. You can copy files to the USB drive.

Use the following command to copy a configuration file to the USB drive:

```
Switch# copy {running-config|startup-config} usb1 <file path>
```

In this example, the running configuration file is copied to a directory on the USB drive:

```
Switch# copy running-config usb1 configuration/myconfig.cfg
```

To dismount a USB device, enter:

```
Switch# system eject-usb
```

Firmware Image Downgrade

Note: When upgrading to CNOS 10.7 or a later firmware version, we recommend that you save a copy of the switch's startup configuration by using one of the following commands:

- Copy the configuration file to a remote FTP/SCP/SFTP/TFTP server:

```
Switch# copy file config-10-6 {ftp|scp|sftp|tftp} <server URL and file path>
```

- Copy the configuration file to a USB drive:

```
Switch# copy file config-10-6 usb1 <file path>
```

For example, back up the startup configuration to a remove SFTP server:

```
Switch# copy file config-10-6 sftp
sftp://10.120.33.12/configs/10-6-config-backup.cfg
```

When performing a firmware downgrade from CNOS 10.7 or later to CNOS 10.6 or an earlier version, the following warning message appears:

```
WARNING: Downgrade from 10.7.x or later to 10.6.x or earlier version
detected. Prior to proceeding with the downgrade, please save/backup the
10.6.x or earlier version startup-config file by using the 'copy file
config-10-6' command. After the downgrade, once the switch comes up on
10.6.x or earlier version, the saved 10.6.x or earlier version
startup-config file needs to be copied over to the running and startup
configuration manually.
```

After you downgrade to firmware image to CNOS 10.6 or an earlier version, copy the backed up startup configuration to the switch.

Resetting the Switch to the Factory Defaults

To reset the switch to its factory default settings, use the following procedure:

1. Erase the switch start-up configuration:

```
Switch# write erase

Warning: This command will erase the startup-configuration.
Do you wish to proceed anyway? (y/n)  [n] y
```

   Enter **y** at the prompt to confirm the erasing process.

2. Reload the switch:

```
Switch# reload
```

Converting the Switch Software Image from CNOS to ENOS

If you want to return to the legacy 8.x ENOS image, you must reinstall it.

Notes:

- For the G8296 and the G8332, Lenovo Cloud Network OS image cannot coexist on the switch with your legacy 8.x Lenovo NOS. All previous configuration will be lost.
- For the G8272, Lenovo offers the capability to store both CNOS and ENOS images on the switch. The first time the switch reboots with ENOS, the CNOS configuration is set to factory default. If you already installed the legacy 8.x ENOS image on your switch, please go to "Switching Between ENOS and CNOS Images Loaded on the G8272" on page 119.
- The ThinkSystem switches only run Cloud NOS; they do not run Lenovo Enterprise NOS.

1. Download the ENOS boot image to the switch and enter **y** to confirm the download operation.

```
Switch# copy tftp tftp://<tftp server IP>/G8296-8.4.2.0_Boot.imgs system-image
boot vrf management
Confirm download operation? (y/n) [n] y
Download in progress
..........
Copy Success

Install image...This takes about 90 seconds. Please wait
Check image signature succeeded
Extracting image: 100%
Installing eNOS RFS:
Updating flash: 100%
Extracting image: 100%
Installing eNOS Kernel:
Updating flash: 100%
Extracting image: 100%
Installing eNOS DFT:
Updating flash: 100%
Extracting image: 100%
Installing uboot:
Updating flash: 100%
Boot image installation succeeded.
```

2. Download the ENOS system image to the switch and enter **y** to confirm the download operation:

```
Switch# copy tftp tftp://<tftp server IP>/G8296-8.4.2.0_OS.imgs system-image
os vrf management
Confirm download operation? (y/n) [n] y
Download in progress
.........
Copy Success
Install image...This takes about 90 seconds. Please wait
Check image signature succeeded
Extracting image: 100%
Installing E-NOS image to image1
Installing image to E-NOS image1: 100%
OS image installation succeeded.
```

Notes:

- You can also install the boot and system images using the following commands:

```
Switch# copy tftp tftp://<tftp server IP>/<switch_model>-8.4.2.0_Boot.imgs
system-image all vrf management
```

```
Switch# copy tftp tftp://<tftp server IP>/<switch_model>-8.4.2.0_OS.imgs
system-image all vrf management
```

- If you use the `all` argument instead of `boot` or `os`, an "`image installation failed`" message will appear for whichever type of image you are not installing. You can ignore these error messages.

3. Reboot the switch.

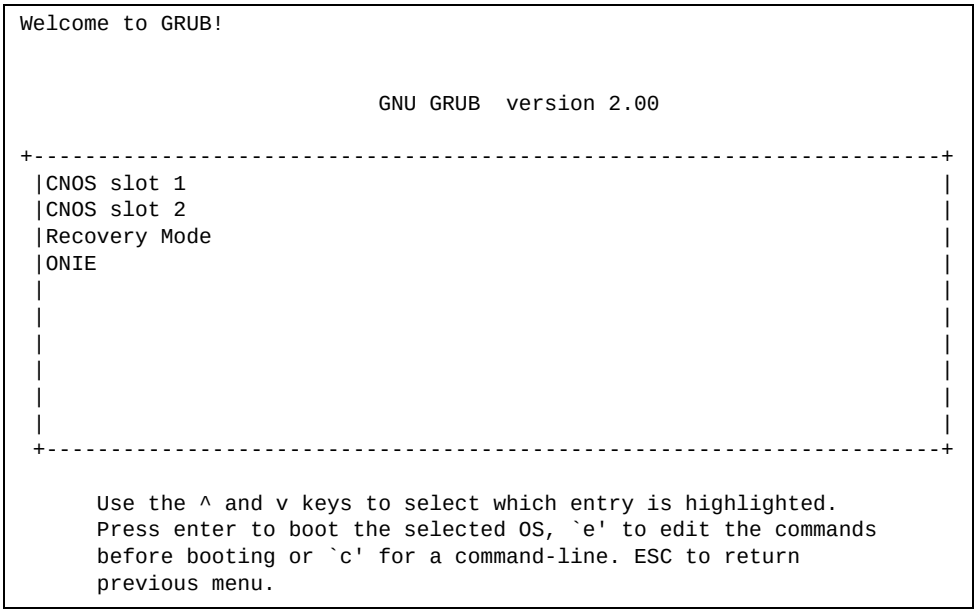
```
Switch# reload
```

The NE10032/NE2572 GRUB Menu

Note: This section applies only to the NE10032 and the NE2572.

For the NE10032 and NE2572 switches all images are preloaded, and all booting options, such as switching boot images, are included in the GNU GRUB bootloader. To boot CNOS or switch images on the NE10032 or NE2572:

1. Boot the switch. Eventually the GNU GRUB bootloader displays. Select the image you want to use (either `CNOS slot 1` or `CNOS slot 2`).



2. The system will automatically load CNOS and prompt you to log in.

NE10032/NE2572 Rescue Mode

The Rescue Mode option allows you to recover from a failed software or boot image upgrade using TFTP or a USB drive.

To enter Rescue Mode, select **Recovery Mode** in the GRUB menu. The following menu appears.

```
Entering Rescue Mode.
Please select one of the following options:
        T) Configure networking and tftp download an image
        U) Install image from USB stick
        F) Filesystem menu
        I) Select which image to boot
        C) Reset configuration to factory default
        Z) Reset the Network Administrator (admin) password
        B) Reset the password required to enter Privileged EXEC mode
        R) Reboot
        E) Exit
```

The Rescue Mode menu allows you to perform the following actions:

- To recover from a failed software or boot image upgrade using TFTP, press **T** and follow the screen prompts. For more details, see "Recovering from a Failed Image Upgrade using TFTP" on page 121.
- To recover using an install image from a USB stick, press **U**.
- To check if the switch is ready to run Cloud NOS software, press **F**. It performs a check to see if the filesystem is optimally partitioned and updates it accordingly.
- To select which image to boot, press **I**.
- To reset the switch configuration to factory defaults, press **C**.
- To reset the Network Administrator account (admin) password, press **Z**.
- To reset the password required to enter Privileged EXEC mode, press **B**.
- To restart the reload process from the beginning, press **R**.
- To exit the Rescue Mode menu, press **E**.

The Boot Management Menu

Note: This section does not apply to the NE10032 or the NE2572.

The Boot Management menu allows you to switch the NOS image, reset the default user password, or recover from a failed software installation.

You can interrupt the startup process and enter the Boot Management menu from the serial console port. When the system displays the following message, press **Shift + B**. The Boot Management menu displays.

```
The system is going down for reboot NOW!
INIT: reboot: Restarting system

...

Press shift-B for startup menu or shift-R for recovery mode: ..
Running Startup Menu

...

Boot Management Menu
Boot Management Menu
        M - Change boot mode (ENOS vs CNOS)
        I - Change booting image
        C - Change configuration to factory default
        R - Boot in recovery mode (tftp download of images to recover
switch)
        P - Reset the Network Administrator (admin) password
        B - Reset the password required to enter privileged exec mode
        Q - Reboot
        E - Exit
Please choose your menu option:
```

The Boot Management menu allows you to perform the following actions:

- For the G8272, to switch between ENOS and CNOS images, enter **M** and follow the screen prompts. ENOS refers to Lenovo Enterprise Network OS and CNOS refers to Lenovo Cloud Network OS. For further details, see "Switching Between ENOS and CNOS Images Loaded on the G8272" on page 119.
- To change the booting image, enter **I** and follow the screen prompts.
- To boot in recovery mode, enter **R**.
- To reset the default user password, enter **P** and follow the screen prompts.
- To enter the ONIE submenu, enter **O**.

Note: ONIE is not supported on the G8332.

- To reset the Network Administrator account (admin) password, enter **P**.
- To reset the password required to enter Privileged EXEC mode, enter **B**.
- To reload the switch, enter **Q**. The reloading process starts again.
- To exit the Boot Management menu, enter **E**. The reloading process continues.

Note: The ONIE submenu is available only if you have activated ONIE by installing an appropriate license key. For more details, see Chapter 3, "System License Keys".

Switching Between ENOS and CNOS Images Loaded on the G8272

If you have both ENOS and CNOS images loaded on your device, you can switch from one to another by using the Boot Management menu. To do so, follow these steps:

1. Reboot the switch.

```
Switch# reload
```

2. When the phrase "`Booting Lenovo NOS`" appears, press **Shift + B** to enter the Boot Management Menu.

```
Boot Management Menu
        M - Change boot mode (ENOS vs CNOS)
        I - Change booting image
        R - Boot in recovery mode (tftp download of images to recover
switch)
        P - Password reset
        O - ONIE boot menu
        Q - Reboot
        E - Exit
Please choose your menu option:
```

3. Enter **M** to change the boot mode.

```
Please choose your menu option: M
```

4. Enter **E** to enter ENOS Boot Mode or **C** to enter CNOS Boot Mode.

```
Currently booting in CNOS mode
Enter boot mode: ENOS or CNOS: E
Boot Management Menu
        M - Change boot mode (ENOS vs CNOS)
        I - Change booting image
        C - Change configuration block
        R - Boot in recovery mode (tftp download of images to recover
switch)
        O - ONIE boot menu
        Q - Reboot
        E - Exit
Please choose your menu option:
```

5. At the Boot Management Menu, enter **Q** to reboot.

   Note: All previous CNOS/ENOS configurations are stored and re-applied when switching back to the corresponding OS.

Boot Recovery Mode

The Boot Recovery Mode allows you to recover from a failed software or boot image upgrade using TFTP download.

To enter Boot Recovery Mode you must select the `Startup in recovery mode` option from the Boot Management Menu.

```
Entering Rescue Mode.
Please select one of the following options:
        T) Configure networking and tftp download an image
        U) Install image from USB stick
        P) Physical presence test (low security mode)
        F) Run filesystem check
        I) Select which image to boot
        C) Reset configuration to factory default
        R) Reboot
        E) Exit

Option? :
```

The Boot Recovery Mode menu allows you to perform the following actions:

- To recover from a failed software or boot image upgrade using TFTP, press **T** and follow the screen prompts. For more details, see "Recovering from a Failed Image Upgrade using TFTP" on page 121.
- To recover using an install image from a USB stick, press **U**.
- To enable the loading of a special image, press **P** and follow the screen prompts. For more details, see "Physical Presence" on page 123.
- To check if the switch is ready to run Cloud NOS software, press **F**. It performs a check to see if the filesystem is optimally partitioned and updates it accordingly.
- To select which image to boot, press **I** and follow the screen prompts. Press **Q** to quit.
- To reset the switch configuration to factory defaults, press **C**.
- To restart the reload process from the beginning, press **R**.
- To exit Boot Recovery Mode menu, press **E**.

Recovering from a Failed Image Upgrade using TFTP

Use the following procedure to recover from a failed image upgrade using TFTP:

1. Connect a PC to the console port of the switch.
2. Open a terminal emulator program that supports the Telnet protocol (for example, HyperTerminal, SecureCRT, or PuTTY) and input the proper hostname or IP address and the port to connect to the console interface of the switch.
3. Reload the switch and access the Boot Management menu by pressing **Shift + B** when the following message appears and the dots are being displayed.

```
Press shift-B for startup menu or shift-R for recovery mode: ...
```

4. Enter Boot Recovery Mode by selecting **R**. The Recovery Mode menu appears.
5. To start the recovery process using TFTP, select **T**. The following message appears:

```
Performing TFTP rescue. Please answer the following questions (enter 'q'
to quit):
```

6. Enter the IP address of the management port:

```
IP addr :
```

7. Enter the network mask of the management port:

```
Netmask :
```

8. Enter the gateway of the management port:

```
Gateway :
```

9. Enter the IP address of the TFTP server:

```
Server addr:
```

10. Enter the file path and the filename of the image:

```
Image Filename:
```

After the procedure is complete, the Recovery Mode menu is redisplayed.

Following is an example of a successful recovery procedure using TFTP:

```
Entering Rescue Mode.
Please select one of the following options:
        T) Configure networking and tftp download an image
        U) Install image from USB stick
        P) Physical presence test (low security mode)
        F) Run filesystem check
        I) Select which image to boot
        C) Reset configuration to factory default
        R) Reboot
        E) Exit

Option? : t
Performing TFTP rescue. Please answer the following questions (enter 'q'
to quit):
IP addr :10.241.6.4
Netmask :255.255.255.128
Gateway :10.241.6.66
Server addr:10.72.97.135
Image Filename: G8xxx-CNOS-10.9.2.0.imgs
        Netmask : 255.255.255.128
        Gateway : 10.241.6.66
Configuring management port.....................
Installing image G8xxx-CNOS-10.9.2.0.imgs from TFTP server 10.72.97.135

Extracting images ... Do *NOT* power cycle the switch.
Installing Application: Image signature verified.
Installing image as standby image: 100%

Standby image update succeeded
Updating install log. File G8xxx-CNOS-10.9.2.0.imgs installed from
10.72.97.135 at 15:29:30 on 12-3-2015
Please select one of the following options:
        T) Configure networking and tftp download an image
        U) Install image from USB stick
        P) Physical presence test (low security mode)
        F) Run filesystem check
        I) Select which image to boot
        C) Reset configuration to factory default
        R) Reboot
        E) Exit

Option? :
```

Physical Presence

Use the following procedure to enable the installation of special images on the switch, when a deeper troubleshooting analysis is required:

1. Connect a PC to the console port of the switch.
2. Open a terminal emulator program that supports a serial port connection and select the following serial port characteristics:
   - Default Baud Rate: 9,600 bps
   - Data Bits: 8
   - Stop Bits: 1
   - Parity: None
   - Flow Control: None
3. Boot the switch and access the Boot Management menu by pressing **Shift + B** when the following message appears and the dots are being displayed.

```
Press shift-B for startup menu or shift-R for recovery mode: ...
```

4. Enter Boot Recovery Mode by selecting **R**.
5. To begin the Physical Presence procedure, select **P**. The following warning message appears and you are prompted for confirmation (enter **y** to confirm):

```
WARNING: the following test is used to determine physical presence and if
completed will put the switch in low security mode.

Do you wish to continue y/n? y
```

6. A security test will be performed. The system location (blue) LED blinks a number of times between 1 and 12. When prompted, enter that number:

```
Hit a key to start the test. The blue location LED will blink a number of
times.

...........
How many times did the LED blink?
```

7. After entering the correct number, the Recovery Mode menu reappears. To install a special image, use TFTP (for details, see page 121).

   Note: You have three attempts to successfully complete the security test. After three incorrect attempts, the switch reboots.

   After the test is completed, the switch is put in low security mode. This mode allows you to install special images on the switch. To revert to normal security mode, you must reboot the switch or select **P** again in the Recovery Mode menu.

ONIE Submenu

In the ONIE (Open Network Install Environment) submenu you can choose from different ONIE operations such as installing and uninstalling NOS images, upgrading ONIE, and using ONIE rescue and recovery mode to troubleshoot a broken system.

Note: ONIE is not supported on the G8332.

For more detailse about ONIE, see "ONIE" on page 125.

Note: The ONIE submenu will only be available if you have activated ONIE by installing an appropriate license key. For more details, see Chapter 3, "System License Keys".

To enter the ONIE submenu you must select the "ONIE submenu" option from the Boot Management Menu.

```
ONIE Menu
     I - Boot ONIE OS installer
     N - Boot NOS mode (system default)
     R - Boot ONIE rescue mode
     U - Boot ONIE self update mode
     D - Boot ONIE OS uninstaller
     E - Exit ONIE menu

Please choose your menu option:
```

The ONIE submenu allows you to perform the following actions:

- To boot the switch in ONIE install mode, enter **I**.
- To boot the switch using the installed NOS image, enter **N**.
- To boot the switch in ONIE rescue mode, enter **R**.
- To boot the switch in ONIE update mode, press **U**.
- To boot the switch in ONIE uninstall mode, press **D**.
- To exit the ONIE submenu and return to the Boot Management Menu, enter **E**.

For more information about the ONIE submenu, see the *Lenovo Network ONIE User Guide* for your switch.

ONIE

The Open Network Install Environment (ONIE) is a small Linux-based operating system that provides an open install environment for networking devices without operating systems.

ONIE enables a network switch ecosystem for end-users to choose among different Network Operating Systems (NOS). Practically, ONIE boots on a switch, discovers NOS installer images available on the local network or USB drive, copies the chosen image to the switch, and provides an environment where the installer can load the NOS onto the switch.

The NE10032 and the NE2572 switches come with ONIE pre-installed.

To use ONIE on the G8296, G8272, NE1032, NE1032T, or NE1072T, you must first install a license key. For more details on how to obtain and install such a license, see Chapter 3, “ONIE License Key“.

Note: ONIE is not supported on the G8332.

For more details on ONIE and how to install and use it, see the *Lenovo Network ONIE User Guide* for your switch.

Part 2: Securing the Switch

This section discusses the following switch security topics:

Chapter 5. Securing Administration

Secure switch management is needed for environments that perform significant management functions across the Internet. Common functions for secured management are described in the following sections:

- "Secure Shell and Secure Copy" on page 130
- "End-user Access Control" on page 134

Note: SNMP read and write functions are enabled by default. For best security practices, if SNMP is not needed for your network, we recommend that you disable these functions prior to connecting the switch to the network (see Chapter 31, "Simple Network Management Protocol").

Secure Shell and Secure Copy

Because using Telnet does not provide a secure connection for managing the switch, Secure Shell (SSH) and Secure Copy (SCP) features have been included for switch management. SSH and SCP use secure tunnels to encrypt and secure messages between a remote administrator and the switch.

SSH is a protocol that enables remote administrators to log securely into the switch over a network to execute management commands. The SSH module consists of a SSH server and a SSH client. By default, the SSH server listens on TCP port number 22. Once a SSH client establishes a connection to the SSH server, the client acts as a virtual terminal through which the remote system is accessed.

SCP is typically used to copy files securely from one machine to another. SCP uses SSH for encryption of data on the network. On the switch, SCP is used to download and upload the switch configuration via secure channels.

SSH is enabled by default and using this features provides the following benefits:

- Identifying the administrator using Name/Password
- Authentication of remote administrators
- Encrypting messages between the remote administrator and the switch
- Secure copy support

Lenovo Cloud Network Operating System implements the SSH version 2.0 standard and is confirmed to work with SSH version 2.0-compliant clients such as the following:

- OpenSSH_5.4p1 for Linux
- Secure CRT Version 5.0.2 (build 1021)
- Putty SSH release 0.60

SSH Encryption and Authentication

The following encryption and authentication methods are supported for SSH:

- Server Host Authentication: Client RSA authenticates the switch at the beginning of every connection
- Key Exchange: RSA, DSA
- Encryption: 3DES-CBC, DES
- User Authentication: Local password authentication, TACACS+

Generating RSA/DSA Host Key for SSH Access

To support the SSH host feature, a RSA or DSA host key is required. The host key is 2048 bits long and is used to identify the switch.

To configure a new RSA or DSA host key, connect to the switch through the console port or via a Telnet session, and enter the following command to manually generate the host key:

- To generate a new DSA key:

```
Switch(config)# ssh key dsa
```

- To generate a new RSA key:

```
Switch(config)# ssh key rsa
```

When the switch reboots, it will retrieve the host key from the FLASH memory.

Note: The switch will perform only one session of key/cipher generation at a time. Thus, a SSH/SCP client will not be able to log in if the switch is performing key generation at that time. Also, key generation will fail if a SSH/SCP client is logging in at that time.

SSH Integration with TACACS+ Authentication

SSH is integrated with TACACS+ authentication. After the TACACS+ server is enabled on the switch, all subsequent SSH authentication requests will be redirected to the specified TACACS+ server for authentication. The redirection is transparent to the SSH client.

Configuring SSH on the Switch

To configure SSH parameters, use to following procedure:

1. Configure the number of unsuccessful SSH login attempts (the default value is 3):

```
Switch(config)# ssh login-attempts <1-10>
```

2. Optionally, you can change the SSH server port (the default port is 22):

```
Switch(config)# ssh server port <1-65535>
```

Note: To change the number of SSH login attempts and server port, the SSH feature must be disabled.

3. Optionally, you can configure a DSA or RSA host key:

```
Switch(config)# ssh key {dsa|rsa}
```

4. Check the current SSH server settings:

```
Switch# show ssh server
```

Using SSH Client Commands

This section shows the format for using some client commands.

To log onto an SSH server:

1. Connect via IPv4 or IPv6:
   - IPv4:

     ```
     Switch# ssh <username>@<server IPv4 address>
     ```

     Example**:**

     ```
     Switch# ssh admin@205.178.15.157
     ```

   - IPv6:

     ```
     Switch# ssh6 <server IPv6 address>
     ```

     Example**:**

     ```
     Switch# ssh6 FE80::0202:B3FF:FE1E:8329
     ```

2. Optionally, you can specify the SSH server port used to establish the connection:

   ```
   Switch# ssh <username>@<server IPv4 address> port <TCP port (1-65535)>
   ```

3. Optionally, you can also specify the Virtual Routing and Forwarding (VRF) instance used for the session:

   ```
   Switch# ssh <username>@<server IPv4 address> port <TCP port (1-65535)> vrf {default|
   |management}
   ```

Using Secure Copy

You can use SCP to copy files from or to a remote server. This includes the copying of the running and startup configurations, or technical support files.

Copying a File Using SCP

To copy a file to a remote server using SCP, use the following command:

```
Switch# copy file <filename> scp
```

To copy a file from a remote server using SCP, use the following command:

```
Switch# copy scp file <filename>
```

Copying the Startup Configuration Using SCP

To copy the startup configuration file to a remote server using SCP, use the following command:

```
Switch# copy startup-config scp
```

To copy the startup configuration file from a remote server using SCP, use the following command:

```
Switch# copy scp startup-config
```

Copying the Running Configuration Using SCP

To copy the running configuration file to a remote server using SCP, use the following command:

```
Switch# copy running-config scp
```

Copying Technical Support Files Using SCP

To copy the technical support dump file to a remote server using SCP, use the following command:

```
Switch# copy tech-support scp
```

End-user Access Control

Cloud NOS allows an administrator to define accounts that permit end-users to perform switch operations via CLI commands. Once end-user accounts are configured and enabled, the switch requires username/password authentication.

For example, an administrator can assign a user, who can then log into the switch and perform operational commands (effective only until the next switch reboot).

Considerations for Configuring End-user Accounts

Note the following considerations when you configure end-user accounts:

- A maximum of 100 user IDs are supported on the switch
- CNOS offers end-user support for console, Telnet, and SSH access to the switch
- The length of the username must be between 2 and 28 alphanumeric characters
- Passwords for end-users must be between 8 and 80 alphanumeric characters in length for TACACS+, Telnet, SSH, and console access

Strong Passwords

Cloud NOS requires the use of strong passwords for users to access the switch. Strong passwords enhance security because they make password guessing more difficult.

The following rules must be followed when creating a password for a user:

- Minimum length: 8 characters; maximum length: 80 characters
- Must contain at least one uppercase letter
- Must contain at least one lowercase letter
- Must contain at least one number
- Cannot be same as the username
- When changing passwords no four consecutive characters can be the same as in the old password

A user without a password will not be allowed to log in on the switch.

User Access Control

The end-user access control commands allow you to configure end-user accounts. Any changes to a user will only take place once that user logs out and initiates a new session.

To displays the currently logged in user, use the following command:

```
Switch# show users
```

Setting up Users

Up to 100 users can be configured on the switch. Use the following commands to define a username and set the user password:

1. Create the user:

```
Switch(config)# username <username>
```

Note: The username must be between 2 and 28 lowercase alphanumeric characters long and can contain minus-hyphens. The first characters of the username must be a lowercase letter.

2. Define a password for the user:

```
Switch(config)# username <username> password <password>
```

Note: The password must be between 8 and 80 alphanumeric characters long and must contain at least one uppercase letter and one number.

3. Check the current user accounts:

```
Switch# show user-accounts
```

The following words are reserved and cannot be used as usernames:

Table 3. *Words Not Permitted as Usernames*

adm	bin	daemon	ftp	ftpuser
games	gdm	gopher	halt	lp
mail	mailnull	man	mtsuser	news
shutdown	sync	sys	uucp	xfs
root	vcsa	lighttpd	tcpdump	oprofile
ntp	dhcpd	sshd	nosx	obs
proxy	backup	list	irc	gnats
tss	cyrus	messagebus		

Defining a User's Access Level

Every user account will have a specific access level or role attached. The user role defines what operations the user will be allowed to perform on the switch. The user can have one of two roles:

- `network-admin`: complete read and write access to the switch
- `network-operator`: only read access to the switch

To view the current settings for each role, use the following command:

```
Switch# show role
```

To change a user's role, use the following command:

```
Switch(config)# username <username> role {network-admin|network-operator}
```

Note: If a user is created without specifying an access level, the default user role will be network-operator.

To view the current user roles for each user, use the following command:

```
Switch# show user-accounts
```

Deleting a User

To delete a user:

1. Delete the user:

```
Switch(config)# no username <username>
```

2. Verify if the user has been removed:

```
Switch# show user-accounts
```

The Default User

The user `admin` is automatically installed on the switch by default. This is used to initially set up the switch.

Its default role is `network-admin` and the default password is `admin`.

The `admin` user account cannot be removed, nor its user role changed. However, the password associated with this account can be modified by using the following command:

```
Switch(config)# username admin password <new password>
```

Password History Checking

With this option enabled, when setting up a new password for a user, it will be checked against older passwords used for that account. If the new password matches any of the previously four passwords, it will not be accepted by the switch and another password must be provided.

Note: Password History Checking applies only to the switch local user database. If access to the device is granted through the use of Authentication, Authorization, and Accounting (AAA), password history checking isn't available. For more details about AAA, see "Authentication, Authorization, and Accounting" on page 152.

To enable or disable password history checking, use the following command:

```
Switch(config)# [no] password history-checking
```

By default, password history checking is disabled.

When this option is enabled on the switch, checking new passwords against older ones is enforced under any situation, expect the following:

- during switch initialization

  Password history checking will be bypassed to prevent errors that may be caused by this action when the switch configuration is loading.

- during administrative password recovery

  Password history checking will be bypassed to ensure that the recovery of the administrator password is successful. For more details about administrative password recovery, see "Administrator Password Recovery" on page 138.

A history of the previous used passwords will be created for each individual user. When deleting a user from the switch local database, its history is also deleted.

Notes:

- When deleting the switch configuration, all password histories stored on the device will also be deleted. This also happens when password history checking is disabled on the switch.
- However, the password histories are persistent across switch reloads and software image upgrades.

Administrator Password Recovery

In case you have changed the password of the `admin` user and have forgotten it, follow these steps to reset the password to the default value:

1. Connect to the switch using the console port.
2. Reload the switch:

```
Switch# reload
reboot system? (y/n): y

Broadcast message from root@switch (Mon Feb 15 15:53:53 2016):

The system is going down for reboot NOW!
INIT: reboot: Restarting system


U-Boot 2014.01 (Oct 07 2015 - 10:47:24) - ONIE lenovo

CPU0:  P2020, Version: 2.1, (0x80e20021)
Core:  e500, Version: 5.1, (0x80211051)
Clock Configuration:
       CPU0:1200 MHz, CPU1:1200 MHz,
       CCB:600  MHz,
       DDR:400  MHz (800 MT/s data rate) (Asynchronous), LBC:37.500 MHz
L1:    D-cache 32 KiB enabled
       I-cache 32 KiB enabled
Board: G8xxx
I2C:   ready
DRAM:  4 GiB (DDR3, 64-bit, CL=6, ECC on)
Booting Lenovo NOS....
Press shift-B for startup menu or shift-R for recovery mode: ...
```

3. During the reload process, the following message will appear. Press **Shift + B** to enter Boot Management.

```
Boot Management Menu
        M - Change startup mode (E-NOS vs C-NOS)
        I - Change booting image
        R - Startup in recovery mode (tftp download of images to recover
switch)
        P - Password reset
        Q - Reboot
        E - Exit
Please choose your menu option:
```

4. Enter *Password reset* from the Boot Management menu by entering **P**. You are prompted for confirmation:

```
Confirm resetting system password: y/n? y
Password reset requested. Please reboot to complete the process
```

5. Reload the switch by selecting the *Reboot* option. Press **Q**:

```
Boot Management Menu
        M - Change startup mode (E-NOS vs C-NOS)
        I - Change booting image
        R - Startup in recovery mode (tftp download of images to recover
switch)
        P - Password reset
        Q - Reboot
        E - Exit
Please choose your menu option: q
```

6. After the reload is complete, you will be able to log into the switch using the default user `admin` with the default password `admin`.

7. You can change the default password by using the following command:

```
Switch(config)# username admin password <new password>
```

Chapter 6. AAA Protocols

Secure switch management is needed for environments that perform significant management functions across the Internet. The following are some of the functions for secured IPv4 management and device access:

RADIUS

Cloud NOS supports the RADIUS (Remote Authentication Dial-in User Service) method to authenticate and authorize remote administrators for managing the switch. This method is based on a client/server model. The Remote Access Server (RAS)—the switch—is a client to the back-end database server. A remote user (the remote administrator) interacts only with the RAS, not the back-end server and database.

RADIUS authentication consists of the following components:

- A protocol with a frame format that utilizes UDP over IP (based on RFC 2865 and RFC 2866)
- A centralized server that stores all the user authorization information
- A client: in this case, the switch

The switch—acting as the RADIUS client—communicates to the RADIUS server to authenticate and authorize a remote administrator using the protocol definitions specified in RFC 2865 and RFC 2866. Transactions between the client and the RADIUS server are authenticated using a shared key that is not sent over the network. In addition, the remote administrator passwords are sent encrypted between the RADIUS client (the switch) and the back-end RADIUS server.

RADIUS Basics

RADIUS offers the following advantages:

- RADIUS uses UDP-based speed-oriented transport
- RADIUS separates accounting, while authentication and authorization are treated together

How RADIUS Authentication Works

The RADIUS authentication process follows these steps:

1. A remote administrator connects to the switch and provides a user name and password.
2. Using Authentication/Authorization protocol, the switch sends request to authentication server.
3. The authentication server checks the request against the user ID database.
4. Using RADIUS protocol, the authentication server instructs the switch to grant or deny administrative access.

RADIUS Authentication Features in Cloud NOS

CNOS supports the following RADIUS authentication features:

- Supports RADIUS client on the switch, based on the protocol definitions in RFC 2865 and RFC 2866.
- For the G8272 and G8296 switches, CNOS supports user-configurable RADIUS application port. The default port is 1812 for authentication and 1813 for accounting.
- Supports MS-CHAP-V2 authentication method, based on the definitions in RFC 2759.
- Allows RADIUS secret password of 65 bytes.
- Supports user-configurable RADIUS server retry and time-out values:
  - Time-out value = 1-60 seconds
  - Retries = 0-5
- The switch will time out if it does not receive a response from the RADIUS server in 0-5 retries. The switch will also automatically retry connecting to the RADIUS server before it declares the server down.Allows network administrator to define privileges for one or more specific users to access the switch at the RADIUS user database.

Switch User Accounts

The user accounts in Table 4 can be defined in the RADIUS server dictionary file.

Table 4. *User Accounts and RADIUS*

User Account	Description and Tasks Performed	Password
Operator	The Operator manages all functions of the switch. The Operator can reset ports, except the management port.	`oper`
Administrator	The super-user Administrator has complete access to all commands, information, and configuration commands on the switch, including the ability to change both the user and administrator passwords.	`admin`

RADIUS Attributes for Cloud NOS User Privileges

When the user logs in, the switch authenticates his level of access by sending the RADIUS access request (the client authentication request) to the RADIUS authentication server.

All user privileges, other than those assigned to the Administrator, must be defined in the RADIUS dictionary. The file name of the dictionary is RADIUS vendordependent. The following RADIUS attributes are defined for user privilege levels:

Table 5.

User Name/Access	Vendor Code	Value
Operator	26543	`network-operator`
Admin	26543	`network-admin`

Configuring RADIUS on the Switch

Use the following procedure to configure Radius authentication on your switch.

1. Configure the IPv4/IPv6 addresses of the RADIUS servers, and enable RADIUS authentication and accounting.

```
Switch(config)# radius-server host 10.10.1.1
```

2. Configure the RADIUS secret.

```
Switch(config)# radius-server host 10.10.1.1 key [0|7] <1-65 character secret>
```

Notes:

- Setting up a specific key for an individual RADIUS server will overwrite the globally configured key.
- By default, the RADIUS key is not encrypted. To specify the encryption level of the key, use the following parameters:
  - **0** - the key is unencrypted (clear-text)
  - **7** - the key is encrypted

3. If desired, you may change the default UDP port numbers used to listen to RADIUS.

   The well-known ports for RADIUS are 1812 for authentication and 1813 for accounting.

```
Switch(config)# radius-server host 10.10.1.1 auth-port <UDP port (0-65535)>
Switch(config)# radius-server host 10.10.1.1 acc-port <UDP port (0-65535)>
```

4. Configure the number retry attempts for contacting the RADIUS server, and the timeout period.

```
Switch(config)# radius-server host 10.10.1.1 retransmit 3
Switch(config)# radius-server host 10.10.1.1 timeout 5
```

TACACS+

CNOS supports authentication and authorization with networks using the Terminal Access Controller Access-Control System Plus (TACACS+) protocol. The switch functions as the Network Access Server (NAS) by interacting with the remote client and initiating authentication and authorization sessions with the TACACS+ access server. The remote client is defined as someone requiring management access to the switch either through a data port or the management port.

TACACS+ Basics

TACACS+ offers the following advantages:

- TACACS+ uses TCP-based connection-oriented transport
- TACACS+ offers full packet encryption in authentication requests
- TACACS+ separates authentication, authorization, and accounting

How TACACS+ Authentication Works

TACACS+ authentication follows these steps:

1. The remote administrator connects to the switch and provides username and password.
2. Using the authentication/authorization protocol, the switch sends a request to authentication server.
3. The authentication server checks the request against the user ID database.
4. Using the TACACS+ protocol, the authentication server instructs the switch to grant or deny administrative access to the remote user.

   During a session, if additional authorization checking is needed, the switch checks with a TACACS+ server to determine if the user is granted permission to use a specific command.

   Notes:

   - A username can have a maximum length of 32 characters, consisting only of lowercase letters and numbers. The username must also start with a letter. Usernames that start with a number are invalid.
   - A password can have a maximum length of 255 characters, consisting of lowercase or uppercase letters, numbers, and special characters.

TACACS+ Authentication Features in Cloud NOS

Authentication is the action of identifying a user and is generally done when the user first attempts to log into a device, or tries to gain access to its services. CNOS supports ASCII inbound login to the device.

Note: PAP, CHAP, and ARAP login methods, TACACS+ change password requests, and one-time password authentication are not supported.

Authorization

Authorization is the action of determining a user's privileges on the device and usually takes place after authentication.

The default mapping between TACACS+ authorization levels and CNOS management access levels is shown in Table 6. The authorization levels must be defined on the TACACS+ server.

Table 6. *Default TACACS+ Authorization Levels*

CNOS User Access Level	TACACS+ level
`operator`	1
`admin`	15 or 16

If the remote user is successfully authenticated by the authentication server, the switch verifies the privileges of the remote user and authorizes the appropriate access.

Accounting

Accounting is the action of recording a user's activities on the device for the purposes of billing and/or security. It follows the authentication and authorization actions. If the authentication and authorization is not performed via TACACS+, there are no TACACS+ accounting messages sent out.

You can use TACACS+ to record and track software login access, configuration changes, and interactive commands.

The switch supports the following TACACS+ accounting attributes:

- protocol (Telnet or SSH)
- start_time
- stop_time

Configuring TACACS+ Authentication on the Switch

You can configure up to 4 TACACS+ authentication servers. To set a TACACS+ server on the switch, follow these steps:

1. Enable TACACS+ on the switch:

```
Switch(config)# feature tacacs+
```

2. Configure the IP addresses of a TACACS+ server. Optionally, you can specify the TACACS+ server port.

```
Switch(config)# tacacs-server host <IP address> port <1-65535>
```

Note: If you want to configure a fifth TACACS+ server, you must first delete one of the existing four servers by using the following command:

```
Switch(config)# no tacacs-server host <IP address>
```

3. Configure the TACACS+ encryption/decryption key by using one of the following options:

   - Set up a global key for all TACACS+ servers:

```
Switch(config)# tacacs-server key [0|7] <1-63 character key>
```

   - Set up a key for each individual TACACS+ server:

```
Switch(config)# tacacs-server host <IP address> key [0|7] <1-63 character key>
```

   Notes:

   - Setting up a specific key for an individual TACACS+ server will overwrite the globally configured key.
   - By default, the TACACS+ key is not encrypted. To specify the encryption level of the key, use the following parameters:
     - **0** - the key is unencrypted (clear-text)
     - **7** - the key is encrypted

4. Check the current TACACS+ settings and configured servers:

```
Switch> show tacacs-server
```

Lightweight Directory Access Protocol

Lightweight Directory Access Protocol (LDAP) is a protocol for accessing distributed directory information services over a network. Cloud NOS uses LDAP for authentication and authorization. With an LDAP client enabled, the switch will authenticate a user and determine the user's privilege level by checking with one or more directory servers instead of a local database of users. This prevents customers from having to configure local user accounts on multiple switches; they can maintain a centralized directory instead.

Configure an LDAP Profile

To configure LDAP on the switch:

1. Enable the LDAP feature:

```
Switch(config)# feature ldap
```

2. Configure LDAP profile information and enter LDAP Configuration mode.

```
Switch(config)# ldap-server profile <profile name (1-16 characters)>
```

3. Configure the distinguished name (DN):

```
Switch(config-ldap-profile)# base-dn "<distinguished name (1-128 characters)>"
```

4. Set the LDAP binding method:

```
Switch(config-ldap-profile)# bind-mode {prompted|predefined}
```

5. Set the retransmission count for LDAP connections:

```
Switch(config-ldap-profile)# retransmit <count (1-5)>
```

6. Set the LDAP connection local timeout period, in seconds:

```
Switch(config-ldap-profile)# time <time (1-60)>
```

7. Set the LDAP transmit mode and security options:

```
Switch(config-ldap-profile)# security {ldaps [ignore]|startTLS [ignore]|
|clear}
```

8. Set the LDAP server IP address:

```
Switch(config-ldap-profile)# host {<IP address>|<hostname>} [interface
{ethernet <chassis number/port number>|mgmt 0}
```

Note: The **interface** argument is only used when connecting to an LDAP server IPv6 link local address.

9. (Optional) Set the TCP port to use for LDAP:

```
Switch(config-ldap-profile)# port <TCP port (1-65535)>
```

If no value is specified, the switch will use default TCP port 389.

10. (Optional) Set the Public Key Infrastructure (PKI) to use for this LDAP profile:

```
Switch(config-ldap-profile)# pki <PKI name>
```

If no value is configured, the switch will use the global PKI.

11. (Optional) Set a customized LDAP group attribute:

```
Switch(config-ldap-profile)# attribute group <attribute (1-64 characters)>
```

If no value is configured, the switch will use the default value `memberOf`.

12. (Optional) Set the local authorization method:

```
Switch(config-ldap-profile)# authorization {rbac|bitmap}
```

13. (Optional) Set a customized LDAP permission name:

```
Switch(config-ldap-profile)# attribute permission-name <name (1-32 characters)>
```

If no value is configured, the switch uses the following default value: `LenovoNetworkPermission`

14. Set a customized LDAP attribute permission bitmap or permission role:

```
Switch(config-ldap-profile)# attribute permission-value {bitmap|role}
{admin|oper|deny} <role>
```

15. (Optional) Set a customized LDAP username:

```
Switch(config-ldap-profile)# attribute username <name (1-32 characters)>
```

If no value is configured, the switch will use the default value `uid`.

16. Set the DN for binding with the LDAP server:

```
Switch(config-ldap-profile)# predefined-credential dn <DN (1-255 characters)>
```

For example:

```
Switch(config-ldap-profile)# predefined-credential dn
cn=Manager,dc=my-domain,dc=com
```

17. Set the password for the DN:

```
Switch(config-ldap-profile)# predefined-credential key <password (1-64 characters)>
```

18. Set the group filter string for searching:

```
Switch(config-ldap-profile)# group-filter <string (1-256 characters)>
```

Note: The group-filter option only works for bitmap security mode.

19. Exit LDAP configuration mode:

```
Switch(config-ldap-profile)# exit
```

Create an LDAP Server Group

1. Create a group of LDAP servers in AAA:

```
Switch(config)# aaa group server ldap <group name>
```

where *group name* is the name of the group of LDAP servers. This command also enters you into LDAP Group Configuration mode.

Note: All group members must use the same protocols.

2. (Optional) Add a server to the current group:

```
Switch(config-ldap)# server <server profile name>
```

3. Set the VRF for this LDAP server group:

```
Switch(config-ldap)# use-vrf {default|management}
```

Only users who log in from an interface that is in this VRF will be allowed to login. Other users will get a timeout error when trying to authenticate with the servers.

Configure Global LDAP Settings

To configure global LDAP settings on the switch:

1. Set the global PKI profile to be used by LDAP:

```
Switch(config)# ldap-server pki <PKI name>
```

2. Specify the server group for console user login authentication:

```
Switch(config)# aaa authentication login console group <group list> [local|
|none]
```

3. Specify the server group for remote user login authentication:

```
Switch(config)# aaa authentication login default group <group list> [local|
|none]
```

4. Enable the display of error messages when authentication fails:

```
Switch(config)# aaa authentication login error-enable
```

View LDAP Settings

To display the running LDAP configuration, enter:

```
Switch(config)# show running-config ldap
```

To display the running AAA configuration, enter:

```
Switch(config)# show running-config aaa [all]
```

To display the configured groups, enter:

```
Switch(config)# show aaa groups
```

To display the running authentication settings, enter:

```
Switch(config)# show aaa authentication [login error-enable]
```

Authentication, Authorization, and Accounting

Authentication, Authorization, and Accounting (AAA) allows the switch to use secure protocols to access the switch. The AAA mechanism uses RADIUSor TACACS+ as an underlying protocol. For AAA to work properly, you must configure the RADIUS or TACASCS+ protocol and a RADIUS or TACACS+ server. Once these are set up, all services can be configured through AAA. For more information about configuring RADIUS, see "RADIUS" on page 142. For more information about configuring TACACS+, see "TACACS+" on page 145.

AAA uses RADIUS and TACACS+ to provide authentication, authorization, and accounting. After setting up a RADIUS or TACACS+ server, you must configure the switch through AAA to use the respective server.

Authentication is the service that AAA provides to authenticate users that can log into the switch. Authentication is supported at login for either a remote protocol connection like SSH or Telnet (named default), or for the console.

Authorization is the service that AAA provides to give specific users specific rights. Some users may have administrator privileges, while other users may execute only basic level commands. All this can be configured on the server that is used by AAA, which has to be set up to query the server for this information.

Accounting is the service that AAA provides to log all user login and logout actions on the switch. This is useful for administrators that want to keep a clear log of anyone logging in or attempting to do so.

AAA Groups

You can put already defined RADIUS/TACACS+ servers together under a common group using AAA. You can configure all the servers inside a group using a single set of commands. AAA groups have specific parameters that are applied to the service using a certain group and to all the servers configured inside that group.

Note: When configuring an AAA group, each group must contain only servers that were previously defined using the same protocol.

Each server can be a member of multiple AAA groups. When multiple servers are configured in an AAA group, the switch will start querying the first server. If the query fails (there is no response from the first server), the next server is interrogated. Any answer (positive or negative) is considered authoritative for the query and it is final.

Group Lists

When configuring AAA services (authentication, authorization, and accounting), you can set up a list of AAA groups for each service. The *group list* can have up to a maximum of 8 AAA groups, each separated by space. The groups are queried one after the other in the order they were specified. If the query fails (no answer from the AAA group), the next group is interrogated.

Group lists can end with `local` or `none` or both. If all other groups fail, then, if `local` was specified, local authentication will be used, or, if `none` was used, no authentication will be required.

Note: A group list must contain at least one other group besides `local` or `none`.

Configuring AAA Groups

To create and configure an AAA group, follow these steps:

1. Create the AAA group:

```
Switch(config)# aaa group server tacacs+ <group name>
Switch(config-tacacs)#
```

Note: After creating the group, you will enter AAA Group configuration mode. To create a RADIUS group definition, use the following command:

```
Switch(config)# aaa group server radius <group name>
Switch(config-radius)#
```

2. Add the desired TACACS+ servers to the current group:

```
Switch(config-tacacs)# server <IP address>
```

Note: Only servers that were already defined using RADIUS/TACACS+ can be added to the group.

3. Optionally, you can set the Virtual Routing and Forwarding (VRF) instance for the current group:

```
Switch(config-tacacs)# use-vrf {default|management} <VRF instance>
```

4. Check the currently configured AAA groups:

```
Switch> show aaa groups
```

Authentication

Authentication can be configured separately for remote Telnet or SSH connections, or connections via the console port. You can choose to use either the pluggable authentication module (PAM) by specifying a group of servers (see "AAA Groups" on page 152) or local authentication (local database on the switch).

When using PAM, only the users defined on the authentication server can log in with the privilege levels and security configuration given by the server. The user database is kept remote and when the user tries to log in, AAA will query the defined server and provide access.

In addition to PAM, RADIUS offers MS-CHAP-V2 authentication method. However, when using this method, changing the password or domain related operations are not allowed.

Role-based authentication is supported. To avoid authorizing each command separately, the switch sends a privilege level request to the AAA server. Based on the obtained privileged level, the user is allowed or denied various CLI commands.

For Telnet or console connections you do not need to create local users on the switch for them to log in. The user will be created on demand and will be kept indefinitely.

You are not required to create a username on the switch for a user that logs in using Secure Shell (SSH) via RADIUS/TACACS+.

A maximum number of failed login attempts can be set. When this number is reached, the user is locked out of the switch. Only the system administrator cannot be locked out. Any other user can be unlocked by using the following command in Privileged EXEC mode:

```
Switch# clear aaa local user lockout username <username>
```

Configuring AAA Authentication

To configure authentication, follow these steps:

1. Configure authentication for console sessions:
   - Configure authentication to use an AAA group:

     ```
     Switch(config)# aaa authentication login console group <group list>
     ```

     Note: Use the following command to enable MS-CHAP-V2 authentication option:

     ```
     Switch(config)# aaa authentication login mschapv2 enable
     ```

   - Configure authentication to use the local database:

     ```
     Switch(config)# aaa authentication login console local
     ```

   - Disable authentication:

     ```
     Switch(config)# aaa authentication login console none
     ```

2. Configure authentication for Telnet or SSH sessions:
   - Configure authentication to use an AAA group:

     ```
     Switch(config)# aaa authentication login default group <group list>
     ```

   - Configure authentication to use the local database:

     ```
     Switch(config)# aaa authentication login default local
     ```

   - Disable authentication:

     ```
     Switch(config)# aaa authentication login default none
     ```

3. Configure the maximum number of failed login attempts:

   ```
   Switch(config)# aaa local authentication attempts max-fail <1-25>
   ```

4. Optionally, you can configure the display of error messages for failed login attempts:

   ```
   Switch(config)# aaa authentication login error-enable
   ```

5. Check the current AAA authentication settings:

   ```
   Switch> show aaa authentication
   ```

   In case no TACACS+ servers are reachable, you can configure local authentication by using the following commands:
   - for console sessions:

     ```
     Switch(config)# aaa authentication login console group <group list> local
     ```

   - for telnet or SSH sessions:

     ```
     Switch(config)# aaa authentication login default group <group list> local
     ```

   Note: The switch will first try to contact the RADIUS/TACACS+ servers configured in the specified AAA group. If this fails, it will then turn to local authentication.

Authorization

Authorization enables control over the commands that are executed on the switch in Privileged EXEC and Global Configuration command modes. Every command is sent to the TACACS+ server and is executed only if the server authorizes it.

Notes:

- AAA Authorization is available only for remote connections and not for connections using the console port.
- AAA Authorization is not supported on RADIUS.

Configuring AAA Authorization

To configure authorization, follow these steps:

1. Configure authorization for User EXEC mode switch commands:
   - Configure authorization to use an AAA group:

     ```
     Switch(config)# aaa authorization commands default group <group list>
     ```

   - Configure authorization to use the local database:

     ```
     Switch(config)# aaa authorization commands default local
     ```

2. Configure authorization for Global Configuration mode switch commands:
   - Configure authorization to use an AAA group:

     ```
     Switch(config)# aaa authorization config-commands default group <group list>
     ```

   - Configure authorization to use the local database:

     ```
     Switch(config)# aaa authorization config-commands default local
     ```

3. Check the current AAA authorization settings:

   ```
   Switch> show aaa authorization
   ```

Accounting

To enable accounting, select the group of servers where accounting information will be stored. Local accounting can also be enabled. For TACACS+ only login and logout information will be logged.

Configuring AAA Accounting

To configure accounting, follow these steps:

1. Configure accounting to use one of the following:
   - an AAA group:

     ```
     Switch(config)# aaa accounting {default|console} group <group list>
     ```

   - the local database:

     ```
     Switch(config)# aaa accounting {default|console} local
     ```

2. Check the current AAA accounting settings:

   ```
   Switch> show aaa accounting
   ```

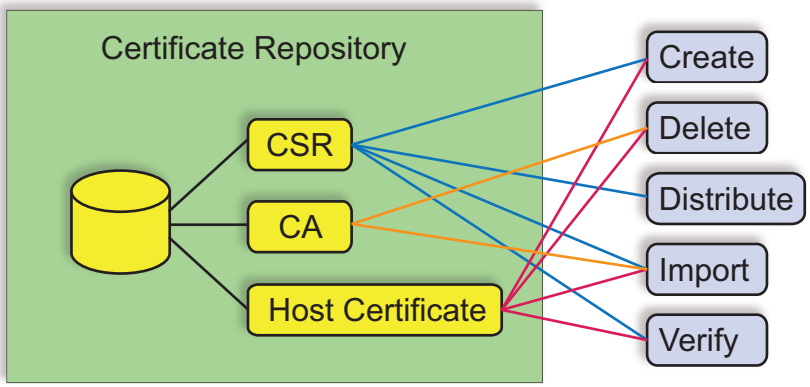
Public Key Infrastructure

A public key infrastructure (PKI) is a set of roles, policies, and procedures needed to create, manage, distribute, use, store, and revoke digital certificates and manage public-key encryption. The purpose of a PKI is to facilitate the secure electronic transfer of information for network activities such as e-commerce, internet banking and confidential email. It is required for activities where simple passwords are an inadequate authentication method. It provides more rigorous proof to confirm the identity of the parties involved in communication and validates the information being transferred.

PKI Components

Figure 1 shows the components of a PKI.

Figure 1. The Architecture of a PKI



The PKI is comprised of the following components:

- Certificate-related operations:
  - Create
    You can create a public and private key pair, including associate subject name, serial number, and validity period with that public key.
  - Delete
    You can delete certificates.
  - Distribute
    You can export the certificate to an outside server. For example,you need to export the Certificate Signing Request (CSR) to an outside server to get signed.
  - Import
    You can import a certificate to a switch.
  - Verify
    You can verify an imported switch before it gets used by other modules.
- The certificate repository

  A database based on VRF containing the host certificates and CSR.
- Truststore

  A database for Certificate Authority (CA) certificates.

Implementing a PKI System

Follow these steps to set up a PKI profile.

1. Name the PKI:

```
Switch(config)# pki <name (1-16 characters)>
```

This puts you into PKI Configuration Mode.

Note: The maximum number of PKI profiles allowed is 10.

2. Using SFTP, import your CAs:

```
Switch(config-pki)# ca import <SFTP_URL> vrf {default|management}
```

where *SFTP_URL* is the location of the CA file. The typical format of this URL is:

```
sftp://username@address:directory/filename
```

3. Obtain a host certificate.

- To generate a host certificate on the switch, enter the following:

```
Switch(config-pki)# host-cert generate
Country Name (2 letter code) [US]:
State or Province Name (full name) [CA]:
Locality Name (eg, city) [Santa Clara]:
Organization Name (eg, company) [Lenovo Networking Operating System]:
Organizational Unit Name (eg, section) [Network Engineering]:
Common Name (eg, FQDN or YOUR name) []:
Email (eg, email address) []:
Validate time (days) [180]:
```

The values in square brackets ([]) are the default values.

- To import a certificate, enter the following command:

```
Switch(config-pki)# host-cert certificate import <SFTP_URL> [vrf
{default|management}]
```

where *SFTP_URL* is the location of the CA file. The typical format of this URL is:

```
sftp://username@address:directory/filename
```

4. Obtain a CSR:
   - To generate a CSR on the switch, enter the following:

```
Switch(config-pki)# csr generate
Country Name (2 letter code) [US]:
State or Province Name (full name) [CA]:
Locality Name (eg, city) [Santa Clara]:
Organization Name (eg, company) [Lenovo Networking Operating System]:
Organizational Unit Name (eg, section) [Network Engineering]:
Common Name (eg, FQDN or YOUR name) []:
Email (eg, email address) []:
Validate time (days) [180]:
```

     The values in square brackets ([]) are the default values.

   - To import a signed CSR, enter the following command:

```
Switch(config-pki)# csr import <SFTP_URL> [vrf {default|management}]
```

     where *SFTP_URL* is the location of the CA file. The typical format of this URL is: `sftp://username@address:directory/filename`

   - To export a CSR, enter the following command:

```
Switch(config-pki)# csr export <SFTP_URL> [vrf {default|management}]
```

     where *SFTP_URL* is the location of the CA file. The typical format of this URL is: `sftp://username@address:directory/filename`

5. (Optional) To enable a PKI for the REST server on the switch, enter:

```
Switch(config)# restApi pki <PKI name (1-16 characters)> vrf {management|default}
```

Removing PKI Components

To delete a PKI, enter:

```
Switch(config)# no pki <PKI_name (1-16 characters)>
```

If the PKI is in use, an error message will display, and the PKI will not be deleted.

To delete a CA, enter:

```
Switch(config)# pki <PKI_name (1-16 characters)>
Switch(config-pki)# ca delete <Subject>
```

where:

Table 7.

Argument	Definition
PKI_name	The name of the PKI.
Subject	The CA subject, in the form of: `C=US, ST=MD, L=Baltimore, CN=Test/emailAddress=test@example.com` where: • `C=`*<country>* – for example, `US` • `ST=`*<state or province name>* – for example, `CA` • `L=<locality name>`, • `CN=`*<common name>* • `emailAddress=`*<email>* – for example, `test@example.com`

To remove a host certificate and the private key associated with it, enter:

```
Switch(config-pki)# host-cert delete
```

Viewing PKI Components

To view all PKIs, enter:

```
Switch# show pki
```

To view a host certificate associated with a specific PKI, enter:

```
Switch# show pki <PKI_name (1-16 characters)> host-certificate [base64]
```

To view a CSR associated with a specific PKI, enter:

```
Switch# show pki <PKI_name (1-16 characters)> csr [base64]
```

To view a CA associated with a specific PKI, enter:

```
Switch# show pki <PKI_name (1-16 characters)> ca [base64|brief]
```

SSH Public Key Authentication

Public Key Authentication (PKA) is a cryptographic system that offers an alternative for local SSH authentication, by providing the switch with a pair of keys: a public key and a private key. For more details about SSH, see "Secure Shell and Secure Copy" on page 130.

When connecting to switch via SSH, the SSH server encrypts messages exchanged during the session using the public key. Only the SSH client that has the matching private key can decrypt the messages and thus successfully authenticate with the SSH server.

SSH Public Key Authentication uses the Rivest–Shamir–Adleman (RSA) public key cryptosystem with a length of at least 2,048 bits.

When configuring the SSH public key, you must specify a username to be associated with the public key. You can import a public key from the SSH server by using one of the following commands:

- Import the public key using SFTP:

```
Switch(config)# username <username> sshkey <SSH key label> import sftp
<SFTP URL> [vrf {<VRF instance>|default|management}]
```

For example:

```
Switch(config)# username admin sshkey sshpk_label1 import sftp
sftp://jsmith@10.144.137.90/id_rsa_test.pub vrf management
```

- Directly importing the public key:

```
Switch(config)# username <username> sshkey <SSH key label> import line
<SSH public key>
```

For example:

```
Switch(config)# username admin sshkey sshpk_label2 import line ssh-rsa
AAAAB3NzaC1yc2EAAAADAQABAAABAQCtSrkOnNBOoduXSuZ9SCGLq0yeq5/O5qF82yXBlZ
Asc+HOhUaEhSLieHqPpogWmAxmbHV/E/3KqzqKapmpbP0GwqZx8a4dCW13i3JwceSiYbWO
hDtuOIzklrotuI40E50Ga9N1FNGxWeWvl0f/7f7pkoA5klx9n37jmQqEFiW9c/jEvX6E2l
c6P6vMk0X3YcxLKunTDmKOpcADlRymrCelI9V9AFgbPwEwFMx3lIQw3hjGey0sR5kHbrLC
Px15BS79sx6XbvLNlO6XfygIqY06MZv2uh7vTXZnJfRwjy+A14z2PkF3litpC5NaNEhSLy
VaGb4tNilqCOrbXNdAdprP stack@ubuntu-115
```

Note: You can configure up to ten public keys to a single username.

To display the public keys associated with a username, use the following command:

```
Switch> show user-account
```

For example:

```
Switch> show user-account

user:admin

role:network-admin

ssh public key:

sshpk_label1:
ssh-rsa
AAAB3NzaC1yc2EAAAADAQABAAABAQDZXSHylc40U9ByMtHoC2E9K10npyotacOMcTKP/zAXRb
GeZT9CU58LPLneRYzkZQ1o6EQs0Hx+0codt6kYfOnqVYsl5xRrKPNQYSxUVQYBwKZCigb7LwU
PogaiX81hOl20sMxAzbLTx3YydzEtlSELfzPdqj+FHErycMUy0mmc1azIJc/USl/ZBmvW7K0U
dVjwj1DBcQlZYdUXYNxKG/+YR3LpdpHkJnsxtDobdW94G3rqR2bTdcHXWcrZjCnpzQEcYjrDw
HSd09EJwQZ5a+KoRtkuZsYYyqP5s/jAwyk4+B5saRidtD2n4H3qzKCq7U4PpZEiFF3D0sgcU/
0Du7fT stack@ubuntu-226

sshpk_label2:
ssh-rsa
AAAAB3NzaC1yc2EAAAADAQABAAABAQCtSrkOnNBOoduXSuZ9SCGLq0yeq5/O5qF82yXBlZAsc
+HOhUaEhSLieHqPpogWmAxmbHV/E/3KqzqKapmpbP0GwqZx8a4dCW13i3JwceSiYbWOhDtuOI
zklrotuI40E50Ga9N1FNGxWeWvl0f/7f7pkoA5klx9n37jmQqEFiW9c/jEvX6E2lc6P6vMk0X
3YcxLKunTDmKOpcADlRymrCelI9V9AFgbPwEwFMx3lIQw3hjGey0sR5kHbrLCPx15BS79sx6X
bvLNlO6XfygIqY06MZv2uh7vTXZnJfRwjy+A14z2PkF3litpC5NaNEhSLyVaGb4tNilqCOrbX
NdAdprP stack@ubuntu-115
```

To delete a specific public key associated a username, use the following command:

```
Switch(config)# no username <username> sshkey <SSH key label>
```

For example:

```
Switch(config)# no username admin sshkey sshpk_label2
```

To delete all public keys associated with a username, use the following command:

```
Switch(config)# no username <username> sshkey
```

By default, the switch does not use SSH public key authentication, instead using password authentication. When SSH public key authentication is enabled, it is the first method used to authenticate to the SSH server. If it fails, password authentication can be used instead.

To enable SSH public key authentication, use the following command:

```
Switch(config)# ssh login-authentication public-key enable
```

To disable SSH public key authentication, use the following command:

```
Switch(config)# no ssh login-authentication public-key enable
```

To check whether SSH public key authentication is enabled or not, use the following command:

```
Switch> show ssh server

ssh server enabled port: 22
authentication-retries 6
public-key enable
```

Chapter 7. Access Control Lists

An Access Control Lists (ACL) is a list of filters that permit or deny traffic for security purposes. They can also be used with Quality of Service (QoS) to classify and segment traffic to provide different levels of service to different traffic types. Each filter defines the conditions that must match for inclusion in the filter and the actions that are performed when a match is made.

This chapter discusses the following topics:

Supported ACL Types

Lenovo Cloud Network Operating System supports the following types of ACLs:

- Internet Protocol version 4 (IPv4) ACLs:

  IPv4 ACLs classify packets using Layer 3 and Layer 4 header fields of IPv4 packets. The following command creates an IPv4 ACL:

  ```
  Switch(config)# ip access-list <IP ACL name>
  ```

  Note: ACLs are not supported with IPv6.

- Media Access Control (MAC) ACLs:

  MAC ACLs classify packets using Layer 2 fields. The following command creates a MAC ACL:

  ```
  Switch(config)# mac access-list <MAC ACL name>
  ```

- Address Resolution Protocol (ARP) ACLs:

  An ARP ACL filters ARP request and reply packets using various ARP fields. The following command creates an ARP ACL:

  ```
  Switch(config)# arp access-list <ARP ACL name>
  ```

Based on where they are applied, ACLs can be classified as follows:

- Port-Based ACLs (PACLs)

  A PACL can be applied to all packets received on a switched port. The PACLs can be MAC or IPv4 PACLs.

- Router ACLs (RACLs)

  A RACL can be applied to all packets received on a routed port (ingress RACL) or all packets going out of a routed port (egress RACL) on a physical port or an SVI. The RACLs can be MAC or IPv4 RACLs.

- VLAN ACLs (VACLs)

  A VACL is an ACL that is applied to all ports belonging to a VLAN rather than a single port. VACLs can be MAC or IPv4 ACLs.

- Management ACLs (MACLs)

  Management ACLs allow you to add an access list to incoming VTY (Virtual Teletype) lines. This way, you can control who can access the switch.

Summary of Packet Classifiers

ACLs allow you to classify packets according to a variety of content in the packet header, such as the source address, destination address, source port number, and destination port number. Once classified, packet flows can be identified for more processing.

IPv4 ACLs, MAC ACLs, and ARP ACLs, allow you to classify packets based on the following:

- IPv4 ACLs:
  - AH Packet
  - any protocol packet
  - EIGRP protocol packet
  - ESP packet
  - GRE packet
  - IANA assigned protocol number (0-255)
  - ICMP Packet
  - IGMP packet
  - IPv4 Encapsulation packet
  - KA9Q NOS compatible IP over IP tunneling
  - OSPF packet
  - IPCOMP packet
  - PIM packet
  - TCP Packet
  - UDP Packet
  - Source IPv4 address and subnet mask
  - Destination IPv4 address and subnet mask
  - Type of Service value
  - TCP/UDP application source host and mask
  - TCP/UDP source port as shown in Table 8
  - TCP/UDP application destination host and mask
  - TCP/UDP destination port as shown in Table 8
  - TCP flag value as shown in Table 9
- MAC ACLs:
  - Source MAC address
  - Destination MAC address
  - Ethernet type (ARP, IPv4, MPLS, RARP etc.)
  - Ethernet Priority (IEEE 802.1p Priority)
  - VLAN number and mask

- ARP ACLs:
  - Source IPv4 address and subnet mask
  - Destination IPv4 address and subnet mask
  - Source MAC address
  - Destination MAC address

Table 8. *TCP/UDP Applications*

Port	TCP/UDP Application	Port	TCP/UDP Application	Port	TCP/UDP Application
20	ftp-data	79	finger	179	bgp
21	ftp	80	http	194	irc
22	ssh	109	pop2	220	imap3
23	telnet	110	pop3	389	ldap
25	smtp	111	sunrpc	443	https
37	time	119	nntp	520	rip
42	name	123	ntp	554	rtsp
43	whois	143	imap	1645/1812	Radius
53	domain	144	news	1813	Radius
69	tftp	161	snmp	1985	Accounting
70	gopher	162	snmptrap		hsrp

Table 9. *TCP Flag Values*

Flag	Value
URG	0x0020
ACK	0x0010
PSH	0x0008
RST	0x0004
SYN	0x0002
FIN	0x0001

Summary of ACL Actions

An ACL must have a set of rules to classify the packet. The first token of each rule indicates the action to be performed on those packets that match the rule.

The following actions are supported:

- All ACL types support Permit and Drop actions
- VACLs also support Redirect actions

Note: All ACLs have an implicit default deny action to drop those packets that do not match any of the ACL rules. This default action applies to all IPv4 packets in an IPv4 ACL, and to any packet for MAC and ARP ACLs on the respective port or VLAN.

Configuring Port ACLs (PACLs)

A PACL is configured if an ACL is assigned to a Layer 2 switched interface or port channel. The following are sample PACL configurations:

```
Switch(config)# interface ethernet 1/5
Switch(config-if)# switchport
Switch(config-if)# ip port access-group <IP ACL name> in
Switch(config-if)# exit
```

```
Switch(config)# interface ethernet 1/10
Switch(config-if)# switchport
Switch(config-if)# mac port access-group <MAC ACL name>
Switch(config-if)# exit
```

Configuring Router ACLs (RACLs)

A RACL is configured if an ACL is assigned to a Layer 3 routed interface, port channel, or SVI. The following is a sample PACL configuration applied on a physical routed port:

```
Switch(config)# interface ethernet 1/5
Switch(config-if)# no switchport
Switch(config-if)# ip access-group <IP ACL name> {in|out}
Switch(config-if)# exit
```

While a PACL, a RACL, or both can be configured to an interface, only one of them will be active on that interface, depending upon whether that interface is a Layer 2 or a Layer 3 interface. However, two ACLs of the same type cannot be configured on the same interface.

A packet can match different ACL types at the same time. When that happens, actions are taken according to the order of precedence.

To apply an IPv4 ACL to an SVI, enter:

```
Switch(config)# interface vlan <VLAN number (1-4093)>
Switch(config-if)# ip access-group <IPv4 ACL> {in|out}
[apply-routed-packets-only]
```

where:

Parameter	Description
no	(Optional) Remove the specified ACL.
IPv4 ACL	The name of the ACL to be applied to the specified VLAN
in	Apply this ACL to ingress IPv4 packets.
out	Apply this ACL to egress IPv4 packets.
apply-routed-packets-only	(Optional) Only match those IPv4 packets that are routedin the specified VLAN by the IPv4 ACLs already applied on L3 VLAN interfaces.

To remove an IPv4 ACL from an SVI, enter:

```
Switch(config)# interface vlan <VLAN number (1-4093)>
Switch(config-if)# no ip access-group <IPv4 ACL> {in|out}
[routed-packets-only]
```

Configuring VLAN ACLs (VACLs)

A VACL is an ACL that can be assigned to a VLAN rather than to a switch port as with IPv4 ACLs. This is particularly useful in a virtualized environment where traffic filtering and metering policies must follow virtual machines (VMs) as they migrate between hypervisors.

VACLs can be configured for all user-created VLANs except for reserved VLANs.

Individual VACL filters are configured in a similar fashion to IPv4 ACLs.

To create or change a VACL, follow these steps:

1. From Configuration Mode, enter VLAN Access Map Configuration Mode:

```
Switch(config)# vlan access-map <ACL name>
Switch(config-access-map)#
```

2. Enter an action for the VACL to take.

   To drop or forward matching packets, use the following command:

```
Switch(config-access-map)# action {drop|forward}
```

   To redirect matching packets, use the following command:

```
Switch(config-access-map)# action redirect {ethernet <chassis number/port number>|port-channel <LAG number>}
```

   Note: Because the redirected packet will be subjected to the usual VLAN membership check, make sure the interface to where the packet is redirected has the same VLAN membership as the VACL.

3. Enter a match for the VACL to use.

   - To configure a rule to match an IP ACL, use the following command:

```
Switch(config-access-map)# match ip address <IP ACL>
```

   - To configure a rule to match a MAC ACL, use the following command:

```
Switch(config-access-map)# match mac address <MAC ACL>
```

4. Once a VACL filter is created, it can be assigned to or removed from a list of VLANs.

   - To assign a VACL filter to a VLAN, use the following command:

     ```
     Switch(config)# vlan filter <VACL name> vlan-list <VLAN ID (1-4093)>
     ```

   - To remove a VACL filter from a VLAN, use the following command:

     ```
     Switch(config)# no vlan filter <VACL name> vlan-list <VLAN ID (1-4093)>
     ```

   In this example, traffic from VLAN 3 ports is forwarded.

   ```
   Switch(config)# vlan access-map myVACL
   Switch(config-access-map)# action forward
   Switch(config-access-map)# match <ip/mac> address <access-list name>
   Switch(config-access-map)# exit
   Switch(config)#

   Switch(config)# vlan filter myVACL vlan-list 3
   ```

   Without setting a match statement for the VACL, when exiting it's configuration mode, it will be deleted:

   ```
   Switch(config)# vlan access-map myVACL
   Switch(config-access-map)# action forward
   Switch(config-access-map)# exit
   Switch(config)# vlan filter myVACL vlan-list 3%vlan access map myVACL is
   not found
   ```

Configuring Management ACLs (MACLs)

Management ACLs allow you to add an access list to incoming VTY (Virtual Teletype) lines. This way, you can control who can access the switch. The Management ACL attached to VTY lines applies to all the packet destined to the switch CPU, coming from interfaces that are part of VRFs where MACLs are attached.

To create a Management ACL, follow these steps:

1. Change the mode to the default VFRs VTY interface:

```
Switch(config)# line vty vrf default
```

2. Attach or detach an ACL to a VTY interface:

```
Switch(config-vrf-vti)# ip access-class <access list name> in
```

Notes:

- The total number of ACL rules applied to all the VTY interfaces must be less than 4096.
- Adding a very large number of rules to an ACL may increase the time required to apply the settings during the initial configuration and when rebooting the switch.
- Only IPv4 ACLs can be attached to VTY interfaces.
- A management ACL can be attached to a VTY port that is part of the default VRF.
- The same ACL can be used on VTY in management ACL and VTY in default VRF at the same time.
- An ACL cannot be attached to a VTY interface and a non-VTY interface at the same time.

ACL Order of Precedence

Some types of ACLs cannot be attached multiple times on the same bind point, such as attaching two different ACLs on the same interface as PACL or two different ACLs on the same VLAN as VACLs. If this happens, the second ACL will overwrite the first, thus making the second ACL active.

When a packet is received on a port, the ACLs are applied in the following order:

1. PACLs and RACLs are applied on physical ports and Link Aggregation Groups (LAGs).

   ACLs are attached on physical ports as Port ACL and Routed Port ACLs as shown:

   - Port ACL:

   ```
   Switch(config)# interface ethernet 1/1
   Switch(config-if)# switchport
   Switch(config-if)# ip port access-group testAcl in
   ```

   - Routed Port ACL:

   ```
   Switch(config)# interface ethernet 1/2
   Switch(config-if)# no switchport
   Switch(config-if)# ip access-group testAcl in
   ```

2. Ingress VACLs:

   ```
   Switch(config)# vlan filter testVlanAcl vlan-list 10-100
   ```

3. Ingress RACLs applied on a logical Layer 3 interface (SVI interface):

   ```
   Switch(config)# interface vlan 3
   Switch(config-if)# no switchport
   Switch(config-if)# ip access-group testAcl in
   ```

4. ARP ACLs
5. Egress router ACLs

   Although the packets are processed in the order mentioned here, the ACLs are further grouped and are prioritized within each group as follows:

   - **Group 1**
     - (Highest priority) ACLs attached to physical port (port ACL and routed port ACL)
     - (Middle priority) VLAN ACLs (VLAN access-map)
     - (Lowest priority) ACLs attached to the VLAN interface.
   - **Group 2**
     - (Highest Priority) MAC ACLs
     - (Lowest priority) ARP ACLs

When a packet matches ACLs in both groups, the ACL that has drop or redirect actions would be effective. If none of the matched ACLs have deny or redirect actions, all the actions in those ACLs will be applied to the packet.

Creating and Modifying ACLs

Each ACL is defined by a group of rules. You can create the following types of ACLs:

- **IPv4 ACLs**
  Each command defines one filter rule for matching traffic criteria. Each filter rule must also include an action (permit or deny the packet). For example:

```
Switch(config)# ip access-list myACL
Switch(config-acl)# permit udp any lt 301 10.2.2.1 0.0.0.255
```

  This example configures ACL 'myACL' to permit UDP traffic from any host, that has a UDP source port smaller than 301, and that goes to hosts that belong to the network 10.2.2.0/24. All other traffic will be dropped by the implicit `deny` rule.

- **MAC ACLs**
  Each command defines one filter rule for matching traffic criteria. Each filter rule must also include an action (permit or deny the packet). For example:

```
Switch(config)# mac access-list myMAC-ACL
Switch(config-mac-acl)# permit 001b.6384.45e6 0000.0000.ffff
8c89.a502.93af 0000.0000.ffff cos 2
```

  This example configures MAC ACL 'myMAC-ACL' to permit traffic from MAC host 001B.6384.45E6 with source wildcard 0000.0000.FFFF that goes to MAC host 8C89.A502.93AF with destination wildcard 0000.0000.FFFF using Class of Service (CoS) 2. All other traffic will be dropped by the implicit `deny` rule.

- **ARP ACLs**
  Each command defines one filter rule for matching traffic criteria. Each filter rule must also include an action (permit or deny the packet). For example:

```
Switch(config)# arp access-list myARP-ACL
Switch(config-arp-acl)# permit ip any mac 0007.e94d.4a85 0000.0000.ffff
```

  This example configures ARP ACL 'myARP-ACL' to permit traffic from any IP source address with source MAC address 0007.E94D.4A85 and source wildcard 0000.0000.FFFF. All other traffic will be dropped by the implicit `deny` rule.

Creating an IPv4 ACL

To create an IPv4 ACL, follow these steps:

1. From Configuration Mode, enter ACL Configuration Mode for the ACL:

```
Switch(config)# ip access-list <ACL name>
Switch(config-acl)#
```

Note: The ACL name is case-sensitive.

2. Assign rules to the ACL using the following syntax:

```
Switch(config-acl)# [<sequence number>] {deny|permit} <protocol> <source IP address>
<source wildcard IP mask> [<operand> <port number>] <destination IP address> <destination wildcard
IP mask> [<operand> <port number>] [<bit to match on>]
```

Note: You can enter more than one rule for an ACL.

3. Verify the IPv4 ACL configuration:

```
Switch(config)# show ip access-lists <ACL name>
```

Note: To change a filtering rule, you must first remove it using the **no** command in front of the command that created the group:

```
Switch(config-acl)# no [<sequence number>] {deny|permit} <protocol> <source IP
address> <source wildcard IP mask> [<operand> <port number>] <destination IP address> <destination
wildcard IP mask> [<operand> <port number>] [<bit to match on>]
```

You can also use the following command to remove a filtering rule:

```
Switch(config-acl)# no <sequence number>
```

Removing an IPv4 ACL

To remove an ACL, enter:

```
Switch(config)# no ip access-list <ACL name>
```

Resequencing an IPv4 ACL

Sometimes you may want to fit a rule between two existing numbers. Use the **resequence** command in Configuration Mode to change the numbering scheme but keep the existing rules in order:

```
Switch(config)# resequence ip access-list <ACL name> <starting number>
<increment>
```

For example:

```
Switch(config)# resequence ip access-list myACL 10 5
```

The rules configured for ACL 'myACL' will be reassigned sequence numbers starting with number 10. Following rules will have a sequence number equal to the previous rule's sequence number plus an increment of 5. In other words, the first rule in the ACL will have a sequence number of 10, the second rule 15, the third rule 20, and so forth.

Creating a MAC ACL

To create a MAC ACL, follow these steps:

1. From Configuration Mode, enter MAC ACL Configuration Mode for the ACL:

```
Switch(config)# mac access-list <ACL name>
Switch(config-mac-acl)#
```

Note: The ACL name is case-sensitive.

2. Assign rules to the ACL using the following syntax:

```
Switch(config-mac-acl)# [<sequence number>] {deny|permit} {{<source MAC address>
[<source wildcard MAC mask>]}|any|host <source MAC address>} {{<destination MAC address>
[<destination wildcard MAC mask>]}|any|host <destination MAC address>} {<protocol>|cos
<cos>|vlan <VLAN ID (1-4093)>} [cos <cos>] [vlan <VLAN ID (1-4093)>]
```

Note: You can enter more than one rule for an ACL.

3. Verify the MAC ACL configuration:

```
Switch(config)# show mac access-lists <ACL name>
```

Note: To change a filtering rule, you must first remove it using the **no** command in front of the command that created the group:

```
Switch(config-mac-acl)# no [<sequence number>] {deny|permit} {{<source MAC
address> [<source wildcard MAC mask>]}|any|host <source MAC address>} {{<destination MAC
address> [<destination wildcard MAC mask>]}|any|host <destination MAC address>} {<protocol>|
cos <cos>|vlan <VLAN ID (1-4093)>} [cos <cos>] [vlan <VLAN ID (1-4093)>]
```

You can also use the following command to remove a filtering rule:

```
Switch(config-acl)# no <sequence number>
```

Removing a MAC ACL

To remove a MAC ACL, use the following command:

```
Switch(config)# no mac access-list <ACL name>
```

Resequencing a MAC ACL

If you want to fit a rule between two existing numbers, use the **resequence** command to change the numbering scheme but keep the existing rules in order:

```
Switch(config)# resequence mac access-list <ACL name> <starting number> <increment>
```

For example:

```
Switch(config)# resequence mac access-list myACL 10 5
```

The rules configured for ACL myACL will be reassigned sequence numbers starting with 10. Following rules will have a sequence number equal to the previous rule's sequence number plus an increment of 5; the first rule will have a sequence number of 10, the second rule 15, the third rule 20, and so forth.

Creating an ARP ACL

To create an ARP ACL, follow these steps:

1. From Configuration Mode, enter ARP ACL Configuration Mode for the ACL:

```
Switch(config)# arp access-list <ACL name>
Switch(config-arp-acl)#
```

Note: The ACL name is case-sensitive.

2. Assign rules to the ACL using the following syntax:

```
Switch(config-arp-acl)# [<sequence number>] {deny|permit} [request|response]
ip {<source IPv4 address>|any|host <single source address> {mac {<source MAC address>
<source wildcard MAC mask>|any|host <source MAC address>}}}
```

Note: You can enter more than one rule for an access list.

3. Verify the ARP ACL configuration:

```
Switch(config)# show arp access-lists <ACL name>
```

Note: To change a filtering rule, you must first remove it using the no command in front of the command that created the group:

```
Switch(config-arp-acl)# no [<sequence number>] {deny|permit} [request|
|response] ip {<source IPv4 address>|any|host <single source address> {mac {<source MAC
address> <source wildcard MAC mask>|any|host <source MAC address>}}}
```

You can also use the following command to remove a filtering rule:

```
Switch(config-acl)# no <sequence number>
```

Removing an ARP ACL

To remove an ARP ACL, use the following command:

```
Switch(config)# no arp access-list <ACL name>
```

Resequencing an ARP ACL

Sometimes you may want to fit a rule between two existing numbers. Use the **resequence** command in Configuration Mode to change the numbering scheme but keep the existing rules in order:

```
Switch(config)# resequence arp access-list <ACL name> <starting number> <increment>
```

For example:

```
Switch(config)# resequence arp access-list myACL 10 5
```

The rules configured for ACL myACL will be reassigned sequence numbers starting with number 10. Following rules will have a sequence number equal to the previous rule's sequence number plus an increment of 5. In other words, the first rule in the ACL will have a sequence number of 10, the second rule 15, the third rule 20, and so forth.

Remarks and ACLs

A *remark* is comment text added to an ACL to make the ACL easier to understand. The following rules apply to ACL remarks:

- Remarks are supported for IPv4, MAC, and ARP access lists.
- All remarks are single line.
- The maximum length of a remark must not exceed 100 characters. Leading and trailing spaces are not counted in the 100 character limit.
- Remarks can only contain characters permitted by the CLI. No special characters, such as "?" or newline, are allowed in remarks.
- You can add as many remarks to a single ACL as the sequence number of the ACL permits. The maximum number of ACL filter entries is 2048.
- You can add a remark at any particular sequence location, as long as it does not conflict with an existing entry at that particular location.
- ACL remarks are displayed in the running configuration.
- ACL remarks are persistent across reboots.

Add ACL Remarks

To add remarks to an IPv4 ACL, in the appropriate ACL Configuration mode (IPv4, MAC, or ARP), enter:

```
Switch(config-acl)# [<sequence number>] remark <remark>
```

```
Switch(config-mac-acl)# [<sequence number>] remark <remark>
```

```
Switch(config-arp-acl)# [<sequence number>] remark <remark>
```

where:

Parameter	Description
sequence number	(Optional) The sequence number at which you want the remark inserted; an integer from 1-2147483645. If omitted, the remark is automatically appended with a sequence number ten higher than the last sequence number.
remark	The comment text; a string up to 100 characters long.

Remove ACL Remarks

To remove remarks from an ACL, in the appropriate ACL Configuration mode (IPv4, MAC, or ARP), enter:

```
Switch(config-acl)# no [<sequence number>] remark <remark>
```

```
Switch(config-mac-acl)# no [<sequence number>] remark <remark>
```

```
Switch(config-arp-acl)# no [<sequence number>] remark <remark>
```

where:

Parameter	Description
sequence number	(Optional) The sequence number at which you want the remark inserted. If omitted, the remark is automatically appended with a sequence number ten higher than the last sequence number.
remark	The *exact* text of the remark to be removed.

Note: If multiple remarks contain the same text, only the first occurrence of the remark will be removed. To remove a specific duplicate remark, remove it by sequence number, as in:

```
Switch(config-mac-acl)# no [<sequence number>]
```

View ACL Remarks

To view the remarks of a specific ACL, use the following command:

```
Switch# show access-lists <ACL name>
```

Viewing ACL Rule Statistics

ACL Rule statistics display how many packets have matched each ACL rule. Use ACL Rule statistics to check filter performance or to debug the ACL rule filter configuration.

You must enable statistics for each ACL that you wish to monitor:

```
Switch(config)# {arp|ip|mac} access-list myacl
Switch(config-acl)# statistics per-entry
```

ACL Configuration Examples

The following are examples of configuring ACLs.

ACL Example 1

Use this configuration to block traffic to a specific host. In the following example, all traffic that ingresses on ethernet port 1/1 is denied, if it is destined for IP address 100.10.1.1.

1. Create an ACL:

```
Switch(config)# ip access-list myACL1
Switch(config-acl)#
```

2. Configure the ACL:

```
Switch(config-acl)# deny any any host 100.10.1.1
Switch(config-acl)# permit any any any
Switch(config-acl)# exit
```

3. Apply ACL 'myACL1' to ethernet interface 1/1:

```
Switch(config)# interface ethernet 1/1
Switch(config-if)# ip port access-group myACL1 in
Switch(config-if)# exit
```

ACL Example 2

Use this configuration to block traffic from a network destined for a specific host address. In the following example, all traffic that ingresses on ethernet port 1/2 with source IP from network 100.10.2.0/24 and destination IP 200.20.2.2 is denied.

1. Create an ACL:

```
Switch(config)# ip access-list myACL2
Switch(config-acl)#
```

2. Configure the ACL:

```
Switch(config-acl)# deny any 100.10.2.0/24 host 200.20.2.2
Switch(config-acl)# permit any any any
Switch(config-acl)# exit
```

3. Apply ACL 'myACL2' to ethernet interface 1/2:

```
Switch(config)# interface ethernet 1/2
Switch(config-if)# ip port access-group myACL2 in
Switch(config-if)# exit
```

ACL Example 3

Use the following configuration to deny all IGMP packets that ingress on a port.

1. Create an ACL:

```
Switch(config)# ip access-list myACL3
Switch(config-acl)#
```

2. Configure the ACL:

```
Switch(config-acl)# deny igmp any any
Switch(config-acl)# permit any any any
Switch(config-acl)# exit
```

3. Apply ACL 'myACL3' to ethernet interface 1/3:

```
Switch(config)# interface ethernet 1/3
Switch(config-if)# ip port access-group myACL3 in
Switch(config-if)# exit
```

ACL Example 4

Use the following configuration to permit access from any host to hosts with destination MAC address 11:05:00:10:00:00 and MAC wildcard FF:F5:FF:FF:FF:FF, and deny access to all other hosts.

1. Create a MAC ACL:

```
Switch(config)# mac access-list myMAC-ACL4
Switch(config-mac-acl)#
```

2. Configure the MAC ACL:

```
Switch(config-mac-acl)# permit any 11:05:00:10:00:00 FF:F5:FF:FF:FF:FF
Switch(config-mac-acl)# deny any any
Switch(config-mac-acl)# exit
```

3. Apply MAC ACL 'myMAC-ACL4' to ethernet interface 1/4:

```
Switch(config)# interface ethernet 1/4
Switch(config-if)# mac port access-group myMAC-ACL4
Switch(config-if)# exit
```

ACL Example 5

This configuration blocks egress traffic from a specific network to any destination. In this example, all traffic from the network 100.10.2.0/24 to any destination egressing from routed port 3 is denied.

1. Create an ACL:

```
Switch(config)# ip access-list myACL5
Switch(config-acl)#
```

2. Configure the ACL:

```
Switch(config-acl)# deny any 100.10.2.0/24 any
Switch(config-acl)# permit any any any
Switch(config-acl)# exit
```

3. Apply ACL `myACL5` to ethernet interface 1/5:

```
Switch(config)# interface ethernet 1/5
Switch(config-if)# ip access-group myACL5 out
Switch(config-if)# exit
```

ACL Example 6

This configuration creates an ARP ACL with multiple matching rules:

1. Create an ARP ACL:

```
Switch(config)# arp access-list myARP-ACL6
Switch(config-arp-acl)#
```

2. Add rules to the ACL:

```
Switch(config-arp-acl)# statistics per entry
Switch(config-arp-acl)# 10  deny ip any mac host 0033.3333.3333
Switch(config-arp-acl)# 20  permit ip any mac 0044.4444.4444
0000.0000.FFFF
Switch(config-arp-acl)# 30  permit ip host 20.20.20.2 mac host
0011.1111.1111
Switch(config-arp-acl)# 50  permit ip host 40.40.40.2 mac 0055.5555.5555
0000.0000.FFFF
Switch(config-arp-acl)# 60  deny ip host 50.50.50.2 mac any
Switch(config-arp-acl)# 70  deny ip 30.30.30.2 0.0.0.255 mac
0022.2222.2222 0000.0000.FFFF
Switch(config-arp-acl)# 80  deny ip 40.40.40.2 0.0.0.255 mac any
Switch(config-arp-acl)# 90  permit ip 50.50.50.2 0.0.0.255 mac host
0055.5555.5555
Switch(config-arp-acl)# exit
```

3. Configure the inspection filter:

```
Switch(config)# ip arp inspection filter myARP-ACL vlan 20,30,40,50
```

ACL Example 7

This configuration allows Telnet and SSH from any host in subnet 10.10.10.0/24, and denies all other subnets or protocols to the VTYs.

1. Create an IP ACL named `remoteAccess`:

```
Switch(config)# ip access-list remoteAccess
```

2. Add rules to the ACL:

```
Switch(config-arp-acl)# 10 permit tcp 10.10.10.0/24 any eq telnet
Switch(config-arp-acl)# 20 permit tcp 10.10.10.0/24 any eq 22
Switch(config-arp-acl)# 50 deny tcp any any eq telnet
Switch(config-arp-acl)# 60 deny tcp any any eq 22
Switch(config-arp-acl)# exit
```

3. Change the mode to the default VFR instance for the VTY interface:

```
Switch(config)# line vty vrf default
Switch(config-vfr-vty)# ip access-class remoteAccess in
```

4. Change the mode to the management VFR instance for the VTY interface:

```
Switch(config)# line vty vrf management
Switch(config-vfr-vty)# ip access-class remoteAccess in
```

ACL Example 8

Use this configuration to match an ACL rule to an established TCP connection.

1. Create an ACL:

```
Switch(config)# ip access-list myACL6
Switch(config-acl)#
```

2. Add rules to the ACL:

```
Switch(config-acl)# 10 permit tcp any any urg established
```

3. Apply ACL `myACL6` to ethernet interface 1/6:

```
Switch(config)# interface ethernet 1/6
Switch(config)# no switchport
Switch(config-if)# ip access-group myACL6 out
Switch(config-if)# exit
```

ACL Logging

ACL logging provides insight into traffic as it passes the network or is dropped by the network switch. ACL logging can be CPU intensive and can slow traffic going through the switch. There are two main factors that contribute to the CPU load increase from ACL logging:

- process switching of packets that match log-enabled access control entries (ACEs)
- generating and transmitting log messages.

The logging option applies to an individual ACE and causes packets that match the ACE to be logged. Logging includes the packet's source and destination IP addresses.

Using the configuration commands detailed in this section, you can strike a balance between traffic visibility and the corresponding impact on the switch CPU load.

Note: ACL Logging is not supported for Management ACLs.

Configure ACL Logging

To set up ACL logging on your switch:

1. Enter ACL configuration mode:

```
Switch(config)# ip access-list <ACL name>
```

2. Enable ACL logging for each ACE:
   - Log all rejected traffic:

```
Switch(config-acl)# <sequence number> deny any any any log
Switch(config-acl)# exit
```

   - Log only rejected ICMP traffic:

```
Switch(config-acl)# <sequence number> deny icmp any any log
Switch(config-acl)# exit
```

   - Log only specific rejected ICMP packets:

```
Switch(config-acl)# <sequence number> deny igmp any any dscp af11
fragments log
Switch(config-acl)# exit
```

Note: The **log** keyword appears at the end of every possible ACE configuration. If enabled, ACL logs will be generated when the rules of the ACL match traffic.

3. Set the maximum number of log entries cached in the software:

```
Switch(config)# logging ip access-list cache entries <entries>
```

where *entries* is the maximum number of entries; an integer from 1-1048576. The default value is 8000.

Note: Each entry corresponds to a specific traffic flow that is matched by an ACL rule that has the `log` option enabled.

4. Set the log update interval, in seconds:

```
Switch(config)# logging ip access-list cache interval <seconds>
```

where *seconds* is the cache interval; an integer from 5-3600. The default value is 300.

Note: The interval configured allows only one packet per interval to be processed no matter how many log-enabled ACEs exist.

5. Set how often log messages are generated and sent after the initial packet match:

```
Switch(config)# logging ip access-list cache threshold <cache interval>
```

where *cache* is the cache interval. The default value is 0.

Note: These commands use a threshold described as a number of packets, not as a time interval. This configured threshold is applied per flow and does not disable the initial match log message or the interval periodic update.

6. Set the ACL log level accepted by the syslog:

```
Switch(config)# logging level acllog <level>
```

where *level* is the ACL log level; an integer from 0-7 that signifies the following:

Level	Meaning
0	emergencies
1	alerts
2	critical
3	errors
4	warnings
5	notifications
6	information
7	debug

The default value is 6 (information).

7. Clear the ACL cache:

```
Switch(config)# clear logging ip access-list cache
```

8. Display the IP access list cache:

```
Switch(config)# show logging ip access-list cache
```

9. Display the status of the IP access list cache:

```
Switch(config)# show logging ip access-list status
```

Part 3: Switch Basics

This section discusses basic switching functions:

Chapter 8. Interface Management

The term *interface* can refer to a physical switch port or a logical port, a VLAN, or a Link Aggregation Group (LAG).

This section discusses the following topics:

Interface Management Overview

Interface Management (IFM) is part of the system infrastructure that acts as a logical interface abstraction for software components (applications) running on the switch. It is provided by the Network Service Module (NSM). NSM follows a server-client model and, as a server, it handles interface interactions with other switch applications, which are clients to the NSM server.

NSM clients include applications like: Neighbor Discovery Protocol (NDP), Routing Information Base (RIB), Spanning Tree Protocol (STP), Link Aggregation Control Protocol (LACP), Internet Group Management Protocol (IGMP), Border Gateway Protocol (BGP), and more. NSM clients subscribe to the services provided by the NSM server to deal with interface events, like a link going up or down. When an interface event occurs, NSM handles the event accordingly and then notifies all of its clients.

All interfaces are assigned a unique internal identifier called an interface index (ifindex). The *ifindex* is a 32-bit integer attributed to the interface by NSM. Once an ifindex has been assigned to an interface, it is forever bound to it.

During CLI interactions with the switch, interfaces are identified by their names, and not by their ifindex.

To view the `ifindex` of all interfaces, use the following command:

```
Switch> show interface snmp-ifindex
-------------------------------------------------------------------------
Port                        IFMIB Ifindex (hex)
-------------------------------------------------------------------------
Ethernet1/1                 410001  (0x00064191)
Ethernet1/2                 410002  (0x00064192)
Ethernet1/3                 410003  (0x00064193)
Ethernet1/4                 410004  (0x00064194)
...
Ethernet1/54/4              410072  (0x000641d8)
loopback0                        8  (0x00000008)
mgmt0                            3  (0x00000003)
po100                       100100  (0x00018704)
po1000                      101000  (0x00018a88)
po2000                      102000  (0x00018e70)
Vlan1                            9  (0x00000009)
Vlan100                         13  (0x0000000d)
Vlan200                         14  (0x0000000e)
Vlan300                         15  (0x0000000f)
```

Note: An interface cannot be configured until it is created. Also, if the interface is removed, its configuration is lost. For example, the configuration of a 40 Gigabit Ethernet (GbE) port will be lost once the port is split into four 10 GbE breakout ports. There are some interfaces created by default on the switch that cannot be removed.

The switch supports both IPv4 and IPv6 addressing on Layer 3 interfaces, such as routed ports, loopback interfaces or Switch Virtual Interfaces. For more details, see Chapter 16, “Basic IP Routing“ and Chapter 19, “Internet Protocol Version 6“.

Management Interface

The Management Interface is a special physical port on the switch that allows you to perform switch management tasks.

It is a Layer 3 interface and it cannot be configured as a Layer 2 port.

The management interface cannot forward traffic. To keep it separate from other interfaces, the management port is part of the management Virtual Routing and Forwarding (VRF) instance, while other interfaces are part of the default VRF instance.

To configure the management interface, use the following command:

```
Switch(config)# interface mgmt 0
Switch(config-if)#
```

Notes:

- After running the above command, you will enter Interface Configuration mode for the management port.
- By default, the management interface is created by the switch and it cannot be removed.

To view detailed information about the management interface, use the following command:

```
Switch(config)# show interface mgmt 0

Interface mgmt0
  Hardware is Management Ethernet  Current HW addr: a897.dcde.2500
  Physical:a897.dcde.2500  Logical:(not set)
  index 3 metric 1 MTU 1500 Bandwidth 1000000 Kbit
  no switchport
  arp ageing timeout 1500
  <UP,BROADCAST,RUNNING,ALLMULTI,MULTICAST>
  VRF Binding: Associated with management
  Speed auto Duplex full
  IPV6 DHCP IA-NA client is enabled.
  inet 10.241.41.27/25 broadcast 10.241.41.127
  inet6 fe80::aa97:dcff:fede:2500/64
  RX
    131249 input packets 5 unicast packets 128053 multicast packets
    3191 broadcast packets 23903151 bytes
  TX
    6749 output packets 0 unicast packets 6749 multicast packets
    0 broadcast packets 939061 bytes
```

Physical Ports

The following Lenovo switches are 1U rack-mountable aggregation devices:

- RackSwitch G8272
- RackSwitch G8332
- ThinkSystem NE1032T RackSwitch
- ThinkSystem NE1032 RackSwitch
- ThinkSystem NE1072T RackSwitch
- ThinkSystem NE10032 RackSwitch
- ThinkSystem NE2572 RackSwitch

The Lenovo RackSwitch G8296 is a 2U rack-mountable aggregation device.

All of these switches use a wire-speed, non-blocking switching fabric that provides simultaneous wire-speed transport of multiple packets at low latency on all ports.

G8272 Physical Port Capabilities

The G8272 has the following port capabilities:

- Forty-eight 10 Gigabit Ethernet (GbE) Small Form Pluggable Plus (SFP+) ports which also support legacy 1 GbE connections
- Six 40 GbE Quad Small Form Pluggable Plus (QSFP+) ports, each of which can optionally be used as four 10 GbE ports

SFP+ ports, when used in 10 GbE mode, can be populated with optical transceiver modules, or active or passive Direct-Attach Cables (DACs). When used in legacy 1 GbE mode, the ports can be populated with optical or copper transceiver modules.

QSFP+ ports can be populated with optical QSFP+ modules or passive DACs, including those that allow the port to be used as four 10 GbE ports.

By default, the G8272 has the following interface (port) configuration:

- ethernet interfaces 1-48 are configured as 10 GBit/s ports
- ethernet interfaces 49-54 are configured as 40 GBit/s ports

Table 10 shows the available port modes and supported speeds for the G8272:

Table 10. *Available Port Modes and Supported Speeds for the G8272*

Port Mode	Supported Speeds
1x40G	40G
4x10G	10G
1x10G	10G

G8296 Physical Port Capabilities

The G8296 has the following port capabilities:

- Eighty-six 10 Gigabit Ethernet (GbE) Small Form Pluggable Plus (SFP+) ports which also support legacy 1 GbE connections
- Ten 40 GbE Quad Small Form Pluggable Plus (QSFP+) ports, of which two ports can optionally be used as four 10 GbE ports

SFP+ ports, when used in 10 GbE mode, can be populated with optical transceiver modules, or active or passive Direct-Attach Cables (DACs). When used in legacy 1 GbE mode, the ports can be populated with optical or copper transceiver modules.

QSFP+ ports can be populated with optical QSFP+ modules or passive DACs, including those that allow the port to be used as four 10 GbE ports.

By default, the G8296 has the following interface (port) configuration:

- ethernet interfaces 1-86 are configured as 10 GBit/s ports
- ethernet interfaces 87-96 are configured as 40 GBit/s ports

Table 11 shows the available port modes and supported speeds for the G8296:

Table 11. *Available Port Modes and Supported Speeds for the G8296*

Port Mode	Supported Speeds
1x40G	40G
4x10G	10G
1x10G	10G

G8332 Physical Port Capabilities

The G8332 has the following port capabilities:

- Thirty-two 40 GbE Quad Small Form Pluggable Plus (QSFP+) ports, of which ports 2-25 can optionally be used as four 10 GbE ports

QSFP+ ports can be populated with optical QSFP+ modules or passive DACs, including those that allow the port to be used as four 10 GbE ports.

By default, the G8332 has the following interface (port) configuration:

- ethernet interfaces 1-32 are configured as 40 GBit/s ports

Table 12 shows the available port modes and supported speed for the G8332:

Table 12. *Available Port Modes and Supported Speeds for the G8332*

Port Mode	Supported Speed
1x40G	40G
4x10G	10G
1x10G	10G

NE1032 Physical Port Capabilities

The NE1032 has the following port capabilities:

- Thirty-two 10 Gigabit Ethernet (GbE) Small Form Pluggable Plus (SFP+) ports which also support legacy 1 GbE connections

SFP+ ports, when used in 10 GbE mode, can be populated with optical transceiver modules, or active or passive Direct-Attach Cables (DACs). When used in legacy 1 GbE mode, the ports can be populated with optical or copper transceiver modules.

By default, the NE1032 has the following interface (port) configuration:

- ethernet interfaces 1-32 are configured as 10 GBit/s ports

Table 13 shows the available port modes and supported speeds for the NE1032:

Table 13. *Available Port Modes and Supported Speeds for the NE1032*

Port Mode	Supported Speeds
1x10G	10G

NE1032T Physical Port Capabilities

The NE1032T has the following port capabilities:

- Twenty-four 100/1000/10G BASE-T RJ45 ports
- Eight Gigabit Ethernet (GbE) Small Form Pluggable Plus (SFP+) ports which also support legacy 1 GbE connections

The 10G BASE-T RJ45 ports, when used in 10 GbE mode, must use CAT6 copper cabling. When used in 100/1000 base T mode, the ports can be populated with CAT5E copper cabling.

SFP+ ports, when used in 10 GbE mode, can be populated with optical transceiver modules, or active or passive Direct-Attach Cables (DACs). When used in legacy 1 GbE mode, the ports can be populated with optical or copper transceiver modules.

By default, the NE1032T has the following interface (port) configuration:

- Ethernet interfaces 1-32 are configured as 10 GBit/s ports

Table 14 shows the available port modes and supported speeds for the NE1032T:

Table 14. *Available Port Modes and Supported Speeds for the NE1032T*

Port Mode	Supported Speeds
1x10G	10G
1x10G-Base-T	100 Mbps-Auto Negotiation, 1G-Auto Negotiation, 10G-Auto Negotiation, 1G+10G-Auto Negotiation

NE1072T Physical Port Capabilities

The NE1072T has the following port capabilities:

- Forty-eight 100/1000/10G BASE-T RJ45 ports
- Six 40 GbE Quad Small Form Pluggable Plus (QSFP+) ports, all of which can optionally be used as four 10 GbE ports

The 10G BASE-T RJ45 ports, when used in 10 GbE mode, must use CAT6 copper cabling. When used in 100/1000 base T mode, the ports can be populated with CAT5E copper cabling.

QSFP+ ports can be populated with optical QSFP+ modules or passive DACs, including those that allow the port to be used as four 10 GbE ports.

By default, the NE1072T has the following interface (port) configuration:

- ethernet interfaces 1-48 are configured as 10 GBit/s ports
- ethernet interfaces 49-54 are configured as 40 GBit/s ports

Table 15 shows the available port modes and supported speeds for the NE1072T:

Table 15. *Available Port Modes and Supported Speeds for the NE1072T*

Port Mode	Supported Speeds
1x40G	40G
4x10G	10G
1x10G-Base-T	100 Mbps-Auto Negotiation, 1G-Auto Negotiation, 10G-Auto Negotiation, 1G+10G-Auto Negotiation

NE2572 Physical Port Capabilities

The NE2572 has the following port capabilities:

- Forty-eight 25 Gigabit Ethernet (GbE) SFP28 ports supporting 10GbE and 25GbE connections. Ports 9-48 also support legacy 1GbE connection with no auto negotiation.

  Note: Due to hardware limitations of the switch ASIC, when using a 1 GbE SFP Copper transceiver, the link state change can be detected with a delay of 2-3 seconds. Also, during reload, you may see a temporary link up state even though the link is down configuration wise. This may have an impact to link failovers with this type of transceiver. The switch stabilizes and resumes under normal operation.

- Six additional 100 Gigabit Ethernet (GbE) QSFP28 ports supporting 10GbE, 25GbE, 40 GbE, 50GbE and 100GbE connections.

QSFP28 ports can be populated with Optical QSFP28/QSFP+ modules or Quad Direct Attach Cables (QDACs), including those that allow breakout to four 10 GbE or 25GbE SFP28/SFP+ ports.

SFP28 port can be populated with Optical or Copper SFP28/SFP+ transceivers or SFP28/SFP+ Direct Attach Cables (DACs). When used in legacy 1 GbE mode, the ports can be populated with optical or copper transceiver modules.

The following per-port hardware profiles are available for QSFP28 ports:

- One 40 GbE port
- Two 50 GbE ports
- Four 10 GbE ports
- Four 25 GbE ports
- One 100 GbE port

Table 16 shows the available port modes and supported speeds for the NE2572:

Table 16. *Available Port Modes and Supported Speeds for the NE2572*

Port Mode	Supported Speeds
1x100G	100G, 100G-Auto Negotiation
2x50G	50G, 50G-Auto Negotiation
4x25G	25G, 25G-Auto Negotiation
1x40G	40G
4x10G	10G
1x25G	25G, 25G-Auto Negotiation
1x10G	10G

For NE2572, switch ports configured in 25Gbps hardware profile port mode can have their port speed changed to 10Gbps or back to 25Gbps without needing to reload the switch.

You need to configure the same hardware profile port mode and the same port speed on both end-ports of the link.

You need install transceivers that support both 25Gbps and 10Gbps speeds, else you also need to change the transceiver each time the port speed is modified.

NE10032 Physical Port Capabilities

The NE10032 has the following port capabilities:

- Thirty-two 100 Gigabit Ethernet (GbE) QSFP28 ports supporting 10GbE, 25GbE, 50GbE and 100GbE connections
- One hundred and twenty-eight 10 GbE QSFP28 ports
- One hundred and twenty-eight 25 GbE QSFP28 ports
- Thirty-two 40 GbE QSFP28 ports
- Sixty-four 50 GbE QSFP28 ports
- custom profile
- default profile

QSFP28 ports can be populated with Optical QSFP28/QSFP+ modules or Quad Direct Attach Cables (QDACs), including those that allow breakout to four 25GbE SFP28/SFP+ ports.

By default, the NE10032 has ethernet interfaces 1-32 configured as 100 GBit/s ports.

The following per-port hardware profiles are available:

- One 40 GbE port
- Two 50 GbE ports
- Four 10 GbE ports
- Four 25 GbE ports
- One 100 GbE port

Table 17 shows the available port modes and supported speeds for the NE10032:

Table 17. *Available Port Modes and Supported Speeds for the NE10032*

Port Mode	Supported Speeds
1x100G	100G, 100G-Auto Negotiation
2x50G	50G, 50G-Auto Negotiation
4x25G	25G, 25G-Auto Negotiation
1x40G	40G
4x10G	10G

For NE10032, switch ports configured in 25Gbps hardware profile port mode can have their port speed changed to 10Gbps or back to 25Gbps without needing to reload the switch.

You need to configure the same hardware profile port mode and the same port speed on both end-ports of the link.

You need install transceivers that support both 25Gbps and 10Gbps speeds, else you also need to change the transceiver each time the port speed is modified.

CLI Port Format

During CLI interactions, physical ports are referred to as ethernet interfaces and have the following port numbering scheme:

- 10, 40, or 100 GbE ports: *<chassis number>/<port number>*

  For example, physical port 10:

```
interface ethernet 1/10
```

- 10, 25, or 50 GbE breakout ports: *<chassis number>/<port number>/<subport number>*

  For example, breakout port 3 of physical port 52:

```
interface ethernet 1/52/3
```

Note: If a port in 25 GbE mode has the name `ethernet 1/25/1`, the same name is associated in the 50 GbE mode for the first 50 GbE port from the QSFP cage, such as port lanes 1-2. If a port in 25 GbE mode has the name `ethernet 1/25/2`, the same name is associated in the 50 GbE mode for the second 50 GbE port from the QSFP cage, such as port lanes 3-4.

In CLI commands, ethernet interfaces can be used in the following ways:

- as a single interface:

```
Switch(config)# interface ethernet 1/10
```

- as a continuos range:

```
Switch(config)# interface ethernet 1/10-24
```

- as a discrete range:

```
Switch(config)# interface ethernet 1/10, ethernet 1/20-22
```

To configure an ethernet interface, use the following command:

```
Switch(config)# interface ethernet <chassis number>/<port number>
Switch(config-if)#
```

For example:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)#
```

Notes:

- After running the above command, you will enter Interface Configuration mode for the specified ethernet port.
- Ethernet interfaces cannot be removed using the CLI.

To view detailed information about an ethernet interface, use the following command:

```
Switch(config)# show interface ethernet <chassis number>/<port number>

Interface Ethernet1/1
  Hardware is Ethernet  Current HW addr: a48c.dbba.7603
  Physical:a48c.dbba.7603  Logical:(not set)
  Description: IXIA
  index 410001 metric 1 MTU 9216 Bandwidth 10000000 Kbit FEC is NA
  Port Mode is trunk
  <UP,BROADCAST,RUNNING,ALLMULTI,MULTICAST>
  VRF Binding: Not bound
  Speed 10000 Mb/s Duplex full
  Last link flapped never
  Last clearing of "show interface" counters never
  30 seconds input rate 0 bits/sec, 0 bytes/sec, 0 packets/sec
  30 seconds output rate 2579 bits/sec, 322 bytes/sec, 4 packets/sec
  Load-Interval #2: 5 minute (300 seconds)
     input rate 0 bps, 0 pps; output rate 2352 bps, 4 pps
  RX
    0 unicast packets  0 multicast packets  0 broadcast packets
    0 input packets  0 bytes
    0 jumbo packets  0 storm suppression packets
    0 giants  0 input error  0 short frame  0 overrun  0 underrun
    0 watchdog  0 if down drop
    0 input with dribble  0 input discard(includes ACL drops)
    0 Rx pause
  TX
    6 unicast packets  7322 multicast packets  93 broadcast packets
    7421 output packets  525471 bytes
    0 jumbo packets
    0 output errors  0 collision  0 deferred  0 late collision
    0 lost carrier  0 no carrier  0 babble
    0 Tx pause
  0 interface resets
Automatic policy provisioning is disabled on this interface
Automatic policy host discovery is disabled on this interface
Layer3 vlan encapsulation is disabled on this interface.
```

Port Aggregation

Multiple physical ports can be aggregated to act as a single logical port called a Link Aggregation Group (LAG). Port aggregation provides link redundancy, increased bandwidth, and traffic balancing across the ethernet ports.

By default, no physical ports are aggregated. Thus, no LAGs are configured on the switch.

To create or modify an existing LAG, use the following command:

```
Switch(config)# interface port-channel <1-4096>
Switch(config-if)#
```

Note: After running the above command, you enter Interface Configuration mode for the specified LAG.

To delete a LAG, use the following command:

```
Switch(config)# no interface port-channel <1-4096>
```

To view detailed information about a LAG, use the following command:

```
Switch(config)# show interface port-channel <1-4096>

Interface po100
  Hardware is AGGREGATE  Current HW addr: a48c.dbba.760a
  Physical:(not set)  Logical:(not set)
  index 100100 metric 1 MTU 9216 Bandwidth 300000000 Kbit FEC is NA
  Port Mode is trunk
  <UP,BROADCAST,RUNNING,MULTICAST>
  VRF Binding: Not bound
  Speed 25000 Mb/s Duplex full
  Members in this port-channel:
    Ethernet1/9, Ethernet1/10, Ethernet1/11, Ethernet1/12,
    Ethernet1/49/1, Ethernet1/49/2, Ethernet1/49/3, Ethernet1/49/4,
    Ethernet1/50/1, Ethernet1/50/2, Ethernet1/50/3, Ethernet1/50/4
  lacp suspend-individual  admin: Suspended
  Last clearing of "show interface" counters never
  30 seconds input rate 46795 bits/sec, 5849 bytes/sec, 90 packets/sec
  30 seconds output rate 72835 bits/sec, 9104 bytes/sec, 89 packets/sec
  Load-Interval #2: 5 minute (300 seconds)
     input rate 44690 bps, 86 pps; output rate 69592 bps, 85 pps
  RX
    0 unicast packets  166286 multicast packets  0 broadcast packets
    166286 input packets  10961241 bytes
    0 jumbo packets  0 storm suppression packets
    0 giants  0 input error  0 short frame  0 overrun  0 underrun
    0 watchdog  0 if down drop
    0 input with dribble  0 input discard(includes ACL drops)
    0 Rx pause
  TX
    0 unicast packets  165288 multicast packets  0 broadcast packets
    165288 output packets  16490463 bytes
    0 jumbo packets
    0 output errors  0 collision  0 deferred  0 late collision
    0 lost carrier  0 no carrier  0 babble
    0 Tx pause
  0 interface resets
Automatic policy provisioning is disabled on this interface
Automatic policy host discovery is disabled on this interface
Layer3 vlan encapsulation is disabled on this interface.
```

For more details about port aggregation, see Chapter 11, “Ports and Link Aggregation“.

Loopback Interfaces

A loopback interface is a virtual Layer 3 interface. It is usually used by different applications to communicate when they run on the same switch. Loopback interfaces are used exclusively on the switch and they do not pass packets to other interfaces. Any traffic that is sent to a loopback interface is immediately passed back to the switch as if it was received from another device. If a packet is routed to a loopback interface, but it is not destined for that interface, it will be discarded.

It is used to allow Border Gateway Protocol (BGP) sessions to be always up, even when the outgoing switch interface is not available. BGP sessions can use a loopback interface as their termination address.

Open Shortest Path First (OSPF) and other Layer 3 protocols can use the IP address of a loopback interface as their router ID.

To create or configure a loopback interface, use the following command:

```
Switch(config)# interface loopback <0-7>
Switch(config-if)#
```

Note: After running the above command, you will enter Interface Configuration mode for the specified loopback interface.

To delete a loopback interface, use the following command:

```
Switch(config)# no interface loopback <0-7>
```

Notes:

- By default, loopback interface 0 is created on the switch and it cannot be deleted.
- Loopback interfaces cannot be configured as Layer 2 interfaces. They are automatically created as Layer 3 interfaces and this setting is unchangeable.

To view detailed information about a loopback interface, use the following command:

```
Switch(config)# show interface loopback <0-7>

Interface loopback0
  Hardware is Loopback
  index 8 metric 1 MTU 1500 Bandwidth 0 Kbit
  no switchport
  arp ageing timeout 1500
  <UP,LOOPBACK,RUNNING>
  VRF Binding: Not bound
  DHCP client is disabled.
  Encapsulation LOOPBACK
    0 packets input 0 bytes
    0 multicast frames 0 compressed
    0 input errors 0 frame 0 overrun 0 fifo
    0 packets output 0 bytes 0 underruns
    0 output errors 0 collisions 0 fifo
```

Switch Virtual Interfaces

A Switch Virtual Interface (SVI) is a VLAN that is used as a virtual Layer 3 interface. When a VLAN is created, its associated SVI is also created. An SVI is deleted when its related VLAN is deleted.

By default, VLAN 1 is created on the switch, and thus, VLAN 1 SVI is also created.

An SVI behaves as an ordinary Layer 3 interface:

- IP addresses can be configured
- Layer 2 commands are not allowed
- It supports all features that can run on Layer 3 interfaces

A VLAN can be associated with only one SVI. For more information about VLANs, see Chapter 10, “VLANs“.

Notes:

- You can configure up to a maximum of 256 SVIs.
- Before configuring an SVI interface, you must first create the appropriate Layer 2 VLAN. For more details, see “Creating a VLAN” on page 230.

To configure an SVI, use the following command:

```
Switch(config)# interface vlan <1-4094>
Switch(config-if)#
```

Note: After running this command, you enter Interface Configuration mode for the specified SVI.

To remove the configuration of a SVI interface, you must delete its associated VLAN. For more details, see “Deleting a VLAN” on page 231.

Note: The SVI associated with VLAN 1 cannot be deleted because VLAN 1 also cannot be removed from the switch.

To view detailed information about an SVI, enter:

```
Switch(config)# show interface vlan <1-4094>

Interface Vlan1
  Hardware is VLAN  Current HW addr: a897.dcde.2501
  Physical:(not set)  Logical:(not set)
  index 9 metric 1 MTU 1500 Bandwidth 0 Kbit
  no switchport
  arp ageing timeout 1500
  <UP,BROADCAST,RUNNING,MULTICAST>
  VRF Binding: Not bound
  DHCP client is disabled.
  Last clearing of "show interface" counters never
```

Basic Interface Configuration

This section covers some of the basic options available when configuring an interface, like its port speed, MAC address, or description.

To configure an interface, you must enter its Configuration mode.

To view a brief overview of all interfaces, enter:

```
Switch(config)# show interface brief

Ethernet        PVID   Type Mode   Status  Reason          Speed    Port
Interface       NVLAN                                              Ch#
--------------------------------------------------------------------------------
Ethernet1/1     1      eth  access up      none            25000    --
Ethernet1/2     --     eth  routed up      none            25000    --
Ethernet1/3     192    eth  access up      none            25000    --
Ethernet1/4     1000   eth  access up      none            25000    --
Ethernet1/5     --     eth  routed up      none            10000    --
Ethernet1/6     1      eth  access up      none            10000    --
Ethernet1/7     1      eth  access up      none            10000    --
Ethernet1/8     1      eth  access up      none            10000    --
Ethernet1/9     1      eth  access up      none            25000    --
Ethernet1/10    1      eth  access up      none            25000    --
...
```

To view the basic interface capabilities, enter:

```
Switch(config)# show interface capabilities

Ethernet1/1
  Model:                NE2572-X10G-SUP
  Type (SFP capable):   SFP28 10G BASE
  MDIX:                 no
  Speed:                10000
  Duplex:               full/half

  Trunk encap. type:    802.1Q
  Port-channel:         yes
  Flowcontrol:          rx-(off/on),tx-(off/on)
  QOS scheduling:       rx-(8q1t),tx-(8q1t)
  CoS rewrite:          no
  ToS rewrite:          no
  SPAN:                 yes
  Port mode:            Routed,Switch
...
```

By default, the switch ethernet interfaces are configured as Layer 2 ports. To configure an ethernet interface as a Layer 3 port (routed port), see Chapter 17, “Routed Ports“.

To view information about discarded incoming packets, enter:

```
Switch(config)# show interface ingress-discard-details

Ethernet1/1
+---------------------------------------+----------------------------+
|       Counter Description             |     Count                  |
|                                       |                            |
+---------------------------------------+----------------------------+
  IPv4 Discards                                        0
  IPv6 Discards                                        0
  STP Discards                                         0
  Policy Discards                                      100
  ACL Drops                                            0
  Receive Drops                                        0
  Vlan Discards                                        33
  IBP/CBP Discards                                     0
  OBM LP                                               0
  OBM HP                                               0
+---------------------------------------+----------------------------+
...
```

where:

Parameter	Description
`IPv4 Discards`	IPv4 packets not sent to the CPU.
`IPv6 Discards`	IPv6 packets not sent to the CPU.
`STP Discards`	Packets received when the interface is not in STP forwarding mode.
`Policy Discards`	Packets discarded because of an input policy on the interface, such as storm control.
`ACL Drops`	ACL packets dropped.
`Receive Drops`	Dropped packets where no output port could be determined for the packet, such as: • VLAN check failed • MTU check failed • ACL Drops action is hit • Traffic was destined to a non-existing route • Traffic was destined to an IP address for which the ARP entry is incomplete • Multicast traffic dropped because of a null output interface
`VLAN Discards`	VLAN-based discards, such as VLAN tagged packets incoming on a port that is not a member of the VLAN.

Parameter	Description
IBP/CBP Discards	Packets discarded due to either Ingress Back Pressure (reaching ingress buffer threshold for the interface), or because the Cell Buffer Pool is full (no buffer is available).
OBM LP	Oversubscription Buffer Management low priority dropped packets.
OBM HP	Oversubscription Buffer Management high priority dropped packets.

To view information about discarded outgoing packets, enter:

```
Switch(config)# show interface egress-discard-details

Ethernet1/1
+---------------------------------------+----------------------------+
|       Counter Description             |     Count                  |
|                                       |                            |
+---------------------------------------+----------------------------+
  HOL-blocking Discards                                 0
  MMU Discards                                          0
  Cell Error Discards                                   0
  MMU Aging Discards                                    0
  Other Discards                                        34
+---------------------------------------+----------------------------+
...
```

where:

Parameter	Description
HOL-blocking Discards	Packets discarded due to a head of line blocking condition.
MMU Discards	Packets discarded by the memory management unit.
Cell Error Discards	Packet cell purge errors.
MMU Aging Discards	Packets discarded because of an excessive transit delay through the MMU.
Other Discards	Packets dropped because of any other condition. This includes packets dropped by STP not being in a forwarding state.

To display all interface statistics, enter:

```
Switch(config)# show interface counters

Port                                    InOctets                InUcastPkts
-------------------------------------------------------------------------------
Eth1/1                                         0                         0
Eth1/2                                         0                         0
Eth1/3                                         0                         0
Eth1/4                                   4527156                       463
Eth1/5                                         0                         0
Eth1/6                                         0                         0
Eth1/7                                     24876                       404
Eth1/8                                     22850                       222
Eth1/9                                     22830                       223
Eth1/10                                    22855                       226
...
```

Forwarding Error Correction

The NE10032 and the NE2572 switches support forwarding error correction (FEC). This option is disabled by default. To enable FEC, enter:

```
Switch# fec {auto|cl74|cl91|off}
```

where:

Parameter	Description
`auto`	(Default) Enables and configures FEC automatically based on the port speed of the interface:
`cl74`	Enables FEC with clause 74 for interfaces configured with 25 Gb/s or 40 Gb/s port speeds.
`cl91`	Enables FEC with clause 91 for interfaces configured with 50Gb/s port speeds.
`off`	Disables FEC on the interface.

Note: The command is applicable only for 25G, 40G, 50G and 100G ports.

- auto (default). The FEC is chosen according with speed. 100G: cl91, 25G and 50G: cl74, 40G: off.
- cl91. Clause 91
- cl74. Clause 74
- off. FEC is disabled

To reset FEC to its default value, enter:

```
Switch# no fec
```

Interface Description

To add a short description to an interface, use the following command:

```
Switch(config-if)# description <text string>
```

Note: Interface descriptions can have up to a maximum of 80 characters.

To view the description of an interface, use the following command:

```
Switch(config)# show interface description
```

To reset the interface description to its default value, use the following command:

```
Switch(config-if)# no description
```

Interface Duplex

A duplex system is a point-to-point system consisting of two network devices that can communicate between them in both directions (transmission and reception).

There are three configurable duplex modes:

- full duplex - both devices can communicate with each other simultaneously;
- half duplex - both device can communicate with each other, but not simultaneously;
- auto-negotiation - the duplex mode is automatically decided by the device.

To configure the duplex mode of an interface, enter:

```
Switch(config-if)# duplex {auto|full|half}
```

To view the current duplex for an interface, use the following command:

```
Switch(config)# show interface status

--- --------------------------------------------------------------------------
Port           Name             Status    Vlan      Duplex  Speed   Type
--------------------------------------------------------------------------------
Ethernet1/1     --                up      1         full    10000   eth
Ethernet1/2     --                up      trunk     full    10000   eth
Ethernet1/3     --                up      1         full    10000   eth
Ethernet1/4     --                up      1         full    10000   eth
Ethernet1/5     --                up      1         full    10000   eth
Ethernet1/6     --                up      1         full    10000   eth
...
```

By default, the duplex mode is auto-negotiation.

To reset the duplex mode configuration to its default, use the following command:

```
Switch(config-if)# no duplex
```

Interface MAC Address

To view the current MAC address of an interface, use the following command:

```
Switch(config)# show interface mac-address

------------------------------------------------------------------------------
Interface                Mac-Address     Burn-in Mac-Address
------------------------------------------------------------------------------
Ethernet1/1              a897.dcde.2503  a897.dcde.2503
Ethernet1/2              a897.dcde.2504  a897.dcde.2504
Ethernet1/3              a897.dcde.2505  a897.dcde.2505
Ethernet1/4              a897.dcde.2506  a897.dcde.2506
Ethernet1/5              a897.dcde.2507  a897.dcde.2507
...
Ethernet1/54             a897.dcde.2538  a897.dcde.2538
mgmt0                    a897.dcde.2500  a897.dcde.2500
po1                      0e00.0000.0001  (not set)
Vlan1                    a897.dcde.2501  (not set)
```

Note: This command is available for every type of switch interface.

Interface Maximum Transmission Unit

The Maximum Transmission Unit (MTU) is the size (in bytes) of the largest data unit that a protocol can send across the interface.

For each network layer, there is a different size limitation:

- G8332, G8296, G8272, NE10032, and NE2572:
  - Layer 2 packets: 64 - 9,216 bytes
  - Layer 3 IPv4 packets: 576 - 9,216 bytes
  - Layer 3 IPv6 packets: 1,280 - 9,216 bytes
- NE1032, NE1032T, and NE1072T:
  - Layer 2 packets: 64 - 9,216 bytes
  - Layer 3 IPv4 packets: 576 - 9,198 bytes
  - Layer 3 IPv6 packets: 1,280 - 9,198 bytes

To configure the MTU of an interface, use the following command:

```
Switch(config-if)# mtu <64-9216 (bytes)>
```

By default, the MTU is:

- 9,216 bytes for Layer 2 interfaces
- 1,500 bytes for Layer 3 interfaces

Table 18 shows Layer 2 MTU configuration details:

Table 18. *Layer 2 MTU Details*

L2 Switching	Ingress Port MTU	Egress Port MTU	Result (store-n-forward)	Result (cut-thro)
Packet Length	Less or equal	Less or equal	MTU size accepted by both ports. Packet is routed forward.	MTU size accepted by both ports. Packet is routed forward.
	Less or equal	Greater	Oversized at egress. Packet is dropped.	Oversized at egress. L2 switching truncates the packet. The NIC should report CRC errors.
	Greater	Less or equal	Oversized at ingress. Packet is dropped.	Oversized at ingress. L2 switching truncates the packet. The NIC should report CRC errors.
	Greater	Greater	Oversized at ingress and egress. Packet is dropped.	Oversized at ingress and egress. L2 switching truncates the packet. The NIC should report CRC errors.

Table 19 shows Layer 3 MTU configuration details::

Table 19. *Layer 3 MTU Details*

L3 Routing	Ingress Interface MTU	Egress Interface MTU	Result (store-n-forward)	Result (cut-thro)
Packet Length	Less or equal	Less or equal	MTU size accepted by both interfaces. Packet is routed forward.	MTU size accepted by both interfaces. Packet is routed forward.
	Less or equal	Greater	Oversized at egress. Packet is fragmented at CPU (slow path).	Oversized at egress. Packet is fragmented at CPU (slow path).
	Greater	Less or equal	Oversized at ingress. Packets are dropped at ingress.	Oversized at ingress. Packet is truncated. The NIC should report CRC errors.
	Greater	Greater	Oversized at ingress and egress. Packets are dropped.	Oversized at ingress and egress. Packets are dropped.

To reset the MTU of an interface to its default value, use the following command:

```
Switch(config-if)# no mtu
```

Interface Speed

For physical ethernet interfaces and the management interface, the port speed can be configured to different values than the default setting. Port speed refers to the maximum amount of data (in bits) that can pass across an interface at any given second.

The switch offers some of the following bits per second (BPS) rates:

- 100 Mbps (0.1 Gb/s)
- 1000 Mbps (1 Gb/s)
- 10000 Mbps (10 Gb/s)
- 100000 Mbps (100 Gb/s)
- 25000 Mbps (25 Gb/s)
- 40000 Mbps (40 Gb/s)
- 50000 Mbps (50 Gb/s)
- auto-negotiation - the speed is automatically decided by the device (NE10032/NE2572 only)

Note: Some of the list BPS rates may not be available, depending upon your switch model.

To configure the port speed of a physical ethernet interface or the management interface, enter:

```
Switch(config-if)# speed {<bits/s>|auto}
```

Note: Only the parameters `10`, `100`, `1000`, and `auto` are allowed for management ports.

By default, the port speed of an interface is auto-negotiation if the port is capable of auto-negotiation.

To reset the port speed to its default value, enter:

```
Switch(config-if)# no speed
```

For the NE10032 and the NE2572, switch ports configured in 25Gbps hardware profile port mode can have their port speed changed to 10Gbps or back to 25Gbps without needing to reload the switch.

You need to configure the same hardware profile port mode and the same port speed on both end-ports of the link.

You need install transceivers that support both 25Gbps and 10Gbps speeds, else you also need to change the transceiver each time the port speed is modified.

Flow Control

Flow Control manages the rate of data transmission between two devices, when the transmitter sends traffic faster then the receiver can process. It allows the receiver to control the transmission speed and prevents traffic loss.

Flow Control can be enabled for both egress and ingress traffic.

To enable or disable flow control on an interface, use the following command:

```
Switch(config-if)# flowcontrol {send|receive} {on|off}
```

To view the current flow control configuration, use the following command:

```
Switch(config)# show interface flowcontrol

Port          Send FlowControl  Receive FlowControl  RxPause  TxPause
              admin   oper      admin   oper
-----------   ------- --------  ------- -----------  -------  --------
Ethernet1/1   on      on        off     off                0         0
Ethernet1/2   off     off       off     off                0         0
Ethernet1/3   off     off       off     off                0         0
Ethernet1/4   off     off       off     off                0         0
Ethernet1/5   off     off       off     off                0         0
Ethernet1/6   off     off       off     off                0         0
Ethernet1/7   off     off       off     off                0         0
...
```

By default, flow control is disabled on all interfaces.

To reset flow control to its default setting, use the following command:

```
Switch(config-if)# no flowcontrol
```

Note: On the NE2572, due to hardware limitation, flow control cannot be enabled on a port with a 1G SFP/CuSFP adapter.

Storm Control

Excessive transmission of traffic can result in a network storm. A network storm can overwhelm the local network with constant broadcast or multicast traffic, thus degrading network performance. Common symptoms of a network storm are denial-of-service (DoS) attacks, slow network response times, and network operations timing out.

Storm Control allows the monitoring of incoming traffic levels for a set time interval. During that interval, traffic level (a percentage of the total interface bandwidth) is compared to the configured traffic storm control level. If ingress traffic reaches the storm control level, the switch drops all packets until the time interval ends.

The switch can be configured to limit the available bandwidth for broadcast, multicast, and unknown unicast packets. Unicast packets whose destination MAC address is not in the Forwarding Database (FDB) are considered unknown unicast packets. When an unknown unicast packet is encountered, the switch handles it

like a broadcast packet and floods it to all other ports in the VLAN (broadcast domain). A high rate of unknown unicast traffic can have the same negative effects as a broadcast storm.

To configure the bandwidth available on an interface for different types of packets, use the following command:

```
Switch(config-if)# storm-control {broadcast|multicast|unicast} level
<bandwidth percentage>
```

Note: The *bandwidth percentage* value can be defined up to two decimals.

By default, storm control is disabled on all switch interfaces.

To disable storm control on an interface, use the following command:

```
Switch(config-if)# no storm-control {broadcast|multicast|unicast} level
```

Interface Shutdown

Each individual interface can be administratively brought up or down. To put an interface in the administratively up state, enter:

```
Switch(config-if)# no shutdown
```

To put an interface in the administratively down state, enter:

```
Switch(config-if)# shutdown
```

To view the link state of an interface, enter:

```
Switch(config)# show interface status

--- --------------------------------------------------------------------------
Port           Name             Status    Vlan      Duplex  Speed   Type
--------------------------------------------------------------------------------
Ethernet1/1     --                up      1         full    10000   eth
Ethernet1/2     --                up      trunk     full    10000   eth
Ethernet1/3     --                up      1         full    10000   eth
...
```

Chapter 9. Forwarding Database

The forwarding database (FDB) table is used by a Layer 2 device (switch/bridge) to store the MAC addresses that have been learned and their corresponding ports. The MAC addresses are either dynamically learned from the source addresses of incoming traffic, or manually configured by the system administrator.

When an Ethernet frame is received, the switch dynamically builds the FDB table by using the source MAC address of the received frames. If the FDB table does not contain any information on the destination MAC address of the received frames, it will flood the Ethernet frame out to all ports in the broadcast domain. When the recipient replies, the switch adds its relevant source MAC address and port ID to the FDB table.

The following topics are discussed in this chapter:

MAC Learning

MAC addresses can be learned only when both global and port based learning are enabled.

By default, MAC address learning is enabled.

Interface based MAC learning can only be enabled or disabled on Ethernet ports or Link Aggregation Groups (LAGs). All the Ethernet interfaces belonging to a LAG (static or dynamic) need to have the same MAC learning configuration.

To globally configure MAC learning, use the following commands:

```
Switch(config)# [no] mac-learn disable
```

To configure MAC learning on each switch interface, use the following command:

```
Switch(config-if)# [no] mac-learn disable
```

To display current MAC learning status, use the following command:

```
Switch# show mac address-table learning [interface ethernet <chassis
number/port number>]
```

To clear the FDB table of dynamic MAC entries, use the following command:

```
Switch# clear mac address-table dynamic [address <MAC address>|interface
{ethernet <chassis number/port number>|port-channel <LAG number>}] [vlan <VLAN
number (1-4093)>]
```

Static MAC addresses

To avoid flooding all LAN ports, entries can be manually configured in the MAC address table. These static MAC entries are retained across switch reloads.

A static MAC address cannot be configured with a non-existing VLAN.

To configure a static MAC address, use the following command:

```
Switch(config)# mac address-table static <MAC address> vlan <VLAN ID (1-4093)>
interface {ethernet <chassis number/port number>|port-channel <LAG number>}
```

In addition, you can enter a multicast address as a statically configured MAC address. A multicast address can accept more than one interface as its destination.

To delete a static entry from the FDB table, use the following command:

```
Switch(config)# no mac address-table static <MAC address> vlan <VLAN ID (1-4093)>
[interface {ethernet <chassis number/port number>|port-channel <LAG number>}]
```

To clear the FDB table of static MAC entries, use the following command:

```
Switch# clear mac address-table static [address <MAC address>|interface
{ethernet <chassis number/port number>|port-channel <LAG number>}] [vlan <VLAN
number (1-4093)>]
```

Note: Static MAC address will override any matching dynamic entry in the database.

To display static MAC address configuration, use the following command:

```
Switch# show mac address-table static [address <MAC address>] [interface
{ethernet <chassis number/port number>|port-channel <LAG number>}] [vlan <VLAN
number (1-4093)>]
```

Aging Time

You can configure the amount of time that a MAC entry remains in the FDB table. This is called *aging time*.

To configure the aging time, in seconds, use the following command:

```
Switch(config)# mac address-table aging-time <0-1,000,000>
```

To configure MAC entries to be stored permanently in the FDB table, you can set the aging time to 0, by using the following command:

```
Switch(config)# mac address-table aging-time 0
```

The default value is 1800 seconds. To reset the aging time to its default value, use the following command:

```
Switch(config)# no mac address-table aging-time
```

To display the MAC entry aging time, use the following command:

```
Switch(config)# show mac address-table aging-time
```

Note: For more information on the FDB available commands, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

Chapter 10. VLANs

This chapter describes network design and topology considerations for using Virtual Local Area Networks (VLANs). VLANs commonly are used to split up groups of network users into manageable broadcast domains, to create logical segmentation of workgroups, and to enforce security policies among logical segments. The following topics are discussed in this chapter:

VLAN Overview

A Local Area Network (LAN) is a group of inter-connected computers and other end devices that share the same limited geographical area, such as a school, residence, or office building. End devices in a LAN are physically separated from other end devices in different LANs.

A Virtual Local Area Network (VLAN) is a group of end devices that is logically separated by function or application, and not by their physical locations. A VLAN has the same attributes as a physical LAN, but you can group together end devices that are part of different LANs.

Setting up VLANs is a way of segmenting networks to increase network flexibility without changing the physical network topology. With network segmentation, each switch port connects to a segment that is a single broadcast domain. When a switch port is configured to be a member of a VLAN, it is added to a group of ports (workgroup) that belong to one broadcast domain.

Ports are grouped into broadcast domains by assigning them to the same VLAN. Frames received in one VLAN can only be forwarded within that VLAN, and unicast, multicast, and broadcast frames are forwarded and flooded only to ports belonging to the same VLAN.

VLAN Configuration

The switch supports up to 4094 VLANs. Each can be identified with a number between 1 and 4094.

VLANs are divided into four ranges as described in Table 20:

Table 20. *VLAN Ranges*

VLAN number	Usage
1	This is the default VLAN. It is created automatically and all switch ports are part of it by default. You cannot modify or delete this VLAN.
2-3999	You can create, modify, and delete any VLAN included in this range.
4000-4093	These VLANs are reserved by default. For more information, see "Reserved VLANs" on page 241
4094	This VLAN is reserved for internal use. You cannot create, modify, or delete this VLAN.
4095	This is reserved and unused in accordance with the IEEE 802.1Q standard.

To view the current VLAN information, use the following command:

```
Switch> show vlan

Flags:
u - untagged egress traffic for this VLAN
t - tagged egress traffic for this VLAN

VLAN    Name                             Status  IPMC FLOOD Ports

======= ================================ ======= ========== ===============
1       default                          ACTIVE  Disabled
                                                            Ethernet1/1(u)
2       VLAN000                          ACTIVE  Disabled
                                                            Ethernet1/1(t)
                                                            Ethernet1/2(u)
3       VN0003                           ACTIVE  Disabled
                                                            Ethernet1/1(t)
                                                            Ethernet1/3(u)
4       VLAN0004                         ACTIVE  Disabled
                                                            Ethernet1/1(t)
                                                            Ethernet1/4(u)
...
```

To view the reserved VLANs, enter:

```
Switch> show vlan reserved
Reserved VLAN range: 4000-4094
```

Note: VLAN 4094 is always reserved for internal use.

Creating a VLAN

You can create VLANs falling in the normal VLAN range.

You can create a single VLAN or a range of VLANs using a single command. The VLAN range can be either continuos (for example, 20-25) or discrete (for example, 20, 22, 25, 30).

The default VLAN (VLAN 1) is created automatically when the switch boots up for the first time and persists across later reloads.

When you create a new VLAN, it will remain unused until you assign a port to it. By default, all switch ports belong to the default VLAN (VLAN 1).

To create a VLAN, use the following command:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)#
```

Note: After running the preceding command, you will enter VLAN Configuration mode for the specified VLAN or range of VLANs.

For example:

```
Switch(config)# vlan 100-105
Switch(config-vlan)#
```

To view the current list of VLANs, use the following command:

```
Switch> show vlan

Flags:
u - untagged egress traffic for this VLAN
t - tagged egress traffic for this VLAN

VLAN    Name                           Status  IPMC FLOOD Ports

======= ============================== ======= ========== ===============
1       default                        ACTIVE  Disabled
                                                          Ethernet1/1(u)
                                                          ...
100     VLAN0100                       ACTIVE  Disabled
                                                          Ethernet1/1(t)
                                                          Ethernet1/2(u)
101     VLAN0101                       ACTIVE  Disabled
                                                          Ethernet1/3(t)
                                                          Ethernet1/4(u)
102     VLAN0102                       ACTIVE  Disabled
                                                          Ethernet1/5(t)
                                                          Ethernet1/6(u)
...
```

Deleting a VLAN

You can delete VLANs falling in the normal VLAN range.

You can delete a single VLAN or a range of VLANs using a single command. The VLAN range can be either continuos (for example, 20-25) or discrete (for example, 20, 22, 25, 30).

Note: You cannot delete the default VLAN or an internally reserved VLAN.

To delete a VLAN, use the following command:

```
Switch(config)# no vlan <VLAN ID (1-4093)>
```

For example:

```
Switch(config)# no vlan 100-105
```

You can delete a VLAN which is already associated to a port. If the VLAN is the access VLAN of a switch access port, the VLAN remains configured as the access VLAN, but the switch access port will not be able to forward any traffic until the VLAN is created again.

If the VLAN is the native VLAN of a switch trunk port, the VLAN remains configured as the native VLAN, but the switch trunk port will not be able to forward any untagged traffic until the VLAN is created again.

If the VLAN belongs to the allowed VLAN list of a switch trunk port, the VLAN remains in the allowed VLAN list, but the switch trunk port will not be able to forward any traffic carried in the VLAN until the VLAN is created again.

Configuring the State of a VLAN

You can change the operational state of a VLAN belonging to the normal VLAN range to be active or suspended. You can change the state of a single VLAN or a range of VLANs using a single command.

If a VLAN is in active state, it will forward traffic through the ports that are part of that VLAN. If the VLAN is in suspended state, it will not pass any traffic.

By default, when a VLAN is created, it will be in the active operational state.

Notes:

- You cannot change the state of the default VLAN (VLAN 1). It will always remain in the active operational state.
- You also cannot change the operational state of an internally reserved VLAN.

To change the operational state of a VLAN, use the following commands:

- to change the state to active:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# state active
```

- to change the state to suspended:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# state suspend
```

To reset the VLAN operational state to its default value, use the following command:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# no state
```

To view the current state of each VLAN, use the following command:

```
Switch> show vlan

Flags:
u - untagged egress traffic for this VLAN
t - tagged egress traffic for this VLAN

VLAN    Name                           Status  IPMC FLOOD Ports

======= ============================== ======= ========== ===============
1       default                        ACTIVE  Disabled
                                                          Ethernet1/1(u)
                                                          ...
100     VLAN0100                       ACTIVE  Disabled
                                                          Ethernet1/1(t)
                                                          Ethernet1/2(u)
...
```

You can change the operation state of a VLAN to suspended even if that VLAN is already associated to a switch port. If the VLAN is the access VLAN of a switch access port, the VLAN remains configured as the access VLAN, but the switch access port will not be able to forward any traffic until the VLAN's state is changed to active.

If the VLAN is the native VLAN of a switch trunk port, the VLAN remains configured as the native VLAN, but the switch trunk port will not be able to forward any traffic carried in the VLAN until the VLAN's state is changed to active.

If the VLAN belongs to the allowed VLAN list of a switch trunk port, the VLAN remains in the allowed VLAN list, but the switch trunk port will not be able to forward any traffic carried in the VLAN until the VLAN's state is changed to active.

Configuring the Name of a VLAN

You can change the name of a VLAN belonging to the normal VLAN range to any alphanumeric string with a maximum length of 32 characters.

The name of a VLAN must be unique to that VLAN. No two VLANs can have the same identical name. The names are case-sensitive. For example, the name '*VLAN-test*' is considered different from '*VLAN-TEST*'.

The name of the default VLAN (VLAN 1) is '*default*'. For all other VLANs the default name used when creating that VLAN is in the format '*VLANxxxx*', where *'xxxx*' represent the four digits of the VLAN number (including leading zeros). For example, the default name of VLAN 2 is '*VLAN0002'*.

Note: You cannot change the name of the default VLAN or an internally reserved VLAN.

To change the name of a VLAN, use the following command:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# name <VLAN name>
```

To reset the name of a VLAN to its default value, use the following command:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# no name
```

To view the current names of each VLAN, use the following command:

```
Switch> show vlan

Flags:
u - untagged egress traffic for this VLAN
t - tagged egress traffic for this VLAN

VLAN    Name                            Status  IPMC FLOOD Ports

======= ============================== ======= ========== ===============
1       default                         ACTIVE  Disabled
                                                           Ethernet1/1(u)
                                                           ...
100     VLAN0100                        ACTIVE  Disabled
                                                           Ethernet1/1(t)
                                                           Ethernet1/2(u)
...
```

Configuring a Switch Access Port

You can configure an ethernet physical interface or a Link Aggregation Group (LAG) as a switch access port. By default, all the switch ports are in access mode.

A port in access mode can be part only of a single VLAN and it will carry traffic just for that one VLAN. That VLAN is called the Access VLAN.

To configure a port as an access port, use the following command (for this example ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# switchport mode access
```

To reset a port to its default operational mode, use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# no switchport mode
```

By default, the access VLAN for an interface is the default VLAN (VLAN 1). You can configure the access VLAN to be the default VLAN or a VLAN belonging to the normal VLAN range.

Configuring the Access VLAN

You can configure the access VLAN to be an uncreated VLAN. Until that VLAN is created, the switch access port will not be able to forward any traffic. As soon as it is created, the associated port will start forwarding traffic.

To change the access VLAN of a port, use the following command (for this example ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# switchport access vlan <VLAN ID (1-4093)>
```

To reset a port's access VLAN to the default access VLAN (VLAN 1), use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# no switchport access vlan
```

Note: Any access mode configuration settings are reset when the port's operational mode is changed from access to another mode.

A switch port in access operational mode accepts untagged, priority-tagged, and tagged traffic carried in the access VLAN and discard all tagged ingress traffic carried in other VLANs. Egress traffic out of the switch access port is sent untagged. For more details, see "Native VLAN Tagging Overview" on page 242.

To view the current operational mode of a port, use the following command (for this example ethernet interface 1/12 is used):

```
Switch> show interface ethernet 1/12 switchport

Interface Ethernet1/2
  Switchport              : enabled
  Switchport mode         : access
  Ingress filter          : enable
  Tag Ingress PVID        : disabled
  Acceptable frame types  : all
  Default/Native Vlan     : 110
  Configured Vlans        : 110
  Enabled Vlans           : 110
  Egress-Tagged Vlans     : None
  Private-VLAN            : Disabled
  Private-VLAN Port Type  : None
  Primary/Secondary VLAN  : None/None
```

Configuring a Switch Trunk Port

You can configure an ethernet physical interface or a Link Aggregation Group (LAG) as a switch trunk port. By default, all the switch ports are in access mode.

A port in trunk mode can be part of any number of VLANs and it will carry traffic for all configured VLANs.

To configure a port as a trunk port, use the following command (for this example ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# switchport mode trunk
```

To reset a port to its default operational mode, use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# no switchport mode
```

Configuring the Allowed VLAN List

The allowed VLAN list is the group of VLANs assigned to a trunk port for which traffic will be forwarded across the trunk link. By default, the allowed VLAN list consists of all VLANs (1-3999). The trunk port will forward traffic only for VLANs that are created on the switch. If a VLAN is in the allowed VLAN list, but it is not created, the trunk port will not forward traffic for that VLAN. If a VLAN that is in the allowed VLAN list is created after the port is configured as a trunk port, traffic for that VLAN will start to be forwarded as soon the VLAN is created.

For example, the currently created VLANs are the default VLAN and VLANs 100-105. When configuring ethernet interface 1/12 as a trunk port, by default its allowed VLAN list will include all VLANs, but will only forward traffic for VLANs 1 and 100-105. If VLAN 106 is created on the switch, ethernet interface 1/12 will start forwarding traffic for VLAN 106 as well.

You can configure an uncreated VLAN to a switch trunk port as a member of the allowed VLAN list. The switch trunk port will not be able to forward traffic carried in that VLAN until it is created.

To change the allowed VLAN list of a port, use the following command (for this example ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# switchport trunk allowed vlan <VLAN ID (1-4093)>
```

For example:

```
Switch(config-if)# switchport trunk allowed vlan 100-105,300,320
```

You can also add new VLANs to the current allowed VLAN list, remove VLANs from the list, or specify the list to contain all VLANs or none.

Considering the previous example, the allowed VLAN list currently contains VLANs 100-105, 300, and 320. The following command will add VLAN 110 to that list:

```
Switch(config-if)# switchport trunk allowed vlan add 110
```

If you want to remove VLAN 110 from the list, use the following command:

```
Switch(config-if)# switchport trunk allowed vlan remove 110
```

If you want to add all VLANs to the list, use the following command:

```
Switch(config-if)# switchport trunk allowed vlan all
```

If you want to add all VLANs to the list except VLAN 110, use the following command:

```
Switch(config-if)# switchport trunk allowed vlan except 110
```

If you do not want any allowed VLANs on the current port, use the following command:

```
Switch(config-if)# switchport trunk allowed vlan none
```

To reset a port's allowed VLAN list to its default settings, use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# no switchport trunk allowed vlan
```

Configuring the Native VLAN

When a port is configured as a switch trunk port, it will tag traffic packets with their appropriate VLAN number. All packets coming from the allowed VLAN list will be tagged when they are carried across the trunk, except for packets belonging to the native VLAN. Packets coming from the native VLAN are carried across the trunk untagged.

By default, the native VLAN for an interface is the default VLAN (VLAN 1). You can configure the native VLAN to be the default VLAN or a VLAN belonging to the normal VLAN range.

You can configure the native VLAN to be an uncreated VLAN. The switch trunk port will not be able to forward untagged, priority-tagged, or tagged traffic carried in that VLAN until the native VLAN is created and added to its allowed VLAN list.

To change the native VLAN of a port, use the following command (for this example ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# switchport trunk native vlan <VLAN ID (1-4093)>
```

To reset a port's native VLAN to the default native VLAN (VLAN 1), use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# no switchport trunk native vlan
```

Note: Any trunk mode configuration settings are reset when the port's operational mode is changed from trunk to another mode.

A port configured in trunk operational mode accepts tagged traffic carried in allowed VLANs and discard traffic carried in VLANs excluded from the allowed VLAN list on ingress side. Egress traffic carried in any allowed VLAN except the native VLAN is sent tagged on egress side.

The trunk port accepts untagged, priority-tagged, and tagged traffic carried in the native VLAN on the ingress side if native VLAN tagging is disabled on the port. Egress traffic carried in the native VLAN out of the trunk port is sent untagged on egress side if native VLAN tagging is disabled on the trunk port. Otherwise, the traffic is sent tagged with the native VLAN ID. For mode details, see "Native VLAN Tagging Overview" on page 242.

To view the current operational mode of a port, use the following command (for this example ethernet interface 1/12 is used):

```
Switch> show interface ethernet 1/12 switchport

Interface Ethernet1/33
  Switchport              : enabled
  Switchport mode         : trunk
  Ingress filter          : enable
  Tag Ingress PVID        : disabled
  Acceptable frame types  : all
  Default/Native Vlan     : 10
  Configured Vlans        : 1-500
  Enabled Vlans           : 1-500
  Egress-Tagged Vlans     : 1-9,11-500
  Private-VLAN            : Disabled
  Private-VLAN Port Type  : None
  Primary/Secondary VLAN  : None/None
```

Configuring Hybrid Switchport Mode

Hybrid switchport mode is a trunk switchport mode that lets you have more than one egress untagged VLAN. Like a trunk port, a hybrid port can carry multiple VLANs to receive and pass traffic for them. The hybrid switchport mode lets you control which VLANs receive tagged vs. untagged egress traffic. Unlike trunk switchport mode, the native VLAN is not considered the only VLAN that can send untagged traffic.

Hybrid Switchport Mode Rules

The following rules apply to hybrid switchport mode:

- You can configure an ethernet interface or a Link Aggregation Group (LAG) in hybrid mode.
- A hybrid port can have any number of VLANs configured on the interface and can carry traffic for several VLANs simultaneously.
- The hybrid port is a trunk port that can have more than one egress untagged VLAN. Unlike a trunk port, a hybrid port by default allows traffic of all the allowed range of VLANs to pass through untagged; the native VLAN is not the only VLAN that can send untagged traffic.
- VLAN options set for hybrid ports apply only to outgoing traffic.
- A hybrid port has a native VLAN and an allowed VLAN list.
- You can configure either the native VLAN or a VLAN in the normal VLAN range to be the default VLAN. By default, the native VLAN is VLAN 1.
- You can add or remove the default VLAN or VLANs in the normal VLAN range to or from the allowed VLAN list. By default, the allowed VLAN list consists of all VLANs that are not reserved.
- If 802.1Q tunnel mode is not enabled on the bridge hybrid port, the bridge hybrid port will accept tagged traffic carried on allowed VLANs and discards traffic carried in VLANs excluded from the allowed VLAN list on the ingress side.
- If the native VLAN is part of the allowed VLAN list, the bridge hybrid port will accept untagged, priority-tagged, and tagged traffic from the native VLAN on the ingress side.

- Based on egress tagging options, the egress traffic carried by the native VLAN out of the bridge hybrid port is sent untagged or tagged with the native VLAN ID. By default, a hybrid port sends outgoing native VLAN traffic untagged. If egress tagging is set on the native VLAN, the hybrid port sends the traffic from the native VLAN tagged with the native VLAN ID
- You can set the egress traffic type on a list of VLANs included in the allowed VLAN list of a bridge hybrid port.
- All configurations related to hybrid switchport mode are lost when you change the hybrid port to another mode.

Configuring a Hybrid Switchport

To configure a port as a hybrid switchport:

1. In Interface Configuration mode, set the bridge port to function in hybrid mode:

```
Switch(config-if)# switchport mode hybrid
```

2. Set the native VLAN for the hybrid switchport:

```
Switch(config-if)# switchport hybrid native vlan <VLAN number (1-4094)>
```

where *VLAN ID* is the ID of the native VLAN.

Note: To set the native VLAN for hybrid mode back to the default VLAN, enter:

```
Switch(config-if)# no switchport hybrid native vlan
```

3. Add VLANs to or remove VLANs from the allowed VLAN list for the hybrid switchport:

```
Switch(config-if)# switchport hybrid allowed vlan {<VLAN list>|add <VLAN
list>|all|except <VLAN list>|none|remove <VLAN list>}
```

where:

Table 21.

Parameter	Description
VLAN list	A range or comma-separated list of allowed VLANs.
add	Add the following VLANs to the allowed list.
except	Add all VLANs except the following.
none	No VLANs.
remove	Remove the following VLANs from the allowed list.

Note: To reset the allowed VLAN list for the hybrid switchport to the default (all allowed), enter:

```
Switch(config-if)# no switchport hybrid allowed vlan
```

4. Set (or unset) the egress traffic type to tagged for specific VLANs:

```
Switch(config-if)# [no] switchport hybrid egress-tagged vlan <VLAN list>
```

where *VLAN list* is the list of VLANs to use tagged egress traffic. The default is untagged VLAN traffic.

To see the hybrid switchport settings of a specific interface, enter:

```
Switch# show interface <interface name> switchport
```

To see information about all hybrid switchports associated with the specified VLANs, enter:

```
Switch# show interface hybrid vlan <VLAN number or VLAN list>
```

To get information about hybrid switchports in the running configuration, enter:

```
Switch# show running-config interface {ethernet <chassis number>/<port number>|
|port-channel <LAG number (1-4096)>}
```

To see information about bridging characteristics of the Layer 2 interface, enter:

```
Switch# show interface switchport
```

Reserved VLANs

Some features, such as Layer 3 ports (routed ports), require internal VLANs for their operations. You can reserve a contiguous block of VLANs to guarantee the delivery and operation of features with such requirements. These reserved VLANs cannot be created, deleted, modified, or manipulated.

To change the range of VLANs reserved for internal use, use the command:

```
Switch(config)# system vlan reserve <VLAN range>
```

To reset the reserved VLAN range to the default (4000-4094), use the command:

```
Switch(config)# no system vlan reserve
```

To display the reserved VLAN range, use the command:

```
Switch# show system vlan reserved
```

Note: When reserving VLANs, consider the following:

- The reserved VLAN numbers must be a contiguous range.
- You cannot create, delete, modify, or manipulate the VLANs in the reserved VLAN range.
- VLAN 4094 is always reserved.
- The default VLAN cannot be used as a reserved VLAN.
- The operation fails if you try to change the range of reserved VLANs or delete those VLANs.
- You cannot reserve VLANs that already exist on switch, you must either delete them or select another range.

Note: We recommend that you configure the Reserved VLAN range before using the switch in production mode. If there are already routed ports configured, you will have to reboot the switch.

Native VLAN Tagging Overview

When a packet enters a switch trunk link, a tag is added to its frame header to represent the VLAN membership of the frame's port. Each frame must be distinguishable as being within exactly one VLAN. A frame entering the trunk link that does not contain a VLAN tag is assumed to be flowing on the native VLAN.

This can lead to a security vulnerability in the network. It is advised to enable the tagging of native VLAN traffic. This ensures that all packets going out of the trunk link will be tagged and it prevents the reception of untagged packets.

If native VLAN tagging is disabled, the switch is vulnerable to VLAN hopping attacks. The basic concept behind a VLAN hopping attack is for an attacking host on a VLAN to gain access to traffic on other VLANs that would normally not be accessible.

To address such potential attacks, native VLAN tagging performs the following:

- on the ingress side, all untagged data traffic is dropped when native VLAN tagging is not explicitly configured for egress traffic
- on the egress side, all traffic is tagged; if traffic belongs to the native VLAN then it is tagged with the native VLAN ID

Native VLAN tagging can be configured globally or on each interface. The switch port must be in trunk operational mode for native VLAN tagging to function.

By default, native VLAN tagging is globally disabled on the switch. Globally enabling or disabling native VLAN tagging affects all trunk ports that do not have native VLAN tagging individually configured, which is the default setting for 802.1Q trunk ports. Until a native VLAN tagging is configured on each trunk port, individual tagging behavior is dependent on the global configuration.

When native VLAN tagging is disabled on a switch trunk port, all untagged ingress packets are accepted and carried in the native VLAN. All tagged packets belonging to VLANs in the allowed VLAN list are accepted as long as that VLAN is active and tagged packets belonging to VLANs not in the allowed VLAN list are discarded. If the ingress packet is priority-tagged, it is regarded as an untagged packet and it is carried in the native VLAN.

If an egress packet belongs to the native VLAN then it is sent untagged. Other tagged packets belonging to VLANs in the allowed VLAN list are sent with the VLAN preserved. If the egress packet is priority-tagged and belongs to the native VLAN, it is sent untagged (the priority tag is removed). Otherwise, the priority-tagged packet is tagged with a new VLAN ID and its priority tag is removed in advance. In other words, the packet is not sent in Q-in-Q format.

When native VLAN tagging is enabled on a switch trunk port, all untagged ingress packets will be discarded unless native VLAN tagging is not explicitly configured for egress traffic. Otherwise, all untagged ingress packets are accepted in the trunk link and carried in the native VLAN. If the ingress packet is priority-tagged, it is accepted in the native VLAN only if tagging is explicitly configured for egress traffic. Otherwise, the packet is discarded.

All egress packets are tagged. If a packet belongs to the native VLAN then it is tagged with the native VLAN ID. If the egress packet is priority-tagged, it is tagged with a new VLAN ID and its priority tag is removed in advance. In other words, the packet is not sent in Q-in-Q format.

Note: Control protocol data units (PDU) are accepted as untagged on the native VLAN of a switch trunk port, even if native VLAN tagging is enabled.

Configuring Native VLAN Tagging

Native VLAN tagging is supported both on physical ethernet interfaces and on Link Aggregation Groups (LAG). A LAG inherits the native VLAN tagging configuration of its first trunk port member. When adding a switch trunk port to a LAG, the port must have the same native VLAN tagging configuration as the LAG. Otherwise, the trunk port will be rejected from the LAG.

To globally enable or disable native VLAN tagging, use the following command:

```
Switch(config)# [no] vlan dot1q tag native
```

If you want to enable native VLAN tagging just for egress traffic, use the following command:

```
Switch(config)# vlan dot1q tag native egress-only
```

Note: If native VLAN tagging is enabled only for egress traffic, all untagged ingress packets are accepted in the switch trunk port and are carried in the native VLAN. Otherwise, the ingress packets are discarded.

Native VLAN tagging can be configured independently on each ethernet interface or LAG. To enable native VLAN tagging on a per-interface basis, use the following command (for this example, ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# switchport trunk native vlan tag enable
```

To enable native VLAN tagging only for egress traffic, use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# switchport trunk native vlan tag egress-only
```

To disable native VLAN tagging on an interface, use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# switchport trunk native vlan tag disable
```

To delete native VLAN tagging configuration of an interface, use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# no switchport trunk native vlan tag
```

Note: This makes native VLAN tagging on that interface dependent on the global configuration.

To view the current native VLAN tagging settings for all interfaces, use the following command:

```
Switch> show vlan dot1q tag native

Tag native vlan global setting: enabled
-------------------------------------------------------
Port Tag Native VLAN Status
-------------------------------------------------------
Eth1 enabled
Eth5 disabled
Eth13 enabled (egress-only)
...
```

Port VLAN ID Ingress Tagging

The Port VLAN ID (PVID) is the default VLAN ID assigned to a switch port to designate the VLAN of which the port is a member. Any packets received by the switch on such a port has a tag added to their frame containing the PVID of the port. The packets are then forwarded in the VLAN corresponding to the PVID of the receiving port.

PVID Ingress Tagging offers tunneling support at the ingress port level through the insertion of VLAN tags.

For egress traffic, through the use of Native VLAN Tagging the switch can choose to remove or not the outer VLAN tag of a packet if it is the Native VLAN ID of the egress port.

For ingress traffic, the default action of the switch is to add the PVID of the ingress port to any untagged packets. If the arriving packet is tagged with a VLAN ID, the switch does not add the PVID tag and the existing VLAN ID tag is used as the outer VLAN tag.

When PVID Ingress Tagging is enabled on a switch port, packets received on that port are tagged with the PVID of the port regardless if the packet is already tagged or it is untagged. If the packet is already tagged, its original VLAN ID tag is not removed and the PVID of the receiving port is added over the existing VLAN ID, resulting a double tagged packet.

PVID Ingress Tagging adds the Native VLAN ID as the outer VLAN tag for switch ports configured as trunk ports, and the Access VLAN ID for switch ports configured as access ports.

Notes:

- PVID Ingress Tagging affects only ingress traffic, while Native VLAN Tagging affects only egress traffic.
- PVID Ingress Tagging cannot be enabled on the switch management interface.
- For the G8272, G8296, and G8332, inconsistent behavior occurs when PVID Ingress Tagged traffic is received on a virtual port.

By default, PVID Ingress Tagging is disabled. To enable or disable PVID Ingress Tagging on a switch port, use the following command:

```
Switch(config)# interface ethernet <chassis number>/<port number>
Switch(config-if)# [no] switchport mode dot1q-tunnel
```

To display the current PVID Ingress Tagging settings, use the following command:

```
Switch> show dot1q-tunnel [interface ethernet <chassis number>/<port number>|
|port-channel <1-4096>]
```

IP Subnet VLAN Assignment

The IP subnet VLAN assignment feature lets you configure the switch to assign a VLAN based on the IP subnet for incoming untagged or priority-tagged packets. This feature can also assign a priority to untagged traffic.

IP subnet VLAN mappings are configurable and are maintained as a table similar to Table 22:

Table 22. *Example of IP Subnet VLAN Mappings*

Source IP Address	Subnet Mask	VLAN ID	Priority (Optional)
192.168.1.0	255.255.255.0	2	7
192.168.2.0	255.255.255.0	3	5
192.168.1.5	255.255.255.255	4	6

For example, if the incoming traffic source IP address belongs to subnet 192.168.2.0/24, the traffic will be assigned to VLAN 3 with priority 5. The rules are global and apply to all enabled ports.

The subnet VLAN table is a longest prefix match table. For example, if the source IP address of the received untagged packet is 192.168.1.5, it will match two entries in Table 22. Since 192.168.1.5/32 is the longest-prefix match, this packet will be assigned to VLAN 4 with priority 6.

The IP subnet VLAN assignment function can be controlled per ethernet port or port aggregation, and only takes effect on enabled ports. By default, this function is disabled on all ports. When dealing with a port aggregation, the following rules apply:

- The configuration will apply to all members of the port aggregation.
- All member ports of an aggregation must have the same configuration.
- When ports are removed from an aggregation, the IP subnet VLAN configuration remains on them.

IP subnet VLAN assignment is disabled by default on all ports. To enable this feature on a port, enter:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# vlan classifier subnet-vlan enable
Switch(config-if)# exit
```

To configure IP subnet VLAN assignment, configure the IP subnet based VLAN classification rule:

```
Switch(config)# vlan classifier subnet-vlan ip {<IP address/prefix length>|
|<IP address>/<subnet mask>} vlan <VLAN number (1-4093)> [priority <priority>]
```

where:

Table 23.

Parameter	Description
IP address	An IPv4 address.
mask	Shorthand mask for an IP address.
submask	If the IPv4 address does not have a submask (/M), you need to use one in the form of an IPv4 address.
VLAN ID	The ID of the target VLAN; an integer from 1-4093.
priority	(Optional) The priority; an integer from 0-7.

To delete the configuration rule based on the IP address or target VLAN ID, enter:

```
Switch(config)# no vlan classifier subnet-vlan [ip {<IP address/prefix length>|
|<IP address>/<subnet mask>}|vlan <VLAN number (1-4093)>]
```

If no parameters are specified, all rules are deleted.

To enable or disable the subnet VLAN classification on ports, in Interface Configuration mode, enter:

```
Switch(config-ip)# [no] vlan classifier subnet-vlan enable
```

To display the mapping rule base for a specific IP address or VLAN ID, enter:

```
Switch# show vlan classifier subnet-vlan [ip {<IP address/prefix length>|
|<IP address>/<subnet mask>}|vlan <VLAN number (1-4093)>]
```

If no parameters are specified, all rules are displayed.

To display the IP subnet VLAN state of an interface, enter:

```
Switch# show vlan classifier subnet-vlan state [interface {ethernet
<chassis number>/<port number>|port-channel <LAG number (1-4096)>}]}
```

To display the VLAN classification-related information in the running configuration, enter:

```
Switch# show running-config vlan classifer
```

IPMC Flooding

IP Multicast (IPMC) is a method of sending IP traffic to a group of interested devices in a single transmission. When sending a multicast packet, a device uses an IP multicast address from the range:

- for IPv4: `224.0.0.0/4` (`224.0.0.0` - `239.255.255.255`)
- for IPv6: `ff00::/8`

If the switch does not understand multicast addresses then it will flood the unknown traffic to all the members of a VLAN. In this scenario the switch has to filter the packets sent to multicast groups they are not subscribed to.

By default, IPMC flooding is enabled on all VLANs, meaning that unknown IP multicast traffic is forwarded across all VLAN member interfaces. If IPMC flooding is disabled, the switch will discard all unknown multicast IP traffic that has a destination IP address outside the reserved multicast range. For IPv4 addressing that range is 224.0.0.X (224.0.0.0 - 224.0.0.255).

To enable or disable the flooding of unknown IPMC traffic in a VLAN, use the following command:

```
Switch(config-vlan)# [no] flood
```

To enable or disable IPMC flooding for a specific family of IP addresses, use the following command:

- for IPv4:

```
Switch(config-vlan)# [no] flood ipv4
```

- for IPv6:

```
Switch(config-vlan)# [no] flood ipv6
```

To check the IPMC flood configuration of a VLAN, use the following command:

```
Switch> show vlan id <1-4096>

Flags:
u - untagged egress traffic for this VLAN
t - tagged egress traffic for this VLAN
VLAN    Name                      Status  IPMC FLOOD Ports

======= ========================= ======= ========== ====================
1       default                   ACTIVE  Disabled
                                                     Ethernet1/3(u)
                                                     Ethernet1/4(u)
                                                     Ethernet1/5(u)
...
```

Private VLANs

Private VLANs provide Layer 2 isolation between the ports within the same broadcast domain. Private VLANs can control traffic within a VLAN domain and provide port-based security for host servers.

Lenovo's Private VLAN implementation follows RFC 5517.

By default, Private VLAN is enabled on the switch. If Private VLAN is disabled, use the following command to globally enable Private VLAN on the switch:

```
Switch(config)# private-vlan enable
```

To globally disable Private VLAN, use the following command:

```
Switch(config)# no private-vlan enable
```

Use Private VLANs to partition a VLAN domain into sub-domains. Each sub-domain is comprised of one primary VLAN and one or more secondary VLANs, as follows:

- Primary VLAN—carries unidirectional traffic downstream from promiscuous ports. Each Private VLAN domain has only one primary VLAN.
- Secondary VLAN—Secondary VLANs are internal to a private VLAN domain, and are defined as follows:
  - Isolated VLAN—carries unidirectional traffic upstream from the host servers toward ports in the primary VLAN. Each Private VLAN configuration can contain only one isolated VLAN.
  - Community VLAN—carries upstream traffic from ports in the community VLAN to other ports in the same community, and to ports in the primary VLAN. Each Private VLAN configuration can contain multiple community VLANs.

To configure a VLAN as a primary VLAN, enter VLAN Configuration Mode and use the following command:

```
Switch(config)# vlan <VLAN ID (2-4093)>
Switch(config-vlan)# private-vlan primary
```

To configure a VLAN as a isolated VLAN, use the following command:

```
Switch(config-vlan)# private-vlan isolated
```

To configure a VLAN as a community VLAN, use the following command:

```
Switch(config-vlan)# private-vlan community
```

To remove the Private VLAN configuration and revert to functioning as a regular VLAN, use the following command according to the Private VLAN type:

```
Switch(config-vlan)# no private-vlan {primary|isolated|community}
```

After you define the primary VLAN and one or more secondary VLANs, to create a functional PVLAN domain, you must associate the secondary VLAN(s) with the primary VLAN.

To associate the current primary Private VLAN to other secondary VLANs, use the following command:

```
Switch(config-vlan)# private-vlan association <VLAN ID or range (2-4093)>
```

To add VLANs to the current secondary Private VLAN list, use the following command:

```
Switch(config-vlan)# private-vlan association add <VLAN ID or range (2-4093)>
```

To remove VLANs from the current secondary Private VLAN list, use the following command:

```
Switch(config-vlan)# private-vlan association remove <VLAN ID or range
(2-4093)>
```

To clear the current secondary Private VLAN list, use the following command:

```
Switch(config-vlan)# no private-vlan association
```

Private VLAN Ports

Private VLAN ports are defined as follows:

- Promiscuous—A promiscuous port is a port that belongs to the primary VLAN. The promiscuous port can communicate with all the interfaces, including ports in the secondary VLANs (Isolated VLAN and Community VLANs).
- Host—A host port is a port that belongs to a secondary Private VLAN. Host ports behave differently depending on the associated secondary VLAN type:
  - Isolated—A host port that belongs to an isolated VLAN has complete Layer 2 separation from other ports within the same private VLAN (including other isolated ports), except for the promiscuous ports.

    Only the traffic which is received by a promiscuous port can be egressed on a host port which is added to an isolated Private VLAN.

    Traffic received on an isolated port is forwarded only to promiscuous ports.
  - Community—A host port that belongs to a community VLAN can communicate with other ports in the same community VLAN, and with promiscuous ports.

    These interfaces are isolated at Layer 2 from all other interfaces in other communities and from isolated ports within the Private VLAN domain.

To configure an ethernet port as a Private VLAN port, enter Interface Configuration Mode for that port and use the following command:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# switchport mode private-vlan
```

To configure the Private VLAN port as a promiscuous port, use the following command to map the port with a previously configured primary VLAN:

```
Switch(config-if)# switchport private-vlan mapping <Primary VLAN ID (2-4093)>
```

To remove the promiscuous port configuration from an ethernet interface or a Link Aggregation Group (LAG), use the following command:

```
Switch(config-if)# no switchport private-vlan mapping <Primary VLAN ID (2-4093)>
```

To configure the Private VLAN port as a host port, use the following command to associated the port with a previously configured secondary Private VLAN:

```
Switch(config-if)# switchport private-vlan association <Primary VLAN ID (2-4093)> <Secondary VLAN ID (2-4093)>
```

To remove the host port configuration from an ethernet interface or a LAG, use the following command:

```
Switch(config-if)# no switchport private-vlan association <Primary VLAN ID (2-4093)> <Secondary VLAN ID (2-4093)>
```

Private VLAN Configuration Guidelines and Restrictions

The following guidelines apply when configuring Private VLANs:

- Management VLANs cannot be Private VLANs. Management ports cannot be members of a Private VLAN;
- The default VLAN 1 cannot be a Private VLAN;
- We recommend that you disable IGMP Snooping on Private VLANs to avoid IGMP Snooping functioning incorrectly;
- The Private VLAN port type (promiscuous or host) cannot be manually configured through the use of CLI commands. Instead, it is determined when configuring a port mapping or association;
- All VLANs that comprise the Private VLAN must belong to the same Spanning Tree Group (STG). Otherwise, when ports are associated with secondary VLANs, they are automatically moved in the STG of the Primary VLAN. When the association is removed, the ports are moved to default STG;
- A Private VLAN domain consists of a primary VLAN and one or more associated secondary VLANs;
- A secondary VLAN can be associated with only one primary VLAN;
- A Private VLAN domain must have one primary VLAN;
- A Private VLAN domain can have zero or only one isolated VLAN;
- A Private VLAN domain can have zero or multiple community VLANs;
- You can associate a regular VLAN to a primary VLAN, but it is not operational until it is configured as a secondary VLAN;

- Multiple Private VLANs can be mapped to the same interface, but the VLANs must be in different Private VLAN domains;
- Ethernet ports configured as access, trunk, or hybrid ports can also be configured as Private VLAN ports;
- When an ethernet port is configured as a trunk port, it can belong to multiple PVLAN domains if its Private VLAN type is consistent across all the PVLAN domains. It must be configured as either primary or host;
- When a Private VLAN association is created on an ethernet port configured as a trunk or hybrid port, all other Private VLANs are removed from the port's allowed VLAN list. If the allowed VLAN list includes all VLANs, the list is changed to allow all VLANs except the Private VLANs that are not associated with the port;
- When a VLAN is configured as a Private VLAN, it is removed from the allowed VLAN list of trunk or hybrid ports configured in Private VLAN mode;
- Mapping a Layer 3 interface to a Private VLAN is supported only on primary VLANs. Layer 3 interfaces mapped to a primary VLAN are not visible to secondary VLANs;
- A Private VLAN cannot be deleted or operate in the suspended state until its Private VLAN configuration is removed from the associated VLAN;
- Layer 3 routing within a Private VLAN domain is not supported;
- Ping is supported in the same Private VLAN domain between hosts connected to the primary VLAN and hosts connected to secondary VLANs, regardless of the Ping's direction. It also works between the switch and hosts connected to the primary VLAN;
- Ping is not supported in the same Private VLAN domain between the switch and hosts connected to secondary VLANs, regardless of the Ping's direction;
- A Private VLAN port can also be configured as a member of a regular VLAN. It behaves like a private port in Private VLANs and like a regular port in regular VLANs;
- Access, trunk, or hybrid ports that have no associations with a Private VLAN can accept Private VLANs in their allowed VLAN list and forward Private VLAN traffic as described in RFC 5517. Such ports are called Inter-Switch Links (ISLs);

  Note: These ports are not the same as vLAG ISLs.
- MAC learning happens only on the primary VLAN;
- Traffic tagged with the primary VLAN is discarded on Private VLAN secondary ports associated with the Private VLAN domain;
- When the Private VLAN feature is disabled, its configuration is not removed from the switch, but instead rendered inactive.

Private VLAN Configuration Example

Follow this procedure to configure a Private VLAN domain.

Note: Messages informing you to disable IGMP Snooping on Private VLANs appear regardless if you already disabled it or not.

1. Configure two secondary VLANs:
   - An isolated VLAN:

```
Switch(config)# vlan 701
Switch(config-vlan)# private-vlan isolated

Note: Please remove the IGMP snooping configuration on this Private
VLAN(s).

Switch(config-vlan)# no ip igmp snooping
Switch(config-vlan)# exit
```

   - And a community VLAN:

```
Switch(config)# vlan 702
Switch(config-vlan)# private-vlan community

Note: Please remove the IGMP snooping configuration on this Private
VLAN(s).

Switch(config-vlan)# no ip igmp snooping
Switch(config-vlan)# exit
```

2. Select a VLAN. Define it as a primary Private VLAN and associate it with the two previously configured secondary VLANs:

```
Switch(config)# vlan 700
Switch(config-vlan)# private-vlan primary

Note: Please remove the IGMP snooping configuration on this Private
VLAN(s).

Switch(config-vlan)# no ip igmp snooping
Switch(config-vlan)# private-vlan association 701,702
Switch(config-vlan)# exit
```

3. Configure a promiscuous port for the primary VLAN:

```
Switch(config)# interface ethernet 1/2
Switch(config-if)# switchport mode private-vlan
Switch(config-if)# switchport private-vlan mapping 700

% INFO: The interface(s) were removed from the Private VLANs they are not
associated/mapped with.

Switch(config-if)# exit
```

4. Configure host ports for the secondary VLANs:
   - Configure a host port and add it to an isolated Private VLAN:

```
Switch(config)# interface ethernet 1/3
Switch(config-if)# switchport mode private-vlan
Switch(config-if)# switchport private-vlan association 700 701

% INFO: The interface(s) were removed from the Private VLANs they are
not associated/mapped with.

Switch(config-if)# exit
```

   - Configure a host port and add it to a community Private VLAN:

```
Switch(config)# interface ethernet 1/4
Switch(config-if)# switchport mode private-vlan
Switch(config-if)# switchport private-vlan association 700 702

% INFO: The interface(s) were removed from the Private VLANs they are
not associated/mapped with.

Switch(config-if)# exit
```

5. Verify the configuration:

```
Switch(config)# show vlan private-vlan

Private VLAN is enabled
Primary  Secondary  Type             Interfaces
-------  ---------  ---------------  --------------------
700      -          primary          Ethernet1/2
700      701        isolated         Ethernet1/3
700      702        community        Ethernet1/4

Interface        PMode   PPMode  PConfig  VLANS
---------------  ------  ------  -------  -----------------
Ethernet1/2      Access  Promis  Conf     700
Ethernet1/3      Access  Host    Conf     701
Ethernet1/4      Access  Host    Conf     702
```

VLAN Topologies and Design Considerations

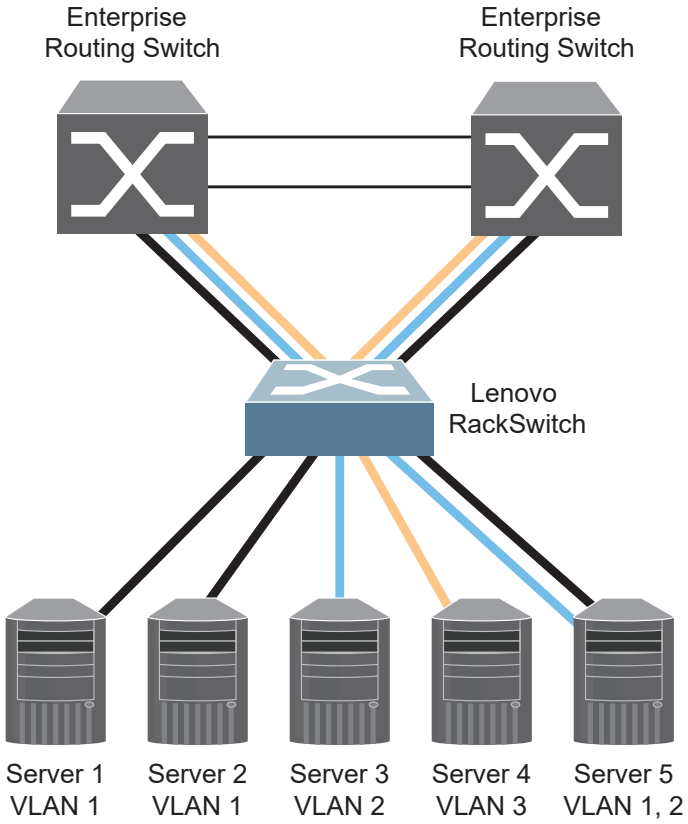
Note the following when working with VLAN topologies:

- By default, the switch software is configured so that trunk operational mode and native VLAN tagging are disabled on all switch ports.
- By default, the switch software is configured so that all switch ports are members of the default VLAN (VLAN 1).
- When using the Multiple Spanning Tree Protocol (MSTP), Spanning Tree Groups (STG) 1 to 64 can include multiple VLANs.
- All ports involved in both aggregation and port mirroring must have the same VLAN configuration. If a port is on a LAG with a mirroring port, the VLAN configuration cannot be changed. For more information about aggregation, see Chapter 11, "Ports and Link Aggregation" and Chapter 36, "Port Mirroring".

Multiple VLANs with Trunk Mode Adapters

Figure 2 illustrates a network topology described in Note: on page 257 and the configuration example on page page 258.

Figure 2. Multiple VLANs with VLAN-Tagged Gigabit Adapters



The features of this VLAN are described in the following table.

Table 24.

Component	Description
Lenovo RackSwitch	This switch is configured with three VLANs that represent three different IP subnets. Five ports (ethernet ports 1/11-1/15) are connected downstream to servers. Two ports (ethernet ports 1/19 and 1/20) are connected upstream to routing switches. Uplink ports are members of all three VLANs and are in trunk mode.
Server 1	This server is a member of VLAN 1 and has presence in only one IP subnet. The associated switch port (ethernet port 1/11) is only a member of VLAN 1, so the port is in access mode.
Server 2	This server is a member of VLAN 1 and has presence in only one IP subnet. The associated switch port (ethernet port 1/12) is only a member of VLAN 1, so the port is in access mode.
Server 3	This server belongs to VLAN 2 and it is logically in the same IP subnet as Server 5. The associated switch port (ethernet port 1/13) is in access mode.
Server 4	A member of VLAN 3, this server can communicate only with other servers via a router. The associated switch port (ethernet port 1/14) is in access mode.
Server 5	A member of VLAN 1 and VLAN 2, this server can communicate with Server 1, Server 2, Server 3 and the upstream switches. It cannot communicate with Server 4. The associated switch port (ethernet port 1/15) is in trunk mode.
Enterprise Routing Switches	These switches must have all three VLANs (VLAN 1, 2 and 3) configured. They can communicate with Server 1, Server 2 and Server 5 via VLAN 1. They can communicate with Server 3 and Server 5 via VLAN 2. They can communicate with Server 4 via VLAN 3. The switch ports are in trunk mode.

Note: Switch trunk port mode is required only on ports that are connected to other switches or on ports that connect to tag-capable end stations, such as servers with trunk mode adapters.

To configure a specific VLAN on a trunk port, the following conditions must be met:

- The port must be in trunk mode.
- The VLAN must be in the trunk port's allowed VLAN range. By default, the range includes all VLANs.
- The VLAN must be un-reserved.
- The VLAN must be created.

The order in which the conditions above are met is not relevant. However, all conditions must be met collectively. When all the conditions are met, the VLAN is enabled on the port. If one of the conditions is broken, the VLAN is disabled.

VLAN Configuration Example

Use the following procedure to configure the example network shown in Figure 2 on page 256.

1. Enable trunk mode on server ports that support multiple VLANs and add VLANs to the trunk link.

```
Switch(config)# interface ethernet 1/15
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlans 1,2
Switch(config-if)# exit
```

2. Enable trunk mode on uplink ports that support multiple VLANs.

```
Switch(config)# interface ethernet 1/19
Switch(config-if)# switchport mode trunk
Switch(config-if)# exit

Switch(config)# interface ethernet 1/20
Switch(config-if)# switchport mode trunk
Switch(config-if)# exit
```

3. Configure server ports that belong to a single VLAN.

```
Switch(config)# interface ethernet 1/13
Switch(config-if)# switchport access vlan 2
Switch(config-if)# exit

Switch(config)# interface ethernet 1/14
Switch(config-if)# switchport access vlan 3
Switch(config-if)# exit
```

By default, all ports are members of the default VLAN (VLAN 1), so configure only those ports that belong to other VLANs. In this example, ethernet ports 1/11 to 1/12 are by default switch access ports and are members of VLAN 1, and do not require any further configuration.

Chapter 11. Ports and Link Aggregation

Link Aggregation Groups (LAGs) can provide super-bandwidth, multi-link connections between the switch and other LAG-capable devices. A LAG is a group of ports that act together, combining their bandwidth to create a single, larger virtual link. This chapter provides configuration background and examples for aggregating multiple ports together:

Port Configuration Profiles

The following Lenovo switches are 1U rack-mountable aggregation devices:

- RackSwitch G8272
- RackSwitch G8332
- ThinkSystem NE1032T RackSwitch
- ThinkSystem NE1032 RackSwitch
- ThinkSystem NE1072T RackSwitch
- ThinkSystem NE10032 RackSwitch
- ThinkSystem NE2572 RackSwitch

The Lenovo RackSwitch G8296 is a 2U rack-mountable aggregation device.

All of these switches use a wire-speed, non-blocking switching fabric that provides simultaneous wire-speed transport of multiple packets at low latency on all ports.

G8272 Port Configuration

The G8272 has the following port capabilities:

- Forty-eight 10 Gigabit Ethernet (GbE) Small Form Pluggable Plus (SFP+) ports which also support legacy 1 GbE connections
- Six 40 GbE Quad Small Form Pluggable Plus (QSFP+) ports, each of which can optionally be used as four 10 GbE ports

SFP+ ports, when used in 10 GbE mode, can be populated with optical transceiver modules, or active or passive Direct-Attach Cables (DACs). When used in legacy 1 GbE mode, the ports can be populated with optical or copper transceiver modules.

QSFP+ ports can be populated with optical QSFP+ modules or passive DACs, including those that allow the port to be used as four 10 GbE ports.

By default, the G8272 has the following interface (port) configuration:

- ethernet interfaces 1-48 are configured as 10 GBit/s ports
- ethernet interfaces 49-54 are configured as 40 GBit/s ports

The G8272 supports three different port profiles:

- default - forty-eight 10 GBit/s SFP+ ports and six 40 GBit/s QSFP+ ports
- 72x10G - seventy-two 10 GBit/s SFP+ ports
- custom port mode

In 72x10G port mode, each of the six 40 GBit/s ports is split into four 10 GBit/s breakout ports, adding up to a total of seventy-two 10 GBit/s ports.

To change the port mode to the 72x10G profile, use the following command:

```
Switch(config)# hardware profile portmode 72x10G
```

You can configure a custom port profile on the switch, changing an ethernet interface port mode from 40 GBit/s to 10 GBit/s or vice versa, and have different numbers of 10 GBit/s and 40 GBit/s ports than the default configuration. For example, you can configure sixty-four 10 GBit/s ports and two 40 Gbit/s ports.

Note: The maximum number of 40 GBit/s ports configurable on the switch is six.

To create a custom port profile, use the following command:

```
Switch(config)# hardware profile portmode custom 4x 10G ethernet <chassis
number>/<port number>
```

Note: This command will configure the specified port to run in 10 GBit/s mode.

You can specify a single ethernet port or a range of ports. The range can be either continuos (for example, 20-25) or discrete (for example, 20, 22, 25, 30).

For example:

- Configure a single ethernet interface to run in 10 GBit/s mode:

```
Switch(config)# hardware profile portmode custom 4x10G ethernet 1/50
```

- Configure a range of ethernet interfaces to run in 10 GBit/s mode:
  - continuos range:

```
Switch(config)# hardware profile portmode custom 4x10G ethernet
1/51-54
```

  - discrete range:

```
Switch(config)# hardware profile portmode custom 4x10G ethernet
1/49, ethernet 1/53, ethernet 1/54
```

When a 40 GBit/s port is split into four 10 GBit/s breakout ports, the ethernet interface associated with that port will include four subports.

For example, before changing ethernet port 54 to 10 GBit/s port mode, the port will be displayed as follows:

```
Switch> show interface ethernet 1/54 brief

--------------------------------------------------------------------------
Ethernet      VLAN  Type Mode   Status  Reason             Speed  Port
Interface                                                        Agg#
--------------------------------------------------------------------------
Ethernet1/54  1     eth  access down    Link not connected  auto   --
```

After spliting the port into four 10 GBit/s breakout ports, the port will be displayed as follows:

```
Switch> show interface ethernet 1/54/1-4 brief

--------------------------------------------------------------------------------
Ethernet      VLAN  Type Mode   Status  Reason              Speed  Port
Interface                                                        Agg#
--------------------------------------------------------------------------------
Ethernet1/54/1  1   eth  access down    Link not connected  auto   --
Ethernet1/54/2  1   eth  access down    Link not connected  auto   --
Ethernet1/54/3  1   eth  access down    Link not connected  auto   --
Ethernet1/54/4  1   eth  access down    Link not connected  auto   --
```

To configure 10 GBit/s breakout ports, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number/subport number>
```

For example:

```
Switch(config)# interface ethernet 1/54/2
```

When configuring a custom port profile on an ethernet interface, you can reset the interface's port mode to its default settings by using the following command:

```
Switch(config)# no hardware profile portmode custom ethernet <chassis number/
/port number/subport number>
```

To reset the switch port configuration to the default profile, use the following command:

```
Switch(config)# hardware profile portmode default
```

To view the current configured port profile, use the following command:

```
Switch# show hardware profile portmode

Current port mode:
        Port Ethernet1/49 is set in 10G mode
        Port Ethernet1/50 is set in 10G mode
        Port Ethernet1/51 is set in 10G mode
        Port Ethernet1/52 is set in 10G mode
        Port Ethernet1/53 is set in 10G mode
        Port Ethernet1/54 is set in 10G mode
```

G8296 Port Configuration

The G8296 has the following port capabilities:

- Eighty-six 10 Gigabit Ethernet (GbE) Small Form Pluggable Plus (SFP+) ports which also support legacy 1 GbE connections
- Ten 40 GbE Quad Small Form Pluggable Plus (QSFP+) ports, of which two ports (87 and 88) can optionally be used as four 10 GbE ports

SFP+ ports, when used in 10 GbE mode, can be populated with optical transceiver modules, or active or passive Direct-Attach Cables (DACs). When used in legacy 1 GbE mode, the ports can be populated with optical or copper transceiver modules.

QSFP+ ports can be populated with optical QSFP+ modules or passive DACs, including those that allow the port to be used as four 10 GbE ports.

By default, the G8296 has the following interface (port) configuration:

- ethernet interfaces 1-86 are configured as 10 GBit/s ports
- ethernet interfaces 87-96 are configured as 40 GBit/s ports

The G8296 supports three different port profiles:

- default - eighty-six 10 GBit/s SFP+ ports and ten 40 GBit/s QSFP+ ports
- 94x10G + 8x40G - ninety-four 10 GBit/s SFP+ ports and eight 40 GBit/s QSFP+ ports
- custom port mode

In 94x10G + 8x40G port mode, two of the ten 40 GBit/s ports are split into four 10 GBit/s breakout ports, adding up to a total of ninety-four 10 GBit/s ports and eight 40 GBit/s ports. The two 40 GBit/s ports that can be split into four 10 GBit/s breakout ports are ethernet ports 87 and 88.

To change the port mode to the 94x10G + 8x40G profile, use the following command:

```
Switch(config)# hardware profile portmode 94x10G+8x40G
```

You can configure a custom port profile on the switch, changing an ethernet interface port mode from 40 GBit/s to 10 GBit/s or vice versa, and have different numbers of 10 GBit/s and 40 GBit/s ports than the default configuration. For example, you can configure ninety 10 GBit/s ports and nine 40 Gbit/s ports.

Note: The maximum number of 40 GBit/s ports configurable on the switch is ten. The minimum number is eight.

To create a custom port profile, use the following command:

```
Switch(config)# hardware profile portmode custom ethernet <chassis number/
/port number>
```

Note: This command will configure the specified port to run in 10 GBit/s mode.

You can specify a single ethernet port or a range of ports. The range can be either continuos (for example, 20-25) or discrete (for example, 20, 22, 25, 30).

For example:

- Configure a single ethernet interface to run in 10 GBit/s mode:

```
Switch(config)# hardware profile portmode custom ethernet 1/88
```

- Configure a range of ethernet interfaces to run in 10 GBit/s mode:
  - continuos range:

```
Switch(config)# hardware profile portmode custom ethernet 1/87-88
```

  - discrete range:

```
Switch(config)# hardware profile portmode custom ethernet 1/87,
ethernet 1/88
```

When a 40 GBit/s port is split into four 10 GBit/s breakout ports, the ethernet interface associated with that port will include four subports.

For example, before changing ethernet port 88 to 10 GBit/s port mode, the port will be displayed as follows:

```
Switch> show interface ethernet 1/88 brief

--------------------------------------------------------------------------
Ethernet      VLAN  Type Mode   Status  Reason              Speed  Port
Interface                                                          Agg#
--------------------------------------------------------------------------
Ethernet1/88  1     eth  access down    Link not connected  auto   --
```

After spliting the port into four 10 GBit/s breakout ports, the port will be displayed as follows:

```
Switch> show interface ethernet 1/88/1-4 brief

--------------------------------------------------------------------------
Ethernet      VLAN  Type Mode   Status  Reason              Speed  Port
Interface                                                          Agg#
--------------------------------------------------------------------------
Ethernet1/88/1  1   eth  access down    Link not connected  auto   --
Ethernet1/88/2  1   eth  access down    Link not connected  auto   --
Ethernet1/88/3  1   eth  access down    Link not connected  auto   --
Ethernet1/88/4  1   eth  access down    Link not connected  auto   --
```

To configure 10 GBit/s breakout ports, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number/subport number>
```

For example:

```
Switch(config)# interface ethernet 1/88/2
```

When configuring a custom port profile on an ethernet interface, you can reset the interface's port mode to its default settings by using the following command:

```
Switch(config)# no hardware profile portmode custom ethernet <chassis number/
/port number/subport number>
```

To reset the switch port configuration to the default profile, use the following command:

```
Switch(config)# hardware profile portmode default
```

To view the current configured port profile, use the following command:

```
Switch# show hardware profile portmode

Current port mode:
        Port Ethernet1/87 is set in 10G mode
        Port Ethernet1/88 is set in 10G mode
```

G8332 Port Configuration

The G8332 has the following port capabilities:

- Thirty-two 40 GbE Quad Small Form Pluggable Plus (QSFP+) ports, of which twenty-four ports (2 to 25) can optionally be used as four 10 GbE ports

QSFP+ ports can be populated with optical QSFP+ modules or passive DACs, including those that allow the port to be used as four 10 GbE ports.

By default, the G8332 has the following interface (port) configuration:

- ethernet interfaces 1-32 are configured as 40 GBit/s ports

The G8332 supports three different port profiles:

- default - thirty-two 40 GBit/s QSFP+ ports
- 96x10G + 8x40G - ninety-six 10 GBit/s SFP+ ports and eight 40 GBit/s QSFP+ ports
- custom port mode

In 96x10G + 8x40G port mode, twenty-four of the thirty-two 40 GBit/s ports are split into four 10 GBit/s breakout ports, adding up to a total of ninety-six 10 GBit/s ports and eight 40 GBit/s ports. The twenty-four 40 GBit/s ports that can be split into four 10 GBit/s breakout ports are ethernet ports from 2 to 25 (included).

To change the port mode to the 96x10G + 8x40G profile, use the following command:

```
Switch(config)# hardware profile portmode 96x10G+8x40G
```

You can configure a custom port profile on the switch, changing an ethernet interface port mode from 40 GBit/s to 10 GBit/s or vice versa, and have different numbers of 10 GBit/s and 40 GBit/s ports than the default configuration. For example, you can configure ninety-two 10 GBit/s ports and nine 40 Gbit/s ports.

Note: The maximum number of 40 GBit/s ports configurable on the switch is thirty-two. The minimum number is eight.

To create a custom port profile, use the following command:

```
Switch(config)# hardware profile portmode custom <port mode> ethernet <chassis number>/<port number>
```

where:

Argument	Description
port mode	The number of ports x the speed, such as `96x10G` or `10x40G`.
chassis number	The ethernet chassis number.
slot number	The ethernet slot number.

Note: This command will configure the specified port to run in 10 GBit/s mode.

You can specify a single ethernet port or a range of ports. The range can be either continuos (for example, 20-25) or discrete (for example, 20, 22, 25, 30).

For example:

- Configure a single ethernet interface to run in 10 GBit/s mode:

```
Switch(config)# hardware profile portmode custom 4x10G ethernet 1/2
```

- Configure a range of ethernet interfaces to run in 10 GBit/s mode:
  - continuos range:

```
Switch(config)# hardware profile portmode custom 4x10G ethernet
1/2-10
```

  - discrete range:

```
Switch(config)# hardware profile portmode custom 4x10G ethernet
1/11, ethernet 1/12
```

When a 40 GBit/s port is split into four 10 GBit/s breakout ports, the ethernet interface associated with that port will include four subports.

For example, before changing ethernet port 2 to 10 GBit/s port mode, the port will be displayed as follows:

```
Switch> show interface ethernet 1/2 brief

--------------------------------------------------------------------------------
Ethernet        VLAN   Type Mode   Status  Reason                 Speed    Port
Interface                                                                Agg#
--------------------------------------------------------------------------------
Ethernet1/2     1      eth  access down    Administratively down   40000    --
```

After spliting the port into four 10 GBit/s breakout ports, the port will be displayed as follows:

```
Switch> show interface brief

--------------------------------------------------------------------------------
Ethernet        VLAN   Type Mode   Status  Reason                 Speed    Port
Interface                                                                Agg#
--------------------------------------------------------------------------------
Ethernet1/1     1      eth  access down    Administratively down   40000    --
Ethernet1/2/1   1      eth  trunk  up      none                   10000    --
Ethernet1/2/2   1      eth  access down    Administratively down   10000    --
Ethernet1/2/3   1      eth  access down    Administratively down   10000    --
Ethernet1/2/4   1      eth  access down    Administratively down   10000    --
Ethernet1/3/1   1      eth  access down    Administratively down   10000    --
Ethernet1/3/2   1      eth  access down    Administratively down   10000    --
Ethernet1/3/3   1      eth  access down    Administratively down   10000    --
```

To configure 10 GBit/s breakout ports, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number/subport number>
```

For example:

```
Switch(config)# interface ethernet 1/2/2
```

When configuring a custom port profile on an ethernet interface, you can reset the interface's port mode to its default settings by using the following command:

```
Switch(config)# no hardware profile portmode custom ethernet <chassis number/
//port number/subport number>
```

To reset the switch port configuration to the default profile, use the following command:

```
Switch(config)# hardware profile portmode default
```

To view the current configured port profile, use the following command:

```
Switch# show hardware profile portmode

Current port mode:
Port Ethernet1/2 is set in 10G mode
Port Ethernet1/3 is set in 10G mode
```

NE1032 Port Configuration

The NE1032 has the following port capabilities:

- Thirty-two 10 Gigabit Ethernet (GbE) Small Form Pluggable Plus (SFP+) ports which also support legacy 1 GbE connections

SFP+ ports, when used in 10 GbE mode, can be populated with optical transceiver modules or active or passive Direct-Attach Cables (DACs). When used in legacy 1 GbE mode, the ports can be populated with optical or copper transceiver modules.

By default, the NE1032 has the following interface (port) configuration:

- Ethernet interfaces 1-32 are configured as 10 GBit/s ports

NE1032T Port Configuration

The NE1032T has the following port capabilities:

- Twenty-four 100/1000/10G BASE-T RJ45 ports
- Eight Gigabit Ethernet (GbE) Small Form Pluggable Plus (SFP+) ports which also support legacy 1 GbE connections

The 10G BASE-T RJ45 ports, when used in 10 GbE mode, must use CAT6 copper cabling. When used in 100/1000 base T mode, the ports can be populated with CAT5E copper cabling.

Note: When configuring the port in 100 Mbps mode, it is recommended to use Category 5 Ethernet crossover cables.

SFP+ ports, when used in 10 GbE mode, can be populated with optical transceiver modules, or active or passive Direct-Attach Cables (DACs). When used in legacy 1 GbE mode, the ports can be populated with optical or copper transceiver modules.

By default, the NE1032T has the following interface (port) configuration:

- Ethernet interfaces 1-32 are configured as 10 GBit/s ports

NE1072T Port Configuration

The NE1072T has the following port capabilities:

- Forty-eight 100/1000/10G BASE-T RJ45 ports.
- Six 40 GbE Quad Small Form Pluggable Plus (QSFP+) ports, all of which ports can optionally be used as four 10 GbE SFP+ ports

The 10G BASE-T RJ45 ports, when used in 10 GbE mode, must use CAT6 copper cabling. When used in 100/1000 base T mode, the ports can be populated with CAT5E copper cabling.

Note: When configuring the port in 100 Mbps mode, it is recommended to use Category 5 Ethernet crossover cables.

QSFP+ ports can be populated with optical QSFP+ modules or passive DACs, including those that allow the port to be used as four 10 GbE ports.

By default, the NE1072T has the following interface (port) configuration:

- ethernet interfaces 1-48 are configured as 10 GBit/s ports
- ethernet interfaces 49-54 are configured as 40 GBit/s ports

The NE1072T supports three different port profiles:

- default: 48x10G + 6x40G - forty-eight 10 GBit/s SFP+ ports and six 40 GBit/s QSFP+ ports
- seventy-two 10 GBit/s QSFP+ ports
- custom port mode

In 48x10G + 6x40G port mode, there are six 40 GBit/s ports that can be split into four 10 GBit/s ports. These are ethernet ports from 49 to 54.

To change the port mode to the 72x10G profile, use the following command:

```
Switch(config)# hardware profile portmode 72x10G
```

You can configure a custom port profile on the switch, changing an ethernet interface port mode from 40 GBit/s to 10 GBit/s or vice versa, and have different numbers of 10 GBit/s and 40 GBit/s ports than the default configuration. For example, you can configure 52 10 GBit/s ports and 5 40 Gbit/s ports.

Note: The maximum number of 40 GBit/s ports configurable on the switch is six.

To create a custom port profile, use the following command:

```
Switch(config)# hardware profile portmode custom ethernet <chassis number/
/port number>
```

Note: This command will configure the specified port to run in 10 GBit/s mode.

You can specify a single ethernet port or a range of ports. The range can be either continuos (for example, 20-25) or discrete (for example, 20, 22, 25, 30).

For example:

- Configure a single ethernet interface to run in 10 GBit/s mode:

```
Switch(config)# hardware profile portmode custom 4x10G ethernet 1/50
```

- Configure a range of ethernet interfaces to run in 10 GBit/s mode:
  - continuos range:

```
Switch(config)# hardware profile portmode custom 4x10G ethernet
1/49-52
```

  - discrete range:

```
Switch(config)# hardware profile portmode custom 4x10G ethernet
1/49, ethernet 1/50
```

When a 40 GBit/s port is split into four 10 GBit/s breakout ports, the ethernet interface associated with that port will include four subports.

For example, before changing ethernet port 50 to 10 GBit/s port mode, the port will be displayed as follows:

```
Switch> show interface ethernet 1/50 brief

--------------------------------------------------------------------------------
Ethernet        VLAN   Type Mode   Status  Reason                 Speed    Port
Interface                                                                Agg#
--------------------------------------------------------------------------------
Ethernet1/50    1      eth  access down    Administratively down  40000    --
```

After spliting the port into four 10 GBit/s breakout ports, the port will be displayed as follows:

```
Switch> show interface brief

--------------------------------------------------------------------------------
Ethernet        VLAN   Type Mode   Status  Reason                 Speed    Port
Interface                                                                Agg#
--------------------------------------------------------------------------------
Ethernet1/1     1      eth  access down    Administratively down  40000    --
Ethernet1/50/1  1      eth  trunk  up      none                   10000    --
Ethernet1/50/2  1      eth  access down    Administratively down  10000    --
Ethernet1/50/3  1      eth  access down    Administratively down  10000    --
Ethernet1/50/4  1      eth  access down    Administratively down  10000    --
```

To configure 10 GBit/s breakout ports, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number/subport number>
```

For example:

```
Switch(config)# interface ethernet 1/50/2
```

When configuring a custom port profile on an ethernet interface, you can reset the interface's port mode to its default settings by using the following command:

```
Switch(config)# no hardware profile portmode custom ethernet <chassis number/
/port number/subport number>
```

To reset the switch port configuration to the default profile, use the following command:

```
Switch(config)# hardware profile portmode default
```

To view the current configured port profile, use the following command:

```
Switch# show hardware profile portmode

Current port mode:
Port Ethernet1/1 is set in 10G mode
Port Ethernet1/50 is set in 40G mode
```

NE10032 Port Configuration

The NE10032 has the following port capabilities:

- Thirty-two 100 Gigabit Ethernet (GbE) QSFP28 ports supporting 10GbE, 25GbE, 50GbE and 100GbE connections

The QSFP28 ports accept approved QSFP28 transceivers. The QSFP28 optical transceiver provides an MTP cable connector for connecting to external ports.

Note: The QSFP28 AOC Mellanox Transceiver is not accepted by the Arista DCS-7160-48YC6. The 100G link using the QSFP28 Mellanox AOC Transceiver does not work between the Arista DCS-7160-48YC6 and the NE10032.

By default, the NE10032 has the following interface (port) configuration

- ethernet interfaces 1-32 are configured as 100 GBit/s ports

The NE10032 supports the following port profiles:

- default: 32x100G - thirty-two 100 GBit/s QSFP28 ports
- custom port mode
- 128x10G - 128 10 Gbig/s QSFP28 ports
- 128x25G - 128 25 Gbig/s QSFP28 ports
- 32x40G - 32 40 Gbig/s QSFP28 ports
- 64x50G - 64 50 Gbig/s QSFP28 ports

You can configure a custom port profile on the switch, changing one or more Ethernet interfaces from 100 Gbit/s port mode to one of the following modes:.

Parameter	Mode
`1x40G`	1x40G mode
`2x50G`	2x50G mode
`4x10G`	4x10G mode
`4x25G`	4x25G mode

To create a custom port profile, use the following command:

```
Switch(config)# hardware profile portmode custom <parameter> ethernet <chassis number/<port number>
```

Switch ports configured in 25Gbps hardware profile port mode can have their port speed changed to 10Gbps or back to 25Gbps without needing to reload the switch. You need to configure the same hardware profile port mode and the same port speed on both end-ports of the link. You need install transceivers that support both 25Gbps and 10Gbps speeds, else you also need to change the transceiver each time the port speed is modified.

You can specify a single ethernet port or a range of ports. The range can be either continuous (for example, 20-25) or discrete (for example, 20, 22, 25, 30).

For example:

- Configure a single ethernet interface to run in 25 GBit/s mode:

```
Switch(config)# hardware profile portmode custom 4x25G ethernet 1/32
```

- Configure a range of ethernet interfaces to run in 10 GBit/s mode:
  - continuous range:

```
Switch(config)# hardware  profile portmode custom 4x10G ethernet
1/24-29
```

  - discrete range:

```
Switch(config)# hardware profile  portmode custom 4x10G ethernet
1/24, ethernet 1/29
```

When a 100 GBit/s port is split into breakout ports, the ethernet interface associated with that port will include the appropriate number of subports.

For example, before changing ethernet port 1 to 10 GBit/s port mode, the port will be displayed as follows:

```
Switch> show interface ethernet 1/50 brief

--------------------------------------------------------------------------------
Ethernet        VLAN   Type Mode   Status  Reason                 Speed    Port
Interface                                                                Agg#
--------------------------------------------------------------------------------
Ethernet1/1     1      eth  access down    Administratively down  100000   --
```

After spliting the port into four 10 GBit/s breakout ports, the port will be displayed as follows:

```
Switch> show interface brief

--------------------------------------------------------------------------------
Ethernet        VLAN   Type Mode   Status  Reason                 Speed    Port
Interface                                                                Agg#
--------------------------------------------------------------------------------
Ethernet1/1     1      eth  access down    Administratively down  100000   --
Ethernet1/1/1   1      eth  trunk  up      none                    25000   --
Ethernet1/1/2   1      eth  access down    Administratively down   25000   --
Ethernet1/1/3   1      eth  access down    Administratively down   25000   --
Ethernet1/1/4   1      eth  access down    Administratively down   25000   --
```

To configure 25 GBit/s breakout ports, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number/subport number>
```

For example:

```
Switch(config)# interface ethernet 1/1/2
```

When configuring a custom port profile on an ethernet interface, you can reset the interface's port mode to its default settings by using the following command:

```
Switch(config)# no hardware profile portmode custom ethernet <chassis number/
/port number/subport number>
```

To reset the switch port configuration to the default profile, use the following command:

```
Switch(config)# hardware profile portmode default
```

To view the current configured port profile, use the following command:

```
Switch# show hardware profile portmode

Current port mode:
Port Ethernet1/1 is set in 100G mode
Port Ethernet1/32 is set in 25G mode
```

NE2572 Port Configuration

The NE2572 has the following port capabilities:

- Forty-eight 25 Gigabit Ethernet (GbE) SFP28 ports supporting 10GbE and 25GbE connections. Ports 9-48 also support legacy 1GbE connection with no auto negotiation.

  Note: Due to hardware limitations of the switch ASIC, when using a 1 GbE SFP Copper transceiver, the link state change can be detected with a delay of 2-3 seconds. Also, during reload, you may see a temporary link up state even though the link is down configuration wise. This may have an impact to link failovers with this type of transceiver. The switch stabilizes and resumes under normal operation.

- Six additional 100 Gigabit Ethernet (GbE) QSFP28 ports supporting 10GbE, 25GbE, 40GbE, 50GbE and 100GbE connections.

QSFP28 ports can be populated with Optical QSFP28/QSFP+ modules or Quad Direct Attach Cables (QDACs), including those that allow breakout to four 25GbE SFP28/SFP+ ports.

SFP28 port can be populated with Optical or Copper SFP28/SFP+ transceivers or SFP28/SFP+ Direct Attach Cables (DACs). When used in legacy 1 GbE mode, the ports can be populated with optical or copper transceiver modules.

Note: The QSFP28 AOC Mellanox Transceiver is not accepted by the Arista DCS-7160-48YC6. The 100G link using the QSFP28 Mellanox AOC Transceiver does not work between the Arista DCS-7160-48YC6 and the NE2572.

The NE2572 supports the following port profiles:

- default: 48x25G + 6x100G - forty-eight 25 GBit/s SFP28 ports + six 100 GBit/s QSFP28 ports
- 48x10G + 12x50 - forty-eight 10 GBit/s SFP+ ports + twelve 50 GBit/s QSFP+ ports
- 48x10G + 6x100 Gbig/s - forty-eight 10 GBit/s SFP+ ports + six 100 GBit/s QSFP+ ports

- 48x10G + 6x40 Gbig/s - forty-eight 10 GBit/s SFP+ ports + six 40 GBit/s QSFP+ ports
- 48x25G + 12x50 Gbig/s - forty-eight 25 GBit/s SFP+ ports + twelve 50 GBit/s QSFP+ ports
- 72x10G - seventy-two 10 GBit/s SFP+ ports
- 72x25G - seventy-two 25 GBit/s SFP+ ports
- custom port mode

In 48x25G + 6x100G port mode, the six 100 GBit/s ports that can be split into four 10GBit/s or 25GBit/s or two 50Gbit/s breakout ports are ethernet ports from 49 to 54 (included).

To change the port mode to the 48x10G + 6x40G profile, use the following command:

```
Switch(config)# hardware profile portmode 48x10G+6x40G
```

You can configure a custom port profile on the switch, changing an ethernet interface port mode from 100 GBit/s to 25GBit/s or vice versa, and have different numbers of 25 GBit/s and 100 GBit/s ports than the default configuration.

To create a custom port profile, use the following command:

```
Switch(config)# hardware profile portmode custom 4x10G ethernet
<chassis number>/<port range>
```

Notes:

- This command configures the specified port to run in 10Gbps mode.
- Switch ports configured in 25Gbps hardware profile port mode can have their port speed changed to 10Gbps or back to 25Gbps without needing to reload the switch. You need to configure the same hardware profile port mode and the same port speed on both end-ports of the link. You need install transceivers that support both 25Gbps and 10Gbps speeds, else you also need to change the transceiver each time the port speed is modified.
- For the SFP28 ports (Ethernet ports 1-48), you must specify a four-port ethernet port range. For example, to configure a ethernet interfaces 1/41 through 1/44 to run in 10 GBit/s mode, enter:

  ```
  Switch(config)# hardware profile portmode custom 4x10G ethernet
  1/41-44
  ```

  Trying to configure a single Ethernet port such as 1/40 or a discrete range of Ethernet ports, such as 1/40,41,42,43 will result in an error.
- The Quad ports (QSFP28 ports 49-55) do not have the four-port restriction.

When a 100 GBit/s port is split into four 10 GBit/s breakout ports, the ethernet interface associated with that port will include four subports.

For example, before changing ethernet port 1/50 to 10 GBit/s port mode, the port will be displayed as follows:

```
Switch> show interface ethernet 1/50 brief

--------------------------------------------------------------------------------
Ethernet        VLAN   Type Mode   Status  Reason                 Speed    Port
Interface                                                                Agg#
--------------------------------------------------------------------------------
Ethernet1/50    1      eth  access down    Administratively down  40000    --
```

After spliting the port into four 10 GBit/s breakout ports, the port will be displayed as follows:

```
Switch> show interface brief

--------------------------------------------------------------------------------
Ethernet        VLAN   Type Mode   Status  Reason                 Speed    Port
Interface                                                                Agg#
--------------------------------------------------------------------------------
Ethernet1/1     1      eth  access down    Administratively down  40000    --
Ethernet1/50/1  1      eth  trunk  up      none                   10000    --
Ethernet1/50/2  1      eth  access down    Administratively down  10000    --
Ethernet1/50/3  1      eth  access down    Administratively down  10000    --
Ethernet1/50/4  1      eth  access down    Administratively down  10000    --
```

To configure 10 GBit/s breakout ports, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number/subport number>
```

For example:

```
Switch(config)# interface ethernet 1/50/2
```

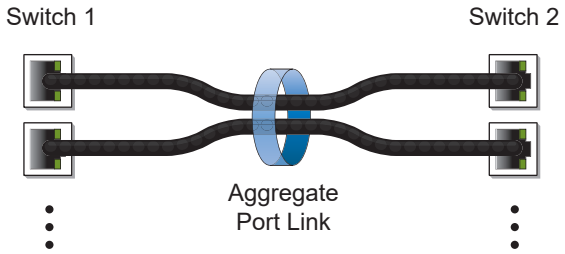
When configuring a custom port profile on an ethernet interface, you can reset the interface's port mode to its default settings by using the following command:

```
Switch(config)# no hardware profile portmode custom ethernet <chassis number/
/port number/subport number>
```

Aggregation Overview

When using LAGs between two switches, as shown in Figure 3, you can create a virtual link between the switches that operates with combined throughput levels and depends on how many physical ports are included. The physical links in a LAG operate as a single logical connection.

Figure 3. Port LAG



LAGs are also useful for connecting the switch to third-party devices supporting link aggregation, such as Cisco routers and switches with EtherChannel technology (not ISL aggregation technology), or Sun's Quad Fast Ethernet Adapter. LAG technology is compatible with such devices if they are configured manually.

LAG traffic is statistically distributed among the ports in a LAG, based on a variety of configurable options.

Also, since each LAG is comprised of multiple physical links, the LAG is inherently fault tolerant. As long as one connection between the switches is available, the trunk remains active and statistical load balancing is maintained whenever a port in a LAG is lost or returned to service.

A LAG can be statically configured or dynamically aggregated through the use of a network protocol, like the Link Aggregation Control Protocol (LACP). For more details about LACP, see "Link Aggregation Control Protocol" on page 282.

When creating a LAG, you must assign it a number from 1 to 4096. The switch supports the following maximum number of LAGs, either statically configured or dynamically aggregated using LACP:

- G8272: maximum 72 LAGs
- G8296: maximum 96 LAGs
- G8332: maximum 104 LAGs
- NE1032: maximum 32 LAGs
- NE1032T: maximum 32 LAGs
- NE1072T: maximum 72 LAGs
- NE10032: maximum 128 LAGs
- NE2572: maximum 72 LAGs

Creating a LAG

To create a LAG, use the following command:

```
Switch(config)# interface port-channel <1-4096>
Switch(config-if)#
```

Note: Upon creating a LAG, you will enter Interface Configuration command mode, where you'll be able to configure the settings of the LAG.

To remove a LAG, use the following command:

```
Switch(config)# no interface port-channel <1-4096>
```

Static LAGs

You can create a static LAG that contains multiple physical links. Static LAGs do not require protocols like LACP to run on the switch to maintain the configured aggregation.

When you create a static LAG, the LAG members (switch ports) take on specific settings necessary for the correct operation of the aggregation.

Before configuring a static LAG, consider the following:

- Consider how existing VLANs will be affected by the addition of a LAG.
- Determine which switch ports (up to 32) are to become LAG members (the specific ports making up the LAG).
- Ensure that the chosen switch ports are in the up link state.
- Member ports must be all configured either as switch access ports or as switch trunk ports, and must have the same VLAN membership. For more details, see "Configuring a Switch Access Port" on page 234 and "Configuring a Switch Trunk Port" on page 235.
- LAG member ports must have the same Spanning Tree Protocol (STP) configuration.
- LAG member ports must have MAC address learning and flow control configuration.
- The same maximum transmission unit (MTU) size must be configured on all LAG member ports.
- The same bandwidth, speed, duplex, and auto-negotiation settings must be configured on all LAG member ports.
- Consider how the existing spanning tree will react to the new LAG configuration.

Static LAG Configuration Rules

When configuring a static LAG, you should consider the following configuration rules that determine how a LAG will react in any network topology:

- All links must originate from one logical source device and lead to one logical destination device. Usually, a LAG connects two physical devices together with multiple links. However, in some networks, a single logical device may include multiple physical devices, such as when using VLAGs (see Chapter 13, "Virtual Link Aggregation Groups"). In such cases, links in a LAG are allowed to connect to multiple physical devices because they act as one logical device.
- A physical switch port cannot be member of multiple LAGs. It can belong to only a single LAG.
- Aggregation from third-party devices must comply with Cisco EtherChannel technology.
- Each LAG inherits its port configuration (speed, flow control, native VLAN tagging) from the first member port. As additional ports are added to the LAG, their settings must be changed to match the LAG configuration.

- The maximum number of physical links in a LAG is 32. After reaching this limit, no more links can be added to the LAG.
- When a port becomes a member of a LAG, its MAC address and STP configuration are replaced with the ones of the LAG.
- When a port joins or leaves a LAG, the following parameters are unaffected: interface description, LLDP settings, LACP port priority, and link state.

Configuring a Static LAG

To add a physical port to a static LAG, use the following steps:

1. Configure the ethernet interface's port mode and VLAN membership.
   - as a switch access port:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan <VLAN ID (1-4093)>
Switch(config-if)# exit
Switch(config)#
```

   - as a switch trunk port:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan <VLAN ID (1-4093)>
Switch(config-if)# exit
Switch(config)#
```

2. Create a LAG and configure the same port mode and VLAN membership as the previously configured ethernet interface.
   - access port mode:

```
Switch(config)# interface port-channel <1-4096>
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan <VLAN ID (1-4093)>
Switch(config-if)# exit
Switch(config)#
```

   - trunk port mode:

```
Switch(config)# interface port-channel <1-4096>
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan <VLAN ID (1-4093)>
Switch(config-if)# exit
Switch(config)#
```

3. Add the interface to a LAG without an aggregation protocol:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# channel-group <1-4096> mode on
Switch(config-if)# exit
Switch(config)#
```

4. Check the current LAG configuration:

```
Switch(config)# show interface port-channel <1-4096>

Interface po1
  Hardware is AGGREGATE  Current HW addr: a897.dcde.2503
  Physical:(not set)  Logical:(not set)
  index 100001 metric 1 MTU 9216 Bandwidth 0 Kbit
  Port Mode is access
  <UP,BROADCAST,MULTICAST>
  VRF Binding: Not bound
  Members in this port-channel:
    Ethernet1/1, Ethernet1/2, Ethernet1/3, Ethernet1/4, Ethernet1/5
...
```

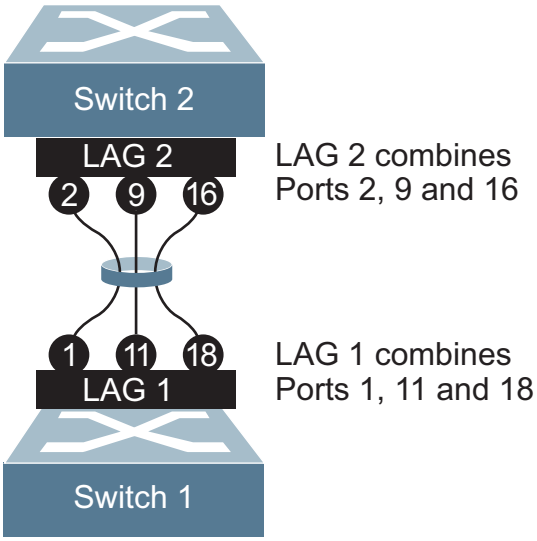
To remove an interface from a LAG, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# no channel-group
```

Static LAG Configuration Example

In the following example, three ports are aggregated between two switches.

Figure 4. LAG Configuration Example



Prior to configuring each switch in this example, you must connect to the appropriate switches as the administrator.

Note: For details about accessing and using any of the commands described in the following example, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

1. On Switch 1:

   a. Add ethernet interfaces 1, 11, and 18 to LAG 1:

```
Switch(config)# interface ethernet 1/1, ethernet 1/11, ethernet 1/18
Switch(config-if-range)# channel-group 1 mode on
Switch(config-if-range)# exit
```

   Note: LAG 1 is automatically created when you assign ethernet interfaces 1, 11, and 18 to it.

   b. Check the configured LAG settings:

```
Switch(config)# show interface port-channel 1
```

2. On Switch 2:

   a. Add ethernet interfaces 2, 9, and 16 to LAG 2:

```
Switch(config)# interface ethernet 1/2, ethernet 1/9, ethernet 1/16
Switch(config-if-range)# channel-group 2 mode on
Switch(config-if-range)# exit
```

   Note: LAG 2 is automatically created when you assign ethernet interfaces 2, 9, and 16 to it.

   b. Check the configured LAG settings:

```
Switch(config)# show interface port-channel 2
```

3. Connect the switch ports that will be members in the LAG.

   LAG 1 on Switch 1 is now connected to LAG 2 on Switch 2.

   Note: In this example, two switches are used. If a third-party device supporting link aggregation is used (such as Cisco routers and switches with EtherChannel technology or Sun's Quad Fast Ethernet Adapter), LAGs on the third-party device must be configured manually. Connection problems could arise when using automatic LAG negotiation on the third-party device.

Link Aggregation Control Protocol

The Link Aggregation Control Protocol (LACP) is an IEEE 802.3ad standard for grouping several physical ports into one logical port (known as a Link Aggregation Group - LAG) with any device that supports the standard. Please refer to IEEE 802.3ad-2002 for a full description of the standard.

The 802.3ad standard allows standard ethernet links to form a single Layer 2 link using Link Aggregation Control Protocol (LACP). Link aggregation is a method of grouping physical link segments of the same media type and speed in full duplex, and treating them as if they were part of a single, logical link segment. If a link in a LACP LAG fails, traffic is reassigned dynamically to the remaining link(s) of the dynamic LAG.

LACP ensures that a local LAG does not attempt to send traffic to a remote single interface. With LAG enabled on the switch, a local LAG can only transmit packets to a remote LAG also configured with LACP.

LACP allows the exchange of aggregation information between the two LAG participants in the form of Link Aggregation Control Protocol Data Units (LACPDUs). If the information is not agreed upon, the LAG will not form.

In comparison with a static LAG, LACP has the following advantages:

- If a physical link fails, LACP will detect the error and remove the link from the aggregate, ensuring packets are not lost due to the failure.
- Both of the participating devices can mutually confirm the LAG configuration. In the case of static link aggregation, configuration errors are often not detected as quickly.

Up to a maximum of 32 physical ports can be configured on a single LACP LAG.

By default, LACP is globally enabled on the switch and it cannot be disabled. However, it can be enabled or disabled for individual interfaces.

Configuring LACP

Before configuring ethernet ports as members of an LACP LAG, you must ensure they meet the same configuration requirements (such as switch port mode or VLAN membership) as specified for static LAGs. For more details, see page 278.

To include a physical port in a LACP LAG, you must add the port to the desired LAG and specify its channel mode. You can configure a port with the following channel modes:

- on - configures the port as part of a static LAG without an aggregation protocol
- active - enables LACP on the interface and configures the port as an active member of the LACP negotiation that starts the negotiations by sending LACP packets to other ports
- passive - configures the port as a passive member of the LACP negotiation that only responds to received LACP packets from ports in the active state

Note: LACP is enabled on ports configured in the passive state only when an active LACP device is detected at the other end of the physical link.

A port in LACP active state will be able to form a LAG with another port that is either in the active or passive state. A port in LACP passive state will form a LAG with another port only if that port is in the active state.

Note: Two ports in LACP passive state will not form a LAG, because neither will start the negotiation process.

An interface configured as a static LAG member does not participate in LACP traffic. Thus, when a LACP active port tries to negotiate with that interface, it will not receive any reply and will become an individual link with the interface.

To configure an interface as a LACP LAG member, use the following command to add that interface to the desired LAG and specify its LACP state:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# channel-group <1-4096> mode {active|passive}
```

To remove an interface from a LACP LAG, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# no channel-group
```

System Priority

A switch running LACP has an assigned system priority. LACP uses the configured system priority with the switch's MAC address to generate a LACP system ID.

The system priority is also used during negotiations with other devices. The switch with the lowest configured system priority determines which physical ports participate in the LACP aggregation. If both switches have the same system priority, the LACP system ID is used to determine the controlling device.

To configure the switch LACP system priority, use the following command:

```
Switch(config)# lacp system-priority <1-65535>
```

By default, the system priority has a value of 32768. To reset the switch's system priority to the default value, use the following command:

```
Switch(config)# no lacp system-priority
```

Port Priority

Each physical interface that is a member of an LACP LAG has an assigned port priority. LACP uses the configured port priority with the port number to form the LACP port ID.

To configure the port priority of an interface, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# lacp port-priority <1-65535>
```

By default, the port priority of an interface is 32768. To reset the port priority to its default value, use the following command:

```
Switch(config-if)# no lacp port-priority
```

LACP Timeout

An interface that is a member of a LACP LAG will send LACPDUs at a regular interval. After not receiving any response to three consecutive LACPDUs, the link is timed out and the state of the interface transitions to individual. Interfaces in the individual or suspended state will function as normal physical ports.

You can configure a short or a long timeout interval. A short timeout interval is equal to three seconds, meaning that LACPDUs are sent every second. A long timeout interval has a value of 90 seconds, with LACPDUs being sent every 30 seconds.

To configure the timeout interval of an interface, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# lacp timeout {short|long}
```

By default, LACP uses a long timeout interval. To reset an interface LACP timeout interval to this value, use the following command:

```
Switch(config-if)# no lacp timeout
```

LACP Individual

A port with LACP enabled (active or passive) that cannot join a LACP LAG has its state changed to individual and is able to form an individual link. This can be useful when a LACP enabled port is connected to port with LACP disabled or when two LACP enabled ports are both in the passive state. In such scenarios, LACP individual helps avoid the loss of traffic.

By default, LACP enabled ports transition to suspend. This behavior cannot be globally changed on the switch. However, it can be enabled or disabled on LAGs.

Note: LACP individual can only be enabled or disabled on LACP enabled port aggregations. Static LAGs member are unaffected.

Although, this behavior is helpful in preventing traffic loss, it can cause problems by permitting loops to be created by mismatching port configurations.

Ports with LACP enabled can be configured to transition to the suspended state instead of individual. Ports in the suspended state are not able to process traffic.

To configure a LACP enabled interface to transition to the individual state after it times out, use the following commands:

```
Switch(config)# interface port-channel <1-4096>
Switch(config-if)# no lacp suspend-individual
```

To configure an LACP enabled interface to transition to suspended state after it times out, use the following commands:

```
Switch(config-if)# lacp suspend-individual
```

Note: LACP individual can only be configured for LAGs. When the LACP individual configuration is changed, it applies the modification to all member ports.

Note: When upgrading the firmware to CNOS 10.9 from 10.7 or an earlier version, the following LACP behavior occurs:

- For Link Aggregation Groups (LAGs) with default configuration, before the upgrade, LACP enabled ports transition to individual state when not receiving Link Aggregation Control Protocol Data Units (LACPDUs). After the firmware upgrade, the LACP configuration remains the same, but LACP enabled ports now transition to suspended state when no LACPDUs are received.

  To configure the LACP enabled ports as individual, use the following command on a LAG:

```
Switch(config)# interface port-channel <LAG number (1-4096)>
Switch(config-if)# no lacp suspend-individual
```

- For LAGs with non-default configuration, if before the upgrade LACP enabled ports transition to suspended state when not receiving LACPDUs, then after the firmware upgrade this behavior remains the same. However, the LACP configuration is changed to reflect the new default behavior: the LACP individual setting for LAGs is removed from the switch's running configuration.

LACP Minimum Links

The LACP minimum links feature is used to configure the minimum number of member ports that must be in the link-up state and bundled in the LACP portchannel. You can use this feature to prevent low-bandwidth LACP port channels from becoming active. This feature also causes LACP port channels to become inactive if they have too few active member ports to supply your required minimum bandwidth.

When the number of all link-up and aggregated member ports is less than the LACP minimum links number, those member ports will go into standby state. Interfaces in standby state do not forward data traffic but continue to run the LACP protocol.

To set the number of LACP minimum links, enter:

```
Switch(config-if)# lacp min-links <number of LACP minimum links (1-32)>
```

To reset this feature, enter:

```
Switch(config-if)# no lacp min-links
```

To view the number of minimum links, enter:

```
Switch(config-if)# show lacp min-links [interface port-channel <1-4096>]
```

Notes:

- The LACP min-links number must be equal to or less than the maximum number of physical links in one LAG.
- The LACP minimum links feature can be configured on a LAG, but it will only be active when the LAG is an LACP LAG.

LACP Configuration Example

Use the following procedure to configure LACP for ethernet ports 1, 2, and 3 to participate in link aggregation.

1. Ensure that ethernet ports 1, 2, and 3 have the same port mode settings and are members of the same VLAN (in this example, VLAN 10 is used). Configure the ethernet ports as one of the following:

   - switch access ports:

```
Switch(config)# interface ethernet 1/1-3
Switch(config-if-range)# switchport mode access
Switch(config-if-range)# switchport access vlan 10
Switch(config-if-range)# exit
```

   - switch trunk ports:

```
Switch(config)# interface ethernet 1/1-3
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk native vlan 10
Switch(config-if-range)# switchport trunk allowed vlan 10
Switch(config-if-range)# exit
```

2. Create a LAG (in this example, LAG 1 is used) and ensure that its port mode settings and VLAN membership are the same as the ones configured on ethernet ports 1, 2, and 3. Configure the LAG with one of the following port modes:

   - access port mode:

```
Switch(config)# interface port-channel 1
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan 10
Switch(config-if)# exit
```

   - trunk port mode:

```
Switch(config)# interface port-channel 1
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk native vlan 10
Switch(config-if)# switchport trunk allowed vlan 10
Switch(config-if)# exit
```

3. (Optional) Configure the port priority and timeout of the LAG members:

```
Switch(config)# interface ethernet 1/1-3
Switch(config-if-range)# lacp port-priority <1-65535>
Switch(config-if-range)# lacp timeout {short|long}
Switch(config-if-range)# exit
```

4. (Optional) Configure the LACP system priority:

```
Switch(config)# lacp system-priority <1-65535>
```

5. Configure the ports as members of LAG 1 and set them in LACP active mode:

```
Switch(config)# interface ethernet 1/1-3
Switch(config-if-range)# channel-group 1 mode active
Switch(config-if-range)# exit
```

LAG Hashing

Traffic in a LAG is statistically distributed among member ports using a hash process where various address and attribute bits from each transmitted frame are recombined to specify the particular LAG physical port the frame will use.

LAG hashing can be only configured globally on the switch, thus affecting all existing LAGs.

Note: LAG hashing is enabled by default on the switch and cannot be disabled.

The switch uses RTAG7 as its hashing method. It offers different information options from which to choose the parameters used to calculate the hash value. To achieve the most even traffic distribution, configure options that exhibit a wide range of values for your specific network. Avoid hashing on information that is not usually present in the expected traffic or which does not vary.

The switch can use the following packet information options to calculate the hash value for traffic balancing:

- Packet ingress physical interface
- Layer 2 information:
  - destination MAC address
  - source MAC address
  - source and destination MAC addresses
- Layer 3 information:
  - destination IP address
  - source IP address
  - source and destination IP addresses
- Layer 4 information:
  - destination port number
  - source port number
  - source and destination port numbers

Notes:

- All packet information options are mutually exclusive when calculating the hash value. Only one of these options can be selected.
- The packet ingress physical interface can also be used in combination with of the above options to calculate the hash value.

When the hash value is calculated using Layer 3 or Layer 4 packet information, the associated Layer 2 is also applied to non-IP protocol traffic. Table 25 presents the applied hashing criteria associated with every hashing configuration:

Table 25. *Hashing Criteria*

Hash configuration	Layer 2 Criteria	Layer 3 Criteria	Layer 3 Criteria
destination MAC	destination MAC	destination MAC	destination MAC
source MAC	source MAC	source MAC	source MAC
source and destination MAC	source and destination MAC	source and destination MAC	source and destination MAC
destination IP	destination MAC	destination IP	destination IP
source IP	source MAC	source IP	source IP
source and destination IP	source and destination MAC	source and destination IP	source and destination IP
destination port	destination MAC	destination IP	destination IP, destination port
source port	source MAC	source IP	source IP, source port
source and destination port	source and destination MAC	source and destination IP	source and destination IP, source and destination port

By default, the hash value is calculated using the source and destination IP addresses. This means that for Layer 3 or Layer 4 packets the hash value is calculated using the source and destination IP addresses, and for Layer 2 packets the hash value is calculated using the source and destination MAC addresses.

To check the current LAG hash configuration, use the following command:

```
Switch> show port-channel load-balance

port-channel Load-Balancing Configuration:
System: source-dest-ip

port-channel Load-Balancing Addresses Used Per-Protocol:
Non-IP: source-dest-mac
IP: source-dest-ip
```

LAG Hashing Configuration

To configure what packet information options are used to calculate the hash value, use the following command:

```
Switch(config)# port-channel load-balance ethernet <hash method>

Switch(config)# port-channel load-balance ethernet ?
  destination-ip    Load distribution on the destination IP address
  destination-mac   Load distribution on the destination MAC address
  destination-port  Load distribution on the destination TCP/UDP port
  source-dest-ip    Load distribution on the source and destination IP
                    address
  source-dest-mac   Load distribution on the source and destination MAC
                    address
  source-dest-port  Load distribution on the source and destination
                    TCP/UDP port
  source-interface  Load distribution on the source ethernet interface
  source-ip         Load distribution on the source IP address
  source-mac        Load distribution on the source MAC address
  source-port       Load distribution on the source TCP/UDP port
```

For more details about this command, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9.*

To reset the hashing method to its default settings, use the following command:

```
Switch(config)# no port-channel load-balance ethernet
```

To view the LAG hash value, use the following command:

```
Switch> show port-channel load-balance forwarding-path interface
port-channel <1-4096> <hash parameters>

Switch> show port-channel load-balance forwarding-path interface
port-channel 1 ?
  src-interface  Optional source interface (physical switch port only)
  dst-mac        Destination MAC Address
  src-mac        Source MAC Address
  dst-ip         Destination IP Address
  src-ip         Source IP Address
  dst-ipv6       Destination IPV6 Address
  src-ipv6       Source IPV6 Address
  l4-dst-port    Destination Port
  l4-src-port    Source Port
```

For more details about this command, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9.*

The *hash parameters* include the following:

- Packet ingress physical interface
- source and destination MAC addresses
- source and destination IPv4 or IPv6 addresses
- source and destination port numbers

The hash parameters used to calculate the hashing value are decided by the LAG hashing configuration and the traffic type. If there is IP or port information input, then the traffic type is Layer 3 or Layer 4. If there is no such information input, then the traffic type is Layer 2. Any unspecified hash parameters are substituted with 0.

For example, if the LAG hashing configuration is source and destination IP addresses, and IP information is contained in the input, then the Layer 2 and Layer 4 information is ignored when calculating the hash value.

```
Switch> show port-channel load-balance forwarding-path interface
port-channel <1-4096> dst-ip 10.158.70.96 src-ip 10.169.2.36 src-mac
78AA.F560.EF0F l4-src-port 14255 l4-dst-port 16874

Missing params will be substituted by 0's.
Load-balance Algorithm on switch: source-dest-ip
Outgoing port id: Ethernet 1/1

Param(s) used to calculate load balance:
destination-ip: 10.158.70.96
source-ip: 10.169.2.36
```

If the LAG hashing configuration is source and destination IP addresses, and no IP information is contained in the input, then the default IPv4 address (0.0.0.0) is used when calculating the hash value:

```
Switch> show port-channel load-balance forwarding-path interface
port-channel <1-4096> src-mac 78AA.F560.EF0F l4-src-port 14255 l4-dst-port
16874

Missing params will be substituted by 0's.
Load-balance Algorithm on switch: source-dest-ip
Outgoing port id: Ethernet 1/1

Param(s) used to calculate load balance:
destination-ip: 0.0.0.0
source-ip: 0.0.0.0
```

Chapter 12. Spanning Tree Protocol

When multiple paths exist between two points on a network, Spanning Tree Protocol (STP) or one of its enhanced variants ensure that the switch uses the most efficient network path.

Lenovo Cloud Network Operating System supports Multiple Spanning Tree Protocol (MSTP) and Rapid Per VLAN Spanning Tree Plus (Rapid PVST+).

IEEE 802.1D (2004), Rapid Spanning Tree Protocol (RSTP), allows devices to detect and eliminate logical loops in a bridged or switched network. When multiple paths exist, STP configures the network so only the most efficient path is used. If that path fails, STP automatically configures the best alternative active path on the network to sustain network operations. RSTP is an enhanced version of IEEE 802.1D (1998) STP, providing more rapid convergence of the Spanning Tree network path states on STG 1.

Rapid Per VLAN Spanning Tree Plus (Rapid PVST+) is based on RSTP to provide rapid Spanning Tree convergence, but supports multiple spanning tree instances, allowing one Spanning Tree Group (STG) per VLAN.

Based on IEEE 802.1Q (2005), the Multiple Spanning Tree Protocol (MSTP) provides both rapid convergence and load balancing in a VLAN environment. MSTP allows multiple STGs, with multiple VLANs in each.

This chapter covers the following topics:

STP Overview

The Spanning Tree Protocol (STP) builds a logical loop-free network topology. The primary function of STP is to prevent bridge loops from being created. Bridge loops occur when there are more than a single Layer 2 path between two endpoints. For example, two switch ports are connected to each other, or two switches have multiple connections between them. While having multiple redundant connection improves network availability, these connections can create bridge loops, that generate broadcast storms and reduce network performance.

STP creates a spanning tree in the network of Layer 2 connected bridges. It disables the links that are not part of the spanning tree, leaving a single active path between any two connected endpoints.

In Rapid PVST+, the switch can be configured with up to a maximum of 500 VLANs. The operational behavior of the switch depends on the maximum number of interfaces on the VLANs.

By default, STP is globally enabled on the switch, running Rapid PVST+. To disable it, use the following command:

```
Switch(config)# spanning-tree mode disable
```

To enable STP or change the STP mode between Rapid PVST+ or MSTP, use the following command:

```
Switch(config)# spanning-tree mode {mst|rapid-pvst}
```

To reset the STP mode to the default value, use the following command:

```
Switch(config)# no spanning-tree mode
```

To display STP information, use the following command:

```
Switch> show spanning-tree
```

To enable or disable STP on a switch ethernet port or Link Aggregation Group (LAG), use the following commands:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree {enable|disable}
```

```
Switch(config)# interface port-channel <1-4096>
Switch(config-if)# spanning-tree {enable|disable}
```

To display STP information for a specified switch ethernet port or Link Aggregation Group (LAG), use the following command:

```
Switch> show spanning-tree interface {ethernet <chassis number/port number>|
|port-channel <1-4096>}
```

Bridge Protocol Data Units

To create a Spanning Tree, the switch generates a configuration Bridge Protocol Data Unit (BPDU), which it then forwards out of its ports. All switches in the Layer 2 network participating in the Spanning Tree gather information about other switches in the network through an exchange of BPDUs.

A bridge sends BPDU packets at a configurable regular interval (2 seconds by default). The BPDU is used to establish a path, much like a hello packet in IP routing. BPDUs contain information about the transmitting bridge and its ports, including bridge MAC addresses, bridge priority, port priority and path cost.

The generic action of a switch on receiving a BPDU is to compare the received BPDU to its own BPDU that it will transmit. If the priority of the received BPDU is better than its own priority, it will replace its BPDU with the received BPDU. Then, the switch adds its own bridge ID number and increments the path cost of the BPDU. The switch uses this information to block any necessary ports.

Note: If STP is globally disabled, BPDUs from external devices will transit the switch transparently. If STP is globally enabled, for ports where STP is turned off, inbound BPDUs will instead be discarded.

Determining the Path for Forwarding BPDUs

When determining which port to use for forwarding and which port to block, the switch uses information in the BPDU, including each bridge ID. A technique based on the "lowest root cost" is then computed to determine the most efficient path for forwarding.

BPDU Guard

The BPDU Guard will put a switch interface into the shut down (error disabled) state when a BPDU is received on that interface. The administrator can manually put the interface in the up state or, if Error Disable Recovery is enabled, it will automatically bring the interface up (for more information, see "Error Disable Recovery" on page 299).

Note: BPDU Guard will function even when STP is disabled. However, it will not work when BPDU Filter is also enabled.

By default, BPDU Guard is disabled. You can enable it on each of the switch interfaces by using the following command:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree bpduguard enable
```

To disable BDPU Guard on an interface, use the following command:

```
Switch(config-if)# spanning-tree bpduguard disable
```

To reset the BPDU Guard to its default configuration, use the following command:

```
Switch(config-if)# no spanning-tree bpduguard
```

BPDU Filter

The BPDU Filter prevents the transmission or reception of BPDUs on a switch interface.

Notes:

- When the BPDU Filter is enabled on an interface, the BPDU Guard will not function, because all BPDUs will be dropped by the switch.
- BPDU Filter will function even when STP is disabled.

By default, BPDU Filter is disabled. You can enable it on each of the switch interfaces by using the following command:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree bpdufilter enable
```

To disable BDPU Filter on an interface, use the following command:

```
Switch(config-if)# spanning-tree bpdufilter disable
```

To reset the BPDU Filter to its default configuration, use the following command:

```
Switch(config-if)# no spanning-tree bpdufilter
```

Root Guard

The root guard feature provides a way to enforce the root bridge placement in the network. It keeps a new device from becoming root and thereby forcing STP re-convergence. If a root-guard enabled port detects a root device, that port will be placed in a blocked state and then automatically recovered.

Note: This differs from BPDU Guard, where the port is blocked and recovered only if Error Disabled Recovery is also enabled, or the port is manually brought back up by an administrator.

To configure the root guard at the port level, use the following commands:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree guard root
```

Note: When you enable root guard on a switch interface, it will disable loop guard, if configured to run on that interface.

To disable the root guard, use the following command:

```
Switch(config-if)# no spanning-tree guard
```

By default, root guard is disabled.

Loop Guard

In general, STP resolves redundant network topologies into loop-free topologies. The loop guard feature performs additional checking to detect loops that might not be found using Spanning Tree. When a port is blocked by STP and it erroneously transitions to the forwarding state, a loop is created in the topology.

Loop guard checks if any BDPUs are received on a non-designated port. If the port doesn't receive any BDPUs, loop guard prevents the port from transitioning into the forwarding state and sends the port into the loop-inconsistent state. In this state, the port is blocked and no traffic is not forwarded. If loop guard is disabled, when the port does not receive BPDUs, it will transition into the forwarding state, thus creating a bridge loop.

To configure the loop guard at the port level, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree guard loop
```

Note: When you enable loop guard on a switch interface, it will disable root guard, if configured to run on that interface.

To disable the loop guard, use the following command:

```
Switch(config-if)# no spanning-tree guard
```

By default, loop guard is disabled.

Port Priority

The port priority helps determine which bridge port becomes the root port or the designated port. The case for the root port is when two switches are connected using a minimum of two links with the same path-cost. The case for the designated port is in a network topology that has multiple bridge ports with the same path-cost connected to a single segment, the port with the lowest port priority becomes the designated port for the segment.

Use the following command to configure the port priority:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree port-priority <0-224>
```

Note: Port priority must be configured in increments of 32 (such as 0, 64, 96, 128 and so on). If the specified port priority value is not evenly divisible by 32, the value will be automatically rejected.

The default port priority is 128. To reset it to its default value, use the following command:

```
Switch(config-if)# no spanning-tree port-priority
```

Port Path Cost

The port path cost assigns lower values to high-bandwidth ports, such as 10 Gigabit Ethernet, to encourage their use. The objective is to use the fastest links so that the route with the lowest cost is chosen. A value of `auto` (the default) indicates that the default cost will be computed for an auto-negotiated link or LAG speed.

To globally configure the calculation method for the default path cost, use the following command:

```
Switch(config)# spanning-tree pathcost method <method type>
```

where *method type* is one of the following:

- `long`: 32 bit based values
- `short`: 16 bit based values

Note: When using MSTP mode, the switch uses only the `long` method for calculating path cost.

By default, the switch uses 16 bit based values (`short`) when calculating the default path cost.

To reset the calculation method to the default value, use the following command:

```
Switch(config)# no spanning-tree pathcost method
```

You can also configure the port path cost differently on each interface by using the following command:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree cost {<1-200000000>|auto}
```

By default, the port path cost is automatically calculated based on the ethernet port speed. To reset the port path cost to its default setting, use the following command:

```
Switch(config-if)# no spanning-tree cost
```

Error Disable Recovery

When BPDU Guard is enabled on a switch interface, it will put that interface in the error disabled (shutdown) state when a BPDU is received.

To bring the interface back up, the administrator can manually put it in the up state or he can configure Error Disable Recovery to automatically transition interface from the error disabled state to the up state after a certain time interval.

By default, Error Disable Recovery is disabled on the switch. To enable or disable it, use the following command:

```
Switch(config)# [no] errdisable recovery cause bpduguard
```

By default, Error Disable Recovery will bring the port back up after 300 seconds (five minutes) since it was detected as being in the error disabled state.

To configure the recovery time interval (in seconds), use the following command:

```
Switch(config)# errdisable recovery interval <30-65535>
```

To reset the recovery time interval to its default value, use the following command:

```
Switch(config)# no errdisable recovery interval
```

Port Type and Link Type

The following port and link types are supported by STP.

Edge Port

A port that does not connect to a bridge is called an *edge port*. Since edge ports are assumed to be connected to non-STP devices (such as directly to hosts or servers), they are placed in the forwarding state as soon as the link is up.

Edge ports send BPDUs to connected STP devices like normal STP ports, but do not receive BPDUs. If a port with `edge` enabled does receive a BPDU, it immediately begins working as a normal (non-edge) port, and participates fully in Spanning Tree.

To configure a port as an edge port or as non-edge port, use the following command:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# [no] spanning-tree port type edge
```

Link Type

The link type determines how the port behaves in regard to Multiple Spanning Tree. Use the following command to define the link type for the port:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree link-type <type>
```

where *type* corresponds to the duplex mode of the port, as follows:

- `point-to-point`

  A full-duplex direct link to another device (point-to-point).

- `shared`

  A half-duplex link that is shared by multiple network devices.

- `auto`

  The switch automatically configures the link type.

Note: Any STP port in full-duplex mode can be manually configured as a shared port when connected to a non-STP-aware shared device (such as a typical Layer 2 switch) used to interconnect multiple STP-aware devices.

By default, the selected duplex mode is `auto`.

To reset the duplex mode to its default value, use the following command:

```
Switch(config-if)# no spanning-tree link-type
```

Rapid Per VLAN Spanning Tree Plus

Using STP, network devices detect and eliminate logical loops in a bridged or switched network. When multiple paths exist, the Spanning Tree Protocol (STP) configures the network so that a switch uses only the most efficient path. If that path fails, STP automatically sets up another active path on the network to sustain network operations.

Rapid Per VLAN Spanning Tree Plus (Rapid PVST+) creates a spanning tree topology that is implemented per VLAN. A single instance of STP runs on each configured VLAN where STP was not manually disabled. Each Rapid PVST+ instance on a VLAN has a single root switch. Using Rapid PVST+, spanning trees converge much faster than spanning trees using 802.1D STP. Spanning tree re-configurations can happen in less than a second.

Note: In Rapid PVST+, the switch can be configured with up to a maximum of 500 VLANs. The operational behavior of the switch depends on the maximum number of interfaces on the VLANs.

To configure the switch to use Rapid PVST+, use the following command:

```
Switch(config)# spanning-tree mode rapid-pvst
```

Note: By default, STP is enabled on the switch and runs using Rapid PVST+.

To disable STP on the switch, use the following command:

```
Switch(config)# spanning-tree mode disable
```

Rapid PVST+ is configured for each active VLAN, allowing different spanning tree topologies to be created using different parameters.

To enable or disable Rapid PVST+ on a VLAN, use the following command:

```
Switch(config)# [no] spanning-tree vlan <VLAN ID (1-4093)>
```

Notes:

- Rapid PVST+ cannot be disabled on VLAN 1.
- Rapid PVST+ can be configured on a single VLAN or on a range of VLANs, either in a continuous format (1-10), in a discrete format (3, 5, 90), or a as a combination of the two (1-5, 7, 9-12, 45).
- VLAN creation is not allowed if the new VLAN would exceed the limit of STGs.
- If the switch is running in Multiple Spanning Tree Protocol (MSTP) mode and the number of VLANs exceeds the maximum supported number, STP mode cannot be changed to Rapid PVST+.

To display STP information about a VLAN, use the following command:

```
Switch> show spanning-tree vlan <VLAN ID (1-4093)>
```

Rapid PVST+ Parameters

You can configure the following parameters for Rapid PVST+ per VLAN:

- bridge priority
- port priority
- port path cost
- forward delay
- hello timer
- maximum age interval

Bridge Priority

The bridge priority parameter controls which bridge on the network is the STG root bridge. To make one switch become the root bridge, configure the bridge priority lower than all other switches and bridges on your network. The lower the value, the higher the bridge priority. Use the following command to configure the bridge priority per VLAN:

```
Switch(config)# spanning-tree vlan <VLAN ID (1-4093)> priority <0-61440>
```

Note: Priority must be configured in increments of 4096 (such as 0, 4096, 8192, or 12288).

By default, the bridge priority is set to 32768. To reset the bridge priority to its default value, use the following command:

```
Switch(config)# no spanning-tree vlan <VLAN ID (1-4093)> priority
```

Port Priority

The port priority helps determine which bridge port becomes the root port or the designated port. The case for the root port is when two switches are connected using a minimum of two links with the same path-cost. The case for the designated port is in a network topology that has multiple bridge ports with the same path-cost connected to a single segment, the port with the lowest port priority becomes the designated port for the segment.

Use the following command to configure the port priority per VLAN:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree vlan <VLAN ID (1-4093)> port-priority <0-224>
```

Note: Port priority must be configured in increments of 32 (such as 0, 64, 96, or 128). If the specified port priority value is not evenly divisible by 32, the value will be automatically rejected.

The default port priority is 128. To reset it to its default value, use the following command:

```
Switch(config-if)# no spanning-tree vlan <VLAN ID (1-4093)> port-priority
```

Port Path Cost

The port path cost assigns lower values to high-bandwidth ports, such as 10 Gigabit Ethernet, to encourage their use. The objective is to use the fastest links so that the route with the lowest cost is chosen. A value of `auto` (the default) indicates that the default cost will be computed for an auto-negotiated link or LAG speed.

To configure the port path cost differently on each interface, use the following command per VLAN:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree vlan <VLAN ID (1-4093)> cost {<1-200,000,000>|
auto}
```

By default, the port path cost is automatically calculated based on the ethernet port speed. To reset the port path cost to its default setting, use the following command:

```
Switch(config-if)# no spanning-tree vlan <VLAN ID (1-4093)> cost
```

Forward Delay

Forward delay specifies the amount of time that a bridge port has to wait before it changes from the discarding and learning states to the forwarding state.

Use the following command to configure the forward delay (in seconds) per VLAN:

```
Switch(config)# spanning-tree vlan <VLAN ID (1-4093)> forward-time <4-30>
```

By default, the forward delay is 15 seconds. To reset it to its default value, use the following command:

```
Switch(config)# no spanning-tree vlan <VLAN ID (1-4093)> forward-time
```

Hello Timer

The Hello timer specifies how often the bridge transmits a configuration BPDU. Any bridge that is not the root bridge uses the root bridge hello timer value.

Use the following command to configure the hello timer (in seconds) per VLAN:

```
Switch(config)# spanning-tree vlan <VLAN ID (1-4093)> hello-time <1-10>
```

By default, the hello timer is 2 seconds. To reset it to its default value, use the following command:

```
Switch(config)# no spanning-tree vlan <VLAN ID (1-4093)> hello-time
```

Maximum Age Interval

The maximum age interval specifies the maximum time the bridge waits without receiving a configuration BPDU before it reconfigures the spanning tree topology.

Use the following command to configure the maximum age interval (in seconds) per VLAN:

```
Switch(config)# spanning-tree vlan <VLAN ID (1-4093)> max-age <6-40>
```

By default, the maximum age interval is 20 seconds. To reset it to its default value, use the following command:

```
Switch(config)# no spanning-tree vlan <VLAN ID (1-4093)> max-age
```

Rapid PVST+ Configuration

The following is an example of configuring Rapid PVST+ on the switch. In this example there are two different STP configurations for two different VLAN ranges.

1. Configure port and VLAN membership on the switch.
2. Configure the switch to use Rapid PVST+:

```
Switch(config)# spanning-tree mode rapid-pvst
```

3. Configure the Rapid PVST+ parameters based on VLAN:

```
Switch(config)# spanning-tree vlan 1-10 priority 4096
Switch(config)# spanning-tree vlan 1-10 forward-time 5
Switch(config)# spanning-tree vlan 1-10 hello-time 3
Switch(config)# spanning-tree vlan 1-10 max-age 10

Switch(config)# spanning-tree vlan 11-20 priority 8192
Switch(config)# spanning-tree vlan 11-20 forward-time 10
Switch(config)# spanning-tree vlan 11-20 hello-time 5
Switch(config)# spanning-tree vlan 11-20 max-age 50
```

4. Configure the port parameters:

```
Switch(config)# interface ethernet 1/1-10
Switch(config-if)# spanning-tree vlan 1-10 port-priority 32
Switch(config-if)# spanning-tree vlan 1-10 cost 2300
Switch(config-if)# exit
Switch(config)#

Switch(config)# interface ethernet 1/11-20
Switch(config-if)# spanning-tree vlan 11-20 port-priority 96
Switch(config-if)# spanning-tree vlan 11-20 cost 15000
Switch(config-if)# exit
```

5. Verify the Rapid PVST+ configuration:

```
Switch# show spanning-tree vlan 1-20
```

Multiple Spanning Tree Protocol

Multiple Spanning Tree Protocol (MSTP) extends Rapid Spanning Tree Protocol (RSTP), allowing multiple Spanning Tree Groups (STGs) that may each include multiple VLANs. MSTP was originally defined in IEEE 802.1s (2002) and was later included in IEEE 802.1Q (2005).

In MSTP mode, the switch supports up to 64 instances of Spanning Tree, corresponding to STGs 1-64, with each STG acting as an independent, simultaneous instance of RSTP.

MSTP allows frames assigned to different VLANs to follow separate paths, with each path based on an independent Spanning Tree instance. This approach provides multiple forwarding paths for data traffic, thereby enabling load-balancing, and reducing the number of Spanning Tree instances required to support a large number of VLANs.

Due to Spanning Tree's sequence of discarding, learning, and forwarding, lengthy delays may occur while paths are being resolved. Ports defined as *edge* ports ("Port Type and Link Type" on page 300) bypass the Discarding and Learning states, and enter directly into the Forwarding state.

Note: By default, STP is enabled on the switch and runs using Rapid PVST+.

MSTP can be enabled by specifying the STP mode:

```
Switch(config)# spanning-tree mode mst
```

To display MSTP information, use the following command:

```
Switch> show spanning-tree mst <0-64>
```

Common Internal Spanning Tree

The Common Internal Spanning Tree (CIST) or MST0 provides a common form of Spanning Tree Protocol, with one Spanning-Tree instance that can be used throughout the MSTP region. CIST allows the switch to interoperate with legacy equipment, including devices that run IEEE 802.1D (1998) STP.

CIST allows the MSTP region to act as a virtual bridge to other bridges outside of the region, and provides a single Spanning-Tree instance to interact with them.

Port States

The port state controls the forwarding and learning processes of Spanning Tree. In MSTP, the port state has been consolidated to the following: `discarding`, `learning`, and `forwarding`.

Due to the sequence involved in these STP states, considerable delays may occur while paths are being resolved. To mitigate delays, ports defined as *edge* ports ("Port Type and Link Type" on page 300) may bypass the `discarding` and `learning` states and enter directly into the `forwarding` state.

MST Region

A group of interconnected bridges that share the same attributes is called an MST region. Each bridge within the region must share the following attributes:

- Region name (up to a maximum of 32 alphanumeric characters)
- Revision number
- VLAN-to STG mapping scheme

MSTP provides rapid re-configuration, scalability, and control due to the support of regions and multiple Spanning Tree instances support within each region.

To enter the MST Region Configuration mode, use the following command:

```
Switch(config)# spanning-tree mst configuration
Switch(config-mst)#
```

To assign a name to the MST region, use the following command:

```
Switch(config-mst)# name <region name>
```

To assign a revision number to the MST region, use the following command:

```
Switch(config-mst)# revision <0-65535>
```

By default, the MST region revision number is 0.

The administrator may manually assign VLANs to specific MSTIs (Multiple Spanning Tree instances).

1. If no VLANs exist (other than default VLAN 1), see "Creating a VLAN" on page 230 for information about creating VLANs and assigning ports to them.
2. Assign the VLAN to a MSTI using the following command:

```
Switch(config)# spanning-tree mst configuration
Switch(config-mst)# instance <0-64> vlan <VLAN ID (1-4093)>
```

MSTP Parameters

You can configure the following parameters for MSTP per MST instance:

- hop count
- forward delay
- hello timer
- maximum age interval
- bridge priority
- port priority
- port path cost

Hop Count

To compute the STP topology inside the MST region, the protocol uses, along with the path cost to the root, a hop-count system similar to the IP time-to-live (TTL) mechanism.

Use the following command to configure the maximum number of hops inside the region:

```
Switch(config)# spanning-tree mst max-hops <1-255>
```

By default, the maximum number of hops is 20. To reset it to its default value, use the following command:

```
Switch(config)# no spanning-tree mst max-hops
```

Forward Delay

Forward delay specifies the amount of time that a bridge port has to wait before it changes from the discarding and learning states to the forwarding state.

Use the following command to configure the forward delay (in seconds):

```
Switch(config)# spanning-tree mst forward-time <4-30>
```

By default, the forward delay is 15 seconds. To reset it to its default value, use the following command:

```
Switch(config)# no spanning-tree mst forward-time
```

Hello Timer

The Hello timer specifies how often the bridge transmits a configuration BPDU. Any bridge that is not the root bridge uses the root bridge hello timer value.

Use the following command to configure the hello timer (in seconds):

```
Switch(config)# spanning-tree mst hello-time <1-10>
```

By default, the hello timer is 2 seconds. To reset it to its default value, use the following command:

```
Switch(config)# no spanning-tree mst hello-time
```

Maximum Age Interval

The maximum age interval specifies the maximum time the bridge waits without receiving a configuration BPDU before it reconfigures the spanning tree topology.

Use the following command to configure the maximum age interval (in seconds):

```
Switch(config)# spanning-tree mst max-age <6-40>
```

By default, the maximum age interval is 20 seconds. To reset it to its default value, use the following command:

```
Switch(config)# no spanning-tree mst max-age
```

Bridge Priority

The bridge priority parameter controls which bridge on the network is the STG root bridge. To make one switch become the root bridge, configure the bridge priority lower than all other switches and bridges on your network. The lower the value, the higher the bridge priority. Use the following command to configure the bridge priority:

```
Switch(config)# spanning-tree mst <0-64> priority <0-61440>
```

Note: Priority must be configured in increments of 4096 (such as 0, 4096, 8192, or 12288).

By default, the bridge priority is set to 32768. To reset the bridge priority to its default value, use the following command:

```
Switch(config)# no spanning-tree mst <0-64> priority
```

Port Priority

The port priority helps determine which bridge port becomes the root port or the designated port. The case for the root port is when two switches are connected using a minimum of two links with the same path-cost. The case for the designated port is in a network topology that has multiple bridge ports with the same path-cost connected to a single segment, the port with the lowest port priority becomes the designated port for the segment.

Use the following command to configure the port priority per MST instance:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree mst <0-64> port-priority <0-224>
```

Note: Port priority must be configured in increments of 32 (such as 0, 64, 96, or 128). If the specified port priority value is not evenly divisible by 32, the value will be automatically rejected.

The default port priority is 128. To reset it to its default value, use the following command:

```
Switch(config-if)# no spanning-tree mst <0-64> port-priority
```

Port Path Cost

The port path cost assigns lower values to high-bandwidth ports, such as 10 Gigabit Ethernet, to encourage their use. The objective is to use the fastest links so that the route with the lowest cost is chosen. A value of `auto` (the default) indicates that the default cost will be computed for an auto-negotiated link or LAG speed.

To configure the port path cost differently on each interface, use the following command per MST instance:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# spanning-tree mst <0-64> cost {<1-200,000,000>|auto}
```

Note: The maximum configurable port path cost depends on the path cost calculation method used. If the switch uses the `short` method type, then port path cost can range from *1* to *65,535*. If the switch uses the `long` method type, then port path cost can range from *1* to *200,000,000*.

By default, the port path cost is automatically calculated based on the ethernet port speed. To reset the port path cost to its default setting, use the following command:

```
Switch(config-if)# no spanning-tree mst <0-64> cost
```

MSTP Configuration

Note the following when configuring Multiple Spanning Tree Groups:

- You may configure up to 64 MST instances and 4094 VLANs.
- Switches must have the same MST configuration identification elements (name, revision number and VLAN to MSTI mapping) to be in the same MST region.
- MST regions appear as virtual bridges connecting to single spanning trees.
- When you enable MSTP, a default revision number of 0 and a blank region name are automatically configured.
- The switch supports a single instance of the MSTP Algorithm consisting of the CIST and up to 64 MSTIs.
- A VLAN can only be mapped to one MST instance or to the CIST. One VLAN mapped to multiple spanning trees is not allowed. All the VLANs are mapped to the CIST by default. Once a VLAN is mapped to a specified MST instance, it is removed from the CIST.

MSTP Configuration Example

This section provides steps to configure MSTP on the switch.

1. Configure port and VLAN membership on the switch.
2. Configure the switch to use MSTP:

```
Switch(config)# spanning-tree mode mst
```

3. Configure the Multiple Spanning Tree region parameters:

```
Switch(config)# spanning-tree mst configuration
Switch(config-mst)# name Lenovo
Switch(config-mst)# revision 5
Switch(config-mst)# instance 1 vlan 10
Switch(config-mst)# exit
```

4. Configure bridge priority for instance number 1:

```
Switch(config)# spanning-tree mst 1 priority 4096
```

5. Configure MSTP timers:

```
Switch(config)# spanning-tree mst hello-time 5
Switch(config)# spanning-tree mst max-age 10
Switch(config)# spanning-tree mst forward-time 25
```

6. Configure edge ports:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# spanning-tree port type edge
```

7. Configure BPDU guard:

```
Switch(config-if)# spanning-tree bpduguard enable
Switch(config-if)# exit
```

8. Enable the timeout mechanism for a port to be recovered automatically from being operationally shut down by BPDU:

```
Switch(config)# errdisable recovery cause bpduguard
Switch(config)# errdisable recovery interval 30
```

9. Configure Root Guard:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# spanning-tree guard root
```

10. Enable BPDU filtering:

```
Switch(config-if)# spanning-tree bpdufilter enable
```

11. Configure link type:

```
Switch(config-if)# spanning-tree link-type point-to-point
```

12. Configure path cost value and port priority:

```
Switch(config-if)# spanning-tree cost 10000
Switch(config-if)# spanning-tree port-priority 64
```

Note: To configure these parameters per instance, use the following commands:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# spanning-tree mst 1-10 port-priority 64
Switch(config-if)# spanning-tree mst 1-10 cost 10000
```

13. Configure max hops value:

```
Switch(config)# spanning-tree mst max-hops 20
```

14. Configure path cost method:

```
Switch(config)# spanning-tree pathcost method long
```

15. Verify MSTP configuration:

```
Switch# show spanning-tree mst
```

Chapter 13. Virtual Link Aggregation Groups

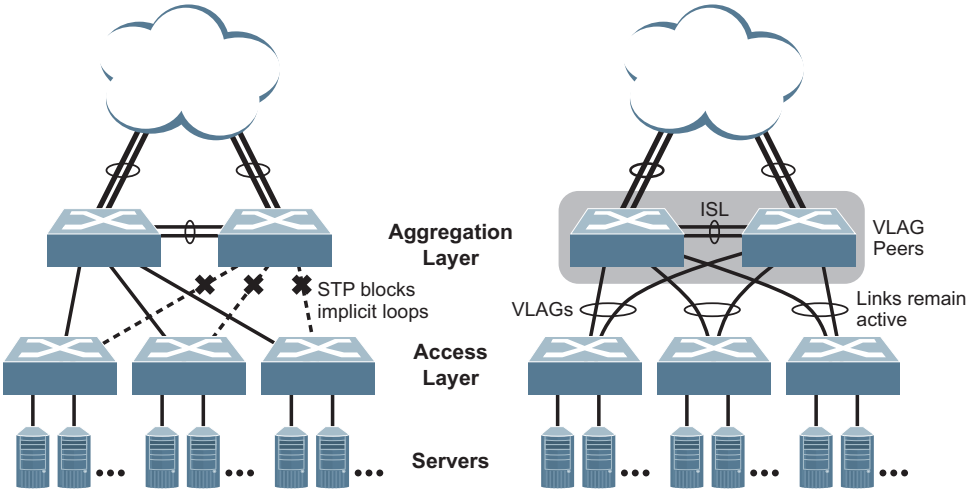
Virtual Link Aggregation Groups (vLAGs) are a mechanism which allows the redundant uplinks to remain active by utilizing all available bandwidth.

This section discusses the following topics:

vLAG Overview

In many data center environments, downstream servers or switches connect to upstream devices which consolidate traffic. For example, see Figure 5.

Figure 5. Typical Data Center Switching Layers with STP versus vLAG



As shown in Figure 5, a switch in the access layer may be connected to more than one switch in the aggregation layer to provide for network redundancy. Typically, Spanning Tree Protocol (STP - see Chapter 12, "Spanning Tree Protocol") is used to prevent broadcast loops, blocking redundant uplink paths. This has the unwanted consequence of reducing the available bandwidth between the layers by as much as 50%. In addition, STP may be slow to resolve topology changes that occur during a link failure and can result in considerable MAC address flooding.

Two switches are paired into vLAG peers and act as a single virtual entity for the purpose of establishing a multi-port aggregation. Ports from both peers can be grouped into a vLAG and connected to the same LAG-capable target device. From the perspective of the target device, the ports connected to the vLAG peers appear to be a single LAG connecting to a single logical device. The target device uses the configured Tier ID to identify the vLAG peers as this single logical device. It is important that you use a unique Tier ID for each vLAG pair you configure. The vLAG-capable switches synchronize their logical view of the access layer port structure and internally prevent implicit loops. The vLAG topology also responds more quickly to link failure and does not result in unnecessary MAC flooding.

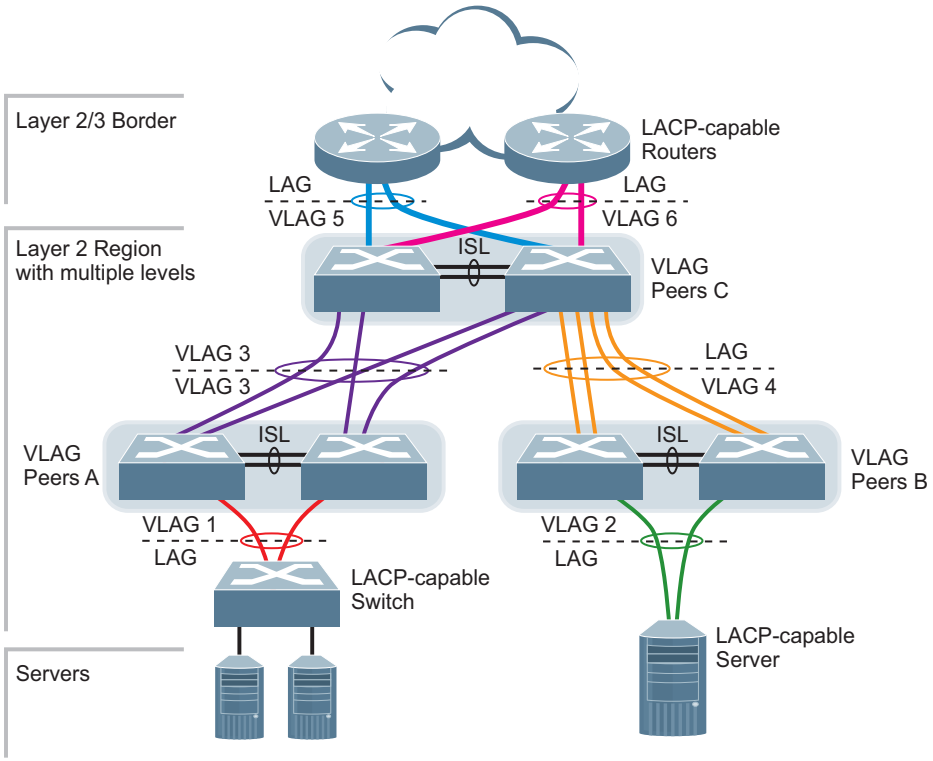
vLAGs also support Layer 2 MultiPathing, which offers redundancy and traffic load balancing across multiple paths between network nodes.

A vLAG can be set up as either a static LAG or an LACP LAG.

We recommend that you deploy vLAG only in a multi-layer network topology such as Leaf-Spine, and not in loop topologies.

vLAGs are useful in multi-layer environments for both uplink and downlink redundancy to any regular LAG-capable device, such as in Figure 6.

Figure 6. vLAG Application with Multiple Layers



Wherever ports from both peered switches are aggregated to another device, the aggregated ports must be configured as a vLAG. For example, vLAGs 1 and 3 must be configured for both vLAG Peer A switches. vLAGs 2 and 4 must be configured for both vLAG Peer B switches. vLAGs 3, 5, and 6 must be configured on both vLAG Peer C switches. Other devices connecting to the vLAG peers are configured using regular static or LACP LAGs.

Note: Do not configure a vLAG for connecting only one switch in the peer set to another device or peer set. For instance, in vLAG Peer C, a regular LAG is employed for the downlink connection to vLAG Peer B because only one of the vLAG Peer C switches is involved.

vLAG Capacities

Servers or switches that connect to the vLAG peers using a multi-port vLAG are considered vLAG clients. vLAG clients are not required to be vLAG-capable. The ports participating in the vLAG are configured as regular LAGs on the vLAG client end.

On the vLAG peers, the vLAGs are configured similarly to regular LAGs, using many of the same features and rules. See Chapter 11, "Ports and Link Aggregation" for general information concerning all port LAGs.

Each vLAG begins as a regular port LAG on each vLAG-peer switch. The vLAG may be either a static LAG or a LACP LAG, and consumes one slot from the overall LAG capacity pool. The LAG type must match that used on vLAG client devices. Additional configuration is then required to implement the vLAG on both vLAG peer switches.

Depending on the switch type, you may configure up to a maximum number of LAGs, with all types (regular or vLAG, static or LACP) sharing the same pool:

- G8272: maximum of 72 LAGs
- G8296: maximum of 96 LAGs
- G8332: maximum of 104 LAGs
- NE1032T: maximum of 32 LAGs
- NE1032: maximum of 32 LAGs
- NE1072T: maximum of 72 LAGs
- NE10032: maximum of 128 LAGs
- NE2572: maximum of 72 LAGs

For the G8272, G8296, G8332, NE1072T, NE10032, and NE2572 the maximum number of supported vLAG instances is 64.

For the NE1032 and NE1032T, the maximum number of supported vLAG instances is 24.

vLAG Benefits

Using vLAGs offers the following benefits:

- Enables a single device to use a LAG across two upstream switches
- STP blocked interfaces are eliminated
- Topology loops are also eliminated
- Enables the use of all available uplink bandwidth
- Allows fast convergence times in case of link or device failure
- Allows link-level resilience
- Enables high availability

vLAG Synchronization Mechanism

All vLAG status and protocol synchronization information is transmitted between vLAG peers using the inter-switch link (ISL) LAG. vLAG uses a Layer 2 transport protocol (Edge Control Protocol or ECP) for communicating across the ISL LAG.

If the transport channel used by ECP for communication stops working, the ISL is marked as down. If vLAG health check detects that the primary switch is still functioning, the ports of the secondary switch that are members of the vLAG instance are shut down (error disabled) to avoid creating loops.

To view information about the ECP transport channel, use the following command:

```
Switch# show vlag ecp channels
```

The state of the transport channel used by ECP is detected periodically by vLAG hello packets. Both vLAG peers send hello packets every 5 seconds. If no hello packets are received for 30 seconds, the channel is marked as down.

ECP is a transport protocol that operates between two peers over an IEEE 802 LAN. ECP provides reliable, in-order delivery of ULPDUs (Upper Layer Protocol Data Units).

To view information about the upper layer protocols associated with ECP, use the following command:

```
Switch# show vlag ecp upper-layer-protocols
```

ECP has the following service characteristics:

- Reliable delivery of ULPDUs, that is resilient against frame loss
- Delivery of ULPDUs to the recipient Upper Layer Protocol (ULP) in the order that they were transmitted by the sending ULP
- Delivery of a single copy of each ULPDU to the recipient
- Flow control that provides protection against buffer overrun on the receiving side

vLAG System MAC

vLAG supports both static LAGs and LACP LAGs. For connections between an access switch and an end host, vLAGs that are configured using LACP LAGs will use a special reserved MAC address called vLAG system MAC.

The vLAG system MAC address is created using the vLAG tier ID. Together with the LACP system priority, the MAC address is used to generate a LACP system ID, which is used during LACP negotiation. For more details about LACP, see "Link Aggregation Control Protocol" on page 282.

vLAG and LACP Individual

LACP enabled physical interfaces that are members of a LAG that do not receive any Link Aggregation Control Protocol Data Units (LACPDUs) after a set amount of time are expelled from the LAG and transition to individual state. Interfaces in the individual state function as normal physical ports. For more details, see "LACP Individual" on page 284.

This behavior can lead to the creation of loops when the vLAG does not connect the switch to an end host. To avoid such scenarios, only LACP LAGs with LACP individual enabled interfaces that are connected to an end device should be added to the vLAG. When you assign an LACP LAG to a vLAG, the switch displays a warning if it detects that the LAG member ports have LACP individual enabled.

```
warning: port-channel 1 with lacp individual enabled is added for VLAG
instance 1
```

Notes:

- The LAG used for the vLAG ISL cannot have LACP individual enabled.
- When the upper layer protocol (for example, STP) is disabled, you must manually ensure that there are no loops.

vLAG and LACP System Priority

To reduce configuration dependency, LACP system priority information is synchronized between the vLAG peers. The secondary switch will use the system priority of the primary switch to reaggregate with the access switch, regardless of its own priority. This ensures that LACP LAG member ports that participate in a vLAG are aggregated in the same LAG on the access switch, even if the LACP system priorities of the primary and secondary switches do not match.

If the secondary switch becomes the primary, it will replace its current LACP system priority with its original value and then reaggregate with the access switch.

FDB Synchronization

To prevent the flooding of unknown unicast packets and offer local preference, the Forwarding Databases (FDB) are synchronized between the vLAG peers.

MAC addresses learned by a switch on its vLAG ports are synchronized across the corresponding vLAG ports of its peer. MAC addresses not learned on vLAG ports are synchronized over the ISL of the vLAG peers.

Note: Up to 32k MACs can be synchronized.

A peer MAC address is added as a static unicast FDB entry across the ISL to avoid unnecessary traffic flooding of the vLAG peer. A peer MAC address also permits Address Resolution Protocol (ARP) entries to be shared across the ISL when FDB learning is disabled after the FDB synchronization process starts, thus allowing Layer 3 traffic to the peer to work properly.

FDB synchronization will start as soon as the first vLAG instance is formed and will stop when the last vLAG instance will be disbanded.

The member ports of the vLAG ISL will disable MAC learning once FDB synchronization starts and enable it once the FDB synchronization stops. This happens regardless of the configured MAC learning settings of the ports prior to the starting of FDB synchronization.

Synchronized MAC entries will not be aged or cleaned by the local switch. When this happens, the MAC entries will be re-installed in the FDB. To avoid certain scenarios where an aged MAC entry is not re-installed fast enough, thus triggering a traffic flood, vLAG uses a timer to periodically check the status of all FDB entries and re-install any MAC addresses that are scheduled for cleaning. For more details, see "FDB Refresh" on page 330.

To get FDB learning and aging callbacks, vLAG uses the FDB interrupt mechanism.

vLAG and STP

The switch supports the Spanning Tree Protocol (STP) running over individual vLAG instances. It supports both STP modes: Rapid PVST+ and MSTP. For more details about STP, see Chapter 12, "Spanning Tree Protocol".

Bridge protocol data units (BPDU) are received by both vLAG peers and are sent only through the link that received the BPDUs from the upstream switches. A BPDU is a data message transmitted across a local area network to detect loops in network topologies. A BPDU contains information regarding ports, switches, port priority, and addresses, which is necessary to configure and maintain the spanning tree topology.

Note: If a vLAG switch with STP enabled is connected to a switch with STP disabled, BPDUs will be flooding back to vLAG switch causing the vLAG port be put into the backup state and discard traffic if there are multiple links.

Both vLAG peers use the vLAG system MAC address as the designated bridge ID on their vLAG member ports. The root bridge ID remains unchanged.

The ISL LAG forwards traffic even if the root bridge is configured on a switch not participating in the vLAG. In this scenario, it is possible that the switch will display two root ports. MSTP will consider the ports that are members of the ISL LAG as such only if the ISL has formed. If the ISL fails, the ports are considered regular ports and may be blocked.

STP will calculate the path cost of non-vLAG ports as normal. For vLAG ports, the protocol assigns a fixed value of 1, regardless of the path cost method used.

For regular LAGs, STP uses a dynamic calculation to determine the path cost of the LAG. This method is based on the path cost of the LAG member ports. When a LAG member's state changes to down, the path cost of the LAG is recalculated.

For LAGs participating in a vLAG, STP uses a fixed path cost value of 1, instead of the dynamic calculation described above. This means that a vLAG has better path preference than a regular single port. However, when a vLAG member's state changes to down, the path cost of the LAG is not recalculated.

The path cost of the LAGs involved in the vLAG can be changed to another value than 1, but this must be manually configured on both vLAG peers. The new path cost must be identical on both primary and secondary switches. When this condition is not met, the results of the STP path cost calculation are incorrect.

To ensure that vLAG works properly with MSTP, the vLAG peers must be part of the same MST region. When this condition is not met, the vLAG ports of the secondary switch will be considered as being disabled (not error disabled) in the MSTP configuration. This will negatively affect traffic flow through the vLAG. Once the vLAG peers are correctly configured as being part of the same MST region, the vLAG ports of the secondary switch will transition to the up state.

BPDU guard and BPDU filter will consider the vLAG as a single link. For example, when the BPDU guard will receive a BPDU packet, the vLAG ports from both vLAG peers will be put in the error disabled state.

As long as one of the vLAG instances running on the vLAG peers has not failed, a vLAG port is visible in the STP configuration, even if the interface is in the administratively down or error disabled state. This means that the status of the vLAG port is not determined by its physical state, but instead by the vLAG. STP considers the vLAG port as being a single logical link and is oblivious if one of the vLAG members fails. STP will mark the vLAG port as being in the down state only if the vLAG link fails on both vLAG peers.

vLAG and VRRP

The switch supports both vLAG and VRRP running simultaneously. To enable vLAG peer switches to function as a gateway, VRRP must be in active-active mode. Both the primary and secondary vLAG switches can forward Layer 3 traffic across the virtual router instance independent of their VRRP state (master or backup virtual router). The backup virtual router will act as a master when the vLAG is formed. For more details about VRRP, see "Virtual Router Redundancy Protocol" on page 577.

Notes:

- Only a maximum of 64 VRRP instances can be configured on a switch that is part of a vLAG.
- The VRRP Advertisement Timer cannot be configured with a time interval below 100 centiseconds (1 second).

vLAG VRRP Passive Mode (Half Active-Active)

In passive mode or half active-active mode, the vLAG backup virtual router checks if its vLAG peer is the master virtual router. If none of the vLAG peer switches is the master virtual router, a Layer 3 routing entry for the VRRP domain will not be installed on the vLAG backup virtual router. Only the master virtual router and its vLAG peer, which is also the backup virtual router, are in the IP active state. The vLAG backup virtual router will install a Layer 3 routing entry. If the master virtual router fails, the newly elected master virtual router and its vLAG peer, that has become the backup virtual router, will transition to the IP active state.

Note: vLAG VRRP passive mode is applicable only in a 4xVRRP configuration, a two vLAGs configuration, or a vLAG multiple tier configuration.

To enable vLAG VRRP passive mode on the switch, use the following command:

```
Switch(config)# no vlag vrrp active
```

vLAG VRRP Active Mode (Full Active-Active)

When the vLAG peer switches are in VRRP active mode or full active-active mode, they are in the IP active state. This means that the vLAG peer switches will install the Layer 3 routing entry regardless of their virtual router role or that their vLAG peer are the master or backup virtual router.

Note: vLAG VRRP active mode is applicable only in a 4xVRRP configuration, a two vLAGs configuration, or a vLAG multiple tier configuration.

By default, vLAG peers function in VRRP active mode. To enable it, use the following command:

```
Switch(config)# vlag vrrp active
```

vLAG LACP Misconfigurations or Cabling Errors

On a single switch, LACP can ensure that only one LAG forms within an aggregation group, despite incorrect configurations or cabling. In a vLAG topology, LACP misconfiguration or erroneous cabling can cause the formation of two LAGs within an aggregation group, thus creating a network loop.

The switch detects such LACP misconfigurations or cabling errors. After detection, vLAG suspends the ports that are part of the vLAG on the secondary switch and a syslog message is generated. Once the misconfiguration or cabling error is corrected, vLAG includes the suspended ports to be part of the LAG.

Any misconfiguration are checked only on the secondary vLAG switch. The vLAG primary switch synchronizes partner information with the secondary switch, followed by a misconfiguration check on the secondary vLAG switch. When a misconfiguration occurs, the following syslog message is generated:

```
LACP port <port name>'s received partner info is mismatch with vLAG
instance <1-64>'s expected one, it will be suspended.
```

Note: On the primary vLAG switch, no misconfiguration syslog messages are displayed.

vLAG Configuration Consistency Check

vLAG operates simultaneously on two different switches that perform as one logical device. If there any incompatible configuration differences between the two vLAG peers, this may lead to undesirable effects, such as traffic loss.

The vLAG Configuration Consistency Check ensures that the network behaves correctly. Using the vLAG synchronization mechanism, vLAG Consistency Check verifies the configurations of the vLAG peers for incompatibilities. Each configuration parameter is classified accordingly with its associated priority and different actions are applied when an incompatibility is detected based upon the parameter's priority.

Whenever a high priority parameter is detected as being inconsistent across vLAG peers, a syslog message with a critical severity level is logged and the following actions are taken:

- if the inconsistent parameter is global or related to the ISL, the Link Aggregation Groups (LAGs) of all the vLAG instances on the vLAG secondary switch are put into the down state
- if the inconsistent parameter is related to the vLAG instance, the LAG associated with that instance is put into the down state

If the detected inconsistency refers to a low priority parameter, by default the switch will only record a syslog message with a warning severity level for that inconsistency. To allow the switch to perform the same actions as when dealing with high priority parameters, strict consistency checking must be manually enabled.

The following table lists the parameters verified during a configuration consistency check:

Table 26. *Configuration Consistency Check Parameters*

Switch Feature	Parameter	Type of parameter	Priority
FDB	Global MAC address learning	Global	high
FDB	MAC address learning per interface	Instance	high
VLAN	Switch port mode	ISL/instance	high
VLAN	Access VLAN	ISL/instance	high
VLAN	Native VLAN	ISL/instance	high
VLAN	Allowed VLAN list	ISL/instance	high
VLAN	Global 802.1Q native VLAN tagging	Global	high
VLAN	802.1Q native VLAN tagging per interface	ISL/instance	high
VLAN	Tag ingress	ISL/instance	high
vLAG	VRRP active	Global	high
vLAG	Peer gateway	Global	high
LACP	Aggregation group type	Instance	high
LACP	Suspend individual	Instance	low
STP	STP mode	Global	high
STP	STP path cost	Global	high
STP	MST region name	Global	high
STP	MST region revision number	Global	high
STP	MST instance to VLAN mapping	Global	high
STP	MST maximum age timer	Global	low

Table 26. *Configuration Consistency Check Parameters (continued)*

Switch Feature	Parameter	Type of parameter	Priority
STP	MST maximum number of hops	Global	low
STP	MST hello timer	Global	low
STP	MST forwarding timer	Global	low
STP	STP port mode	Instance	high
STP	STP port path cost	Instance	high
STP	STP port type	Instance	high
STP	MST port path cost	Instance	high
STP	STP port BPDU filter	Instance	low
STP	STP port BPDU guard	Instance	low
STP	STP port root guard	Instance	low
STP	STP port loop guard	Instance	low
STP	STP link type	Instance	low
STP	STP port priority	Instance	low
STP	MST port priority	Instance	low

By default, configuration consistency checking is enabled on the switch. To function properly, consistency checking must be enabled on both vLAG peers.

To disable configuration consistency checking, use the following command:

```
Switch(config)# vlag config-consistency disable
```

To enable configuration consistency checking, use the following command:

```
Switch(config)# no vlag config-consistency disable
```

By default, strict configuration consistency checking is disabled. To enable or disable strict configuration consistency checking, use the following command:

```
Switch(config)# [no] vlag config-consistency strict
```

vLAG and IGMP Snooping

For more details about IGMP Snooping, see "Internet Group Management Protocol" on page 443.

Multicast Router Synchronization

When the switch receives an IGMP Query message or a Protocol Independent Multicast (PIM) Hello message, it installs an IGMP multicast router. The switch sends a vLAG synchronization message to its vLAG peer, which also installs the new IGMP multicast router. If the switch receives the IGMP Query message or PIM Hello message on a non-vLAG port, the vLAG peer will install the multicast router on the ISL LAG.

IGMP Groups Synchronization

When the switch receives an IGMP Report message, it installs an IGMP group in its IGMP group table. The switch sends a vLAG synchronization message to its vLAG peer, which also installs the new IGMP group. If the switch receives the IGMP Report messages on a non-vLAG port, the vLAG peer will install the IGMP group on the ISL LAG.

When the switch receives an IGMP Leave message, it removes the specified IGMP group from the IGMP group table. The switch sends a vLAG synchronization message to its vLAG peer, which also removes the IGMP group. The IGMP Leave message is forwarded to multicast routers, except those installed on the ISL LAG.

IGMP groups can be statically configured on switch ports that are part of the vLAG or the ISL LAG. The IGMP group configuration must be consistent on both vLAG peer switches.

Note: The same IGMP group cannot simultaneously be dynamically installed or statically configured on the same switch interface if vLAG is enabled on the switch.

IGMP Querier Synchronization

The IGMP Querier can be enable on both vLAG peer switches. The vLAG peers must share the same IP address and have the same IGMP Querier configuration.

After the IGMP Querier election, both vLAG peer switches can act as the Querier at the same time, but only the vLAG primary switch will send IGMP Query messages when the vLAG is in formed state. The *other querier present timer* will be synchronized between the vLAG peers.

When an STP topology change occurs on a switch interface, the vLAG primary switch will initiate General Query messages across all interface/VLAN pairs belonging to the Spanning Tree Group (STG) specified in the Topology Change Notification (TCN) message. If the switch does not receives any replies to the General Query message, the IGMP group entries are deleted from the IGMP group table.

Note: When vLAG and IGMP run together and STP is also enabled on the switch, it is recommended that TCN flood is disabled to avoid IGMP table deletion after the vLAG switches recover from a failure. To disable TCN flood, use the following command:

```
Switch(config)# no ip igmp snooping tcn flood
```

vLAG Peer Gateway

The two vLAG peer switches cannot be used as a gateway for a network route. This occurs because the two switches have different MAC addresses and when traffic reaches the vLAG, it can be sent to either of the two vLAG peers. For example, if a packet that has the Layer 2 destination the MAC address of one vLAG switch is sent to the other switch, the packet will be discarded.

The vLAG Peer Gateway allows a vLAG switch to function as the active gateway for traffic that is addressed to its vLAG peer. It enables the local forwarding of such packets between vLAG peers without using the ISL. This optimizes the use of the ISL and avoids potential traffic loss.

Note: If redirect errors are enabled on the vLAG VLAN inteface and an Internet Control Message Protocol (ICMP) request arrives with a secondary IP (DIP) and a secondary MAC (DMAC) from a vLAG peer switch, the access switch receives duplicate ICMP replies. To avoid this, disable ICMP redirect errors for all vLAG VLANs, on both vLAG switches. For more details on ICMP, see "Internet Control Message Protocol" on page 416.

By default, the vLAG Peer Gateway is disabled. For it to function properly, it must be enabled on both vLAG peers.

To enable or disable the vLAG Peer Gateway, use the following command:

```
Switch(config)# [no] vlag peer-gateway
```

To check the status of the vLAG Peer Gateway, use the following command:

```
Switch> show vlag information
```

vLAGs versus regular LAGs

Though similar to regular LAGs in many regards, vLAGs differ from regular LAGs in the following ways:

- A vLAG can consist of multiple ports on two vLAG peers, which are connected to one logical client device such as a server, switch, or another vLAG device.
- The participating ports on the client device are configured as regular LAG member ports.
- The vLAG peers must be the same model and run the same software version.
- vLAG peers require a dedicated inter-switch link (ISL) for synchronization. The ports used to create the ISL must have the following properties:
  - ISL ports must be configured for all vLAG VLANs
  - ISL ports must be placed into a regular LAG (either static or LACP)
  - A minimum of two ports on each switch are recommended for ISL use
- Dynamic routing protocols, such as OSPF, cannot terminate on vLAGs.
- vLAGs are configured using additional commands.
- It is recommended that end-devices connected to vLAG switches use NICs with dual-homing. This increases traffic efficiency, reduces ISL load, and provides faster link failover.

Configuring vLAGs

It is recommended that any vLAG configuration is done without traffic flowing through the vLAG peers. This can cause FDB flush events, resulting in a delayed stabilization of the vLAG configuration.

Note: The vLAG peers can be reloaded while traffic is flowing, but vLAG configuration changes are not recommended during the switch startup process if vLAG Startup Delay has been enabled on the switch.

When configuring vLAG or making changes to your vLAG configuration, consider the following vLAG behavior:

- When vLAG is enabled, you may see two root ports on the secondary vLAG switch. One of these will be the actual root port for the secondary vLAG switch and the other will be a root port synchronized with the primary vLAG switch.
- The STG to VLAN mapping on both vLAG peers must be identical.

The following parameters must be identically configured on the vLAG ports of both the vLAG peers:

- VLANs
- Native VLAN tagging
- Native VLAN/PVID
- STP mode
- BPDU Guard setting
- STP port setting
- MAC aging timers
- Static MAC entries
- ACL configuration parameters
- QoS configuration parameters

When configuring a vLAG, the participating switches are checked for matching on the following parameters:

- Tier ID - it is used to divide vLAG domains. Different domains cannot be aggregated together.
- System type - both vLAG peers must be the same switch model to reduce the impact of different system performance and capability.
- CNOS version - it is used to avoid vLAG feature compatibility issues.

If the Tier ID or system type do not match, the vLAG will not form. If the peers use different CNOS versions, the vLAG will form, but notification messages will be displayed every 10 seconds, informing you to upgrade to the same CNOS version.

By default, the vLAG feature is disabled.

To enable or disable vLAG, use the following command:

```
Switch(config)# [no] vlag enable
```

vLAG ISL

vLAG uses an Inter-Switch Link (ISL) connection to synchronize information between the two vLAG peers. The ISL is a dedicated regular LAG (static or LACP) that must be formed from at least two physical interfaces.

We recommend that the total bandwidth of the ISL LAG be larger than the total bandwidth of the vLAG ports. When a vLAG port fails, its traffic is forwarded through the ISL LAG.

To configure the LAG used by the ISL, use the following command:

```
Switch(config)# vlag isl port-channel <1-4096>
```

Note: This command also triggers the forming of the ISL between the vLAG peers.

To delete the vLAG ISL, use the following command:

```
Switch(config)# no vlag isl port-channel
```

vLAG Role Election

For a centralized vLAG operation, vLAG assigns a role to each of the two switches participating in the vLAG: primary and secondary. The primary switch controls the centralized operation.

Each vLAG role is determined by comparing the local vLAG priorities and MAC addresses of the participating switches. The switch with the lower priority will become the primary. If the switches are configured with identical priorities, the switch with the smaller MAC address will be elected as the primary.

The vLAG role election is not preemptive. If a switch is already elected as the primary, another switch that joins the vLAG will become the secondary and remain in that role even if its priority or MAC address are smaller than those of the primary switch.

To configure the vLAG priority of a switch, use the following command:

```
Switch(config)# vlag priority <0-65535>
```

By default, the switch has a vLAG priority of 0. To reset the priority to the default value, use the following command:

```
Switch(config)# no vlag priority
```

vLAG Instance

vLAGs are configured using an instance ID. The instance ID is used to identify which LAGs are connected to downstream devices as a vLAG. A single vLAG instance can group LAGs with different IDs on the vLAG peers. For example, vLAG instance 1 can bind LAG 1 from the primary vLAG peer with LAG 6 from the secondary vLAG peer.

The instance ID must be the same for both vLAG peers.

The maximum number of configurable vLAG instances is 64.

When creating a vLAG, you must also assign a LAG to it. To create a vLAG instance, use the following command:

```
Switch(config)# vlag instance <1-64> port-channel <1-4096>
```

Note: Only one LAG can be assigned to a vLAG on a single switch.

By default, vLAG instances are disabled. To enable or disable a vLAG instance, use the following command:

```
Switch(config)# [no] vlag instance <1-64> enable
```

To remove the associated LAG from the vLAG instance, use the following command:

```
Switch(config)# no vlag instance <1-64> port-channel
```

Note: When removing the assigned LAG from an enabled vLAG instance, the instance will also be disabled.

To remove a vLAG instance, use the following command:

```
Switch(config)# no vlag instance <1-64>
```

vLAG formation depends on the state of the two participating LAGs (local and remote). The possible states of the vLAG are:

- DOWN - both the local and remote LAGs are in the down state
- LOCAL_UP - only the local LAG is in the up state
- REMOTE_UP - only the remote LAG is in the up state
- FORMED - both the local and remote LAGs are in the up state

Note: If the ISL is in the down state, vLAG synchronization is not possible and the remote vLAG will be treated as being in the down state regardless of its real state.

FDB Refresh

vLAG uses a timer (FDB refresh interval) to periodically check the status of synchronized FDB entries. If a MAC address is detected as waiting to be removed from the FDB, the address will instead be re-installed in the FDB.

The FDB refresh interval is shorter than the MAC aging time, which can be configured by using the following command:

```
Switch(config)# mac address-table aging-time <0-1000000 seconds>
```

By default, FDB refresh is enabled. To enable or disable FDB refresh, use the following command:

```
Switch(config)# [no] vlag mac-address-table refresh
```

Note: If MAC aging time is configured below 40 seconds, FDB refresh will not work regardless if it is enabled or not on the switch.

vLAG Tier ID

vLAG uses a Tier Identifier to separate different vLAG domains. This is helpful when configuring multiple vLAGs in a multi-tier network environment, because vLAG domains with different configured tier IDs cannot be aggregated together.

To configure the tier ID of a vLAG, use the following command:

```
Switch(config)# vlag tier-id <1-512>
```

To remove a vLAG's tier ID, use the following command:

```
Switch(config)# no vlag tier-id
```

vLAG Startup Delay

A startup delay is used to prevent traffic loss while a vLAG peer reloads. During the reload process, a switch's vLAG ports are in the error disabled state. Once the ISL is established, the vLAG ports transition to the up state one at a time only after the configured startup delay has passed.

The startup delay is initiated only after the ISL is established. Until this timer has expired, all vLAG ports will be maintained in the error disabled state. This delay will allow the switch to properly initiate BGP or OSPF for routing traffic through the upstream links. This ensures that traffic will flow smoothly once the vLAG ports are up.

Any vLAG ports configured in the administrative up or down state will retain their state after the startup delay has passed. During the delay, their status is error disabled.

During the startup delay interval, administratively up ports that become members of the vLAG instance will be error disabled and administratively up ports that leave the vLAG instance will transition back to the up state.

Any vLAG ports that are configured in the administrative up state during the startup delay are immediately put in the error disabled state until the delay interval expires.

Note: vLAG configuration changes are not recommended during the reload process of a vLAG peer on which the startup delay timer has not expired.

To configure the startup delay, in seconds, use the following command:

```
Switch(config)# vlag startup-delay <0-3600>
```

By default, the startup delay is 120 seconds (2 minutes). To reset the interval to its default value, use the following command:

```
Switch(config)# no vlag startup-delay
```

Note: The startup delay is cancelled if the two vLAG peers reload simultaneously or the ISL fails.

vLAG Auto-recovery

During network operations, it is common for the vLAG peers to be reloaded simultaneously. In this scenario, if the vLAG ports are in the error disabled state, traffic will be lost. To avoid traffic loss, bring the ports up manually. When this is not done, an auto-recovery mechanism is required to automatically transition ports from the error disabled state to the up state.

vLAG auto-recovery lets the switch automatically re-enable any error disabled vLAG ports after a specified time interval if it detects that its vLAG peer is not functional.

During the reloading process, the auto-recovery timer is initiated. If the ISL is established between the vLAG peers before the auto-recovery timer expires, the timer is cancelled.

If the auto-recovery timer expires or the ISL fails before that, auto-recovery stops the vLAG startup-delay process and then determines the status of the vLAG peer through Health Check. If the peer is functional, all of the switch's vLAG ports are maintained in the error disabled state. If the vLAG peer is not detected as functional, the switch assumes the role of the primary, and then transitions all of its vLAG ports to the up state.

To configure the auto-recovery interval, in seconds, use the following command:

```
Switch(config)# vlag auto-recovery <240-3600>
```

Notes:

- It is recommended that the auto-recovery interval be longer than the reload duration of the switch. Some vLAG ports might remain in the error disabled state if this condition is not met.
- Any changes to the vLAG auto-recovery mechanism will not take effect until the switch is reloaded.

vLAG auto-recovery is always enabled and cannot be disabled. By default, the auto-recovery interval is set to 300 seconds (5 minutes). To reset the interval to its default value, use the following command:

```
Switch(config)# no vlag auto-recovery
```

Health Check

The status of a vLAG peer is usually monitored through the ISL. You can configure vLAG Health Check to provide an alternate way of checking the status of the peer when the ISL fails.

Health Check detects and mitigates the failure of the vLAG ISL. When Health Check determines that the vLAG peer is still functioning, but the ISL has failed, the path from the secondary switch to the access switch is shut down.

The Health Check mechanism can be configured either over the management interface or over an ethernet port.

Note: Health Check supports both IPv4 and IPv6 addressing. When using IPv6 addressing, only global addresses are allowed. Link local IPv6 addresses are not permitted.

To configure vLAG peer IP address used for Health Check, use the following command:

```
Switch(config)# vlag hlthchk peer-ip <peer IP address> [vrf {<VRF instance name>|
|default|management}]
```

To remove the vLAG peer, use the following command:

```
Switch(config)# no vlag hlthchk peer-ip
```

If a switch is reload and its ISL is in the down state, the switch is not elected. When both the primary and secondary switches are reloaded with ISL in the down state, all the ports that are members of the vLAG from both switches will transition to the error disabled state.

For the Health Check mechanism to work, the vLAG peers must be in the same subnetwork (preferably directly connected).

The Health Check mechanism uses hello messages to determine the status of the vLAG peer. The hello messages are exchanged periodically between the vLAG peers over a TCP session.

To configure the interval, in seconds, between consecutive hello messages, use the following command:

```
Switch(config)# vlag hlthchk keepalive-interval <2-300>
```

By default, hello messages are exchanged every 5 seconds. To reset the hello interval to its default value, use the following command:

```
Switch(config)# no vlag hlthchk keepalive-interval
```

The hello messages are used to maintain the TCP session between the vLAG peers. After sending a certain number of consecutive hello messages and not receiving any reply, the local switch will declare its vLAG peer as being in the down state.

To configure the number of unanswered hello messages, use the following command:

```
Switch(config)# vlag hlthchk keepalive-attempts <1-24>
```

By default, the vLAG peer is marked as down after the local switch does not receive a reply to 3 consecutive hello messages. To reset the number of attempts to the default value, use the following command:

```
Switch(config)# no vlag hlthchk keepalive-attempts
```

When a TCP session between the two vLAG peers cannot be established, the Health Check mechanism will retry to reconnect to the peer at a certain interval. To configure the retry interval, in seconds, use the following command:

```
Switch(config)# vlag hlthchk retry-interval <1-300>
```

By default, the retry interval is set at 30 seconds. To reset it to this value, use the following command:

```
Switch(config)# no vlag hlthchk retry-interval
```

Basic Health Check Configuration Example

To configure the vLAG Health Check mechanism, follow these steps:

1. Configure the management interface or an ethernet port of the switch:

```
Switch(config)# interface mgmt 0
Switch(config-if)# ip address 10.10.10.1 255.255.255.0
Switch(config-if)# exit
```

Note: Configure a similar interface on vLAG Peer 2. For example, use IP address 10.10.10.2.

2. Specify the IPv4 address of the vLAG peer:

```
Switch(config)# vlag hlthchk peer-ip 10.10.10.2 vrf management
```

Note: For vLAG Peer 2, the interface should be configured as 10.10.10.2 and the health check peer IP should be configured as 10.10.10.1, pointing back to vLAG Peer 1.

The local health check peer IP address cannot be configured manually. It is automatically configured with the IP address of the interface Health Check is using, within the same subnetwork as the peer's vLAG health check IP address.

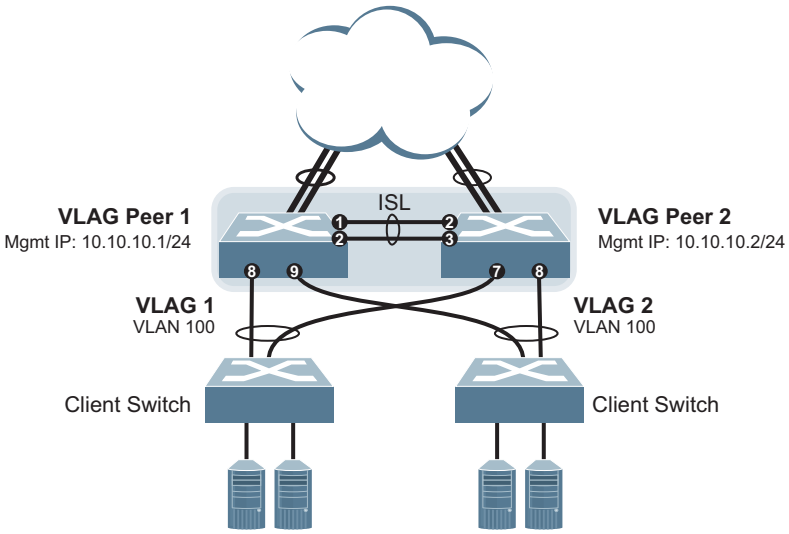
After configuring the peer IP address, the Health Check mechanism will attempt to establish a TCP session with the specified switch. To close the connection, use the following command:

```
Switch(config)# no vlag hlthchk peer-ip
```

Basic vLAG Configuration Example

Figure 7 shows an example configuration where two vLAG peers are used for aggregating traffic from downstream devices.

Figure 7. Basic vLAGs



In this example, each client switch is connected to both vLAG peers. On each client switch, the ports connecting to the vLAG peers are configured as members of a LACP LAG. The vLAG peer switches share a dedicated ISL for synchronizing vLAG information. On the individual vLAG peers, each port leading to a specific client switch (and part of the client switch's port LAG) is configured as a vLAG.

In the following example configuration, only the configuration for vLAG 1 on vLAG Peer 1 is shown. vLAG Peer 2 and all other vLAGs are configured in a similar fashion.

Note: When making changes to a running vLAG configuration, impact can be minimized by temporarily disabling vLAG configuration consistency check.

Configuring the ISL

The ISL connecting the vLAG peers is shared by all their vLAGs. The ISL needs to be configured only once on each vLAG peer.

Note: Lenovo recommends setting one unused VLAN as the native VLAN for the ISL path.

1. Configure the ISL ports and place them into a port LAG:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk allowed vlan 100
Switch(config-if-range)# channel-group 10 mode active
Switch(config-if-range)# exit
```

Notes:

- In this case, a LACP LAG is shown. A static LAG can be configured instead.
- The ISL ports and vLAG ports must be members of the same VLANs.
- LAG 10 is automatically created when you assign the ethernet ports to it.
- All VLANs can be added to the allowed VLAN list by using the following command:

```
Switch(config)# interface port-channel 10
Switch(config-if)# switchport trunk allowed vlan all
```

When adding all VLANs to the allowed VLAN list of a switch trunk port, VLAN configuration needs to be the same on both vLAG peers to avoid configuration consistency check failure.

2. Associate the LAG to the ISL:

```
Switch(config)# vlag isl port-channel 10
```

3. Configure Health Check:

```
Switch(config)# vlag htlhchk peer-ip 10.10.10.2 vrf management
```

4. Configure VLAG Tier ID:

```
Switch(config)# vlag tier-id 10
```

5. Configure the ISL for the vLAG peer.

Make sure you configure the vLAG peer (vLAG Peer 2) with the same ISL aggregation type (LACP or static), the same VLAN for vLAG and ISL ports, STP mode, and tier ID used on vLAG Peer 1.

Configuring the vLAG

To configure the vLAG, follow these steps:

1. Create VLAN 100:

```
Switch(config)# vlan 100
Switch(config-vlan)# exit
```

2. Configure the vLAG ports:

```
Switch(config)# interface ethernet 1/8
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 100
Switch(config-if)# channel-group 1 mode active
Switch(config-if)# exit

Switch(config)# interface ethernet 1/9
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 100
Switch(config-if)# channel-group 2 mode active
Switch(config-if)# exit
```

Notes:

- In MSTP mode, VLANs are automatically mapped to CIST.
- LAGs 1 and 2 are automatically created when you assign ethernet interfaces 8 and 9 to them.

3. Associate the ports with their respective vLAGs:

```
Switch(config)# vlag instance 1 port-channel 1
Switch(config)# vlag instance 1 enable
Switch(config)# vlag instance 2 port-channel 2
Switch(config)# vlag instance 2 enable
```

4. Enable vLAG globally:

```
Switch(config)# vlag enable
```

5. Verify the completed configuration:

```
Switch# show vlag information
```

6. Repeat the configuration for vLAG Peer 2.

   For each corresponding vLAG on the peer, the port LAG type (LACP or static), VLAN, STP mode, and Tier ID must be the same as on vLAG Peer 1.

vLAG Configuration - VLANs Mapped to a MST Instance

Follow the steps in this section to configure vLAG in environments where the STP mode is MSTP and no previous vLAG was configured.

Configuring the ISL

The ISL connecting the vLAG peers is shared by all their vLAGs. The ISL needs to be configured only once on each vLAG peer. Ensure you have the same region name, revision, and VLAN-to-STG mapping on both vLAG switches.

Note:

1. Configure STP:

```
Switch(config)# spanning-tree mode mst
```

2. Configure the ISL ports and place them into a LAG (LACP or static):

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk allowed vlan 100
Switch(config-if-range)# channel-group 1 mode active
Switch(config-if-range)# exit
```

Notes:

- In this case, a LACP LAG is shown. A static LAG can be configured instead.
- ISL ports and vLAG ports must be members of the same VLAN.

3. Associate the LAG to the ISL:

```
Switch(config)# vlag isl port-channel 1
```

4. Configure the vLAG Tier ID:

```
Switch(config)# vlag tier-id 10
```

5. Configure the ISL for the vLAG peer.

   Make sure you configure the vLAG peer (vLAG Peer 2) with the same ISL aggregation type (LACP or static), the same VLAN for vLAG and ISL ports, STP mode, and tier ID used on vLAG Peer 1.

Configuring the vLAG

To configure the vLAG, follow these steps:

1. Create the VLAN:

```
Switch(config)# vlan 100
Switch(config-vlan)# exit
```

2. Configure the vLAG ports:

```
Switch(config)# interface ethernet 1/3
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 100
Switch(config-if)# channel-group 3 mode active
Switch(config-if)# exit

Switch(config)# interface ethernet 1/4
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 100
Switch(config-if)# channel-group 4 mode active
Switch(config-if)# exit
```

Notes:

- In MSTP mode, VLANs are automatically mapped to CIST.
- LAGs 3 and 4 are automatically created when you assign ethernet interface 3 and 4 to them.

3. Map the VLAN to an MST instance:

```
Switch(config)# spanning-tree mst configuration
Switch(config-mst)# instance 1 vlan 100
```

4. Associate the ports with their respective vLAGs:

```
Switch(config)# vlag instance 1 port-channel 3
Switch(config)# vlag instance 1 enable
Switch(config)# vlag instance 2 port-channel 4
Switch(config)# vlag instance 2 enable
```

5. Enable vLAG:

```
Switch(config)# vlag enable
```

6. Verify the completed configuration:

```
Switch# show vlag information
```

7. Configure the ISL for the vLAG peer.

   For each corresponding vLAG on the peer, the port LAG type (LACP or static), VLAN, STP mode, and Tier ID must be the same as on vLAG Peer 1.

Configuring vLAGs in Multiple Layers

Figure 8. vLAG in Multiple Layers

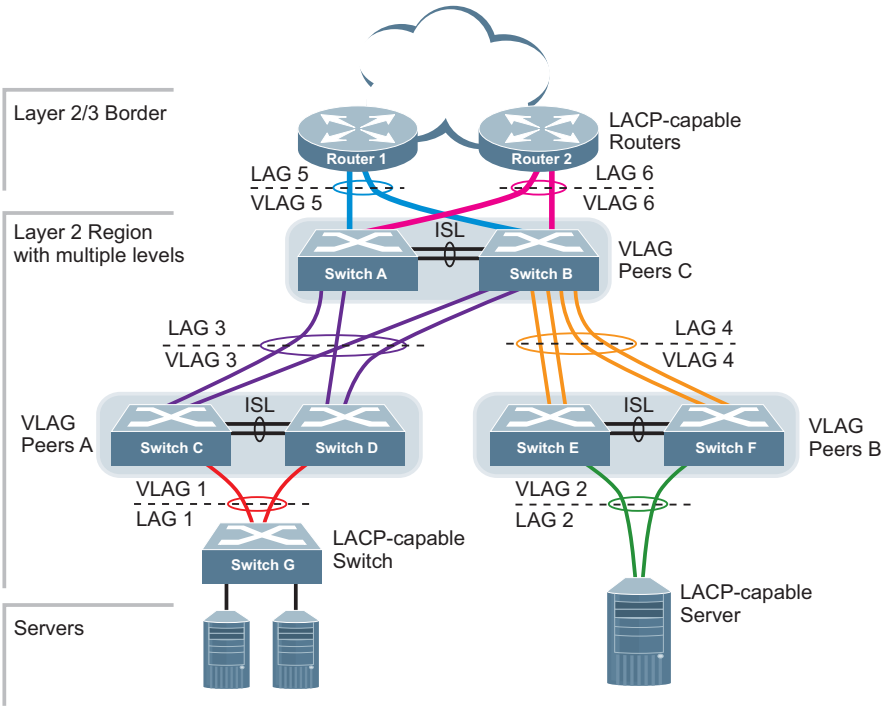


Figure 8 shows an example of a vLAG being used in a multi-layer environment. Following are the configuration steps for the topology.

Task 1: Configure Layer 2/3 Border Region

Consider the following:

- Border routers 1 and 2 are connected to Switch A through ethernet port 1
- Border routers 1 and 2 are connected to Switch B through ethernet port 2

Configure Border Router 1

1. Create a VLAN:

```
Switch(config)# vlan 50
Switch(config-vlan)# exit
```

2. Configure the ports on border router 1 as follows:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 50
Switch(config-if)# channel-group 5 mode active
Switch(config-if)# exit
```

Configure Border Router 2

1. Create a VLAN:

```
Switch(config)# vlan 60
Switch(config-vlan)# exit
```

2. Configure the ports on border router 2 as follows:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 60
Switch(config-if)# channel-group 6 mode active
Switch(config-if)# exit
```

Task 2: Configure switches in the Layer 2 region

Given the following:

- ISL ports on switches A - F: ports 1, 2
- Ports connecting switches A and B to the Layer 2/3 border routers: ports 5, 6
- Ports on switches A and B connecting to switches C and D: ports 10, 11
- Ports on switches C and D connecting to switches A and B: ports 10, 11
- Ports on switch B connecting to switch E: ports 15, 16
- Ports on switch B connecting to switch F: ports 17, 18
- Ports on switch E connecting to switch B: ports 15, 16
- Ports on switch F connecting to switch B: ports 17, 18
- Port on switches C and D connecting to switch G: port 3
- Port on switches E and F connecting to server: port 3

Configuring Switch A

1. Configure the vLAG tier ID and enable vLAG globally:

```
Switch(config)# vlag tier-id 10
Switch(config)# vlag enable
```

2. Configure the ISL ports on Switch A:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk allowed vlan 30,50,60,100
Switch(config-if-range)# channel-group 10 mode active
Switch(config-if-range)# exit
```

3. Associate the LAG to the ISL:

```
Switch(config)# vlag isl port-channel 10
```

4. Create VLANs 30, 50, 60 and 100:

```
Switch(config)# vlan 30,50,60,100
Switch(config-vlan)# exit
```

5. Configure the ports on Switch A connecting to the Layer 2/3 border routers:

```
Switch(config)# interface ethernet 1/5
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 50
Switch(config-if)# channel-group 5 mode active
Switch(config-if)# exit

Switch(config)# interface ethernet 1/6
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 60
Switch(config-if)# channel-group 6 mode active
Switch(config-if)# exit
```

6. Configure the ports on switch A connecting to switches C and D:

```
Switch(config)# interface ethernet 1/10-11
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 30
Switch(config-if)# channel-group 3 mode active
Switch(config-if)# exit
```

7. Associate the previously configured ports with their respective vLAGs:

```
Switch(config)# vlag instance 3 port-channel 3
Switch(config)# vlag instance 3 enable

Switch(config)# vlag instance 5 port-channel 5
Switch(config)# vlag instance 5 enable

Switch(config)# vlag instance 6 port-channel 6
Switch(config)# vlag instance 6 enable
```

Configuring Switch B

1. Configure the vLAG tier ID and enable vLAG globally:

```
Switch(config)# vlag tier-id 10
Switch(config)# vlag enable
```

2. Configure the ISL ports on Switch B:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk allowed vlan 30,40,50,60,100
Switch(config-if-range)# channel-group 10 mode active
Switch(config-if-range)# exit
```

3. Associate the LAG to the ISL:

```
Switch(config)# vlag isl port-channel 10
```

4. Create VLANs 30, 40, 50, 60 and 100:

```
Switch(config)# vlan 30,40,50,60,100
Switch(config-vlan)# exit
```

5. Configure the ports on Switch B connecting to the Layer 2/3 border routers:

```
Switch(config)# interface ethernet 1/5
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 50
Switch(config-if)# channel-group 5 mode active
Switch(config-if)# exit

Switch(config)# interface ethernet 1/6
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 60
Switch(config-if)# channel-group 6 mode active
Switch(config-if)# exit
```

6. Configure the ports on switch B connecting to switches C and D:

```
Switch(config)# interface ethernet 1/10-11
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 30
Switch(config-if)# channel-group 3 mode active
Switch(config-if)# exit
```

7. Configure the ports on switch B connecting to switches E and F:

```
Switch(config)# interface ethernet 1/15-18
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 40
Switch(config-if)# channel-group 4 mode active
Switch(config-if)# exit
```

8. Associate the previously configured ports with their respective vLAGs:

```
Switch(config)# vlag instance 3 port-channel 3
Switch(config)# vlag instance 3 enable

Switch(config)# vlag instance 4 port-channel 4
Switch(config)# vlag instance 4 enable

Switch(config)# vlag instance 5 port-channel 5
Switch(config)# vlag instance 5 enable

Switch(config)# vlag instance 6 port-channel 6
Switch(config)# vlag instance 6 enable
```

Configuring Switches C and D

1. Configure the vLAG tier ID and enable vLAG globally:

```
Switch(config)# vlag tier-id 20
Switch(config)# vlag enable
```

2. Configure the ISL ports on Switch C:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk allowed vlan 10,30,100
Switch(config-if-range)# channel-group 10 mode active
Switch(config-if-range)# exit
```

3. Associate the LAG to the ISL:

```
Switch(config)# vlag isl port-channel 10
```

4. Create VLANs 10, 30 and 100:

```
Switch(config)# vlan 10,30,100
Switch(config-vlan)# exit
```

5. Configure the ports on Switch C connecting to switches A and B:

```
Switch(config)# interface ethernet 1/10-11
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 30
Switch(config-if)# channel-group 3 mode active
Switch(config-if)# exit
```

6. Configure the ports on switch C connecting to switch G:

```
Switch(config)# interface ethernet 1/3
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 10
Switch(config-if)# channel-group 1 mode active
Switch(config-if)# exit
```

7. Associate the previously configured ports with their respective vLAGs:

```
Switch(config)# vlag instance 1 port-channel 1
Switch(config)# vlag instance 1 enable

Switch(config)# vlag instance 3 port-channel 3
Switch(config)# vlag instance 3 enable
```

8. Repeat these steps for Switch D.

Configuring Switch E

1. Configure the vLAG tier ID and enable vLAG globally:

```
Switch(config)# vlag tier-id 30
Switch(config)# vlag enable
```

2. Configure the ISL ports on Switch E:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk allowed vlan 20,40,100
Switch(config-if-range)# channel-group 10 mode active
Switch(config-if-range)# exit
```

3. Associate the LAG to the ISL:

```
Switch(config)# vlag isl port-channel 10
```

4. Create VLANs 20, 40 and 100:

```
Switch(config)# vlan 20,40,100
Switch(config-vlan)# exit
```

5. Configure the ports on Switch E connecting to switch B:

```
Switch(config)# interface ethernet 1/15-16
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 40
Switch(config-if)# channel-group 4 mode active
Switch(config-if)# exit
```

6. Configure the ports on switch E connecting to the server:

```
Switch(config)# interface ethernet 1/3
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 20
Switch(config-if)# channel-group 2 mode active
Switch(config-if)# exit
```

7. Associate the previously configured ports with their respective vLAGs:

```
Switch(config)# vlag instance 2 port-channel 2
Switch(config)# vlag instance 2 enable

Switch(config)# vlag instance 4 port-channel 4
Switch(config)# vlag instance 4 enable
```

Configuring Switch F

1. Configure the vLAG tier ID and enable vLAG globally:

```
Switch(config)# vlag tier-id 30
Switch(config)# vlag enable
```

2. Configure the ISL ports on Switch F:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk allowed vlan 20,40,100
Switch(config-if-range)# channel-group 10 mode active
Switch(config-if-range)# exit
```

3. Associate the LAG to the ISL:

```
Switch(config)# vlag isl port-channel 10
```

4. Create VLANs 20, 40 and 100:

```
Switch(config)# vlan 20,40,100
Switch(config-vlan)# exit
```

5. Configure the ports on Switch E connecting to switch B:

```
Switch(config)# interface ethernet 1/17-18
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 40
Switch(config-if)# channel-group 4 mode active
Switch(config-if)# exit
```

6. Configure the ports on switch E connecting to the server:

```
Switch(config)# interface ethernet 1/3
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 20
Switch(config-if)# channel-group 2 mode active
Switch(config-if)# exit
```

7. Associate the previously configured ports with their respective vLAGs:

```
Switch(config)# vlag instance 2 port-channel 2
Switch(config)# vlag instance 2 enable

Switch(config)# vlag instance 4 port-channel 4
Switch(config)# vlag instance 4 enable
```

Chapter 14. Quality of Service

Quality of Service features allow you to allocate network resources to mission-critical applications at the expense of applications that are less sensitive to such factors as time delays or network congestion. You can configure your network to prioritize specific types of traffic, ensuring that each type receives the appropriate Quality of Service (QoS) level.

The following topics are discussed in this section:

QoS Overview

QoS helps you allocate guaranteed bandwidth to critical applications and limit bandwidth for less critical applications. Applications such as video and voice must have a specific amount of bandwidth to work correctly; using QoS, you can provide that bandwidth when necessary. Also, you can put a high priority on applications that are sensitive to timing out or that cannot tolerate delay, by assigning their traffic to a high-priority queue.

By assigning QoS levels to traffic flows on your network, you can ensure that network resources are allocated where they are needed most. QoS features allow you to prioritize network traffic, thereby providing better service for selected applications.

The basic QoS model works as follows:

- Classify traffic:
  - Match the DSCP or IP Precedence value
  - Match the IP RTP priority
  - Match the protocol (ARP, DHCP, IS-IS etc) value
  - Match the 802.1p priority value
  - Match the ACL filter parameters
- Perform actions:
  - Define the bandwidth and burst parameters
  - Select the actions to perform on in-profile and out-of-profile traffic
  - Mark the 802.1p Priority and DSCP or IP Precedence values
  - Set the QoS group (with or without re-marking)
- Queue and schedule traffic:
  - Place the packets in one of the COS queues
  - Schedule transmission based on the COS queue
  - Configure Traffic Shaping
  - Define a guaranteed bandwidth
  - Configure Strict Priority queuing

Class Maps

A *class map* is a named object that represents a class of traffic. In the class map, you specify a set of match criteria for classifying the packets. You can then reference class maps in policy maps.

You define the following class and policy maps types when you create them:

- *control plane (CoPP)*: receives packets that are necessary to configure the switch hardware and for remote switch management
- *qos*: defines a QoS class map that is used to match packets to a specified class
- *queuing*: defines a queuing class map that is used to match packets to a specified class

To configure a class map, use one of the following commands:

```
Switch(config)# class-map type control-plane match-any <CoPP class map name>
Switch(config-cmap-control-plane)#
```

```
Switch(config)# class-map type qos {match-all|match-any} <class map name>
Switch(config-cmap-qos)#
```

```
Switch(config)# class-map type queuing match-any <queue name>
Switch(config-cmap-que)#
```

QoS Classification Types

You can classify traffic by matching packets based on predefined classification criteria, as follows:

- Access Control List (ACL)
- Class of Service (CoS)
- DiffServ Code Point (DSCP)
- UDP or TCP port number
- Precedence
- Protocol

Using ACL Filters

Access Control Lists (ACLs) are filters that allow you to classify and segment traffic, so you can provide different levels of service to different traffic types. Each filter defines the conditions that must match for inclusion in the filter, and also the actions that are performed when a match is made.

To set an QoS ACL filter, use the following command:

```
Switch(config)# class-map type qos {match-all|match-any} <class map name>
Switch(config-cmap-qos)# match [not] access-group name <ACL name>
```

The switch allows you to classify packets based on various parameters. For example:

- Ethernet: source MAC, destination MAC, VLAN number/mask, ethernet type, priority
- IPv4: source IP address/mask, destination address/mask, type of service, IP protocol number
- TCP/UPD: source port, destination port, TCP flag
- Packet format

For ACL details, see Chapter 7, "Access Control Lists".

Summary of QoS Actions

Actions determine how the traffic is treated. The switch QoS actions include the following:

- Re-mark a new DSCP or IP Precedence
- Re-mark the 802.1p field
- Set the QOS group

Using Class of Service Filters

You can classify traffic based on the class of service (CoS). To do that, use the following command:

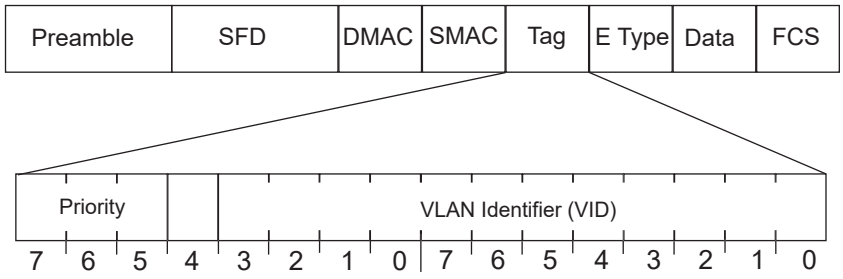
```
Switch(config-cmap-qos)# match [not] cos <CoS value (0-7)>
```

Using 802.1p Priority to Provide QoS

The switch provides Quality of Service functions based on the priority bits in a packet's VLAN header (the priority bits are defined by the 802.1p standard within the IEEE 802.1Q VLAN header). The 802.1p bits, if present in the packet, specify the priority to be given to the packet during forwarding. Packets with a numerically higher (non-zero) priority are given forwarding preference over packets with lower priority values.

The IEEE 802.1p standard uses eight levels of priority (0-7). Priority 7 is assigned to highest priority network traffic, such as OSPF or RIP routing table updates. Priorities 5-6 are assigned to delay-sensitive applications such as voice and video, while lower priorities are assigned to standard applications. A value of 0 (zero) indicates a "best effort" traffic prioritization and this is the default when traffic priority has not been configured on your network. The switch can filter packets based on the 802.1p values.

Figure 9. Layer 2 802.1q/802.1p VLAN tagged packet



Ingress packets receive a priority value, as follows:

- **Tagged packets**—switch reads the 802.1p priority in the VLAN tag
- **Untagged packets**—switch tags the packet and assigns an 802.1p priority value, based on the port's default 802.1p priority

Egress packets are placed in a COS queue based on the priority value and scheduled for transmission based on the scheduling weight of the COS queue. Higher COS queue numbers provide forwarding precedence.

Using DiffServ Code Point (DSCP) Filters

The switch uses the Differentiated Services (DiffServ) architecture to provide QoS functions. DiffServ is described in IETF RFCs 2474 and 2475.

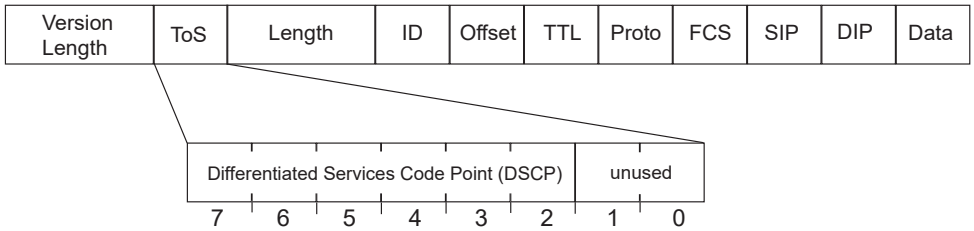
The six most significant bits in the Type of Service (ToS) byte of the IP header are defined as DiffServ Code Points (DSCP). Packets are marked with a certain value depending on the type of treatment the packet must receive from the network device. DSCP is a measure of the Quality of Service (QoS) level of the packet.

The switch can classify traffic by reading the DiffServ Code Point (DSCP) or IEEE 802.1p priority value, or by using filters to match specific criteria. When network traffic attributes match those specified in a traffic pattern, the policy instructs the switch to perform specified actions on each packet that passes through it. The packets are assigned to different Class of Service (CoS) queues and scheduled for transmission.

Differentiated Services Concepts

To differentiate between traffic flows, packets can be classified by their DSCP value. The Differentiated Services (DS) field in the IP header is an octet and the first six bits, called the DS Code Point (DSCP), can provide QoS functions. Each packet carries its own QoS state in the DSCP. There are 64 possible DSCP values (0-63).

Figure 10. Layer 3 IPv4 packet



The switch can perform the following actions to the DSCP:

- Read the DSCP value of ingress packets
- Re-mark the DSCP value to a new value
- Map the DSCP value to a Class of Service queue (COSq)

The switch can use the DSCP value to direct traffic prioritization.

With DiffServ you can establish policies to direct traffic. A policy is a traffic-controlling mechanism that monitors the characteristics of the traffic (for example, its source, destination, and protocol) and performs a controlling action on the traffic when certain characteristics are matched.

Per Hop Behavior

The DSCP value determines the Per Hop Behavior (PHB) of each packet. The PHB is the forwarding treatment given to packets at each hop. QoS policies are built by applying a set of rules to packets, based on the DSCP value, as they hop through the network.

The default settings are based on the following standard PHBs, as defined in the IEEE standards:

- Expedited Forwarding (EF)—This PHB has the highest egress priority and lowest drop precedence level. EF traffic is forwarded ahead of all other traffic. EF PHB is described in RFC 2598.
- Assured Forwarding (AF)—This PHB contains four service levels, each with a different drop precedence, as shown in the following table. Routers use drop precedence to determine which packets to discard last when the network becomes congested. AF PHB is described in RFC 2597.

Table 27. *Assured Forwarding service levels*

Drop Precedence	Class 1	Class 2	Class 3	Class 4
Low	AF11 (DSCP 10)	AF21 (DSCP 18)	AF31 (DSCP 26)	AF41 (DSCP 34)
Medium	AF12 (DSCP 12)	AF22 (DSCP 20)	AF32 (DSCP 28)	AF42 (DSCP 36)
High	AF13 (DSCP 14)	AF23 (DSCP 22)	AF33 (DSCP 30)	AF43 (DSCP 38)

- Class Selector (CS)—This PHB has eight priority classes, with CS7 representing the highest priority and CS0 representing the lowest priority, as shown in the following table. CS PHB is described in RFC 2474.

Table 28. *Class Selector priority classes*

Priority	Class Selector	DSCP
Highest	CS7	56
	CS6	48
	CS5	40
	CS4	32
	CS3	24
	CS2	16
	CS1	8
Lowest	CS0	0

QoS Levels

Table 29 shows the default service levels provided by the switch, listed from highest to lowest importance:

Table 29. *Default QoS Service Levels*

Service Level	Default PHB	802.1p Priority
Critical	CS7	7
Network Control	CS6	6
Premium	EF, CS5	5
Platinum	AF41, AF42, AF43, CS4	4
Gold	AF31, AF32, AF33, CS3	3
Silver	AF21, AF22, AF23, CS2	2
Bronze	AF11, AF12, AF13, CS1	1
Standard	DF, CS0	0

Using TCP/UDP Port Filters

You can define the TCP/UDP port used by Real-time Transport Protocol (RTP) processes as the classification criterion.

To apply this filter, use the following command:

```
Switch(config-cmap-qos)# match [not] ip rtp <TCP port or UDP port>
```

Using Precedence Filters

You can define the precedence as the classification criterion. The precedence value is from 0 to 7 and it can be one of the following:

- `routine`: Routine precedence (0)
- `priority`: Priority precedence (1)
- `immediate`: Immediate precedence (2)
- `flash`: Flash precedence (3)
- `flash-override`: Flash override precedence (4)
- `critical`: Critical precedence (5)
- `internet`: Internetwork control precedence (6)
- `network`: Network control precedence (7)

To apply this filter, use the following command:

```
Switch(config-cmap-qos)# match [not] precedence <precedence value (0-7)>
```

Using Protocol Filters

To define a protocol as a QoS filter, use the following command:

```
Switch(config-cmap-qos)# match [not] protocol <protocol name>
```

where *protocol name* is one of the following:

- `arp` - Address Resolution Protocol
- `bridging` - Bridging
- `cdp` - CISCO Discovery Protocol
- `clns` - Connectionless Network Service
- `clns-es` - CLNS End Systems
- `clns-is` - CLNS Intermediate Systems
- `dhcp` - Dynamic Host Configuration
- `isis` - Intermediate System to Intermediate System
- `ldp` - Label Distribution Protocol
- `netbios` - NetBIOS extended user interface

Queuing Classification Types

The switch has the following eight predefined queues:

- `1p7q1t-out-q-default` (queue 0 or default queue)
- `1p7q1t-out-pq1` (queue 1 or priority queue)
- `1p7q1t-out-q2` (queue 2)
- `1p7q1t-out-q3` (queue 3)
- `1p7q1t-out-q4` (queue 4)
- `1p7q1t-out-q5` (queue 5)
- `1p7q1t-out-q6` (queue 6)
- `1p7q1t-out-q7` (queue 7)

`1p7q1t` refers to how many priority queues, standard queues, and thresholds are supported. In this case, there are:

- 1 priority queue
- 7 standard queues
- 1 threshold

To apply this filter, use the following command:

```
Switch(config)# class-map type queuing match-any <queue name>
```

You can filter packets to different queues based on a CoS or QoS group.

Class Map Configuration Examples

Following are two basic configuration examples for QoS and queueing class maps.

QoS Class Map Configuration Example

To configure a QoS class map, follow these steps:

1. Create a new QoS class map:

```
Switch(config)# class-map type qos cmap-qos-01
Switch(config-cmap-qos)#
```

2. Define the classification criteria (multiple ones can be configured):

```
Switch(config-cmap-qos)# match protocol arp
Switch(config-cmap-qos)# match precedence 3
```

3. Verify the QoS class map configuration:

```
Switch# show class-map type qos

  Type qos class-maps
  ===================
      class-map type qos match-any class-default

      class-map type qos cmap-qos-01
         match precedence 3
         match protocol arp
```

Queueing Class Map Configuration Example

To configure a queueing class map, follow these steps:

1. Create a new queueing class map:

```
Switch(config)# class-map type queuing match-any 1p7q1t-out-q2
Switch(config-cmap-que)#
```

2. Define the classification criteria (multiple ones can be configured):

```
Switch(config-cmap-que)# match cos 5
Switch(config-cmap-que)# match qos-group 2
```

3. Verify the QoS class map configuration:

```
Switch# show class-map type queueing

  Type queuing class-maps
  =======================
      class-map type queuing match-any 1p7q1t-out-q4

      class-map type queuing match-any 1p7q1t-out-q2
         match qos-group 2
         match cos 5
...
```

Policy Maps

A *policy map* is a named object that represents a set of policies that are to be applied to a set of traffic classes, such as limiting the bandwidth or dropping a packet.

The following predefined policy maps are used as default service policies:

- `control-plane`: Control Plane Protection (CoPP)
- `qos`: Quality of Service (QoS)
- `queuing`

To set a policy map, use the following command:

```
Switch(config)# policy-map type {control-plane|qos|queing} <policy-map name>
```

Ingress Policing

The switch can use ingress policing to monitor the data rates for a particular class of traffic. When the data rate exceeds user-configured values, the switch drops packets immediately.

Defining Single-Rate and Dual-Rate Policers

You can define single-rate and dual-rate policers. While single-rate policers monitor the committed information rate (CIR) of traffic, dual-rate policers monitor both CIR and peak information rates (PIR) of traffic. The system also monitors associated burst sizes.

Only one action can be configured for each condition.

To configure polices, use the following command:

```
Switch(config-pmap-c-qos)# police [cir] {<committed-rate> [<data-rate>]|percent
<CIR-link-percent>} [bc <committed-burst-rate> [<link-speed>]] [pir] {<peak-rate>
[<data-rate>]|percent <CIR-link-percent>} [be <peak-burst-rate> [<link-speed>]] [conform
<conform actions>] [exceed <exceed actions>] [violate <violate actions>]
```

where*:*

Parameter	Description
`cir`	The use of the committed information rate, or desired bandwidth, as a bit rate or a percentage of the link rate.
committed-rate	an integer from 8,000 bps to the maximum rate of the link, in steps that are multiples of 8,000 bps.
data-rate	one of the following units: • `bps:` bits per second • `kbps`: 1,000 bits per second • `mbps`: 1,000,000 bits per second • `Gbps`: 1,000,000,000 bits per second

Parameter	Description
`percent`	the rate as a percentage of the interface bandwidth.
`bc`	how much the CIR can be exceeded as a bit rate or for how long can the CIR be exceeded.
committed-burst-rate	one of the following options: • `bytes`: bytes • `kbytes`: 1,000 bytes • `mbytes`: 1,000,000 bytes • `ms`: milliseconds • `us`: microseconds
`pir`	the peak information rate value.
`be`	how much the PIR can be exceeded as a bit rate or for how long can the PIR be exceeded.
`conform`	whether to take action if the traffic data rate is within bounds. The following actions are allowed: • `transmit`: Send the packet. This action is applicable only when the packet conforms to the parameters. • `set-prec-transmit`: Set the IP precedence field to a specified value and send the packet. • `set-dscp-transmit`: Set the Differentiated Service Code Point (DSCP) field to a specified value and send the packet. • `set-cos-transmit`: Set the class of service (CoS) field to a specified value and send the packet. The default action is `transmit`.
`exceed`	whether to take action if traffic data rate is exceeded. The following actions are available: • `drop`: Drop the packet. This is only available when the packet exceeds or violates the parameters. • `set-dscp-transmit`: Set the Differentiated Service Code Point (DSCP) field to a specified value and send the packet. • `set-cos-transmit`: Set the class of service (CoS) field to a specified value and send the packet.
`violate`	whether to take action if traffic data rate violates the set rate values. The following actions are available: • `drop`: Drop the packet. This is only available when the packet exceeds or violates the parameters. • `set-dscp-transmit`: Set the Differentiated Service Code Point (DSCP) field to a specified value and send the packet. • `set-cos-transmit`: Set the class of service (CoS) field to a specified value and send the packet.

Marking

Marking is a method that you use to modify the QoS fields of the incoming and outgoing packets.

To mark QoS fields, use the following command:

```
Switch(config-pmap-c-qos)# set {cos <0-7>|dscp <0-63>|precedence <0-7>|
|qos-group <0-7>}
```

Queuing Policing

Traffic queuing is a mechanism allowing the switch to order the packets and it applies to output data. Device modules can support multiple queues, which you can use to control the sequencing of packets in different traffic classes.

Bandwidth

Bandwidth on egress queues can be configured to allocate a minimum percentage of the interface bandwidth to a queue. To set the bandwidth, use the following command:

```
Switch(config-pmap-c-que)# bandwidth {<rate> {bps|kbps|mbps|gbps}|percent
<percent value>}
```

You can configure the bandwidth by specifying its bit rate, or as a percentage of the underlying link rate.

You can also configure the data rate as a percentage of the bandwidth that is not allocated to other classes by using the following command:

```
Switch(config-pmap-c-que)# bandwidth remaining percent <percent value>
```

Shaping

You can configure shaping on an egress queue to impose a maximum rate on it. A data rate may be configured by either using a bit rate, or as a percentage of the underlying interface link rate.

To configure shaping, use the following command:

```
Switch(config-pmap-c-que)# shape [average] {<rate> {bps|kbps|mbps|gbps}|
percent <percent value>}
```

Priority

You can configure only one level of priority on an egress priority queue. To do so, use the following command:

```
Switch(config-pmap-c-que)# priority [level 1]
```

Policy Map Configuration Examples

Following are two basic examples of configuring QoS and queueing policy maps.

QoS Policy Map Configuration Example

To configure a QoS policy map, follow these steps:

1. Create a new QoS policy map:

```
Switch(config)# policy-map type qos pmap-qos-01
Switch(config-pmap-qos)#
```

2. Select an existing QoS class map:

```
Switch(config-pmap-qos)# class type qos cmap-qos-01
Switch(config-pmap-c-qos)#
```

3. Configure the ingress policing or marking:

```
Switch(config-pmap-c-qos)# police cir 2 mbps conform transmit
Switch(config-pmap-c-qos)# set cos 3
```

4. Verify the QoS policy map configuration:

```
Switch# show policy-map type qos

Type qos policy-maps
====================

policy-map type qos pmap-qos-01
 class type qos cmap-qos-01
  set cos 3
  police cir 2 mbps conform transmit
```

Queuing Policy Map Configuration Example

To configure a queueing policy map, follow these steps:

1. Create a new queueing policy map:

```
Switch(config)# policy-map type queuing pmap-que-01
Switch(config-pmap-que)#
```

2. Select an existing queueing class map:

```
Switch(config-pmap-que)# class type queuing 1p7q1t-out-q3
Switch(config-pmap-c-que)#
```

3. Configure the queueing policing:

```
Switch(config-pmap-c-que)# bandwidth percent 25
```

4. Verify the queueing policy map configuration:

```
Switch# show policy-map type queueing

Type queuing policy-maps
========================

policy-map type queuing default-out-policy
 class type queuing 1p7q1t-out-pq1
  priority level 1
 class type queuing 1p7q1t-out-q2
 class type queuing 1p7q1t-out-q3
 class type queuing 1p7q1t-out-q-default
  bandwidth remaining percent 25

policy-map type queuing pmap-que-01
 class type queuing 1p7q1t-out-q2
 class type queuing 1p7q1t-out-q3
  random-detect  minimum-threshold percent 5 maximum-threshold percent 35
  bandwidth percent 25
```

Control Plane Protection

Control Plane Protection (CoPP) receives packets that are required for the internal protocol state machines. This type of traffic is usually received at low rate. However, in some situations such as DOS attacks, the switch may receive this traffic at a high rate. If the control plane protocols are unable to process the high rate of traffic, the switch may become unstable.

The control plane receives packets that are channeled through protocol-specific packet queues. Multiple protocols can be channeled through a common packet queue. However, one protocol cannot be channeled through multiple packet queues. These packet queues are applicable only to the packets received by the software and does not impact the regular switching or routing traffic. Packet queues with a higher number have higher priority.

You can configure the bandwidth for each packet queue. Protocols that share a packet queue will also share the bandwidth.

To configure CoPP:

1. Enter Control Plane Configuration mode by using the following command:

```
Switch(config)# control-plane
```

2. To apply the control plane service policy, use the following command:

```
Switch(config-cp)# service-policy input copp-system-policy
```

3. To modify a control-plane policy-map, use the following command:

```
Switch(config)# [no] policy-map type control-plane <policy-map name>
```

4. To modify a control-plane class map that is used to match packets to a specified class, use the following command:

```
Switch(config)# [no] class-map type control-plane match-any <class map name>
```

5. To view CoPP switch configuration, use the following commands:

```
Switch(config)# show class-map type control-plane
Switch(config)# show policy-map type control-plane
Switch(config)# show policy-map interface control-plane
```

Control Plane Configuration Examples

To configure a CoPP class map, use the following steps:

1. Since new CoPPs cannot be created, modify one of the predefined CoPP class maps. To view the current CoPP class maps, use the following command:

```
Switch(config)# show class-map type control-plane

  Type control plane class-maps
  =============================
      class-map match-any copp-s-lacp

      class-map match-any copp-s-default

      class-map match-any copp-s-bfd

      class-map match-any copp-s-arpresponse

      class-map match-any copp-s-arprequest

      class-map match-any copp-s-authentication
            QOS-ACCESS-LIST-NAME: copp-system-acl-authentication
...
```

2. Enter configuration mode for one of the above CoPP class maps:

```
Switch(config)# class-map type control-plane match-any copp-s-bfd
Switch(config-cmap-control-plane)#
```

3. Configure the classification criteria for the CoPP class map:

```
Switch(config-cmap-control-plane)# match access-group name myACL
```

Note: You cannot define multiple classification criteria for a single CoPP class map.

4. Verify the configuration:

```
Switch# show class-map type control-plane

  Type control plane class-maps
  =============================
      class-map match-any copp-s-lacp

      class-map match-any copp-s-default

      class-map match-any copp-s-bfd
            QOS-ACCESS-LIST-NAME: myACL

      class-map match-any copp-s-arpresponse

      class-map match-any copp-s-arprequest

      class-map match-any copp-s-authentication
            QOS-ACCESS-LIST-NAME: copp-system-acl-authentication
...
```

To configure a CoPP policy map, use the following steps:

1. Since new CoPPs cannot be created, modify the predefined CoPP policy map (copp-system-policy). To view the current CoPP policy maps, use the following command:

```
Switch(config)# show policy-map type control-plane

Type control-plane policy-maps
==============================

policy-map type control-plane copp-system-policy
 class type control-plane copp-s-default
  police pps 20000
 class type control-plane copp-s-ntp
  police pps 200
 class type control-plane copp-s-arprequest
  police pps 500
 class type control-plane copp-s-nd
  police pps 500
...
```

2. Enter configuration mode for one of the above CoPP policy maps:

```
Switch(config)# policy-map type control-plane match-any copp-system-policy
Switch(config-pmap-control-plane)#
```

3. Enter configuration mode for one of the above CoPP class maps:

```
Switch(config-pmap-control-plane)# class type control-plane copp-s-ntp
Switch(config-pmap-c-control-plane)#
```

4. Configure the number of packet per second processed by the switch for the current class map:

```
Switch(config-pmap-c-control-plane)# police pps 100
```

Note: The switch will not process more than the configured number of packets per second for each type of traffic. The excess packets will be dropped.

5. Verify the configuration:

```
Switch# show policy-map type control-plane

Type control-plane policy-maps
==============================

policy-map type control-plane copp-system-policy
 class type control-plane copp-s-default
  police pps 20000
 class type control-plane copp-s-ntp
  police pps 100
 class type control-plane copp-s-arprequest
  police pps 500
 class type control-plane copp-s-nd
  police pps 500
...
```

WRED

Weighted Random Early Detection (WRED) is a congestion avoidance algorithm that helps prevent a TCP collapse, where a congested port indiscriminately drops packets from all sessions. The transmitting hosts wait to retransmit, resulting in a dramatic drop in throughput. Often times, this TCP collapse repeats in a cycle, which results in a saw-tooth pattern of throughput. WRED selectively drops packets before the queue gets full, allowing majority of the traffic to flow smoothly.

WRED discards packets based on the CoS queues. Packets are discarded in order of their priority, from lowest to highest.

WRED calculates the average size of the queue. If the average queue size is below a configured minimum threshold, then an arriving packet is immediately queued. If the average queue size is between the minimum and maximum threshold, then an arriving packet is either queued or discarded depending on the configured drop probability. If the average queue size is over the maximum threshold, then an arriving packets is immediately discarded.

For implementing WRED, you must define a profile with a minimum threshold, a maximum threshold, and a maximum drop probability. The profiles can be defined on a port or a CoS.

Explicit Congestion Notification

Explicit Congestion Notification (ECN) extends the functionality of WRED by marking packets instead of discarding them when the average queue length exceeds the configured threshold. Network devices configured with WRED and ECN use the marking of packets as a signal that the network is congested and packet transmission is slowed down.

Regardless if ECN is enabled or not, if the number of packets in the queue is below the minimum threshold, all the packets are transmitted.

Without ECN enabled, if the number of packets in the queue is between the minimum and maximum thresholds, the WRED algorithm determines if an arriving packet should be queued or discarded based on the drop probability.

When ECN is enabled and an arriving packet indicates that its endpoints are ECN-capable, if the WRED algorithm determines that the packet should be discard, it is instead marked. The marked packet is then transmitted at a later time.

ECN improves congestion avoidance by allowing the network to mark packets for later transmission, instead of discarding them from the queue. This enhances throughput and application performance by accommodating applications that are sensitive to delay or packet loss.

ECN also enables ECN-capable network devices and end hosts to respond to network congestions before a queue overflows and packets are discarded.

Configuring WRED

WRED can be configured only on physical ports and not on LAGs. WRED is applicable only to known unicast traffic.

To configure WRED, use the following command:

```
Switch(config)# policy-map type queuing <policy map name>
Switch(config-pmap-que)# class type queuing <class map name>
Switch(config-pmap-c-que)# random-detect [minimum-threshold] {<min-threshold>
[<unit>]|percent <min-percent>} [maximum-threshold] {<max-threshold> [<unit>]|
|percent <max-percent>} {drop-probability <0-100>} [ecn]
```

where *unit* is one of the following:

- `bytes` - configures the threshold in bytes
- `kbytes` - configures the threshold in kilobytes
- `mbytes` - configures the threshold in megabytes
- `ms` - configures the threshold in milliseconds
- `packets` - configures the threshold in number of packets
- `us` - configures the threshold in microseconds

WRED Configuration Example

Follow these steps to enable WRED and configure a global and/or port-level profile. If you configure global and port-level profiles, WRED uses the port-level profile to make transmit/discard decisions when experiencing traffic congestion.

1. Configure a policy-map of type queuing:

```
Switch(config)# policy-map type queuing policy-1
```

2. Assign a system defined class-map to the policy-map configured at step 1:

```
Switch(config-pmap-que)# class type queuing 1p7q4t-out-pq2
```

3. Enable WRED for the class-map by specifying (in bytes) the minimum and the maximum thresholds, and the drop probability when the maximum threshold is reached:

```
Switch(config-pmap-c-que)# random-detect [minimum-threshold] <min-threshold>
bytes [maximum-threshold] <max-threshold> bytes drop-probability <0-100> [ecn]
```

4. Use the following command to view global WRED information:

```
Switch(config)# show policy-map type queuing

Type queuing policy-maps
========================

policy-map type queuing default-out-policy
 class type queuing 1p7q1t-out-pq1
  priority level 1
 class type queuing 1p7q1t-out-q2
 class type queuing 1p7q1t-out-q3
 class type queuing 1p7q1t-out-q-default
  bandwidth remaining percent 25

policy-map type queuing policy_queue1
 class type queuing 1p7q1t-out-q5
  shape average 4 bps
  random-detect  minimum-threshold 12000 packets maximum-threshold 30000
    packets drop-probability 50 ecn
 class type queuing 1p7q1t-out-q3
...
```

Use the following command to view port-level WRED information:

```
Switch(config)# show policy-map interface ethernet 1/4 output

Global statistics status : disabled

Ethernet1/4

 Service-policy (queuing) output: policy-1

 Class-map (queuing):  1p7q1t-out-q2 (match any)
   random-detect  minimum-threshold 35000 bytes maximum-threshold 250000 bytes
     drop-probability 50 ecn
```

WRED Limitations

WRED has the following limitations:

- ECN does not work with WRED for unknown unicast, multicast, and broadcast packets.
- If WRED is configured with a minimum threshold higher than 2,142 packets, the queue begins to discard packets before the minimum threshold is reached, and thus ECN is not triggered.

Interface Service Policy

An input QoS policy is a service policy applied to incoming traffic on an Ethernet interface for classification. For type queuing, the output policy is applied to all outgoing traffic that matches the specified class.

Apply an Interface Service Policy

To apply a policy to an interface, use one of the following commands:

```
Switch(config-if)# service-policy [type qos] input <policy-map-name>
```

```
Switch(config-if)# service-policy type queuing output <policy-map-name>
```

Interface Service Policy Limitations

- Service policy is applied only to ingress traffic for type QoS and to egress traffic for type queuing.
- The device restricts QoS policies to one per interface per direction (ingress or egress) for each of the policy types QoS and queuing.
- Queuing policy maps are not support for Aggregator Port.

Microburst Detection

Microbursts are short peaks in data traffic that manifest as a sudden increase in the number of data packets transmitted over a specific millisecond-level time frame, potentially overwhelming network buffers. Microburst detection allows users to analyze and mitigate microburst-related incidents, thus preventing network congestion.

Microburst Detection can be enabled or disabled on each switch interface. To enabled it on an interface, use the following command (for this example, ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# microburst-detection enable threshold <threshold value>
```

To disable microburst detection on an interface, use the following command:

```
Switch(config-if)# no microburst-detection enable
```

To configure the polling interval (in milliseconds) used by microburst detection to evaluate traffic burst:

```
Switch(config)# microburst-detection interval <5-5000>
```

Note: By default, microburst detection is disabled.

To see the current microburst statistics, use the following command:

```
Switch# show statistics microburst
```

Following is a basic configuration example for Microburst Detection.

1. Enter Interface Configuration mode and enabled Microburst Detection, choosing a threshold value:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# microburst-detection enable threshold 20
Switch(config-if)# exit
```

2. Configure the polling interval:

```
Switch(config)# microburst-detection interval 100
```

3. See the current microburst statistics:

```
Switch# show statistics microburst
------------------------------------------------------------------------
Interface     # of uburst  avg size  max size  avg duration  max duration
------------------------------------------------------------------------
Ethernet1/12            0         0         0             0             0
```

Chapter 15. CEE

This chapter provides conceptual background and configuration examples for using Converged Enhanced Ethernet (CEE) features of the switch, with an emphasis on RoCEv1, RoCEv2, iSCSI solutions. The following topics are addressed in this chapter:

- "Converged Enhanced Ethernet" on page 373

  Converged Enhanced Ethernet (CEE) refers to a set of IEEE standards developed primarily to enable FCoE, requiring enhancing the existing Ethernet standards to make them lossless on a per-priority traffic basis, and providing a mechanism to carry converged (LAN/SAN/IPC) traffic on a single physical link. CEE features can also be used in traditional LAN (non-FCoE) networks to provide lossless guarantees on a per-priority basis, and to provide efficient bandwidth allocation.

- "RoCE and iSCSI" on page 372

  RDMA over Converged Ethernet (RoCE) allows remote direct memory access (RDMA) over an Ethernet network. This provides accelerated communications between applications hosted on clusters of servers and storage arrays, low latency and overall a better performance compared to software based protocols. Internet Small Computer System Interface (iSCSI) protocol is used over RoCe to allow a block-level storage capability similar to Fibre Channel (FC) SAN technology, which is the same system of encapsulating the SCSI protocol within an external "carrier." The difference is that the iSCSI SAN uses Ethernet instead of FC transport technology.

- "Priority-Based Flow Control" on page 376

  Priority-Based Flow Control (PFC) extends 802.3x standard flow control to enable the switch to pause traffic based on the 802.1p priority value in each packet's VLAN tag. PFC is vital for FCoE/RoCE/iSCSI environments, where RoCE/iSCSI/FCoE traffic must remain lossless and must be paused during congestion, while LAN traffic on the same links is delivered with "best effort" characteristics.

- "Enhanced Transmission Selection" on page 379

  Enhanced Transmission Selection (ETS) provides a method for allocating link bandwidth based on the 802.1p priority value in each packet's VLAN tag. Using ETS, different types of traffic (such as lossless LAN, SAN, and management) that are sensitive to different handling criteria can be configured either for specific bandwidth characteristics, low-latency, or best-effort transmission, despite sharing converged links as in an FCoE environment.

- "Data Center Bridging Capability Exchange" on page 385

  Data Center Bridging Capability Exchange Protocol (DCBX) allows neighboring network devices to exchange information about their capabilities. This is used between CEE-capable devices for the purpose of discovering their peers, negotiating peer configurations, and detecting misconfigurations.

- "CEE Configuration Examples" on page 388

  This section provides the following CEE configuration examples:

  - Default configuration
  - Configuration with RoCEv2 and another Biz-critical LAN application or iSCSI

RoCE and iSCSI

RDMA over Converged Ethernet (RoCE) allows remote direct memory access (RDMA) over an Ethernet network. RoCE provides direct memory to memory transfers at the application level without involving the host CPU. Both the transport processing and the memory translation and placement are performed by hardware resulting in dramatically lower latency and higher performance. There are two RoCE versions, RoCEv1 and RoCEv2: RoCEv1 is an Ethernet link layer protocol and hence allows communication between any two hosts in the same Ethernet broadcast domain, while RoCEv2 is designed to allow lossless traffic in the layer 3 network environment.

Internet Small Computer System Interface (iSCSI) is an Internet Protocol (IP)-based storage networking standard for linking data storage facilities. It provides block-level access to storage devices by carrying SCSI commands over a TCP/IP network. iSCSI takes a popular high-performance local storage bus and emulates it over a wide range of networks, creating a storage area network (SAN). Unlike some SAN protocols, iSCSI requires no dedicated cabling; it can be run over existing IP infrastructure. As a result, iSCSI is often seen as a low-cost alternative to Fibre Channel.

RoCE Requirements

The following are required for implementing RoCE using the switches with CNOS 10.9 software:

- An underlying lossless Ethernet network is required for RoCE traffic only to avoid systematic packet drops resulting from resource contention within network switches and adapters.
- CEE must be turned on (see "Turning CEE On or Off" on page 373). When CEE is on, the DCBX, PFC, and ETS features are enabled and configured with default settings. These features may be reconfigured, but must remain enabled for RoCE to function.

Converged Enhanced Ethernet

Converged Enhanced Ethernet (CEE) refers to a set of IEEE standards designed to allow different physical networks with different data handling requirements to be converged together, simplifying management, increasing efficiency and use, and leveraging legacy investments without sacrificing evolutionary growth.

CEE standards were developed primarily to enable Fibre Channel/RoCE/iSCSI traffic to be carried over Ethernet networks. This required enhancing the existing Ethernet standards to make them lossless on a per-priority traffic basis, and to provide a mechanism to carry converged (LAN/SAN/IPC) traffic on a single physical link. Although CEE standards were designed with FCoE in mind, they are not limited to FCoE installations. CEE features can be utilized in traditional LAN (non-FCoE) networks to provide lossless guarantees on a per-priority basis, and to provide efficient bandwidth allocation based on application needs.

Turning CEE On or Off

By default, CEE is turned off. To turn CEE on or off, use the following command:

```
Switch(config)# [no] cee enable
```

CAUTION:
Turning CEE on automatically changes some 802.1p QoS and 802.3x standard flow control settings on the switch. Read the following material carefully to determine whether you need to take action to reconfigure expected settings.

We recommended that you backup your configuration before turning CEE on. Having the backup configuration file allows you to manually re-create the equivalent configuration once CEE is turned on, and also allows you to recover your prior configuration if you need to turn CEE off.

When CEE is turned on, the following default CEE configuration is automatically triggered if no specific configurations are made to ETS/PFC/DCBX:

- DCBX is enabled on all ports, and ETS/PFC/App-proto are advertised.
- PFC is configured on all ports and `priority-3` is set.
- The default ETS configuration is the following:

```
PGID    BW%   COSq  Priorities
============================
0       10    0      0 1 2
1       0     NA
2       40    2      4 5 6 7
3       50    3      3
4       0     4
5       0     5
6       0     6
7       0     7
15      NA    1
```

- No default application protocol is configured.

Notes:

- You can change the default ETS/PFC/DCBX configuration without enabling CEE, but the configuration will not be effective. The new configuration will be effective only when enabling CEE.
- On the NE2572, due to hardware limitation, CEE cannot be enabled on a port having a 1G SFP/CuSFP adapter.

Effects on Link Layer Discovery Protocol

When CEE is turned on, DCBX is turned on and starts sending and receiving DCBX Type-Length-Values(TLVs) on LLDP Protocol Data Units(PDU).

Effects on 802.1p Quality of Service

While CEE is off (the default), the switch allows 802.1p priority values to be used for Quality of Service (QoS) configuration (see page 347). 802.1p QoS default settings are shown in Table 30, but can be changed by the administrator.

When CEE is turned on, 802.1p QoS is replaced by ETS (see "Enhanced Transmission Selection" on page 379). As a result, while CEE is turned on, the 802.1p QoS configuration commands are no longer available on the switch (the menu is restored when CEE is turned off).

In addition, when CEE is turned on, prior 802.1p QoS settings are replaced with new defaults designed for use with ETS priority groups (PGIDs) as shown in Table 30.

Table 30. *802.1p QoS Configuration with CEE On*

PGID	BW%	COSq	Priorities
0	10	0	0, 1, 2
1	0	NA	
2	40	2	4, 5, 6, 7
3	50	3	3
4	0	4	
5	0	5	
6	0	6	
7	0	7	
15	NA	1	

When CEE is on, the default ETS configuration also allocates a portion of link bandwidth to each PGID as shown in Table 31:

Table 31. *Default ETS Bandwidth Allocation*

PGID	Typical Use	Bandwidth
0	LAN	10%
3	RoCE/iSCSI	50%
2	Latency-sensitive LAN	40%

If the prior, non-CEE configuration used 802.1p priority values for different purposes, or does not expect bandwidth allocation as shown in Table 31 on page 375, when CEE is turned on, have the administrator reconfigure ETS settings as appropriate.

It is recommended that a configuration backup be made prior to turning CEE on or off. Viewing the configuration file will allow the administrator to manually re-create the equivalent configuration under the new CEE mode, and will also allow for the recovery of the prior configuration if necessary.

Effects on Flow Control

When CEE is off (the default), 802.3x standard flow control is enabled on all switch ports by default.

When CEE is turned on, standard flow control is disabled on all ports, and in its place, PFC (see "Priority-Based Flow Control" on page 376) is enabled on all ports for 802.1p priority value 3. This default is chosen because priority value 3 is commonly used to identify lossless traffic in a CEE environment and must be guaranteed lossless behavior. PFC is disabled for all other priority values.

Each time CEE is turned off, the prior 802.3x standard flow control settings will be restored (including any previous changes from the defaults).

It is recommended that you make a backup of the configuration before turning CEE on or off. Viewing the configuration file will allow you to manually re-create the equivalent configuration under the new CEE mode, and will also allow for the recovery of the prior configuration if necessary.

When CEE is on, any two priorities can be enabled at the same time. PFC can be enabled only on any two priorities based on the requirement, with the exception of the NE10032, which supports only one PFC priority. If flow control is required on additional priorities on any given port, consider using standard flow control on that port, so that regardless of which priority traffic becomes congested, a flow control frame is generated.

Priority-Based Flow Control

Priority-based Flow Control (PFC) is defined in IEEE 802.1Qbb. PFC extends the IEEE 802.3x standard flow control mechanism. Under standard flow control, when a port becomes busy, the switch manages congestion by pausing all the traffic on the port, regardless of the traffic type. PFC provides more granular flow control, allowing the switch to pause specified types of traffic on the port, while other traffic on the port continues.

PFC pauses traffic based on 802.1p priority values in the VLAN tag. The administrator can assign different priority values to different types of traffic and then enable PFC for up to two specific priority values: priority value 3, and one other. The configuration can be applied globally for all ports on the switch. Then, when traffic congestion occurs on a port (caused when ingress traffic exceeds internal buffer thresholds), only traffic with priority values where PFC is enabled is paused. Traffic with priority values where PFC is disabled proceeds without interruption but may be subject to loss if port ingress buffers become full.

PFC requires CEE to be turned on ("Turning CEE On or Off" on page 373). When CEE is turned on, PFC is enabled on priority value 3 by default. Optionally, the administrator can also enable PFC on one other priority value, providing lossless handling for another traffic type, such as for a business-critical LAN application.

Note: For any given port, only one flow control method can be implemented at any given time: either PFC or standard IEEE 802.3x flow control.

PFC Configuration

PFC requires CEE to be turned on ("Turning CEE On or Off" on page 373). When CEE is turned on, standard flow control is disabled on all ports, and PFC is enabled on all ports for 802.1p priority value 3. This default is chosen because priority value 3 is commonly used to identify RoCE/iSCSI traffic in a CEE environment and must be guaranteed lossless behavior. PFC is disabled for all other priority values by default, but can be enabled for one additional priority value.

PFC configuration can also be used in some mixed environments where traffic with PFC-enabled priority values occurs only on ports connected to CEE devices, and not on any ports connected to non-CEE devices. In such cases, PFC can be configured globally on specific priority values even though not all ports make use them.

PFC has the following characteristics:

- PFC is not restricted to CEE and FCoE networks. In any LAN where traffic is separated into different priorities, PFC can be enabled on priority values for loss-sensitive traffic.
- If you want to enable PFC on a priority, add the priority to a priority group. For example, you can assign Priority 5 to PGID 2.
- If you want to enable PFC on a priority, do one of the following:
  - Create a separate PG (separate COS Q) (or)
  - Move the priority to the existing PG in which PFC is turned on.

  Option 1 will be more preferred as you have separate Q and separate ETS configuration.

- When configuring ETS and PFC on the switch, perform ETS configuration before performing PFC configuration.
- If two priorities are enabled on a port, the switch sends PFC frames for both priorities, even if only traffic tagged with one of the priorities is being received on that port.
- The administrator can enable or disable PFC on a port-by-port basis.

Notes:

- When using PFC configuration in conjunction with the ETS feature (see "Enhanced Transmission Selection" on page 379), ensure that only pause-tolerant traffic (such as lossless traffic) is assigned priority values where PFC is enabled. Pausing other types of traffic can have adverse effects on LAN applications that expect uninterrupted traffic flow and tolerate dropping packets during congestion.
- The NE10032 only supports one PFC enabled priority. When you enable CEE,,priority 3 will be enabled by default, but you can disable PFC on priority 3 and enable PFC on another priority.
- On the NE2572, due to hardware limitation, PFC cannot be enabled on a port having a 1G SFP/CuSFP adapter. You must disable PFC on the port before inserting the 1G SFP adapter.

PFC Configuration Example

Note: DCBX may be configured to permit sharing PFC configuration with or from external devices. This example assumes that PFC configuration is being performed manually. See "Data Center Bridging Capability Exchange" on page 385 for more information on DCBX.

For example, the following topology is used.

Table 32. *PFC Configuration*

802.1p Priority	Usage	PFC Setting
0-2	LAN	Disabled
3	RoCE	**Enabled**
4-7	Business-critical LAN	Disabled
others	(not used)	Disabled

In this example, PFC is to facilitate lossless traffic handling for RoCE (priority value 3).

Assuming that CEE is off, the example topology shown in Table 32 can be configured using the following commands:

1. Turn CEE on.

```
Switch(config)# cee enable
```

Note: Turning CEE on will automatically change some 802.1p QoS and 802.3x standard flow control settings and menus (see "Turning CEE On or Off" on page 373).

2. Optionally, set a PFC description:

Note: PFC is enabled on priority 3 by default.

```
Switch(config)# cee pfc priority 3 description "RoCEv2"
                                                (Optional description)
```

3. Save the configuration.

Enhanced Transmission Selection

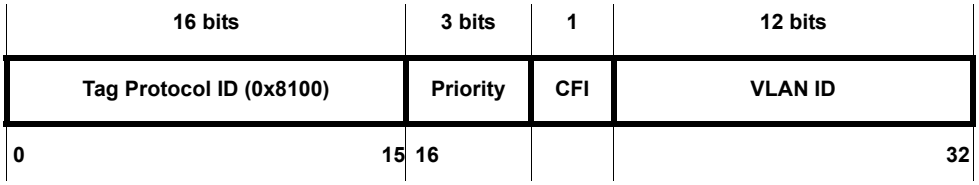
Enhanced Transmission Selection (ETS) is defined in IEEE 802.1Qaz. ETS provides a method for allocating port bandwidth based on 802.1p priority values in the VLAN tag. Using ETS, different amounts of link bandwidth can specified for different traffic types (such as for LAN, SAN, and management).

ETS is an essential component in a CEE environment that carries different types of traffic, each of which is sensitive to different handling criteria, such as Storage Area Networks (SANs) that are sensitive to packet loss, and LAN applications that may be latency-sensitive. In a single converged link, such as when implementing FCoE, ETS allows SAN and LAN traffic to coexist without imposing contrary handling requirements upon each other.

The ETS feature requires CEE to be turned on (see "Turning CEE On or Off" on page 373).

802.1p Priority Values

Under the 802.1p standard, there are eight available priority values, with values numbered 0 through 7, which can be placed in the priority field of the 802.1Q VLAN tag:



Servers and other network devices may be configured to assign different priority values to packets belonging to different traffic types (such as SAN and LAN).

ETS uses the assigned 802.1p priority values to identify different traffic types. The various priority values are assigned to priority groups (PGID), and each priority group is assigned a portion of available link bandwidth.

Priorities values within in any specific ETS priority group are expected to have similar traffic handling requirements with respect to latency and loss.

An administrator may assign 802.1p priority values for a variety of purposes. However, when CEE is tugrned on, the switch sets the initial default values for ETS configuration as shown in Table 33.

Table 33. *Default ETS Priority Group*

Typical Traffic Type	802.1p Priority	PGID	Bandwidth Allocation
LAN	0	0	10%
LAN	1	0	10%
LAN	2	0	10%
SAN	3	3	50%

Table 33. *Default ETS Priority Group*

Typical Traffic Type	802.1p Priority	PGID	Bandwidth Allocation
Latency-Sensitive LAN	4	2	40%
Latency-Sensitive LAN	5	2	40%
Latency-Sensitive LAN	6	2	40%
Latency-Sensitive LAN	7	2	40%

In the assignment model shown in Table 33, priorities values 0 through 2 are assigned for regular Ethernet traffic, which has "best effort" transport characteristics.

Because CEE and ETS features are generally associated with FCoE, Priority 3 is typically used to identify FCoE (SAN) traffic.

Priorities 4-7 are typically used for latency sensitive traffic and other important business applications. For example, priority 4 and 5 are often used for video and voice applications such as IPTV, Video on Demand (VoD), and Voice over IP (VoIP). Priority 6 and 7 are often used for traffic characterized with a "must get there" requirement, with priority 7 used for network control which is requires guaranteed delivery to support configuration and maintenance of the network infrastructure.

Priority Groups

For ETS use, each 801.2p priority value is assigned to a priority group which can then be allocated a specific portion of available link bandwidth. To configure a priority group, a priority group must be assigned a priority group ID (PGID), one or more 802.1p priority values, and allocated link bandwidth.

PGID

Each priority group is identified with number (0 through 7, and 15) known as the PGID.

PGID 0 through 7 may each be assigned a portion of the switch's available bandwidth.

PGID 8 through 14 are reserved as per the 802.1Qaz ETS standard.

PGID 15 is a strict priority group. It is generally used for critical traffic, such as network management. Any traffic with priority values assigned to PGID 15 is permitted as much bandwidth as required, up to the maximum available on the switch. After serving PGID 15, any remaining link bandwidth is shared among the other groups, divided according to the configured bandwidth allocation settings.

Make sure all 802.1p priority values assigned to a particular PGID have similar traffic handling requirements. For example, PFC-enabled traffic must not be grouped with non-PFC traffic. Also, traffic of the same general type must be assigned to the same PGID. Splitting one type of traffic into multiple 802.1p priorities, and then assigning those priorities to different PGIDs may result in unexpected network behavior.

Each 802.1p priority value may be assigned to only one PGID. However, each PGID may include multiple priority values. Up to eight PGIDs may be configured at any given time.

Assigning Priority Values to a Priority Group

Each priority group may be configured from its corresponding ETS Priority Group, available using the following command:

```
Switch(config)# cee ets priority-group pgid <group number (0-7, or 15)> priority
   <priority list>
Switch(config)# cee ets priority-group pgid <group number (0-7, or 15)>
description <description>
                                                    (Optional description)
```

where *priority list* is one or more 802.1p priority values (with each separated by a comma). For example, to assign priority values 0 through 2:

```
Switch(config)# cee ets priority-group pgid <group number (0-7, or 15)> priority
   0,1,2
Switch(config)# cee ets priority-group pgid <group number (0-7, or 15)>
description "ETS"
                                                    (Optional description)
```

Note: Within any specific PGID, the PFC settings (see "Priority-Based Flow Control" on page 376) must be the same (enabled or disabled) for all priority values within the group. If the PFC setting is inconsistent within a PGID, an error is reported when attempting to apply the configuration.

When assigning priority values to a PGID, the specified priority value will be automatically removed from its old group and assigned to the new group when the configuration is applied.

For PGIDs 0 through 7, bandwidth allocation can also be configured through the ETS Priority Group menu. See for "Allocating Bandwidth" on page 381 for details.

Allocating Bandwidth

Follow these guidelines when allocating bandwidth.

Allocated Bandwidth for PGID 0 Through 7

You may allocate a portion of the switch's available bandwidth to PGIDs 0 through 7. Available bandwidth is defined as the amount of link bandwidth that remains after priorities within PGID 15 are serviced (see "Unlimited Bandwidth for PGID 15" on page 382), and assuming that all PGIDs are fully subscribed. If any PGID does not fully consume its allocated bandwidth, the unused portion is made available to the other priority groups.

Priority group bandwidth allocation can be configured using the following command:

```
Switch(config)# cee ets bandwidth-percentage <bandwidth allocation>
```

where *bandwidth allocation* represents the percentage of link bandwidth, specified as a number between 0 and 100, in 1% increments.

The following bandwidth allocation rules apply:

- Bandwidth allocation must be 0% for any PGID that has no assigned 802.1p priority values.
- Any PGID assigned one or more priority values must have a bandwidth allocation greater than 9%.
- Total bandwidth allocation for groups 0 through 7 must equal exactly 100%. Increasing or reducing the bandwidth allocation of any PGID also requires adjusting the allocation of other PGIDs to compensate.

If these conditions are not met, the switch will report an error when applying the configuration.

To achieve a balanced bandwidth allocation among the various priority groups, packets are scheduled according to a weighted deficit round-robin (WDRR) algorithm. WDRR is aware of packet sizes, which can vary significantly in a CEE environment, making WDRR more suitable than a regular weighted round-robin (WRR) method, which selects groups based only on packet counts.

Note: Actual bandwidth used by any specific PGID may vary from configured values by up to 10% of the available bandwidth in accordance with 802.1Qaz ETS standard. For example, a setting of 10% may be served anywhere from 0% to 20% of the available bandwidth at any given time.

Unlimited Bandwidth for PGID 15

PGID 15 is permitted unlimited bandwidth and is generally intended for critical traffic (such as switch management). Traffic in this group is given highest priority and is served before the traffic in any other priority group.

If PGID 15 has low traffic levels, most of the switch's bandwidth will be available to serve priority groups 0 through 7. However, if PGID 15 consumes a larger part of the switch's total bandwidth, the amount available to the other groups is reduced.

Note: Consider traffic load when assigning priority values to PGID 15. Heavy traffic in this group may restrict the bandwidth available to other groups.

Configuring ETS

Consider an example with two business critical applications:

Table 34. *ETS Configuration*

Priority	Usage	PGID	Bandwidth
0	LAN (best effort delivery)	0	8%
1	LAN (best effort delivery)	0	8%
2	LAN (best effort delivery)	0	8%
3	FCoE or RoCE (PFC enabled)	3	40%
4	Business Critical LAN (lossless Ethernet, with PFC)	4	16%
5	Latency-sensitive LAN	2	10%
6	Latency-sensitive LAN	2	10%
7	Network Management (strict)	15	NA

In this example, Business critical LAN traffic (priority 4) is moved from PG 2 to PG 4 and Network management traffic (priority 7) is moved to PG 15 (strict priority). This leaves latency-sensitive LAN traffic (priorities 5 and 6) in PG 2 itself. Also, a new group for network management traffic has been assigned. Finally, the bandwidth allocation for priority groups 3, 4, and 5 are revised.

Note: DCBX may be configured to permit sharing or learning PFC configuration with or from external devices. This example assumes that PFC configuration is being performed manually. See "Data Center Bridging Capability Exchange" on page 385 for more information on DCBX.

This example can be configured using the following commands:

1. Turn CEE on.

```
Switch(config)# cee enable
```

Notes:

- Turning CEE on will automatically change some 802.1p QoS and 802.3x standard flow control settings and menus (see "Turning CEE On or Off" on page 373).
- The NE10032 only supports one PFC enabled priority. When you enable CEE, priority 3 will be enabled by default, but you can disable PFC on priority 3 and enable PFC on another priority.

2. Create a new PGID-4 for Business critical LAN traffic:

```
Switch(config)#cee ets priority-group pgid 4 priority 4
```

3. Assign bandwidth to the configured Priority Group:

```
Switch(config)#cee ets bandwidth-percentage 0 8 2 10 3 40 4 20
```

4. Enable PFC on priority 4 for lossless:

```
Switch(config)#cee pfc priority 4 enable
```

5. Optionally, set configuration descriptions:

```
Switch(config)#cee ets priority-group pgid 0 description "Regular LAN"
Switch(config)#cee ets priority-group pgid 2 description
"Latency-sensitive LAN"
Switch(config)#cee ets priority-group pgid 3 description "RoCEv2 Traffic"
Switch(config)#cee ets priority-group pgid 4 description "Biz-critical
LAN"
Switch(config)#cee ets priority-group pgid 15 description "Network
Management"
Switch(config)#cee pfc priority 0 description "Regular LAN"
Switch(config)#cee pfc priority 3 description "RoCEv2"
Switch(config)#cee pfc priority 4 description "Biz-Critical LAN"
```

Note: Priority group 15 is permitted unlimited bandwidth. As such, the commands for priority group 15 do not include bandwidth allocation.

6. Save the configuration.

To view the configuration, use the following commands:

```
Switch(config)# show cee ets
ETS Global Admin Configuration:
PGID    BW%   COSq  Priorities          Description
================================================================================
=====
0       8     0      0 1 2              "Regular LAN"
1       0     NA
2       10    2      5 6                "Latency-sensitive LAN"
3       40    3      3                  "RoCEv2 Traffic"
4       16    4      4                  "Biz-critical LAN"
5       0     5
6       0     6
7       0     7
15      NA    1      7                  "Network Management"
```

```
Switch(config)# show cee pfc
Global Admin PFC State: On
Priority  State  Description
============================
   0      Dis    "Regular LAN"
   1      Dis
   2      Dis
   3      Ena    "RoCEv2"
   4      Ena    "Biz-Critical LAN"
   5      Dis
   6      Dis
   7      Dis
```

Data Center Bridging Capability Exchange

Data Center Bridging Capability Exchange (DCBX) protocol is a vital element of CEE. DCBX allows peer CEE devices to exchange information about their advanced capabilities. Using DCBX, neighboring network devices discover their peers, negotiate peer configurations, and detect misconfigurations.

DCBX provides two main functions on the switch:

- Peer information exchange

  The switch uses DCBX to exchange information with connected CEE devices. For normal operation of any FCoE implementation on the switch, DCBX must remain enabled on all ports participating in FCoE.

- Peer configuration negotiation

  DCBX also allows CEE devices to negotiate with each other for the purpose of automatically configuring advanced CEE features such as PFC, ETS and Application protocol. The administrator can determine which CEE feature settings on the switch are communicated to and matched by CEE neighbors, and also which CEE feature settings on the switch may be configured by neighbor requirements.

The DCBX feature requires CEE to be turned on (see "Turning CEE On or Off" on page 373).

DCBX Modes

Interfaces can use one of the following DCBX modes:

- CEE DCBX (1.01)
- IEEE DCBX (802.1Qaz)

Default mode is IEEE DCBX. The DCBX mode is determined by auto-negotiation with the peer. If the peer/remote port is capable of sending DCBX TLVs in IEEE mode, the interface is set to IEEE DCBX mode. If the peer/remote port doesn't support IEEE mode, the interface uses CEE DCBX mode.

DCBX Settings

When CEE is turned on, DCBX is enabled for peer information exchange on all ports. For configuration negotiation, the following default settings are configured:

- PFC: Enabled on 802.1p priority 3
- ETS
  - Priority group 0 includes priority values 0 through 2, with bandwidth allocation of 10%
  - Priority group 2 includes priority values 4 through 7, with bandwidth allocation of 40%
  - Priority group 3 includes priority value 3, with bandwidth allocation of 50%
- No application protocol is configured by default.

Note: The user may choose to configure RoCEv1/RoCEv2/iSCSI instead of FCoE.

Enabling and Disabling DCBX

When CEE is turned on, DCBX is enabled by default on all ports. Enabling or disabling DCBX TLVs on any port is possible by using the following command:

```
Switch(config-if)# [no] cee dcbx enable
```

When CEE is turned on and DCBX is enabled on a port, Link Layer Detection Protocol (LLDP) is used to exchange DCBX parameters between CEE peers. Also, the interval for LLDP transmission time is set to one second for the first five initial LLDP transmissions, after which it is returned to the administratively configured value. The minimum delay between consecutive LLDP frames is also set to one second as a DCBX default.

Peer Configuration Negotiation

CEE peer configuration negotiation can be enabled or disabled on a per-port basis for a particular CEE feature.For each supported feature, the administrator can configure the following flag:

- The `advertise` flag

  When this flag is set for a particular feature, the switch settings will be transmit to the remote CEE peer. If the peer is capable of the feature, and willing to accept the switch settings, it will be automatically reconfigured to match the switch.

Note: By default, the `advertise` flag is set for ETS, PFC and for application protocol.

These flags are available for the following CEE features:

- Application Protocol

  DCBX exchanges information regarding FCoE and FIP snooping, including the 802.1p priority value used for FCoE traffic. The `advertise` flag is set or reset using the following command:

  ```
  Switch(config-if)# [no] cee dcbx app-proto advertise
  ```

- PFC

  DCBX exchanges information regarding whether PFC is enabled or disabled on the port. The `advertise` flag is set or reset using the following command:

  ```
  Switch(config-if)# [no] cee dcbx pfc advertise
  ```

- ETS

  DCBX exchanges information regarding ETS priority groups, including their 802.1p priority members and bandwidth allocation percentages. The `advertise` flag is set or reset using the following command:

  ```
  Switch(config-if)# [no] cee dcbx ets advertise
  ```

Configuring DCBX

Consider the following example:

- RoCEv2 is used on ports 1/1-1/10.
- All other ports are disabled or are connected to regular (non-CEE) LAN devices.

In this example, the switch acts as the central point for CEE configuration. FCoE-related ports will be configured for advertising CEE capabilities, but not to accept external configuration. Other LAN ports that use CEE features will also be configured to advertise feature settings to remote peers, but not to accept external configuration. DCBX will be disabled on all non-CEE ports.

This example can be configured using the following commands:

1. Turn CEE on.

```
Switch(config)# cee enable
```

Note: Turning CEE on will automatically change some 802.1p QoS and 802.3x standard flow control settings and menus (see "Turning CEE On or Off" on page 373).

2. Disable DCBX for each non-CEE port as appropriate:

```
Switch(config-if)# no cee dcbx enable
```

3. Save the configuration.

CEE Configuration Examples

This section provides examples on how to configure CEE on the switch.

CEE Example 1

In this example, the default CEE configuration is explained:

1. By default, PFC is enabled on priority 3. Optionally, set descriptions for priority and priority group.

```
Switch(config)# cee pfc priority 3 description RoCEv2_priority
Switch(config)# cee ets priority-group pgid 3 description RoCEv2_Traffic
```

2. Optionally, configure `rocev2` as the application protocol.

```
Switch(config)# cee app-proto RoCEv2_Traffic rocev2 priority 3
```

3. Turn CEE on.

```
Switch(config)# cee enable
```

4. Verify the configuration:

```
Switch(config)# show cee ets
ETS Global Admin Configuration:
PGID    BW%   COSq  Priorities          Description
================================================
0       10    0      0 1 2
1       0     NA
2       40    2      4 5 6 7
3       50     3      3                 RoCEv2_Traffic
4       0     4
5       0     5
6       0     6
7       0     7
15      NA    1

Switch(config)# show cee pfc
Global Admin PFC State: On
Priority  State  Description
============================
   0      Dis
   1      Dis
   2      Dis
   3      Ena    RoCEv2_priority
   4      Dis
   5      Dis
   6      Dis
   7      Dis


Switch(config)# show cee app-proto
Advertise   Protocol    ProtoId   Priorities          ConfigName
=========================================================================
On       UDP      RoCEv2   3            RoCEv2_Traffic
```

CEE Example 2

In this example, CEE is configured with RoCEv2 and another Biz-critical LAN application or iSCSI:

1. Create a new PGID 4 for iSCSI traffic.

```
Switch(config)# cee ets priority-group pgid 4 priority 4
```

2. Allocate bandwidth to the Priority Groups.

```
Switch(config)# cee ets bandwidth-percentage 0 10 2 20 3 50 4 20
```

3. Enable PFC on priority 4 for lossless.

```
Switch(config)# cee pfc priority 4 enable
```

4. By default, PFC is enabled on priority 3. Optionally, set descriptions for priority and priority group 3.

```
Switch(config)# cee pfc priority 3 description RoCEv2_priority
Switch(config)# cee ets priority-group pgid 3 description RoCEv2_Traffic
```

5. Optionally, configure `rocev2` as the application protocol for priority 3.

```
Switch(config)# cee app-proto RoCEv2_Traffic rocev2 priority 3
```

6. Optionally, set descriptions for priority and priority group 4.

```
Switch(config)# cee ets priority-group pgid 4 description iSCSI_Traffic
Switch(config)# cee pfc priority 4 description iSCSI
```

7. Optionally, configure `iSCSI` as the application protocol for priority 4.

```
Switch(config)# cee app-proto iSCSI_Traffic iscsi priority 4
```

8. Turn CEE on.

```
Switch(config)# cee enable
```

9. Verify the configuration:

```
Switch(config)# show cee ets
ETS Global Admin Configuration:
PGID    BW%   COSq  Priorities          Description
=========================================================
0       10    0      0 1 2
1       0     NA
2       20    2      5 6 7
3       50    3      3                  RoCEv2_Traffic
4       20    4      4                  iSCSI
5       0     5
6       0     6
7       0     7
15      NA    1

Switch(config)# show cee pfc
Global Admin PFC State: On
Priority  State  Description
============================
   0      Dis
   1      Dis
   2      Dis
   3      Ena    RoCEv2_priority
   4      Ena    iSCSI
   5      Dis
   6      Dis
   7      Dis


Switch(config)# show cee app-proto
Admin Configuration:
Application Protocol Willing mode is not supported on the Switch.
Advertise   Protocol    ProtoId   Priorities          ConfigName
=============================================================================
On          UDP         RoCEv2     3                  RoCEv2_Traffic
On          TCP         iSCSI      4                  iSCSI_Traffic
```

Part 4: IP Routing

This section discusses Layer 3 switching functions. In addition to switching traffic at near line rates, the application switch can perform multi-protocol routing. This section discusses basic routing and advanced routing protocols:

Chapter 16. Basic IP Routing

This chapter provides configuration background and examples for using the switch to perform IP routing functions. The following topics are addressed in this chapter:

IP Routing

Internet Protocol (IP) Routing is the mechanism by which traffic travels across multiple networks, from its source to its destination. IP routing sends packets outside the local network by using Layer 3 protocols, like Address Resolution Protocol (ARP), Border Gateway Protocol (BGP), or Open Shortest Path First (OSPF).

The switch builds a forwarding table that correlates destination IP addresses with their next-hop addresses. A next-hop address is the IP address of the network device that is next in line between the switch and the destination device. If a packet is intended for a certain device, the switch will check its forwarding table for the IP address of the destination device. Once a match is found, the switch will send the packet through the interface on which the next-hop address is present. The next-hop device will perform the same process until the packet reaches its destination.

The switch uses a combination of configurable switch interfaces and IP routing options. The switch IP routing capabilities provide the following benefits:

- Connects the server IP subnets to the rest of the backbone network.
- Provides the ability to route IP traffic between multiple Virtual Local Area Networks (VLANs) configured on the switch.

The switch supports both IPv4 and IPv6 routing. For more detailed information about IPv6 routing, see Chapter 19, “Internet Protocol Version 6“.

IP routing runs only on Layer 3 interfaces, such as:

- switch Virtual Interfaces (SVIs)
- the management interface
- ethernet interfaces configured as routed ports

For more information about Layer 3 interfaces, see Chapter 8, “Interface Management“ and Chapter 17, “Routed Ports“.

By default, IP routing is enabled on the switch.

To enable or disable the forwarding of IPv4 traffic, use the following command:

```
Switch(config)# [no] ip forwarding
```

To enable or disable the forwarding of IPv6 traffic, use the following command:

```
Switch(config)# [no] ipv6 forwarding
```

Direct and Indirect Routing

Direct routing is used when both source and destination devices are present in the same network, the switch sends the packet directly from one device to the other. Forwarding table entries for direct routes are referred to as directly connected routes and are marked in the IP forwarding table with the letter 'C'.

When the source and destination devices are not in the same network, the packet must be forwarded by a network node (router) that knows how to reach the destination device. This network node is called a next-hop device (router).

Static Routing

Static routing means that the packet is forwarded using a manually configured route. Configuring a static route teaches the switch how to reach the specified destination IP address. Forwarding table entries for static routes are marked with the letter 'S'.

Static routing is recommended for small networks, because every static route needs to be manually configured on each switch or router in the network.

To add or remove a static IPv4 route, use the following command:

```
Switch(config)# [no] ip route <IPv4 address>/<prefix length> <next-hop address>
```

For example:

```
Switch(config)# ip route 10.10.10.0/24 10.28.12.10
```

To add or remove a static IPv6 route, use the following command:

```
Switch(config)# [no] ipv6 route <IPv6 address>/<prefix length> <next-hop address>
```

For example:

```
Switch(config)# ipv6 route 2001:1::1/128 fe80::a8bb:ccff:fe00:300
```

For more details about the above commands, consult the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

Note: The switch supports up to a maximum of 256 static routes, either IPv4 or IPv6.

To view configured static routes, use the following command:

```
Switch# show {ip|ipv6} static-route
```

IPv4 Next-hop Health Check

IPv4 next-hop health checking is used to verify if the IPv4 next-hop is reachable or not. It uses Address Resolution Protocol (ARP) to periodically send ARP request to the next-hops that have associated routes present in the switch's routing table.

If health check for a next-hop fails, the routes associated with that hop are deactivated. When health check is successful for a previously unreachable next-hop, the routes associated with that hop are reactivated.

By default, next-hop health checking is disabled on the switch.

To configure next-hop health checking, use the following command:

```
Switch(config)# ip next-hop healthcheck interval <5-60 (seconds)>
```

Note: This command only configures the time interval between consecutive next-hop reachability checks. If next-hop reachability is lost or recovered, then additional time is required for the associated routes to be deactivated or reactivated.

To disable next-hop health checking, use the following command:

```
Switch(config)# no ip next-hop healthcheck
```

Note: Next-hop health checking does not work for IPv6 next-hops.

Dynamic Routing

In dynamic routing, the packet is forwarded using routes that the switch learns automatically via routing protocols, such as BGP or OSPF. Routing protocols are used by switches or routers to exchange routing information. Forwarding table entries for dynamic routes are marked with different letters depicting the protocol through which the route was learned. For example, 'B' is used for routes learned through BGP and 'O' for routes learned through OSPF.

Dynamic routing is fault tolerant. If a learned link goes down, the switch can learn another route to the destination IP address. Another advantage is the low administrative overhead compared to configuring static routing.

One of the disadvantages of dynamic routing is the increased memory and CPU usage due to the processing of routing information received from other routers.

For more information about routing protocols, see Chapter 22, "Border Gateway Protocol" and Chapter 23, "Open Shortest Path First".

Note: The switch supports up to a maximum of 15870 IPv4 dynamic routes or 6143 IPv6 dynamic routes.

To remove a route from the forwarding table, use the following command:

```
Switch# clear {ip|ipv6} route <IP address>/<prefix length>
```

To delete all routes from the forwarding table, use the following command:

```
Switch# clear {ip|ipv6} route *
```

Default Gateway

The default gateway is the next-hop address that the switch uses when forwarding packets for which it does not have a dynamic or static route. The default gateway is a static route configured with `0.0.0.0/0` as its destination IP address.

To configure an IPv4 address as the default gateway for IPv4 traffic, use the following command:

```
Switch(config)# ip route 0.0.0.0/0 <next-hop address>
```

To configure an IPv6 address as the default gateway for IPv6 traffic, use the following command:

```
Switch(config)# ipv6 route 0::0/0 <next-hop address>
```

Note: Routes that have a specific destination take precedence over the default gateway.

Virtual Routing and Forwarding

Virtual Routing and Forwarding (VRF) allows multiple instances of a routing table to work simultaneously on a switch.

VRF provides the following advantages:

- Network paths can be segmented without using multiple devices.
- The routing instances are independent; the same or overlapping IP addresses can be used without conflicting with each other.
- VRF acts like a logical router (LSR), but while a LSR may include many routing tables, a VRF instance uses only a single routing table.
- VRF uses routing tables known as forwarding information bases (FIBs). Each VRF context created is associated with a FIB ID.

By default, the switch has two pre-defined VRF instances:

- the default VRF instance (`FIBID 0`)

  All switch ethernet ports are attached by default to this VRF instance.

- the management VRF instance (`FIBID 1`)

  This VRF instance is reserved for switch management and only the management interface is a member of this instance.

You can create custom named VRF instances and configure various switch interfaces and protocols to run using the specified VRF instance.

Notes:

- Up to 65 VRF instances can be configured on the switch; 63 instances for data traffic, one default, and one for management traffic.
- The supported BGP routes IPv4/IPv6/EVPN existing in BGP is limited to a maximum of 120.000 on all existing VRFs. When the limit is exceeded, a message is displayed: Memory for route nodes exceeded. Ignoring route.

To create a new custom VRF instance, use the following command:

```
Switch(config)# vrf context <VRF instance name>
```

For example, create a new custom VRF instance called ‘vrf-04’:

```
Switch(config)# vrf context vrf-04
```

To delete an existing VRF instance, use the following command:

```
Switch(config)# no vrf context <VRF instance name>
```

Notes:

- The *VRF instance name* can be up to 63 characters and it is not case-sensitive
- Creating or deleting a VRF instance does not affect the functionality of already existing VRF instances
- After deleting a VRF instance, all switch interfaces and protocols that used it are attached to the default VRF instance

To configure a VRF instance, use the following command to enter VRF configuration mode for the specified VRF instance:

```
Switch(config)# vrf context {<VRF instance name>|management}
Switch(config-vrf)#
```

After entering VRF configuration mode, you can set up IP routes that are stored in the routing table of the current VRF instance. To configure a static IP route, use the following commands:

- IPv4 routes:

```
Switch(config-vrf)# ip route <IPv4 destination prefix> <IPv4 gateway address> [<prefix distance (1-255)>] [tag <tag number (0-4294967295)>]
```

- IPv6 routes:

```
Switch(config-vrf)# ipv6 route <IPv6 destination prefix> <IPv6 gateway address> [<prefix distance (1-255)>] [tag <tag number (0-4294967295)>]
```

You can also configure Bidirectional Forwarding Detection (BFD) for static IP routes present in the VRF instance. For mode details about BFD, see “Bidirectional Forwarding Detection” on page 402.

By default, BFD is disabled. To enable BFD for a static IP route, use the following commands:

- IPv4 routes:

```
Switch(config-vrf)# ip route static bfd {<interface name>|ethernet <chassis number/port number>|mgmt 0|vlan <VLAN number (1-4094)>} <IPv4 gateway address>
```

- IPv6 routes:

```
Switch(config-vrf)# ipv6 route static bfd {<interface name>|ethernet <chassis
number/port number>|loopback <loopback interface number (0-7)>|mgmt 0|port-channel
<LAG number (1-4096)>|vlan <VLAN number (1-4094)>} <IPv6 gateway address>
```

A Route Distinguisher (RD) can be configured for each custom VRF instance. The RD is an 8-byte field added to the IPv4 address of the Virtual Private Network (VPN) route, resulting in an 12-byte unique VPN-IPv4 address, thus distinguishing between distinct VPN routes.

Note: Each RD value must be unique on the switch.

A Route Distinguisher has three major fields:

- the type field
- the administrator field
- the assigned number field

The type field determines how to interpret the administrator and assigned number fields, as shown in the following table:

Table 35. *Route Distinguisher Fields*

Type Field	Administrator Field	Assigned Number Field
type 0 (2 bytes)	*ASN2* - Autonomous System number (2 bytes)	*NN* - assigned number (4 bytes)
type 1 (2 bytes)	*IPv4* address (4 bytes)	*NN* - assigned number (2 bytes)
type 2 (2 bytes)	*ASN4* - Autonomous System number (4 bytes)	*NN* - assigned number (2 bytes)

To configure a RD for the current VRF instance, use the following command:

```
Switch(config-vrf)# rd <route distinguisher value>
```

For example:

```
Switch(config-vrf)# rd 65000:100
```

Some CLI commands allow you to specify the VRF instance. For a list of all commands that support VRF instances, please consult the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9.*

For example, when configuring a remote syslog server, you can specify the VRF instance to use when routing traffic from the switch to the syslog server.

```
Switch(config)# logging server <IP address> vrf {default|management}
```

Or, you can configure Network Time Protocol (NTP) to use a specific VRF instance when synchronizing the internal clock of the switch.

```
Switch(config)# ntp use-vrf {<VRF instance name>|default|management}
```

By default, switch interfaces, except the management interface, operate using the default VRF instance. You can change the VRF instance used by an interface using the following command:

```
Switch(config-if)# vrf member {<VRF instance name>|default|management}
```

For example, changing the VRF membership of ethernet port 1/12 from the default VRF instance to a custom VRF instance called 'VRF-Red':

```
Switch(config-if)# vrf member VRF-Red
```

Notes:

- You must first create the VRF instance and then associate the interface with the VRF instance.
- When changing the VRF instance membership of an interface, its Layer 3 configuration is discarded. The following message appears after issuing the command:

```
% Warning: Deleted all L3 config on interface(s)
```

Routing Information Base

The Routing Information Base (RIB) is a table in which the switch keeps information about known routes, like the destination IP address, the next-hop address, or the associated metric (path cost). It consists of static entries (routes manually configured) and dynamic entries (routes learned through routing protocols like BGP or OSPF).

The main objective of routing protocols is the construction of the RIB. This implies the exchange of routing information between neighboring network devices.

A route redistribution can be requested by a routing protocol. When the switch receives the request, it will share its routing information based upon the protocol that made the request. For example, if BGP requested a route redistribution, the switch will share all the routes it has learned through BGP.

Any route changes on the switch will trigger route updates to be sent to the neighboring devices. A route update is shared only if the Hardware Specific Layer (HSL) gives a positive acknowledgement for that route.

Routing protocols, such as BGP, can use the Next-Hop Lookup service to check the availability of a route.

RIB supports the maintaining of routes in a stale state for the duration of a graceful restart of the BGP service. This means that traffic forwarding is not disturbed for the duration of the restart.

There are scenarios in which the switch is not directly connect to the next-hop device through an interface. Such occurrences are called indirect next-hops.

RIB supports both normal and ECMP routes with indirect next-hops. If there is a direct route through which the next-hop is reachable (the route leads directly to the next-hop), RIB will install the direct route, instead of an indirect one.

Bidirectional Forwarding Detection

Bidirectional Forwarding Detection (BFD) is a Layer 3 detection protocol used to detect failures in the forwarding path of adjacent network routers.

For BFD to work properly, a session must be established between two devices (or BFD peers). This means BFD must be configured on both BFD peers. Once BFD has been enabled on the connecting interfaces and on the peers, a BFD session is established, followed by the negotiation of BFD timers.

Note: The switch supports up to a maximum of 100 BFD sessions.

BFD uses few system resources and provides a fast failure detection, that is independent of all media types, encapsulations, topologies, and routing protocols, like BGP or OSPF. Once a failure is detected, BFD notifies the routing protocols of the local switch to trigger a routing table update, thus reducing network convergence time.

BFD control packets are encapsulated in User Datagram Protocol (UDP) packets, that have an assigned destination port of 3784 or 3785 and source port between 49152 and 65535. BFD control packets are always sent as unicast packets to the configured BFD peer.

BFD sessions are supported for both IPv4 and IPv6 addressing.

By default, BFD is enabled on the switch. It can be enabled or disabled for each individual interface. BFD can be enabled on ethernet interfaces or loopback interfaces.

To enable or disable BFD on an interface, use the following command:

```
Switch(config-if)# [no] bfd {ipv4|ipv6}
```

Note: BFD cannot be enabled or disabled globally on the switch. It can be enabled or disabled on individual interfaces.

To configure the exchange of BFD control packets during BFD sessions, use the following command:

```
Switch(config)# [no] bfd {ipv4|ipv6} interval <interval> minrx <minrx>
multiplier <multiplier>
```

You can also configure these parameters on an interface. They can be different than those configured globally on the switch.

```
Switch(config-if)# [no] bfd interval <50-999> minrx <50-999> multiplier <3-50>
```

Notes:

- The configured intervals at which the switch sends and expects BFD control packets are only the desired values. BFD will negotiate with its BFD peer the actual values used during the BFD session when exchanging packets.
- These parameters apply to BFD control packets while BFD echo mode is disabled. If BFD echo mode is enabled, the configured parameters are applied to BFD echo packets instead.

BFD Asynchronous Mode

BFD operates in asynchronous mode, meaning that control packets are periodically exchanged between BFD peers. If a BFD peer sends consecutive control packets to its peer and does not receive any reply from the other device, it will declare the BFD session to be down.

BFD Echo Mode

If a switch is configured with BFD Echo mode, it sends its peer a series of echo packets and requests the peer to send back (echo) those hello packets the switch previously sent. If hello packets from the echoed traffic are not received by the switch, it will declare the BFD session as being down.

BFD Echo mode can run independently on each BFD peer.

By default, BFD echo mode is disabled and it can be enabled on each switch interface. To enable or disable BFD echo mode on an interface, use the following command:

```
Switch(config-if)# [no] bfd echo
```

BFD Echo mode uses a timer called slow timer that determines how fast a new BFD session is established. The slow timer also specifies the interval that asynchronous BFD sessions use to exchange control packets, replacing the BFD interval. While control packets are transmitted using the slow timer, echo packets still use the configured BFD interval.

To globally configure the BFD slow timer, in milliseconds, use the command:

```
Switch(config)# bfd slow-timer <1000-30000>
```

By default, the slow timer is set to 2000 milliseconds (2 seconds). To reset the slow timer to its default value, use the command:

```
Switch(config)# no bfd slow-timer
```

BFD Peer Support

BFD provides failure detection in the forwarding path for destinations that are directly connected one hop or more away from the switch. The maximum number of hops connecting a switch and its BFD peer is 255.

To add or remove a static single hop BFD peer on an interface, use the command:

```
Switch(config-if)# [no] bfd neighbor src-ip <source IP address> dest-ip
<destination IP address>
```

Note: The *IP address* can be either an IPv4 address or an IPv6 address.

To add or remove a static multi-hop BFD peer on an interface, use the command:

```
Switch(config-if)# [no] bfd neighbor src-ip <source IP address> dest-ip
<destination IP address> multihop
```

Different parameters (interval, minrx, and multiplier) can be globally configured for multi hop peers:

```
Switch(config)# [no] bfd multihop-peer <peer IP address> interval <50-999> minrx
<50-999> multiplier <3-50>
```

You can configure the following parameters when setting up a BFD multi-hop peer:

- the interval of outgoing BFD control and echo packets;
- the minimum rate at which to receive BFD control and echo packets;
- the number of missed BFD control and echo packets before a BFD multi-hop peer is declared unavailable.

BFD Static Routes

BFD can also be enabled on static IP routes. Only one BFD session is created for multiple static routes using the same next-hop address that run through a particular switch interface.

Note: BFD is supported only on single hop static routes, and not on multi-hop static routes.

To enable or disable BFD on a static IP route, use the command:

```
Switch(config)# [no] {ip|ipv6} route static bfd <interface> <BFD peer address>/
<prefix length>
```

Note: The *BFD peer address* can be either an IPv4 address or an IPv6 address, depending on the type of static route.

For example:

```
Switch(config)# ip route static bfd ethernet 1/12 10.10.10.0/24
```

BFD Authentication

BFD supports the enabling or disabling of authentication for BFD sessions between peers. If authentication does not match for both peers, received packets are discarded.

BFD authentication is enabled by specifying an authentication algorithm and key-chain:

- authentication algorithms:
  - simple - plain text password
  - keyed-md5 - Keyed Message Digest 5 hash algorithm
  - keyed-sha1 - Keyed Secure Hash Algorithm I
  - keyed-sha256 - Keyed Secure Hash Algorithm 256
  - meticulous-keyed-md5 - Meticulous Keyed Message Digest 5 hash algorithm
  - meticulous-keyed-sha1 - Meticulous Keyed Secure Hash Algorithm I
  - meticulous-keyed-sha256 - Meticulous Keyed Secure Hash Algorithm 256
- authentication key-chains:
  - key-id - a single key
  - key-chain - multiple keys

A key contains the secret data and the time when it becomes valid. The authentication algorithm and key-chain must be configured on both BFD peers, and must be identical. If any mismatch occurs, the BFD session cannot be established.

By default, BFD sessions are established without authentication. To configure BFD authentication on an interface, use one of the following commands:

- configure authentication to use a single key:

```
Switch(config-if)# [no] bfd [ipv4|ipv6] authentication <authentication
algorithm> key-id <0-255 (key ID)> key <key string>
```

- configure authentication to use a key-chain, containing multiple keys:

```
Switch(config-if)# [no] bfd [ipv4|ipv6] authentication <authentication
algorithm> key-chain <key-chain name>
```

For example:

```
Switch(config-if)# bfd authentication meticulous-keyed-sha1 key-chain kch7
```

Authentication can also be configured for multi-hop BFD peers:

```
Switch(config-if)# [no] bfd multihop-peer <peer IP address> authentication
<authentication algorithm> key-id <0-255 (key ID)> key <key string>
```

```
Switch(config-if)# [no] bfd multihop-peer <peer IP address> authentication
<authentication algorithm> key-chain <key-chain name>
```

Generalized TTL Security Mechanism

The Generalized TTL Security Mechanism (GTSM) provides the switch's IP-based control plane with protection from CPU utilization based attacks. It relies on a packet's TTL or hop limit to protect the switch from packets sent in a rapid succession.

By default, GTSM is disabled. To enable or disable GTSM for BFD, use the following command:

```
Switch(config)# bfd gtsm {enable|disable}
```

By default, GTSM uses a TTL or hop limit of 255. To change the TTL or hop limit, run the following command:

```
Switch(config)# bfd gtsm ttl <1-255>
```

To reset the TTL or hop limit to its default value of 255, use the following command:

```
Switch(config)# no bfd gtsm ttl <1-255>
```

BFD and BGP

When BFD detects a forwarding failure, it immediately notifies its client protocols.

BFD can work together with BGP to prevent the use of aggressive keep-alive timers. To keep this timer below 10 or 30 seconds, it is recommended to use BFD as well. BFD is compatible with both eBGP and iBGP single or multi-hop peers.

BFD and OSPF

When BFD detects a forwarding failure, it immediately notifies its client protocols.

BFD can work together with OSPF to increase route convergence as an alternative to adjusting the OSPF Hello Interval and Dead Interval. BFD improves the speed of failure detection by having shorter timer limits than the OSPF failure detection mechanisms.

Routing Between IP Subnets

The physical layout of most corporate networks has evolved over time. Classic hub/router topologies have given way to faster switched topologies, particularly now that switches are increasingly intelligent. The switch is intelligent and fast enough to perform routing functions at wire speed.

The combination of faster routing and switching in a single device allows you to build versatile topologies that account for legacy configurations.

For example, consider a corporate campus that has migrated from a router-centric topology to a faster, more powerful, switch-based topology. As is often the case, the legacy of network growth and redesign has left the system with a mix of illogically distributed subnets.

This is a situation that switching alone cannot cure. Instead, the router is flooded with cross-subnet communication. This compromises efficiency in two ways:

- Routers can be slower than switches. The cross-subnet side trip from the switch to the router and back again adds two hops for the data, slowing throughput considerably.
- Traffic to the router increases, increasing congestion.

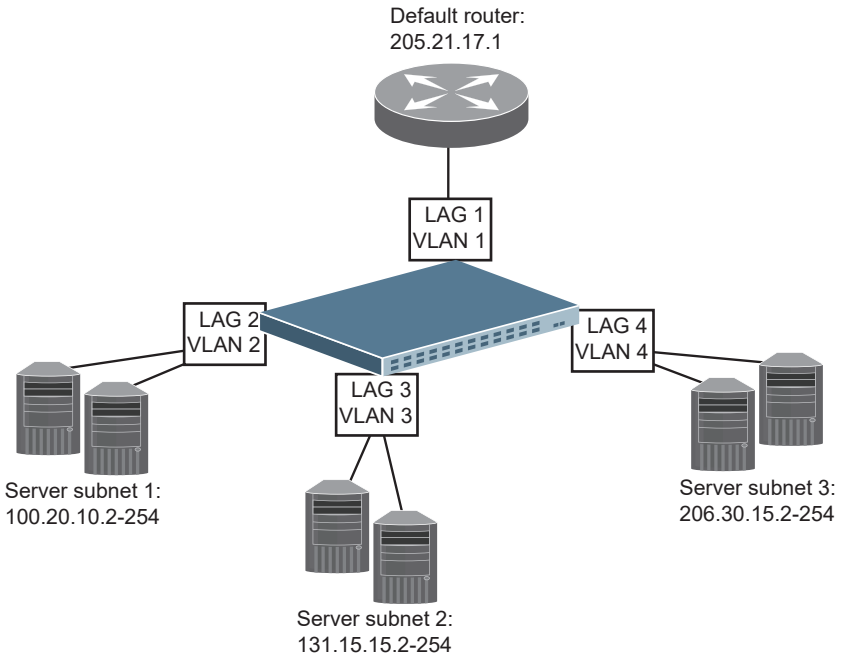
Even if every end-station could be moved to better logical subnets (a daunting task), competition for access to common server pools on different subnets still burdens the routers.

This problem is solved by using switches with built-in IP routing capabilities. Cross-subnet LAN traffic can now be routed within the switches with wire speed switching performance. This eases the load on the router and saves the network administrators from reconfiguring every end-station with new IP addresses.

Example of Subnet Routing

Consider the role of the switch in the following configuration example:

Figure 11. Switch-Based Routing Topology



The switch connects the Gigabit Ethernet and Fast Ethernet LAGs from various switched subnets throughout one building. Common servers are placed on another subnet attached to the switch. A primary and backup router are attached to the switch on yet another subnet.

Without Layer 3 IP routing on the switch, cross-subnet communication is relayed to the default gateway (in this case, the router) for the next level of routing intelligence. The router fills in the necessary address information and sends the data back to the switch, which then relays the packet to the proper destination subnet using Layer 2 switching.

With Layer 3 IP routing in place on the switch, routing between different IP subnets can be accomplished entirely within the switch. This leaves the routers free to handle inbound and outbound traffic for this group of subnets.

Using VLANs to Segregate Broadcast Domains

If you want to control the broadcasts on your network, use VLANs to create distinct broadcast domains. Create one VLAN for each server subnet and one for the router.

Configuration Example

This section describes the steps used to configure the example topology shown in Figure 11 on page 408.

1. Assign an IP address for each router and each server.

   The following IP addresses are used:

   Table 36. *Subnet Routing Example: IP Address Assignments*

Subnet	Devices	IP Addresses
1	Default router	205.21.17.1
2	Web servers	100.20.10.2-254
3	Database servers	131.15.15.2-254
4	Terminal Servers	206.30.15.2-254

2. Assign an IP interface for each subnet attached to the switch.

   Since there are four IP subnets connected to the switch, four interfaces are needed:

   Table 37. *Subnet Routing Example: IP Interface Assignments*

Interface	Devices	IP Interface Address
Port 1	Default router	205.21.17.3
Port 2	Web servers	100.20.10.1
Port 3	Database servers	131.15.15.1
Port 4	Terminal Servers	206.30.15.1

3. Determine which switch ports belong to which VLANs.

   The following table adds port and VLAN information:

   Table 38. *Subnet Routing Example: Optional VLAN Ports*

Devices	LAG	Switch Ports	VLAN
Default router	1	22	1
Web servers	2	1 and 2	2
Database servers	3	3 and 4	3
Terminal Servers	4	5 and 6	4

Note: To perform this configuration, you must be connected to the switch Command Line Interface (CLI) as the administrator.

4. Add the switch ports to their respective VLANs:

```
Switch(config)# vlan 1-4
Switch(config-vlan)# exit

Switch(config)# interface ethernet 1/22
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 1
Switch(config-if)# channel-group 1 mode on
Switch(config-if)# exit

Switch(config)# interface ethernet 1/1-2
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 2
Switch(config-if)# channel-group 2 mode on
Switch(config-if)# exit

Switch(config)# interface ethernet 1/3-4
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 3
Switch(config-if)# channel-group 3 mode on
Switch(config-if)# exit

Switch(config)# interface ethernet 1/5-6
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 4
Switch(config-if)# channel-group 4 mode on
Switch(config-if)# exit
```

5. Now that the ports are separated into LAGs, the VLANs are assigned to the appropriate interfaces for each subnet. From Table 38 on page 409, the settings are made as follows:

```
Switch(config)# interface vlan 1
Switch(config-if)# ip address 205.21.17.3/24
Switch(config-if)# exit

Switch(config)# interface vlan 2
Switch(config-if)# ip address 100.20.10.1/24
Switch(config-if)# exit

Switch(config)# interface vlan 3
Switch(config-if)# ip address 131.15.15.1/24
Switch(config-if)# exit

Switch(config)# interface vlan 4
Switch(config-if)# ip address 206.30.15.1/24
Switch(config-if)# exit
```

6. Configure the default gateway to the routers' addresses.

   The default gateway allows the switch to send outbound traffic to the router:

```
Switch(config)# ip route 0.0.0.0/0 205.21.17.1
```

7. Verify the configuration.

```
Switch# show vlan

VLAN    Name                             Status  IPMC FLOOD Ports
======= ================================ ======= ========== ===============
1       default                          ACTIVE  IPv4,IPv6  Ethernet1/1(u)
                                                            Ethernet1/2(u)
                                                            Ethernet1/6(u)
                                                            Ethernet1/7(u)
                                                            Ethernet1/8(u)
                                                            Ethernet1/9(u)
                                                            Ethernet1/11(u)
                                                            Ethernet1/12(u)
                                                            Ethernet1/13(u)
                                                            Ethernet1/17(u)
                                                            Ethernet1/18(u)
                                                            Ethernet1/19(u)
                                                            Ethernet1/21(u)
...
```

```
Switch# show interface brief

--------------------------------------------------------------------------------
Ethernet      VLAN  Type Mode   Status  Reason                 Speed Port
Interface                                                     
Agg#
--------------------------------------------------------------------------------
Ethernet1/1   1     eth  access down    Link not connected     auto   --
Ethernet1/2   1     eth  access down    Link not connected     auto   --
Ethernet1/3   19    eth  access up      none                   10000  --
Ethernet1/4   20    eth  access down    Administratively down  auto   --
Ethernet1/5   --    eth  routed down    Administratively down  auto   --
Ethernet1/6   1     eth  access down    Link not connected     auto   --
Ethernet1/7   1     eth  access down    Link not connected     auto   --
Ethernet1/8   1     eth  access down    Link not connected     auto   --
Ethernet1/9   1     eth  access down    Link not connected     auto   --
Ethernet1/10  --    eth  routed down    Administratively down  auto   --
...
```

```
Switch# show ip interface brief

Interface            IP-Address      Admin-Status          Link-Status
Ethernet1/5          21.1.1.1        administratively down down
Ethernet1/10         191.1.1.1       administratively down down
Ethernet1/14         16.1.1.2        up                    up
Ethernet1/20         116.0.0.1       up                    down
Ethernet1/22         22.1.1.2        administratively down down
mgmt0                10.241.40.13    up                    up
Vlan17               17.1.1.2        up                    down
Vlan18               18.1.1.2        up                    down
Vlan19               19.1.1.1        up                    up
Vlan20               20.1.1.1        up                    down
Vlan23               23.1.1.2        up                    down
Vlan24               24.1.1.2        up                    down
```

Examine the resulting information. If any settings are incorrect, make the appropriate changes.

ECMP Routes

Equal-Cost Multi-Path (ECMP) is a forwarding mechanism that routes packets along multiple paths of equal cost. ECMP provides equally-distributed link load sharing across the paths. ECMP routes allow the switch to choose between several next-hops toward a given destination. The switch performs periodic health checks (ping) on each ECMP gateway. If a gateway fails, it is removed from the routing table and an SNMP trap is sent.

RIB Support for ECMP Routes

RIB supports the adding of multiple next-hops to the same route. Such routes are called Equal Cost Multiple Paths (ECMP) routes.

The maximum number of different next-hops permitted for a route can be changed. To configure the maximum number of different paths for an ECMP route, use the following command:

```
Switch(config)# maximum-paths <1-32>
```

By default, the switch allows up to 32 paths for a single route. To reset this number to its default value, use the following command:

```
Switch(config)# no maximum-paths
```

ECMP Hashing

In case of an ECMP route, the next-hop address will be chosen based on a hash algorithm. The hashing parameters used are:

- source IP address
- destination IP address
- source and destination IP addresses
- Layer 4 source port
- Layer 4 destination port
- Layer 4 source and destination ports

To configure the hashing parameters, use the following command:

```
Switch(config)# ip load-sharing <hashing parameters> [universal-id <1-4294967295>]
```

Note: The universal ID is used to randomize the hashing result for each pair of source and destination addresses.

By default, the hash algorithm utilizes the all four hashing parameters and has a universal ID of 1431655765. To reset the hash algorithm to its default settings, use the following command:

```
Switch(config)# no ip load-sharing
```

To view the current hash settings, use the following command:

```
Switch# show ip load-sharing
```

When ECMP is configured in a multi-tier network, where multiple redundant paths are present, the hash algorithm on neighboring switches, that have the same hashing parameters, may calculate the same path for outgoing traffic. This results in a congestion of traffic on a upstream switch, while leaving other ECMP routes completely unused, thus negating the redundancy of the network.

To avoid such scenarios, a hash offset can be introduced in the hash algorithm calculations. The hash offset is just a number that is taken into account when calculating the hashing result. By default, the hash offset is set to 0, therefore having no influence on the hash calculation. When it is set to a non-zero value, the hash offset ensures that a different ECMP route is chosen.

Use the following command to set an ECMP hash offset:

```
Switch(config)# hardware ecmp hash-offset <0-15>
```

To reset it to its default value, use the following command:

```
Switch(config)# no hardware ecmp hash-offset
```

Note: ECMP hashing is not available for IPv6 traffic.

Configuring ECMP Static Routes

To configure ECMP static routes, add the same route multiple times, each with the same destination IP address, but with a different gateway IP address. These routes become ECMP routes.

1. Add a static route (IP address, prefix length and gateway).

```
Switch(config)# ip route 10.10.1.1/32 100.10.1.1
```

2. Continue adding static routes with the same IP address and prefix length, but a different gateway address.

```
Switch(config)# ip route 10.10.1.1/32 200.20.2.2
...
```

3. Select an ECMP hashing method (optional).

```
Switch(config)# ip load-sharing source-dest-ip
```

You may add up to 32 gateways for each static route.

4. Use the following command to check the status of ECMP static routes:

```
Switch(config)# show ip route static
```

Weighted ECMP Routes

In traditional ECMP with next hops, each next hop is added to the ECMP multipath once so traffic is distributed equally among the next hops. However, in some scenarios, traffic may use one path more than others, causing congestion. A lack of balance can occur because the ECMP hashing algorithm only considers the source, destination, or both when selecting the path, but not the use of the link.

Weighted ECMP lets you configure the multipath based on the use of each link, thus avoiding congestion and obtaining a better balance of traffic. This is achieved by adding the next hops in the multipath from one to four times.

Requirements for Weighted ECMP

To use weighted ECMP routes, you must have the following:

- ECMP route support
- Change hardware multipath group size to at least 128 paths once weighted ECMP is enabled

Notes:

- The next hop weights are reset when you enable or disable weighted ECMP, or when you change the maximum number of paths
- The ECMP route weights are set dynamically and are not part of the running or startup configurations

Configure Weighted ECMP

To configure weighted ECMP routes:

1. Enable weighted ECMP on the switch:

```
Switch(config)# ip ecmp weight enable
```

2. Configure the ECMP weight for a route:
   - specify its next-hop IPv4 or IPv6 address:

```
Switch(config)# ip ecmp weight 143.61.90.178 3
```

   - or specify its switch interface:

```
Switch(config)# ip ecmp weight interface ethernet 1/12 3
```

3. Check the weighted ECMP configuration:

```
Switch(config)# show ip ecmp weight interface ethernet 1/12
```

To disable weighted ECMP routes, enter:

```
Switch(config)# no ip ecmp weight enable
```

Dynamic Host Configuration Protocol

Dynamic Host Configuration Protocol (DHCP) is a transport protocol that provides a framework for automatically assigning IP addresses and configuration information to other IP hosts or clients in a large TCP/IP network. Without DHCP, the IP address must be entered manually for each network device. DHCP allows a network administrator to distribute IP addresses from a central point and automatically send a new IP address when a device is connected to a different place in the network.

The switch accepts gateway configuration parameters if they have not been configured manually. The switch ignores DHCP gateway parameters if the gateway is statically configured.

DHCP is an extension of another network IP management protocol, Bootstrap Protocol (BOOTP), with an additional capability of being able to allocate reusable network addresses and configuration parameters for client operation.

Built on the client/server model, DHCP allows hosts or clients on an IP network to obtain their configurations from a DHCP server, thereby reducing network administration. The most significant configuration the client receives from the server is its required IP address.

The switch support DHCP for both IPv4 and IPv6 addressing.

To enable or disable DHCP, use the following command:

```
Switch(config)# [no] feature dhcp
```

By default, DHCP is enabled on the management port, but disabled on all other switch Layer 3 interfaces.

For more details about DHCP, see "DHCP IP Address Services" on page 58.

Internet Control Message Protocol

The Internet Control Message Protocol (ICMP) is used to send error messages indicating, for example, that a network device is unreachable. ICMP messages are primarily used for diagnostic and control purposes.

ICMP errors are sent back to the source device of the IP packet. For example, when a packet crosses a network node, its TTL decreases by one. When the TTL reaches zero, the packet is discarded and an ICMP error message is sent to source device.

ICMP messages are used by many network utilities, such as Traceroute or Ping.

ICMP messages are identified by type and code, that is used to identify the type of message. Following are a few of the most common ICMP message types:

- 0 - echo reply

  An echo reply is generated when the switch receives an echo request (ping) and it indicates that the switch can be reached.

- 3 - destination unreachable

  It means that there is error along the path to the destination device. This type has multiple codes that indicate the cause.

- 5 - redirect

  The switch detects that the packet is not optimally forwarded to its destination.

- 11 - time exceeded

  The TTL of the packet has reached zero.

ICMP can be configured independently on each switch interface.

To view the current settings regarding ICMP, use the following command:

```
Switch# show ip interface

IP Interface Status for VRF (default)
 loopback0, Interface Status: link up/admin up
 IP MTU:1500 bytes (using link MTU)
 IP icmp redirects: enabled
 IP icmp unreachables (except port): disabled
 IP icmp port-unreachable: enabled

 Vlan1, Interface Status: link up/admin up
 IP address: 205.21.17.1, IP subnet: 205.21.17.0/24
 IP MTU:1500 bytes (using link MTU)
 IP icmp redirects: enabled
 IP icmp unreachables (except port): disabled
 IP icmp port-unreachable: enabled
...
```

ICMP Redirects

The switch generates an ICMP redirect message when it detects that a packet is not optimally forwarded to the destination and sends the message to inform the source device to send future packets along the optimal path across the network. This kind of ICMP messages are identified as type 5.

For example, the switch, a host device and a neighboring router are all directly connected with each other. The switch is configured as the default gateway for the host. The host sends the switch a packet with a destination that is reachable only through the router. The switch sends host an ICMP redirect error and informs the host to send subsequent packets directly to the router, thus reducing the number of hops to the destination by one.

By default, ICMP redirect errors are enabled on all interfaces.

To enable or disable ICMP redirect error messages, use the following command:

```
Switch(config-if)# [no] ip redirects
```

ICMP Port Unreachable

The switch generates an ICMP port unreachable message when the interface of destination device is unavailable and sends the message to inform the source device of this. This kind of ICMP messages are identified as type 3, having error code 3.

By default, ICMP port unreachable errors are enabled on all interfaces.

To enable or disable ICMP port unreachable error messages, use the following command:

```
Switch(config-if)# [no] ip port-unreachable
```

ICMP Unreachable (except Port)

The switch generates an ICMP unreachable message when the destination device is not available. This kind of ICMP messages are identified as type 3 and have multiple error codes, ranging from 0 to 15. For example, an error code 1 means that the destination device could not be reached, while an error code 2 means that the protocol for which the packet was intended is not available, but the destination device is reachable.

By default, ICMP unreachable errors, except port unreachable messages, are disabled on all interfaces.

To enable or disable ICMP unreachable error messages (except port unreachable), use the following command:

```
Switch(config-if)# [no] ip unreachables
```

Chapter 17. Routed Ports

By default, all ports on the switch behave as switch ports, which are capable of performing Layer 2 switch functions, such as VLANs, STP, or bridging. Switch ports also provide a physical point of access for the switch IP interfaces, which can perform global Layer 3 functions, such as routing for BGP or OSPF.

However, switch ports can also be configured as routed ports. Routed ports are configured with their own IP address belonging to a unique Layer 3 network and behave similar to a port on a conventional router. Routed ports are typically used for connecting to a server or to a router.

This section discusses the following topics:

Routed Ports Overview

When a switch port is configured as a routed port, it forwards Layer 3 traffic and no longer performs Layer 2 switching functions.

By default, all ethernet ports are configured as switch access ports. To configure the port to operate as a routed port, see "Configuring a Routed Port" on page 423.

You can also assign an IP address to a routed port and configure OSPF to route IP traffic through the interface.

A routed port has the following characteristics:

- Does not participate in bridging.
- Does not belong to any user-configurable VLAN.
- Does not implement any Layer 2 functionality, such as the Spanning Tree Protocol (STP).
- Is always in a forwarding state.
- Can participate in IPv4 or IPv6 routing.
- Can be configured with basic IP protocols, such as Internet Control Message Protocol (ICMP) and with Layer 3 protocols, such as Open Shortest Path First (OSPF) or Virtual Router Redundancy Protocol (VRRP).
- Layer 3 applications can be enabled, such as Network Time Protocol (NTP) or Dynamic Host Configuration Protocol (DHCP).
- Layer 3 configuration is saved even when the interface is shutdown.
- MAC address learning is always enabled.
- Native VLAN tagging is disabled.
- Flooding is disabled.
- Bridge Protocol Data Unit (BPDU)-guard is disabled.
- Link Aggregation Control Protocol (LACP) is disabled.
- Multicast threshold is disabled.

Notes:

- Ports on which Link Aggregation Control Protocol (LACP) is enabled or are part of a Link Aggregation Group (LAG) cannot be changed to routed ports.
- Ports with configured static MAC addresses cannot be changed to routed ports.
- By default, SVI interfaces not configured with an IP address forward traffic towards its destination.
- For the Lenovo G8296 RackSwitch, the maximum number of routed ports is 94.

When a switch port is configured as a routed port, the following configuration changes are automatically implemented:

- The port is removed from all the VLANs it belonged to.
- The port is added to the first available internal VLAN on which flooding is disabled. The ID of this internal VLAN will be between 4000 - 4093, starting in descending order from 4093. The internal VLAN is assigned to the Common Internal Spanning Tree (CIST). You cannot change the VLAN number assigned to the routed port.
- STP is disabled and the port is set to a forwarding state.
- All the Layer 2 configuration is lost.
- The port will be deleted from the bridge.
- MAC Access Control Lists (ACL) from the Layer 2 port will be removed.

When a routed port is changed back to a switch port, the following changes take place:

- All relevant Layer 3 configuration is lost. Common Layer 3 and Layer 2 settings will be preserved during the transition.
- The ARP entry corresponding to the IP address is lost.
- The switch port is added to the default VLAN (VLAN 1).
- STP is turned on and the port is added to the default STG (STG 1).
- The switch port can participate in STG and VLAN flooding.
- The switch port can participate in bridging.
- LACP port attributes are set to default.
- Multicast threshold remains disabled.
- BPDU guard remains disabled.
- QoS configurations is lost.
- IP Access Control Lists (ACL) are removed.

Note: When you configure a routed port back to a switch port, it does not restore the Layer 2 configuration it had before it was changed to a routed port.

802.1Q Encapsulation

802.1Q encapsulation inserts a 802.1Q tag into Ethernet frames transmitted through a Layer 3 routed port that identifies to which VLAN the frame belongs.

802.1Q encapsulation adds a 802.1Q tag after the source and destination MAC address fields of the outgoing routed packet. The tag contains the VLAN identifier which can be configured for each Layer 3 routed interface.

Configuring 802.1Q encapsulation on a Layer 3 routed port also enables the receiving of VLAN tagged packets on that switch interface only if the VLAN tag of the received packet has the same value as the configured 802.1Q tag.

To configure 802.1Q encapsulation on a Layer 3 routed port, use the following command:

```
Switch(config-if)# encapsulation dot1q <VLAN ID (1-4093)>
```

To disable 802.1Q encapsulation, use the following command:

```
Switch(config-if)# no encapsulation dot1q
```

Note: 802.1Q encapsulation can be enabled only on Layer 3 routed ports.

Configuring a Routed Port

Use only the ISCLI to configure routed ports. Configurations made using SNMP cannot be saved or applied.

Note: You cannot configure a management interface to be a routed port.

Following are the basic steps for configuring a routed port:

1. Enter the interface configuration mode for the port (for this example, ethernet interface 1/12 is used).

```
Switch(config)# interface ethernet 1/12
```

2. Enable routing.

```
Switch(config-if)# no switchport
```

3. Assign an IP address.

   a. an IPv4 address:

```
Switch(config-if)# ip address <IPv4 address>/<prefix length>
```

   b. an IPv6 address:

```
Switch(config-if)# ipv6 address <IPv6 address>/<prefix length>
```

4. Optionally, make sure the interface is in uplink state:

```
Switch(config-if)# no shutdown
```

5. Optionally, you can set the maximum transmission unit (MTU) size in bytes for received or sent frames for the routed port:

```
Switch(config-if)# mtu <64-9216>
```

   Note: The default value is 1,500 bytes.

6. Check the interface configuration:

```
Switch(config-if)# show interface ethernet 1/12

Interface Ethernet1/12
  Hardware is Ethernet  Current HW addr: a897.dcde.2501
  Physical:a897.dcde.250e  Logical:(not set)
  index 11 metric 1 MTU 1500 Bandwidth 10000000 Kbit
  no switchport
  arp ageing timeout 1500
  <UP,BROADCAST,MULTICAST>
  VRF Binding: Not bound
  Speed 10000 Mb/s Duplex full
  DHCP client is disabled.
...
```

Configuring OSPF on Routed Ports

The following OSPF configuration commands are supported on routed ports:

```
Switch(config-if)# ip ospf ?

  A.B.C.D              Address of interface
  authentication       Enable authentication
  authentication-key   Authentication password (key)
  bfd                  Bidirectional Forwarding Detection (BFD)
  cost                 Interface cost
  database-filter      Filter OSPF LSA during synchronization and
                       flooding
  dead-interval        Interval after which a neighbor is declared dead
  hello-interval       Time between HELLO packets
  message-digest-key   Message digest authentication password (key)
  mtu                  OSPF interface MTU
  mtu-ignore           Ignores the MTU in DBD packets
  network              Network type
  passive-interface    Suppress routing updates on an interface or on all
                       interfaces
  priority             Router priority
  retransmit-interval  Time between retransmitting lost link state
                       advertisements
  shutdown             Shutdown OSPF
  transmit-delay       Link state transmit delay

Switch(config-if)# ip router ospf 0 ?

  area        Set the OSPF area ID
  multi-area  Set the multi-area-adjacency
```

See Chapter 23, "Open Shortest Path First," for details on the OSPF protocol and its configuration.

For a full description of the above OSPF commands, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

Note: OSPFv3 cannot be configured on routed ports.

OSPF Configuration Example

The following example includes the basic steps for configuring OSPF on a routed port:

1. Enable OSPF on the switch and configure the OSPF router ID:

```
Switch(config)# router ospf
Switch(config-router)# router-id <IPv4 address>
Switch(config-router)# exit
Switch(config)#
```

2. Make the routed port part of OSPF area 0:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# ip router ospf 0 area 0
```

Chapter 18. Address Resolution Protocol

The Address Resolution Protocol (ARP) is a protocol that maps an IPv4 address to a MAC address. ARP uses a request and reply mechanism to determine the MAC address of the destination host.

This section discusses the following topics:

ARP Overview

When an IP packet is sent across the local network, from one device to another, the source host must know the MAC address of the destination host. If the address is known, the source device encapsulates the IP packet in a layer 2 frame containing the destination MAC address and then transmits the packet over the LAN. If the MAC address is unknown, the source device uses ARP to determine it.

The protocol sends an ARP broadcast message across the local network, requesting the MAC address of the device with the specified destination IP address. When the owner of the IP address receives the ARP broadcast, it will send the requesting device an ARP unicast message containing its MAC address. The source device will store the received MAC address in its ARP table and start sending traffic. The source MAC address is also kept in the ARP table of the destination device.

MAC addresses learned using ARP are kept in an ARP table, which is independent of the Forwarding Database (FDB). The ARP tables consists of MAC addresses and their associated IP addresses. The ARP table can contain up to a maximum of 48,000 entries.

To view the contents of the ARP table, use the following command:

```
Switch> show ip arp
```

ARP only operates in the boundaries of a single network and it is never routed across network nodes.

Notes:

- ARP only works in IPv4 local networks. In IPv6 environments, the functionality of ARP is provided by the Neighbor Discovery Protocol (NDP). For more details, see "Neighbor Discovery" on page 438.
- ARP can only be configured on routed ports or switch virtual interfaces (SVI). When a routed port using ARP changes to a switch port, any ARP entries (dynamic or static) associated with that port are removed from the ARP table.
- The same HW table is shared by both IGMP and ARP entries, thus one of these features could fill the entire table leaving the other one unable to add its own entries. If an ARP entry cannot be added to the HW when configuring an IP address on an interface, an error message is displayed on the console: Can't set interface IP address; HW ARP table full.

ARP Aging Timer

Because the ARP table has a limited size, ARP periodically removes unused entries by assigning each entry an aging timer. When the timer expires, the entry is refreshed by sending an ARP request. If ARP does not receive any replies for three consecutive requests, the entry is removed from the ARP table.

The aging timer of an ARP entry is reset if the switch receives an IP packet from the device mapped to that entry before the timer expires.

To configure the aging time of ARP entries, in seconds, use the following command:

```
Switch(config)# ip arp timeout <60-28800>
```

By default, the aging time of ARP entries is 1500 seconds (25 minutes). To reset the aging time to its default value, use the following command:

```
Switch(config)# no ip arp timeout
```

Notes:

- The aging time of ARP entries can be also individually configured for each routed port or switch virtual interface (SVI).
- Static ARP entries are permanent and are not affected by aging.

To view the aging time of ARP entries, use the following command:

```
Switch> show ip arp
```

ARP Inspection

Access Control Lists (ACLs) can be configured to filter ARP packets received on VLANs. An ARP ACL is used to deny or permit ARP requests or replies based on various fields from the ARP packet. For more details on how to configure an ARP ACL, see Chapter 7, "Access Control Lists".

To enable or disable ARP inspection, use the following command:

```
Switch(config)# [no] ip arp inspection filter <ARP ACL name> vlan <VLAN ID>
```

For example, enable ARP inspection for VLANs 100-105 to filter traffic based on an ARP ACL called `arp-acl-22`:

```
Switch(config)# ip arp inspection filter arp-acl-22 vlan 100-105
```

To display DAI information, use the following command:

```
Switch> show ip arp inspection
```

Static ARP Entries

Up to a maximum of 512 static ARP entries can be configured on the switch.

Static ARP entries do not have an aging timer associated with them. They are permanently kept in the ARP table until they are manually removed. A static ARP entry will overwrite any dynamic entries associated with the specified IP address.

Static ARP entries are configured individually on each routed port of the switch.

To add a static ARP entry, use the following command:

```
Switch(config-if)# ip arp <IPv4 address> <MAC address>
```

To remove a static ARP entry, use the following command:

```
Switch(config-if)# no ip arp <IPv4 address>
```

Static ARP Configuration Example

To add a static ARP entry, use the following steps:

1. Configure the ethernet interface as a routed port (for this example, ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# no switchport
```

2. Configure the IPv4 address of the routed port:

```
Switch(config-if)# ip address <IPv4 address>/<prefix length>
```

For example:

```
Switch(config-if)# ip address 10.0.0.1/24
```

3. Configure the static ARP entry:

```
Switch(config-if)# ip arp <IPv4 address> <MAC address>
```

Note: The IP address used for the static ARP entry must be part of the same network as the routed port.

For example:

```
Switch(config-if)# ip arp 10.0.0.93 0080.c8e8.1efc
Switch(config-if)# exit
```

4. Verify the ARP table:

```
Switch(config)# exit
Switch# show ip arp static
```

ARP Entry States

ARP assigns a state to each entry in the ARP table. Depending on the state of each entry, ARP will take certain actions.

The following list describes each state and the actions taken by ARP:

- NOARP - is used for neighbors that do not require ARP, like interfaces connect using Point-to-Point Protocol (PPP).
- PERMANENT - is used for static ARP entries. ARP entries with this state are not affected by aging and are not removed from the ARP table, unless they are manually deleted.
- INCOMPLETE - is used for unmapped IP addresses. An ARP request has been sent and the protocol is waiting for an ARP reply, containing the MAC address that needs to be assigned to the incomplete entry.
- REACHABLE - is used for mapped IP addresses. When an ARP reply is received, the MAC address is associated with the destination IP address and the ARP entry is now complete. The aging timer is started for that entry. If an IP packet is received from a device mapped to an ARP entry before its aging timer expires, the timer is reset.
- STALE - is used when the base reachable timer for an ARP entry has expired. Although the entry is still present in the ARP table, its reachability has not been confirmed for the duration of the timer. The next time a packet is sent to the owner of the MAC address associated with a stale ARP entry, the reachability verification process will be started.
- DELAY - is used when an IP packet needs to be sent to a device mapped to a stale ARP entry. This is temporary, until the switch sends an ARP request.
- PROBE - is used when the protocol rechecks an expired entry. An ARP request is sent to determine the MAC address of the destination IP address.
- FAILED - is used for ARP entries that could not be rechecked. If the switch does not receive any ARP replies after three consecutive requests, the entry is marked as failed and it is removed when the ARP table is refreshed.

To view the state of ARP entries, use the following command:

```
Switch> show ip arp
```

ARP Table Refresh

Each ARP entry is checked periodically to determine its state. Based on the entry's state, ARP undertakes certain actions, like refreshing the entry or removing it from the ARP table.

An ARP table refresh can be manually triggered. The switch will recheck each dynamic ARP entry by placing it in the probe state and sending an ARP request. If the switch does not received any ARP replies after three consecutive requests, it places the ARP entry in the incomplete state. If the switch receives an ARP reply, the entry is placed in the reachable state. After all the ARP entries are checked, the switch removes the incomplete entries from the ARP table.

To manually trigger a refresh of the ARP table, use the following command:

```
Switch# clear ip arp
```

To enable refreshing the ARP table right after it expires, use the following command:

```
Switch(config)# ip arp timeout refresh
```

Note: This command does not reset the timeout to the default value.

To disable refreshing the ARP table right after it expires, use the following command:

```
Switch(config)# no ip arp timeout refresh
```

To disable refreshing the ARP table right after it expires and reset the timeout value to the default value, use the following command:

```
Switch(config)# no ip arp timeout
```

To delete all dynamic entries from the ARP table, use the following command:

```
Switch# clear ip arp force-delete
```

To display current configuration of ARP refresh and timeout, use the following command:

```
Switch# show ip arp
```

Proxy ARP

Proxy ARP is a technique in which a device on a given network answers ARP requests intended for another device. The proxy ARP is aware of the location of the traffic's destination and offers its own MAC address as the destination. The received traffic is then routed by the proxy device to the intended destination via another interface or a tunnel. Proxy ARP is primarily used when hosts in the connected subnet are separated by features such as a private VLAN. Proxy ARP is defined in RFC 1027.

CNOS supports restricted proxy ARP mode. This feature enables the proxy device to respond to ARP requests if the following are both true:

- The destination IP address is not on the same physical network as the source of the request.
- The proxy device has a route to the target address of the ARP request.

Proxy ARP Limitations

The following limitations apply to proxy ARP:

- Proxy ARP can only be enabled on routed interfaces (Ethernet or VLAN); it cannot be enabled on management or loopback interfaces.
- The proxy device must have an active route to the destination address of the ARP request.

Configure Proxy ARP

Proxy ARP is disabled by default. It can be enabled or disabled in Interface Configuration mode for a specific interface. To enable or disable proxy ARP, use the command:

```
Switch(config-if)# [no] ip proxy-arp
```

Chapter 19. Internet Protocol Version 6

Internet Protocol version 6 (IPv6) is a network layer protocol intended to expand the network address space. IPv6 is a robust and expandable protocol that meets the need for increased physical address space. The switch supports the following RFCs for IPv6-related features:

- RFC 1981
- RFC 2460
- RFC 4291
- RFC 4429
- RFC 4861
- RFC 4862
- RFC 4443

The following topics are discussed in this section:

IPv6 Address Format

The IPv6 address is 128 bits (16 bytes) long and is represented as a sequence of eight 16-bit hex values, separated by colons.

Each IPv6 address has two parts:

- Subnet prefix representing the network to which the interface is connected
- Local identifier, either derived from the MAC address or user-configured

The preferred hexadecimal format is as follows:

```
xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx
```

Example IPv6 address:

```
FEDC:BA98:7654:BA98:FEDC:1234:ABCD:5412
```

Some addresses can contain long sequences of zeros. A single contiguous sequence of zeros can be compressed to :: (two colons). For example, consider the following IPv6 address:

```
FE80:0:0:0:2AA:FF:FA:4CA2
```

The address can be compressed as follows:

```
FE80::2AA:FF:FA:4CA2
```

Unlike IPv4, a subnet mask is not used for IPv6 addresses. IPv6 uses the subnet prefix as the network identifier. The prefix is the part of the address that indicates the bits that have fixed values or are the bits of the subnet prefix. An IPv6 prefix is written in address/prefix-length notation. For example, in the following address, 64 is the network prefix:

```
21DA:D300:0000:2F3C::/64
```

IPv6 addresses can be either user-configured or automatically configured. Automatically configured addresses always have a 64-bit subnet prefix and a 64-bit interface identifier. In most implementations, the interface identifier is derived from the switch's MAC address, using a method called EUI-64.

Most Cloud NOS 10.9 features permit IP addresses to be configured using either IPv4 or IPv6 address formats. Throughout this manual, *IP address* is used in places where either an IPv4 or IPv6 address is allowed. In places where only one type of address is allowed, the type (IPv4 or IPv6) is specified.

IPv6 Address Types

IPv6 supports three types of addresses:

- unicast (one-to-one)
- multicast (one-to-many)
- anycast (one-to-nearest)

Multicast addresses replace the use of broadcast addresses.

Unicast Address

Unicast is a communication between a single host and a single receiver. Packets sent to a unicast address are delivered to the interface identified by that address. IPv6 defines the following types of unicast address:

- Global Unicast address: An address that can be reached and identified globally. Global Unicast addresses use the high-order bit range up to FF00, therefore all non-multicast and non-link-local addresses are considered to be global unicast. A manually configured IPv6 address must be fully specified. Autoconfigured IPv6 addresses are comprised of a prefix combined with the 64-bit EUI. RFC 4291 defines the IPv6 addressing architecture.

  The interface ID must be unique within the same subnet.

- Link-local unicast address: An address used to communicate with a neighbor on the same link. Link-local addresses use the format `FE80::EUI`

  Link-local addresses are designed to be used for addressing on a single link for purposes such as automatic address configuration, neighbor discovery, or when no routers are present.

  Routers must not forward any packets with link-local source or destination addresses to other links.

Multicast

Multicast is communication between a single host and multiple receivers. Packets are sent to all interfaces identified by that address. An interface may belong to any number of multicast groups.

A multicast address (FF00 - FFFF) is an identifier for a group interface. The multicast address most often encountered is a solicited-node multicast address using prefix `FF02::1:FF00:0000/104` with the low-order 24 bits of the unicast or anycast address.

The following well-known multicast addresses are pre-defined. The group IDs defined in this section are defined for explicit scope values, as follows:

`FF00:::::::0` through `FF0F:::::::0`

Anycast

Packets sent to an anycast address or list of addresses are delivered to the nearest interface identified by that address. Anycast is a communication between a single sender and a list of addresses.

Anycast addresses are allocated from the unicast address space, using any of the defined unicast address formats. Thus, anycast addresses are syntactically indistinguishable from unicast addresses. When a unicast address is assigned to more than one interface, thus turning it into an anycast address, the nodes to which the address is assigned must be explicitly configured to know that it is an anycast address.

IPv6 Interfaces

Each IPv6 interface supports multiple IPv6 addresses. You can manually configure up to 1024 IPv6 addresses for each interface.

You can manually configure up to 1024 IPv6 addresses for each interface, as follows:

- Initial IPv6 address is a global unicast or anycast address.

```
Switch(config)# interface {<interface name>|ethernet <slot/chassis number>
|loopback <interface number>|mgmt <interface number>|port-channel <LAG number>|
|vlan <VLAN ID (1-4093)>}
Switch(config-if)# ipv6 address <IPv6 address>
```

- Second IPv6 address can be a unicast or anycast address.

```
Switch(config-ip-if)# ipv6 address <IPv6 address> secondary
Switch(config-ip-if)# exit
```

Each IPv6 address can belong to only one VLAN interface. Each VLAN interface can support multiple IPv4/IPv6 addresses.

Neighbor Discovery

The switch uses Neighbor Discovery protocol (ND) to gather information about other router and host nodes, including the IPv6 addresses. Host nodes use ND to configure their interfaces and perform health detection. ND allows each node to determine the link-layer addresses of neighboring nodes and to keep track of each neighbor's information. A neighboring node is a host or a router linked directly to the switch. The switch supports Neighbor Discovery as described in RFC 4861.

You can configure up to 256 IPv6 static neighbors for each interface.

Neighbor Discovery Overview

Neighbor Discover messages allow network nodes to exchange information, as follows:

- *Neighbor Solicitations* allow a node to discover information about other nodes.
- *Neighbor Advertisements* are sent in response to Neighbor Solicitations. The Neighbor Advertisement contains information required by nodes to determine the link-layer address of the sender, and the sender's role on the network.
- IPv6 hosts use *Router Solicitations* to discover IPv6 routers. When a router receives a Router Solicitation, it responds immediately to the host.
- Routers uses *Router Advertisements* to announce its presence on the network, and to provide its address prefix to neighbor devices. IPv6 hosts listen for Router Advertisements, and uses the information to build a list of default routers. Each host uses this information to perform autoconfiguration of IPv6 addresses.
- *Redirect messages* are sent by IPv6 routers to inform hosts of a better first-hop address for a specific destination. Redirect messages are only sent by routers for unicast traffic, are only unicast to originating hosts, and are only processed by hosts.

ND configuration for general advertisements, flags, and interval settings, as well as for defining prefix profiles for router advertisements, is performed on a per-interface basis using the following commands:

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config)# interface vlan <VLAN ID (1-4093)>
Switch(config-if)# [no] ipv6 nd <arguments>
Switch(config-if)# exit
```

To add or remove entries in the static neighbor cache, use the following command:

```
Switch(config-if)# [no] ipv6 neighbor <IPv6 address>
```

To view the neighbor discovery information for the specified interface, use the following command:

```
Switch(config)# show ipv6 nd interface <name>
```

To clear the neighbor cache, use the following command:

```
Switch# clear ipv6 neighbor
```

Router Nodes

Each IPv6 interface can be configured as a router node. A router node's IP address is configured manually. Router nodes can send Router Advertisements. To configure the IPv6 interface as a routed port, see Chapter 17, "Routed Ports".

Note: When IPv6 forwarding is turned on, all IPv6 interfaces configured on the switch can forward packets.

Neighbor Table Threshold

When the common Neighbor Table (NT) is learned via neighbor protocol, the item is synchronized to the hardware services layer module and to the chip NT.

A packet cannot be routed through Layer 3 via a link-local neighbor because IPv6 link-local addresses are only used locally, so link-local neighbors do not need to be stored in the switch chip NT. While the hardware layer is receiving NT entries from the common NT, cache amount and threshold value are compared. If the switch cache amount is larger, synchronization will terminate and the item will be deleted from the common NT and synchronized to the switch's chip NT.

To prevent the NT from expanding beyond chip capacity, the NT threshold value is equal to the global threshold value. Table 39 shows the switch chip capacities and NT threshold values for devices supported by CNOS.

Table 39. *Switch Chip Capacities and Neighbor Table Threshold Values*

Switch	Switch Chip Capacity	Threshold value
G8272	40960 (40K)	40000
G8296	40960 (40K)	40000
G8332	40960 (40K)	40000
NE1032	34816 (33K)	32000
NE1032T	34816 (33K)	32000
NE1072T	34816 (33K)	32000
NE10032	20480 (20K)	16000
NE2572	20480 (20K)	16000

Some space needs to be reserved in the chip NT for the local Layer 3 interface and to prevent hash conflicts in the chip NT. The common NT capacity is 200K, which si shared by global and link-local NTs. The reserved space prevents triggering garbage collection early in building the common NT.

To view all IPv6 NT entries, use the command:

```
Switch> show ipv6 neighbor global
```

Supported Applications

The following applications have been enhanced to provide IPv6 support.

- **Ping**

  The **ping6** command supports IPv6 addresses. Use the following format to ping an IPv6 address:

```
Switch# ping6 <IPv6 address> [vrf {default|management}] [interface
<destination interface>|source <IPv6 source address>] [count <number of pings>]
[interval <delay time between packets>] [packet-size <length>] [timeout <interval>]
```

- **Traceroute**

  The **traceroute6** command supports IPv6 addresses (but not link-local addresses). Use the following format to perform a traceroute to an IPv6 address:

```
Switch# traceroute6 <IPv6 address> [vrf {default|management}] [interface
<destination interface>] [source <IPv6 source>]
```

- **Telnet**

  The **telnet6** command supports IPv6 addresses (but not link-local addresses). Use the following format to Telnet to IPv6 address:

```
Switch# telnet6 <IPv6 address> [vrf {default|management}] [port <port
number>]
```

- **SSH**

```
Switch# ssh6 <IPv6 address> [vrf {default|management}] [port <port number>]
```

  Secure Shell (SSH) connections over IPv6 are supported (but not link-local addresses). The following syntax is required from the client:

- **TFTP**

  The TFTP commands support both IPv4 and IPv6 addresses. Link-local addresses are not supported.

- **FTP**

  The FTP commands support both IPv4 and IPv6 addresses. Link-local addresses are not supported.

IPv6 Configuration Examples

This section provides steps to configure IPv6 on the switch.

IPv6 Example 1

Use the following example to configure IPv6 neighbor discovery prefix settings on the router.

1. Enable IPv6 on an interface.

```
Switch(config)# interface ethernet 1/2
Switch(config-if)# no switchport
Switch(config-if)# ipv6 address 12ef:4533::0f30/64
```

Neighbor discovery is automatically enabled.

2. Advertise the IPv6 prefix in the router-advertisement messages.

```
Switch(config-if)# ipv6 nd prefix
```

3. Verify the interface configuration.

```
Switch(config-if)# show ipv6 nd interface
```

IPv6 Example 2

Use the following example to configure IPv6 neighbor discovery reachable time.

1. Enable IPv6 on an interface.

```
Switch(config)# interface ethernet 1/2
Switch(config-if)# no switchport
Switch(config-if)# ipv6 address ee33:a239:22::bcd3/32
```

Neighbor discovery is automatically enabled.

2. Configure the time when a node considers a neighbor to be up.

```
Switch(config-if)# ipv6 nd reachable-time 10
```

3. Verify the configuration.

```
Switch(config-if)# show ipv6 nd interface
```

IPv6 Configuration Considerations and Limitations

When you configure an interface for IPv6, consider the following guidelines:

- A single interface can accept multiple IPv6 addresses.
- Reserved IPv6 addresses are not supported on the interface (for example, 1::1/64).
- Health checks are not supported for IPv6 gateways.
- IPv6 interfaces support Path MTU Discovery. The CPU's MTU is fixed at 1500 bytes.
- Support for jumbo frames (1,500 to 9,216 byte MTUs) is limited. Any jumbo frames intended for the CPU must be fragmented by the remote node. The switch can re-assemble fragmented packets up to 9k. It can also fragment and transmit jumbo packets received from higher layers.

When configuring IPv6, the following limitations apply:

- Most other Lenovo Cloud Network Operating System 10.9 features permit IP addresses to be configured using either IPv4 or IPv6 address formats. However, the following switch features support IPv4 only:
  - Open Shortest Path First (OSPF) version 2

Chapter 20. Internet Group Management Protocol

Internet Group Management Protocol (IGMP) is used by IPv4 Multicast routers to learn about the existence of host group members on their directly attached subnet. The IPv4 multicast routers get this information by broadcasting IGMP Membership Queries and listening for IPv4 hosts reporting their host group memberships. This process is used to set up a client/server relationship between an IPv4 multicast source that provides the data streams and the clients that want to receive the data.

The switch supports three versions of IGMP:

- IGMPv1: Defines the method for hosts to join a multicast group. However, this version does not define the method for hosts to leave a multicast group. See RFC 1112 for details.
- IGMPv2: Adds the ability for a host to signal its desire to leave a multicast group. See RFC 2236 for details.
- IGMPv3: Adds support for source filtering by which a host can report interest in receiving packets only from specific source addresses or from all but specific source addresses, sent to a particular multicast address. See RFC 3376 for details.

The switch can perform IGMP Snooping and supports both static and dynamic IGMP groups and multicast routers. The switch can act as a Querier and participate in the IGMP Querier election process.

The following topics are discussed in this chapter:

IGMP Terms

The following are commonly used IGMP terms:

- Multicast traffic: Flow of data from one source to multiple destinations.
- Group: A multicast stream to which a host can join. Multicast groups have IP addresses in the range: 224.0.2.0 to 239.255.255.255.
- IGMP Querier: A router or switch in the subnet that generates *Membership Queries.*
- IGMP Snooper: A Layer 3 device that forwards multicast traffic only to hosts that are interested in receiving multicast data. This device can be a router or a Layer 3 switch.
- Multicast Router: A router configured to make routing decisions for multicast traffic. The router identifies the type of packet received (unicast or multicast) and forwards the packet to the intended destination.
- Membership Report: A report sent by the host that indicates an interest in receiving multicast traffic from a multicast group.
- Leave: A message sent by the host when it wants to leave a multicast group.
- Fast Leave: A process by which the switch stops forwarding multicast traffic to a port as soon as it receives a Leave message.
- Membership Query: Message sent by the Querier to verify if hosts are listening to a group.
- General Query: A *Membership Query* sent to all hosts. The Group address field for general queries is 0.0.0.0 and the destination address is 224.0.0.1.
- Group-specific Query: A *Membership Query* sent to a specific multicast group.
- Group-and-Source-Specific Query: A *Membership Query* sent to a specific multicast address from any of a specified list of sources.

How IGMP Works

When IGMP is not configured, switches forward multicast traffic through all ports, increasing network load. When IGMP is configured on a switch, multicast traffic flows as follows:

- A server sends multicast traffic to a multicast group.
- The multicast router sends *Membership Queries* to the switch, which forwards them to all ports in a given VLAN.
- Hosts respond with *Membership Reports* if they want to join a group. The switch forwards these reports to the multicast router.
- The switch forwards multicast traffic only to hosts that have joined a group and to the multicast router.
- The multicast router periodically sends *Membership Queries* to ensure that a host wants to continue receiving multicast traffic. If a host does not respond, the IGMP Snooper stops sending traffic to the host.
- An IGMPv2 host can initiate the Leave process by sending an IGMPv2 Leave packet to the IGMP Snooper.
- When a host sends an IGMP Leave packet, the IGMP Snooper sends *Group-specific Queries* to find out if any other host connected to the port is interested in receiving the multicast traffic. If it does not receive a Join message in response, the IGMP Snooper removes the group entry and passes on the information to the multicast router.

The switch supports the following:

- IGMP version 1, 2, and 3
- 64 static multicast routers
- 64 dynamic multicast routers
- up to 128 static IGMP groups
- 8191 dynamic IGMP groups, if there are no reserved IGMP static group entries, or 8063, if there are 128 reserved IGMP static group entries

Note: Unknown multicast traffic is sent to all ports if the IPMC flood option is enabled and no Membership Report was learned for that specific IGMP group. If the flood option is disabled, unknown multicast traffic is discarded if no hosts are learned on a switch.

To enable or disable IP multicast (IPMC) flood, use the following commands:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# [no] flood [ipv4|ipv6]
```

For more details, see "IPMC Flooding" on page 249.

The same HW table is shared by both IGMP and ARP entries, thus one of these features could fill the entire table leaving the other one unable to add its own entries. If an IGMP group entry cannot be added to the HW, an error message is displayed on the console: Group limit exceeded - hardware hash collision.

Note: The IGMP group is initially added in the software tables and it is displayed to the user (by using the **`show ip igmp snooping groups`** command), but it will be removed when the actual HW programming fails.

IGMP Capacity and Default Values

The following table lists the maximum and minimum values of the switch variables.

Table 40. *Switch IGMP Variables Table*

Variable	Maximum
VLANs - Snooping	4092
Static multicast routers	64
Dynamic multicast routers	64
Static Group - Snooping	128
Dynamic Groups - Snooping	8191

The following table lists the default settings for IGMP features and variables.

Table 41. *IGMP Default Configuration Settings*

Field	Default Value
IGMP Snooping	Enabled for all VLANs
IGMP Snooping Version	3
IPMC Flood	Enabled for all VLANs
IGMP FastLeave	Disabled for all VLANs
IGMP multicast router Timeout	255 Seconds
IGMP Group Timeout	260 Seconds
IGMP Report Suppression	Enabled for all VLANs
IGMP Query-Interval Variable	125 Seconds
IGMP Query-Max-Response-Time Variable	10 Seconds
IGMP Last-Member-Query-Interval Variable	1 Second
IGMP Robustness Variable	2

Note: The IGMP multicast router Timeout is calculated as:

$$robustness \times query\ interval + \frac{query\ max\ response\ time}{2} = 2 \times 125 + \frac{10}{2} = 255\ seconds$$

Note: The IGMP Group Timeout is calculated as:

$$robustness \times query\ interval + query\ max\ response\ time = 2 \times 125 + 10 = 260\ seconds$$

IGMP Snooping

IGMP Snooping allows a switch to listen to the IGMP conversation between hosts and multicast routers. With IGMP Snooping enabled, the switch learns the ports interested in receiving multicast data and forwards it only to those ports. Thus, IGMP Snooping conserves network resources.

The switch can sense IGMP *Membership Reports* from attached hosts and acts as a proxy to set up a dedicated path between the requesting host and a local IPv4 multicast router. After the path is established, the switch blocks the IPv4 multicast stream from flowing through any port that does not connect to a host member, thus conserving bandwidth.

If the IGMP Snooping switch receives a Query, it forwards the Query to all interfaces members of the VLAN on which is was received. Any Reports sent in reply to that Query are forwarded only on interfaces with multicast routers present.

By default, IGMP Snooping is globally enabled on the switch. To globally enable or disable IGMP Snooping, use the following command:

```
Switch(config)# [no] ip igmp snooping
```

IGMP Snooping can also be enabled or disabled for each VLAN. To enable or disable IGMP Snooping on a VLAN, use the following command:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# [no] ip igmp snooping
```

Note: If IGMP Snooping is disabled globally, it will also be disabled on any VLAN, regardless of the VLAN settings.

IGMP Snooping can monitor all version and types of IGMP messages (v1, v2 and v3). If the IGMP is configured to version 2, IGMPv3 packets will be ignored by the switch.

To change the IGMP version used on a VLAN, use the following command:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# ip igmp snooping version {2|3}
```

The default IGMP version is 3. You can reset the IGMP version used by a VLAN using the following command:

```
Switch(config-vlan)# no ip igmp snooping version
```

To view the current IGMP Snooping settings, use the following command:

```
Switch> show ip igmp snooping
```

IGMPv3 Snooping

IGMPv3 includes new Membership Report messages that extend IGMP functionality. The switch provides snooping capability for all types of IGMPv3 *Membership Reports*.

IGMPv3 supports Source-Specific Multicast (SSM). SSM identifies session traffic by both source and group addresses.

The IGMPv3 implementation keeps records on the multicast hosts present in the network. If a host is already registered, when it receives a new `IS_INC, TO_INC, ALLOW, BLOCK, IS_EXC` or `TO_EXC` report from same host, the switch makes the correct transition to new (port-host-group) registration based on the IGMPv3 RFC (RFC 3376). The registrations of other hosts for the same group on the same interface are not changed.

The switch supports the following IGMPv3 filter modes:

- INCLUDE mode: The host requests membership to a multicast group and provides a list of IPv4 addresses from which it wants to receive traffic.
- EXCLUDE mode: The host requests membership to a multicast group and provides a list of IPv4 addresses from which it does not want to receive traffic. This indicates that the host wants to receive traffic only from sources that are not part of the Exclude list.

IGMPv3 Snooping is compatible with IGMPv1 and IGMPv2 Snooping.

Spanning Tree Topology Change

If a Spanning Tree topology changes happens on an interface, the switch receives a Topology Change Notification (TCN) message. After 30 seconds from the moment the TCN message is received, the IGMP Snooping switch deletes all dynamically learned IGMP multicast groups, but does not delete multicast routers associated with that interface. After deleting the IGMP entries, the switch sends General Queries on all interface/VLAN pairs belonging to the Spanning Tree Group (STG) specified in the TCN message, except for interface/VLAN pairs on which a multicast router is already present. The reports received in reply to the General Queries enable the switch to re-learn IGMP multicast groups.

This mechanism happens even if the switch is not elected as an IGMP Querier. In this case, the source IPv4 address of the General Queries messages will be 0.0.0.0.

This mechanism can only be configured globally for the switch and it cannot be enabled or disabled only on a certain interface.

By default, this mechanism is enabled on the switch. To enable or disable it, use the following command:

```
Switch(config)# [no] ip igmp snooping tcn flood
```

IGMP Querier

For IGMP Snooping to function, you must have a multicast router on a VLAN to generate IGMP Membership Query packets. Enabling the IGMP Querier feature on the switch allows it to participate in the Querier election process. If the switch is elected as the Querier, it will send periodic IGMP Query packets for the VLAN. Hosts that want to receive multicast traffic will respond to the Membership Query packets with IGMP Report messages, which are used by the Querier to establish an appropriate forwarding list.

Querier Election

If multiple multicast routers exist on the VLAN, only one can be elected as a Querier. The multicast routers elect the one with the lowest source IPv4 address as the Querier. The Querier performs all periodic Membership Queries. All other multicast routers (non-Queriers) do not send IGMP Query packets.

Notes:

- When IGMP Querier is enabled on a VLAN, the switch performs the role of an IGMP Querier only if it meets the IGMP Querier election criteria.
- Any query packet with the source IP address 0.0.0.0 does not participate in the Querier selection.

Each time the Querier switch sends an IGMP Query packet, it initializes a *general query timer*. If a Querier receives a General Query packet from a multicast router with a lower IP address, it transitions to a non-Querier state and initializes an *other querier present timer*. When this timer expires, the multicast router transitions back to the Querier state and sends a General Query packet.

While the Querier switch is in a non-Querier state, only Query packets that have a lower IP address than the elected Querier switch will be processed. This will cause an update of the Querier information.

By default, IGMP Snooping Querier is disabled on all VLANs.

Follow these to configure a basic IGMP Querier:

1. Configure the source IPv4 address for IGMP Querier on a VLAN.

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# ip igmp snooping querier <Querier IP address>
```

2. Verify the configuration.

```
Switch> show ip igmp snooping querier
```

To disable IGMP Querier for a VLAN, use the following command:

```
Switch(config-vlan)# no ip igmp snooping querier
```

When IGMP Querier is enabled on a VLAN, the switch waits a random amount of time between zero and five seconds, and then will send a number of consecutive General Query packets, waiting a certain period of time between each General Query. The number of General Queries is called Startup Query Count and time interval between each packet is called Startup Query Interval.

After the IGMP Querier is enabled, the random time interval the switch waits is used to avoid sending too many IGMP Queries at the same time, if IGMP Querier is simultaneously enabled on multiple VLANs.

To configure the Startup Query Count, use the following command:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# ip igmp snooping startup-query-count <1-10>
```

The default value is the same as the configured robustness value, which by default is 2 (for more information about robustness, see "Robustness Variable" on page 467). You can reset the Startup Query Count to this value by using the following command:

```
Switch(config-vlan)# no ip igmp snooping startup-query-count
```

To configure the Startup Query Interval (in seconds), use the following command:

```
Switch(config-vlan)# ip igmp snooping startup-query-interval <1-18000>
```

The default value is a quarter of the Query Interval (which by default is 125 seconds, resulting in a default value of 31 seconds for the Startup Query Interval). You can reset the Startup Query Interval to this value by using the following command:

```
Switch(config-vlan)# no ip igmp snooping startup-query-interval
```

After the switch sends out the number of General Query packets as configured by the Startup Query Count and Interval, it will use Query Interval for sending further General Query packets if is elected as Querier.

To configure the Query Interval (in seconds), use the following command:

```
Switch(config-vlan)# ip igmp snooping query-interval <1-18000>
```

Note: When setting values for the Query Interval that are higher than 128 seconds, some of these values will be automatically adjusted by the switch to be consistent with the value used within the generated query packets. When this occurs, the switch will display a logging message.

The default value is 125 seconds. You can reset the Query Interval to this value by using the following command:

```
Switch(config-vlan)# no ip igmp snooping query-interval
```

Note: This command is not the same as configuring the Query Interval to 125 seconds. For IGMPv3, the Non-Querier switches get their Robustness and Query Interval values from the elected Querier switch. When the Query Interval is configured on a Non-Querier switch, the specified value is enforced regardless if it is the same as the default value or not (in this case, the default value is the Query Interval configured on the elected Querier switch). To configure the Non-Querier switch to take on the same value as the one configured on the elected Querier, the above command must be used.

The Querier Timeout is a time interval used by Non-Querier switches. If a Non-Querier switch does not receive a Query from Querier switch for a time interval equal to the configured Querier Timeout, it transitions to the Querier state.

To configure the Querier Timeout (in seconds), use the following command:

```
Switch(config-vlan)# ip igmp snooping querier-timeout <1-65535>
```

The default value is automatically calculated and is equal with the multicast router timeout on that VLAN. The factory default value for the Querier Timetout is 255 seconds.

When the Querier Timeout is manually configured, the specified value is enforced and is not automatically determined anymore, regardless if the manually configured timeout is the same as the default value or not. To configure the switch to automatically determine the Querier Timeout, use the following command:

```
Switch(config-vlan)# no ip igmp snooping querier-timeout
```

Multicast Router Discovery

For each VLAN, IGMP Snooping keeps track of switch ports that are connected to Multicast Routers (multicast routers) by checking IGMP queries sent by multicast routers.

An IGMP Snooping switch forwards multicast traffic and IGMP control messages (report and leave messages) by using information about the presence of multicast routers on switch ports.

You can also configure a static multicast router on a specific ethernet port or Link Aggregation Group (LAG). For more details, see Static Multicast Router.

When a IGMP query packet with *0.0.0.0* as the source IPv4 address is received, the switch learns a multicast router on the receiving interface only if IGMP Snooping Querier is disabled.

If IGMP Querier is enabled, a multicast router is learned when receiving an IGMP query packet only if both of the following conditions are met:

- the source IP address is not *0.0.0.0*, and
- the query's source IP address is strictly lower than the Querier's IP address

Multicast Routers can be discovered and dynamically learned by the switch using the Protocol Independent Multicast (PIM) Hello messages. Multicast routers learned through IGMP Queries have a higher precedence than multicast routers learned through PIM Hello messages. A multicast router dynamically learned through PIM Hello messages has an expiration timer based on the Hello hold time.

IGMP Query Messages

An IGMP Snooping switch periodically receives General Query messages from the elected IGMP Querier on a VLAN and learns that the switch port on which such queries are received is a multicast router port. The switch forwards IGMP General Query messages to all interfaces that belong to the VLAN on which the messages have been received.

The IGMP Snooping switch keeps track of the Querier version and other parameters, like the Robustness Variable or the Query Interval. This information is gathered from IGMP General Query messages. After a Spanning Tree topology change happens, the switch will send General Queries using the same IGMP version as the one used by the Querier.

When a host sends an IGMP Report indicating its interest in receiving multicast traffic, the IGMP Snooping switch forwards the Report message only using ports that have a multicast router.

To configure the maximum response time (in seconds) during which a switch can reply after received IGMP Query message, use the following command:

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# ip igmp snooping query-max-response-time <1-25>
```

The default value is 10 seconds and you can reset the maximum response time to that value by using the following command:

```
Switch(config-vlan)# no ip igmp snooping query-max-response-time
```

IGMP Groups

One IGMP entry is allocated for each unique join multicast traffic request, based on the VLAN and IGMP group address. If multiple ports join the same IGMP group using the same VLAN, only a single IGMP entry is used.

The IGMP Snooping switch keeps track of group membership with group records as: (Group, group-timer, {Filter - Include/Exclude}, {Source-records}). For IGMPv1 and IGMPv2 group membership records, the filter and source records are set to the default values. The group membership state is updated when receiving IGMPv1, IGMPv2 and IGMPv3 Report messages that force the compatibility between different IGMP versions.

You can add or remove a static member of a multicast group for an ethernet port or LAG belonging to a VLAN (for this example, ethernet interface 1/12 is used):

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# [no] ip igmp snooping static-group <multicast group IP
address> interface ethernet 1/12
```

To configure the maximum number of IGMP multicast group table entries that are reserved for IGMP static groups, use the following command:

```
Switch(config)# ip igmp snooping static-group max-limit <0-128>
```

Notes:

- Configuring the maximum number of reserved IGMP static groups can result in a failure when the following conditions are met:
  - The limit is set to a value lower than the current number of configured IGMP static groups. To set the limit to the desired value, the excess IGMP static groups must be removed.
  - The limit is set to a value higher than the number of empty IGMP multicast group table entries. To set the limit to the desired value, the excess IGMP dynamic groups must be removed.
- An IGMPv3 static or dynamic multicast group can occupy more than one entry in the IGMP multicast group table. The previous command only limits the number of table entries and not the number of IGMP static groups.
- The reserved IGMP multicast group table entries are exclusively used for IGMP static groups and cannot be used to learn IGMP dynamic groups even if there are no IGMP static groups configured on the switch.

By default, the switch does not reserve any IGMP multicast group table entries for IGMP static groups. To reset the reserved number to its default value, use the following command:

```
Switch(config)# no ip igmp snooping static-group max-limit
```

To remove all IGMP static groups entries from the IGMP multicast group table, use the following command:

```
Switch(config)# no ip igmp snooping static-group all
```

The IGMP Snooping switch uses group membership state information to configure the multicast forwarding interfaces.

Static and dynamic IGMP entries for the same or different multicast groups can be present on an interface at the same time. When a group is present, both statically and dynamically, on the same interface, only one IGMP entry will be shown in the group table with both the static (S) and dynamic (D) flags. A static multicast group will not interfere with the dynamic learning of the same group on a different interface or in the same or different VLAN.

To view all IGMP multicast groups, use the following command:

```
Switch> show ip igmp snooping groups
```

To delete all dynamic entries from the multicast group table of an IGMP Snooping switch, use the following command:

```
Switch# clear ip igmp snooping group *
```

Note: When clearing an IGMPv2 multicast group, the switch automatically generates Leave messages for those groups and sends the messages to all interface with multicast routers present.

To delete a specific multicast group, use the following command:

```
Switch# clear ip igmp snooping group <multicast group IPv4 address>
```

To delete all dynamic IGMP multicast group entries associated with a VLAN, use the following command:

```
Switch# clear ip igmp snooping group vlan <VLAN ID (1-4093)>
```

IGMP Snooping Configuration Guidelines

Consider the following guidelines when you configure IGMP Snooping:

- When multicast traffic flood is disabled, the multicast traffic sent by the multicast server is discarded if no hosts are learned on the switch.
- The multicast router periodically sends IGMP Queries.
- The switch learns the multicast router on the interface connected to the router when it sees Query messages. The switch then floods the IGMP queries on all other interfaces, including Link Aggregation Groups (LAG).
- Multicast hosts send IGMP Membership Reports as a reply to the IGMP Queries sent by the multicast router.
- When an IGMP Snooping switch receives an IGMPv2 Leave message from a group member on a certain interface, it sends an IGMPv2 Group-specific Query on that interface to determine if there any more group members interested in receiving multicast traffic. If the switch does not receive any Membership Reports during a certain time interval, it removes the interface from the multicast group and forwards the IGMPv2 Leave message to all multicast routers.

IGMP Snooping Configuration Example

This section provides steps to configure IGMP Snooping on the switch. For this example, ethernet interface 1/12 and VLAN 100 are used.

1. Create VLAN 100:

```
Switch(config)# vlan 100
Switch(config-vlan)# exit
Switch(config)#
```

2. Set ethernet interface 1/12 as a member of VLAN 100:

   a. If the interface is configured as an access switch port:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# switchport access vlan 100
Switch(config)# exit
```

   b. If the interface is configured as a trunk switch port:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# switchport trunk allowed vlan add 100
Switch(config)# exit
```

3. (Optional) Enable IGMP Snooping on VLAN 100:

```
Switch(config)# vlan 100
Switch(config-vlan)# ip igmp snooping
```

4. Disable IP multicast (IPMC) flooding:

```
Switch(config-vlan)# no flood
```

5. (Optional) Enable IGMPv3 Snooping.

```
Switch(config-vlan)# ip igmp snooping version 3
```

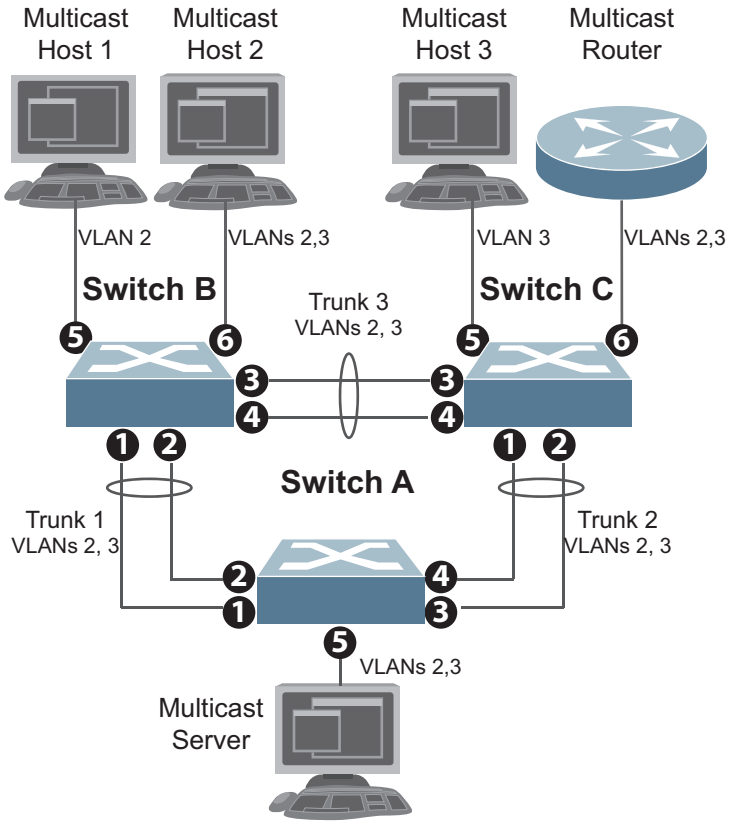
6. Check IGMP Snooping settings:

```
Switch> show ip igmp snooping

Global IGMP Snooping information
 IGMP Snooping Enabled
 IGMP Snooping V1/V2 Report Suppression Enabled
 General query transmission on TCN Enabled
 Static entries limit: 0
 Report forwarding rate: 6000

IGMP Snooping information for Vlan1
 IGMP Snooping enabled
 IGMP Snooping Version: 3
 Robustness: 2 (operational: 2)
 Query Interval: 125 seconds (operational: 125 seconds)
 Group Membership Interval: 260 seconds
 Query Response Interval: 10 seconds
 Last Member Query Count: 2
 Last Member Query Interval: 1000 milliseconds
 IGMPv2 fast-leave: disabled
 IGMPv1/v2 Report suppression: enabled
 IGMPv3 Report suppression: disabled
 Router port detection using: IGMP Queries, PIM Hello
 Snooping Querier disabled
 Querier timeout: 255 seconds (default, operational: 255 seconds)
 Querier Startup Query Count: 2
 Querier Startup Query Interval: 31 seconds
 Number of router-ports: 0
 Number of Groups: 0
 Number of Joins: 0
 Number of Leaves: 0
 Active Ports:
  Ethernet1/12
```

Advanced IGMP Snooping Configuration Example

Figure 12 shows an example topology. Switches B and C are configured with IGMP Snooping.

Figure 12. Topology



Devices in this topology are configured as follows:

- STG 2 includes VLAN 2; STG 3 includes VLAN 3.
- The multicast server sends IP multicast traffic for the following groups:
  - VLAN 2, 225.10.0.11 – 225.10.0.12, Source: 22.10.0.11
  - VLAN 2, 225.10.0.13 – 225.10.0.15, Source: 22.10.0.13
  - VLAN 3, 230.0.2.1 – 230.0.2.2, Source: 22.10.0.1
  - VLAN 3, 230.0.2.3 – 230.0.2.5, Source: 22.10.0.3
- The multicast router sends IGMP Query packets in VLAN 2 and VLAN 3. The multicast router's IP address is 10.10.10.10.
- The multicast hosts send the following IGMP Reports:
  - IGMPv2 Report, VLAN 2, Group: 225.10.0.11, Source: *
  - IGMPv2 Report, VLAN 3, Group: 230.0.2.1, Source: *
  - IGMPv3 IS_INCLUDE Report, VLAN 2, Group: 225.10.0.13, Source: 22.10.0.13
  - IGMPv3 IS_INCLUDE Report, VLAN 3, Group: 230.0.2.3, Source: 22.10.0.3

- The hosts receive multicast traffic as follows:
  - Host 1 receives multicast traffic for groups (*, 225.10.0.11), (22.10.0.13, 225.10.0.13)
  - Host 2 receives multicast traffic for groups (*, 225.10.0.11), (*, 230.0.2.1), (22.10.0.13, 225.10.0.13), (22.10.0.3, 230.0.2.3)
  - Host 3 receives multicast traffic for groups (*, 230.0.2.1), (22.10.0.3, 230.0.2.3)
- The multicast router receives all the multicast traffic.

Prerequisites

Before you configure IGMP Snooping, ensure you have performed the following actions:

- Configured VLANs.
- Enabled IGMP on the VLANs.
- Configured a switch or multicast router as the Querier.
- Identified the IGMP version(s) you want to enable.

IGMP Configuration

This section provides the configuration details of the switches shown in Figure 12.

Switch A Configuration

1. Create VLANs 2 and 3.

```
Switch(config)# vlan 2,3
Switch(config-vlan)# exit
```

2. Configure ethernet interfaces 1/1 - 1/5 as switch trunk ports and add VLANs 2 and 3 to their allowed VLAN lists:

```
Switch(config)# interface ethernet 1/1-5
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk allowed vlan 2,3
Switch(config-if-range)# exit
```

3. Assign a bridge priority lower than the default value to enable the switch to become the STP root in STG 2 and 3:

```
Switch(config)# spanning-tree mst 2 priority 4096
Switch(config)# spanning-tree mst 3 priority 4096
```

4. Configure ethernet ports 1, 2, 3 and 4 as LACP LAG members:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if-range)# channel-group 1 mode active
Switch(config-if-range)# exit

Switch(config)# interface ethernet 1/3-4
Switch(config-if-range)# channel-group 2 mode active
Switch(config-if-range)# exit
```

Switch B Configuration

1. Create VLANs 2 and 3:

```
Switch(config)# vlan 2,3
Switch(config-vlan)# exit
```

2. Configure ethernet interfaces 1/1 - 1/4 and 1/6 as switch trunk ports and add VLANs 2 and 3 to their allowed VLAN lists:

```
Switch(config)# interface ethernet 1/1-4, ethernet 1/6
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk allowed vlan 2,3
Switch(config-if-range)# exit
```

3. Configure ethernet interface 1/5 as a switch access port and add VLAN 2 as its access VLAN:

```
Switch(config)# interface ethernet 1/5
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan 2
Switch(config-if)# exit
```

4. Configure STP edge port:

```
Switch(config)# interface ethernet 1/5-6
Switch(config-if-range)# spanning-tree port type edge
Switch(config-if-range)# exit
```

5. Configure ethernet ports 1, 2, 3 and 4 as LACP LAG members:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if)# channel-group 1 mode active
Switch(config-if)# exit

Switch(config)# interface ethernet 1/3-4
Switch(config-if)# channel-group 3 mode active
Switch(config-if)# exit
```

6. Configure IGMP Snooping:

```
Switch(config)# vlan 2,3
Switch(config-vlan)# no flood
Switch(config-vlan)# ip igmp snooping
Switch(config-vlan)# ip igmp snooping version 3
Switch(config-vlan)# exit
```

Switch C Configuration

1. Create VLANs 2 and 3:

```
Switch(config)# vlan 2,3
Switch(config-vlan)# exit
```

2. Configure ethernet interfaces 1/1 - 1/4 and 1/6 as switch trunk ports and add VLANs 2 and 3 to their allowed VLAN lists:

```
Switch(config-vlan)# interface ethernet 1/1-4, ethernet 1/6
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 2,3
Switch(config-if)# exit
```

3. Configure ethernet interface 1/5 as a switch access port and add VLAN 3 as its access VLAN:

```
Switch(config)# interface ethernet 1/5
Switch(config-if)# switchport mode access
Switch(config-if)# switchport access vlan 3
Switch(config-if)# exit
```

4. Configure STP edge ports:

```
Switch(config)# interface ethernet 1/5-6
Switch(config-if)# spanning-tree port type edge
Switch(config-if)# exit
```

5. Configure ethernet ports 1, 2, 3 and 4 as LACP LAG members:

```
Switch(config)# interface ethernet 1/1-2
Switch(config-if)# channel-group 2 mode active
Switch(config-if)# exit

Switch(config)# interface ethernet 1/3-4
Switch(config-if)# channel-group 3 mode active
Switch(config-if)# exit
```

6. Configure IGMP Snooping:

```
Switch(config)# vlan 2,3
Switch(config-vlan)# no flood
Switch(config-vlan)# ip igmp snooping
Switch(config-vlan)# ip igmp snooping version 3
Switch(config-vlan)# exit
```

Troubleshooting

This section provides the steps to resolve common IGMP Snooping configuration issues. The topology described in Figure 12 is used as an example.

Multicast traffic from non-member groups reaches the host or multicast router

- Check if traffic is unregistered. For unregistered traffic, an IGMP entry is not displayed in the IGMP groups table.

```
Switch> show ip igmp snooping groups
```

- Ensure IPMC flooding is disabled.

```
Switch(config)# vlan <VLAN ID (1-4093)>
Switch(config-vlan)# no flood
```

- Check the egress port's VLAN membership. The ports to which the hosts and multicast router are connected must be used only for VLAN 2 and VLAN 3.

```
Switch> show vlan id 2,3
```

Note: To avoid such a scenario, disable IPMC flooding for all VLANs enabled on the switches (if this is an acceptable configuration).

- Check IGMP Reports on switches B and C for information about the IGMP groups.

```
Switch> show ip igmp snooping groups
```

If the non-member IGMP groups are displayed in the table, close the application that may be sending the IGMP Reports for these groups.

Identify the traffic source by using a sniffer on the hosts and reading the source IP/MAC address. If the source IP/MAC address is unknown, check the port statistics to find the ingress port.

```
Switch> show interface ethernet <chassis number/port number> counters
```

- Ensure no static multicast MACs, static multicast groups or static multicast routers are configured.

Not all multicast traffic reaches the appropriate receivers.

- Ensure hosts are sending IGMP Reports for all the groups. Check the VLAN on which the groups are learned.

```
Switch# show ip igmp snooping groups
```

If some of the groups are not displayed, ensure the multicast application is running on the host device and the generated IGMP Reports are correct.

- Ensure multicast traffic reaches the switch to which the host is connected.

  Close the application sending the IGMP Reports. Clear the IGMP groups by disabling, then re-enabling the port.

  Note: To clear all IGMP groups, use the following command:

  ```
  Switch# clear ip igmp snooping group *
  ```

  However, this will clear all the IGMP groups and will influence other hosts.
- Ensure multicast server is sending all the multicast traffic.
- Ensure no static multicast MACs, static multicast groups or static multicast routes are configured.

IGMP queries sent by the multicast router do not reach the host.

- Ensure the multicast router is learned on switches B and C.

  ```
  Switch> show ip igmp snooping mrouter
  ```

  If it is not learned on switch B but is learned on switch C, check the link state of the LAG, VLAN membership and STP convergence.

  If it is not learned on any switch, ensure the multicast application is running and is sending correct IGMP Query packets.

  If it is learned on both switches, check the link state, VLAN membership and STP port states for the ports connected to the hosts.

IGMP Reports/Leaves sent by the hosts do not reach the multicast router

- Ensure IGMP Queries sent by the multicast router reach the hosts.
- Ensure the multicast router is learned on both switches. Note that the multicast router may not be learned on switch B immediately after a LAG failover/failback.

  ```
  Switch> show ip igmp snooping mrouter
  ```

- Ensure the host's multicast application is started and is sending correct IGMP Reports/Leaves.

  ```
  Switch> show ip igmp snooping groups
  Switch> show ip igmp snooping statistics
  ```

A host receives multicast traffic from the incorrect VLAN

- Check port VLAN membership.
- Check IGMP Reports sent by the host.
- Check multicast data sent by the server.

The multicast router is learned on the incorrect LAG

- Check link state. LAG 1 might be down or in STP discarding state.
- Check STP convergence.
- Check port VLAN membership.

Hosts receive multicast traffic at a lower rate than normal

- Ensure a storm control is not configured on the LAGs.

```
Switch(config)# interface ethernet <chassis number/port number>
Switch(config-if)# no storm-control multicast level
```

- Check link speeds and network congestion.

Additional IGMP Features

The following topics are discussed in this section:

Report Suppression

An IGMP Snooping switch will forward to a multicast router all IGMPv1 and IGMPv2 reports. To reduce IGMP traffic on a VLAN, you can enable the suppression of such reports.

Report suppression will forward only the first occurrences of IGMPv1 and IGMPv2 reports for any multicast group. Any subsequent reports from the same multicast group are not forwarded to the multicast router.

When receiving a Query packet, the switch replies with the learned IGMP groups.

By default, report suppression is enabled on the switch for all VLANs. Report suppression can be enabled or disabled globally or for each VLAN.

To globally enable or disable report suppression, use the following command:

```
Switch(config)# [no] ip igmp snooping report-suppression
```

To enable or disable report suppression on a VLAN, use the following command:

```
Switch(config-vlan)# [no] ip igmp snooping report-suppression
```

Notes:

- If report suppression is disabled globally, any individual VLAN configuration is ignored and report suppression is disabled for all VLANs.
- IGMPv3 reports cannot be suppressed.
- Report suppression does not affect static multicast routers.

Fast Leave

When an IGMP Snooping switch receives an IGMPv2 Leave message from a group member on a certain interface, it sends an IGMPv2 Group-specific Query on that interface to determine if there any more group members interested in receiving multicast traffic. If the switch does not receive any Membership Reports during a time interval called last-member-query-time, it removes the interface from the multicast group and forwards the IGMPv2 Leave message to all multicast routers.

The IGMP Snooping switch will send a particular number of IGMPv2 Group-specific Queries waiting a certain period of time between each query. The number of queries is called last-member-query-count and the period of time between each query is called last-member-query-interval.

The last-member-query-time is defined as the last-member-query-interval multiplied by the last-member-query-count. While the last-member-query-time is not directly configurable, you can configure its components.

To configure the last-member-query-interval (in seconds), use the command:

```
Switch(config-vlan)# ip igmp snooping last-member-query-interval <1-25>
```

The default value is one second and you can reset the last-member-query-interval to this value by using the following command:

```
Switch(config-vlan)# no ip igmp snooping last-member-query-interval
```

The last-member-query-count is equal to the value of the robustness variable. To modify the robustness variable, see "Robustness Variable" on page 467.

If Fast Leave is enabled on a VLAN, the IGMP Snooping switch immediately removes an interface from the multicast group when receiving an IGMPv2 Leave message on that interface and forwards the Leave message to all multicast routers.

Note: Fast Leave is specific to IGMPv2, because it is the only IGMP version that uses Leave packets. Enable Fast Leave on ports that have only one host connected. If more than one host is connected to a port, you may lose some hosts unexpectedly.

To enable or disable Fast Leave on a VLAN, use the following command:

```
Switch(config-vlan)# [no] ip igmp snooping fast-leave
```

Static Multicast Router

A static multicast router can be configured for a particular ethernet interface or Link Aggregation Group (LAG) on a particular VLAN. Any static multicast routers do not have to be learned through IGMP Snooping, but they can be also learned this way.

An multicast router is kept as an entry in the multicast group table of a IGMP Snooping switch. If the multicast router is both statically configured and dynamically learned, it will appear only as one IGMP entry, but will have both static (S) and dynamic (D) flags.

To add or remove a static multicast router on an interface of a VLAN, use the following command (for this example, ethernet interface 1/12 is used):

```
Switch(config-vlan)# [no] ip igmp snooping mrouter interface ethernet 1/12
```

To remove all static multicast routers from a VLAN interface, use the following command:

```
Switch(config-vlan)# no ip igmp snooping mrouter all
```

To view all static and dynamic multicast routers, use the following command:

```
Switch> show ip igmp snooping mrouter
```

Robustness Variable

The Robustness Variable allows tuning for the expected packet loss on a network. In this scenario, the robustness variable can be increased to reduce the impact of traffic loss.

You can increase this value by using the following command:

```
Switch(config-vlan)# ip igmp snooping robustness-variable <1-7>
```

You can reset IGMP Robustness to its default value by using the command:

```
Switch(config-vlan)# no ip igmp snooping robustness-variable
```

Chapter 21. Secure Mode

Secure mode enables you to determine which protocols can be enabled. In secure mode, only secured traffic and secured authentication management are allowed.

The following topics are discussed in this chapter:

Secure Mode Overview

The concept of “secure mode” introduces the

- **Legacy Mode**

  Legacy Mode maintains the existing security behavior of the switch. All communication protocols currently supported by switch software continue to be allowed and supported in this mode. All behaviors of the switch remain the same; the only difference is you can set the mode which will take effect after the next reboot of the switch.

- **Secure Mode**

  In *Secure Mode*, only secure communication protocols are allowed to be enabled. Communication protocols that are deemed to be not secure are disabled and not allowed to run on the switch.

Note: Once a switch has entered Secure Mode, it cannot return to Legacy Mode without a reboot.

Secure mode places the switch in a state where the following rules are in effect:

- Older and less secure ciphers will be inaccessible. Currently ssh and REST use these ciphers, but any changes will apply to any future cipher suite uses.
- Communication protocols deemed insecure, such as telnet, will be disabled, requiring the use of secure protocols; in this case, ssh.
- When protocols have newer, more secure versions, these protocols will be restricted to the secure version. For example, SNMP will be restricted to version 3 and ssh will be limited to version 2.0.

Using Protocols With Secure Mode

Some protocols can be used with secure mode. This section explains which protocols can and cannot operate with secure mode on the switch.

Insecure Protocols

When you are in secure mode, the following protocols are deemed “insecure” and are disabled:

- HTTP
- SNMPv1
- SNMPv2
- Telnet
- Telnet6
- FTP
- TFTP server

Except for the TFTP server, these protocols cannot be enabled when the switch is operating in Secure Mode because the commands to enable or disable them disappear with secure mode enabled.

The following protocols, although deemed “insecure” by secure mode, are enabled by default and can be disabled.

- Radius
- TACACS+
- LDAP (with no clear-text support in secure mode)
- TFTP client (signed images only)
- DHCP client
- SysLog

Secure Protocols

The following protocols are deemed “secure” and are enabled by default in Secure Mode:

- SCP Server
- SNMPv3 Client
- SFTP Client
- SSHv2 Server
- SSHv2 Client
- HTTPS Server

You can disable these protocols.

Only the following NIST 800-131a compliant cryptographic algorithms are allowed:

- SSH (Server and Client)
- KexAlgorithms:
  - ecdh-sha2-nistp256
  - ecdh-sha2-nistp384
  - ecdh-sha2-nistp521
  - diffie-hellman-group14-sha1
- Ciphers:
  - aes128-ctr
  - aes192-ctr
  - aes256-ctr
  - aes128-gcm@openssh.com
  - aes256-gcm@openssh.com
- MACs:
  - hmac-sha2-256
  - hmac-sha2-512
  - hmac-sha1-etm@openssh.com
  - hmac-sha2-256-etm@openssh.com
  - hmac-sha2-512-etm@openssh.com

Table 42 contains a list of secure mode compliant ciphers.

Table 42. *Secure mode compliant ciphers*

Cipher Name	Key Exchange	Authenti-cation	Encryption	MAC
ECDHE-RSA-AES256-GCM-SHA384	ECDH	RSA	AESGCM(256)	AEAD
ECDHE-RSA-AES256-SHA384	ECDH	RSA	AES(256)	SHA384
ECDHE-RSA-AES128-GCM-SHA256	ECDH	RSA	AESGCM(128)	AEAD
ECDHE-RSA-AES128-SHA256	ECDH	RSA	AES(128)	SHA256

Insecure Protocols Unaffected by Secure Mode

The following protocols are deemed “insecure” but can be enabled in all Security Policy Modes:

- Ping
- Ping IPv6
- Traceroute
- Traceroute IPv6
- TFTP IPv6
- SNMPv3 IPv6
- bootp

Notes:

- Telnet IPv6 and TFTP IPv6 are disabled in Secure Mode.
- TFTP IPv6 is allowed in Secure Mode for signed image transfers only.

In secure mode, only protocols that are deemed to be secure are allowed to run.:

When in secure mode, the following insecure protocols and the commands to configure them disappear:

- SNMPv1
- SNMPv2
- Telnet (server and client)
- Telnet IPv6 (server and client)
- FTP (server and client)
- TFTP server
- TFTP client (except for signed image transfers)

Enabling and Disabling Secure Mode

To enable Secure Mode on the switch, enter:

```
Switch(config)# secure mode enable
```

Note: The switch will remain in Legacy Mode until you reboot.

To disable Secure Mode on the switch, enter:

```
Switch(config)# no secure mode enable
```

Note: The switch will remain in Secure Mode until you reboot.

To display the running and configured security policies, enter:

```
Switch(config)# show security mode
```

Chapter 22. Border Gateway Protocol

Border Gateway Protocol (BGP) is an Internet protocol that enables routers on a network to advertise routing information with each other about the segments of the IP (IPv4 or IPV6) address space they can access within their network and with routers on external networks. BGP allows you to decide what is the "best" route for a packet to take from your network to a destination on another network rather than simply setting a default route from your border router(s) to your upstream provider(s). BGP is defined in RFC 4271.

The switch can advertise their IP interfaces and IP addresses using BGP and take BGP feeds from as many as 96 BGP router peers. This allows more resilience and flexibility in balancing traffic from the Internet.

The following topics are discussed in this section:

BGP Overview

BGP is an inter-Autonomous System routing protocol. The primary function of BGP is to exchange network reachability information with other BGP systems. This information is sufficient for constructing a graph of Autonomous System (AS) connectivity for this reachability, from which routing loops may be pruned and, at the AS level, policy decisions may be enforced.

Routing information exchanged via BGP supports the destination-based forwarding paradigm, which assumes a router forwards a packet based solely on the destination address carried in the IP header of the packet. This, in turn, determines the policy decisions that can and cannot be enforced using BGP.

BGP supports only those policies conforming to the destination-based forwarding paradigm over IPv4 as described in RFC 4271.

To establish BGP sessions between peers, BGP must have a router ID, which is sent to BGP peers in the OPEN message when a BGP session is established. The BGP router ID is a 32-bit value that is represented by an IPv4 address. You can configure the router ID.

By default, Cloud NOS can select a router ID among all the IP addresses of all interfaces automatically. If there are loopback interfaces with configured IPv4 address, the highest address among them is chosen as the router ID. If no loopback interfaces exist, the highest IPv4 address whose interface is in the up state will become the router ID. If that interface goes down, the current router ID is kept.

The BGP router ID must be unique to the BGP peers in a network. If BGP does not have a router ID, it cannot establish any peering sessions with BGP peers.

To configure the router ID, use the following command:

```
Switch(config)# router-id <IPv4 address>
```

To view the router ID, use the following command:

```
Switch# show router-id

Router ID: 191.1.1.1 (automatic)
```

```
Switch# show router-id

Router ID: 26.4.4.4 (config)
```

To reset the router ID to its default value (the one automatically chosen by the switch), use the following command:

```
Switch(config)# no router-id
```

Internal Routing Versus External Routing

To ensure effective processing of network traffic, every router on your network needs to know how to send a packet (directly or indirectly) to any other location/destination in your network. This is referred to as *internal routing* and can be done with static routes or using active, internal dynamic routing protocols, such as OSPF.

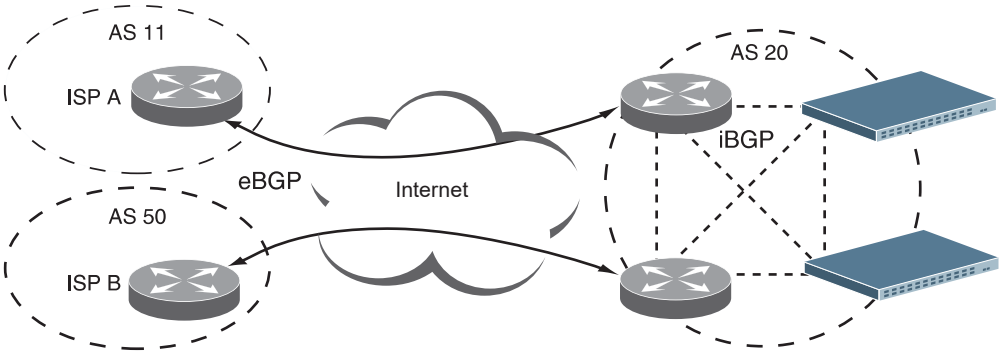
Static routes must have a higher degree of precedence than dynamic routing protocols. If the destination route is not in the route cache, the packets are forwarded to a default gateway which may be incorrect if a dynamic routing protocol is enabled.

It is also useful to tell routers outside your network (upstream providers or *peers*) about the routes you can access in your network. External networks (those outside your own) that are under the same administrative control are referred to as *autonomous systems* (AS). Sharing of routing information between autonomous systems is known as *external routing*.

External BGP (eBGP) is used to exchange routes between different autonomous systems whereas internal BGP (iBGP) is used to exchange routes within the same autonomous system. An iBGP is a type of internal routing protocol you can use to do active routing inside your network. It also carries AS path information, which is important when you are an ISP or doing BGP transit.

The iBGP peers have to maintain reciprocal sessions to every other iBGP router in the same AS (in a full-mesh manner) to propagate route information throughout the AS. If the iBGP session shown between the two routers in AS 20 was not present (as indicated in Figure 13), the top router would not learn the route to AS 50, and the bottom router would not learn the route to AS 11, even though the two AS 20 routers are connected via the switch.

Figure 13. iBGP and eBGP



When there are many iBGP peers, having a full-mesh configuration results in large number of sessions between the iBGP peers. In such situations, configuring a route reflector eliminates the full-mesh configuration requirement, prevents route propagation loops, and provides better scalability to the peers. For details, see "Route Reflector" on page 479.

Typically, an AS has one or more *border routers*—peer routers that exchange routes with other ASs—and an internal routing scheme that enables routers in that AS to reach every other router and destination within that AS. When you *advertise* routes to border routers on other autonomous systems, you are effectively committing to carry data to the IPv4 space represented in the route being advertised. For example, if you advertise 192.204.4.0/24, you are declaring that if another router sends you data destined for any address in 192.204.4.0/24, you know how to carry that data to its destination.

Route Reflector

The Cloud NOS implementation conforms to the BGP Route Reflection specification defined in RFC 4456.

As per RFC 4271 specification, a route received from an iBGP peer cannot be advertised to another iBGP peer. This makes it mandatory to have full-mesh iBGP sessions between all BGP routers within an AS. A route reflector—a BGP router—breaks this iBGP loop avoidance rule. It does not affect the eBGP behavior.

Route reflection is an alternative to using a full mesh. This approach allows a BGP speaker known as a route reflector (RR) to advertise iBGP learned routes to certain iBGP peers. It represents a change in the commonly understood concept of iBGP, and the addition of two new optional non-transitive BGP attributes to prevent loops in routing updates.

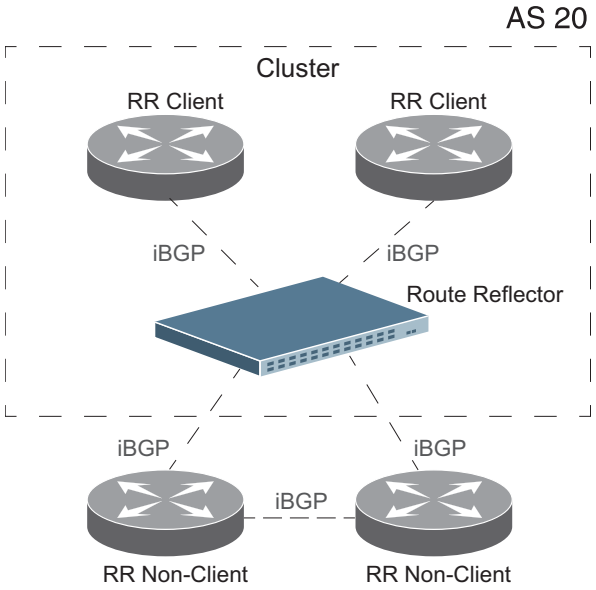
A route reflector has two groups of internal peers: clients and non-clients. A route reflector reflects between these groups and among the clients. The non-client peers must be fully meshed. The route reflector and its clients form a cluster.

When a route reflector receives a route from an iBGP peer, it selects the best path based on its path selection rule. It then does the following based on the type of peer it received the best path from:

- A route received from a non-client iBGP peer is reflected to all clients.
- A route received from an iBGP client peer is reflected to all iBGP clients and iBGP non-clients.

In Figure 14, the switch is configured as a route reflector. All clients and non-clients are in the same AS.

Figure 14. iBGP Route Reflector



The following attributes are used by the route reflector functionality:

- **Originator ID**

  BGP identifier (BGP router ID) of the route originator in the local AS. If the route does not have the originator ID attribute (it has not been reflected before), the router ID of the iBGP peer from which the route has been received is copied into the Originator ID attribute.This attribute is never modified by subsequent route reflectors. When a router identifies its own ID as the originator ID, it ignores the route.

- **Cluster list**

  Sequence of the cluster ID (the router ID) values representing the reflection path that the route has passed. The value can be configured with the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# cluster-id {<ID (1-4294967295)>|<IPv4 address>}
```

  The value configured with this command (or the router ID of the route reflector if `cluster-id` is not configured) is prepended to the cluster list attribute. When a route reflector detects its own cluster ID in the cluster list, it ignores the route.

Route Reflection Configuration Example

To configure BGP route reflection:

1. Configure an AS.

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)#
```

2. Configure a route reflector client.

```
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# address-family {ipv4|ipv6} unicast
Router(config-router-neighbor-af)# route-reflector-client
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
Switch(config-router)# exit
```

Note: When a client is configured on the switch, the switch automatically gets configured as a route reflector.

3. Verify configuration.

```
Switch(config)# show ip bgp neighbors <neighbor address>

BGP neighbor is 10.1.1.2, remote AS 400, local AS 400, internal link
  BGP version 4, remote router ID 0.0.0.0
  BGP state = Idle
  Last read 00:00:03, hold time is 180, keepalive interval is 60 seconds
  Received 121 messages, 0 notifications, 0 in queue
  Sent 123 messages, 3 notifications, 0 in queue
  Route refresh request: received 0, sent 0
  Minimum time between advertisement runs is 5 seconds
 For address family: IPv4 Unicast
  BGP table version 1, neighbor version 0
  Index 1, Offset 0, Mask 0x2
  Route-Reflector Client
  0 accepted prefixes, maximum limit 15870
  Threshold for warning message 75(%)
  0 announced prefixe
...
```

Note: The BGP neighbors displayed will only be IPv4 or IPv6 neighbors, depending upon the type of *neighbor address* you enter.

Once configured as a route reflector, the switch, by default, passes routes between clients. If required, you can disable this by using the following command:

```
Switch# configure [terminal]
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# address-family {ipv4|ipv6} unicast
Switch(config-router-af)# no client-to-client reflection
Switch(config-router-af)# exit
Switch(config-router)# exit
```

You can view the route reflector BGP attributes attached to a BGP route using the following command:

```
Switch(config)# show ip bgp attribute-info

attr[3] nexthop 0.0.0.0
```

Restrictions

Consider the following restriction when configuring route reflection functionality:

- When a route reflector client is enabled/disabled, the session is restarted.
- When a Cluster ID is changed, all iBGP sessions are restarted.

Forming BGP Peer Routers

Two BGP routers become peers or neighbors once you establish a TCP connection between them. You can configure BGP peers statically or dynamically. While it may be desirable to configure static peers for security reasons, dynamic peers prove to be useful in cases where the remote address of the peer is unknown. For example in B-RAS applications, where subscriber interfaces are dynamically created and the address is assigned dynamically from a local pool or by using RADIUS.

For each route removed from the route table, if the route has already been sent to a peer, an update message containing the route to withdraw is sent to that peer.

For each Internet host, you must be able to send a packet to that host, and that host has to have a path back to you. This means that whoever provides Internet connectivity to that host must have a path to you. Ultimately, this means that they must "hear a route" which covers the section of the IP space you are using; otherwise, you will not have connectivity to the host in question.

BGP Peers and Dynamic Peers

A BGP speaker does not discover another BGP speaker automatically. You must configure the relationships between BGP speakers. A BGP peer is a BGP speaker that has an active TCP connection to another BGP speaker.

Cloud NOS accepts an IP address range to establish BGP sessions. For example, if you configure BGP to use IPv4 prefix 192.168.2.0/24, BGP will establishes a session with 192.168.1.2 but will reject a session from 192.168.2.2.

Static Peers

You can configure BGP static peers by using the following commands:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# address-family {ipv4|ipv6} unicast
```

Static peers always take precedence over dynamic peers. Consider the following:

- If the remote address of an incoming BGP connection matches both a static peer address and an IP address from a dynamic group, the peer is configured statically and not dynamically.
- If a new static peer is enabled while a dynamic peer for the same remote address exists, BGP automatically removes the dynamic peer.
- If a new static peer is enabled when the maximum number of BGP peers were already configured, then BGP deletes the dynamic peer that was last created and adds the newly created static peer. A syslog will be generated for the peer that was deleted.

Dynamic Peers

To configure dynamic peers, you must define a range of IP addresses (in the following format: IP address/subnet mask). BGP waits to receive an open message initiated from BGP speakers within that range. Dynamic peers are automatically created when a peer from the same subnet initiates a TCP connection. Dynamic peers are passive. When they are not in the established state, they accept inbound connections but do not initiate outbound connections.

When the BGP speaker receives an open message from a dynamic peer, the AS number from the packet must match the configured remote AS number.

All static BGP peer attributes can also be configured for dynamic peers.

To set the maximum number of dynamic peers for a group that can simultaneously be in an established state, enter the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address>/<prefix> remote-as <AS number>
Switch(config-router-neighbor)# maximum-peers <1-96>
```

If you reset this limit to a lower number, and if the dynamic peers already established for the group are higher than this new limit, then BGP deletes the last created dynamic peer(s) until the new limit is reached.

Note: The maximum number of static and dynamic peers established simultaneously cannot exceed the maximum peers (96) that the switch can support.

The following are the basic commands for configuring dynamic peers:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address>/<prefix> remote-as <AS number>
```

You cannot remove dynamic peers manually. However, you can stop a dynamic peer using the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# no neighbor <neighbor address>/<prefix>
```

The stop command interrupts the BGP connection until the peer tries to reestablish the connection.

Also, when a dynamic peer state changes from established to idle, BGP removes the dynamic peer.

Loopback Interfaces

In many networks, multiple connections may exist between network devices. In such environments, it may be useful to employ a loopback interface for a common BGP router address, rather than peering the switch to each individual interface.

Note: To ensure that the loopback interface is reachable from peer devices, it must be advertised using an interior routing protocol (such as OSPF), or a static route must be configured on the peer.

To configure an existing loopback interface for BGP neighbor, use the following commands:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address>
Switch(config-router-neighbor)# update-source loopback <0-7>
```

What is a Route Map?

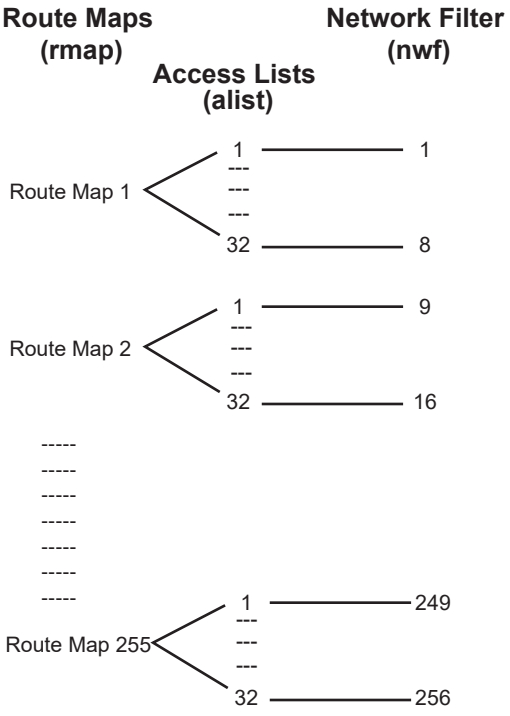
A route map is used to control and modify routing information. Route maps define conditions for redistributing routes from one routing protocol to another or controlling routing information when injecting it in and out of BGP. For example, a route map is used to set a preference value for a specific route from a peer router and another preference value for all other routes learned via the same peer router. For example, the following command is used to enter the Route Map mode for defining a route map:

```
Switch(config)# route-map <route map name>
Switch(config-route-map)# ?
```

A route map allows you to match attributes, such as metric, network address, and AS number. It also allows users to overwrite the local preference metric and to append the AS number in the AS route. See "BGP Failover Configuration" on page 511.

Cloud NOS allows you to configure up to 255 route maps. Each route map can have up to 32 access lists. Each access list consists of a network filter. A network filter defines an IP address and subnet mask of the network that you want to include in the filter. Figure 15 illustrates the relationship between route maps, access lists, and network filters.

Figure 15. Distributing Network Filters in Access Lists and Route Maps



Next Hop Peer IP Address

Next hop peer IP address can be configured only for route maps used in BGP. When a route map is applied on ingress, the next hop of learned routes is replaced with peer IP address. When applied on egress, the next hop of the redistributed routes is replaced with the local IP address.

```
Switch(config)# route-map <route map name>
Switch(config-route-map)# set ip next-hop peer-address
```

Incoming and Outgoing Route Maps

A BGP peer router can be configured to support up to two simultaneous route maps; one incoming route map and one outgoing route map.

If a route map is not configured in the incoming route map list, the router imports all BGP updates. If a route map is configured in the incoming route map list, the router ignores all unmatched incoming updates. If you set the action to `deny`, you must add another route map to permit all unmatched updates.

Route maps in an outgoing route map list behave similar to route maps in an incoming route map list. If a route map is not configured in the outgoing route map list, all routes are advertised or permitted. If a route map in the outgoing route map list is set to `permit`, matched routes are advertised and unmatched routes are ignored.

Precedence

You can set a priority to a route map by specifying a precedence value with the following command (Route Map mode):

```
Switch(config)# route-map <route map name> <sequence number (1-65535)>
```

The smaller the value the higher the precedence. If two route maps have the same precedence value, the smaller number has higher precedence.

Configuration Overview

To configure route maps:

1. Create the IP address prefix-list, specifying the IPv4 address and subnet mask of the network that you want to match.

```
Switch(config)# ip prefix-list <prefix list name> permit <IP address>/<prefix length>
```

2. Define a network filter.

```
Switch(config)# route-map <route map name>
Switch(config-route-map)# match ip address prefix-list <prefix list name>
```

Enable the network filter. You can distribute up to 256 network filters among 255 route maps each containing 32 access lists.

3. (Optional) Configure the AS filter attributes.

```
Switch(config)# ip as-path access-list <ACL name> permit <Regular expression to match>
Switch(config)# route-map <route map name>
Switch(config-route-map)# match as-path <ACL name>
```

4. (Optional) Set up the BGP attributes.

If you want to overwrite the attributes that the peer router is sending, define the following BGP attributes:

- Specify AS paths that you want to prepend to a matched route and the local preference for the matched route.
- Specify the metric [Multi Exit Discriminator (MED)] for the matched route.

```
Switch(config-route-map)# set as-path prepend <AS number> [<AS number> ...]
Switch(config-route-map)# set local-preference <local preference value>
Switch(config-route-map)# set metric <metric value>
Switch(config-route-map)# exit
```

5. Assign the route map to a peer router.

Select the peer router and then add the route map to the incoming route map list,

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address>
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# route-map <route map name> in
```

or to the outgoing route map list.

```
Switch(config-router-neighbor-af)# route-map <route map name> out
```

Aggregating Routes

Aggregation is the process of combining several different routes in such a way that a single route can be advertised, which minimizes the size of the routing table. You can configure aggregate routes in BGP either by redistributing an aggregate route into BGP or by creating an aggregate entry in the BGP routing table.

To define an aggregate route in the BGP routing table, use the following commands:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# address-family {ipv4|ipv6} unicast
Switch(config-router-af)# aggregate-address <IP address>/<prefix length>
```

The origin code for the aggregated route is either IGP or INCOMPLETE.

An example of creating a BGP aggregate route is shown in "Default Redistribution and Route Aggregation Example" on page 513.

Redistributing Routes

BGP injects local routes in two different ways:

- Using network configuration commands. These commands list networks that are candidates if they appear in the routing table.
- Using redistribution from another routing protocol.

In addition to running multiple routing protocols simultaneously, CNOS software can redistribute information from one routing protocol to another. For example, you can instruct the switch to use BGP to re-advertise static routes. This applies to all of the IP-based routing protocols.

You can also conditionally control the redistribution of routes between routing domains by defining a method known as route maps between the two domains. For more information on route maps, see "What is a Route Map?" on page 485. Redistributing routes is another way of providing policy control over whether to export OSPF routes, fixed routes, and static routes. For an example configuration, see "Default Redistribution and Route Aggregation Example" on page 513.

Default routes can be configured using the following methods:

- Import
- Originate—The router sends a default route to peers if it does not have any default routes in its routing table.
- Redistribute—Default routes are either configured through the default gateway or learned via other protocols and redistributed to peer routers. If the default routes are from the default gateway, enable the static routes because default routes from the default gateway are static routes. Similarly, if the routes are learned from another routing protocol, make sure you enable that protocol for redistribution.
- None

The origin code for the redistributed routes is INCOMPLETE.

The metrics of the non-BGP-learned routes are transferred to the metrics or MEDs of the new BGP route.

A route map can be used for each redistributed protocol to control which routes are redistributed. A route map can also be used to modify the BGP attributes of the redistributed routes. The switch can redistribute directly connected routes, static routes or routes learned through OSPF.

To configure route redistribution, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# address-family {ipv4|ipv6} unicast
Switch(config-router-af)# redistribute {direct|ospf|static} [route-map
<route map name>]
```

To view statistics for redistributed routes, use the following command:

```
Switch# show bgp {ipv4|ipv6} {unicast|multicast} policy statistics
redistribute {direct|static|all}
```

This command displays the following information:

- Route-map: The route-map name (if route-map is applied at redistribution)
- Compared count: How many static and connected routes were considered for redistribution into BGP
- Matched count: How many of these routes actually matched the route-map
- Total compared count: How many static and connected routes can be found in the routing table (including management routes)
- Total matched count: How many static and connected routes were actually redistributed by BGP (all routes minus management routes)

To clear statistics for redistributed routes, use the following command:

```
Switch# clear bgp {ipv4|ipv6} {unicast|multicast} policy statistics
redistribute {direct|static|all}
```

BGP Communities

BGP communities are attribute tags that allow controlled distribution of routing information based on an agreement between BGP peers. Communities are commonly used by transit service providers to enable peering customers to choose specific routing destinations for their outgoing routes. The transit service provider would typically publish a list of well-known or proprietary communities along with their descriptions, and take it upon itself to advertise incoming routes accordingly. For instance, an ISP may advertise that incoming routes tagged with community XY:01 will be advertised only to European peers while incoming routes tagged with community XY:02 will be advertised only to Asian peers.

The switch can be configured to manage the community tags applied to the outgoing route updates. It does not, however, modify any routing decisions based on the community tags.

Up to 32 community tags can be applied to prefixes that pass a route-map. Valid values are between 0:0 and 65535:65535. Newly added communities will replace the existing communities. To set communities to prefixes that pass the route-map, use the following commands:

```
Switch(config)# route-map <route map name>
Switch(config-route-map)# set community <AA:NN (autonomous system number: community number)>
```

To remove all community tags from prefixes that pass the route-map, use the following command:

```
Switch(config-route-map)# set community none
```

To propagate prefixes that pass the route-map with their original community settings, use the following command:

```
Switch(config-route-map)# no set community <AA:NN>
```

To enable or disable community tags forwarding for specific neighbors or neighbor groups, use the following commands:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address>[/<prefix>]
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# send-community
```

BGP Community

A *community* is a group of destinations which share some common property; this may be added to each prefix. Communities are transitive optional attributes. The community attribute can be thought of as a flat, 32-bit value that can be applied to any set of prefixes. It can be read as a 32-bit value or split into two portions, the first two bytes representing an ASN and the last two bytes as a value with a predetermined meaning. The community attribute is always used to do routing policy.

The values 0x00000000 through 0x0000FFFF and 0xFFFF0000 through 0xFFFFFFFF are reserved. Most modern router software displays communities as ASN:VALUE. In this format the communities 1:0 through 65534:65535 are available for use. The convention is to use the ASN of your own network as the leading 16 bits for your internal communities and communities with which you accept and send data.

Each autonomous system administrator may define which communities a destination belongs to. By default, all destinations belong to the general Internet community.

Three communities are defined in RFC 1997 and are standard within BGP implementations:

- **NO-EXPORT (0xFFFFFF01)**

  NO-EXPORT is commonly used within an AS to instruct routers not to export a prefix to eBGP neighbors.

- **NO-ADVERTISE (0xFFFFFF02)**

  NO-ADVERTISE instructs a BGP-speaking router not to send the tagged prefix to any other neighbor, including other iBGP routers.

- **NO-ADVERTISE-SUBCONFED (0xFFFFFF03).**

  NO-ADVERTISE-SUBCONFED is used to prevent a prefix from being advertised to external BGP peers (this includes peers in other members autonomous systems inside a BGP confederation).

BGP community attribute exchange between BGP peers is enabled when the `send-community` command is configured for the specified neighbor.

When multiple values are configured in the same community list statement, a logical AND condition is created. All community values must match to satisfy this AND condition. When multiple values are configured in separate community list statements, a logical OR condition is created. The first list that matches a condition is processed.

To add or remove a community list, use the following command:

```
Switch(config)# [no] ip community-list {standard|expanded} <community list
name> {deny|permit} {<AA:NN>|internet|local-as|no-advertise|no-export}
```

For example, the following command adds a community list called ‘myCommList’, which permits the advertising of routes to the internet community.

```
Switch(config)# ip community-list standard myCommList internet
```

To view the configuration, use the following command:

```
Switch# show ip community-list

Named Community standard list myCommList
    permit internet
```

BGP Extended Community

An upgrade to the standard community with a transitive-optional attribute (Type 16) is called the *extended community*. The current Internet RFC defines the extended community as an 8-octet value, while the community is only a 4-octet value. The first octet specifies the type; an optional second value can specify a subtype. This value dictates the structure given to the remaining octets.

The Type field gives the community some immediate flexibility. The first is the use of bit 0 to represent whether the community is registered with the IANA. The second bit gives the Extended Community a coarse scope, either Transitive, meaning it may be passed between ASs, or Non-Transitive, meaning it should be carried only within the local AS.

BGP extended community attribute exchange between BGP peers is enabled when the `send-community` command is configured for the specified neighbor.

When multiple values are configured in the same extended community list statement, a logical AND condition is created. All extended community values must match to satisfy this AND condition. When multiple values are configured in separate extended community list statements, a logical OR condition is created. The first list that matches a condition is processed.

To add or remove an extended community list, use the following command:

```
Switch(config)# [no] ip extcommunity-list {standard|expanded} <extended
community list name> {deny|permit} {<AA:NN>|rt|soo}
```

For example, the following commands adds an extended community list called 'denyRT-100-SOO-133', which denies routes from route target 34400:100 and site of origin 2500:133:

```
Switch(config)# ip extcommunity-list standard denyRT-100-SOO-133 deny rt
34400:100 soo 2500:133
```

To view the configuration, use the following command:

```
Switch# show ip extcommunity-list

Named extended community standard list denyRT-100-SOO-133
    deny 34400:100 2500:133
```

BGP Confederation

A fully meshed iBGP network becomes complex as the number of iBGP peers grows. You can reduce the iBGP mesh by dividing the autonomous system into multiple sub-autonomous systems and grouping them into a single confederation. A *confederation* is a group of iBGP peers that use the same autonomous system number (confederation identifier) to communicate to external networks. Each sub-autonomous system is fully meshed within itself and has a few connections to other sub-autonomous systems in the same confederation. The peers in sub-autonomous systems communicate with each other using sub-autonomous AS numbers.

To configure the confederation AS, use the following command:

```
Switch(config)# router bgp <AS number>
Switch(config-router)# confederation identifier <confederation AS (1-65535)>
```

To delete the confederation AS, use the following command:

```
Switch(config-router)# no confederation identifier
```

To configure the peer member AS number to be part of the BGP confederation, use the following command:

```
Switch(config)# router bgp <AS number>
Switch(config-router)# confederation peers <member AS (1-65535)> ...
```

Notes:

- You can add multiple confederation members with a single command.
- The member AS number is only visible with the BGP confederation.

BGP Path Attributes

Path attributes are the characteristics of an advertised BGP route. BGP routing policy is set and communicated using the path attributes.

There are four kinds of BGP path attributes:

- Well-known mandatory
- Well-known discretionary
- Optional transitive
- Optional non-transitive

Well-Known Mandatory

Well-known, mandatory attributes must appear in every UPDATE message. If a well-known, mandatory attribute is missing from an UPDATE message, a NOTIFICATION message must be sent to the peer.

Cloud NOS supports the following well-known, mandatory attributes:

- AS_PATH: the sequence of autonomous systems (AS) through the network from the switch to the destination;
- ORIGIN: the origin of the BGP route (IGP, EGP or incomplete);
- NEXT_HOP: the IP address of the next hop on the route.

Well-Known Discretionary

Well-known, discretionary attributes may or may not appear in an UPDATE message, but they must be supported by any BGP software implementation.

Cloud NOS supports the following well-known, discretionary attributes:

- LOCAL_PREF: the preference value of a certain path;
- ATOMIC_AGGREGATE: informs the neighboring AS that the originating routes has aggregated routes.

Optional Transitive

Optional, transitive attributes may or may not be supported in all BGP implementations. If an optional, transitive attribute is sent in an UPDATE message but is not recognized by the receiver, it must be passed on to the next AS.

Cloud NOS supports the following optional, transitive attributes:

- AS4_PATH: informs that the AS number is stored in four-octet format;
- AS4_AGGREGATOR: informs that the aggregator carries an AS number in four-octet format;
- AGGREGATOR: specifies the IP address and AS number of route aggregating BGP peer;
- COMMUNITY: a common policy used by BGP peers that are in the same group;
- EXTENDED COMMUNITIES: an extended range BGP community;

Optional Non-Transitive

Optional, non-transitive attributes may not be supported and will not be passed on if advertised. If an optional, non-transitive attribute is received, the router does not have to pass it on and may safely and quietly ignore the attribute.

Cloud NOS supports the following optional, non-transitive attributes:

- MULTI_EXIT_DISC (MED): indicates the preferred entry point into an AS, when multiple entry points are available;
- ORIGINATOR_ID: the router ID of route origin;
- CLUSTER_LIST: the sequence of the CLUSTER ID (the router ID) values representing the reflection path that the route has passed;
- MP_REACH_NLRI: Multiprotocol Reachable NLRI - advertises a feasible route to a peer or permits a router to advertise the Network Layer address of the BGP peer that should be used as the next hop address to the destinations listed in the Network Layer Reachability Information field;
- MP_UNREACH_NLRI: Multiprotocol Unreachable NLRI - withdraws multiple unfeasible routes from service.

Best Path Selection Logic

A BGP speaker may have several paths to the same destination. The local speaker can select the best paths, and then install it into the routing information base (RIB). The best path selection logic includes the following:

- Exclude paths that matches any of the following conditions.
  - Paths for which the NEXT_HOP is inaccessible
  - Paths for which it's punished by damping
  - Paths that are not synchronized if synchronization is configured
  - Paths from an external BGP (eBGP) neighbor if the local autonomous system (AS) appears in the AS_PATH
- If you enable `bgp enforce-first-as` and the UPDATE does not contain the AS of the neighbor as the first AS number in the AS_SEQUENCE, the router sends a notification and closes the session.
- Paths that are marked as `received-only` in the `show ip bgp` longer-prefixes output have been rejected by the policy. However, the router has stored the paths because you have configured `soft-reconfiguration inbound` for the neighbor that sent the path.

BGP Best Path Selection

If there are multiple paths, BGP compares the best path with the next path until BGP reaches the end of valid paths. The following rules determine the best path:

- Prefer the path with the highest WEIGHT.
- Prefer the path with the highest LOCAL_PREF.
- Prefer the path that was locally originated via a network command, then the path that was locally aggregated.
- Prefer the path with the shortest AS_PATH.
- Prefer the path with the lowest origin type. Interior Gateway Protocol (IGP) is lower than Exterior Gateway Protocol (EGP), and EGP is lower than INCOMPLETE.
- Prefer the path with the lowest multi-exit discriminator (MED).
- Prefer eBGP over Internal Border Gateway Protocol (iBGP) paths.
- Prefer the path with the lowest IGP metric to the BGP next hop.
- When both paths are external, prefer the path that was received first (the oldest one).
- Prefer the route that comes from the BGP router with the lowest router ID.
- If the originator or router ID is the same for multiple paths, prefer the path with the minimum cluster list length.
- Prefer the path that comes from the lowest neighbor address.

BGP Weight

The weight is assigned locally to each individual router, and the value is only understood by that particular router. The value is neither propagated nor carried through in route updates.

A weight can be any integer from 0 to 65535. Routes with a higher weight value have preference when there are multiple routes to the same destination. Routes learned through another BGP peer have a default weight of 0, and routes sourced by the local router (the paths that the router originated) have a default weight of 32768.

To configure the weight of a BGP peer, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# weight <0-65535>
```

To remove the weight associated with a BGP peer, use the following command:

```
Switch(config-router-neighbor)# no weight
```

Local Preference

When there are multiple paths to the same destination, the local preference attribute indicates the preferred path. The path with the higher preference is preferred (the default value of the local preference attribute is 100). Unlike the weight attribute, which is only relevant to the local router, the local preference attribute is part of the routing update and is exchanged among routers in the same AS.

The following commands use the route map local preference method, which affects both inbound and outbound directions.

```
Switch(config)# route-map <route map name>
Switch(config-route-map)# set local-preference <0-4294967295>
```

Metric (Multi-Exit Discriminator) Attribute

This attribute is a hint to external neighbors about the preferred path into an AS when there are multiple entry points. A lower metric value is preferred over a higher metric value. The default value of the metric attribute is 0.

Unlike local preference, the metric attribute is exchanged between ASs; however, a metric attribute that comes into an AS does not leave the AS.

When an update enters the AS with a certain metric value, that value is used for decision making within the AS. When BGP sends that update to another AS, the metric is reset to 0.

Unless otherwise specified, the router compares metric attributes for paths from external neighbors that are in the same AS.

Next Hop

BGP routing updates sent to a neighbor contain the next hop IP address used to reach a destination. In eBGP, the edge router, by default, sends its own IP address as the next hop address. The edge router receiving this next hop attribute, if it has any iBGP connection, will advertise this same IP address as the next hop attribute to other iBGP routers. However, this can sometimes cause routing path failures in Non-Broadcast Multiaccess Networks (NBMA). In some cases the routers inside this AS do not have a direct route to the external IP address in this next hop attribute, causing the route to not be installed in the hardware.

To avoid routing failures, you can manually configure the next hop IP address. When using NBMA networks, you can configure the external BGP speaker to advertise its own IP address as the next hop. With iBGP updates, you can configure the edge iBGP router to send its IP address as the next hop.

Next hop can be configured on a BGP peer or a peer group. Use the following commands:

- Next Hop for a BGP Peer:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor IP address>
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# next-hop-self
```

BGP ECMP

The BGP multipath feature is used for balancing forwarding loads on eBGP or iBGP routers when the destination route can be reached through multiple Equal Cost next hops. Equal cost is determined via the best path selection mechanism, and all paths that have equal cost are considered Multipath Candidates. To be candidates for multipath, paths to the same destination must have the following characteristics equal to the best-path characteristics:

- Weight
- Local preference
- AS path length
- Origin
- MED
- One of the following:
  - Neighboring AS or sub-AS
  - AS path

Best Path Selection Tuning

There are several ways of tuning the BGP path selection. They are available by using the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# bestpath ?

  always-compare-med          Allow comparing MED from different
                              neighbors
  as-path                     AS-path attribute
  compare-confed-aspath       Allow comparing confederation AS path
                              length
  compare-routerid            Compare router-id for identical EBGP paths
  dont-compare-originator-id  Don't Compare originator-id for BGP
  med                         MED attribute
  tie-break-on-age            Prefer old route when compare-route-id is
                              not set
```

- **`bestpath always-compare-med`**

  In best path selection section, BGP speaker compare the MED of 2 paths only when they are from same AS. When customer enables this option, BGP speaker will compare MED even from different AS.

- **`bestpath med`**

  Use this command to specify two MED (Multi Exit Discriminator) attributes:

  - **`bestpath med confed`**

    Enables MED comparison among paths learned from confederation peers. The MEDs are compared only if there is no external Autonomous System (an AS not within the confederation) in the path. If there is an external autonomous system in the path, the MED comparison is not made.

    For example in the following paths, the MED is not compared with Path3 as it is not in the confederation. MED is compared for Path1 and Path2 only.

    ```
    Path1 = 32000 32004, med=4
    Path2 = 32001 32004, med=2
    Path3 = 32003 1, med=1
    ```

  - **`bestpath med missing-as-worst`**

    Considers a missing MED attribute in a path as having a value of infinity, making the path without a MED value the least desirable path. If `missing-as-worst` is disabled, the missing MED is assigned the value of 0, making the path with the missing MED attribute the best path.

  - **`bestpath med non-deterministic`**

    When you enabled, BGP route selection process does not group routes from the same AS, the best route will depend on the order of routes receiving.

  - **`bestpath med remove-recv-med`**

    Removes the receive MED attribute from the MED attribute.

  - **`bestpath med remove-send-med`**

    Removes the send MED attribute from the MED attribute.

- **`bestpath compare-routerid`**

  Use this command to compare router IDs for identical eBGP paths. When comparing similar routes from peers, the BGP router does not consider the router ID of the routes. By default, it selects the first received route. This command causes BGP to include the router ID in the selection process. Similar routes are compared, and the route with lowest router ID is selected.

- **`bestpath tie-break-on-age`**

  Use this command to always select the older preferred route when the switch does not compare router IDS for identical eBGP paths.

- **`bestpath compare-confed-aspath`**

  Use this command to allow comparison of the confederation AS path length. This command specifies that the AS confederation path length must be used when available in the BGP best path decision process.

- **`bestpath dont-compare-originator-id`**

  Use this command to compare "not" an originator ID for an identical eBGP path.

- **`bestpath as-path multipath-relax`**

  Use this command to have the BGP speaker handle the paths received from different autonomous systems for multipath if their AS-path lengths are the same and all other multipath conditions are met.

- **`bestpath as-path ignore`**

  Ignores the AS path length when selecting a BGP route.

BGP Features and Functions

BGP on CNOS has the following features and functions.

AS-Path Filter

When the BGP speaker uses the `as-path` parameter to filter inbound or outbound routes, it compares the regular express of AS-path to the AS path of the inbound outbound routes. If they match and the action is `permit`, the routes are installed or sent to peers. If they match and the action is `deny`, the routes are denied or not sent to peers.

To configure the AS path filter, use the following command:

```
Switch(config)# ip as-path access-list <ACL name> {deny|permit} <regular
expression to match>
```

BGP Capability Code

A BGP speaker can negotiate capability by sending a capability code in an OPEN message when establishing the BGP session. CNOS supports the following capability codes:

Table 43. *BGP Capability Codes*

Capability Code	Capability Name
1	Multiprotocol Extensions for BGP-4
2	Route Refresh Capability for BGP-4
64	Graceful Restart Capability
65	Support for 4-octet AS number capability
67	Support for Dynamic Capability (capability specific)

Administrative Distance

An *administrative distance* is a rating of the trustworthiness of a routing information source. The administrative distance does not influence the BGP path selection algorithm, but it does influence whether BGP-learned routes are installed in the IP routing table.

TTL-Security Check

The BGP TTL Security Check feature protects the eBGP peering session by comparing the value in the TTL field of received IP packets against a hop count that is configured locally for each eBGP peering session:

- If the value in the TTL field of the incoming IP packet is greater than or equal to the locally configured value, the IP packet is accepted and processed normally.
- If the TTL value in the IP packet is less than the locally configured value, the packet is silently discarded, and no ICMP message is generated.

This is designed behavior; a response to a forged packet is unnecessary.

By default, eBGP does not support eBGP multi-hop. To enable or disable the exterior Border Gateway Protocol (eBGP) time-to-live (TTL) value to support eBGP multi-hop, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# [no] ebgp-multihop <1-255>
```

By default, there is no limit to how many hops can separate two BGP peers. To configure the maximum number of hops that separate two peers, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# ttl-security hops <1-254>
```

To reset this limit to its default value (0), use the following command:

```
Switch(config-router-neighbor)# no ttl-security hops
```

Note: When this feature is configured for a multi-hop peering session, the **ebgp-multihop** command cannot be used. If you attempt to use both commands for the same peering session, an error message will be displayed on the console.

Local-AS

The local AS feature allows a router to appear to be a member of a second autonomous system (AS) in addition to its real AS. Local AS allows two ISPs to merge without modifying peering arrangements. Routers in the merged ISP become members of the new autonomous system but continue to use their old AS numbers for their customers. You can only use the Local AS feature with true eBGP peers; you cannot use this feature for two peers that are members of different confederation sub-autonomous systems.

To enable or disable eBGP to prepend the local AS number to the AS path attribute, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# [no] local-as <AS number (1-4294967295)>
```

BGP Authentication

You can configure MD5 authentication between two BGP peers; each segment sent on the TCP connection between the peers is verified. MD5 authentication must be configured with the same password on both BGP peers or the connection between them will not be made. Configuring MD5 authentication causes the BGP speaker to generate and check the MD5 digest of every segment sent on the TCP connection.

To enable or disable BGP to use MD5 authentication when communicating with a certain neighbor, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# [no] password <neighbor password>
```

Note: An unencrypted password can be configured by using the following command:

```
Switch(config-router-neighbor)# [no] password 0 <neighbor password>
```

Note: For dynamic BGP peers, MD5 authentication is not supported.

Originate Default Route

By default, BGP sends the known default routes to neighbors, but will not originate a default route. If a route is configured instead of learned, it will not be sent. To originate default routes to neighbors, the `default-originate` feature must be enabled.

To enable or disable a BGP routing process to distribute a default route, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# address-family {ipv4|ipv6} unicast
Switch(config-router-neighbor-af)# [no] default-originate
```

Optionally, a route map can be specified to allow the default route to be injected conditionally. To do this, use the following command:

```
Switch(config-router-neighbor-af)# [no] default-originate route-map <route
map name>
```

IP Prefix-List Filter

There are several ways to filter BGP routes:

- IP prefix-list filter
- as-path filter
- route-map filter

When the BGP speaker uses the IP prefix list to filter inbound routes or outbound routes, it compares the prefix from the prefix list to the prefix of the inbound routes or outbound routes. If they match and the action is `permit`, the routes are installed or sent to peers. If they match and the action is `deny`, the routes are denied or not sent to peers.

To create or delete an IP prefix list, use the following command:

```
Switch(config)# ip prefix-list <prefix list name> ?

  deny         Specify packets to reject
  description  Prefix-list specific description
  permit       Specify packets to forward
  seq          Sequence number of an entry
```

For more details about the above command, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

For example, the following command adds an IP prefix list called 'pref-list-35' that forwards BGP routes that match IPv4 address 35.0.0.0 with prefix length 8:

```
Switch(config)# ip prefix-list pref-list-35 permit 35.0.0.0/8
```

To view prefix list information, use the following command:

```
Switch# show ip prefix list

ip prefix-list pref-list-35: 1 entries
     seq 5 permit 35.0.0.0/8
```

To enable or disable using IP prefix lists to filter BGP routes, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# address-family {ipv4|ipv6} unicast
Switch(config-router-neighbor-af)# [no] prefix-list <prefix list name> {in|out}
```

For example, to filter inbound BGP routes using the prefix list previously created (pref-list-35), use the following command:

```
Switch(config-router-neighbor-af)# prefix-list pref-list-35 in
```

Dynamic Capability

Dynamic Capability allows the dynamic update of capabilities over an established BGP session without disrupting the session.

By advertising Dynamic Capability to a peer in the open, a BGP speaker tells the peer that the speaker is capable of receiving and properly handling the `CAPABILITY` message from the peer after the BGP session has been established.

By default, Dynamic Capability is disabled. To enable or disable it on the switch, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# [no] dynamic-capability
```

BGP Graceful Restart

Usually when BGP on a router restarts, all the BGP peers detect that the session went down and then came up. This “down/up” transition is called *route flapping*. This causes BGP route re-computation, generation of BGP routing updates, and unnecessary churn to the forwarding tables. It can spread across multiple routing domains and create transient forwarding black holes and transient forwarding loops.

BGP graceful restart specifies a mechanism that allows a BGP speaker to preserve the forwarding state during BGP restart. BGP works in helper mode to help the connected router to perform a graceful restart.

The router can help the peer restart but it cannot preserve its own routing information when restarting. Thus, the peer neighbor cannot preserve the routing information advertised by a BGP router in only graceful restart helper mode.

By default, BGP graceful restart helper functionality is disabled. To enable or disable it on the switch, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# [no] graceful-restart-helper
```

To configure the maximum time (in seconds) to keep a restarting peer's stale routes, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# graceful-restart stalepath-time <1-3600>
```

By default, the maximum time the switch will keep a restarting peer’ stale routes is 360 seconds. To reset this value to its default, use the following command:

```
Switch(config-router)# [no] graceful-restart stalepath-time
```

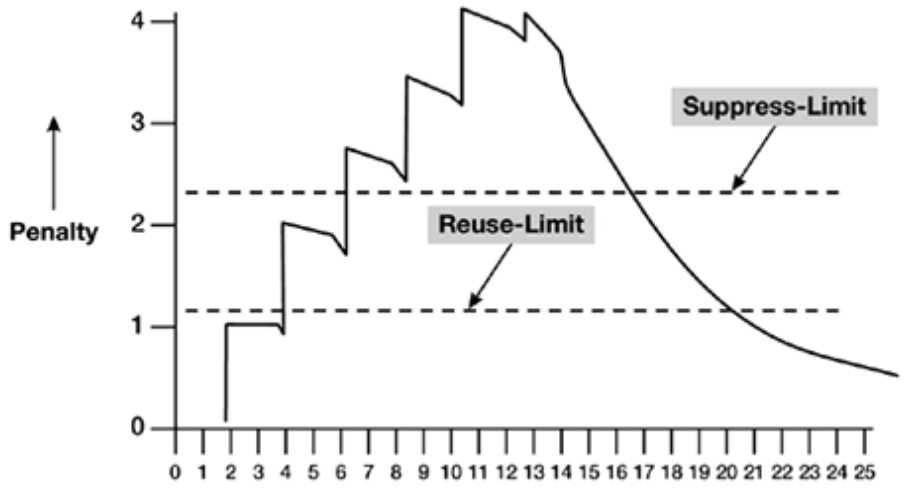
BGP Damping

Route flapping is a symptom of route instability. A route in the routing table may disappear and reappear intermittently when BGP sends a routing table, then withdraws it. A route that appears and disappears intermittently and repeatedly propagates BGP UPDATE and WITHDRAWN messages onto the Internet. If the prefix is constantly flapping, it can result in wasted CPU, bandwidth, and other network resources.

RFC 2439, *BGP Route Flap Damping*, defines a mechanism by which the amount of routing state propagated via BGP can be reduced by reducing the scope of route flap propagation. BGP Route Flap Dampening categorizes routes as either well-behaved or ill-behaved. A well-behaved route shows a high degree of stability during an extended period of time (as determined by configurable limits). An ill-behaved route is no longer advertised; it is suppressed until there is an indication that the route has become stable.

Route flap dampening requires BGP speakers to maintain a history of the advertisement and withdraw of each BGP path implementations provide the capability to tune the suppress-limit, reuse-limit, and half-life values to control how long a misbehaving prefix is suppressed. The general operation of BGP dampening is depicted in Figure 16.

Figure 16. BGP Route Flap Dampening



- A fixed penalty is assessed for each flap. A flap can be either a route withdraw or update with an attribute change.
- If the penalty exceeds the suppress-limit, the route is not advertised.
- The penalty is exponentially decayed based on the half-life value.
- Once the penalty is decayed below the reuse limit, the route is advertised.

The BGP flap dampening feature affects only external BGP routes (those in different ASes). You can also apply it within a confederation, between confederation member ASes. Because routing consistency within an AS is important, do not apply flap damping to iBGP routes, for it will be ignored.)

A value for reachability half time and a different value for unreachability half time is supported. The unreachability half time value must be higher. In this case, when computing the maximum suppress penalty, BGP uses this higher unreachabilty value.

By default, BGP route flap dampening is disabled. To enable or disable it, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# address-family {ipv4|ipv6} unicast
Switch(config-router-af)# [no] dampening [<half-life> [<reuse> <suppress> <maximum
duration> [<unreachability half-life>]]|routemap <route map name>]
```

Note: If the **dampening** command is used without any additional parameters, the switch will assume the default values for those parameters. For more details about this command, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

Soft Reconfiguration Inbound

This feature triggers routing updates for the specified peer without resetting the session. You can use this option if you change an inbound route policy. Soft reconfiguration inbound saves a copy of all routes received from the peer before processing the routes through the inbound route policy. If you change the inbound route policy, Cloud NOS passes these stored routes through the modified inbound route policy to update the route table without tearing down existing peering sessions. Soft reconfiguration inbound can use significant memory resources to store the unfiltered BGP routes.

This feature is disabled by default. To enable or disable it for a BGP peer, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# address-family {ipv4|ipv6} unicast
Switch(config-router-neighbor-af)# [no] soft-configuration inbound
```

BGP Route Refresh

BGP route refresh updates the inbound routing tables dynamically by sending route refresh requests to supporting peers when you change an inbound route policy. The remote BGP peer responds with a new copy of its routes that the local BGP speaker processes with the modified route policy.

The device supports both old and new route refresh capability. BGP peers advertise the route refresh capability as part of the BGP capability negotiation when establishing the BGP peer session.

To initiate a BGP route refresh, use the following command:

```
Switch# clear ip bgp <neighbor address> soft
```

BGP Multiple Address Families

You can manually configure the address families that BGP supports:

- Use the **address-family** command in BGP Configuration Mode to configure features for an address family.

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# address-family {ipv4|ipv6} unicast
Switch(config-router-af)#
```

- Use the **address-family** command in BGP Neighbor Configuration Mode to configure the specific address family for the neighbor.

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# address-family {ipv4|ipv6} unicast
Switch(config-router-neighbor-af)#
```

You must configure address families if you are using route redistribution, address aggregation and other advanced features.

BGP and BFD

Bidirectional forwarding detection (BFD) is a detection protocol designed to provide fast forwarding path failure detection times for media types, encapsulations, topologies, and routing protocols. You can use BFD to detect forwarding path failures at a uniform rate, rather than the variable rates for different protocol hello mechanisms. BFD makes network profiling and planning easier and reconvergence time consistent and predictable.

BFD provides subsecond failure detection between two BGP peers.

By default, BFD is disabled for BGP peers. To enable or disable it for a BGP peer, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# neighbor <neighbor address> remote-as <AS number>
Switch(config-router-neighbor)# [no] bfd
```

If the BGP peer is multiple hops away from the switch, use the following command to enable or disable BFD for that peer:

```
Switch(config-router-neighbor)# [no] bfd multihop
```

BFD is supported with BGP dynamic peers.

BGP Next Hop Tracking

Next hop tracking (NHT) is used to notify the BGP process asynchronously whenever there is any change in the IGP routes. NHT reduces the convergence time of BGP routes when IGP routes are changed.

The BGP process can wait for a configured or a default time after receiving a next hop change trigger from NSM, before it updates the BGP RIB. You can set and unset the time delay.

This feature is enabled by default. To configure BGP next hop tracking, use the following command:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# address-family {ipv4|ipv6} unicast
Switch(config-router-af)# nexthop trigger-delay critical <delay value
(1-4294967295 milliseconds)> non-critical <delay value (1-4294967295 milliseconds)>
```

To disable BGP next hop tracking, use the following command:

```
Switch(config-router-af)# nexthop trigger-delay
```

BGP Tuning

The following commands enable you to tune BGP protocols in BGP Neighbor Address Family Configuration Mode:

- **allowas-in**
- **as-origination-interval**
- **attribute-unchanged**
- **connection-retry-time**
- **description**
- **disallow-infinite-holdtime**
- **enforce-first-as**
- **fall-over**
- **fast-external-fallover**
- **log-neighbor-changes**
- **synchronization**
- **timer**
- **transport connection-mode passive**

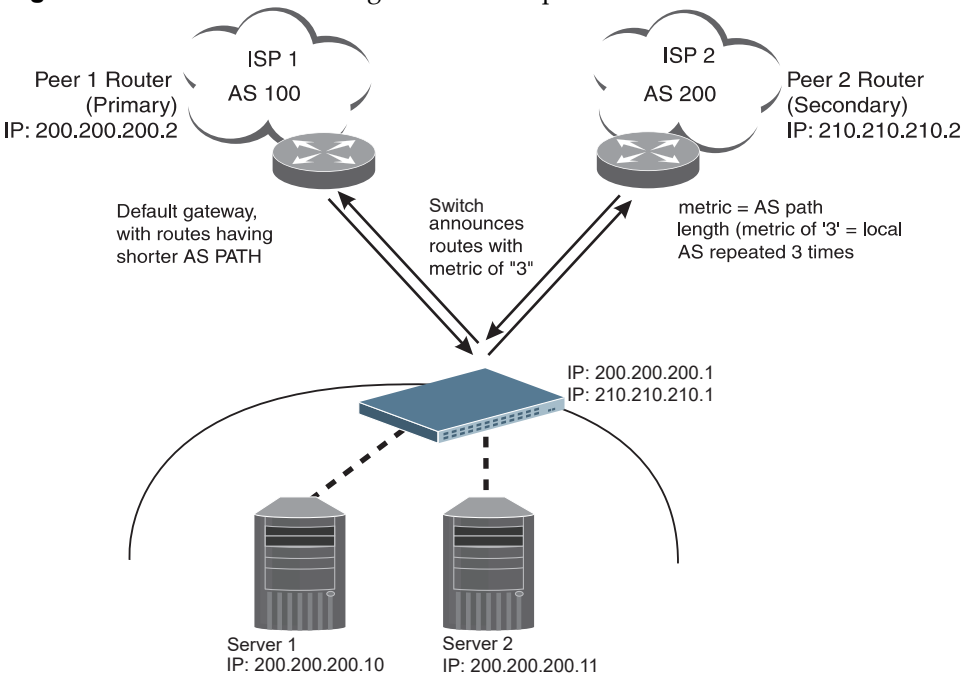
For more information about these commands, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

BGP Failover Configuration

Use the following example to create redundant default gateways for a switch at a Web Host/ISP site, eliminating the possibility, if one gateway goes down, that requests will be forwarded to an upstream router unknown to the switch.

As shown in Figure 17, the switch is connected to ISP 1 and ISP 2. The customer negotiates with both ISPs to allow the switch to use their peer routers as default gateways. The ISP peer routers will then need to announce themselves as default gateways to the switch.

Figure 17. BGP Failover Configuration Example



On the switch, one peer router (the secondary one) is configured with a longer AS path than the other, so that the peer with the shorter AS path will be seen by the switch as the primary default gateway. ISP 2, the secondary peer, is configured with a metric of "3," thereby appearing to the switch to be three router *hops* away.

1. Define the VLANs and IP interfaces using IPv4 addresses.

   The switch will need an IP interface for each default gateway to which it will be connected. Each interface must be placed in the appropriate VLAN. These interfaces will be used as the primary and secondary default gateways for the switch.

```
Switch(config)# interface vlan 1
Switch(config-if)# ip address 200.200.200.1/24
Switch(config-if)# exit

Switch(config)# interface vlan 2
Switch(config-if)# ip address 200.200.200.1/24
Switch(config-if)# exit
```

2. (Optional) Enable IP forwarding. IP forwarding is enabled on switch by default and is used for VLAN-to-VLAN (non-BGP) routing. Make sure IP forwarding is enabled if the default gateways are on different subnets, or if the switch is connected to different subnets that need to communicate through the switch.

```
Switch(config)# ip forwarding
```

3. Configure BGP peer router 1 and 2 with IPv4 addresses.

```
Switch(config)# router bgp <local AS number>
Switch(config-router)# neighbor 200.200.200.2 remote-as 100
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
Switch(config-router)# exit

Switch(config)# router bgp <local AS number>
Switch(config-router)# neighbor 210.210.210.2 remote-as 200
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
Switch(config-router)# exit
```

Note: Only one AS can be configured on the switch. When configuring BGP, choose the local AS number.

4. Verify the configuration:

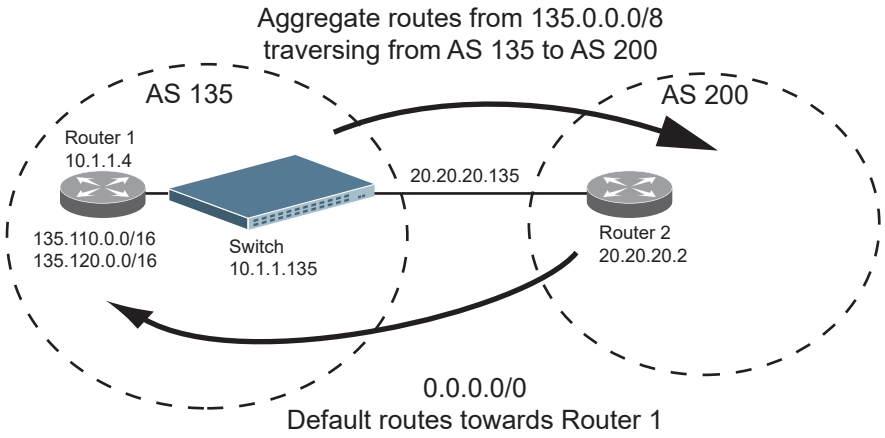
```
Switch# show ip bgp neighbors
```

Default Redistribution and Route Aggregation Example

This example shows you how to configure the switch to redistribute information from one routing protocol to another and create an aggregate route entry in the BGP routing table to minimize the size of the routing table.

As illustrated in Figure 18, you have two routers: one in AS 135 and the other in As 200. Configure the switch to redistribute the default routes from AS 200 to AS 135. At the same time, configure for route aggregation to allow you to condense the number of routes traversing from AS 135 to AS 200.

Figure 18. Route Aggregation and Default Route Redistribution



1. Configure the IP interfaces.
2. Configure the AS number (AS 135) and router ID (10.1.1.135) on the switch.

```
Switch(config)# router-id 10.1.1.135
Switch(config)# router bgp 135
Switch(config-router)#
```

3. Configure Router 1 with IPv4 addresses.

```
Router1(config)# router bgp 135
Router1(config-router)# router-id 10.1.1.4
```

4. Configure redistribution for Router 1.

```
Router1(config-router)# address-family ipv4 unicast
Router1(config-router-af)# redistribute static
```

5. Configure aggregation policy control on Router 1 by configuring the IPv4 routes that you want aggregated.

```
Router1(config-router-af)# aggregate-address 135.0.0.0/8
Router1(config-router-af)# exit
```

6. Configure Router 2 with IPv4 addresses.

```
Router2(config)# router bgp 200
Router2(config-router)# router-id 20.20.20.2
```

7. Configure redistribution for Router 2.

```
Router2(config-router)# address-family ipv4 unicast
Router2(config-router-af)# redistribute static
```

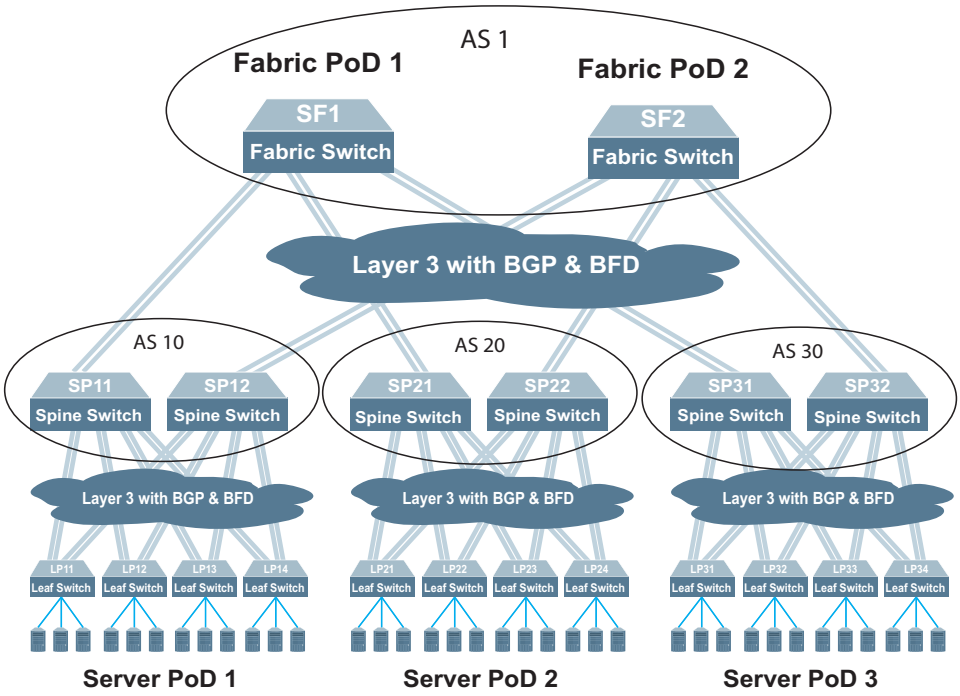
Designing a Clos Network Using BGP

A Clos network is a type of non-blocking, multistage switching architecture that reduces the number of ports required in an interconnected fabric. Instead of a hierarchically oversubscribed system of clusters, a Clos network turns your configuration into a high-performance network.

Clos networks are named after Bell Labs researcher Charles Clos, who determined that throughput is increased in a switching array or fabric if the switches are organized in a leaf-spine hierarchy.

In a leaf-spine topology, a series of leaf switches that form the access layer are fully meshed to a series of spine switches. Figure 19 shows a sample leaf-spine topology with a three-stage multi-7Point of Delivery (PoD) L3 Clos network.

Figure 19. Clos Network Topology



Each fabric switch (SF1 and SF2) serves as a fabric PoD that connects to one of the spine switches in each server PoD using BGP and Bidirectional Forwarding Detection (BFD). The spine switches each connect to four leaf switches using BGP and BFD. Using this kind of configuration, you can add capacity to your network by adding another server PoD instead of reconfiguring your existing infrastructure.

For more information on BFD, see "Bidirectional Forwarding Detection" on page 402.

Clos Network BGP Configuration Example

In this example, from each tier of the network topology, a single switch configuration is covered:

- for the Fabric tier: fabric switch SF1
- for the Spine tier: spine switch SP11
- for the Leaf tier: leaf switch LP11

The configurations for the rest of the switches in each tier are similar to the those presented. Only the IP addresses of the switch interfaces, the neighbor addresses and AS numbers of the BGP peers are different.

Autonomous system (AS) membership is as follows:

- AS 1 includes:
  - SF1
  - SF2
- AS 10 includes:
  - SP11
  - SP12
- AS 20 includes:
  - SP21
  - SP22
- AS 30 includes:
  - SP31
  - SP32
- AS 110 includes LP11
- AS 120 includes LP12
- AS 130 includes LP13
- AS 140 includes LP14
- AS 210 includes LP21
- AS 220 includes LP22
- AS 230 includes LP23
- AS 240 includes LP24
- AS 310 includes LP31
- AS 320 includes LP32
- AS 330 includes LP33
- AS 340 includes LP34

To configure BGP for the Clos Network topology shown in Figure 19 on page 515, follow the steps in the next section.

Configure Fabric Switch SF1

1. Configure the switch ethernet interfaces that are connected to its BGP peers (SP11, SP21 and SP31) as routing ports and assign them IP addresses.

```
Switch(config)# interface ethernet 1/49             (connected to SP11)
Switch(config-if)# no switchport
Switch(config-if)# ip address 1.11.1.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/50             (connected to SP11)
Switch(config-if)# no switchport
Switch(config-if)# ip address 1.11.2.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/51             (connected to SP21)
Switch(config-if)# no switchport
Switch(config-if)# ip address 1.21.1.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/52             (connected to SP21)
Switch(config-if)# no switchport
Switch(config-if)# ip address 1.21.2.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/53             (connected to SP31)
Switch(config-if)# no switchport
Switch(config-if)# ip address 1.31.1.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/54             (connected to SP31)
Switch(config-if)# no switchport
Switch(config-if)# ip address 1.31.2.1/30
Switch(config-if)# exit
```

2. Configure a loopback interface on the switch as a routing port and define its control plane service policy:

```
Switch(config)# interface loopback 0
Switch(config-if)# no switchport
Switch(config-if)# service-policy input copp-system-policy
Switch(config-if)# exit
```

3. Configure the BGP AS number for the switch, the path selection method and the maximum eBGP paths:

```
Switch(config)# router bgp 1
Switch(config-router)# bestpath as-path multipath-relax
Switch(config-router)# address-family ipv4 unicast
Switch(config-router-af)# maximum-paths ebgp 32
Switch(config-router-af)# exit
```

4. Define its BGP peers:

```
Switch(config-router)# neighbor 1.11.1.2 remote-as 10    (BGP peer SP11)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 1.11.2.2 remote-as 10    (BGP peer SP11)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 1.21.1.2 remote-as 20    (BGP peer SP21)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 1.21.2.2 remote-as 20    (BGP peer SP21)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 1.31.1.2 remote-as 30    (BGP peer SP31)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 1.31.2.2 remote-as 30    (BGP peer SP31)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

Configure Spine Switch SP11

1. Configure the switch ethernet interfaces that are connected to its BGP peers (SF1, LP11, LP12, LP13 and LP14) as routing ports and assign them IP addresses.

```
Switch(config)# interface ethernet 1/49              (connected to SF1)
Switch(config-if)# no switchport
Switch(config-if)# ip address 1.11.1.2/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/50              (connected to SF1)
Switch(config-if)# no switchport
Switch(config-if)# ip address 1.11.2.2/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/1               (connected to LP11)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.11.1.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/2               (connected to LP11)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.11.2.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/3               (connected to LP12)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.12.1.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/4               (connected to LP12)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.12.2.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/5               (connected to LP13)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.13.1.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/6               (connected to LP13)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.13.2.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/7               (connected to LP14)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.14.1.1/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/8               (connected to LP14)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.14.2.1/30
Switch(config-if)# exit
```

2. Configure a loopback interface on the switch as a routing port and define its control plane service policy:

```
Switch(config)# interface loopback 0
Switch(config-if)# no switchport
Switch(config-if)# service-policy input copp-system-policy
Switch(config-if)# exit
```

3. Configure the BGP AS number for the switch, the path selection method and the maximum eBGP paths:

```
Switch(config)# router bgp 10
Switch(config-router)# bestpath as-path multipath-relax
Switch(config-router)# address-family ipv4 unicast
Switch(config-router-af)# maximum-paths ebgp 32
Switch(config-router-af)# exit
```

4. Define its BGP peers:

```
Switch(config-router)# neighbor 1.11.1.1 remote-as 1      (BGP peer SF1)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 1.11.2.1 remote-as 1      (BGP peer SF1)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 2.11.1.2 remote-as 110    (BGP peer LP11)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 2.11.2.2 remote-as 110    (BGP peer LP11)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 2.12.1.2 remote-as 120    (BGP peer LP12)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 2.12.2.2 remote-as 120    (BGP peer LP12)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

```
Switch(config-router)# neighbor 2.13.1.2 remote-as 130    (BGP peer LP13)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 2.13.2.2 remote-as 130    (BGP peer LP13)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 2.14.1.2 remote-as 140    (BGP peer LP14)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 2.14.2.2 remote-as 140    (BGP peer LP14)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

Configure Leaf Switch LP11

1. Configure the switch ethernet interfaces that are connected to its BGP peers (SP11 and SP12) as routing ports and assign them IP addresses.

```
Switch(config)# interface ethernet 1/1              (connected to SP11)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.11.1.2/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/2              (connected to SP11)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.11.2.2/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/3              (connected to SP12)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.11.3.2/30
Switch(config-if)# exit

Switch(config)# interface ethernet 1/4              (connected to SP12)
Switch(config-if)# no switchport
Switch(config-if)# ip address 2.11.4.2/30
Switch(config-if)# exit
```

2. Configure a loopback interface on the switch as a routing port and define its control plane service policy:

```
Switch(config)# interface loopback 0
Switch(config-if)# no switchport
Switch(config-if)# service-policy input copp-system-policy
Switch(config-if)# exit
```

3. Configure the BGP AS number for the switch, the path selection method and the maximum eBGP paths:

```
Switch(config)# router bgp 110
Switch(config-router)# bestpath as-path multipath-relax
Switch(config-router)# address-family ipv4 unicast
Switch(config-router-af)# maximum-paths ebgp 32
Switch(config-router-af)# exit
```

4. Define its BGP peers:

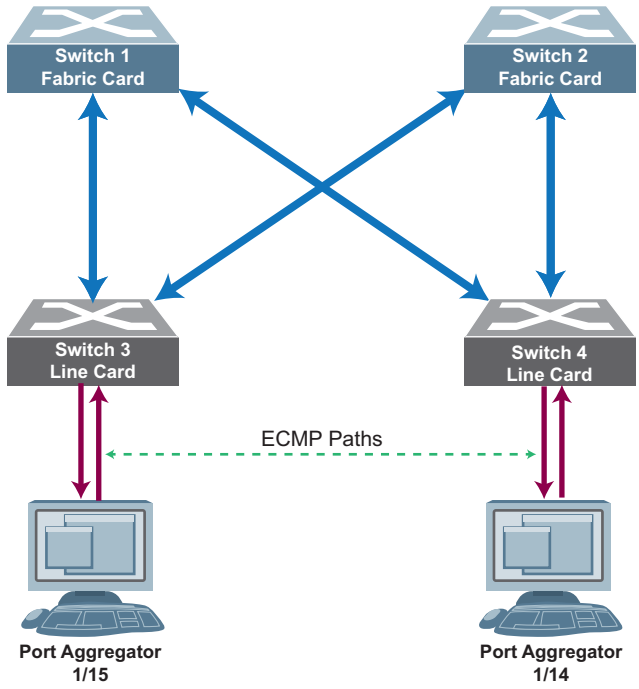
```
Switch(config-router)# neighbor 2.11.1.1 remote-as 10     (BGP peer SP11)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 2.11.2.1 remote-as 10     (BGP peer SP11)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 2.11.3.1 remote-as 20     (BGP peer SP12)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 2.11.4.1 remote-as 20     (BGP peer SP12)
Switch(config-router-neighbor)# advertisement-interval 0
Switch(config-router-neighbor)# bfd
Switch(config-router-neighbor)# address-family ipv4 unicast
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

BGP Unnumbered

The BGP unnumbered feature is useful for quick setup of large configurations for CLOS based network design. In a multi-chassis system you have a set of lower layer, or *line card* switches that all interconnect through a different set of upper layer, or *fabric card* switches to the *fabric chassis*.

Consider the following topology:

Figure 20. BGP Unnumbered Topology



Switch 1 and Switch 2 are fabric card switches that connect to the fabric chassis. The fabric card switches interconnect with the lower layer, or line card switches, which in this example are Switch 3 and Switch 4. The line card switches connect to ethernet ports or Link Aggregation Groups (LAGs).

This topology is applicable on both top-of-rack platforms and Clos chassis routers. This feature lets you configure routing between the line card switches and fabric card switches using the BGP protocol with minimal work. Once you enable BGP unnumbered, the line card switches can automatically generate BGP peering sessions with the fabric card switches.

Once the BGP neighbors are established, the routes are propagated, and traffic is routed via ECMP between servers.

Logical Link Discovery Protocol (LLDP) advertises the local MAC, BGP AS number, and BGP interface name on the links that have BGP unnumbered enabled. Once the peer side receives this information via LLDP, it indicates this to BGP. BGP computes the peer IPv6 link-local address from the MAC and interface name received from LLDP and starts to configure the link-local peer with the remote AS received from the LLDP message.

The BGP IPv6 link-local peer neighbors will be configured with addresses in the IPv4 family to transport IPv4 routes with IPv6 link-local next hops. BGP unnumbered supports Extension of AFI/SAFI Definitions for the IPv4 address Family to include IPv6 next hop address using multi-protocol reachable Network Layer Reachability Information (NLRI). This capability is enabled when feature is set and will be negotiated when receiving open messages from neighbors.

Configure BGP Unnumbered

BGP unnumbered on CNOS works with BGPD and LLDP, and only works with routed ports. To configure BGP unnumbered, you must:

- Enable BGP routing protocol
- Configure the AS number and router ID
- Enable BGP unnumbered routing
- Enable BGP unnumbered routing for the desired routed port interface
- Enable LLDP on each link (LLDP is enabled by default)
- Configure BGP unnumbered only on routed ports
- Have default IPv6 capability on interfaces

Each routed port has a default IPv6 auto-configured link-local address that is derived from the MAC address + the host's Extended Unique Identifier 64-Bit IPv6 interface identifier (EUI-64) to ensure the uniqueness of the address.

For example, to configure BGP unnumbered on Ethernet port 1/1 with AS number 42, router ID 10.11.12.13, and up to 32 EBGP paths:

1. Set up BGP on the router:

```
Switch(config)# router bgp 42
Switch(config-router)# router-id 10.11.12.13
Switch(config-router)# unnumbered
Switch(config-router-unnumbered)# exit
Switch(config-router)# exit
```

2. Configure the port as unnumbered:

```
Switch(config)# interface ethernet 1/1
Switch(config-if)# no switchport
Switch(config-if)# bgp unnumbered
Switch(config-if)# exit
```

BGP Unnumbered and BFD

BGP unnumbered can be used in conjunction with Bidirectional Forwarding Detection (BFD) to extend the capabilities of BGP unnumbered to make setting up large configurations easier and faster by enabling BFD on all BGP unnumbered neighbors. For more details about BFD, see "Bidirectional Forwarding Detection" on page 402.

By default, BGP unnumbered BFD is disabled.

Note: Enabling BFD multi-hop on BGP neighbors is unavailable.

The configuration requirements for BGP unnumbered BFD are the same as for BGP unnumbered:

- Enable LLDP on each link (LLDP is enabled by default)
- Support BGP
- BGP unnumbered must be configured only on routed ports
- Have default IPv6 capability on interfaces

Configure BGP Unnumbered BFD

To enable BGP unnumbered BFD, use the following steps:

1. Enter BGP unnumbered configuration mode:

```
Switch(config)# router bgp <AS number (1-4294967295)>
Switch(config-router)# unnumbered
Switch(config-router-unnumbered)#
```

2. To enable BFD for all BGP unnumbered neighbors, use the following command:

```
Switch(config-router-unnumbered)# bfd
```

Note: Once BGP unnumbered BFD is enabled, the switch is able to establish BFD sessions.

To disable BGP unnumbered BFD, use the following command:

```
Switch(config-router-unnumbered)# no bfd
```

BGP Unnumbered Limitations

The following limitations apply to BGP unnumbered:

- This feature only works on routed ports.
- The IPv4 routes with link-local next-hop will be installed only in hardware and not in the kernel so traffic is routed over hardware only.
- Programs that have packets that need to be routed by the CPU, such as ping or traceroute, will not work with packets with a destination associated with a hardware-only route.
- Routes learned through BGP unnumbered cannot be redistributed in OSPF.
- When establishing BGP sessions between switches that have BGP unnumbered enabled on them, you must use only external BGP (eBGP).
- When deleting all IPv4 routes from the switch, if the switch has learned routes through BGP unnumbered, also delete all IPv6 routes:

```
Switch# clear ip route *
Switch# clear ipv6 route *
```

Note: There are no hardware limitations related to this feature.

Differentiated Services and BGP

BGP works with the differentiated services (DS) computer networking architecture. You can use differentiated services with BGP to provide low-latency to critical network traffic, such as VOIP, while providing best-effort service to non-critical services.

A Differentiated Services Code Point (DSCP) is a method used to classify the way IP packets are queued before being forwarded by a router. Per RFCs 2474 and 2475, DS uses the 6-bit DSCP in the 8-bit DS field in the IP header to classify packets. The DSCP field and ECN (Explicit Congestion Notification) fields replace the IPv4 Type Of Service field in the IPv4 packet header.

When a router receives an IP header with a DSCP, it assigns one of 64 possible forwarding behaviors known as Per Hop Behaviors (PHBs). A PHB provides a particular service level, such as queuing or bandwidth, in accordance with network policy.

Table 44 contains commonly used DSCP values.

Table 44. *Commonly Used DSCP Values*

DSCP Value	Hex Value	Decimal value	Meaning	Drop probability	Equivalent IP precedence value
101 110	0x2e	46	Expedited forwarding (EF)	N/A	101 Critical
000 000	0x00	0	Best effort	N/A	000 - Routine
001 010	0x0a	10	AF11	Low	001 - Priority
001 100	0x0c	12	AF12	Medium	001 - Priority
001 110	0x0e	14	AF13	High	001 - Priority
010 010	0x12	18	AF21	Low	010 - Immediate
010 100	0x14	20	AF22	Medium	010 - Immediate
010 110	0x16	22	AF23	High	010 - Immediate
011 010	0x1a	26	AF31	Low	011 - Flash
011 100	0x1c	28	AF32	Medium	011 - Flash
011 110	0x1e	30	AF33	High	011 - Flash
100 010	0x22	34	AF41	Low	100 - Flash override
100 100	0x24	36	AF42	Medium	100 - Flash override
100 110	0x26	38	AF43	High	100 - Flash override

Commands for Using DS with BGP

To set a DSCP value with BGP, enter:

```
Switch(config-router)# dscp <value>
```

where *value* is the DSCP value; an integer from 0-63.

To display the DSCP value, enter:

```
Switch# show running-config bgp
```

Note: Configuring a DSCP value with BGP will reset BGP adjacencies.

DS with BGP Example

The following example sets BGP AS 100 to use DSCP 45 and then shows the changes on the switch:

```
Switch(config)# router bgp 100
Switch(config-router)# dscp 45
Switch(config-router)# exit

Switch(config)# show running-config bgp

!
router bgp 100
 router-id 10.30.30.25
 bestpath as-path multipath-relax
 dscp 45
 log-neighbor-changes
 address-family ipv4 unicast
...
!
```

BGP and VRF

The BGP process running on the switch checks the router ID before establishing a session with another BGP instance. If the router IDs match, then a session between the two BGP instances cannot be established.

You can assign the router ID of the BGP instance to a specific Virtual Routing and Forwarding (VRF) instance, thus allowing BGP VRF-to-VRF peering on the same switch. This allows to configure a different router ID for each BGP VRF instance. For more details about VRF, see "Virtual Routing and Forwarding" on page 397.

VRF instance assignment of different BGP router IDs allows the support of multi-tenant user systems by virtualizing the physical BGP router as multiple virtual BGP routers. The virtual BGP routers are still part of the same Autonomous System (AS) as the physical router.

The default BGP instance is assigned to the default VRF instance. The default BGP instance is also called the master BGP instance.

VRF in conjunction with the master BGP instance are used in Multi-protocol Border Gateway Protocol (MP-BGP) Ethernet Virtual Private Networks (EVPN). Each BGP VRF instance is considered a VPN client and the master BGP instance acts as a provider edge (PE) router that communicates with other PE routers to exchange VPN routes.

Note: A route distinguisher (RD) should be configured if that VRF is used with BGP.

Configuring a BGP VRF Instance

To configure a new BGP VRF instance, use the following steps:

1. Create a new custom VRF instance:

```
Switch(config)# vrf context <VRF instance name>
Switch(config-vrf)#
```

For example, create a VRF instance called 'vrf01':

```
Switch(config)# vrf context vrf01
```

2. Configure a route distinguisher (RD) for the VRF instance:

```
Switch(config-vrf)# rd <route distinguisher value>
Switch(config-vrf)# exit
Switch(config)#
```

For example:

```
Switch(config-vrf)# rd 65000:100
```

3. Enter the configuration mode for a Switch Virtual Interface (SVI) interface or a Layer 3 routed port:

```
Switch(config)# interface {vlan <VLAN ID>|ethernet <chassis number/port number>}
Switch(config-if)#
```

For example, SVI VLAN 2:

```
Switch(config)# interface vlan 2
```

4. Assign the VRF instance to the current interface:

```
Switch(config-if)# vrf member <VRF instance name>
```

For example:

```
Switch(config-if)# vrf member vrf01
```

5. Configure the IP address of the current interface:

```
Switch(config-if)# ip address <IP address>
Switch(config-if)# exit
Switch(config)#
```

For example:

```
Switch(config-if)# ip address 20.155.67.30
```

6. Enter BGP configuration mode:

```
Switch(config)# router bgp <AS number>
Switch(config-router)#
```

For example:

```
Switch(config)# router bgp 100
```

7. Enter the BGP VRF instance configuration mode:

```
Switch(config-router)# vrf <VRF instance name>
Switch(config-router-vrf)#
```

For example:

```
Switch(config-router)# vrf vrf-red
```

8. From this configuration mode, the BGP VRF instance can be configured as a regular BGP instance.

   For example, you can configure a static BGP peer:

```
Switch(config-router-vrf)# neighbor 20.93.140.70 remote-as 300
Switch(config-router-vrf-neighbor)# address-family ipv4 unicast
Switch(config-router-vrf-neighbor-af)# exit
Switch(config-router-vrf-neighbor)# exit
Switch(config-router)# exit

Switch(c0nfig)# show ip bgp neighbors vrf vrf-red

BGP neighbor is 20.93.140.70, remote AS 300, local AS 400, external link
  BGP version 4, remote router ID 20.55.241.144
  BGP state = Established, up for 18:08:10
  Last read 18:08:10, hold time is 180, keepalive interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received (old and new)
    4-Octet ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
  Received 1090 messages, 0 notifications, 0 in queue
  Sent 1090 messages, 0 notifications, 0 in queue
  Route refresh request: received 0, sent 0
  Minimum time between advertisement runs is 30 seconds
 For address family: IPv4 Unicast
  BGP table version 1, neighbor version 1
  Index 2, Offset 0, Mask 0x4
  0 accepted prefixes, maximum limit 15870
  Threshold for warning message 75(%)
  0 announced prefixes

 Connections established 5; dropped 4
  TTL: 1, TTL Security hops: 0
Local host: 20.93.140.1, Local port: 49370
Foreign host: 20.93.140.2, Foreign port: 179
Nexthop: 20.93.140.1
Nexthop global: fe80::a68c:dbff:fee6:4c01
Nexthop local: ::
BGP connection: non shared network
Last Reset: 18:08:15, due to BGP Notification sent
Notification Error Message: (Cease/Administratively Reset.)

Update packets: 0
Update packets dropped: 0
 - Decode error drops: 0
 - Internal error drops: 0

 For address family: IPv4 Unicast
Withdraw prefixes: 0
Withdraw prefixes dropped: 0
 - Decode error drops: 0
 - Internal error drops: 0
NLRI prefixes: 0
NLRI prefixes dropped: 0
 - Decode error drops: 0
 - Internal error drops: 0
 - Route-map drops: 0
 - Filter drops: 0
 - AS-path loop drops: 0
 - Route reflector drops: 0
 - Next-hop drops: 0
 - Other drops: 0
```

Chapter 23. Open Shortest Path First

Lenovo Cloud Network Operating System supports the Open Shortest Path First (OSPF) routing protocol. The Cloud NOS implementation conforms to the OSPF version 2 specifications detailed in Internet RFC 2328. The following sections discuss OSPF support for the switch:

- "OSPFv2 Overview" on page 534. This section provides information on OSPFv2 concepts, such as types of OSPF areas, types of routing devices, neighbors, adjacencies, link state database, authentication, and internal versus external routing.
- "OSPFv2 Implementation in Cloud NOS" on page 538. This section describes how OSPFv2 is implemented in CNOS, such as configuration parameters, electing the designated router, summarizing routes, defining route maps and so forth.
- "OSPFv2 Configuration Examples" on page 548. This section provides step-by-step instructions on configuring different OSPFv2 examples:
  - Creating a simple OSPF domain
  - Creating virtual links
  - Summarizing routes

OSPFv2 Overview

OSPF is designed for routing traffic within a single IP domain called an Autonomous System (AS). The AS can be divided into smaller logical units known as *areas*.

All routing devices maintain link information in their own Link State Database (LSDB). OSPF allows networks to be grouped together into an area. The topology of an area is hidden from the rest of the AS, thereby reducing routing traffic. Routing within an area is determined only by the area's own topology, thus protecting it from bad routing data. An area can be generalized as an IP subnetwork.

The following sections describe key OSPF concepts.

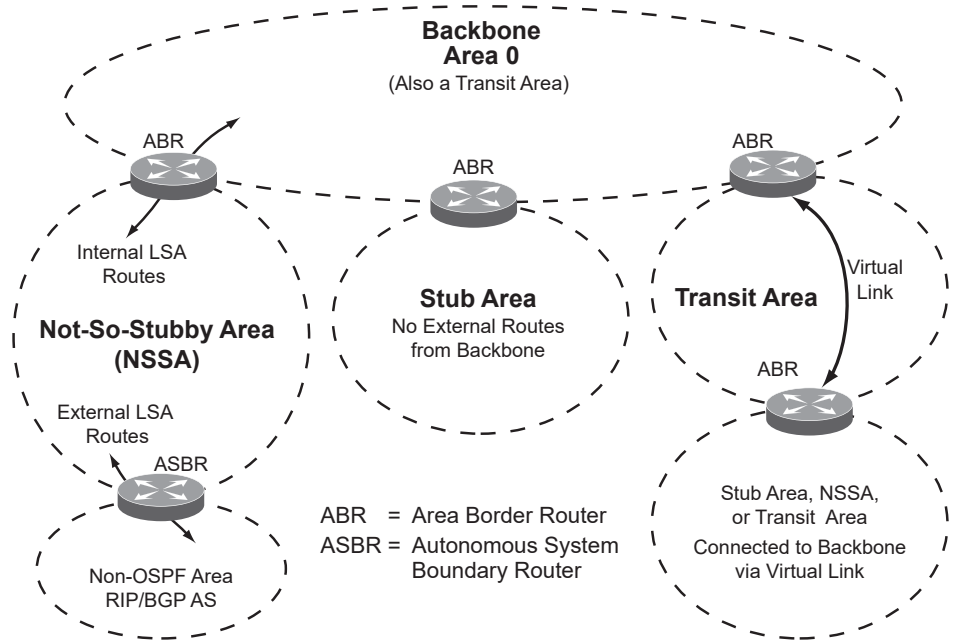
Types of OSPF Areas

An AS can be broken into logical units known as *areas*. In any AS with multiple areas, one area must be designated as area 0, known as the *backbone*. The backbone acts as the central OSPF area. All other areas in the AS must be connected to the backbone. Areas inject summary routing information into the backbone, which then distributes it to other areas as needed.

As shown in Figure 21, OSPF defines the following types of areas:

- Stub Area—an area that is connected to only one other area. External route information is not distributed into stub areas.
- Not-So-Stubby-Area (NSSA)—similar to a stub area with additional capabilities. Routes originating from within the NSSA can be propagated to adjacent transit and backbone areas. External routes from outside the AS can be advertised within the NSSA but can be configured to not be distributed into other areas.
- Transit Area—an area that carries data traffic which neither originates nor terminates in the area itself.

Figure 21. OSPF Area Types

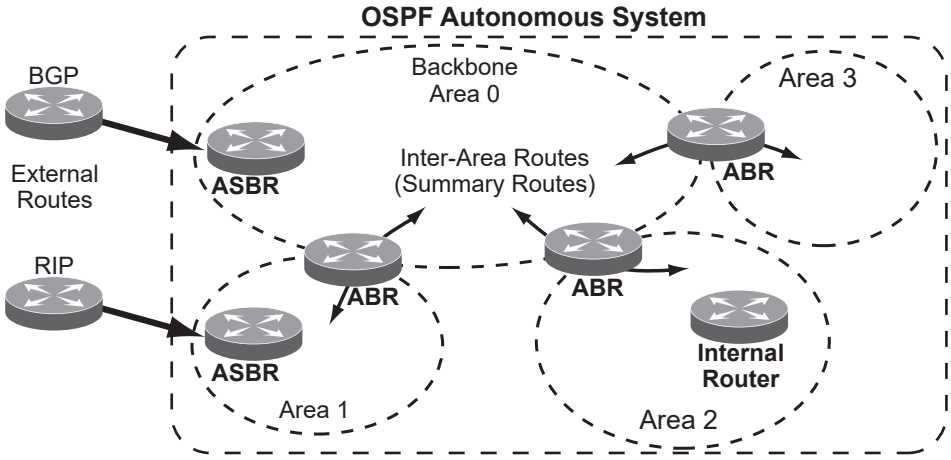


Types of OSPF Routing Devices

As shown in Figure 22, OSPF uses the following types of routing devices:

- Internal Router (IR)—a router that has all of its interfaces within the same area. IRs maintain LSDBs identical to those of other routing devices within the local area.
- Area Border Router (ABR)—a router that has interfaces in multiple areas. ABRs maintain one LSDB for each connected area and disseminate routing information between areas.
- Autonomous System Boundary Router (ASBR)—a router that acts as a gateway between the OSPF domain and non-OSPF domains, such as RIP, BGP, and static routes.

Figure 22. OSPF Domain and an Autonomous System



Neighbors and Adjacencies

In areas with two or more routing devices, *neighbors* and *adjacencies* are formed.

Neighbors are routing devices that maintain information about each others' state. To establish neighbor relationships, routing devices periodically send hello packets on each of their interfaces. All routing devices that share a common network segment, appear in the same area, and have the same health parameters (`hello` and `dead` intervals) and authentication parameters respond to each other's hello packets and become neighbors. Neighbors continue to send periodic hello packets to advertise their health to neighbors. In turn, they listen to hello packets to determine the health of their neighbors and to establish contact with new neighbors.

The hello process is used for electing one of the neighbors as the network segment's Designated Router (DR) and one as the network segment's Backup Designated Router (BDR). The DR is adjacent to all other neighbors on that specific network segment and acts as the central contact for database exchanges. Each neighbor sends its database information to the DR, which relays the information to the other neighbors.

The BDR is adjacent to all other neighbors (including the DR). Each neighbor sends its database information to the BDR just as with the DR, but the BDR merely stores this data and does not distribute it. If the DR fails, the BDR will take over the task of distributing database information to the other neighbors.

The Link-State Database

OSPF is a link-state routing protocol. A *link* represents an interface or routable path from the routing device. By establishing an adjacency with the DR, each routing device in an OSPF area maintains an identical Link-State Database (LSDB) describing the network topology for its area.

Each routing device transmits a Link-State Advertisement (LSA) on each of its *active* interfaces. LSAs are entered into the LSDB of each routing device. OSPF uses *flooding* to distribute LSAs between routing devices. Interfaces may also be *passive*. Passive interfaces send LSAs to active interfaces, but do not receive LSAs, hello packets, or any other OSPF protocol information from active interfaces. Passive interfaces behave as stub networks, allowing OSPF routing devices to be aware of devices that do otherwise participate in OSPF (either because they do not support it, or because the administrator chooses to restrict OSPF traffic exchange or transit).

When LSAs result in changes to the routing device's LSDB, the routing device forwards the changes to the adjacent neighbors (the DR and BDR) for distribution to the other neighbors.

OSPF routing updates occur only when changes occur, rather than periodically. For each new route, if a neighbor is interested in that route (for example, if configured to receive static routes and the new route is static), an update message containing the new route is sent to the adjacency. For each route removed from the route table, if the route has already been sent to a neighbor, an update message containing the route to withdraw is sent.

The Shortest Path First Tree

The routing devices use a link-state algorithm (Dijkstra's algorithm) to calculate the shortest path to all known destinations, based on the cumulative *cost* required to reach the destination.

The cost of an individual interface in OSPF is an indication of the overhead required to send packets across it.

Internal Versus External Routing

To ensure effective processing of network traffic, every routing device on your network needs to know how to send a packet (directly or indirectly) to any other location or destination in your network. This is referred to as *internal routing* and can be done with static routes or using active internal routing protocols, such as OSPF, RIP, or RIPv2.

It is also useful to tell routers outside your network (upstream providers or *peers*) about the routes you have access to in your network. Sharing of routing information between autonomous systems is known as *external routing*.

Typically, an AS will have one or more border routers (peer routers that exchange routes with other OSPF networks) as well as an internal routing system enabling every router in that AS to reach every other router and destination within that AS.

When a routing device *advertises* routes to boundary routers on other autonomous systems, it is effectively committing to carry data to the IP space represented in the route being advertised. For example, if the routing device advertises 192.204.4.0/24, it is declaring that if another router sends data destined for any address in the 192.204.4.0/24 range, it will carry that data to its destination.

OSPFv2 Implementation in Cloud NOS

CNOS supports a single instance of OSPF and up to 8k routes on the network. The following sections describe OSPF implementation in CNOS:

Configurable Parameters

In CNOS, OSPF parameters can be configured through the Industry Standard Command Line Interfaces (ISCLI), or through SNMP. For more information, see Chapter 2, "Switch Administration."

The ISCLI supports the following parameters: interface output cost, interface priority, dead and hello intervals, retransmission interval, and interface transmit delay.

In addition to the preceding parameters, you can specify the following:

- OSPF traps—Traps produce messages upon certain events or error conditions, such as missing a hello, failing a neighbor, or recalculating the SPF.
- Link-State Database size—The size of the LSA database can be specified to help manage the memory resources on the switch.
- Stub area metric—A stub area can be configured to send a numeric metric value such that all routes received via that stub area carry the configured metric to potentially influence routing decisions.
- Default routes—Default routes with weight metrics can be manually injected into transit areas. This helps establish a preferred route when multiple routing devices exist between two areas. It also helps route traffic to external networks.
- Passive—When enabled, the interface sends LSAs to upstream devices, but does not otherwise participate in OSPF protocol exchanges.
- Point-to-Point—For LANs that have only two OSPF routing agents (the switch and one other device), this option allows the switch to significantly reduce the amount of routing information it must carry and manage.

Defining Areas

If you are configuring multiple areas in your OSPF domain, one of the areas must be designated as area 0, known as the *backbone*. The backbone is the central OSPF area and is usually physically connected to all other areas. The areas inject routing information into the backbone which, in turn, disseminates the information into other areas.

Since the backbone connects the areas in your network, it must be a contiguous area. If the backbone is partitioned (possibly as a result of joining separate OSPF networks), parts of the AS will be unreachable, and you will need to configure *virtual links* to reconnect the partitioned areas (see "Virtual Links" on page 543).

Up to 20 OSPF areas can be connected to the switch with CNOS software. To configure an area, the OSPF number must be defined and then attached to a network interface on the switch. The full process is explained in the following sections.

An OSPF area is defined by assigning an *area ID*. The command to define and enable an OSPF area is as follows:

```
Switch(config)# router ospf
Switch(config-router)# area {<area ID (1-4294967295)>|<area ID as IPv4 address>}
```

Using the Area ID to Assign the OSPF Area Number

The OSPF area number can be defined as a decimal number ranging from 1 to 4294967295, or as an IPv4 address. The IPv4 address format is used for compatibility with two different systems of notation used by other OSPF network vendors. There are two valid ways to designate an area ID:

- Single Number

  Most common OSPF vendors express the area ID number as a single number. For example, the Cisco IOS-based router command "`network 1.1.2.0 0.0.0.255 area 1`" defines the area number simply as "`area 1.`"

- Multi-octet (*IP address*): Placing the area number in the last octet (0.0.0.*n*)

  Some OSPF vendors express the area ID number in multi-octet format. For example, "`area 0.0.0.2`" represents OSPF area 2 and can be specified directly on the switch as "`area 0.0.0.2`".

On the switch, using the last octet in the area ID, "`area 1`" is equivalent to "`area 0.0.0.1`".

Note: Although both types of area ID formats are supported, be sure that the area IDs are in the same format throughout an area.

Attaching an Area to a Network

Once an OSPF area has been defined, it must be associated with a network. To attach the area to a network, you must assign the OSPF area ID to an IP interface that participates in the area. The format for the command is as follows:

```
Switch(config)# interface ethernet <chassis number>/<port number>
Switch(config-if)# no switchport
Switch(config-if)# ip address <IP address/mask>
Switch(config-if)# ip router ospf 0 area <area ID> [secondaries none]
Switch(config-if)# exit
```

For example, the following commands could be used to add a network area 0.0.0.10 to the OSPFv2 instance:

```
Switch(config)# interface ethernet 1/2
Switch(config-if)# no switchport
Switch(config-if)# ip address 192.0.2.1/16
Switch(config-if)# ip router ospf 0 area 0.0.0.10
Switch(config-if)# exit
```

Note: OSPFv2 supports IPv4 only.

Interface Cost

The OSPF link-state algorithm (Dijkstra's algorithm) places each routing device at the root of a tree and determines the cumulative *cost* required to reach each destination. You can manually enter the cost for the output route with the following command (Interface IP mode):

```
Switch(config)# interface ethernet <chassis number>/<port number>
Switch(config-if)# ip ospf cost <cost value (1-65535)>
```

Electing the Designated Router and Backup

In any broadcast type subnet, a Designated Router (DR) is elected as the central contact for database exchanges among neighbors. On subnets with more the one device, a Backup Designated Router (BDR) is elected in case the DR fails.

DR and BDR elections are made through the `hello` process. The election can be influenced by assigning a priority value to the OSPF interfaces on the switch. The command is as follows:

```
Switch(config)# interface ethernet <chassis number>/<port number>
Switch(config-if)# ip ospf priority <priority value (0-255)>
```

A priority value of 255 is the highest, and 1 is the lowest. A priority value of zero (0) specifies that the interface cannot be used as a DR or BDR. In case of a tie, the routing device with the highest router ID wins. Interfaces configured with a priority of zero (0) do not participate in the DR or BDR election process. Layer 3 switches with OSPF enabled that are connected between each other by passive interfaces will also not participate in the DR or BDR election process.

Summarizing Routes

Route summarization condenses routing information. Without summarization, each routing device in an OSPF network would retain a route to every subnet in the network. With summarization, routing devices can reduce some sets of routes to a single advertisement, reducing both the load on the routing device and the perceived complexity of the network. The importance of route summarization increases with network size.

Summary routes can be defined for up to 16 IP address ranges using the following command:

```
Switch(config)# router ospf
Switch(config-router)# area <area ID> range {<area range prefix> <area range prefix mask>|
|<area range prefix>/<prefix length>} [advertise|non-advertise]
```

where:

- *area ID* is written as a number from 0 to 4294967295 or as an IPv4 address
- *area range prefix* is the base IP address for the range
- *area range prefix mask* is the IP address mask for the range

For a detailed configuration example, see "Example 3: Summarizing Routes" on page 552.

A filter can be configured to advertise summary routes on an Area Border Router (ABR). This command suppresses incoming and outgoing summary routes between a specific area and the others:

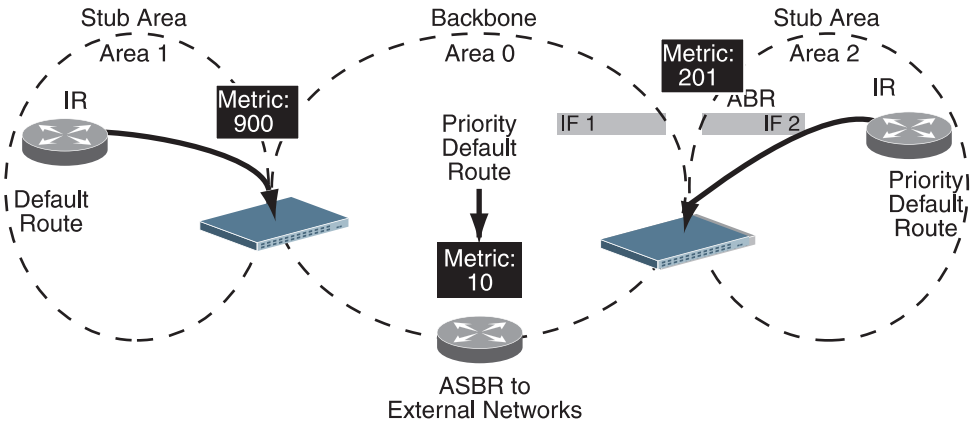
```
Switch(config)# router ospf
Switch(config-router)# area <area id> filter-list route-map <map name>
{in|out}
```

Default Routes

When an OSPF routing device encounters traffic for a destination address it does not recognize, it forwards that traffic along the *default route*. Typically, the default route leads upstream toward the backbone until it reaches the intended area or an external router.

Each switch acting as an ABR automatically inserts a default route into stub. In simple OSPF stub areas with only one ABR leading upstream (see Area 1 in Figure 23), any traffic for IP address destinations outside the area is forwarded to the switch's IP interface, and then into the connected transit area (usually the backbone). Since this is automatic, no further configuration is required for such areas.

Figure 23. Injecting Default Routes



If the switch is in a transit area and has a configured default gateway, it can inject a default route into rest of the OSPF domain. Use the following command to configure the switch to inject OSPF default routes:

```
Switch(config)# router ospf
Switch(config-router)# default-information originate [always] [metric
<metric value (0-16777214)>] [metric-type {1|2}] [route-map <map-name>]
```

In the above command, the `metric` is used to calculate the cost of the default route. The metric value is the inverse proportional of the bandwidth of the default route. A higher bandwidth means a lower metric value, and a lower bandwidth means a higher metric value. A metric value of one (1) informs OSPF that the route has the highest bandwidth, and a metric value of zero (0) informs OSPF that the route is directly connected to the switch.

OSPF supports two types of external metrics for default routes:

- `type 1` - uses the cost of the external route and the cost to reach the autonomous system boundary router (ASBR).
- `type 2` - uses only the cost of the external route, and ignores the cost to reach the ASBR.

By default, OSPF uses type 2 external metric. If both types of metric are present simultaneously in the AS, type 1 external metrics always have precedence over type 2.

When the switch is configured to inject a default route, an AS-external LSA with link state ID 0.0.0.0 is propagated throughout the OSPF routing domain. This LSA is sent with the configured metric value and metric type.

The OSPF default route configuration can be removed with the command:

```
Switch(config)# router ospf
Switch(config-router)# no default-information originate
```

Virtual Links

Usually, all areas in an OSPF AS are physically connected to the backbone. In some cases where this is not possible, you can use a *virtual link*. Virtual links are created to connect one area to the backbone through another non-backbone area (see Figure 21 on page 535).

The area which contains a virtual link must be a transit area and have full routing information. Virtual links cannot be configured inside a stub area or NSSA.

To set a link between two backbone areas that are physically separated through another non-backbone area, use the following command:

```
Switch(config)# router ospf
Switch(config-router)# area <area ID> virtual link <IP address>
Switch(config-router-vlink)#
```

To configure an authentication type and key between virtual link neighbors, use the following commands

1. Configure the authentication type between the virtual link neighbors:

```
Switch(config-router-vlink)# authentication message-digest
```

2. Configure the authentication key between the virtual link neighbors:

```
Switch(config-router-vlink)# authentication <string>
```

3. Configures the message digest key for the virtual link:

```
Switch(config-router-vlink)# message-digest-key <key ID> {md5|sha256}
<string>
```

where `message-digest` enables MD5 or SHA-256 authentication and *string* is the password string.

For a detailed configuration example on Virtual Links, see "Example 2: Virtual Links" on page 550.

Router ID

Routing devices in OSPF areas are identified by a router ID. The router ID is expressed in IP address format. The IP address of the router ID is not required to be included in any IP interface range or in any OSPF area, and may even use the switch loopback interface.

The router ID can be configured in one of the following two ways:

- Dynamically—OSPF protocol configures the highest IP interface IP address as the router ID (loopback interface has priority over the IP interface). This is the default.
- Statically—Use the following command to manually configure the router ID:

```
Switch(config)# router ospf
Switch(config-router)# router-id <IPv4 address>
```

If there is a loopback interface, its IP address is always preferred as the router ID, instead of an IP interface address. The **router-id** command is the preferred method to set the router ID and it is always used in preference to the other methods.

- To modify the router ID from static to dynamic, delete the Router ID using the **no router-id** command and re-initialize the OSPF process.
- To view the router ID, use the following command:

```
Switch# show router-id
```

Authentication

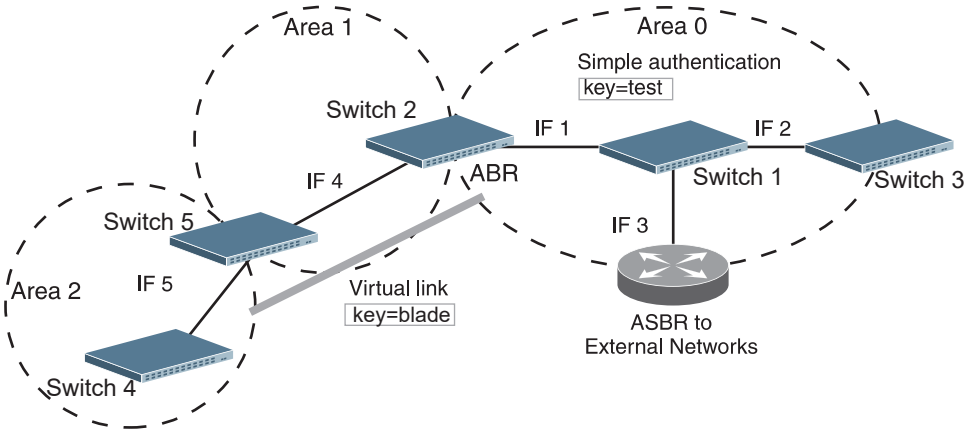
OSPF protocol exchanges can be authenticated so that only trusted routing devices can participate. This ensures less processing on routing devices that are not listening to OSPF packets.

OSPF allows packet authentication and uses IP multicast when sending and receiving packets. Routers participate in routing domains based on pre-defined passwords. CNOS supports simple password (type 1 plain text passwords) and MD5 or SHA-256 cryptographic authentication. This type of authentication allows a password to be configured per interface.

We strongly recommend that you implement MD5 or SHA-256 cryptographic authentication as a best practice.

Figure 24 shows authentication configured for area 0 with the password test. Simple authentication is also configured for the virtual link between area 2 and area 0. Area 1 is not configured for OSPF authentication.

Figure 24. OSPF Authentication



Configuring Plain Text OSPF Passwords

To configure simple plain text OSPF passwords on the switches shown in Figure 24 use the following commands:

1. Enable OSPF authentication for Area 0 on switches 1, 2, and 3.

```
Switch(config)# router ospf
Switch(config-router)# area 0 authentication
Switch(config-router)# exit
```

2. Configure a simple text non-encrypted password for each OSPF interface in Area 0 on switches 1, 2, and 3.

```
Switch(config)# interface vlan 1
Switch(config-if)# ip ospf authentication-key 0 test
Switch(config-if)# exit

Switch(config)# interface vlan 2
Switch(config-if)# ip ospf authentication-key 0 test
Switch(config-if)# exit

Switch(config)# interface vlan 3
Switch(config-if)# ip ospf authentication-key 0 test
Switch(config-if)# exit
```

3. Enable OSPF authentication for Area 2 on switch 4.

```
Switch(config)# router ospf
Switch(config-router)# area 2 authentication
```

4. Configure a simple text non-encrypted password for the virtual link between Area 2 and Area 0 on switches 2 and 4.

```
Switch(config)# router ospf
Switch(config-router)# area 2 virtual-link 1.2.3.4
Switch(config-router-vlink)# authentication
Switch(config-router-vlink)# authentication-key 0 blade
```

Configuring MD5 Authentication

Use the following commands to configure MD5 authentication on the switches shown in Figure 24:

1. Enable OSPF MD5 authentication for Area 0 on switches 1, 2, and 3:

```
Switch(config)# router ospf
Switch(config-router)# area 0 authentication message-digest
Switch(config-router)# exit
```

2. Assign an MD5 key ID to OSPF interfaces on switches 1, 2, and 3:

```
Switch(config)# interface vlan 1
Switch(config-if)# ip ospf message-digest-key 11 md5 MyAuthKey
Switch(config-if)# exit

Switch(config)# interface vlan 2
Switch(config-if)# ip ospf message-digest-key 22 md5 MyAuthKey
Switch(config-if)# exit

Switch(config)# interface vlan 3
Switch(config-if)# ip ospf message-digest-key 33 md5 MyAuthKey
Switch(config-if)# exit
```

Configuring SHA-256 Authentication

Use the following commands to configure SHA-256 authentication on the switches shown in Figure 24:

1. Enable OSPF SHA-256 authentication for Area 0 on switches 1, 2, and 3:

```
Switch(config)# router ospf
Switch(config-router)# area 0 authentication message-digest
Switch(config-router)# exit
```

2. Assign an SHA-256 key ID to OSPF interfaces on switches 1, 2, and 3:

```
Switch(config)# interface vlan 1
Switch(config-if)# ip ospf message-digest-key 11 sha256 MyAuthKey
Switch(config-if)# exit

Switch(config)# interface vlan 2
Switch(config-if)# ip ospf message-digest-key 22 sha256 MyAuthKey
Switch(config-if)# exit

Switch(config)# interface vlan 3
Switch(config-if)# ip ospf message-digest-key 33 sha256 MyAuthKey
Switch(config-if)# exit
```

Loopback Interfaces in OSPF

A loopback interface is an IP interface which has an IP address, but is not associated with any particular physical port. The loopback interface is thus always available to the general network, regardless of which specific ports are in operation. Because loopback interfaces are always available on the switch, loopback interfaces may present an advantage when used as the router ID.

If dynamic router ID selection is used (see "Router ID" on page 543) loopback interfaces can be used to force router ID selection. If a loopback interface is configured, its IP address is automatically selected as the router ID, even if other IP interfaces have lower IP addresses. If more than one loopback interface is configured, the lowest loopback interface IP address is selected.

Loopback interfaces can be advertised into the OSPF domain by specifying an OSPF host route with the loopback interface IP address.

To enable OSPF on an existing loopback interface:

```
Switch(config)# interface loopback <0-7>
Switch(config-if)# ip router ospf 0 area <area ID>
Switch(config-if)# exit
```

Graceful Restart Helper

The CNOS design provides a complete separation of its control plane from the forwarding plane, thus allowing the restart or upgrade of control plane software without disturbing forwarding. Such a restart/upgrade is called *graceful restart*.

In graceful restart, a restarting router is helped by neighbors by announcing links in their LSAs. These neighbors are considered to be in *helper mode* for the duration (grace period) of graceful restart.

The feature is enabled by default. To disable it, use the following command:

```
Switch(config)# graceful-restart ospf helper never
```

OSPF and BFD

Bidirectional forwarding detection (BFD) is a detection protocol designed to provide fast forwarding path failure detection times for media types, encapsulations, topologies, and routing protocols. You can use BFD to detect forwarding path failures at a uniform rate, rather than the variable rates for different protocol hello mechanisms. BFD makes network profiling and planning easier and reconvergence time consistent and predictable.

BFD can work together with OSPF to increase route convergence as an alternative to adjusting the OSPF Hello Interval and Dead Interval. BFD improves the speed of failure detection by having shorter timer limits than the OSPF failure detection mechanisms.

By default, BFD is disabled for OSPF. To enable or disable BFD to work together with OSPF, use the following command:

```
Switch(config)# router ospf
Switch(config-router)# [no] bfd
```

OSPFv2 Configuration Examples

A summary of the basic steps for configuring OSPF on the switch is listed here. Detailed instructions for each of the steps is covered in the following sections:

1. Configure IP interfaces.

   One IP interface is required for each desired network (range of IP addresses) being assigned to an OSPF area on the switch.

2. (Optional) Configure the router ID.
3. Enable OSPF on the switch.
4. Define the OSPF areas.
5. Configure OSPF interface parameters.

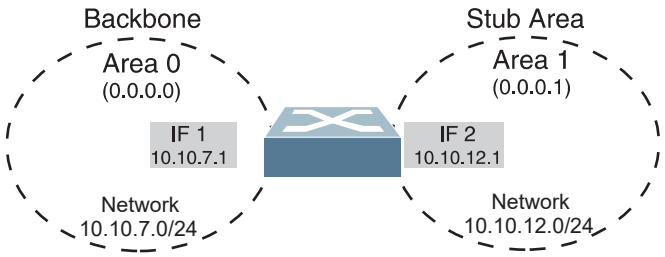
   IP interfaces are used for attaching networks to the various areas.

6. (Optional) Configure route summarization between OSPF areas.
7. (Optional) Configure virtual links.
8. (Optional) Configure host routes.

Example 1: Simple OSPF Domain

In this example, two OSPF areas are defined—one area is the backbone and the other is a stub area. A stub area does not allow advertisements of external routes, thus reducing the size of the database. Instead, a default summary route of IP address 0.0.0.0 is automatically inserted into the stub area. Any traffic for IP address destinations outside the stub area will be forwarded to the stub area's IP interface, and then into the backbone.

Figure 25. A Simple OSPF Domain



Follow this procedure to configure OSPF support as shown in Figure 25:

1. Configure IP interfaces on each network that will be attached to OSPF areas.

   In this example, two IP interfaces are needed:

   - Interface 1 for the backbone network on 10.10.7.0/24
   - Interface 2 for the stub area network on 10.10.12.0/24

```
Switch(config)# interface vlan 1
Switch(config-if)# ip address 10.10.7.1/24
Switch(config-if)# exit

Switch(config)# interface vlan 2
Switch(config-if)# ip address 10.10.12.1/24
Switch(config-if)# exit
```

   Note: OSPFv2 supports IPv4 only.

2. Enable OSPF.

```
Switch(config)# router ospf
Switch(config-router)#
```

3. Define the stub area.

```
Switch(config-router)# area 1 stub
Switch(config-router)# exit
```

4. Attach the network interface to the backbone.

```
Switch(config)# interface vlan 1
Switch(config-if)# ip router ospf 0 area 0
Switch(config-if)# exit
```

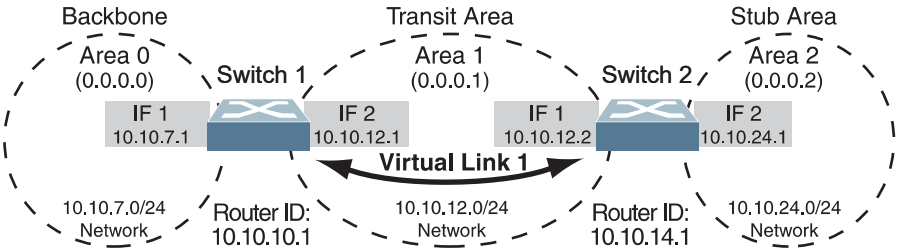
5. Attach the network interface to the stub area.

```
Switch(config)# interface vlan 2
Switch(config-if)# ip router ospf 0 area 1
Switch(config-if)# exit
```

Example 2: Virtual Links

In the example shown in Figure 26, area 2 is not physically connected to the backbone as is usually required. Instead, area 2 will be connected to the backbone via a virtual link through area 1. The virtual link must be configured at each endpoint.

Figure 26. Configuring a Virtual Link



Note: OSPFv2 supports IPv4 only.

Configuring OSPF for a Virtual Link on Switch 1

1. Configure IP interfaces on each network that will be attached to the switch.

   In this example, two IP interfaces are needed:

   - Interface 1 for the backbone network on 10.10.7.0/24
   - Interface 2 for the transit area network on 10.10.12.0/24

```
Switch(config)# interface vlan 1
Switch(config-if)# ip address 10.10.7.1/24
Switch(config-if)# exit

Switch(config)# interface vlan 2
Switch(config-if)# ip address 10.10.12.1/24
Switch(config-if)# exit
```

2. Configure the router ID.

   A router ID is required when configuring virtual links. Later, when configuring the other end of the virtual link on Switch 2, the router ID specified here will be used as the target virtual neighbor (`nbr`) address.

```
Switch(config)# router ospf
Switch(config-router)# router-id 10.10.10.1
```

3. Attach the network interface to the backbone.

```
Switch(config)# interface vlan 1
Switch(config-if)# ip router ospf 0 area 0
Switch(config-if)# exit
```

4. Attach the network interface to the transit area.

```
Switch(config)# interface vlan 2
Switch(config-if)# ip router ospf 0 area 1
Switch(config-if)# exit
```

5. Configure the virtual link.

   The `nbr` router ID configured in this step must be the same as the router ID that will be configured for Switch #2 in Step 2 on page 551.

```
Switch(config)# router ospf
Switch(config-router)# area 1 virtual-link 10.10.14.1
```

Configuring OSPF for a Virtual Link on Switch 2

1. Configure IP interfaces on each network that will be attached to OSPF areas.

   In this example, two IP interfaces are needed:

   - Interface 1 for the transit area network on 10.10.12.0/24
   - Interface 2 for the stub area network on 10.10.24.0/24

```
Switch(config)# interface vlan 1
Switch(config-ip-if)# ip address 10.10.12.2/24
Switch(config-ip-if)# exit

Switch(config)# interface vlan 2
Switch(config-ip-if)# ip address 10.10.24.1/24
Switch(config-ip-if)# exit
```

2. Configure the router ID.

   A router ID is required when configuring virtual links. This router ID must be the same one specified as the target virtual neighbor (`nbr`) on switch 1 in Step 5 on page 551.

```
Switch(config-router)# router-id 10.10.14.1
```

3. Enable OSPF.

```
Switch(config)# router ospf
```

4. Define the stub area.

```
Switch(config-router)# area 2 stub
Switch(config-router)# exit
```

5. Attach the network interface to the transmit area.

```
Switch(config)# interface vlan 1
Switch(config-ip-if)# ip router ospf 0 area 1
Switch(config-ip-if)# exit
```

6. Attach the network interface to the stub area.

```
Switch(config)# interface vlan 2
Switch(config-ip-if)# ip router ospf 0 area 2
Switch(config-ip-if)# exit
```

7. Configure the virtual link.

   The `nbr` router ID configured in this step must be the same as the router ID that was configured for switch #1 in Step 2 on page 550.

```
Switch(config)# router ospf
Switch(config-router)# area 1 virtual-link 10.10.10.1
```

Other Virtual Link Options

- You can use redundant paths by configuring multiple virtual links.
- Only the endpoints of the virtual link are configured. The virtual link path may traverse multiple routers in an area as long as there is a routable path between the endpoints.

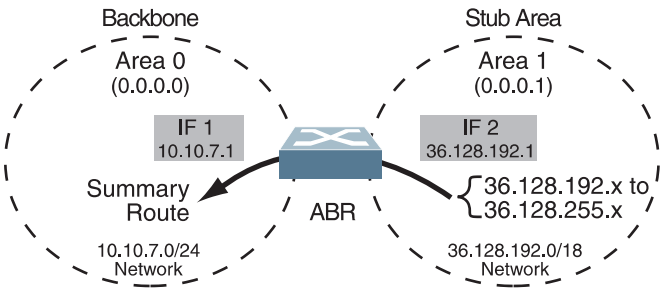
Example 3: Summarizing Routes

By default, ABRs advertise all the network addresses from one area into another area. Route summarization can be used for consolidating advertised addresses and reducing the perceived complexity of the network.

If network IP addresses in an area are assigned to a contiguous subnet range, you can configure the ABR to advertise a single summary route that includes all individual IP addresses within the area.

The following example shows one summary route from area 1 (stub area) injected into area 0 (the backbone). The summary route consists of all IP addresses from 36.128.192.0 through 36.128.255.255 except for the routes in the range 36.128.200.0 through 36.128.200.255.

Figure 27. Summarizing Routes



Notes:

- OSPFv2 supports IPv4 only.
- You can specify a range of addresses to prevent advertising by using the hide option. In this example, routes in the range 36.128.200.0 through 36.128.200.255 are kept private.

Use the following procedure to configure OSPF support as shown in Figure 27:

1. Configure IP interfaces for each network which will be attached to OSPF areas.

```
Switch(config)# interface vlan 1
Switch(config-if)# ip address 10.10.7.1/24
Switch(config-if)# exit

Switch(config)# interface vlan 2
Switch(config-if)# ip address 36.128.192.1/18
Switch(config-if)# exit
```

2. Enable OSPF.

```
Switch(config)# router ospf
```

3. Attach the network interface to the backbone.

```
Switch(config)# interface vlan 1
Switch(config-if)# ip router ospf 0 area 0
Switch(config-if)# exit
```

4. Attach the network interface to the stub area.

```
Switch(config)# interface vlan 2
Switch(config-if)# ip router ospf 0 area 1
Switch(config-if)# exit
```

5. Configure route summarization by specifying the starting address and mask of the range of addresses to be summarized.

```
Switch(config)# router ospf
Switch(config-router)# area 1 range 36.128.192.0/18
Switch(config-router)# exit
```

6. Use the hide command to prevent a range of addresses from advertising to the backbone.

```
Switch(config)# router ospf
Switch(config-router)# area 1 range 36.128.200.0/24 not-advertise
Switch(config-router)# exit
```

Verifying OSPF Configuration

Use the following commands to verify the OSPF configuration on your switch:

```
Switch> show ip ospf
Switch> show ip ospf border-routers
Switch> show ip ospf neighbor
Switch> show ip ospf database
```

Refer to the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9* for information on the preceding commands.

Chapter 24. Route Maps for Routing Protocols

Route maps are used to define route policy by permitting or denying certain routes based on configured set of rules. Each route map consists of multiple clauses that are ordered by their sequence number.

This section discusses the following topics:

Route Maps Overview

Route maps define conditions for redistributing routes from one routing protocol to another. Also, route maps are widely used by routing protocols such as BGP or OSPF, which apply route maps to filter traffic.

The more common applications of route maps are:

- route filtering during redistribution between routing protocols
- route control and attribute modification of BGP routes
- route metric modification during redistribution between routing protocols

To create or modify a route map, use the following command:

```
Switch(config)# route-map <route map name>
Switch(config-route-map)#
```

Note: After creating a route map, you will enter Route Map Configuration mode.

Note: By default, if the rule (permit or deny) is not specified, the switch will configure the route map as a permit rule. Also, if the sequence number is not specified, the switch will configure sequence 10.

To view information about a route map, use the following command:

```
Switch(config)# show route-map <route map name>
```

To delete a route map, use the following command:

```
Switch(config)# no route-map <route map name>
```

Permit and Deny Rules

Route maps contain conditional clauses (match and set) that can be used to permit or deny routes.

A permit rule means that a route must meet all the match clauses to be allowed. A deny rule means that a route that meets at least one of the match clauses will be dropped.

For example, route map is configured to use a prefix-list as a match clause. If the route map is set as a permit rule, then routes that are allowed by the prefix-list will be redistributed.

If the route map is set as a deny rule, then routes that are allowed by the prefix-list will not be redistributed.

To configure a route map permit rule, use the following command:

```
Switch(config)# route-map <route map name> permit
Switch(config-route-map)#
```

Note: After running the above command, you will enter Route Map Configuration mode, where you can create match and set clauses that will be used to check if a route will be redistributed or not.

Rules are configured with a sequence number. The switch will check routes against permit or deny rules in ascending order of their sequence number. Rules with a lower sequence number will be checked before rules with a higher sequence number. A route map can have up to a maximum of 65535 sequences.

Note: If the sequence number is not specified, the switch will configure match and set clauses for sequence 10.

Note: It is recommended that you use multiples of 10 when configuring sequences, in case you require to add more rules between already existing ones.

To configure a route map permit rule and specify its sequence number, use the following command:

```
Switch(config)# route-map <route map name> permit <1-65535 (sequence number)>
```

To configure a route map deny rule and specify its sequence number, use the following command:

```
Switch(config)# route-map <route map name> deny <1-65535>
```

Note: A route map cannot have two rules that share the same sequence number. The newer rule will replace the older one.

For example, sequence 20 is configured as a deny rule. If you then set it up as a permit rule, the new configuration will overwrite the old one. Thus, sequence 20 will become a permit rule.

To delete a rule (permit or deny), use the following command:

```
Switch(config)# no route-map <route map name> {permit|deny} <1-65535>
```

Match and Set Clauses

A rule consists of two types of clauses: match and set. You can consider these clauses in terms of 'IF' and 'THEN' statements from many computer programming languages. If a match clause is true, then a set clause is executed.

To configure a clause, you must enter Route Map Configuration mode. To achieve this, use the following command:

```
Switch(config)# route-map <route map name> {deny|permit} <1-65535 (sequence number)>
Switch(config-route-map)#
```

Match clauses or conditions are used to create permit or deny rules. Only routes that meet the specified match clauses will be redistributed or rejected, depending on the type of the rule.

If multiple rules are created, the switch checks every rule in ascending order of their sequence number. If the first match clause is not met by the route, the clause is not applicable to the route and the switch checks the route against the next match clause.

This goes on until the route meets the conditions of a rule or until the switch has checked all sequences. If a route did not meet all the conditions of a single permit rule, it will be rejected. If a route did not met any of the conditions of any deny rule, it will be redistributed.

Note: Multiple match or set clauses can be configured for each rule. Each clause will be checked in the order they where configured.

To add or remove a match clause, use the following command:

```
Switch(config-route-map)# [no] match <condition>
```

You can create a match clause for the conditions:

- match BGP AS path list;
- match BGP community list;
- match BGP extended community list;
- match next hop interface;
- match destination IP address;
- match next hop IP address;
- match route metric;
- match BGP origin code;
- match route type;
- match tag value.

For example, the following command will create a match clause for routes that have a metric of 1500:

```
Switch(config-route-map)# match metric 1500
```

For more details about the match clause commands, consult the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

Note: Multiple match clauses of the same type can be configured for a single rule. When being checked against the match clauses, the route must met only one of the configured match clauses of the that type.

For example, you if configure a permit rule with two match clauses for route metric (one for 1500 and another for 3000), a route must have either a metric of 1500 or 3000 to met the condition of the rule and be redistributed.

Note: If no match clauses are configured for a rule, all routes will meet the conditions.

Set clauses modify the information of route when the match clauses are met.

To add or remove a set clause, use the following command:

```
Switch(config-route-map)# [no] set <condition>
```

When the route matches the conditions of the rule, you can modify the following parameters:

- set the route aggregator attribute;
- set the BGP AS path;
- set the route atomic aggregate attribute;
- delete the BGP community list;
- set the BGP community list;
- set the BGP extended community list;
- set the BGP route dampening attributes;
- set the IP address of the next hop;
- set the BGP local preference attribute;
- set the route metric;
- set the route metric type;
- set the BGP origin code;
- set the BGP originator ID;
- set the tag value;
- set the BGP route weight attribute.

For example, the following command will create a set clause that will modify the originator ID of a BGP route:

```
Switch(config-route-map)# set originator-id 10.10.125.60
```

For more details about the match clause commands, consult the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

Note: If no set clauses are configured for a permit rule, the route is redistributed without any modifications.

Route Maps Configuration Example

Following are the basic steps and commands for configuring route maps.

1. Configure a route map rule (for example, a permit rule for route map `rmap`):

```
Switch(config)# route-map rmap permit 10
Switch(config-route-map)#
```

2. Configure a match clause for the rule (for example, match the first hop interface to ethernet port 1/10):

```
Switch(config-route-map)# match interface ethernet 1/10
```

3. Optionally, you can configure an set clause for any matching routes (for example, set the routes next hop address):

```
Switch(config-route-map)# set ip next-hop 120.78.33.78
```

4. Optionally, you can configure additional rules (for example, deny routes with destination IP addresses included in prefix list `PrefDeny` or have a metric of 200):

```
Switch(config-route-map)# exit

Switch(config)# route-map rmap deny 20
Switch(config-route-map)# match ip address prefix-list PrefDeny
Switch(config-route-map)# match metric 200
Switch(config-route-map)# exit
```

5. Check the route map configuration:

```
Switch(config)# show route-map rmap

route-map rmap, permit, sequence 10
  Match clauses:
    interface: Ethernet1/10
  Set clauses:
    ip next-hop 120.78.33.78

route-map rmap, deny, sequence 20
  Match clauses:
    ip address prefix-list: PrefDeny
    metric: 200
  Set clauses:
```

Chapter 25. Policy-Based Routing

Policy-based routing (PBR) allows you to forward traffic based on defined policies rather than entries in the routing table. Such policies are defined based on the protocol, source IP, or other information present in a packet header. PBR provides a mechanism for applying the defined policies based on Access Control Lists (ACLs).

You can configure a PBR policy using a route map and making it active by applying the route map to a Layer 3 interface (routed port of a Switch Virtual Interface). For a route map used by PBR, an IP ACL must be specified as the match criteria and the next-hops used for routing the traffic as the set rule. Based on this configuration, the traffic matching the ACL can be routed to one of the specified next-hops, thus ignoring the entries from the routing table. If no match is found or if the route map and ACL denies the traffic, the packet is routed based on the routing table.

PBR applies only to ingress traffic.

This section discusses the following topics:

Route Maps and Access Control Lists for PBR

PBR can be configured by applying a route map to an ingress interface. For more information about route maps, see Chapter 24, "Route Maps for Routing Protocols".

A valid PBR route map sequence must have valid match and set rules. PBR can be configured on an Ethernet switch port interface, but it is not active until it becomes a Layer 3 routed interface.

The match rule is defined using an IP ACL name. A valid ACL must be configured, otherwise the configuration is cached until all the required conditions are met. For more information about ACL, see Chapter 7, "Access Control Lists".

The set rule is defined using route map specific commands in which the next-hops used to redirect the traffic are specified.

Notes:

- Besides PBR, other dynamic routing protocols (BGP and OSPF) use route maps. You can configure a route map for PBR and other routing protocol, but it becomes active for PBR only if the proper fields are configured. PBR parses only relevant route map and ACL information, any other fields are ignored. The routing protocol can reject or ignore a route map configured for PBR if the route map contains irrelevant information.
- After an ACL is mapped to a route map, you cannot delete it until it is unmapped or the route map is deleted. In this scenario, an error message is displayed.

A route map consists of multiple sequences which are parsed based on their priority. The ACL used as the match rule for a route map sequence also consists of multiple sequences which are parsed based on their priority. The lower the route map/ACL sequence ID, the higher the priority. For PBR, the route maps act as packet filters. When PBR is configured on an interface, all incoming packets are filtered based on the match rules. Based on the route map sequence action and on the match ACL sequence action (permit or deny) these packets are routed on either the route map sequence's set rules or the regular routing table.

An ACL can be directly configured on an interface on which a policy is active. In this scenario, the ACL has higher priority over the policy actions. You can use an ACL for both PBR or any other purpose. For example, an ACL used for PBR can also be set directly on an interface. In this case, the PBR rule is not reached, because of the implicit deny rule of the ACL.

Configuring Route Maps

You can define a maximum of 100 route maps and configure a maximum of 100 access list statements in a route map.

You must define route map criteria using `match` and `set` commands.

Match Clauses

IPv4 ACLs can be used to specify the match criteria. All the fields that can be configured for an IP ACL are valid for PBR:

- Source IP
- Destination IP
- Protocol
- DiffServ Code Points (DSCP)
- Precedence
- TCP/UDP source port
- TCP/UDP destination port

If ingress packets do not meet any of the match criteria, or if a deny statement is configured for the matching ACL sequence or the owning route map sequence, the packets are routed based on the entries in the routing table.

Set Clauses

When the match clause is satisfied the following set clause can be used to specify the next-hop used as the destination for routing the packet. The next hop IP address must be the IP address of an interface on the adjacent router. A remote router interface cannot be used to specify the next hop. Packets are routed to the next hop IP address. The PBR policy uses the next hops in the order you specify. If the first next hop is down, then the second next hop is used, and so on.

- For no-health-check next-hops, the priority is set by the position in the list.
- For next-hops with health-check capabilities, the sequence number sets the priority. Once it becomes available again, a high priority next-hop is reinstalled.

The configured next-hop should be in the same VRF as the L3 interface on which the route map is configured. If the next-hop is not be found in the same VRF, PBR considers it unreachable. A maximum of 32 next-hops without health-check capabilities and 32 with health-check capabilities are supported on a route map sequence.

ACL Actions

When a packet is received on an L3 interface with a configured policy, different actions can occur depending on the route map sequence action and the ACL sequence action.

Permit Route Map Sequence

- If the packet matches a Permit ACL sequence, the action specified by the set rule is executed.
- If the packet matches a Deny ACL sequence, the packet is routed according to the regular routing protocol rules.

Deny Route Map Sequence

If the packet matches a Permit or Deny ACL sequence, the packet is routed according to the regular routing protocol rules.

Packets not Matching ACL

If no rules are matched at the end of the route map sequences, normal routing is performed.

Note: Following the rules described in this section, the default Deny All ACL rule is not applicable to PBR.

Configuring Health Check

You can configure tracking/health check parameters for each of the next hop IP address you specify in the route map. The next-hop reachability is determined by it's associated Address Resolution Protocol (ARP) entry status.

A health-check next-hop can be configured by specifying the next-hop sequence number, which represents its priority. A next-hop IP address must be unique among sequences. If the same next-hop is added in a new sequence, the switch will display an error message. You can configure the retry interval, which represents the amount of time between each next-hop reachability check. You can also configure the number of failed checks before a next-hop is considered down, and the next in the list is installed.

If a route map has a mix of next-hops with and without verifying availability, the next-hops with verifying availability have higher precedence. If all next hops configured for verifying availability are unreachable, the first valid non-health-checked next-hop will be used.

Two ARP Request are sent one second apart when a next-hop is configured, regardless of its type (regular or with health-check). For the next-hops without health-check, an ARP Request is sent once every 120 seconds. This way, the switch does not rely only on external factors in order to learn and maintain the next-hop ARP entries.

If the MAC address (associated to an ARP monitored by PBR) changes, the corresponding next-hop will be invalidated and reinstalled.

Static ARPs can be configured for the next-hops used by PBR. The next-hops will always be considered reachable and ARP Requests are not sent by the switch.

Note: If the policy is applied on a Switch Virtual Interface (SVI), you should configure health-check if all/multiple next-hops specified in the route map belong to the same Spanning Tree Group (STG). This is recommended in the case of an STP topology change where all forwarding database (FDB) entries on all the ports in an STG are cleared. In such a scenario, the associated ARP entries are purged and the next hop specified in the PBR policy will not get resolved. VLAN membership changes or link up/down events can also affect PBR. The advantage over regular next-hops is that the next-hops with health-check capabilities are re-validated faster.

Example PBR Configuration

To configure PBR:

1. Create a new IP ACL named `pbr_acl_192_168_2`:

```
Switch(config)# ip access-list pbr_acl_192_168_2
```

2. Add a rule which permits UDP traffic from any source IP, source UDP port 1234, destination IP 192.168.2.10:

```
Switch(config-acl)# 10 permit udp any eq 1234 host 192.168.2.10
```

3. Add a rule which denies UDP traffic from any source IP to destination IP 192.168.2.10:

```
Switch(config-acl)# 20 deny udp any host 192.168.2.10
```

4. Add a rule which permits any type of traffic from any source IP to any destination IP from the 192.168.2.0/24 subnet:

```
Switch(config-acl)# 30 permit any any 192.168.2.0 0.0.0.255
Switch(config-acl)# exit
Switch(config)#
```

5. Create a new IP ACL named `pbr_acl_192_168_3`:

```
Switch(config)# ip access-list pbr_acl_192_168_3
```

6. Add a rule which denies all traffic from any source IP sent to the 192.168.3.20 destination IP:

```
Switch(config-acl)# 10 deny any any host 192.168.3.20
```

7. Add a rule which permits all traffic:

```
Switch(config-acl)# 20 permit any any any
Switch(config-acl)# exit
Switch(config)#
```

8. Create a permit index 10 of the `pbr_rmap` route map:

```
Switch(config)# route-map pbr_rmap permit 10
```

9. Set the match rule as the `pbr_acl_192_168_2` IP ACL:

```
Switch(config-route-map)# match ip address pbr_acl_192_168_2
```

10. Set two regular next-hops:

```
Switch(config-route-map)# set ip next-hop 10.10.10.2 10.10.10.3
```

11. Set two next-hops with health-check capabilities:

```
Switch(config-route-map)# set ip next-hop verify-availability 40.40.40.2
sequence 1 interval 10 retry 3
Switch(config-route-map)# set ip next-hop verify-availability 50.50.50.2
sequence 5
Switch(config-route-map)# exit
Switch(config)#
```

12. Create a permit index 20 of the `pbr_rmap` route map:

```
Switch(config)# route-map pbr_rmap permit 20
```

13. Set the match rule as the `pbr_acl_192_168_3` IP ACL:

```
Switch(config-route-map)# match ip address pbr_acl_192_168_3
```

14. Set a regular next-hop:

```
Switch(config-route-map)# set ip next-hop 10.10.10.2
Switch(config-route-map)# exit
Switch(config)#
```

15. Configure ethernet 1/39 as a routed port and add the policy to this interface:

```
Switch(config)# interface ethernet 1/39
Switch(config-if)# no switchport
Switch(config-if)# ip address 39.39.39.2/24
Switch(config-if)# ip policy route-map pbr_rmap
Switch(config-if)# exit
Switch(config)#
```

16. Enable PBR globally:

```
Switch(config)# feature pbr
```

To display detailed PBR information:

```
Switch(config)# show ip policy interface ethernet 1/39 detail
PBR status: enabled

Interface      Route-map               Status     VRF
Ethernet1/39   pbr_rmap                Active     default


Route-map index: 10, Status: Active

Next-hops:
IP address   Available Idx   Interval Retries
10.10.10.2      Yes     -       -        -
10.10.10.3      No      -       -        -
40.40.40.2      Yes     1       10       3
50.50.50.2      No      5       5        3
Selected next-hop: 40.40.40.2

ACL name: pbr_acl_192_168_2
ACL-sequence    Status
10              A I
20              A I
30              A I
Note: A = Active, I = Installed


Route-map index: 20, Status: Active

Next-hops:
IP address   Available Idx   Interval Retries
10.10.10.2      Yes     -       -        -
Selected next-hop: 10.10.10.2

ACL name: pbr_acl_192_168_3
ACL-sequence    Status
10              A I
20              A I
Note: A = Active, I = Installed
G8296(config)#
```

Configuring PBR with other Features

- On an interface on which VRRP is enabled, the policy becomes active only if this interface is a VRRP master in at least one VRRP instance.
- In a vLAG VRRP Active-Active topology, the policies are active on both vLAG peers.
- When the VRF is changed for an interface, the PBR associated configuration becomes active on the new VRF.
- When a list of no-health-check next-hops is configured for a route map sequence, other routing protocols which use that route map will consider only the first next-hop from that list.
- PBR does not directly depend on IP forwarding being enabled or not, but it can be affected by configuration changes triggered by command (deleted ARP entries).
- PBR does not affect the traffic generated by the switch.

PBR Limitations

- Only one PBR route map can be set on an interface
- An ACL can be used only once in the same route map
- ECMP is not supported. The traffic is routed only to a single next-hop
- Only directly connected next-hops are supported
- PBR supports only IPv4 and unicast traffic

PBR cannot be configured for:

- Management Interface
- Loopback Interface
- Port Channel

Note: If you try to set a policy on an interface which is not supported, the switch will display a message informing you of this.

Part 5: High Availability Fundamentals

Internet traffic consists of myriad services and applications which use the Internet Protocol (IP) for data delivery. However, IP is not optimized for all the various applications. High Availability goes beyond IP and makes intelligent switching decisions to provide redundant network configurations.

This section discusses the following topics:

Chapter 26. Basic Redundancy

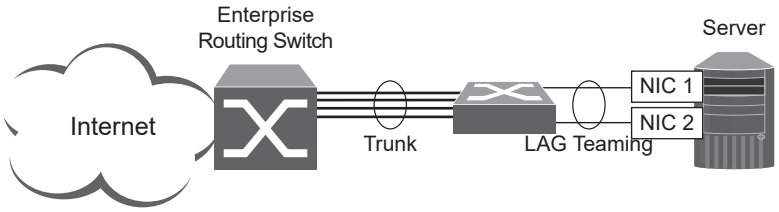
Lenovo Cloud Network Operating System 10.9 includes various features for providing basic link or device redundancy:

Aggregating for Link Redundancy

Multiple switch ports can be combined together to form robust, high-bandwidth LAGs to other devices. Since LAGs are comprised of multiple physical links, the LAG is inherently fault tolerant. As long as one connection between the switches is available, the LAG remains active.

In Figure 28, four ports are aggregated together between the switch and the enterprise routing device. Connectivity is maintained as long as one of the links remain active. The ports on the server are in LAG teaming, allowing the secondary NIC to take over in the event that the primary NIC link fails.

Figure 28. Aggregating Ports for Link Redundancy



For more information on aggregation, see Chapter 11, "Ports and Link Aggregation."

Virtual Link Aggregation

Using the VLAG feature, switches can be paired as VLAG peers. The peer switches appear to the connecting device as a single virtual entity for the purpose of establishing a multi-port LAG. The VLAG-capable switches synchronize their logical view of the access layer port structure and internally prevent implicit loops. The VLAG topology also responds more quickly to link failure and does not result in unnecessary MAC flooding.

VLAGs are useful in multi-layer environments for both uplink and downlink redundancy to any regular LAG-capable device. They can also be used in for active-active VRRP connections.

For more information on VLAGs, see Chapter 13, "Virtual Link Aggregation Groups."

Chapter 27. Virtual Router Redundancy Protocol

The switch supports high-availability network topologies through an enhanced implementation of the Virtual Router Redundancy Protocol (VRRP).

The following topics are discussed in this chapter:

- "VRRP Overview" on page 578. This section discusses VRRP operation and Cloud NOS redundancy configurations.
- "Failover Methods" on page 581. This section describes the three modes of high availability.
- "Cloud NOS Extensions to VRRP" on page 582. This section describes VRRP enhancements implemented in CNOS.
- "Configuring the Switch for Tracking" on page 588. This section describes configuring the switch for tracking.
- "Basic VRRP Configuration" on page 589. This section offers a simple example of a basic virtual router configuration consisting of two VRRP routers.
- "Configuring VRRP High-Availability Using Multiple VIRs" on page 591. This section discusses the more useful and easily deployed redundant configurations.

VRRP Overview

Typically, end devices in a LAN are connected to a larger network using a single router (first-hop router). They have the router's IP address configured as their default gateway. While, this method of configuration has its advantages, its main problem is that it creates a single point-of-failure if the first-hop router goes down.

In a high-availability network topology, no device can create a single point-of-failure for the network or force a single point-of-failure to any other part of the network. This means that your network will remain in service despite the failure of any single device. To achieve this usually requires redundancy for all vital network components.

VRRP offers a higher availability default path without the need for configuring dynamic routing or router discovery protocols on end devices.

VRRP enables redundant router configurations within a LAN, providing alternate router paths for a host to eliminate single points-of-failure within a network. Each participating VRRP-capable routing device is configured with the same virtual router IP address and ID number. One of the VRRP routers is elected as the master, based on a number of priority criteria, and assumes control of the shared virtual router IP address. If the master fails, one of the backup virtual routers will take control of the virtual router IP address and actively process traffic addressed to it.

With VRRP, Virtual Interface Routers (VIR) allow two VRRP routers to share an IP address across the routers. VIRs provide a single Destination IP (DIP) address for upstream routers to reach various servers and provide a virtual default Gateway for the servers. Also, end devices are configured to the virtual router's IP address as their default gateway.

Also, while using VRRP, you can configure two VRRP routers to evenly share traffic during normal running conditions. To achieve this, you assign the first VRRP router's virtual IP address as the default gateway for half of the end devices, and the second VRRP router's IP address as the default gateway for the other half of the end devices. In this scenario, both VRRP routers are members of two different virtual routers. Each VRRP router acts both as the master virtual router in one of the two virtual routers and the backup virtual router in the other virtual router.

Cloud NOS uses VRRP version 3 (VRRPv3), which implements support for IPv6 addresses. For more details, see RFC 5798.

Note: VRRP can be enabled only on Layer 3 interfaces, which on the switch are ethernet interfaces configured as routed ports or Switch Virtual Interfaces (SVIs).

By default, all ports are configured as access switch ports. To configure a switch port as a routed port, use the following command (for this example, ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# no switchport
```

For more details on routed ports, see "Configuring a Routed Port" on page 423.

VRRP Components

Each physical router running VRRP is known as a *VRRP router*.

Virtual Router

Two or more VRRP routers can be configured to form a *virtual router* (RFC 5798). Each VRRP router may participate in one or more virtual routers. Each virtual router consists of a user-configured *virtual router identifier* (VRID) and an IP address. You can configure up to 255 virtual routers.

Virtual Router MAC Address

The VRID is used to build the *virtual router MAC Address*. The five highest-order octets of the virtual router MAC Address are the standard MAC prefix (00-00-5E-00-01) as defined in RFC 5798. The VRID is used to form the lowest-order octet.

Owners and Renters

Only one of the VRRP routers in a virtual router may be configured as the IP address owner. This router has the virtual router's IP address as its real interface address. This router responds to packets addressed to the virtual router's IP address for ICMP pings, TCP connections and so on.

There is no requirement for any VRRP router to be the IP address owner. Most VRRP installations choose not to implement an IP address owner. For the purposes of this chapter, VRRP routers that are not the IP address owner are called *renters*.

Master and Backup Virtual Router

Within each virtual router, one VRRP router is selected to be the master virtual router. See "Selecting the Master VRRP Router" on page 580 for an explanation of the selection process.

Note: If the IP address owner is available, it will always become the virtual router master.

The master virtual router forwards packets sent to the virtual router. It also responds to Address Resolution Protocol (ARP) requests sent to the virtual router's IP address. Finally, the virtual router master sends out periodic advertisements to let other VRRP routers know it is alive and its priority.

Within a virtual router, the VRRP routers not selected to be the master are known as virtual router backups. If the virtual router master fails, one of the virtual router backups becomes the master and assumes its responsibilities.

Virtual Interface Router

At Layer 3, a Virtual Interface Router (VIR) allows two VRRP routers to share an interface across the routers. VIRs provide a single Destination IP (DIP) address for upstream routers to reach various destination networks and provide a virtual default Gateway.

Note: Every VIR must be assigned to an interface and every interface must be assigned to a VLAN. If no port in a VLAN has link up, the interface of that VLAN is down and if the interface of a VIR is down, that VIR goes into INIT state.

Assigning VRRP Virtual Router ID

When configuring a VRRP virtual router, you must assign it a virtual router identifier (ID). The virtual router ID may be configured as any number between 1 and 255. Use the following command to configure the virtual router ID:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# vrrp <1-255>
Switch(config-if-vrrp)#
```

Note: After creating a virtual router with the specified ID, you will enter the VRRP Configuration menu for that virtual router. Also, you can use the same command to configure any existing virtual routers.

Note: This is the configuration method for IPv4 addressing. For IPv6 addressing, see "IPv6 VRRP" on page 586.

VRRP Operation

Only the virtual router master responds to ARP requests. Therefore, the upstream routers only forward packets destined to the master. The master also responds to ICMP ping requests if it is the owner of the pinged IP address or has accept mode enabled. The backup does not forward any traffic, nor does it respond to ARP requests.

If the master is not available, the backup becomes the master and takes over responsibility for packet forwarding and responding to ARP requests.

Selecting the Master VRRP Router

Each VRRP router is configured with a priority between 1–254. A bidding process determines which VRRP router is or becomes the master—the VRRP router with the highest priority.

The master periodically sends advertisements to an IP multicast address. As long as the backups receive these advertisements, they remain in the backup state. If a backup does not receive an advertisement for three advertisement intervals, it initiates a bidding process to determine which VRRP router has the highest priority and takes over as master. In addition to the three advertisement intervals, a manually set hold-off time can further delay the backups from assuming the master status.

If, at any time, a backup determines that it has higher priority than the current master does, it can preempt the master and become the master itself, unless configured not to do so. In preemption, the backup assumes the role of master and begins to send its own advertisements. The current master sees that the backup has higher priority and will stop functioning as the master.

A backup router can stop receiving advertisements for one of two reasons—the master can be down or all communications links between the master and the backup can be down. If the master has failed, it is clearly desirable for the backup (or one of the backups, if there is more than one) to become the master.

Note: If the master is healthy but communication between the master and the backup has failed, there will then be two masters within the virtual router. To prevent this from happening, configure redundant links to be used between the switches that form a virtual router.

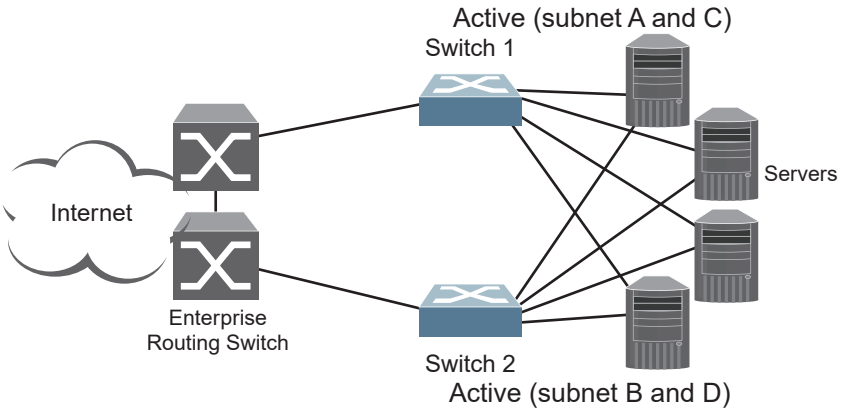
Failover Methods

With service availability becoming a major concern on the Internet, service providers are increasingly deploying Internet traffic control devices, such as application switches, in redundant configurations. Cloud NOS high availability configurations are based on VRRP. The implementation of VRRP includes proprietary extensions.

Active-Active Redundancy

In an active-active configuration, shown in Figure 29, two switches provide redundancy for each other, with both active at the same time. Each switch processes traffic on a different subnet. When a failure occurs, the remaining switch can process traffic on all subnets. For more details and a configuration example, see "Configuring VRRP High-Availability Using Multiple VIRs" on page 591.

Figure 29. Active-Active Redundancy



Cloud NOS Extensions to VRRP

This section describes VRRP enhancements that are implemented in CNOS:

VRRP Advertisement Interval and Sub-second Failover

The master virtual router periodically sends VRRP advertisements to the backup virtual routers to keep them in their backup state. The master virtual router waits a certain amount of time between each advertisement. This period of time is called advertisement interval.

To configure the advertisement interval (in centiseconds or hundredths of a second), use the following command (for this example, interface ethernet 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# vrrp <1-255>
Switch(config-if-vrrp)# advertisement-interval <5-4095>
```

The default value of the advertisement interval is 100 centiseconds or 1 second. To reset the advertisement interval to this value, use the following command:

```
Switch(config-if-vrrp)# no advertisement-interval
```

VRRPv3 supports the sub-second detection of master virtual router failure. To mitigate the potential loss of packets that happens in the time interval between when the master virtual router fails and when the backup virtual router takes its place, the advertisement interval can be configured to lower values than one second.

A backup virtual router detects that the master virtual router is down when three advertisement intervals have passed without the reception of any advertisements from the master. After the backup virtual router detects the failure, it will assume the role of master virtual router. During this time, any traffic that is sent to the downed master virtual router will be lost.

To lessen the volume of lost traffic, you can configure the advertisement interval to sub-second values, thus reducing the time required for the backup virtual router to detect the failure and take the master virtual router's place.

Interface Tracking

VRRP interface tracking allows the tracking of interface states which can modify the priority level of a VRRP router member of a virtual router group. If the tracked interface goes down or if it does not have a configured virtual IP address, the priority level of the virtual router group is lowered by a given value. This allows another VRRP router to become the new group master virtual router.

Only one interface can be tracked at a time for every virtual router group and the tracked interface must be a Layer 3 interface. VRRP does not support Layer 2 interface tracking.

Note: The interface on which you configure VRRP tracking cannot be the interface that is being tracked. For example, ethernet interface 1/1 can be configured to track ethernet interface 1/2, 1/10 or 1/20, but not itself.

You can configure the value that is subtracted from a virtual router group's priority level when the state of the tracked interface changes to down. When the tracked interface returns to an up state, VRRP restores the original priority for the virtual router group.

By default, the tracking of interfaces is disabled.

To configure the subtracted value, use the following command (for this example, interfaces ethernet 1/10 and 1/12 are used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# vrrp <1-255>
Switch(config-if-vrrp)# track interface ethernet 1/10 priority <1-253>
```

Note: VRRP preempt mode must be enabled. For more details, see "VRRP Preemption" on page 585.

To disable the tracking of an interface, use the following command:

```
Switch(config-if-vrrp)# no track interface ethernet 1/10 priority <1-253>
```

Switch Back Delay

Other Layer 3 routing protocols, like OSPF, have a slower convergence time than VRRP. When these routing protocols are enabled on the switch, there can be a situation where the route table of the master virtual router is not completely populated when the VRRP router exchanges roles from master to backup virtual router and then vice versa. Remote network routes can be lost during the convergence time of these routing protocols, resulting in discarded traffic.

To avoid such a scenario, a time delay is used. The delay prevents the original master virtual router from becoming the master after it comes back online until a configured amount of time passes. This is called switch back delay.

By default, the switch back delay is disabled.

To configure the switch back delay (in milliseconds), use the following command (for this example, ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# vrrp <1-255>
Switch(config-if-vrrp)# switch-back-delay <1-500000>
```

To disable the switch back delay, use the following command:

```
Switch(config-if-vrrp)# no switch-back-delay
```

Backward Compatibility with VRRPv2

The Switch uses VRRPv3, which supports IPv6 addresses, but can be configured to be compatible with VRRPv2 as well.

Note: This is only compatible with IPv4 addresses, since VRRPv2 does not have support for IPv6 addressing.

When VRRPv2 compatibility is enabled on the master virtual router, it sends both VRRPv2 and VRRPv3 advertisements at the configured advertisement interval. For more details about the advertisement interval, see "VRRP Advertisement Interval and Sub-second Failover" on page 582.

To enable or disable VRRPv2 backward compatibility, use the following command (for this example, ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# vrrp <1-255>
Switch(config-if-vrrp)# [no] v2-compatible
```

A backup virtual router having VRRPv2 backward compatibility enabled will ignore VRRPv2 advertisements from the master virtual router if it also receives VRRPv3 advertisements.

If a backup virtual router has VRRPv2 backward compatibility enabled and it receives only VRRPv2 advertisements from the master virtual router, it will transform the received advertisement interval into centiseconds.

If the master virtual router has VRRPv2 backward compatibility enabled and the advertisement interval set to a sub-second value, it will ignore this setting and send advertisements to the backup virtual routers every one second.

VRRP Accept Mode

The Switch supports VRRP Accept mode. It makes the master virtual router to accept packets with IP addresses not own by it. Thus, such packets are accepted by the master virtual router if it is the owner of the IP address or accept mode is enabled. The master virtual router will discard any traffic if it is not the owner of the IP address and accept mode is disabled.

If Accept mode is disabled, the master virtual router accepts packets sent to the virtual router only if it is the IP address owner. Any packets sent to the master virtual router with an IP address that it does not own will be discarded.

This restriction causes problems when troubleshooting network connectivity issues. When a host is unreachable, it is common practice to ping the first-hop router to determine if the problem is related to the default gateway of the host. If the host's default gateway is a virtual router that does not respond to pings (or ICMP Echo Requests), this method of troubleshooting is unavailable for use.

Accept mode configures the master virtual router to respond only to ping, traceroute and telnet packets with an IP address not owned by the router. The master virtual router will not respond to any other type of packets. When it responds, it uses the virtual router's IP and MAC addresses.

By default, VRRP accept mode is enabled.

To enable or disable VRRP accept mode, use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# vrrp <1-255>
Switch(config-if-vrrp)# [no] accept-mode
```

VRRP Preemption

When VRRP preemption is enabled on a backup virtual router, if the router has a higher priority than the current master virtual router, it will preempt the lower priority master and assume control.

Note: Even when VRRP preemption is disabled, a backup virtual router will always preempt any other master if the router is the owner of the IP address associated with the virtual router.

By default, VRRP preemption is enabled.

To enable or disable VRRP preemption, use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# vrrp <1-255>
Switch(config-if-vrrp)# [no] preempt
```

VRRP Priority

Priority is used by VRRP in the master virtual router election process. Each VRRP router participating in the election process is assign a priority level between 0 and 255 and the VRRP router with the highest priority becomes the master virtual process.

You can configure a VRRP router with a priority between 1 and 254. The value of 255 is reserved for the VRRP router that owns the IP address associated with the virtual router. The value of 0 is reserved for the master virtual router to indicate that it has stopped participating in the VRRP. This triggers the backup virtual routers to quickly start a new master election process without waiting for the current master virtual router to timeout.

To configure the priority of a VRRP router, use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# vrrp <1-255>
Switch(config-if-vrrp)# priority <1-254>
```

By default, the priority of a VRRP router is 100. To reset the priority to its default value, use the following command:

```
Switch(config-if-vrrp)# no priority
```

Note: If you configure the virtual IP address of the virtual router to have the same IP address as the interface you set up a VRRP router, the previous priority configuration of the VRRP router will be deleted and its new priority will be 255.

Note: If a VRRP router is the owner of the virtual IP address of the virtual router, having a priority of 255, and you configure the virtual IP address to an IP address different than the one owned by the VRRP router, the priority of that VRRP router will be reset to the default.

IPv6 VRRP

VRRPv3 supports both IPv4 and IPv6 addressing. The type of IP addressing used by the VRRP router must be the same as used by the interface on which the VRRP router is configured. For example, if an ethernet interface is configured as an IPv4 address, the VRRP router created on that interface must also be configured with an virtual IPv4 address.

To create an IPv6 VRRP session, use the following command (for this example, ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# vrrp <1-255> ipv6
Switch(config-if-vrrp)#
```

Note: If there is a mismatch between the type of the virtual IP address and the type of the IP address used by the interface or by the VRRP session, you will be prompted with an error message.

When using IPv6 addressing, each VRRP session must be configured with a set of two IPv6 addresses: a link-local address as the primary virtual address and a global IPv6 address.

Note: The link-local IPv6 address must be different than the global IPv6 address.

The link-local address must be the first address in the IPv6 address list used in the VRRP packet. If this address is the same as the virtual IP address associated with the virtual router, then the VRRP router is the owner of the virtual IP address and its priority is set to 255. The VRRP router is advertised with priority 255 in VRRP packets regardless of the global IPv6 address.

Note: The same link-local IPv6 address cannot be used in other VRRP sessions on the same interface.

Even if an interface is configured with the same IPv6 address as the virtual global IPv6 address of a VRRP router, the VRRP router is not considered the owner of the IPv6 address. The link-local address takes precedence over the global address.

Note: Only one global IPv6 address and one link-local address are supported for each VRRP IPv6 session.

To configure a global IPv6 address, use the following command:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# vrrp <1-255> ipv6
Switch(config-if-vrrp)# address <IPv6 address>
```

To delete the global IPv6 address of a VRRP session, use the following command:

```
Switch(config-if-vrrp)# no address <IPv6 address>
```

To configure the link-local IPv6 address of the VRRP session, use the following command:

```
Switch(config-if-vrrp)# address <IPv6 address> primary
```

To delete the link-local IPv6 address of a VRRP session, use the following command:

```
Switch(config-if-vrrp)# no address <IPv6 address> primary
```

To delete all configured IP addresses of a VRRP session, use the following command:

```
Switch(config-if-vrrp)# no address
```

Configuring the Switch for Tracking

Tracking configuration largely depends on user preferences and network environment. Consider the configuration shown in Figure 29 on page 581. Assume the following behavior on the network:

- Upon initialization, switch 1 is the Master Virtual Router and switch 2 is the Backup Virtual Router.
- Switch 1 and 2 are both connected to the each of the four servers on the local network.
- If switch 1 is the master and one of its interfaces goes down, meaning switch 1 is still connected to three out of the four servers, then switch 1 remains the Master Virtual Router.

  This behavior is preferred because running one server down is less disruptive than bringing a new master online and severing all active connections in the process.
- If switch 1 is the master and two or more of its interfaces go down, meaning switch 1 is not connected to at least three of the four servers, then switch 2 becomes the new Master Virtual Router and switch 1 becomes the Backup Virtual Router.
- If switch 2 is the master, it will retain its role as the Master Virtual Router, even when the links between switch 1 and all the servers are restored, as long as switch 2 has at least the same number of actively connected servers as switch 1.
- If switch 2 is the master and the number of actively connected servers is lower than the ones connected to switch 1, it looses its role as the Master Virtual Router. Switch 1 regains its role as the Master Virtual Router and switch 2 becomes the Backup Virtual Router.

You can implement this behavior by configuring the switch for tracking as follows:

1. Set the priority for switch 1 to 101. For more details, see "VRRP Priority" on page 585.
2. Leave the priority for switch 2 at the default value of 100.
3. On both switches, enable tracking based on ethernet interfaces or VLANs. For more details, see "Interface Tracking" on page 583.

   Note: There is no shortcut to setting tracking parameters. The goals must first be set and the outcomes of various configurations and scenarios analyzed to find settings that meet the goals.

Basic VRRP Configuration

The following steps are an example of a basic VRRP configuration:

Configuring Switch 1

1. Enter Global Configuration command mode:

```
Switch> enable
Switch# configure [terminal]
Switch(config)#
```

2. Configure the ethernet port to be part of the virtual router:

```
Switch(config)# interface ethernet 1/1
Switch(config-if)# no switchport
```

3. Assign an IP address to the interface:

   a. either an IPv4 address:

```
Switch(config-if)# ip address 192.168.1.10/24
```

   b. or an IPv6 address:

```
Switch(config-if)# ipv6 address 2001:db8:a0b:12f0::10/32
```

4. Create a virtual router with an assigned ID and configure its virtual IP address:

   a. either using IPv4 addressing:

```
Switch(config-if)# vrrp 1
Switch(config-if-vrrp)# address 192.168.1.1
```

   b. or IPv6 addressing:

```
Switch(config-if)# vrrp 1 ipv6
Switch(config-if-vrrp)# address fe80::2001 primary
Switch(config-if-vrrp)# address 2001:db8:a0b:12f0::76e
```

   Note: The virtual IP address of the VRRP router must be same type as the IP address of the interface on which VRRP is configured.

5. Set the priority of the VRRP router and enable VRRP:

```
Switch(config-if-vrrp)# priority 110
Switch(config-if-vrrp)# no shutdown
```

   Note: Switch 1 has a higher priority and will become the master virtual router.

6. Check the VRRP configuration:

```
Switch# show vrrp detail
```

Configuring Switch 2

1. Enter Global Configuration command mode:

```
Switch> enable
Switch# configure [terminal]
Switch(config)#
```

2. Configure the ethernet port to be part of the virtual router:

```
Switch(config)# interface ethernet 1/1
Switch(config-if)# no switchport
```

3. Assign an IP address to the interface:

   a. either an IPv4 address:

```
Switch(config-if)# ip address 192.168.1.20/24
```

   b. or an IPv6 address:

```
Switch(config-if)# ipv6 address 2001:db8:a0b:12f0::20/32
```

4. Create a virtual router with an assigned ID and configure its virtual IP address:

   a. either using IPv4 addressing:

```
Switch(config-if)# vrrp 1
Switch(config-if-vrrp)# address 192.168.1.1
```

   b. or IPv6 addressing:

```
Switch(config-if)# vrrp 1 ipv6
Switch(config-if-vrrp)# address fe80::2001 primary
Switch(config-if-vrrp)# address 2001:db8:a0b:12f0::76e
```

   Note: The virtual IP address of the VRRP router must be same type as the IP address of the interface on which VRRP is configured.

5. Enable VRRP:

```
Switch(config-if-vrrp)# no shutdown
```

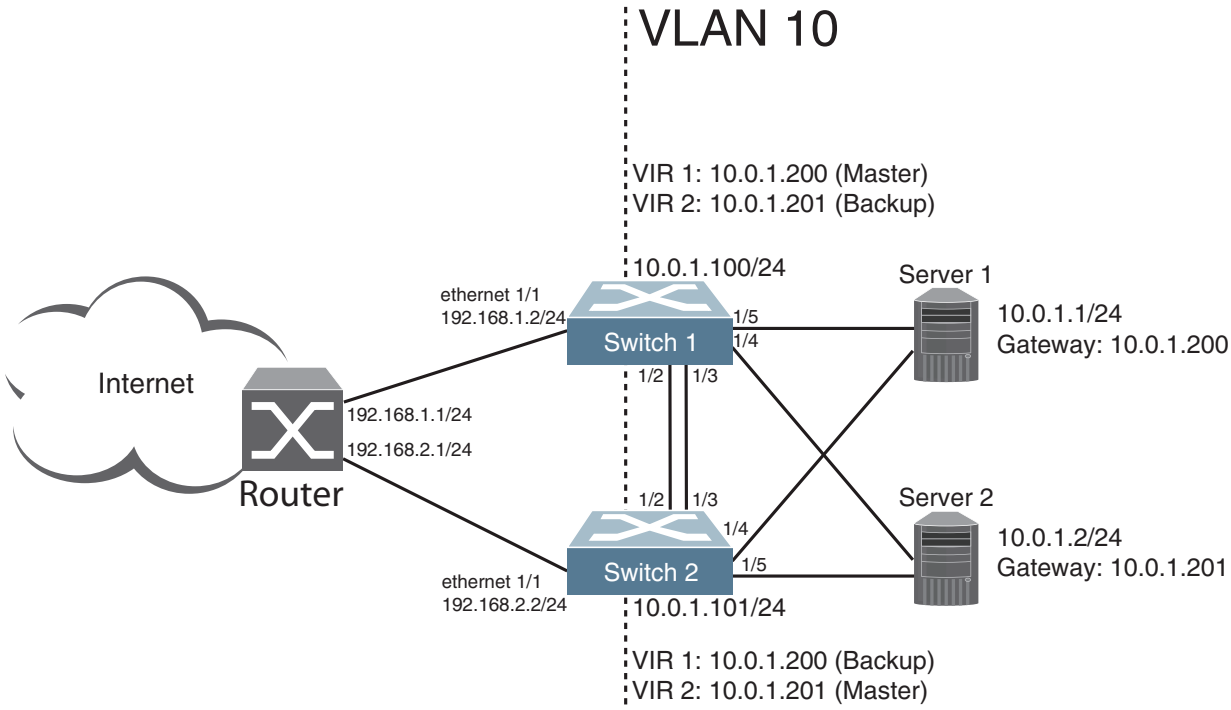
6. Check the VRRP configuration:

```
Switch# show vrrp detail
```

Configuring VRRP High-Availability Using Multiple VIRs

Figure 30 shows an example configuration where two switches are used as VRRP routers in an active-active configuration. In this configuration, both switches respond to packets.

Figure 30. Active-Active Configuration using VRRP



Although this example shows only two switches, there is no limit on the number of switches used in a redundant configuration. It is possible to implement an active-active configuration across all the VRRP-capable switches in a LAN.

In the scenario illustrated in Figure 30, traffic destined for Server 1 (IP address: 10.0.1.1/24) is forwarded through the Router and ingresses on Switch 1 on ethernet port 1/1 (IP address: 192.128.1.2/24). Traffic that is received from Serve 1 is forwarded to the default gateway (192.168.1.1).

If the link between Switch 1 and the Router fails, Switch 2 becomes the Master because it has a higher priority. By configuring VRRP interface tracking, if the link between Switch 1 and the Router fails, the priority of Switch 1 will be lowered, thus allowing Switch 2 to become the new VRRP master.

Switches 1 and 2 communicate through a LAG consisting of ethernet ports 1/2 and 1/3 on each switch. The ports are all members of the same VLAN (VLAN 10).

Switches 1 and 2 have Servers 1 and 2 connected to them through ports 1/4 and 1/5, respectively. These ports are all members of the same VLAN (VLAN 10).

To implement the active-active example, perform the following switch configuration.

Configure Switch 1

1. Configure ethernet port 1/1 as a routed port.

```
Switch(config)# interface ethernet 1/1
Switch(config-if)# no switchport
Switch(config-if)# ip address 192.168.1.2/24
Switch(config-if)# exit
```

2. Configure the default gateway, which points to the Router.

```
Switch(config)# ip route 0.0.0.0/0 ethernet 1/1 192.168.1.1
```

3. Create VLAN 10 and configure server interfaces (ports 1/4 and 1/5).

```
Switch(config)# vlan 10
Switch(config-vlan)# exit

Switch(config)# interface ethernet 1/4-5
Switch(config-if-range)# switchport access vlan 10
Switch(config-if-range)# exit
```

4. Configure two Virtual Interface Routers.

```
Switch(config)# interface vlan 10
Switch(config-if)# ip address 10.0.1.100/24
Switch(config-if)# vrrp 1
Switch(config-if-vrrp)# address 10.0.1.200
Switch(config-if-vrrp)# track interface ethernet 1/1 priority 5
Switch(config-if-vrrp)# priority 101
Switch(config-if-vrrp)# no shutdown
Switch(config-if-vrrp)# exit

Switch(config-if)# vrrp 2
Switch(config-if-vrrp)# address 10.0.1.201
Switch(config-if-vrrp)# no shutdown
Switch(config-if-vrrp)# exit
Switch(config-if)# exit
```

5. Create a LAG and make ethernet ports 1/2 and 1/3 members of that LAG.

```
Switch(config)# interface port-channel 1
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 10
Switch(config-if)# exit

Switch(config)# interface ethernet 1/2-3
Switch(config-if-range)# channel-group 1 mode active
Switch(config-if-range)# exit
```

6. Verify the VRRP configuration.

```
Switch# show vrrp

   Interface     VR  IpVer Pri Time    Pre  State   VR IP addr
-------------------------------------------------------------------
   Vlan10        1   IPV4  101 100  cs  Y   Master  10.0.1.200
   Vlan10        2   IPV4  100 100  cs  Y   Backup  10.0.1.201
```

Configure Switch 2

1. Configure ethernet port 1/1 as a routed port.

```
Switch(config)# interface ethernet 1/1
Switch(config-if)# no switchport
Switch(config-if)# ip address 192.168.2.2/24
Switch(config-if)# exit
```

2. Configure the default gateway, which points to the Router.

```
Switch(config)# ip route 0.0.0.0/0 ethernet 1/1 192.168.2.1
```

3. Create VLAN 10 and configure server interfaces (ports 1/4 and 1/5).

```
Switch(config)# vlan 10
Switch(config-vlan)# exit

Switch(config)# interface ethernet 1/4-5
Switch(config-if-range)# switchport access vlan 10
Switch(config-if-range)# exit
```

4. Configure two Virtual Interface Routers.

```
Switch(config)# interface vlan 10
Switch(config-if)# ip address 10.0.1.101/24
Switch(config-if)# vrrp 1
Switch(config-if-vrrp)# address 10.0.1.200
Switch(config-if-vrrp)# no shutdown
Switch(config-if-vrrp)# exit

Switch(config-if)# vrrp 2
Switch(config-if-vrrp)# address 10.0.1.201
Switch(config-if-vrrp)# track interface ethernet 1/1 priority 5
Switch(config-if-vrrp)# priority 101
Switch(config-if-vrrp)# no shutdown
Switch(config-if-vrrp)# exit
Switch(config-if)# exit
```

5. Create a LAG and make ethernet ports 1/2 and 1/3 members of that LAG.

```
Switch(config)# interface port-channel 1
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 10
Switch(config-if)# exit

Switch(config)# interface ethernet 1/2-3
Switch(config-if-range)# channel-group 1 mode active
Switch(config-if-range)# exit
```

6. Verify the VRRP configuration.

```
Switch# show vrrp

   Interface     VR  IpVer Pri Time    Pre  State   VR IP addr
------------------------------------------------------------------
   Vlan10        1   IPV4  100 100  cs  Y   Backup  10.0.1.200
   Vlan10        2   IPV4  101 100  cs  Y   Master  10.0.1.201
```

Chapter 28. Layer 2 Failover

The main purpose of Layer 2 Failover is to support Network Adapter Teaming. With Network Adapter Teaming, all the NICs on each server share the same IP address, and are configured into a team. One NIC is the primary link, and the other is a standby link. For more details, refer to the documentation for your Ethernet adapter.

The following topics are covered in this chapter:

Note: Only two links per server can be used for Layer 2 LAG Failover (one primary and one backup). Network Adapter Teaming allows only one backup NIC for each server blade.

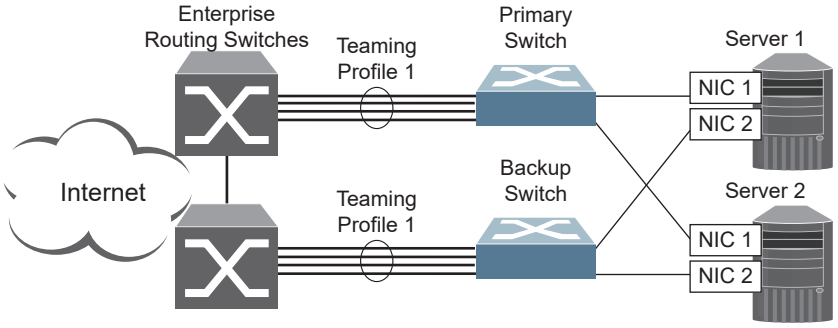
Monitoring LAG Links

Layer 2 Failover can be enabled on any LAG on the switch, including LACP LAGs. LAGs can be added to failover teaming profile groups. Then, if some specified number of monitor links fail, the switch disables all the control ports in the switch. When the control ports are disabled, it causes the NIC team on the affected servers to failover from the primary to the backup NIC. This process is called a failover event.

When the appropriate number of links in a monitor group return to service, the switch enables the control ports. This causes the NIC team on the affected servers to fail back to the primary switch (unless Auto-Fallback is disabled on the NIC team). The backup switch processes traffic until the primary switch's control links come up, which can take up to five seconds.

Figure 31 is an example of Layer 2 Failover. One switch is the primary, and the other is used as a backup. In this example, all ports on the primary switch belong to a single LAG, with Layer 2 Failover enabled, and Failover Limit set to 2. If one or no links in Teaming Profile 1 remain active, the switch temporarily disables all control ports in the teaming profile. This action causes a failover event on Server 1 and Server 2.

Figure 31. Basic Layer 2 Failover



Setting the Failover Limit

The failover limit lets you specify the minimum number of operational links required within each teaming profile before the teaming profile initiates a failover event. For example, if the limit is two, a failover event occurs when the number of operational monitor links in the teaming profile is one or zero. When you set the limit to one, the switch triggers a failover event only when no monitor links in the teaming profile are operational.

Manually Monitoring Port Links

The Manual Monitor (MMON) enables you to configure a set of ports or LAGs to monitor for link failures (a monitor list), and another set of ports or LAGs to disable when number of forwarding monitor links is less than the trigger limit (a control list). When the switch detects a link failure on the monitor list, it automatically disables the items in the control list. When server ports are disabled, the corresponding server's network adapter can detect the disabled link, and trigger a network-adapter failover to another port or LAG on the switch, or another switch.

The switch automatically enables the control list items when the monitor list items return to service.

Note: Control ports will not be re-enabled if they were manually shut down. Control ports will also not be re-enabled if they were shut down or error-disabled by another feature, such as BPDU Guard.

Monitor Port State

A monitor port is considered operational as long as the following conditions are true:

- The port must be in the `Link Up` state.
- If STP is enabled, the port must be in the `Forwarding` state.
- If the port is part of an LACP LAG, the port must be in the `Aggregated` state.

If any of these conditions is false, the monitor port is considered to have failed.

Control Port State

A control port is considered to be disabled only if the teaming profile is in the `triggered` state. The teaming profile is in the `triggered` state only when number of forwarding monitor links is less than limit of the teaming profile.

To view the state of any port, use one of the following commands:

```
Switch# show interface link                 (View interface line status)
Switch# show spanning-tree                  (View spanning tree status)
Switch# show port-channel summary           (View port aggregation status)
Switch# show lacp port-channel              (View port LACP status)
```

L2 Failover with Other Features

L2 Failover works together with static LAGs, Link Aggregation Control Protocol (LACP), and with Spanning Tree Protocol (STP).

Static LAGs

When you add a portchannel (static LAG) to a monitor port of a teaming profile, any ports in that LAG become members of the trigger. You can also add a portchannel to the control port of a teaming profile, but the control ports of a profile must be different from the monitor ports of the profile.

LACP

Link Aggregation Control Protocol allows the switch to form dynamic LAGs. You can use dynamic LAGs in L2 Failover using the same procedures you use for static LAGs. For more information about LACP and dynamic LAGs, see "Link Aggregation Control Protocol" on page 282.

Spanning Tree Protocol

If Spanning Tree Protocol (STP) is enabled on the monitor ports in a teaming profile, the switch monitors the port STP state rather than the link state. A port failure results when STP is not in a Forwarding state (such as Learning, Discarding, or No Link) in all the VLAN or MSTP instances to which the port belongs. The switch automatically disables the appropriate control ports of this teaming profile.

When the switch determines that ports in the teaming profile are in STP Forwarding state in any one of the VLAN or MSTP instances to which the port belongs, then it automatically enables the appropriate control ports. The switch *fails back* to normal operation.

For example, if a monitor port is a member of VLAN instances 1, 2, and 3, a failover will be triggered only if the port is not in a forwarding state in all the three VLAN instances. When the port state in any of the three VLAN instances changes to forwarding, the control port is enabled and normal switch operation is resumed.

Configuration Guidelines

Follow these guidelines when configuring Layer 2 Failover.

- The `limit` option lets you specify the minimum number of operational monitors within a teaming profile. The profile will trigger control ports into a disabled state that would initiate a failover event only when the number of forwarding monitor ports is lower than this limit number.
- Management ports cannot be used as monitor ports or control ports.
- Member ports of an LACP LAG or a static LAG are not allowed to be either monitor ports or control ports.
- No overlapping port memberships are allowed within or across profiles.
  - Monitor ports or control ports of a profile cannot overlap with monitor ports or control ports of another profile.
  - Control ports of a profile must not overlap with its monitor ports.
  - Monitor interfaces of a profile cannot overlap with different teaming profiles.

Configuring Layer 2 Failover

Use the following procedure to configure Layer 2 failover MMON.

1. Enable teaming globally:

```
Switch(config)# teaming enable
```

2. Enable the teaming profile you plan to use.

```
Switch(config)# teaming profile <profile ID> enable
```

3. Specify the failover limit for your teaming profile.

```
Switch(config)# teaming profile <profile ID> limit <limit>
```

4. Specify the links to monitor.

```
Switch(config)# teaming profile <profile ID> mmon monitor interface
{ethernet <chassis>/<port>|port-channel <range>}
```

5. Specify the links to disable when the failover limit is reached.

```
Switch(config)# teaming profile <profile ID> mmon control interface
{ethernet <chassis>/<port>|port-channel <range>}
```

6. View the Layer 2 Failover configuration:

```
Switch(config)# show teaming profile
```

7. View the Layer 2 Failover operation information:

```
Switch(config)# show teaming profile information
```

Part 6: Network Management

This section discusses the following topics:

Chapter 29. Link Layer Discovery Protocol

Lenovo Cloud Network Operating System supports Link Layer Discovery Protocol (LLDP). This chapter discusses the use and configuration of LLDP on the switch:

LLDP Overview

Link Layer Discovery Protocol (LLDP) is an IEEE 802.1AB-2009 standard for discovering and managing network devices. This implementation of LLDP is compatible with the IEEE 802.1AB-2005 standard. LLDP uses Layer 2 (the data link layer), and allows network management applications to extend their awareness of the network by discovering devices that are direct neighbors of already known devices.

With LLDP, the switch can advertise the presence of its ports, their major capabilities, and their current status to adjacent LLDP stations. LLDP transmissions occur on ports at regular intervals or whenever there is a relevant change to their status. The switch can also receive LLDP information advertised from adjacent LLDP-capable network devices.

In addition to discovery of network resources, and notification of network changes, LLDP can help administrators quickly recognize a variety of common network configuration problems, such as unintended VLAN exclusions.

The LLDP transmit function and receive function can be independently configured on a per-port basis. The administrator can allow any given port to transmit only, receive only, or both transmit and receive LLDP information.

The LLDP information to be distributed by the switch ports, and that which has been collected from other LLDP stations, is stored in the switch's Management Information Base (MIB). Network Management Systems (NMS) can use Simple Network Management Protocol (SNMP) to access this MIB information. LLDP-related MIB information is read-only.

Changes, either to the local switch LLDP information or to the remotely received LLDP information, are flagged within the MIB for convenient tracking by SNMP-based management systems.

For LLDP to provide expected benefits, all network devices that support LLDP must be consistent in their LLDP configuration.

Enabling or Disabling LLDP

The switch can be configured to transmit or receive LLDP information on a port-by-port basis.

LLDP is enabled by default on the switch. When LLDP is enabled on the switch, the ports transmit and receive LLDP information.

To enable or disable the transmission of LLDP information, use the following command (for this example ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# [no] lldp transmit
```

To enable or disable the reception of LLDP information, use the following command (for this example ethernet interface 1/12 is used):

```
Switch(config)# interface ethernet 1/12
Switch(config-if)# [no] lldp receive
```

To view the LLDP transmit and receive status, use the following commands:

```
Switch# show lldp interface all
```

LLDP Transmit Features

Numerous LLDP transmit options are available, including scheduled and minimum transmit interval, expiration on remote systems, SNMP trap notification, and the types of information permitted to be shared.

Transmit Interval

The switch can be configured to transmit LLDP information to neighboring devices once each 5 to 32768 seconds. The scheduled interval is global; the same interval value applies to all LLDP transmit-enabled ports. However, to help balance LLDP transmissions and keep them from being sent simultaneously on all ports, each port maintains its own interval clock, based on its own initialization or reset time. This allows switch-wide LLDP transmissions to be spread out over time, though individual ports comply with the configured interval.

The transmit interval represents the number of seconds between two consecutive LLDP transmissions. To configure the global transmit interval (in seconds), use the following command:

```
Switch(config)# lldp timer <5-32768>
```

Note: The configured transmit interval must be equal or greater than four times the configured transmit delay. Trying to configure a lower value results in failure.

The default is 30 seconds. To reset the transmit interval to its default value, use the following command:

```
Switch(config)# no lldp timer
```

Transmit Delay

In addition to sending LLDP information at scheduled intervals, LLDP information is also sent when the switch detects relevant changes to its configuration or status (such as when ports are enabled or disabled). To prevent the switch from sending multiple LLDP packets in rapid succession when port status is in flux, a transmit delay timer can be configured.

The transmit delay timer represents the minimum time permitted between successive LLDP transmissions on a port. Any interval-driven or change-driven updates will be consolidated until the configured transmit delay expires.

To configure the transmit delay (in seconds), use the following command:

```
Switch(config)# lldp transmit-delay <1-8192>
```

Note: The configured transmit delay must be equal or lower than a fourth of the global transmit interval. Trying to configure a greater value results in failure.

The default is 2 seconds. To reset the minimum transmit interval to its default value, use the following command:

```
Switch(config)# no lldp transmit-delay
```

Time-to-Live for Transmitted Information

The transmitted LLDP information is held by remote systems for a limited time. A time-to-live parameter allows the switch to determine how long the transmitted data is held before it expires. The hold time is configured as a multiple of the configured transmission interval.

```
Switch(config)# lldp holdtime-multiplier <2-10>
```

The default value is 4, meaning that remote systems will hold the port's LLDP information for four times the 30 second transmit interval/scheduled interval (`msgtxint`) value, or 120 seconds, before removing it from their MIB.

Note: If the transmission interval has a different value from the default value, the resulting timeout value will be different.

To reset the hold time multiplier to its default value, use the following command:

```
Switch(config)# no lldp holdtime-multiplier
```

LLDP Fast Transmission Initialization

An LLDP enabled switch sends LLDP messages to its peers at the configured transmit interval. By default, this interval is 30 seconds.

When a new peer is detected by the switch, fast LLDP transmission periods can be initiated, that cause LLDP messages to be sent at a shorter time interval than during normal protocol operation. The transmit interval and the transmit delay are set to one second for the first five LLDP transmissions and then they are reset to their previously configured values.

To enable or disable LLDP fast transmission initialization, use the following command:

```
Switch(config)# [no] lldp fast-init enable
```

Trap Notifications

If SNMP is enabled on the switch (see "Using Simple Network Management Protocol" on page 53), each port can be configured to send SNMP trap notifications whenever an update occurs in the LLDP database. By default, trap notification is disabled for each port. The trap notification state can be changed using the following commands:

```
Switch(config)# interface ethernet 1/1
Switch(config-if)# [no] lldp trap-notification
Switch(config-if)# exit
```

LLDP information is also sent when neighbors to the switch are added, removed, or changed. To prevent the switch from sending multiple trap notifications in rapid succession when port status is in flux, a global trap delay timer can be configured.

The trap delay timer represents the minimum time permitted between successive trap notifications on any port. Any interval-driven or change-driven trap notices from the port will be consolidated until the configured trap delay expires.

To configure the minimum trap notification interval (in seconds), use the following command:

```
Switch(config)# lldp trap-interval <5-3600>
```

The default is 5 seconds. To reset the minimum trap notification interval to its default value, use the following command:

```
Switch(config)# no lldp trap-interval
```

If SNMP trap notification is enabled, the notification messages can also appear in the system log. This is enabled by default. To change whether the SNMP trap notifications for LLDP events appear in the system log, use the following command:

```
Switch(config)# [no] logging level lldp <logging level>
```

where *logging level* is one of the following:

Value	Meaning
0	emergencies only
1	alerts
2	critical
3	errors
4	warnings
5	notifications
6	information
7	debugging

Note: After enabling logging for SNMP trap notifications for LLDP events, ensure that logging messages are visible by enabling console session logging:

```
Switch(config)# logging console
```

Changing the LLDP Transmit State

When the port is disabled, or when LLDP transmit is turned off for the port (see "LLDP Transmit Features" on page 608), a final LLDP packet is transmitted with a time-to-live value of 0. Neighbors that receive this packet will remove the LLDP information associated with the switch port from their MIB.

In addition, if LLDP is fully disabled on a port and then later re-enabled, the switch will temporarily delay resuming LLDP transmissions on the port to allow the port LLDP information to stabilize.

To globally configure the reinitialization delay interval (in seconds), use the following command:

```
Switch(config)# lldp reinit <1-10>
```

The default is 2 seconds. To reset the reinitialization delay interval to its default value, use the following command:

```
Switch(config)# no lldp reinit
```

Types of Information Transmitted

When LLDP transmission is permitted on the port (see "Enabling or Disabling LLDP" on page 607), the port advertises the following required information in type/length/value (TLV) format:

- Chassis ID
- Port ID
- LLDP Time-to-Live

LLDP transmissions can also be configured to enable or disable inclusion of optional information, using the following command (Interface Ethernet Mode):

```
Switch(config)# interface ethernet 1/1
Switch(config-if)# [no] lldp tlv-select <type>
```

where *type* is one of the following values:

Value	Definition
link-aggregation	Link Aggregation TLV
mac-phy-status	MAC/PHY Configuration/Status TLV
management-address	Management Address TLV
max-frame-size	Maximum frame size TLV
port-description	Port description TLV
port-protocol-vlan	Port and Protocol VLAN ID TLV
port-vlan	Port VLAN ID TLV

Value	Definition
`power-mdi`	Power via MDI TLV
`protocol-identity`	Protocol identity TLV
`system-capabilities`	System capabilities TLV
`system-description`	System description TLV
`system-name`	System name TLV
`vid-management`	Version ID Management TLV
`vlan-name`	VLAN Name TLV

LLDP Receive Features

The following LLDP receive features are supported by CNOS.

Types of Information Received

When the LLDP receive option is enabled on a port (see "Enabling or Disabling LLDP" on page 607), the port may receive the following TLV information from LLDP-capable remote systems:

- Chassis ID
- Port ID
- LLDP Time-to-Live
- Link Aggregation
- MAC/PHY Configuration/Status
- Management Address
- Maximum Frame Size
- Port Description
- Port and Protocol VLAN ID
- Port VLAN ID
- Power via MDI
- Protocol Identity
- System Capabilities
- System Description
- System Name
- VID Management
- VLAN Name

The switch stores the collected LLDP information in the MIB. Each remote LLDP-capable device is responsible for transmitting regular LLDP updates. If the received updates contain LLDP information changes (to port state, configuration, LLDP MIB structures, deletion), the switch will set a change flag within the MIB for convenient notification to SNMP-based management systems.

Time-to-Live for Received Information

Each remote device LLDP packet includes an expiration time. If the switch port does not receive an LLDP update from the remote device before the time-to-live timer expires, the switch will consider the remote information to be invalid, and will remove all associated information from the MIB.

Remote devices can also intentionally set their LLDP time-to-live to 0, indicating to the switch that the LLDP information is invalid and must be immediately removed.

Viewing Remote Device Information

LLDP information collected from neighboring systems can be viewed in numerous ways:

- Using a centrally-connected LLDP analysis server
- Using an SNMP agent to examine the switch MIB
- Using commands on the switch

The following command displays LLDP neighbor information:

```
Switch# show lldp neighbors
```

For more information on LLDP commands, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9.*

Note: Received LLDP information can change very quickly. When using display commands, it is possible that flags for some expected events may be too short-lived to be observed in the output.

To view detailed information of all remote devices, use the following command:

```
Switch# show lldp neighbors detail

Chassis ID MAC Address: a897.dcde.530d
Port ID Locally Assigned: Ethernet1/11
Local Port ID: Ethernet1/11
Port Description: Ethernet1/11
System Name: LENOVO G8272
System Description: LENOVO RackSwitch G8272, LENOVO NOS version 10.1.2.0
Time remaining: 106 seconds
System Capabilities: B, R
Enabled Capabilities: B, R
Management Address: 192.168.50.50
VLAN ID: 10

Chassis ID MAC Address: a897.dcde.530f
Port ID Locally Assigned: Ethernet1/13
Local Port ID: Ethernet1/13
Port Description: Ethernet1/13
System Name: LENOVO G8272
System Description: LENOVO RackSwitch G8272, LENOVO NOS version 10.1.2.0
Time remaining: 106 seconds
System Capabilities: B, R
Enabled Capabilities: B, R
Management Address: 192.168.50.50
VLAN ID: 10

Chassis ID MAC Address: a897.dcde.5311
Port ID Locally Assigned: Ethernet1/15
Local Port ID: Ethernet1/15
Port Description: Ethernet1/15
System Name: LENOVO G8272
System Description: LENOVO RackSwitch G8272, LENOVO NOS version 10.1.2.0
Time remaining: 106 seconds
System Capabilities: B, R
Enabled Capabilities: B, R
Management Address: 192.168.50.50
VLAN ID: 10

Total entries displayed: 3
```

Debugging LLDP

LLDP debugging is disabled by default.

Note: To ensure that debugging messages are visible, enable the redirecting of debug traces associated with all facilities to the console session:

```
Switch(config)# debug terminal
```

To enable or disable LLDP debugging, use the following command:

```
Switch(config)# [no] debug lldp <type>
```

where *type* is one of the following:

Parameter	Description
`all`	Enable all debugging flags.
`decode`	Enable decode debugging.
`encode`	Enable encode debugging.
`error`	Enable error debugging.
`event`	Enable event debugging.
`interface all` `interface ethernet` *<chassis number/port number>*	Enable debugging on all interfaces or on the specified interface.
`message`	Enable Network Security Monitoring (NSM) message debugging.
`rx`	Enable reception debugging.
`trace`	Enable trace debugging.
`tx`	Enable transmission debugging.

The following types of debugging are available:

- `all`

  Enables all debug flags.

- `event`

  Messages appear when the following events occur:

  - Timer expiration
  - Admin status changes
  - TLV selection changes
  - Timer configuration changes
  - Transmit initialization
  - Receive initialization

- `interface`

  Debugging occurs on all physical interfaces or on the specified interface.

- `message`

  Prints messages between Network Security Monitoring (NSM) and the Linux LLDP process.

- `rx`

  Prints the packet contents when reception occurs.

- `trace`

  Prints the process stage of LLDP packets. For example:

  - Encode/Decode management address
  - TLV/TX packet enters delay timer
  - Begin transmission
  - Begin reception

  When an error is received on the LLDP PDU, the packet content is logged to the internal debug buffer.

- `tx`

  Prints the packet contents when transmission occurs.

- Error

  Prints a message when an error occurs.

To view LLDP debugging information, enter:

```
Switch# show debug lldp
```

LLDP Example Configuration

The following is an example LLDP configuration.

1. Set the global LLDP timer features.

   a. Configure the transmit interval:

```
Switch(config)# lldp timer 8
```

   b. Configure the minimum transmit interval:

```
Switch(config)# lldp transmit-delay 2
```

   c. Configure the hold time multiplier:

```
Switch(config)# lldp holdtime-multiplier 4
```

   d. Configure the reinitialization interval:

```
Switch(config)# lldp reinit 2
```

   e. Configure the minimum trap notification interval:

```
Switch(config)# lldp trap-notification-interval 5
```

2. Set LLDP options for each port.

   a. Enter Interface Configuration mode for each ethernet port:

```
Switch(config)# interface ethernet 1/12
```

   b. Enable LLDP transmission and reception:

```
Switch(config-if)# lldp receive
Switch(config-if)# lldp transmit
```

   c. Enable SNMP trap notifications:

```
Switch(config-if)# lldp trap-notification
```

   d. Configure the port to include port description in its outgoing LLDP messages:

```
Switch(config-if)# lldp tlv-select port-description
Switch(config-if)# exit
```

3. Enable syslog reporting.

```
Switch(config)# logging level lldp 6
```

4. View remote device information.

```
Switch# show lldp neighbors

Capability codes:
  (R) Router, (B) Bridge, (T) Telephone, (C) DOCSIS Cable Device
  (W) WLAN Access Point, (P) Repeater, (S) Station, (O) Other
Device ID            Local Intf      Hold-time  Capability  Port ID
MA_49                Ethernet1/14    120        BR          Ethernet1/14
G8052-71             mgmt0           120        BR          3

Total entries displayed: 2
```

```
Switch# show lldp timers

LLDP Timers:

Holdtime in seconds: 120
Reinit-time in seconds: 2
Transmit interval in seconds: 30
Transmit delay in seconds: 2
Trap interval in seconds: 5
```

```
Switch# show lldp interface ethernet 1/12

Interface Name: Ethernet1/12
--------------
Interface Information
 Enable (tx/rx/trap): Y/Y/N   Port Mac address: a8:97:dc:de:02:0e
```

Chapter 30. Service Location Protocol

The Service Location Protocol (SLP) is a service discovery protocol that allows the switch to find services across the local network without the need for an initial configuration. The switch discovers and selects network services without the requiring the hostname or the address of the service provider. You supply the type of service wanted and a set of attributes that describe it. Based on this information, SLP resolves the network address of the service provider.

Each type of service provided on the network has a unique service type string. Service types and their attributes are catalogued by the Internet Assigned Numbers Authority (IANA).

SLP defines specialized components called agents that perform tasks and support services as follows:

- User Agent (UA) - supports service query functions. It requests service information for user applications. The User Agent retrieves service information from the Service Agent. A Host On-Demand client is an example of a User Agent.
- Service Agent (SA) - provides service registration and service advertisement.

The switch behaves as a Service Agent.

When a Service Agent starts up, it locally registers all of its services and constructs a list of attributes for those services. Service Agents must accept both unicast and multicast SLP requests. This is done using the SLP reserved port 427.

Services Agents respond to Service and Attribute Request messages with Service and Attribute Reply messages. They also store the network addresses of up to a maximum of eight User Agents. When a new User Agent is discovered, the oldest User Agent is deleted from the Service Agent.

SLP multicast messages use `239.255.255.253` as their destination address.

SLP Agents Communication

The User Agent sends multicast Service Request messages to the Service Agents present on the network on behalf of soliciting applications that run on the switch. For example, if a switch application needs access to a printer, the User Agent will send a Service Request across the network to find a printer for the switch application to use.

The Service Agents send in return unicast Service Reply messages with the location of all the network services that satisfy the requirements specified in the Service Request message.

Services are described by the configuration of attributes associated with a type of service. A User Agent can select an appropriate service by specifying the attributes that it needs in a Service Request message. When Service Reply messages are returned, they contain a Uniform Resource Locator (URL) pointing to the service desired and other information needed by the User Agent, such as server load.

SLP Specific Messages

SLP Agents use the following types of messages to communicate with each other:

- `Service Request` - request information about a specific type of service
- `Service Reply` - contains URLs for the type of service solicited in Service Request message, if there are any network services matching the specified requirements
- `Attribute Request` - request service attributes based on the service URL
- `Attribute Reply` - contains the attributes describing the solicited service

SLP Supported Service Attributes

SLP supports the following attributes:

- `level` - the level of the attribute (type: integer)
- `type` - the type of the device (type: string)
- `data-protocols` - the management protocols supported by the device (type: string)
- `serial-number` - the serial number of the device (type: string)
- `mac-address` - the MAC address of the device (type: string)
- `sysoid` - the System Object ID (type: string)
- `ipv4-enabled` - the status of the IPv4 accessibility of the device over the ethernet interface (type: boolean)
- `ipv4-address` - the IPv4 address of the device (type: string)
- `ipv6-enabled` - the status of the IPv6 accessibility of the device over the ethernet interface (type: boolean)
- `ipv6-address` - the IPv6 address of the device (type: string)
- `deviceName` - the custom name of the device or its hostname, if they are configured on the device (type: string)
- `uuid` - the Universally Unique Identifier (UUID - type: string)
- `mtm` - the Machine Type Model (MTM - type: string)

SLP Configuration

By default, SLP is enabled on the switch.

To enable or disable SLP, use the following command:

```
Switch(config)# [no] ip slp enable
```

To view SLP information, use the following command:

```
Switch> show ip slp information
 Protocol Version: 2
 SLP State: enabled
 SLP Listening Port: 427
 SLP listening on interface: 11, IP address: 3.0.0.1
 SLP listening on interface: 3, IP address: 10.241.39.122
 SLP listening on interface: 10, IP address: 10.0.0.1
```

To view User Agent information, use the following command:

```
Switch> show ip slp user-agents
List of UAs:
  IP Address: 10.0.0.7 on port Ethernet1/11, updated 00:05:33 seconds ago
```

To view SLP statistics, use the following command:

```
Switch> show ip slp counters
SLP Send Counters              :      unicast       multicast
        SLP Da Adverts         :            0               0
        SLP Service Requests   :            0               0
        SLP Service Replies    :            0               0
        SLP Service Ack        :            0               0
        SLP Attribute Requests :            0               0
        SLP Attribute Replies  :            0               0
        SLP SrvType Requests   :            0               0
        SLP Service Replies    :            0               0
        SLP Srv Registrations  :            0               0
        SLP Srv Deregistrations:            0               0
        SLP SA Adverts         :            0               0
        SLP Unknown            :            0               0

SLP Receive Counters           :      unicast       multicast
        SLP Da Adverts         :            0               0
        SLP Service Requests   :          448             698
        SLP Service Replies    :            0               0
        SLP Service Ack        :            0               0
        SLP Attribute Requests :            0               0
        SLP Attribute Replies  :            0               0
        SLP SrvType Requests   :            0               0
        SLP Service Replies    :            0               0
        SLP Srv Registrations  :            0               0
        SLP Srv Deregistrations:            0               0
        SLP SA Adverts         :            0               0
        SLP Unknown            :            0               0

Scopes mismatch                :            0               0
Wrong destination              :            0               0
Invalid packets                :            0               0
```

SLP Limitations

SLP does not advertise IPv6 Link Local addresses associated with Layer 3 interfaces. SLP requests received on such interfaces are discarded. However, IPv6 Link Local addresses associated with the management interface are advertised by SLP.

Chapter 31. Simple Network Management Protocol

Lenovo Cloud Network Operating System provides Simple Network Management Protocol (SNMP) version 1, version 2, and version 3 support for access through any network management software, such as IBM Director or HP-OpenView.

Note: SNMP read and write functions are enabled by default. For best security practices, if SNMP is not needed for your network, it is recommended that you disable these functions prior to connecting the switch to the network.

The following topics are discussed in this section:

SNMP Versions

The switch can be accessed using SNMP version 1, version 2, or version 3:

- SNMPv1 is the initial implementation of the SNMP protocol. It operates over protocols such as User Datagram Protocol (UDP) and Internet Protocol (IP).
- SNMPv2c revised version 1 and includes improvements in performance, security, confidentiality, and communication.
- SNMPv3 adds cryptographic encryption to version 2. It also uses new textual conventions, concepts, and terminology.

SNMP Version 1 & Version 2

To access the SNMP agent on the switch, the read and write community strings on the SNMP manager must be configured to match those on the switch. By default, there are no default community strings configured on the switch.

The read and write community strings on the switch can be changed using the following commands on the CLI:

```
Switch(config)# snmp-server community <1-32 characters> [ro|rw|group <word>|
|view <view name> version {v1|v2c} {ro|rw}]
```

Note: The option `ro` provides read-only access. The option `rw` applies read-write access with the specified community string.

The SNMP manager must be able to reach the management interface or any one of the IP interfaces on the switch.

SNMP Version 3

SNMP version 3 (SNMPv3) is an enhanced version of the Simple Network Management Protocol, approved by the Internet Engineering Steering Group in March, 2002. SNMPv3 contains additional security and authentication features that provide data origin authentication, data integrity checks, timeliness indicators and encryption to protect against threats such as masquerade, modification of information, message stream modification and disclosure.

SNMPv3 allows clients to query the MIBs securely.

Note: Only SNMPv3 is enabled by default. To enable all SMTP versions, enter:

```
Switch(config)# snmp-server version v1v2v3
```

For more information on SNMP MIBs, see "SNMP MIBs" on page 629. For more details about the commands used to configure SNMP on the switch, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

SNMP Protocol Details

SNMP works by sending request and responses between a SNMP manager and a SNMP agent. Following are the option that can be configure to be used by switch when communicating with other devices using SNMP.

SNMP Notifications

Cloud NOS generates SNMP notifications as either traps or informs.

For the SNMP manager to receive the SNMP traps sent out by the SNMP agent on the switch, configure the trap host on the switch with the following commands:

```
Switch(config)# snmp-server enable traps [bfd|link [linkDown|linkUp]]
Switch(config)# snmp-server host <IPv4 or IPv6 address> [traps] version {1|2c|3
{auth|noauth|priv}} {<community string>|<SNMPv3 user name>} [udp-port <1-65535>]
```

In the case of informs, the SNMP manager that receives an inform message will acknowledge the message with an SNMP response PDU. If the sender does not receive a response for an inform message, the inform can be sent again. To configure informs, use the following command:

```
Switch(config)# snmp-server host <IPv4 or IPv6 address> informs version {2c|3
{auth|noauth|priv}} {<community string>|<SNMPv3 user name>} [udp-port <1-65535>]
```

By default, SNMP notifications are sent through all of the Virtual Routing and Forwarding (VRF) instances of the switch. To change the VRF used for SNMP notifications, use the following command to select between the management VRF, the default VRF, or both:

```
Switch(config)# snmp-server trap vrf {all|default|management}
```

Note: Only SNMPv3 is enabled by default. To enable all SMTP versions, enter:

```
Switch(config)# snmp-server version v1v2v3
```

SNMP Device Contact and Location

You can assign the device contact information and device location by using the following commands:

```
Switch(config)# snmp-server contact <contact name>
Switch(config)# snmp-server location <location name>
```

One-Time Authentication for SNMP over TCP

You can enable a one-time authentication for SNMP over a TCP session by using the following command:

```
Switch(config)# snmp-server tcp-session
```

Default Configuration

Up to 16 SNMP users can be configured on the switch. To modify an SNMP user, enter the following commands:

```
Switch(config)# snmp-server user <5-32 characters>
```

Users can be configured to use the authentication/privacy options. The switch supports:

- two authentication algorithms:
  - MD5

    ```
    Switch(config)# snmp-server user <username> auth md5 <password>
    ```

  - SHA

    ```
    Switch(config)# snmp-server user <username> auth sha <password>
    ```

- two privacy protocols:
  - DES (CBC-DES Symmetric Encryption Protocol)

    ```
    Switch(config)# snmp-server user <username> auth {md5|sha} <password>
    priv des <privilege password>
    ```

  - AES (AES-128 Advanced Encryption Standard)

    ```
    Switch(config)# snmp-server user <username> auth {md5|sha} <password>
    priv aes <privilege password>
    ```

Configuration Examples

Following are examples of the SNMP operations supported by Lenovo CNOS.

Basic SNMP Configuration Example

1. Enable SNMP on the switch.

```
Switch(config)# snmp-server enable snmp
```

2. Enable the switch to use all versions of SNMP.

```
Switch(config)# snmp-server version v1v2v3
```

3. (Optional) Set an SNMP view with the name `all`, OID Tree `OID-TREE` and type `included`.

```
Switch(config)# snmp-server view all OID-TREE included
```

4. Configure the community parameters.

```
Switch(config)# snmp-server community public group network-operator
Switch(config)# snmp-server community private group network-admin
```

5. View the SNMP configuration.

```
Switch(config)# show running-config snmp
```

User Configuration Example

1. Enable SNMP feature.

```
Switch(config)# snmp-server enable snmp
```

2. Set an SNMP view with the name `all`, OID Tree `OID-TREE` and type `included`.

```
Switch(config)# snmp-server view all OID-TREE included
```

3. Configure an SNMP user with authentication password `password1` and privilege password `password2`.

```
Switch(config)# snmp-server user summer network-admin auth sha password1
priv des password2
```

4. View the SNMP user configuration.

```
Switch(config)# show snmp user
```

Configuring SNMP Trap Hosts

1. Enable SNMP traps.

```
Switch(config)# snmp-server enable traps
```

2. Send SNMPv3 traps messages to an SNMP recipient:

```
Switch(config)# snmp-server host 1.0.0.2 traps version 3 priv test
udp-port 162
```

3. View the SNMP trap configuration.

```
Switch(config)# show snmp trap
```

SNMP MIBs

The CNOS SNMP agent supports SNMP version 3. Security is provided through SNMP community strings. By default, there are no default community strings configured on the switch. The community string can be configured and modified only through the Industry Standard Command Line Interface (ISCLI). Detailed SNMP MIBs and trap definitions of the CNOS SNMP agent are contained in the CNOS enterprise MIB document.

The CNOS SNMP agent supports the following standard MIBs:

- rfc1213.mib
- rfc1573.mib
- rfc1643.mib
- rfc2011.mib
- rfc2012.mib
- rfc2013.mib
- rfc2037.mib
- rfc2233.mib
- rfc2790.mib
- rfc2863.mib
- rfc3411.mib
- rfc3412.mib
- rfc3413.mib
- rfc3414.mib
- rfc3415.mib
- rfc3418.mib
- rfc4363.mib
- lag-mib.mib
- lldp-mib.mib
- rfc4022.mib
- rfc4113.mib
- rfc4133.mib
- rfc4188.mib
- rfc4363.mib
- rfc4273.mib
- rfc4293.mib
- rfc4750.mib

The CNOS SNMP agent supports the following generic traps as defined in:

- RFC 1215:
  - linkDown
  - linkUp
  - egpNeighborLoss
- RFC 4188:
  - newRoot
  - topologyChange
- RFC 4273:
  - bgpEstablishedNotification
  - bgpBackwardTransNotification
- RFC 4750:
  - ospfVirtIfStateChange
  - ospfNbrStateChange
  - ospfVirtNbrStateChange
  - ospfIfConfigError
  - ospfVirtIfConfigError
  - ospfIfAuthFailure
  - ospfVirtIfAuthFailure
  - ospfIfRxBadPacket
  - ospfVirtIfRxBadPacket
  - ospfTxRetransmit
  - ospfVirtIfTxRetransmit
  - ospfOriginateLsa
  - ospfMaxAgeLsa
  - ospfLsdbOverflow
  - ospfLsdbApproachingOverflow
  - ospfIfStateChange
  - ospfNssaTranslatorStatusChange
  - ospfRestartStatusChange
  - ospfNbrRestartHelperStatusChange
  - ospfVirtNbrRestartHelperStatusChange

Chapter 32. Telemetry

Telemetry is an automated communications process in which measurements and other data are collected at remote points and transmitted to receiving equipment for monitoring. This data can then be used for various purposes.

This chapter discusses the following topics:

Network Telemetry Overview

Network telemetry is used by organizations to monitor their network devices, such as switches and routers, and provide this data to software controllers, which can analyze the data. In Lenovo Cloud Network Operating System, telemetry is used for pro-active congestion monitoring.

Telemetry lets you monitor networking devices continuously to detect potential congestion problems, ideally before they happen. This type of monitoring operation must address the following scenarios:

- Long-term congestion

  Packets are dropped by the switch, such as by ports being used close to their line rate, or flows are back pressured for a long period of time due to the lack of buffer space.

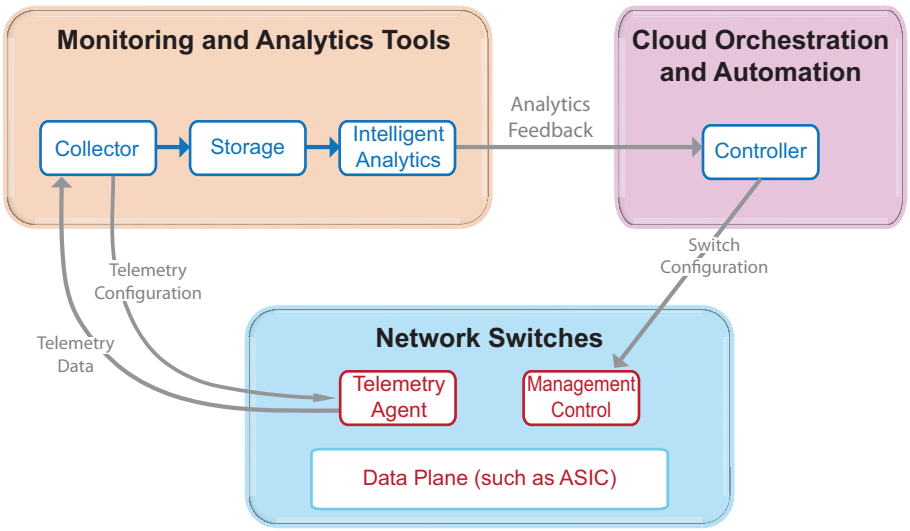
- Microbursts

  Rapid bursts of packets at line rate can temporarily overflow switch buffers and cause packet loss or backpressure. These microbursts do not last long enough to be detected by traditional switch counters, such as SNMP or port statistics. In cloud environments, increased complexity and reduced visibility make detecting microbursts even more difficult.

CNOS Telemetry Architecture

In a complete cloud and data center ecosystem, the ultimate goal is to make sure applications can run in an efficient and reliable fashion. To accomplish this, applications use computing, storage, and network resources as accessories to this goal. Having end-to-end visible information about application performance becomes a critical aspect on modern networks. Telemetry provides real-time monitoring and reporting of how virtual and physical networks are being used. Figure 32 shows the key components of a typical telemetry solution.

Figure 32. Telemetry Ecosystem



In this figure:

- The **Collector** efficiently collects, normalizes, and transforms data. This data will be used to create different views and help solve various telemetry use cases.
- This data is sent to a time-series resource indexing and metric **Storage** service, which provides a scalable means of storing short-term and long-term data.
- **Intelligent Analytics** trigger actions based on defined rules against sampled or event data collected from the network.
- The analytics are sent to the **Cloud Orchestration and Automation Controller**. The controller sends the best switch configuration to the Management Control agent on the switch.
- The **Telemetry Configuration** tells the **Telemetry Agent** which subset of all supported data types must be sent to the **Collector**.
- The **Telemetry Agent** sends the **Telemetry Data** back to the **Collector**, which sends the **Telemetry Configuration** back to the **Telemetry Agent** on the switch.

CNOS has a telemetry agent that is validated using the open source Ganglia monitoring application, which is used in this document as an example. Any application that supports the REST architecture and is capable of exchanging JSON messages over HTTP or HTTPS can be used to interact with the CNOS telemetry agent. The CNOS telemetry agent is built into CNOS and runs on the switch, whereas the telemetry controllers that interact with it run on external systems.

Any external application that uses a standard REST client can interact with the CNOS telemetry agent using the CNOS REST API. For more information about the REST functions supported by the CNOS telemetry agent, see the *CNOS REST API Programming Guide*.

The Ganglia Analytics Application

Note: The Ganglia analytics application is used in this document as an example of an analytics package. Any application that supports the REST architecture and is capable of exchanging JSON messages over HTTP or HTTPS can be used to interact with the CNOS telemetry agent.

Ganglia is an open source application that monitors and collects massive quantities of system metrics in near real time for large installations, such as computer networks where there are hundreds or thousands of nodes to be monitored. Its architecture is based on the separation between polling, storage, and data presentation operations.

The Ganglia software assumes monitored nodes can be organized meaningfully into groups. Ganglia refers to a group of hosts as a cluster, and it requires that at least one cluster of nodes exist. A cluster must have at least one node. The main purpose of grouping nodes into clusters is to achieve scalability by distributing the processing amongst the nodes instead of placing the burden on a centralized collection server.

The Ganglia software consists of the following three daemons and a tool:

- `gmond` (daemon)
- `gmetad` (daemon)
- `gweb` (daemon)
- `gmetric` (tool)

Each daemon is self-contained, needing only its own configuration file to operate. Each daemon will start and can run in the absence of the other two, but you need all three daemons to have a useful installation. Architecturally, the three daemons are cooperative. The Ganglia components interact with the CNOS telemetry agent (telemetryd).

The telemetry agent is logically equivalent to an embedded database that provides message broker services. It uses the abstraction layer to configure and retrieve telemetry information from the Application-Specific Integrated Circuit (ASIC).

The Ganglia Agent

The Ganglia Monitoring Daemon, `gmond`, is responsible for interacting with the monitored node to retrieve telemetry measurements, which are called metrics in Ganglia terminology. These metrics are the actual telemetry information, such as buffers, interfaces, and CPU statistics. In CNOS, `gmond` runs on an external server and interacts with the telemetry agent running on each CNOS switch.

The Central Data Aggregator

The Ganglia Meta Daemon, `gmetad`, polls separate `gmond` processes and stores the metric data to disk for later use. The result is a single meta-cluster data view in Round Robin Database (RRD) and XML formats.

The `gmetad` process stores older values in the RRD files and updates the metric data files, which consist of static allocations of values for various chunks of time.

The Data Visualization Front End

The Ganglia Web user interface, `gweb`, is a PHP program that serves as a front end for data visualization. It needs no preconfiguration, and it allows you to create your own graphs to explore and analyze data in a customized fashion. The `gweb` component is usually installed on the same physical hardware as `gmetad` because it needs access to the RRD databases created by `gmetad`.

The Ganglia Metric Tool

The Ganglia Metric tool, `gmetric`, lets you generate custom reports of the metrics from your own scripts in any language. These metrics are historic "streams" of data containing a sequence of "name, value" pairs with a time stamp associated with each pair, for example, (`cpu_usage, 90%`) at 10 AM today. The full historic sequence can provide data for a range such as the last minute, last five minutes, last ten minutes, last two hours, or last two weeks.

Using Ganglia with CNOS

The Lenovo Ganglia plug-in helps the telemetry agent to integrate with Ganglia. It provides pull and push mode support to collect telemetry BST statistics, translates data to Ganglia metrics, and provides a visualization tool.

The Lenovo Ganglia Plug-in works with Ganglia version 7.3.2. It does not add any scalability restrictions and it employs the distributed nature of Ganglia.

The CNOS Ganglia interface uses a Python script running on a server to communicate with the CNOS telemetry daemon on the switches using unicast HTTPS messages. The plug-in sends HTTPS requests to the CNOS telemetry daemon, gets the JSON response from the switches, extracts the values, generates multiple metrics, and sends them out to `gmetad` with `gmetric`. This mode is used for both telemetry configuration and data collection.

You can download the Lenovo Ganglia plug-in from:

https://github.com/lenovo/networking-telemetry

To install Ganglia to work with CNOS:

1. Make sure your system is running Ubuntu Linux 16.04 or the latest stable release.
2. Make sure the Ubuntu Advanced Packaging Tool (APT) system source is correctly configured:

```
% sudo apt-get update
```

   This is necessary because during the installation, some dependency packages will be downloaded and installed automatically.

3. Install Ganglia:

   Install with everything in one package:

```
% tar zxvf lenovo-ganglia-1.0.04.tar.gz
% cd lenovo-ganglia-1.0.04
% sudo ./install.sh install
```

Install with the Ganglia source code in separate packages:

```
% tar zxvf lenovo-ganglia-1.0.04.tar.gz
% cd lenovo-ganglia-1.0.04/ganglia-src
% wget
https://sourceforge.net/projects/ganglia/files/ganglia-web/3.7.2/ganglia-
web-3.7.2.tar.gz/download
% wget
https://sourceforge.net/projects/ganglia/files/ganglia%20monitoring%20cor
e/3.7.2/ganglia-3.7.2.tar.gz/download
% cd ..
% sudo ./install.sh install
```

4. Start the Ganglia Monitoring and Ganglia Meta Daemons:

```
% sudo service gmond start
% sudo service gmetad start
```

5. Make sure Ganglia is installed correctly by visiting:

   `http://`*<Ganglia Host IP Address>*`/ganglia`

   The default summary page, which includes the overall load, memory, and CPU status, will display.

6. Manually switch the IP list and interface list:

```
% lenovo-gangalia-1.0.04/pull/conf.py
```

7. Manually set the login username and password:

```
% lenovo-gangalia-1.0.04/pull/pull.py
```

8. Start the script to keep collection drop counters:

```
% cd lenovo-gangalia-1.0.04/pull/
% python pull.py
```

Types of Data Supplied by the CNOS Telemetry Agent

The following types of data are supplied by the CNOS telemetry agent.

Buffer Statistics

The following types of buffer statistics are available.

Congestion Drop Statistics

Congestion drop statistics keep track of packet loss caused by the lack of buffers to process the packets. The telemetry agent provides the following reports:

- top-drops

  Ports suffering maximum congestion in the switch and the associated drop counters.

- top-port-queue-drops

  Top port-queue level drop-counters in the switch. Each queue maps to a class of service.

- port-drops

  Per-port total drop counters.

- port-queue-drops

  Port-queue level drop-counters.

You can retrieve congestion drop statistics from the agent periodically (periodic push) or immediately (on demand pull).

Buffer Utilization Statistics

Buffer utilization statistics are associated with different buffer types in the switch. Buffer utilization statistics are presented under the following corresponding categories, called *realms*:

- device, port, port + priority group, service pool, port + service pool
- ingress, egress
- unicast, multicast

You can retrieve buffer utilization statistics periodically (periodic push), immediately (on demand pull), or via spontaneous asynchronous reports (threshold-driven push) from the agent.

Note: For the Lenovo RackSwitch G8272, G8296, and G8332, the buffer utilization counters associated to the egress service pool counter group may remain at high values when traffic flows on a combination of interfaces, which includes at least one 40 Gb/s interface. This can be the case even when the traffic is reduced or stops. The user may be unable to clear these counters even when by using the following management commands:

- REST:

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/clear/statistics
```

- PYTHON:

```
telemetryApi.TelemetryBST_ClearStats().get_bst_clear_stats
```

- CLI:

```
Switch> clear telemetry bst-statistics
```

Buffer Statistics Names

Buffer statistics names use the following conventions:

Prefix	Traffic Type
uc-	unicast traffic (for example, uc-share-buffercount)
mc-	multicast traffic (for example, um-share-threshold)
um-	both unicast and multicast traffic (for example, mc-queue-entries)

Table 45 provides a complete list of realms, indexes, thresholds, and statistics related to buffer utilization.

Table 45. *Buffer Utilization Realms, Indexes, Statistics, and Thresh holds*

Realm	Index # 1	Index # 2	Statistics	Thresholds
device			data	threshold
ingress-port-priority-group	*interface* (such as Ethernet1/7)	priority-group	um-share-buffer-count	um-share-threshold
ingress-port-service-pool	*interface* (such as Ethernet1/7)	service-pool	um-share-buffer-count	um-share-threshold
ingress-service-pool	service-pool		um-share-buffer-count	um-share-threshold
egress-port-service-pool	*interface* (such as Ethernet1/7)		uc-share-buffer-count, um-share-buffer-count, mc-share-buffer-count,	uc-share-threshold, um-share-threshold
egress-service-pool	service-pool		um-share-buffercount, mc-share-buffer-count	um-share-threshold
egress-rqe-queue	queue		rqe-buffer-count	rqe-threshold
egress-cpu-queue	queue		cpu-buffer-count	cpu-threshold

Table 45. *Buffer Utilization Realms, Indexes, Statistics, and Thresh holds*

Realm	Index # 1	Index # 2	Statistics	Thresholds
`egress-uc-queue`	`queue`		`uc-buffer-count`	`uc-threshold`
`egress-mc-queue`	`queue`		`mc-buffer-count`	`mc-threshold`

Note: A threshold value must be greater than zero.

Realm Parameters and Indexes

Realm parameters are necessary to access buffer statistics. These parameters act as indexes for the given buffer.

For example, to access a buffer in the `egress-uc-queue` realm, the realm parameter is the corresponding queue ID. Similarly, to access a buffer in the ingress-port-priority-group realm, the parameters are the interface name and the priority-group ID. The `device` realm has no indexes. No realm has more than two indexes.

Each buffer, given its parameters, may have one or more statistic. For example, the `ingress-port-service-pool` realm buffer, for a given port and service pool ID, has a single statistic called `um-share-buffer-count`. For a given port and service pool ID, the `egress-port-service-pool buffer` offers three statistics:

- `uc-share-buffer-count`
- `um-share-buffer-count`
- `mc-share-buffer-count`

Table 46 and Table 47 show the ranges for some of the parameters used for indexes, thresholds, and statistics.

Table 46. *Telemetry Index Parameter Maximums*

Parameter	Description	Resources per ASIC		
		NE1032 NE1032T NE1072T	G8272 G8296 G8332	NE10032 NE2572
`queue`	Unicast Queues	16,384	2,960	2,600
`queue`	Multicast Queues	720	1,040	2,600
`queue-group`	Unicast Queue Groups	4,096	128	128
`service-pool`	Common Service Pools	1	1	1
`egress-cpu-queue`	ASIC CPU COS Queues	40	40	40
`egress-rqe-queue`	RQE	11	11	11

Table 47. *Telemetry Index Parameter Ranges*

Parameter	Description	Resources per ASIC		
		NE1032 NE1032T NE1072T	**G8272 G8296 G8332**	**NE10032 NE2572**
`service-pool`	Service Pool ID - Non-CEE Mode (default)	0	0	0
	Service Pool ID - CEE Mode	0-1	0-1	0
`priority-group`	Priority Group ID - Non-CEE Mode (default)	7	7	7
	Priority Group ID - CEE Mode	0-7	0-7	0-7

Note: Unless otherwise stated, when a number is used to identify a particular parameter, it is zero-indexed. For example, if a platform supports 720 multicast queues, multicast queue identifiers will range from 0 to 719.

Setting Up the CNOS Telemetry Agent

The setup commands for the CNOS telemetry agent must be done on the CLI. Once this basic configuration is been performed on each switch, the entire operation of the telemetry feature is mostly driven by the REST API because one of the main goals of telemetry is to have a centralized controller automatically discovering and interacting with multiple switches.

Note: For more details about the telemetry REST functions, see the *Lenovo Network REST API Programming Guide For Lenovo Cloud Network Operating System*.

Enable the Telemetry Agent

The CNOS telemetry agent is enabled by default. To enable or disable the CNOS telemetry agent, enter:

```
Switch(config)# [no] feature telemetry
```

Configure the Telemetry Controller

To configure the remote telemetry controller, you must specify its IP address and its TCP port by using the following command:

```
Switch(config)# telemetry controller ip <IP address> port <TCP port(1-65535)>
[vrf {<VRF instance name>|default|management}]
```

Note: You can also specify the Virtual Routing and Forwarding (VRF) instance used for communication between the switch and the remote telemetry controller.

For example, the telemetry controller has IP address 10.155.67.22 and uses TCP port 23902:

```
Switch(config)# telemetry controller ip 10.155.67.22 port 23902
```

By default, the telemetry agent on the switch uses the Hypertext Transfer Protocol (HTTP) to communicate with the remote telemetry controller. To configure the telemetry agent to use HTTP Secure (HTTPS) instead, use the following command:

```
Switch(config)# telemetry controller protocol https
```

You can configure a username and password pair to enable the telemetry agent to authenticate with the remote telemetry controller. To do this, use the following command:

```
Switch(config)# telemetry controller username <username> password
[encrypted] <password>
```

To remove a previously configured controller, use the following command:

```
Switch(config)# no telemetry controller
```

Configure Telemetry Heartbeat

Telemetry heartbeat messages allow telemetry clients or collectors to learn about the switches present in their network. When heartbeat messages are enabled, the switch sends a heartbeat message to each configured remote telemetry controller, notifying them of its presence.

By default, heartbeat messages are enabled on the switch with a time interval of five seconds between consecutive messages.

To enable heartbeat messages and configure the time interval between them, use the following command:

```
Switch(config)# telemetry heartbeat enabled interval <1-600>
```

To disable the transmission of heartbeat messages, use the following command:

```
Switch(config)# telemetry heartbeat disabled
```

Configuring Telemetry Agent Parameters

To get the telemetry agent to provide telemetry data to the controller or collector, you must specify which data you want and how this data will be transferred. This section discusses the types of data you can collect and how to obtain it.

Congestion Drop Statistics

To retrieve congestion drop statistics, follow these steps:

1. Enable the buffer statistics utilization feature using the REST (PUT) URI:

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/feature
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol.
`bst-enable`	Set to 1 to enable BST, 0 to disable it. Enabling BST allows the switch to track buffer utilization statistics.
`send-async-reports`	Set to 1 to enable the transmission of periodic asynchronous reports, 0 to disable this feature.
`collection-interval`	The collection interval, in seconds. This defines how frequently periodic reports will be sent to the configured controller.
`trigger-rate-limit`	The trigger rate limit, which defines the maximum number of threshold-driven triggered reports that the agent is allowed to send to the controller per `trigger-rate-limit-interval`; an integer from 1-5.
`trigger-rate-limit-interval`	The trigger rate limit interval, in seconds; an integer from 10-60.

Element	Description
`send-snapshot-on-trigger`	Set to 1 to enable sending a complete snapshot of all buffer statistics when a trigger happens, 0 to disable this feature.
`async-full-report`	Set to 1 to enable the async full report feature, 0 to disable it. When this feature is enabled, the agent sends full reports containing data related to all statistics. When the feature is disabled, the agent sends incremental reports containing only the statistics that have changed since the last report.

In the following example, setting the `bst-enable` field to 1 enables the buffer statistics and tracking feature on the switch. All other fields must be set to zero for this use case except the trigger-rate-limit, which has a range of 1-5, and the trigger-rate-limit-interval, which has a range from 10-60.

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: PUT
Header: Name: Content-type, Value: application/json
Request Body:
{
    "bst-enable" : 1,
    "send-async-reports" : 0,
    "collection-interval" : 0,
    "trigger-rate-limit" : 1,
    "trigger-rate-limit-interval" : 10,
    "send-snapshot-on-trigger" : 0,
    "async-full-report" : 0
}
```

2. Verify the buffer statistics utilization configuration via the CLI or via REST.
   - CLI:

     ```
     Switch> show telemetry bst-feature
     ```

   - REST (GET):

     http://<*agent-IP-address*>**:**<*agent-port*>**/nos/api/cfg/telemetry/bst/feature**

     where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol

CLI example:

```
Switch> show telemetry bst-feature
BST Enabled                 : enabled
Send Async Reports          : disabled
Collection Interval         : 0 seconds
Stats in Percentage         : enabled
Stat Units in Cells         : disabled
Trigger Rate Limit          : 1
Trigger Rate Limit Interval : 10 seconds
Send Snapshot on Trigger    : disabled
Async Full Reports          : disabled
```

REST example:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: GET
Response Body:
{"stat-units-in-cells": 0, "stats-in-percentage": 1,
"collection-interval": 0, "send-async-reports": 0,
"send-snapshot-on-trigger": 0, "trigger-rate-limit": 1,
"async-full-report": 0, "trigger-rate-limit-interval": 10,
"bst-enable": 1}
```

3. Retrieve the ports with the top congestion drop statistics on the switch:
   - REST (POST):

     http://<*agent-IP-address*>**:**<*agent-port*>**/nos/api/info/telemetry/bst/congestion-drop-counters**

     where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`req-id`	The request ID; an integer

Element	Description
`request-type`	Request type; one of the following: • `top-drops`: Show ports with maximum congestion on the switch and their drop-counters • `top-port-queue-drops`: Show top port-queue level drop-counters on the switch • `port-queue-drops`: Show per port-queue level drop-counters on the switch • `port-drops`: Show per-port total drop-counters on the switch
`request-params`	Request parameters dependent upon the `request-type`. For all congestion ports or port queues, the following parameters are valid. For `top-drops`, the following parameters are valid: • `count`: Number of ports required in the report. The ports are sorted with the port suffering maximum congestion at the top; an integer. • `queue-type`: Filters the report on the queue type; one of the following strings: – `ucast`: Unicast queues – `mcast`: Multicast queues – `all`: All supported queues • `interface-list`: Comma-separated list of ports for the congestion drop counter report; an array. A value of all requests all the ports. • `queue-list`: An array of queue numbers to be considered for the drop report. • `collection-interval`: (Optional) The period in which the statistics are collected from ASIC; An integer from 1-60. Default value: 0.

- CLI:

```
Switch> show telemetry bst-congestion top-drops [count <count>]
```

where *count* (optional) is the number of ports to include in the output. The default value is 64.

The following example retrieves the top three ports experiencing maximum congestion and their associated drop-counters.

REST example:

```
URL: http://10.240.177.153:8090/nos/api/info/telemetry/bst/congestion-
drop-counters
Method: POST
Header: Name: Content-type, Value: application/json
Request Body:
{
    "req-id" : 2,
    "request-type" : "top-drops",
    "request-params": { "count":4 }
}

Response Body:
{
    "time-stamp": "2017-11-20 - 12:56:13 ",
    "report-type": "top-drops",
    "congestion-ctr": [
        {
            "interface": "Ethernet1/38",
            "ctr": "3212203451"
        },
        {
            "interface": "Ethernet1/40",
            "ctr": "2855833510"
        },
        {
            "interface": "Ethernet1/47",
            "ctr": "2855767786"
        },
        {
            "interface": "Ethernet1/18",
            "ctr": "2855598983"
        }
    ]
}
```

CLI example:

```
Switch># show telemetry bst-congestion top-drops count 4
Timestamp                              : 2017-11-20 - 13:00:00
Request identifier                     : 10001
Top ports with congestion drops        : 4
-----------------------------------
interface                    counter
-----------------------------------
Ethernet1/38              3212203451
Ethernet1/40              2855833510
Ethernet1/47              2855767786
Ethernet1/18              2855598983
```

4. Retrieve the port, queue pairs with top congestion drop counters on the switch:
   - REST (POST):

```
http://<agent-IP-address>:<agent-port>/nos/api/info/telemetry/bst/congestion-drop-counters
```

   where:

Argument	Definition
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`req-id`	The request ID; an integer
`request-type`	One of the following: • `top-drops`: Show ports with maximum congestion on the switch and their drop-counters • `top-port-queue-drops`: Show top port-queue level drop-counters on the switch • port-queue-drops: Show per port-queue level drop-counters on the switch • `port-drops`: Show per-port total drop counters on the switch
`request-params`	Request parameters; one of the following strings:: • `qcount`: Number of ports required in the report. The ports are sorted with the port suffering maximum congestion at the top; an integer. • `queue-type`: Filters the report on the queue type; one of the following strings: – `ucast`: Unicast queues – `mcast`: Multicast queues – `all`: All supported queues • `interface-list`: Comma-separated list of ports for the congestion drop counter report; an array. A value of all requests all the ports. • `queue-list`: An array of queue numbers to be considered for the drop report. • `collection-interval`: (Optional) The period in which the counters are collected from ASIC; An integer from 1-60. Default value: 0.

- CLI:

```
Switch> show telemetry bst-congestion top-port-queue-drops [count
<count>]
```

where:

Parameter	Description
count	(Optional) The number of port, queue pairs to include in the output. The default value is 64.
queue-type	(Optional) Queue type to be included. One of: • `all`: Unicast and multicast traffic queues (default) • `mcast`: Multicast traffic queues • `ucast`: Unicast traffic queues

The following example retrieves the top three port, queue pairs experiencing maximum congestion and their associated drop counters for unicast traffic:

```
URL: http://10.240.177.153:8090/nos/api/info/telemetry/bst/congestion-
drop-counters
Method: POST
Header: Name: Content-type, Value: application/json
Request Body:
Request body:
{
"req-id" : 2,
"request-type" : "top-drops",
"request-params":
  {
      "count":4
    }
}
Response Body:
{
    "time-stamp": "2017-11-20 - 12:56:13 ",
    "report-type": "top-drops",
    "congestion-ctr": [
        {
            "interface": "Ethernet1/38",
            "ctr": "484033646"
        },
        {
            "interface": "Ethernet1/40",
            "ctr": "429830595"
        },
        {
            "interface": "Ethernet1/47",
            "ctr": "429817996"
        },
        {
            "interface": "Ethernet1/18",
            "ctr": "429794738"
        }
    ]
}
```

5. Retrieve the per-port total congestion drop counters for a specified set of interfaces:
   - REST (POST):

```
http://<agent-IP-address>:<agent-port>/nos/api/info/telemetry/bst/congestion-drop-counters
```

   where:

Argument	Definition
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`req-id`	The request ID; an integer
`request-type`	One of the following: • `top-drops`: Show ports with maximum congestion on the switch and their drop-counters • `top-port-queue-drops`: Show top port-queue level drop-counters on the switch • `port-queue-drops`: Show per port-queue level drop-counters on the switch • `port-drops`: Show per-port total drop counters on the switch
`request-params`	Request parameters; one of the following strings:: • `qcount`: Number of ports required in the report. The ports are sorted with the port suffering maximum congestion at the top; an integer. • `queue-type`: Filters the report on the queue type; one of the following strings: – `ucast`: Unicast queues – `mcast`: Multicast queues – `all`: All supported queues • `interface-list`: Comma-separated list of ports for the congestion drop counter report; an array. A value of all requests all the ports. • `queue-list`: An array of queue numbers to be considered for the drop report. • `collection-interval`: (Optional) The period in which the counters are collected from ASIC; An integer from 1-60. Default value: 0.

   - CLI:

```
Switch> show telemetry bst-congestion port-drops [interface ethernet <slot>-<chassis>]
```

   where *slot-chassis* is the slot and chassis of a specific ethernet interface.

The following example retrieves the per-port drop counters.

REST example:

```
URL: http://10.240.177.153:8090/nos/api/info/telemetry/bst/congestion-
drop-counters
Method: POST
Header: Name: Content-type, Value: application/json
Request Body:
Request body:
{
 "req-id" : 10,
 "request-type" : "port-drops",
 "request-params":
{
     "interface-list": ["Ethernet1/9","Ethernet1/10"]
}

Response Body:
{
    "time-stamp": "2017-11-20 - 13:01:47 ",
    "report-type": "port-drops",
    "congestion-ctr": [
        {
            "interface": "Ethernet1/9",
            "ctr": "0"
        },
        {
            "interface": "Ethernet1/10",
            "ctr": "0"
        },
    ]
}
```

CLI example:

```
Switch> show telemetry bst-congestion port-drops interface ethernet
1/9-10
0-46
Timestamp                              : 2017-11-20 - 13:02:36
Request identifier                     : 10001
Ports reported                         : 2
-----------------------------------
interface                    counter
-----------------------------------
Ethernet1/9               5092169130
Ethernet1/10                       0
```

Note that not setting the field `collection-interval` instructs the telemetry agent to provide the requested drop counter information immediately. The `interface-list` provides an explicit set of interfaces for which we want to obtain the counters. In the Response Body of this example, the number of packets dropped on interface Ethernet1/1 was 1778, whereas there were no packet drops on the other two interfaces given.

6. Retrieve the total congestion drop counters per port, queue pair for a specified set of interfaces and queues:

   - REST (POST):

```
http://<agent-IP-address>:<agent-port>/nos/api/info/telemetry/bst/congestion-drop-counters
```

   where:

Argument	Definition
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`req-id`	The request ID; an integer
`request-type`	One of the following: • `top-drops`: Show ports with maximum congestion on the switch and their drop-counters • `top-port-queue-drops`: Show top port-queue level drop-counters on the switch • `port-queue-drops`: Show per port-queue level drop-counters on the switch • `port-drops`: Show per-port total drop counters on the switch
`request-params`	Request parameters; one of the following strings:: • `qcount`: Number of ports required in the report. The ports are sorted with the port suffering maximum congestion at the top; an integer. • `queue-type`: Filters the report on the queue type; one of the following strings: – `ucast`: Unicast queues – `mcast`: Multicast queues – `all`: All supported queues • `interface-list`: Comma-separated list of ports for the congestion drop counter report; an array. A value of all requests all the ports. • `queue-list`: An array of queue numbers to be considered for the drop report. • `collection-interval`: (Optional) The period in which the counters are collected from ASIC; An integer from 1-60. Default value: 0.

- CLI:

```
Switch> show telemetry bst-congestion port-queue-drops [interface
ethernet <slot>-<chassis>] [queue <queue number>] [queue-type <queue type>]
```

where:

Parameter	Description
count	(Optional) is the number of ports to include in the output. The default value is 64.
queue	(Optional) Queue number; an integer from 0-7. Default value: all queues.
queue-type	(Optional) Queue type to be included. One of: • `all`: Unicast and multicast traffic queues (default) • `mcast`: Multicast traffic queues • `ucast`: Unicast traffic queues

The following examples retrieve the per-port drop counters.

REST example:

```
URL: http://10.240.177.153:8090/nos/api/info/telemetry/bst/congestion-
drop-counters
Method: POST
Header: Name: Content-type, Value: application/json
Request Body:
{
"req-id" : 2,
"request-type" : "port-queue-drops",
"request-params" :
    {
         "interface-list" : ["Ethernet1/38","Ethernet1/39"],
         "queue-type" : "all",
         "queue-list" : [0,1]
    }
}

Response Body:

    "time-stamp": "2017-11-20 - 13:04:08 ",
    "report-type": "port-queue-drops",
    "congestion-ctr": [
        {
            "interface": "Ethernet1/38",
            "queue-type": "ucast",
            "queue-drop-ctr": [
                [0,"0"],
                [1,"0"]
            ]
        },
        {
            "interface": "Ethernet1/38",
            "queue-type": "mcast",
            "queue-drop-ctr": [
                [0,"6985575610"],
                [1,"0"]
            ]
        },
        {
            "interface": "Ethernet1/39",
            "queue-type": "ucast",
            "queue-drop-ctr": [
                [0,"0"],
                [1,"0"]
            ]
        },
        {
            "interface": "Ethernet1/39",
            "queue-type": "mcast",
            "queue-drop-ctr": [
                [0,"5491324486"],
                [1,"0"]
            ]
        },
    ]
}
```

Note that not setting the field `collection-interval` instructs the telemetry agent to provide the requested drop counter information immediately. The `interface-list` provides an explicit set of interfaces for which we want to obtain the counters. The `queue-type` specifies `all`, which includes unicast and multicast queues.

In the Response Body of this example, the number of packets dropped on interface Ethernet1/38 was 6985575610, the number of packets dropped on interface Ethernet 1/39 was 5491324486, all of them were multicast packets, and they were dropped in queue 0.

CLI example:

```
Switch> show telemetry bst-congestion port-queue-drops interface ethernet
1/38-39 queue 0
Timestamp                              : 2017-11-20 - 13:05:14
Request identifier                     : 10001
(port, queue) entries reported         : 4
-------------------------------------------------------------
interface       queue      queue-type              counter
-------------------------------------------------------------
Ethernet1/38    0          ucast                         0
Ethernet1/38    0          mcast                6985575610
Ethernet1/39    0          ucast                         0
Ethernet1/39    0          mcast                5491324486
```

In the output of this example, the number of packets dropped on interface Ethernet1/38 was 6985575610, the number of packets dropped on interface Ethernet 1/39 was 5491324486, all of them were multicast packets, and they were dropped in queue 0.

BST Buffer Counters

To retrieve BST buffer counters, follow these steps:

1. Enable the buffer statistics utilization feature using the REST (PUT) URI:

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/feature
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol.
`bst-enable`	Set to 1 to enable BST, 0 to disable it. Enabling BST allows the switch to track buffer utilization statistics.
`send-async-reports`	Set to 1 to enable the transmission of periodic asynchronous reports, 0 to disable this feature.

Element	Description
`collection-interval`	The collection interval, in seconds. This defines how frequently periodic reports will be sent to the configured controller.
`trigger-rate-limit`	The trigger rate limit, which defines the maximum number of threshold-driven triggered reports that the agent is allowed to send to the controller per `trigger-rate-limit-interval`; an integer from 1-5.
`trigger-rate-limit-interval`	The trigger rate limit interval, in seconds; an integer from 10-60.
`send-snapshot-on-trigger`	Set to 1 to enable sending a complete snapshot of all buffer statistics counters when a trigger happens, 0 to disable this feature.
`async-full-report`	Set to 1 to enable the async full report feature, 0 to disable it. When this feature is enabled, the agent sends full reports containing data related to all counters. When the feature is disabled, the agent sends incremental reports containing only the counters that have changed since the last report.

In the following example, setting the `bst-enable` field to 1 enables the buffer statistics and tracking feature on the switch. All other fields must be set to zero for this use case except the trigger-rate-limit, which has a range of 1-5, and the trigger-rate-limit-interval, which has a range from 10-60.

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: PUT
Header: Name: Content-type, Value: application/json
Request Body:
{
    "bst-enable" : 1,
    "send-async-reports" : 0,
    "collection-interval" : 0,
    "trigger-rate-limit" : 1,
    "trigger-rate-limit-interval" : 10,
    "send-snapshot-on-trigger" : 0,
    "async-full-report" : 0
}
```

2. Verify the buffer statistics utilization configuration via the CLI or via REST.
   - CLI:

```
Switch> show telemetry bst-feature
```

   - REST (GET):

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/feature
```

   where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol

CLI example:

```
Switch> show telemetry bst-feature
BST Enabled                : enabled
Send Async Reports         : disabled
Collection Interval        : 0 seconds
Stats in Percentage        : enabled
Stat Units in Cells        : disabled
Trigger Rate Limit         : 1
Trigger Rate Limit Interval : 10 seconds
Send Snapshot on Trigger   : disabled
Async Full Reports         : disabled
```

REST example:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: GET
Response Body:
{"stat-units-in-cells": 0, "stats-in-percentage": 1,
"collection-interval": 0, "send-async-reports": 0,
"send-snapshot-on-trigger": 0, "trigger-rate-limit": 1,
"async-full-report": 0, "trigger-rate-limit-interval": 10, "bst-enable":
1}
```

3. Configure buffer statistics tracking using the REST (PUT) URI:

```
http://<agent-IP-address>:<agent-port>/nos/api/info/telemetry/bst/tracking
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`track-peak-stats`	Track peak statistics; 1 to enable, 0 to disable.
`track-ingress-port-priority-group`	Track the ingress port priority group; 1 to enable, 0 to disable.
`track-ingress-port-service-pool`	Track the ingress port service pool; 1 to enable, 0 to disable.
`track-ingress-service-pool`	Track the ingress service pool; 1 to enable, 0 to disable.
`track-egress-port-service-pool`	Track the egress port service pool; 1 to enable, 0 to disable.
`track-egress-service-pool`	Track the egress service pool; 1 to enable, 0 to disable.
`track-egress-uc-queue`	Track the egress unicast queue; 1 to enable, 0 to disable.
`track-egress-mc-queue`	Track the egress multicast queue; 1 to enable, 0 to disable.
`track-egress-cpu-queue`	Track the egress CPU queue; 1 to enable, 0 to disable.
`track-egress-rqe-queue`	Track the egress RQE queue; 1 to enable, 0 to disable.
`track-device`	Track the device; 1 to enable, 0 to disable.

4. Verify the buffer statistics tracking configuration via the CLI or via REST.
   - CLI:

```
Switch> show telemetry bst-tracking
```

   - REST (GET):

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/tracking
```

   where:

Element	Description
`agent-IP-address`	The IP address of the telemetry agent
`agent-port`	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol

   CLI example:

```
Switch> show telemetry bst-tracking
Track Peak Stats                  : disabled
Track Device                      : enabled
Track Ingress Port Priority Group : enabled
Track Ingress Port Service Pool   : enabled
Track Ingress Service Pool        : enabled
Track Egress CPU Queue            : enabled
Track Egress MC Queue             : enabled
Track Egress Port Service Pool    : enabled
Track Egress RQE Queue            : enabled
Track Egress Service Pool         : enabled
Track Egress UC Queue             : enabled
```

   REST example:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: GET
Response Body:
{"track-egress-port-service-pool": 1, "track-egress-rqe-queue": 1,
"track-ingress-port-service-pool": 1, "track-ingress-service-pool": 1,
"track-peak-stats": 1, "track-ingress-port-priority-group": 1,
"track-egress-service-pool": 1, "track-egress-uc-queue" : 1,
"track-egress-mc-queue" : 1, "track-egress-cpu-queue" : 1,
"track-device": 1}
```

5. Retrieve the buffer statistics report on demand.
   - REST (POST):

```
http://<agent-IP-address>:<agent-port>/nos/api/info/telemetry/bst/report
```

   where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`include-ingress-port-priority-group`	Retrieve the ingress port priority group; 1 to enable, 0 to disable.
`include-ingress-port-service-pool`	Retrieve the ingress port service pool; 1 to enable, 0 to disable.
`include-ingress-service-pool`	Retrieve the ingress service pool; 1 to enable, 0 to disable.
`include-egress-port-service-pool`	Retrieve the egress port service pool; 1 to enable, 0 to disable.
`include-egress-service-pool`	Retrieve the egress service pool; 1 to enable, 0 to disable.
`include-egress-rqe-queue`	Retrieve the egress RQE queue; 1 to enable, 0 to disable.
`include-device`	Retrieve the device; 1 to enable, 0 to disable.
`include-egress-uc-queue`	Retrieve the egress unicast queue; 1 to enable, 0 to disable.
`include-egress-mc-queue`	Retrieve the egress multicast queue; 1 to enable, 0 to disable.
`include-egress-cpu-queue`	Retrieve the egress CPU queue; 1 to enable, 0 to disable.

- CLI:

```
Switch> show telemetry bst-report <realm>
```

where *realm* is one of the following:

Realm	Description
`device`	Show BST statistics report for device realm
`egress-cpu-queue`	Show BST statistics report for the egress-cpu-queue realm
`egress-mc-queue`	Show BST statistics report for the egress-mc-queue realm
`egress-port-service-pool`	Show BST statistics report for the egress-port-service-pool realm
`egress-rqe-queue`	Show BST statistics report for the egress-rqe-queue realm
`egress-service-pool`	Show BST statistics report for the egress-service-pool realm
`egress-uc-queue`	Show BST statistics report for the egress-uc-queue realm
`ingress-port-priority-group`	Show BST statistics report for the ingress-port-priority-group realm
`ingress-port-service-pool`	Show BST statistics report for the ingress-port-service-pool realm
`ingress-service-pool`	Show BST statistics report for the ingress-service-pool realm

In the following example, the `include-`*xxx* fields in the request specify the counters we want to retrieve.

```
URL: http://10.240.177.153:8090/nos/api/info/telemetry/bst/report
Method: POST
Header: Name: Content-type, Value: application/json
Request Body:
{
    "include-ingress-port-priority-group" : 1,
    "include-ingress-port-service-pool" : 1,
    "include-ingress-service-pool" : 1,
    "include-egress-port-service-pool" : 1,
    "include-egress-service-pool" : 1,
    "include-egress-rqe-queue" : 1,
    "include-device" : 1
}

Response Body:
{"report": [{"realm": "device", "data": "37"}, {"realm":
"ingress-service-pool", "data": [[0, "47"]]},
{"realm": "ingress-port-service-pool", "data": [{"interface":
"Ethernet1/1", "data": [0, "42"]}, {"interface": "Ethernet1/47", "data":
[0, "43"]}]},
{"realm": "ingress-port-priority-group", "data": [{"interface":
"Ethernet1/1", "data": [7, "47", "0"]}, {"interface": "Ethernet1/47",
"data": [7, "47", "0"]}]},
{"realm": "egress-port-service-pool", "data": [{"interface":
"Ethernet1/48", "data": [0, "43", "0", "0", "0"]}]},
{"realm": "egress-service-pool", "data": [[0, "48", "0", "0"]]},
{"realm": "egress-rqe-queue", "data": [[0, "0"], [1, "0"], [2, "0"], [3,
"0"], [4, "0"], [5, "0"], [6, "0"], [7, "0"], [8, "0"], [9, "0"], [10,
"0"]]}],
"time-stamp": "2017-05-04 - 14:46:24 "}
```

6. Retrieve the buffer statistics threshold report on demand:
   - REST (POST)

     http://<*agent-IP-address*>**:**<*agent-port*>**/nos/api/info/telemetry/bst/threshold**

   - CLI:

     Switch> **show telemetry bst-thresholds** <*realm*>

   where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol

Element	Description
realm	One of the following: • `include-ingress-port-priority-group` • `include-ingress-port-service-pool` • `include-ingress-service-pool` • `include-egress-port-service-pool` • `include-egress-service-pool` • `include-egress-rqe-queue` • `include-device` • `include-egress-cpu-queue` • `include-egress-uc-queue` • `include-egress-mc-queue` If no realm is used, all realms are reported.
`include-ingress-port-priority-group`	Retrieve the ingress port priority group; 1 to enable, 0 to disable.
`include-ingress-port-service-pool`	Retrieve the ingress port service pool; 1 to enable, 0 to disable.
`include-ingress-service-pool`	Retrieve the ingress service pool; 1 to enable, 0 to disable.
`include-egress-port-service-pool`	Retrieve the egress port service pool; 1 to enable, 0 to disable.
`include-egress-service-pool`	Retrieve the egress service pool; 1 to enable, 0 to disable.
`include-egress-rqe-queue`	Retrieve the egress RQE queue; 1 to enable, 0 to disable.
`include-device`	Retrieve the device; 1 to enable, 0 to disable.
`include-egress-uc-queue`	Retrieve the egress unicast queue; 1 to enable, 0 to disable.
`include-egress-mc-queue`	Retrieve the egress multicast queue; 1 to enable, 0 to disable.
`include-egress-cpu-queue`	Retrieve the egress CPU queue; 1 to enable, 0 to disable.

In the following example, the response containing the buffer statistics thresholds on demand has been shortened because the actual response is several pages long.

```
URL: http://10.240.177.153:8090/nos/api/info/telemetry/bst/threshold
Method: POST
Header: Name: Content-type, Value: application/json
Request Body:
{
    "include-ingress-port-priority-group" : 1,
    "include-ingress-port-service-pool" : 1,
    "include-ingress-service-pool" : 1,
    "include-egress-port-service-pool" : 1,
    "include-egress-service-pool" : 1,
    "include-egress-rqe-queue" : 1,
    "include-device" : 1
}

Response Body:
{"report": [{"realm": "device", "data": "100"}, {"realm":
"ingress-service-pool", "data": [[0, "100"]]}, {"realm":
"ingress-port-service-pool", "data": [{"interface": "Ethernet1/1",
"data": [0, "100"]}, {"interface": "Ethernet1/2", "data": [0, "100"]},
...
{"interface": "Ethernet1/32", "data": [0, "100", "100", "0", "0"]}]},
{"realm": "egress-service-pool", "data": [[0, "100", "100", "0"]]},
{"realm": "egress-rqe-queue", "data": [[0, "100"], [1, "50"], [2, "100"],
[3, "100"], [4, "100"], [5, "100"], [6, "100"], [7, "100"], [8, "100"],
[9, "100"], [10, "100"]]}], "time-stamp": "2017-05-04 - 16:45:52 "}
```

Detect Congestion After it Happens

To detect congestion after it has happened, follow these steps:

1. Configure an external controller using the following CLI command:

```
Switch> telemetry controller ip <IP address> port <port>
[vrf {default|management}]
```

where:

Argument	Definition
IP address	Client IP address
port	Port number to be used between 1 and 65535
`default`	(Optional) Have the agent and client associate the default VRF with the client's IP address
`management`	(Optional) Have the agent and client associate the management VRF with the client's IP address

For example, to allow the telemetry agent to send heartbeat messages to the controller at 10.240.177.235 via port 80 to the VRF management port, enabling to the controller to automatically discover the properties of the agent running on CNOS, enter:

```
Switch> telemetry controller ip 10.240.177.235 port 80 vrf management
```

2. Verify the controller configuration using the CLI command:

```
Switch> show telemetry information
```

For example:

```
Switch> show telemetry information
Telemetry admin status   : enabled
Telemetry oper status    : up
Heartbeat status         : disabled
Controllers configured   : 1
Controller 0:
    IP address           : 10.240.177.235
    TCP port             : 80
    VRF                  : management
    Protocol             : HTTP
```

3. Enable the buffer statistics utilization feature using the following REST (PUT) URI:

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/feature
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`bst-enable`	Set to 1 to enable the BST feature, 0 to disable this feature
`send-async-reports`	Set to 1 to send async reports, 0 to disable this feature
`trigger-rate-limit`	Trigger rate limit; an integer from 1-5
`trigger-rate-limit-interval`	Trigger rate limit interval, in seconds; an integer from 10-60
`send-snapshot-on-trigger`	Set to 1 to send a snapshot when a trigger happens, 0 to disable this feature
`async-full-report`	Set to 1 to send a full async report, 0 to disable this feature.

For example, to enable this feature on host 10.240.17.153 on port 8090, use:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: PUT
Header: Name: Content-type, Value: application/json
Request Body:
{
    "bst-enable" : 1,
    "send-async-reports" : 0,
    "collection-interval" : 0,
    "trigger-rate-limit" : 1,
    "trigger-rate-limit-interval" : 10,
    "send-snapshot-on-trigger" : 0,
    "async-full-report" : 0
}
```

4. Verify the buffer statistics utilization configuration via the CLI or via REST.
   - CLI:

     ```
     Switch> show telemetry bst-feature
     ```

     CLI example:

     ```
     Switch> show telemetry bst-feature
     BST Enabled                 : enabled
     Send Async Reports          : disabled
     Collection Interval         : 0 seconds
     Stats in Percentage         : enabled
     Stat Units in Cells         : disabled
     Trigger Rate Limit          : 1
     Trigger Rate Limit Interval : 10 seconds
     Send Snapshot on Trigger    : disabled
     Async Full Reports          : disabled
     ```

- REST (GET):

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/feature
```

where:

Element	Description
`agent-IP-address`	The IP address of the telemetry agent
`agent-port`	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol

REST example:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: GET
Response Body:
{"stat-units-in-cells": 0, "stats-in-percentage": 1,
"collection-interval": 0, "send-async-reports": 0,
"send-snapshot-on-trigger": 0, "trigger-rate-limit": 1,
"async-full-report": 0, "trigger-rate-limit-interval": 10,
"bst-enable": 1}
```

5. Configure the periodic retrieval of congestion drop counters for ports with maximum drop counters using the following REST (POST) URI:

```
http://<agent-IP-address>:<agent-port>/nos/api/info/telemetry/bst/congestion-drop-counters
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`req-id`	The request ID; an integer

Element	Description
`request-type`	Request type; one of the following: • `top-drops`: Show ports with maximum congestion on the switch and their drop-counters • `top-port-queue-drops`: Show top port-queue level drop-counters on the switch • `port-queue-drops`: Show per port-queue level drop-counters on the switch • `port-drops`: Show per-port total drop counters on the switch
`request-params`	Request parameters dependent upon the `request-type`. For all congestion ports or port queues, the following parameters are valid. For `top-drops`, the following parameters are valid: • `count`: Number of ports required in the report. The ports are sorted with the port suffering maximum congestion at the top; an integer. • `queue-type`: Filters the report on the queue type; one of the following strings: – `ucast`: Unicast queues – `mcast`: Multicast queues – `all`: All supported queues • `interface-list`: Comma-separated list of ports for the congestion drop counter report; an array. A value of all requests all the ports. • `queue-list`: An array of queue numbers to be considered for the drop report. • `collection-interval`: (Optional) The period in which the counters are collected from ASIC; An integer from 1-60. Default value: 0.

The following example requests reports to be sent every 300 seconds (five minutes) from the telemetry agent including up to eight ports experiencing maximum congestion and their associated drop counters to the controller whose IP address and port number have been previously configured:

```
URL: http://10.240.177.153:8090/nos/api/info/telemetry/bst/congestion-drop-counters
Method: POST
Header: Name: Content-type, Value: application/json
Body:
{
    "req-id": 1,
    "request-type": "top-drops",
    "request-params": {
        "count": 8
    },
    "collection-interval": 300
}
```

6. Configure the periodic retrieval of congestion drop counters for the queues (per port) with maximum drop counters using the same REST (POST) URI but with a `request-type` of `top-port-queue-drops`.

   REST example

```
URL: http://10.240.177.153:8090/nos/api/info/telemetry/bst/congestion-dro
p-counters
Method: POST
Header: Name: Content-type, Value: application/json
Body:
{
"req-id" : 1,
"request-type" : "top-port-queue-drops",
"request-params":
 {
      "count":2 ,
      "queue-type": "all"  <<< can be ucast/mcast/ucast
 }
}

Response body:
{
    "time-stamp": "2017-11-20 - 12:58:58 ",
    "report-type": "top-port-queue-drops",
    "congestion-ctr": [
        {
            "interface": "Ethernet1/38",
            "queue-type": "mcast",
            "queue-drop-ctr": [
                [
                    0,
                    "2472802159"
                ]
            ]
        },
        {
            "interface": "Ethernet1/47",
            "queue-type": "mcast",
            "queue-drop-ctr": [
                [
                    0,
                    "2198113613"
                ]
            ]
        }
    ]
}
```

   CLI example:

```
Switch> show telemetry bst-congestion top-drops count 2
Timestamp                             : 2017-11-20 - 13:00:00
Request identifier                    : 10001
Top ports with congestion drops       : 2
-----------------------------------
interface                    counter
-----------------------------------
Ethernet1/38              2472802159
Ethernet1/47              2198113613
```

7. Configure the Ganglia analytics application and collector.

   For information on how to configure Ganglia, see:

   http://ganglia.info/?tag=documentation

Predicting Congestion Before it Happens

Follow these steps to use the telemetry agent to predict where and when congestion might occur.

1. Configure an external controller using the following CLI command:

```
Switch> telemetry controller ip <IP address> port <port>
[vrf {default|management}]
```

where:

Argument	Definition
IP address	Client IP address
port	Port number to be used between 1 and 65535
`default`	(Optional) Have the agent and client associate the default VRF with the client's IP address
`management`	(Optional) Have the agent and client associate the management VRF with the client's IP address

For example, to allow the telemetry agent to send heartbeat messages to the controller at 10.240.177.235 via port 80 to the VRF management port, enabling to the controller to automatically discover the properties of the agent running on CNOS, enter:

```
Switch> telemetry controller ip 10.240.177.235 port 80 vrf management
```

2. Verify the controller configuration using the CLI command:

```
Switch> show telemetry information
```

For example:

```
Switch> show telemetry information
Telemetry admin status   : enabled
Telemetry oper status    : up
Heartbeat status         : disabled
Controllers configured   : 1
Controller 0:
    IP address           : 10.240.177.235
    TCP port             : 80
    VRF                  : management
    Protocol             : HTTP
```

3. Enable the buffer statistics utilization feature using the following REST (PUT) URI:

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/feature
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`bst-enable`	Set to 1 to enable the BST feature, 0 to disable this feature
`send-async-reports`	Set to 1 to send async reports, 0 to disable this feature
`trigger-rate-limit`	Trigger rate limit; an integer from 1-5
`trigger-rate-limit-interval`	Trigger rate limit interval, in seconds; an integer from 10-60
`send-snapshot-on-trigger`	Set to 1 to send a snapshot when a trigger happens, 0 to disable this feature
`async-full-report`	Set to 1 to send a full async report, 0 to disable this feature.

For example, to enable this feature on host 10.240.17.153 on port 8090, use:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: PUT
Header: Name: Content-type, Value: application/json
Request Body:
{
    "bst-enable" : 1,
    "send-async-reports" : 0,
    "collection-interval" : 0,
    "trigger-rate-limit" : 1,
    "trigger-rate-limit-interval" : 10,
    "send-snapshot-on-trigger" : 0,
    "async-full-report" : 0
}
```

4. Verify the buffer statistics tracking configuration via the CLI or via REST.
   - CLI:

```
Switch> show telemetry bst-tracking
```

CLI example:

```
Switch> show telemetry bst-tracking
Track Peak Stats                  : disabled
Track Device                      : enabled
Track Ingress Port Priority Group : enabled
Track Ingress Port Service Pool   : enabled
Track Ingress Service Pool        : enabled
Track Egress CPU Queue            : enabled
Track Egress MC Queue             : enabled
Track Egress Port Service Pool    : enabled
Track Egress RQE Queue            : enabled
Track Egress Service Pool         : enabled
Track Egress UC Queue             : enabled
```

   - REST (GET):

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/tracking
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol

REST example:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: GET
Response Body:
{"track-egress-port-service-pool": 1, "track-egress-rqe-queue": 1,
"track-ingress-port-service-pool": 1, "track-ingress-service-pool": 1,
"track-peak-stats": 1, "track-ingress-port-priority-group": 1,
"track-egress-service-pool": 1, "track-device": 1}
```

5. Configure buffer statistics tracking using the following REST (PUT) URI:

```
REST: http://<agent-ip-address>:<agent-port>/nos/api/cfg/telemetry/bst/tracking
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`track-peak-stats`	Set to 1 to peak statistics tracking, 0 to disable this feature
`track-ingress-port-priority-group`	Set to 1 to enable ingress port priority group tracking, 0 to disable this feature
`track-ingress-port-service-pool`	Set to 1 to enable ingress port service pool tracking, 0 to disable this feature
`track-ingress-service-pool`	Set to 1 to enable ingress service pool tracking, 0 to disable this feature
`track-egress-port-service-pool`	Set to 1 to enable egress port service pool tracking, 0 to disable this feature
`track-egress-service-pool`	Set to 1 to enable egress service pool tracking, 0 to disable this feature
`track-egress-rqe-queue`	Set to 1 to enable egress RQE queue tracking, 0 to disable this feature
`track-device`	Set to 1 to enable tracking of this device, 0 to disable this feature
`track-egress-uc-queue`	Set to 1 to enable egress unicast queue, 0 to disable.
`track-egress-mc-queue`	Set to 1 to enable egress multicast queue , 0 to disable.
`itrack-egress-cpu-queue`	Set to 1 to enable egress CPU queue, 0 to disable.

The following example uses the element `"track-peak-stats" : 1` to tell the underlying switching ASIC to track the peak statistics so we do not miss microbursts. The other elements track all types of buffer statistic counters:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/tracking
Method: PUT
Header: Name: Content-type, Value: application/json
Request Body:
{
   "track-peak-stats" : 1,
   "track-ingress-port-priority-group" : 1,
   "track-ingress-port-service-pool" : 1,
   "track-ingress-service-pool" : 1,
   "track-egress-port-service-pool" : 1,
   "track-egress-service-pool" : 1,
   "track-egress-rqe-queue" : 1,
   "track-device" : 1
   "track-egress-uc-queue" :1,
   "track-egress-mc-queue" :1,
   "track-egress-cpu-queue" :1
}
```

6. Verify the buffer statistics tracking configuration.
   - CLI:

     ```
     Switch> show telemetry bst-tracking
     ```

     CLI example:

     ```
     Switch> show telemetry bst-tracking
     Track Peak Stats                  : disabled
     Track Device                      : enabled
     Track Ingress Port Priority Group : enabled
     Track Ingress Port Service Pool   : enabled
     Track Ingress Service Pool        : enabled
     Track Egress CPU Queue            : enabled
     Track Egress MC Queue             : enabled
     Track Egress Port Service Pool    : enabled
     Track Egress RQE Queue            : enabled
     Track Egress Service Pool         : enabled
     Track Egress UC Queue             : enabled
     ```

- REST (GET):

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/tracking
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol

REST example:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: GET
Response Body:
{"track-egress-port-service-pool": 1, "track-egress-rqe-queue": 1,
"track-ingress-port-service-pool": 1, "track-ingress-service-pool": 1,
"track-peak-stats": 1, "track-ingress-port-priority-group": 1,
"track-egress-service-pool": 1, "track-device": 1}
```

7. Configure buffer statistics thresholds using the following REST (PUT) URI:

```
REST: http://<agent-ip-address>:<agent-port>/nos/api/cfg/telemetry/bst/threshold
```

with a JSON request body of:

```
Request Body:
{
    "realm": "<realm>",
    "<index1>": <index1 value>,
    "<index1>": <index1 value>,
    "<threshold>": <threshold value>,
    "<threshold1>": <threshold value>,
    "<threshold2>": <threshold value>,
    ...
    "<thresholdN>": <threshold value>,
}
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
realm	Any of the realms shown in Table 45.

Element	Description
index1	(Optional) The corresponding **Index1** keyword shown in Table 45. **Note:** All realms except `device` have at least one Index value.
index1 value	A valid value for the *index1* keyword.
index2	(Optional) The corresponding Index2 value shown in Table 45.
threshold, threshold1, threshold2,... thresholdN	The corresponding `Threshold` keyword shown in Table 45. There can be multiple thresholds
threshold value	A valid value for the *threshold* keyword.

The following examples configure a threshold for every realm and counter supported by the telemetry agent. In this example, the threshold is set to 50%. This means if the buffer utilization goes above 50%, the agent must send an asychronous report to the configured controller. This helps identify potential congestion issues before they occur. When the buffer utilization for a particular realm and buffer type reaches 100%, the switch will start dropping packets.

Example 1:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/threshold
Method: PUT
Header: Name: Content-type, Value: application/json
Request Body:
{
    "realm": "device",
    "threshold": 50
}
```

Example 2:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/threshold
Method: PUT
Header: Name: Content-type, Value: application/json
{
    "realm": "ingress-port-priority-group",
    "interface": "Ethernet1/1",
    "priority-group": 7,
    "um-share-threshold": 50
}
```

Example 3:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/threshold
Method: PUT
Header: Name: Content-type, Value: application/json
{
    "realm": "ingress-port-service-pool",
    "interface": "Ethernet1/1",
    "priority-group": 7,
    "um-share-threshold": 50
}
```

Example 4:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/threshold
Method: PUT
Header: Name: Content-type, Value: application/json
{
    "realm": "ingress-service-pool",
    "service-pool": 0,
    "um-share-threshold": 50
}
```

Example 5:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/threshold
Method: PUT
Header: Name: Content-type, Value: application/json
{
    "realm": "egress-port-service-pool",
    "interface": "Ethernet1/1",
    "service-pool": 0,
    "uc-share-threshold": 50,
    "um-share-threshold": 50,
    "mc-share-threshold": 50
}
```

Example 6:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/threshold
Method: PUT
Header: Name: Content-type, Value: application/json
{
    "realm": "egress-service-pool",
    "service-pool": 0,
    "um-share-threshold": 50,
    "mc-share-threshold": 50
}
```

Example 7:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/threshold
Method: PUT
Header: Name: Content-type, Value: application/json
{
    "realm": "egress-rqe-queue",
    "queue": 1,
    "rqe-threshold": 50
}
```

Example 8:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/threshold
Method: PUT
Header: Name : Content-type, Value: application/json
 {
    "realm": "egress-cpu-queue",
    "queue": 0,
    "cpu-threshold": 10
 }
```

Example 9:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/threshold
Method: PUT
Header: Name: Content-type, Value: application/json
{
    "realm": "egress-uc-queue",
    "queue": 50,
    "uc-threshold": 10
}
```

Example 10:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/threshold
Method: PUT
Header: Name: Content-type, Value: application/json
{
    "realm": "egress-mc-queue",
    "queue": 1000,
    "uc-threshold": 10
}
```

A few notes about these examples:

- The priority-group is 7 because this is the only value supported while the switch runs in non-CEE mode (default mode).
- The service-pool is 0 because this is the only value supported while the switch runs in non-CEE mode (default mode).
- The queue is 1 because this value falls within the valid range for the egress-rqe-queue realm.
- To make this example useful, we have to configure the thresholds for the entire valid range of parameters because we do not know, in advance, which interfaces, service pools, queues, and so forth may experience high utilization.

8. Configure the Ganglia analytics application and collector.

   For information on how to configure Ganglia, see:

   http://ganglia.info/?tag=documentation

Capacity Planning Based on Trend Analysis

To plan for future network capacity based on long-term, detailed trend analysis, follow these steps.

1. Configure an external controller using the following CLI command:

```
Switch> telemetry controller ip <IP address> port <port>
[vrf {default|management}]
```

where:

Argument	Definition
IP address	Client IP address
port	Port number to be used between 1 and 65535
`default`	(Optional) Have the agent and client associate the default VRF with the client's IP address
`management`	(Optional) Have the agent and client associate the management VRF with the client's IP address

For example, to allow the telemetry agent to send heartbeat messages to the controller at 10.240.177.235 via port 80 to the VRF management port, enabling to the controller to automatically discover the properties of the agent running on CNOS, enter:

```
Switch> telemetry controller ip 10.240.177.235 port 80 vrf management
```

2. Verify the controller configuration using the CLI command:

```
Switch> show telemetry information
```

For example:

```
Switch> show telemetry information
Telemetry admin status   : enabled
Telemetry oper status    : up
Heartbeat status         : disabled
Controllers configured   : 1
Controller 0:
    IP address           : 10.240.177.235
    TCP port             : 80
    VRF                  : management
    Protocol             : HTTP
```

3. Enable the buffer statistics utilization feature using the following REST (PUT) URI:

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/feature
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`bst-enable`	Set to 1 to enable the BST feature, 0 to disable this feature
`send-async-reports`	Set to 1 to send async reports, 0 to disable this feature
`trigger-rate-limit`	Trigger rate limit; an integer from 1-5
`trigger-rate-limit-interval`	Trigger rate limit interval, in seconds; an integer from 10-60
`send-snapshot-on-trigger`	Set to 1 to send a snapshot when a trigger happens, 0 to disable this feature
`async-full-report`	Set to 1 to send a full async report, 0 to disable this feature.

In this example, enabling `bst_enable` enables buffer statistics and tracking on the switch, and enabling `send-async-reports` tells the telemetry agent to send period asynchoronous reports. Setting the value of `collection-interval` to 60 means these reports will be sent every 60 seconds.

Disabling `async-full-report` means the reports will contain only information about about the counters with values that changed since the last report was sent. All other fields must be set to zero for this use case, except for `trigger-rate-limit` and `trigger-rate-limit-interval`.

4. Verify the buffer statistics tracking configuration.
   - CLI:

```
Switch> show telemetry bst-tracking
```

   CLI example:

```
Switch> show telemetry bst-feature
BST Enabled                 : enabled
Send Async Reports          : enabled
Collection Interval         : 60 seconds
Stats in Percentage         : enabled
Stat Units in Cells         : disabled
Trigger Rate Limit          : 1
Trigger Rate Limit Interval : 10 seconds
Send Snapshot on Trigger    : disabled
Async Full Reports          : disabled
```

   - REST (GET):

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/tracking
```

   where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol

   REST example:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: GET
Response Body:
{"stat-units-in-cells": 0, "stats-in-percentage": 1,
"collection-interval": 60, "send-async-reports": 1,
"send-snapshot-on-trigger": 0, "trigger-rate-limit": 1,
"async-full-report": 0, "trigger-rate-limit-interval": 10,
"bst-enable": 1}
```

5. Configure buffer statistics tracking using the following REST (PUT) URI:

```
REST: http://<agent-ip-address>:<agent-port>/nos/api/cfg/telemetry/bst/tracking
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol
`track-peak-stats`	Set to 1 to peak statistics tracking, 0 to disable this feature
`track-ingress-port-priority-group`	Set to 1 to enable ingress port priority group tracking, 0 to disable this feature
`track-ingress-port-service-pool`	Set to 1 to enable ingress port service pool tracking, 0 to disable this feature
`track-ingress-service-pool`	Set to 1 to enable ingress service pool tracking, 0 to disable this feature
`track-egress-port-service-pool`	Set to 1 to enable egress port service pool tracking, 0 to disable this feature
`track-egress-service-pool`	Set to 1 to enable egress service pool tracking, 0 to disable this feature
`track-egress-rqe-queue`	Set to 1 to enable egress RQE queue tracking, 0 to disable this feature
`track-device`	Set to 1 to enable tracking of this device, 0 to disable this feature
`track-egress-uc-queue`	Set to 1 to enable egress unicast queue tracking, 0 to disable tracking
`track-egress-mc-queue`	Set to 1 to enable egress multicast queue tracking, 0 to disable tracking
`track-egress-cpu-queue`	Set to 1 to enable egress CPU queue tracking, 0 to disable tracking

The following example uses the element `"track-peak-stats" : 1` to tell the underlying switching ASIC to track the peak statistics so we do not miss microbursts. The other elements track all types of buffer statistic counters:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/tracking
Method: PUT
Header: Name: Content-type, Value: application/json
Request Body:
{
   "track-peak-stats" : 1,
   "track-ingress-port-priority-group" : 1,
   "track-ingress-port-service-pool" : 1,
   "track-ingress-service-pool" : 1,
   "track-egress-port-service-pool" : 1,
   "track-egress-service-pool" : 1,
   "track-egress-rqe-queue" : 1,
   "track-device" : 1,
   "track-egress-uc-queue" : 1,
   "track-egress-mc-queue" : 1,
   "track-egress-cpu-queue " : 1
}
```

6. Verify the buffer statistics tracking configuration.
   - CLI:

     ```
     Switch> show telemetry bst-tracking
     ```

     CLI example:

     ```
     Switch> show telemetry bst-tracking
     Track Peak Stats                  : disabled
     Track Device                      : enabled
     Track Ingress Port Priority Group : enabled
     Track Ingress Port Service Pool   : enabled
     Track Ingress Service Pool        : enabled
     Track Egress CPU Queue            : enabled
     Track Egress MC Queue             : enabled
     Track Egress Port Service Pool    : enabled
     Track Egress RQE Queue            : enabled
     Track Egress Service Pool         : enabled
     Track Egress UC Queue             : enabled
     ```

- REST (GET):

```
http://<agent-IP-address>:<agent-port>/nos/api/cfg/telemetry/bst/tracking
```

where:

Element	Description
agent-IP-address	The IP address of the telemetry agent
agent-port	The port used by the telemetry agent. The agent-port is 8090 when the CNOS REST server operates using the HTTP protocol and 443 when the CNOS REST server operates using the HTTPS protocol

REST example:

```
URL: http://10.240.177.153:8090/nos/api/cfg/telemetry/bst/feature
Method: GET
Response Body:
{"track-egress-port-service-pool": 1, "track-egress-rqe-queue": 1,
"track-ingress-port-service-pool": 1, "track-ingress-service-pool": 1,
"track-peak-stats": 1, "track-ingress-port-priority-group": 1,
"track-egress-service-pool": 1, "track-device": 1}
```

7. Configure the Ganglia analytics application and collector.

   For information on how to configure Ganglia, see:

   http://ganglia.info/?tag=documentation

Part 7: Hyperconverged Infrastructure

A Hyperconverged Infrastructure provides an integrated compute, storage, and networking system that is easy to manage from end to end. Consolidating the management of these systems to a single tool greatly simplifies the overall system management and reduces the number of resources needed. In many cases, the virtual network domain is managed by Server Administrators, who may have limited network expertise.

This section discusses the following topics:

Chapter 33. Network Virtualization Gateway

The following topics are covered in this chapter:

NSX Integration Concepts

NSX is a VMware virtualized network platform that offers the operational model of a virtual machine over a network. Virtual networks function in a similar way to virtual machines for computers. VMware NSX builds virtual networks inside software, providing a full set of networking services, such as logical switching, routing, firewall, load balancing, VPN, quality of service (QoS), and monitoring.

Virtual networks are managed independently of the underlying type of network hardware. VMware NSX reproduces the entire network model in software, allowing any network topology (simple or complex) to be created and provisioned in a few seconds. Virtual networks can then be deployed over any existing network hardware without generating disruptions in functionality.

VMware NSX uses the Virtual Extensible LAN (VXLAN) protocol to provide network virtualization (NWV) for cloud computing. VXLAN offers the same Ethernet Layer 2 services as the VLAN protocol, but with increased flexibility and scalability. The VXLAN protocol uses an overlay mechanism to tunnel virtualized network traffic over existing Layer 2 or Layer 3 networks. These logical networks must be programmed and managed throughout the network including virtual and physical servers, networking equipment, and storage devices.

The integration of VMware NSX and Lenovo switches offers the following benefits to deploying network virtualization within software defined cloud networking:

- Virtual and physical workloads can be connected upon demand on a common logical segment regardless of hypervisor, IP subnet, or physical location
- Holistic views of the virtual and physical topology increase operational efficiency
- Network virtualization with VMware NSX does not require IP multicast to learn or forward broadcast, unknown unicast, or multicast packets
- A single point of management and control (NSX API) can be used for configuring logical networks across hypervisors and physical access switches

Figure 33. VMware NSX Standalone Architecture

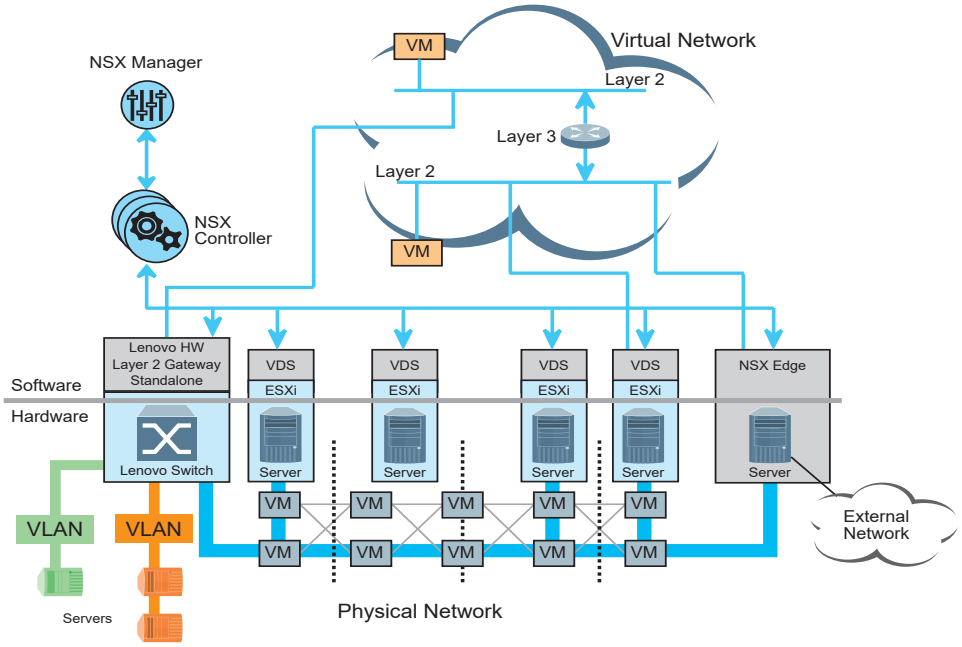
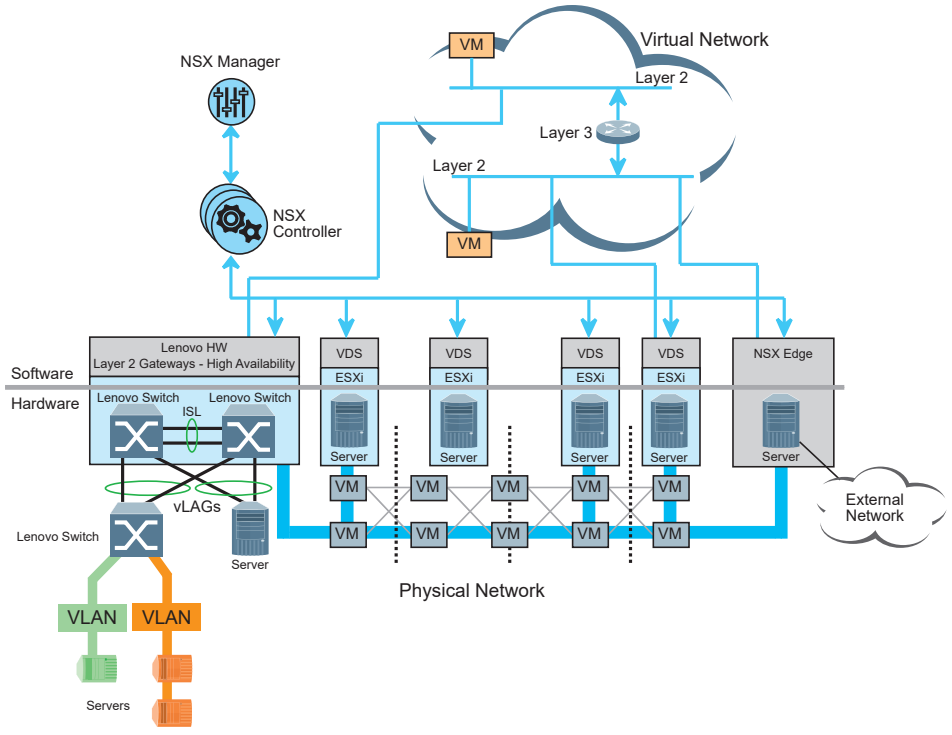


Figure 34. VMware NSX High Availability Architecture



VMware NSX Components

VMware NSX consists of the following components:

- NSX Manager
- NSX Controller
- NSX Edge
- NSX Virtual Switch (vSwitch)

NSX Manager

The NSX Manager is the centralized management component of VMware NSX. It provides a management interface for VMware NSX, through which virtual networks can then be configured.

The NSX Manager is capable of deploying the NSX Controller and NSX Edge, configuring the controller cluster, installing VXLAN, and more.

NSX Controller

The NSX Controller is a distributed state management system that controls virtual networks and overlay transport tunnels. It consists of a cluster of several virtual machines.

It is the central control point for all logical switches and it maintains information about all virtual machines, logical switches, hosts, and VXLANs.

NSX Edge

NSX Edge isolates a virtual network by providing network edge security and gateway services, such as dynamic routing, perimeter firewall, DHCP, NAT, and load balancing.

NSX vSwitch

An NSX vSwitch is the software that creates an abstraction between the servers hypervisors and the physical network. It allows the distribution of virtual workloads on any available infrastructure in the data center, regardless of the underlying physical network infrastructure.

NSX Tunneling

VMware NSX establishes logical connections called tunnels between specific physical devices or virtual machines over the virtual network. This allow the advantage of not needing to change the physical topology of a network. The network separation is achieved through the use of software, thus making it a logical separation and not a physical one.

For example, in a large cloud data center the physical network needs to be restructured to meet the needs of multiple clients. Rather than physically altering the network, VMware NSX provides the option of creating any virtual network topology and deploying it over the existing physical network.

To achieve this logical separation, VMware NSX creates tunnels between the physical or virtual devices needed in a specific topology. A tunnel is created using the VXLAN protocol and it originates and terminates in a VXLAN Tunnel End Point (VTEP).

A VTEP can be created on a VMware vSphere Hypervisor or on a physical switch. Once a tunnel is set up, it gives the impression that the devices (physical or virtual) connected to its VTEPs are communicating across a Layer 2 domain. The underlying Layer 3 infrastructure is invisible to the devices communicating through the tunnel.

A VTEP has an IP address. A tunnel can only have its endpoints (VTEPs) in different subnets. If two virtual machines running on different host devices communicate directly, then unicast traffic is transmitted between the two VTEPs without network flooding.

In some cases of Layer 2 broadcast, unknown unicast, and multicast traffic (BUM traffic) that originates on a virtual machine, packets may need to be sent to all other virtual machines that belong to the same virtual network. The virtual network can span multiple VMware vSphere Hypervisors. BUM traffic that originates on a virtual machine hosted on a single hypervisor may need to be replicated to remote hypervisors which host other virtual machines that are connected to the same virtual network.

When a virtual machine sends traffic to other virtual machines that have VTEPs located in the same subnet, it creates separate copies of the BUM packets and sends them directly to each virtual machine.

If BUM traffic is destined for virtual machines with VTEPs located in a different subnet, the originating virtual machine assigns one VTEP on each subnet as a replicator. The originating virtual machine does not send copies of the BUM packets to each virtual machine that are in the same subnet as the replicator. Instead it sends a single copy of each BUM packet to every replicator. When a replicator receives BUM traffic, it takes the role of creating separate copies of the BUM packets and sending them to each virtual machine on its subnet.

To view the replicators to which the Lenovo VXLAN Gateway is connected, enter:

```
Switch> show nwv vxlan tunnel

Codes: RSN  - Replication Service Node
       VTEP - VXLAN Tunnel End Point

RSN Count: 10
VTEP Count: 254
Tunnel Count: 265

Tunnel IP Address     Tunnel Type    Status
-----------------     -----------    ------
50.10.3.1             Local          UP
172.20.1.22           RSN(Active)    UP
172.20.1.21           RSN(Backup)    UP
172.20.1.23           RSN(Backup)    UP
172.20.1.24           RSN(Backup)    UP
172.20.1.25           RSN(Backup)    UP
172.20.1.26           RSN(Backup)    UP
172.20.1.27           RSN(Backup)    UP
172.20.1.28           RSN(Backup)    UP
172.20.1.29           RSN(Backup)    UP
172.20.1.30           RSN(Backup)    UP
172.20.2.1            Remote         UP
172.20.2.2            Remote         UP
172.20.2.3            Remote         UP
...
```

Note: The replicators are displayed as being tunnel type RSN (Replication Service Node).

If there are multiple replicators configured, then only one of them is set as active, while the rest are set as backups. The Lenovo VXLAN Gateway sends the BUM traffic that was initiated from the connected servers only to the active replicator. If the active replicator fails, its status changes to down and one of the backup replicators takes its role. In the current implementation only the active replicator is used for BUM traffic replication.

Lenovo CNOS uses Bidirectional Forwarding Detection (BFD) over the VXLAN tunnel to speed up failure detection and enable backup replicators to forward VXLAN traffic.

VXLAN

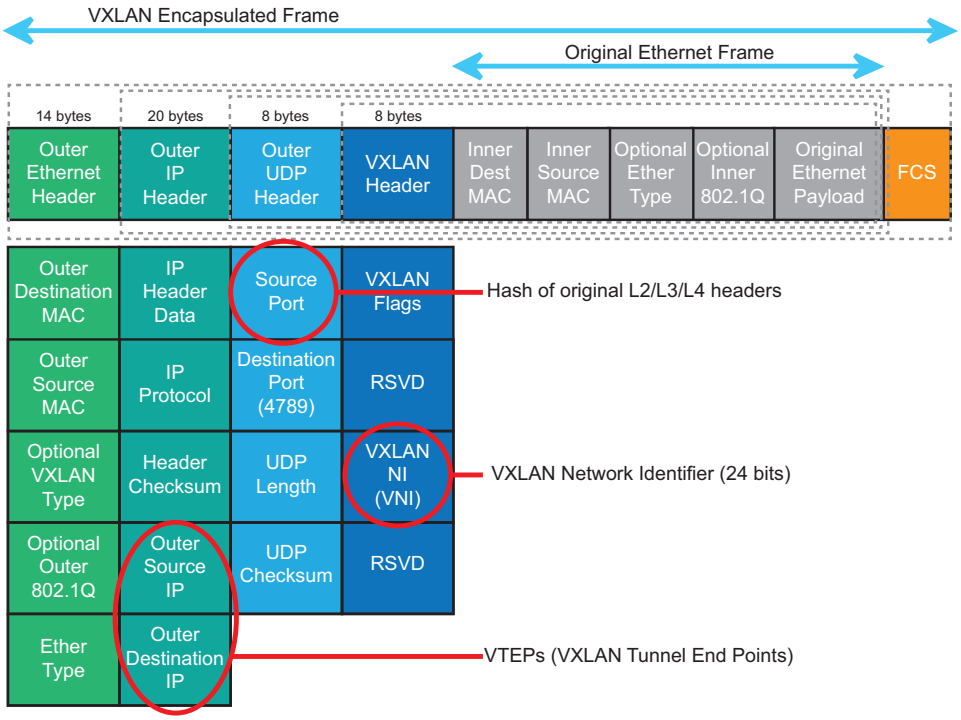
VXLAN is an extension to the VLAN protocol, designed to provide increased scalability in virtual networks. VXLAN is an Ethernet Layer 2 overlay protocol over a Layer 3 network. It uses an encapsulation method similar to VLAN that wraps MAC-based Ethernet Layer 2 frames with Layer 4 UDP packets, using destination UDP port 4789.

In typical physical networks, the number of VLANs is limited to 4094. VXLAN increases scalability up to 16 million logical networks and allows for Layer 2 adjacency across IP networks. This is achieved by adding a 24 bit segment ID to the VXLAN frame. The segment ID differentiates between individual logical networks, allowing millions of isolated Layer 2 VXLAN networks to coexist over the same Layer 3 infrastructure. Similar to VLANs, only virtual machines on the same VXLAN can exchange information with one another.

The virtualization of computing enables the mobility of virtual machines across different physical servers that exist in separate Layer 2 domains. This is done by tunneling virtual traffic over Layer 3 networks. Tunneling allows the dynamic distribution of resources within or across data centers without the limitations of Layer 2 boundaries or the necessity of creating large geographical Layer 2 domains.

VXLAN is an overlay technology that encapsulates Ethernet frames generated by physical or virtual workloads that are connected to the same logical Layer 2 segment. This segment is commonly called a Logical Switch (LS). The VXLAN frame format is shown in Figure 35.

Figure 35. VXLAN Frame Format



VXLAN uses Layer 2 over Layer 3 encapsulation. The Ethernet frame generated by a workload is wrapped within external VXLAN, UDP, IP, and Ethernet headers to ensure its transportation across the network infrastructure that connects the VXLAN endpoints together.

The first step in encapsulation is wrapping the Ethernet frame within a VXLAN header. This header uses a 24 bit VXLAN Network Identifier (VNI) that scales beyond the 4094 limitation of VLANs, allowing up to 16 million logical networks. Similar to VLANs, the VXLAN header is associated to an IP subnet. Internal IP subnet communication is achieved only between devices connected to the same virtual network or logical switch.

The second step is to encapsulate the VXLAN header within a UDP header. The Layer 2, Layer 3, and Layer 4 headers of the original Ethernet frame are hashed to determine the source port for the external UDP header. This ensures the load balancing of VXLAN traffic across equal cost paths available within the transport network infrastructure.

After adding the UDP header, the packet is encapsulated with an external IP header. The source and destination IP addresses of this header are used to uniquely identify the VMware ESXi hosts originating and terminating the VXLAN frame encapsulation. These VMware ESXi hosts are called VXLAN Tunnel End Points (VTEPs).

The final step is to wrap the packet in an external Ethernet header. This header uses the MAC address of VTEP associated with the original Ethernet frame as its source MAC address and the MAC address of the next-hop routing device as its destination MAC address.

Note: VXLAN encapsulation increases the size of the IP packet by wrapping the internal Ethernet frame in an external UDP header. The overall Maximum Transmission Unit (MTU) for all interfaces members of the physical infrastructure that carry the VXLAN frame needs to be increased to a minimum of 1,600 bytes. Use the following command to increase the size of the MTU:

```
Switch(config-if)# mtu <MTU size>
```

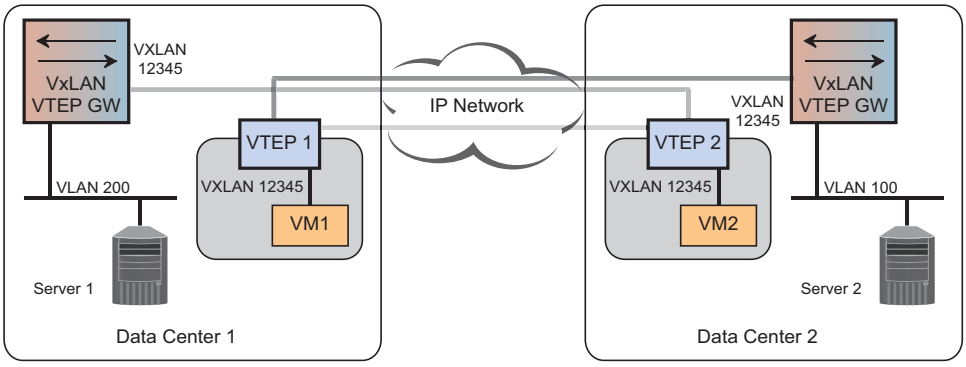
Lenovo VXLAN Gateway

In a typical cloud data center, physical servers and virtual machines need to share the same Layer 2 domain. A physical server is unable to communicate with a virtual machine using the VXLAN protocol.

A VXLAN Gateway is required to enable the communication between physical and virtual devices using the VXLAN protocol. The Gateway enables this by translating the VXLAN packet into a traditional VLAN.

The Lenovo VXLAN Gateway allows physical servers to consistently connect to virtual machines within a cloud infrastructure using VMware NSX for vSphere environment.

Figure 36. VXLAN Gateway Services



The Lenovo VXLAN Gateway provides the following:

- Configuration and monitoring using ISCLI
- Packet counters for virtual ports and networks associated with the VXLAN Gateway
- Open vSwitch Database (OVSDB) Protocol for orchestration from SDN Controller Node
- Full support for Bidirectional Forwarding Detection (BFD) to ensure SDN Replication Cluster availability
- Line rate packet forwarding for both VXLAN and non-VXLAN packets

To enable the VXLAN Gateway on the switch and configure HSC to run in VXLAN Tunnel Endpoint (VTEP) mode, enter:

```
Switch(config)# hsc mode vtep
```

To disable the VXLAN Gateway, enter:

```
Switch(config)# no hsc mode
```

To configure the VTEP, enter:

```
Switch(config)# hsc vtep
Switch(conf-vtep)#
```

Note: After issuing this command, you enter VTEP configuration command mode.

To be part of the virtual network, the switch must inform the Manager which of its IP interfaces is used as a VTEP. To configure the IP address of the local VTEP, enter:

```
Switch(conf-vtep)# tunnel ip <IPv4 address>
```

To delete the VTEP IP configuration, enter:

```
Switch(conf-vtep)# no tunnel
```

To display the tunnels created between the local switch VTEP and other VTEPs across the virtual network, enter:

```
Switch> show nwv vxlan tunnel

Codes: RSN  - Replication Service Node
       VTEP - VXLAN Tunnel End Point

RSN Count: 10
VTEP Count: 254
Tunnel Count: 265

Tunnel IP Address     Tunnel Type    Status
-----------------     -----------    ------
50.10.3.1             Local          UP
172.20.1.22           RSN(Active)    UP
172.20.1.21           RSN(Backup)    UP
172.20.1.23           RSN(Backup)    UP
172.20.1.24           RSN(Backup)    UP
172.20.1.25           RSN(Backup)    UP
172.20.1.26           RSN(Backup)    UP
172.20.1.27           RSN(Backup)    UP
172.20.1.28           RSN(Backup)    UP
172.20.1.29           RSN(Backup)    UP
172.20.1.30           RSN(Backup)    UP
172.20.2.1            Remote         UP
172.20.2.2            Remote         UP
172.20.2.3            Remote         UP
...
```

When using VMware NSX, for the switch to operate as a VXLAN Gateway, it must synchronize network information with the NSX Controller. By default, the switch uses VMware NSX as the Controller provider.

To ensure that the switch uses VMware NSX as the controller provider, enter:

```
Switch(conf-vtep)# controller provider nsx
```

To configure the IP address of the Controller, enter:

```
Switch(conf-vtep)# controller ip <IPv4 address>
```

To configure the TCP port of the Controller, enter:

```
Switch(conf-vtep)# controller port <1-65535>
```

To configure the Virtual Routing and Forwarding (VRF) instance used by the Controller, enter:

```
Switch(conf-vtep)# controller vrf {default|management}
```

To delete the Controller configuration from the switch, enter:

```
Switch(conf-vtep)# no controller
```

To verify the connection to the Controller, enter:

```
Switch> show hsc ovsdb connection

Idx  Type          Peer             State   Inact. ms  Backoff ms  Latest Method
---  ------------  ---------------  ------  ---------  ----------  ------------------
1    SSL (Active)  172.20.1.11:6640 ACTIVE  30000      8000        transact (comment)
2    SSL (Active)  172.20.1.12:6640 ACTIVE  30000      8000        monitor
3    SSL (Active)  172.20.1.13:6640 ACTIVE  30000      8000        transact (select)
```

To display virtual network information, enter:

```
Switch> show hsc vtep virtual-network

Virtual Network Count: 1016
VNI         Name
----------  -------------------------
5001        03b264c5-9540-3666-a34a-c75d828439bc
5002        415585bd-389b-3965-9223-807d77a96791
5003        240ac937-1ec2-371a-a998-47c3ae2e6384
5004        3202111c-f90e-3c81-aa47-2aaceb72b0df
5017        0af78794-5872-396b-82c9-f73ead2565c8
5018        71463aaa-cf04-3fa2-8e7d-fa4558607545
5019        53fdae58-e861-376b-982b-0cd6beade809
...
```

To display information about the VXLAN Gateway, enter:

```
Switch> show hsc vtep

VTEP Information:
Status:                 Enabled
HA Mode:                vLAG
Device Name:            NE_36_NE_37
Tunnel IP:              50.10.3.1
BFD Status:             Enabled

Controller Connections:
Idx  Type                  Peer                      Inact.  Backoff ms
---  --------------------  ------------------------  ------  ---------
1    SSL (NSX Controller)  172.20.1.11:6640          30000   8000
3    SSL (NSX Controller)  172.20.1.12:6640          30000   8000
2    SSL (NSX Controller)  172.20.1.13:6640          30000   8000

VTEP Connections:
Id  Type         Peer                           Vrf         State
--  -----------  -----------------------------  ----------  -------
1   RESTful API  Local                          default     running
2   RESTful API  https://10.241.44.122:443      management  running

Physical Port Count: 1
Total Mappings Count: 1016
Name                      Mappings
------------------------  --------
vlag-instance-1           1016
```

Software Architecture Overview

The software architecture of the Lenovo VXLAN Gateway consists of three processes, each having multiple functional blocks:

- Network Virtualization Daemon (NWVD) - implements the VTEP Manager and the VXLAN core
- OVSDB Management Protocol - implements the Open vSwitch Database and the SSL client
- Hardware Switch Controller (HSC) - handles the interaction with the VMware NSX Controller through OVSDB

NWVD - Network Virtualization Daemon

NWVD communicates with other processes that run locally on the switch and it interacts with multiple CNOS functional blocks to collect information and handle events.

The VTEP Manager is a generic layer for VXLAN configuration, that receives the VXLAN network configuration: VTEPs, virtual networks, VTEP to virtual network mapping and local (switch interfaces) to virtual network mapping. It translates this information to messages for VXLAN to be used in data path calculations.

The VXLAN module receives network information from the VTEP manager (Local Tunnel End Points (LTEP) IP addresses, VTEPs, virtual networks, and more), it gathers all required information from other CNOS modules and sends messages to the Hardware Specific Layer (HSL) process which does the ASIC programming. The VXLAN module also handles events like link up/link down events, VLAN membership changes, route and ARP info changes, and MAC learning notifications from HSL.

The VXLAN module communicates with other CNOS processes to set up the hardware configuration and to receive Forwarding Database (FDB) updates, VLAN updates (create, delete, add port, remove port), ARP entries removal notifications, and route change notifications.

OVSDBD – Open Virtual Switch Database Daemon

The OVSDB module handles the communication with the Controller using the OVSDB management protocol. It includes a handler for protocol messages, a connection manager, and a database manager.

The OVSDB process implements a SSL client which is used to interact with the Network Virtualization Protocol (NVP) controller. The client – server SSL connection uses a private key infrastructure for connection security. This involves a server certificate and a client certificate and key.

Similar with other protocols, OVSDB generates two certificates. By default the names are `ovsdb_mgmt` for the management Virtual Routing and Forwarding (VRF) instance and `ovsdb_default` for the default VRF instance.

To display the OVSDB certificates used by the switch, run the following command:

```
Switch> show ovsdb certificate

ovsdb pki ovsdb_mgmt vrf management
ovsdb pki ovsdb_default vrf default
```

To display all available certificates stored on the switch, enter:

```
Switch> show pki

PKI Profile Name: ovsdb_default
        CSR: non existent
        Host certificate: existent
        CA: 0
        In use:Yes

PKI Profile Name: ovsdb_mgmt
        CSR: non existent
        Host certificate: existent
        CA: 0
        In use:Yes

PKI Profile Name: rest_default
        CSR: non existent
        Host certificate: existent
        CA: 0
        In use:Yes

PKI Profile Name: rest_mgmt
        CSR: non existent
        Host certificate: existent
        CA: 0
        In use:Yes
```

To display a specific certificate, enter:

```
Switch> show pki <certificate name> host-certificate base64
```

You can generate new certificates using the names of the default certificates. For example, you can create a new certificate using the `ovsdb_mgmt` certificate:

```
Switch(config)# pki ovsdb_mgmt
Switch(config-pki)# host-cert generate
```

For example, to display the ovsdb_mgmt certificate, enter:

```
Switch> show pki ovsdb_mgmt host-certificate base64

-----BEGIN CERTIFICATE-----
MIIEAjCCAuqgAwIBAgIJAIItdlYjRJKMMA0GCSqGSIb3DQEBCwUAMIGYMQswCQYD
VQQGEwJVUzETMBEGA1UECAwKQ2FsaWZvcm5pYTEUMBIGA1UEBwwLU2FudGEgQ2xh
cmExLTArBgNVBAoMJExlbm92byBOZXR3b3JrIE9wZXJhdGluZyBTeXN0ZW0gQ05P
UzEdMBsGA1UECwwUTmV0d29yayBFbmdpbmVlcmluZ2kxEDAOBgNVBAMMBzAuMC4w
LjAwHhcNMTcwNTI0MTIyNzU1WhcNMTgwNTI0MTIyNzU1WjCBmDELMAkGA1UEBhMC
VVMxEzARBgNVBAgMCkNhbGlmb3JuaWExFDASBgNVBAcMC1NhbnRhIENsYXJhMS0w
KwYDVQQKDCRMZW5vdm8gTmV0d29yayBPcGVyYXRpbmcgU3lzdGVtIENOT1MxHTAb
BgNVBAsMFE5ldHdvcmsgRW5naW5lZXJpbmdpMRAwDgYDVQQDDAcwLjAuMC4wMIIB
IjANBgkqhkiG9w0BAQEFAAOCAQ8AMIIBCgKCAQEAwKwtmynRgjLWyjUb5IBNmGQ+
8kY2hvs3syQx+wVQYYt+XYi+/D89o68ITZxqTOezfUQJE2SXnTT73lWEJLfvd9F3
ttKFMk3nQijefQpLhI/J3SkZB2B8pnxi5RtSBxXGnNd2+0+nMyeuIC0Dnm8itu93
cd2Ks8iRncALDNOhoQyJTVWxgdEG/rIUFLveeSlKG0SMy25hvtRc44D639+c9eGp
RbRUHFIlpn0AlnMjnSf1rtKeQN9NBUtJNYzEW894J4HePPBUKPltLH+OzqKTT3Zj
yOHPi+hzt2Aey6EaOXyj0q4WbSudiL6zIvqB2N05+yWeJK707TznoZ6++Y8aFQID
AQABo00wSzAdBgNVHQ4EFgQUpf9+p9Hb5MSMDZV3HhQmhfVvvqEwHwYDVR0jBBgw
FoAUpf9+p9Hb5MSMDZV3HhQmhfVvvqEwCQYDVR0TBAIwADANBgkqhkiG9w0BAQsF
AAOCAQEAUJTJCdaVKBH8ZwpjfSRdGRClJWoTole5Qa4DbhhSJR4VbH4QhxuHuaI+
UmrKqve7G7XkaXxf078vB4Z+mQkvIYpWJEm99ZC43swVVKkKCxGm0yikzAmVGnzn
/LJJR4w1EbOXm+OAecG4/QQuvul7KkYLqvjQCSOt4rUUFDAUJSJV5zPQ2c2xqySo
HF6skFpEc1SginCVrzy76AJiEusPEXV8wmi1jFQOkhIIYwdscUJP6MAGnU7Jybji
O3Ar6L4gopIYpACEajGUcahXhT+svxQg+nsB4TgYP3KICjVRRYqxk5AbfLEmEc2j
DKz5wE0oeYxoO0gV7nZbWqtloXGblA==
-----END CERTIFICATE-----
```

You can use other certificate names as long as they meet the following conditions:

- a maximum length of 16 characters
- the name contains “ovsdb”
- the name contains “default” if the certificate is used on the default VRF instance, or “mgmt” if the certificate is used on the management VRF instance

For example, you can generate a certificate called ovsdb_11_mgmt, which can be used on the management VRF instance. Before using the new certificate, you must first generate the certificate using the following command:

```
Switch(config)# pki ovsdb_11_mgmt
Switch(config-pki)# host-cert generate
```

After generation, the new certificate must be assigned to the OVSDB protocol:

```
Switch(config)# ovsdb pki ovsdb_11_mgmt vrf management
```

Once the switch connects to controller, it uses the new certificate. If the new certificate is not assigned to the OVSDB protocol, the switch is not going to use the certificate.

HSC - Hardware Switch Controller

The HSC process (HSCD) is a software module that runs on a switch, which implements the HSC Manager, the OVSDB client, and the RESTful API client. HSCD communicates with other processes within the same switch using inter-process communication (IPC). It also communicates vLAG VTEP switches using RESTful API over SSL.

HSC acts like the interface to the Controller. When creating a VXLAN Gateway, the management IP address of the HSC or the SSL certificate needs to be added to the Controller. The OVSDB server and the HSC agent need to run simultaneously on the HSC.

HSC retrieves the configuration of each vLAG switch, such as hostname, switch description, MAC address and so on, and transmits to each vLAG switch the VTEP IP address and vLAG port list.

When HSC receives the configuration of the vLAG switches, it registers the information with the OVSDB server and monitors the OVSDB tables. The Controller transmits its configuration to OVSDB, which sends an update message to the HSC. The configuration is converted to RESTful API messages and sent to the vLAG switches. The Network Virtualization Daemon (NWVD) on the primary vLAG switch parses the RESTful API messages and call the VXLAN APIs to program the data path.

When configuring the two vLAG switches to act as VXLAN Gateways, there are no master/backup roles. Each switch behaves as standalone and replies with its own configuration to the HSC, which maintains duplicated information.

Because each vLAG switch behaves as standalone, the network is not affected by failover. If one of the two vLAG switches becomes unreachable, due to failure or connection problems, the HSC re-programs the switch when it is reachable once more.

While there is no master role for the vLAG switches when running as VXLAN Gateways, Bidirectional Forwarding Detection (BFD) runs only on one of the switches, because both devices share the same VTEP IP address. HSC decides which switch runs BFD.

Every 30 seconds, HSC gathers BFD and status information from the vLAG switches and sends this information to the Controller as an OVSDB message over SSL. The OVSDB message is sent only if there are value changes.

Lenovo VXLAN uses vLAG to implement NSX High Availability (HA) solution. To facilitate the communication between VXLAN and legacy servers, VXLAN is designed as an added layer on top of vLAG. HA is achieved by means of ECMP running locally on each switch.

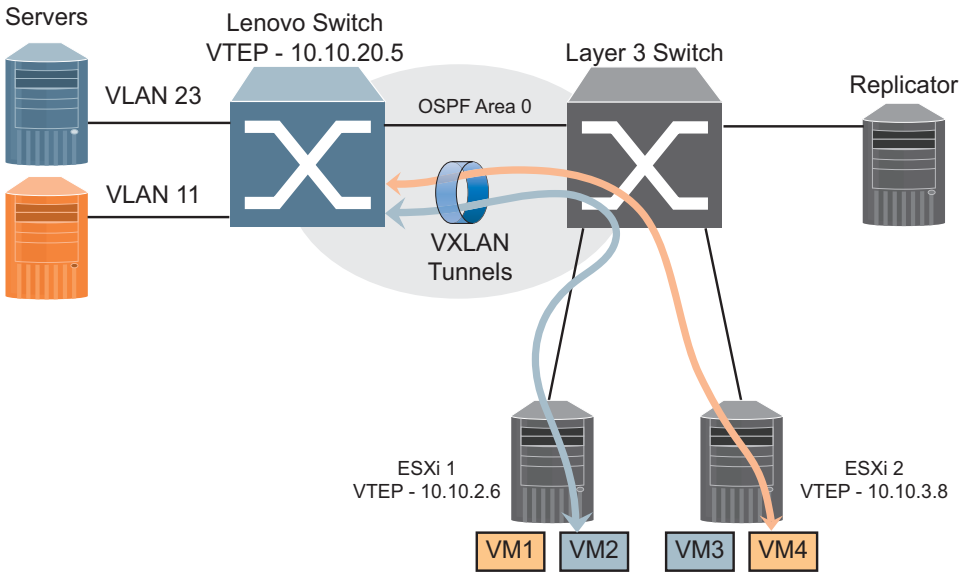
VXLAN Gateway Standalone Topologies

The following deployment topologies are supported by the Lenovo VXLAN Gateway:

VXLAN Tunnels over Layer 3 Routed Network

This topology shows the servers directly connected to the switch ports in access mode while connectivity between the VTEPs is Layer 3 routed.

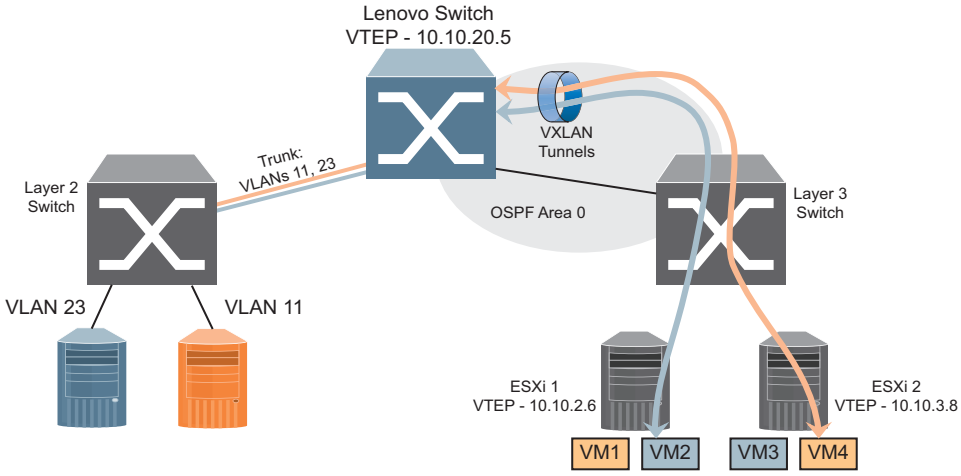
Figure 37. VXLAN Tunneling over Layer 3 Routed Network



Physical Servers on Layer 2 Switches

This topology allows connecting physical servers using VLAN trunks into the switch VXLAN gateway switch.

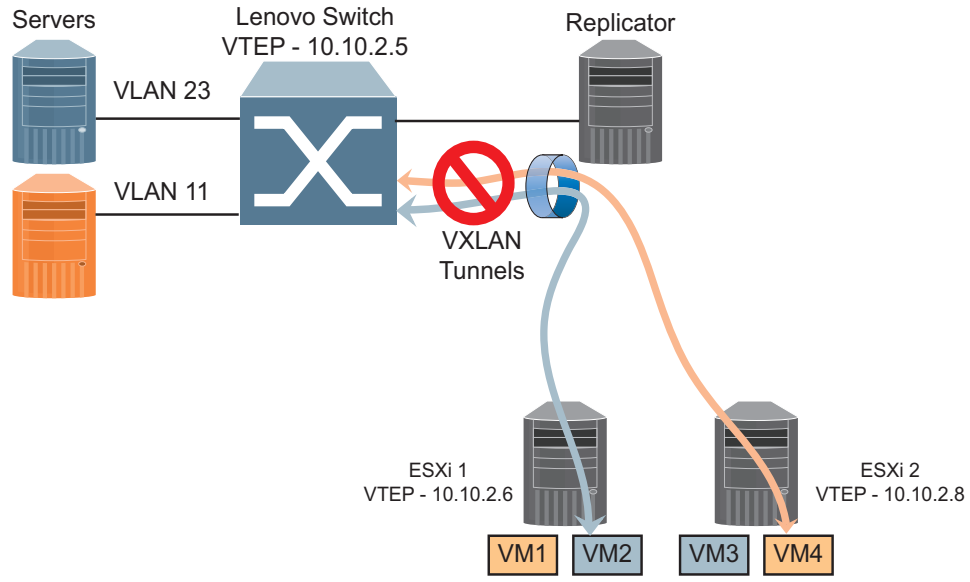
Figure 38. VXLAN Tunneling over VXLAN Gateway Switch



Directly Attached VXLAN Tunnel with a Layer 2 Network (Not Supported)

This topology is not supported when all nodes including ESXi and physical servers are connected directly to the switch VXLAN Gateway switch in a Layer 2 configuration.

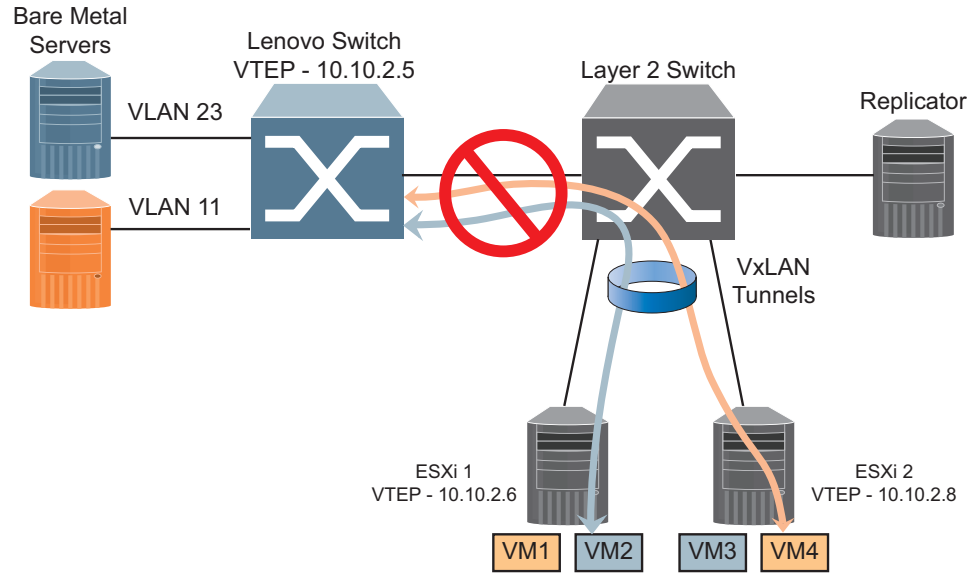
Figure 39. VXLAN Tunneling over Layer 2 Network



VXLAN Tunnels through a Layer 2 Network (Not Supported)

This topology is not supported when multiple VTEPs are connected to the Lenovo VXLAN gateway switch using a Layer 2 switch.

Figure 40. VXLAN Tunneling over Layer 2 Switches



The switch has a hardware restriction that does not allow this kind of topology. It supports only a single next-hop per network port. It cannot initiate tunnels from a single network port to multiple remote Tunnel End Points (TEPs) across a Layer 2 network. Instead, it can initiate tunnels from a single network port to multiple remote TEPs across a Layer 3 network.

High Availability Support

The Lenovo VXLAN Gateway supports Virtual Link Aggregation Group (vLAG) and Equal Cost Multiple Paths (ECMP) to provide an active-active, fully redundant high availability solution.

The VXLAN solution is configured and administered by the NSX Manager through the Management Network. Traffic that is transmitted across this network is used by NSX to manage each device that is part of the VXLAN solution, such as virtual machines and switches.

Data traffic that is not used in the management process is transmitted across the Transport Network. Such traffic includes, for example, the transfer of a file from a legacy server to a virtual machine. The file is divided into smaller packets that are sent to the virtual machine through the Transport Network using FTP.

The Management and Transport Networks can be physically separated or combined. This means that the two networks can have distinct physical links that connect all the devices in the VXLAN solution as shown in Figure 41, or that they share the same physical links as shown in Figure 42.

Figure 41. High Availability Topology Solution with Separated Management and Transport Networks

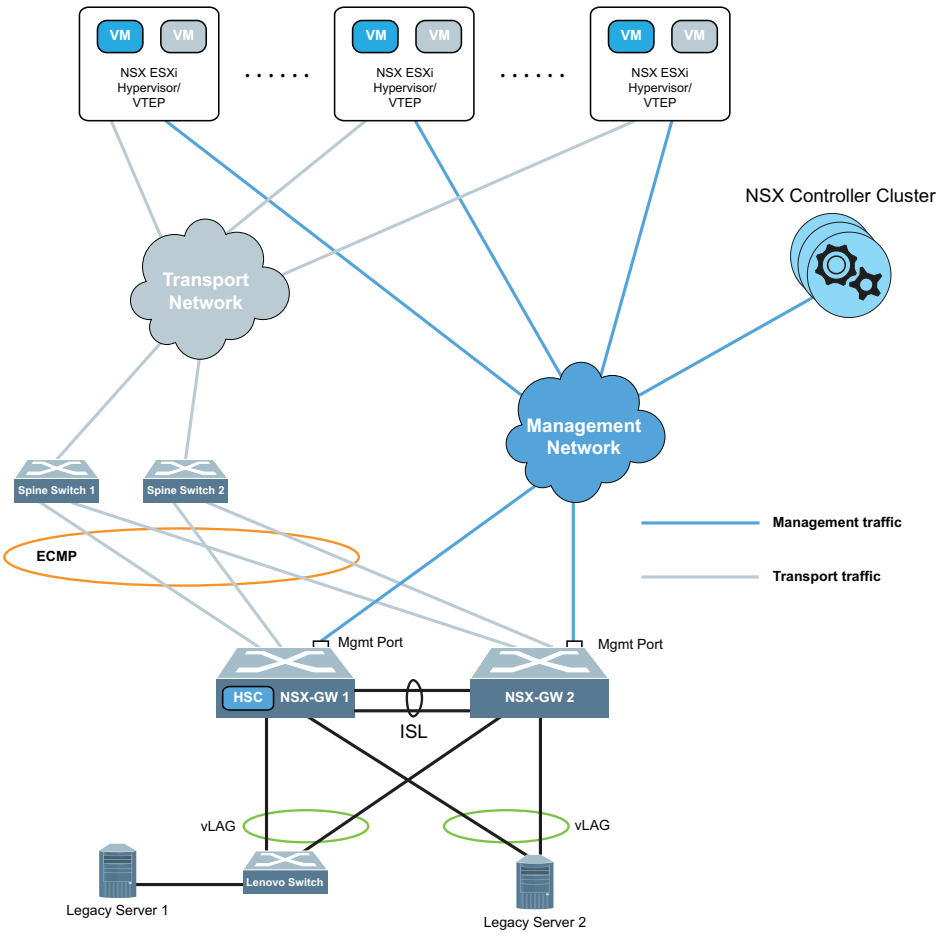
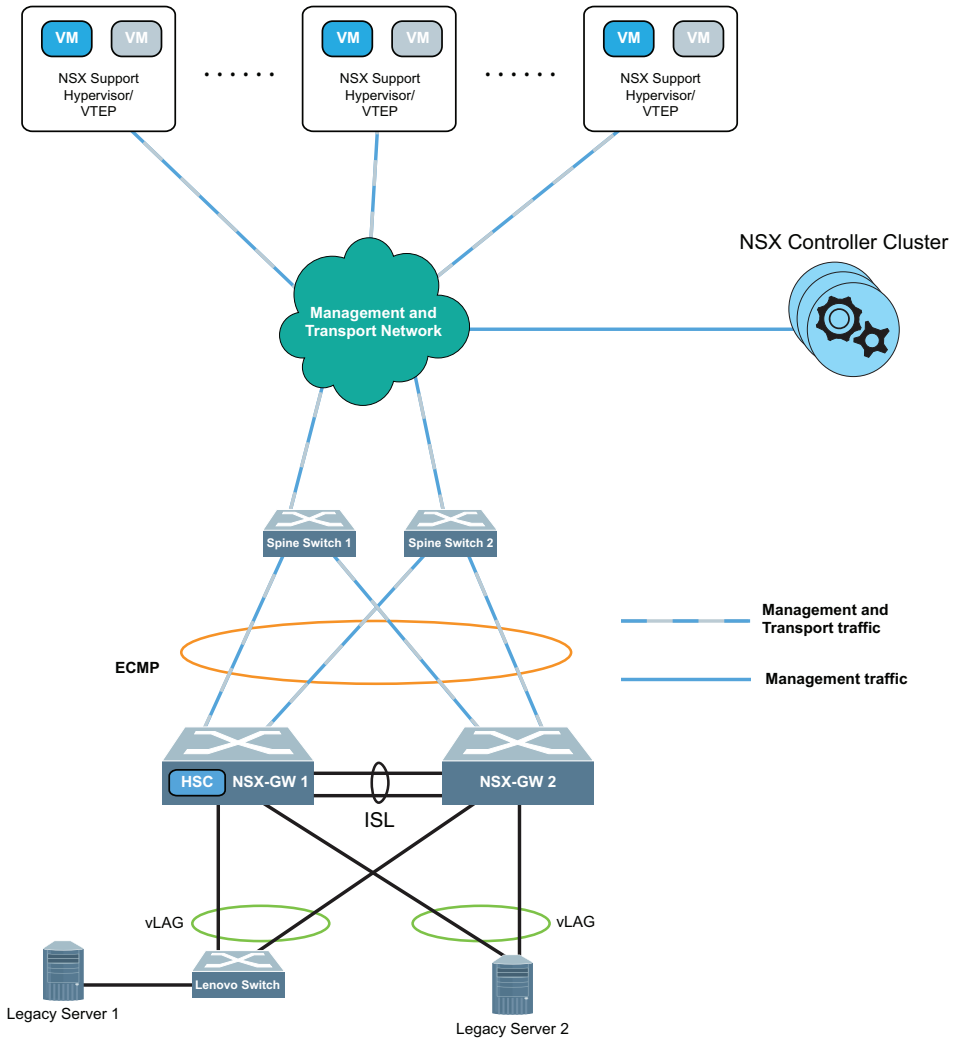


Figure 42. High Availability Topology Solution with Combined Management and Transport Networks



Note: The NSX Manager uses only the Management Network to configure and monitor the VXLAN solution. It does not have a link to the Transport Network. As shown in the two previous figures, regardless if the Management and Transport Networks are separated or combined, the Controller Cluster is connected to the rest of the VXLAN solution only through a management link (colored in blue), and not a transport link (colored in grey).

The connection is established between the Controller and a dedicated piece of software called the Hardware Switch Controller (HSC). The HSC can be embedded in the physical switches or can run as a separate standalone process. The HSC can control one or several physical gateways.

Note: CNOS version 10.9 only supports the HSC embedded in the physical switch.

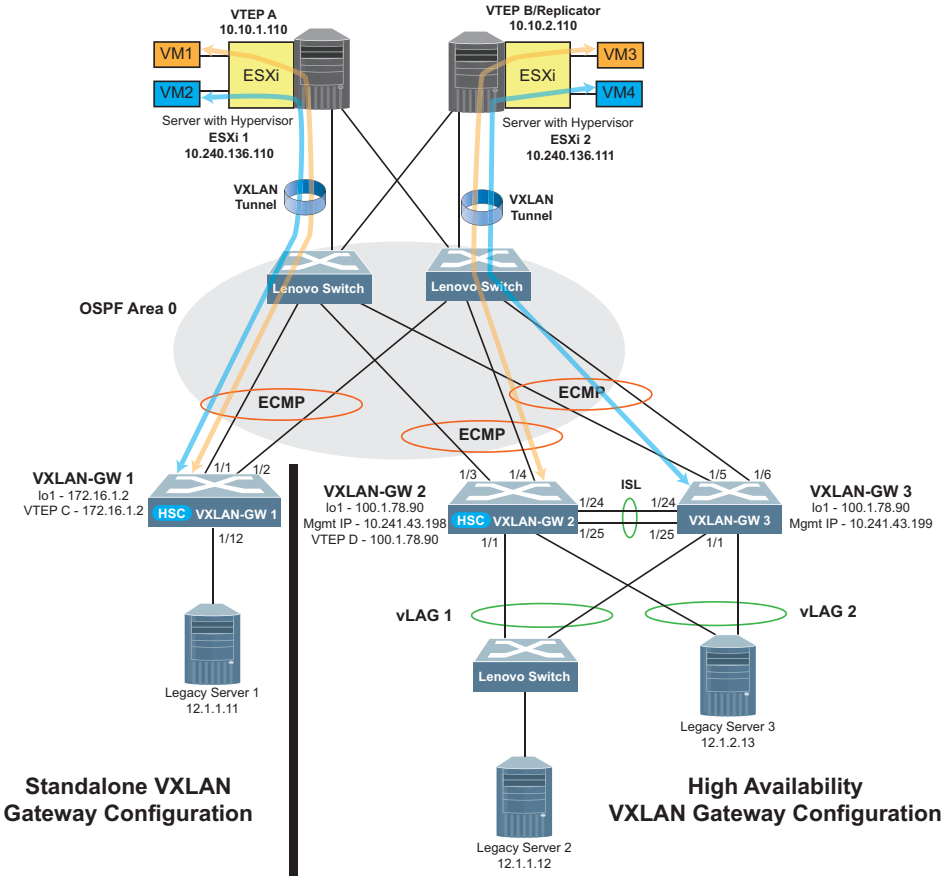
During operation, HSC registers with the Controller and uses the OVSDB protocol to synchronize topology information, MAC to VXLAN Endpoints, and VXLAN ID bindings with the Controller. HSC appropriately programs the Lenovo vLAG switch pairs as the VMware NSX physical gateway via RESTful API. This physical gateway integration allows for the nearly instantaneous synchronization of states between physical and virtual VXLAN Tunnel Endpoints during any network change or workload modification event.

VXLAN Gateway Configuration Example

The following example shows the steps required to configure a VXLAN Gateway for VMware NSX. The figure presents two topology scenarios:

- VXLAN-GW 1 is a standalone switch acting as VTEP C
- VXLAN-GW 2 and VXLAN-GW 3 form the vLAG topology which acts as VTEP D

Figure 43. VXLAN Gateway Example



Standalone VXLAN Gateway Configuration Example

Use the following steps to configure VXLAN-GW 1 as a standalone VXLAN Gateway as shown in the lower left side of Figure 43.

Given the following:

- VTEP C IP address: 172.16.1.2
- HSC is implemented on VXLAN-GW 1

1. Configure the DNS and NTP server addresses to get the correct time and avoid certificate failure check due to certificate expiration.

   a. Enable DNS on the switch and configure DNS server addresses:

```
Switch(config)# ip domain-lookup
Switch(config)# ip name-server <DNS server address> vrf management
```

   b. Enable NTP and configure the NTP server address:

```
Switch(config)# ntp enable
Switch(config)# ntp server <NTP server address> mgt-port
```

2. Configure routed interfaces for ECMP:

```
Switch(config)# interface Ethernet 1/1
Switch(config-if)# no switchport
Switch(config-if)# ip address 172.45.17.2/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/2
Switch(config-if)# no switchport
Switch(config-if)# ip address 172.45.18.2/24
Switch(config-if)# exit
```

3. Assign the hardware VTEP an IP address. The VTEP IP address can be assigned to a routed or to a loopback interface. We recommend using a loopback interface so ECMP can be used to its full benefits. In this example, loopback interface 1 is used:

```
Switch(config)# interface loopback 1
Switch(config-if)# ip address 172.16.1.2 255.255.255.255
Switch(config-if)# exit
```

4. Configure the Controller IP address, port, and VRF instance on the switch:

```
Switch(config)# hsc vtep
Switch(config-vtep)# controller ip 11.1.0.202
Switch(config-vtep)# controller port 6640
Switch(config-vtep)# controller vrf default
```

5. Configure the local VXLAN TEP IP address. The following example uses the VTEP IP address as the IP address of the loopback interface configured at Step 3:

```
Switch(conf-vtep)# tunnel ip 172.16.1.2
```

6. Configure VXLAN on the switch ports that physically participate in the virtual network:

```
Switch(config-vtep)# vtep 1 vxlan-ports ethernet 1/12
```

7. Configure the username and password of the VTEP instance:

```
Switch(config-vtep)# vtep 1 username <username> password <password>
Switch(config-vtep)# exit
```

8. Enable the VXLAN Gateway:

```
Switch(config)# hsc mode vtep
```

9. To verify that the connection to the Controller is active, enter:

```
Switch(config)# show hsc ovsdb connection

Idx  Type          Peer             State   Inact. ms  Backoff ms  Latest Method
---  ------------  ---------------  ------  ---------  ----------  ------------------
1    SSL (Active)  11.1.0.202:6640  ACTIVE  30000      8000        transact (comment)
2    SSL (Active)  11.1.0.203:6640  ACTIVE  30000      8000
3    SSL (Active)  11.1.0.204:6640  ACTIVE  30000      8000        monitor
```

10. The switch is now configured as a VXLAN Gateway. The next step is to add it to the Manager as a Hardware Device:

    a. Generate and obtain the PKI certificate from the switch:

```
Switch(config)# pki ovsdb_mgmt
Switch(config-pki)# host-cert generate
Switch(config-pki)# exit

Switch(config)# show pki ovsdb_mgmt host-certificate base64

-----BEGIN CERTIFICATE-----
MIIDezCCAmOgAwIBAwIBADANBgkqhkiG9w0BAQsFADCBgDELMAkGA1UEBhMCVVMx
FDASBgNVBAcMC1NhbnRhIENsYXJhMSswKQYDVQQKDCJMZW5vdm8gTmV0d29ya2lu
ZyBPcGVyYXRpbmcgU3lzdGVtMRwwGgYDVQQLDBNOZXR3b3JrIEVuZ2luZWVyaW5n
MRAwDgYDVQQDDAcwLjAuMC4wMB4XDTE3MDUwNTA4NTgwN1oXDTI3MDUwMzA4NTgw
N1owgYAxCzAJBgNVBAYTAlVTMRQwEgYDVQQHDAtTYW50YSBDbGFyYTErMCkGA1UE
CgwiTGVub3ZvIE5ldHdvcmtpbmcgT3BlcmF0aW5nIFN5c3RlbTEcMBoGA1UECwwT
TmV0d29yayBFbmdpbmVlcmluZzEQMA4GA1UEAwwHMC4wLjAuMDCCASIwDQYJKoZI
hvcNAQEBBQADggEPADCCAQoCggEBAK+xpPdfJWzU4B4OYHw9E1ImDwisfz8uCaZu
bG93H44+gklSCDAshk6Mj+z97K232Sb+wYYRfV22NZ6vRY02g+oTjr0MYSTn1TCy
eT4E3RJZb66R2+TLS0HO9KCA17Sv+d74rwVDkQI8zO5t1ZfDK2UJDrZiZx4UPLXj
5ncAM+6zYr0z5BhSH+mpVDHyQcAdsTQgkYu81XRLNZjjndGxlfblU3D6rTaAg26y
d9AUXerKem4aAevT4VG817/lVa9SqTLc0bnkGZCNSM2TbDHsuNo9y35koTw0mBOv
FWZGjOeBJUNt7MXcmDkZvm/KhzmGoXQCGHZyeXAvv+H7O9mAXVkCAwEAATANBgkq
hkiG9w0BAQsFAAOCAQEAQbO52RPzXr4qj75epyZExJvPUygv2JGhr8qlhkrvbqch
6o/dyE0wgiFYN1rzpyMJ/DzOS//+fjB3EyMeo23m0lPdafPKShMHIHb7znKkROgz
3dEd8ozyQzLcxP0L6Lb+MTgImTBDlFxuPgXA05L6unVEY6fYv4/aIDv+7n9vhVzk
uExUprCIy4OjCfaKfplcjf4iY7KWTSJkoBjiackM1SoVQLJcNpE2CzDwqaPXQIZS
wMthE7O7QwjB/FsQt6b2xb7SBpzwiBjqq/FdbMV0bogRJRNESK4LYHdqbPbNrjaw
QlzW4WdDyOhOGcw2VWkytQcvEzwv10uTkzZSPmNuSg==
-----END CERTIFICATE-----
```

    b. Using the VMware vSphere Web Client add the switch as a Hardware Device. Attach the physical switch ports configured at Step 6 to Logical Switches as required for network connectivity. For more details on how to add the Hardware Gateway, see the VMware NSX Administration Guide.

High Availability VXLAN Gateway Configuration Example

To configure a high availability solution as shown in the lower right side of Figure 43, you need to configure the HSC and a vLAG between the two VXLAN Gateways (VXLAN-GW 2 and VXLAN-GW 3).

In this example, consider the following:

- the management IP address of NSX-GW 2: 10.241.43.198
- the management IP address of NSX-GW 3: 10.241.43.199
- VTEP D IP address: 100.1.78.90
- the Controller is configured on VXLAN-GW 2 with IP address 11.1.0.202

Basic Switch Configuration

On both VXLAN Gateway switches (VXLAN-GW 2 and VXLAN-GW 3), configure the DNS and NTP server addresses to get the correct time and avoid certificate failure check due to certificate expiration.

1. Enable DNS on the switch and configure DNS server addresses:

```
Switch(config)# ip domain-lookup
Switch(config)# ip name-server <DNS server address> vrf management
```

2. Enable NTP and configure the NTP server address:

```
Switch(config)# ntp enable
Switch(config)# ntp server <NTP server address> mgt-port
```

vLAG Configuration

Configure a vLAG between the VXLAN Gateways (VXLAN-GW 2 and VXLAN-GW 3). On both switches, ethernet ports 1/24 and 1/25 are used as the Inter-Switch Link (ISL) and ethernet ports 1/1 forms the vLAG between them.

Note: The following steps need to be configured on both switches.

1. Create a static or an LACP LAG on ethernet port 1/1:
   - Static LAG:

```
Switch(config)# interface ethernet 1/1
Switch(config-if)# channel-group 2 mode on
Switch(config-if)# exit
```

   - LACP LAG:

```
Switch(config)# interface ethernet 1/1
Switch(config-if)# channel-group 2 mode active
Switch(config-if)# exit
```

2. Create a static LAG on ethernet ports 1/24 and 1/25:

```
Switch(config)# interface ethernet 1/24-25
Switch(config-if-range)# channel-group 1 mode on
Switch(config-if-range)# exit
```

3. Configure the vLAG tier ID:

```
Switch(config)# vlag tier-id 1
```

4. Configure VXLAN-GW 2 as the primary vLAG switch:

```
Switch(config)# vlag priority 1
```

5. Configure VXLAN-GW 3 as the secondary vLAG switch:

```
Switch(config)# vlag priority 2
```

6. Configure the vLAG ISL on the LAG which includes ethernet port 1/24:

```
Switch(config)# vlag isl port-channel 1
```

7. Configure the health check IP address of the peer switch, using the management IP address of the peer switch:
   a. Configure VXLAN-GW 2 with the management IP address of VXLAN-GW 3:

```
Switch(config)# vlag hlthchk peer-ip 10.241.43.199 vrf management
```

   b. Configure VXLAN-GW 3 with the management IP address of VXLAN-GW 2:

```
Switch(config)# vlag hlthchk peer-ip 10.241.43.198 vrf management
```

8. Globally enable the vLAG:

```
Switch(config)# vlag enable
```

9. Configure the vLAG instance and enable it:

```
Switch(config)# vlag instance 1 port-channel 2
Switch(config)# vlag instance 1 enable
```

VXLAN Tunnel Configuration

ECMP takes advantage of the available links and balances the VXLAN encapsulated traffic egressing the VXLAN Gateway. You need to configure the VTEP IP address on a loopback interface for both vLAG switches. Also, routed interfaces or SVI interfaces can be configured for ECMP.

Note: When the VXLAN tunnel is an SVI, we recommend you keep only VXLAN-transport network facing ports as VLAN members. This is required for the VXLAN software module to detect that the tunnel interface is down when all VLAN ports are down (have no route to the VXLAN transport network).

1. Configure routed interfaces for ECMP:

   a. VXLAN-GW 2:

```
Switch(config)# interface Ethernet 1/3
Switch(config-if)# no switchport
Switch(config-if)# ip address 100.1.7.2/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/4
Switch(config-if)# no switchport
Switch(config-if)# ip address 100.1.8.2/24
Switch(config-if)# exit
```

   b. VXLAN-GW 3:

```
Switch(config)# interface Ethernet 1/5
Switch(config-if)# no switchport
Switch(config-if)# ip address 100.1.9.2/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/6
Switch(config-if)# no switchport
Switch(config-if)# ip address 100.1.10.2/24
Switch(config-if)# exit
```

2. On both vLAG switches, configure a loopback interface which is used as the Tunnel IP address. This configuration must be the same on both vLAG peers:

```
Switch(config)# interface loopback 1
Switch(config-if)# ip address 100.1.78.90/32
```

HSC Configuration

Note: HSC needs to run only on a single switch that is part of the vLAG. It is recommended that you configure HSC on the primary vLAG switch.

1. Enter VTEP configuration mode:

```
Switch(config)# hsc vtep
```

2. Enable vLAG High Availability (HA) mode:

```
Switch(config-vtep)# ha mode vlag
```

3. Configure the controller IP address, controller port, and controller VRF:

```
Switch(config-vtep)# controller ip 11.1.0.202
Switch(config-vtep)# controller port 6640
Switch(config-vtep)# controller vrf default
```

4. Configure the VTEP IP address:

```
Switch(config-vtep)# tunnel ip 100.1.78.90
```

Note: The VTEP IP address is the IP address of the loopback interface configured during vLAG Configuration at Step 2.

5. Configure the VXLAN enabled vLAG-instance ports for the local VTEP instance:

```
Switch(config-vtep)# vtep 1 vxlan-ports vlag-instance 1
```

6. Configure the username and password of the local VTEP instance:

```
Switch(config-vtep)# vtep 1 username <username> password <password>
```

7. Configure the VTEP instance corresponding to the vLAG peer:

```
Switch(config-vtep)# vtep 2 ip 10.241.43.199
Switch(config-vtep)# vtep 2 vrf management
Switch(config-vtep)# vtep 2 vxlan-ports vlag-instance 1
```

8. Configure the username and password for the VTEP instance of the vLAG peer:

```
Switch(config-vtep)# vtep 2 username <username> password <password>
Switch(config-vtep)# exit
```

9. Configure HSC to run in VXLAN Tunnel Endpoint (VTEP) mode:

```
Switch(config)# hsc mode vtep
```

NWV Configuration Considerations and Limitations

VXLAN encapsulation increases the size of the IP packet by wrapping the internal Ethernet frame in an external UDP header. The overall Maximum Transmission Unit (MTU) for all interfaces members of the physical infrastructure that carry the VXLAN frame needs to be increased to a minimum of 1,600 bytes.

Use the following command to increase the size of the MTU:

```
Switch(config-if)# mtu <MTU size>
```

For example, increase the size of the MTU to 1,600 bytes:

```
Switch(config-if)# mtu 1600
```

The following limitations apply when configuration Network Virtualization:

- 802.1Q (dot1q) tunnel VLAN is not used during VXLAN processing. Therefore, dot1q tunneling feature in conjunction with VXLAN is not operational;
- In case the vLAG instance goes down on one of the vLAG switches, the MAC addresses learned on that instance are not be moved to the ISL. This means that the traffic is flooded on both the ISL and other potential access ports. The flooding on ISL means that the traffic eventually gets to the vLAG instance on the peer, so no traffic is lost. The hosts on the other access ports drop the traffic as it is not addressed to them.

Chapter 34. Data Center Interconnection

The following topics are covered in this chapter:

Data Center Interconnection Overview

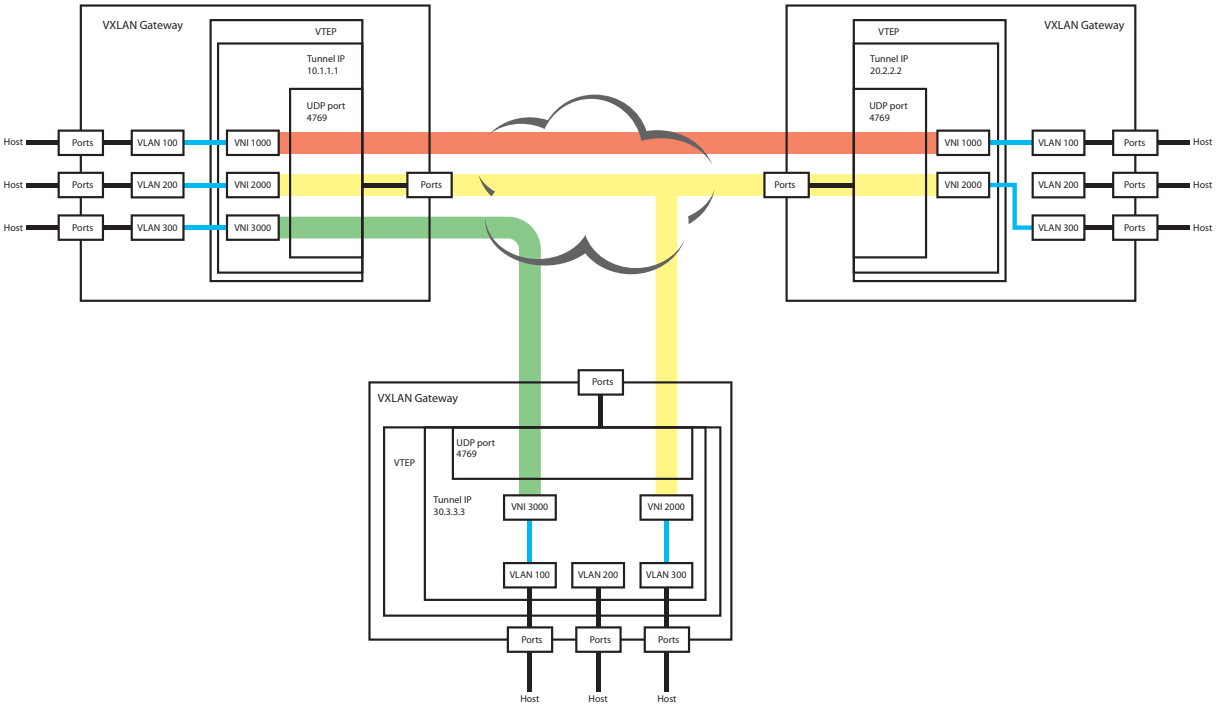
Distributing business applications and data across multiple geographically scattered data centers offers several advantages, such as increased levels of service availability and improved application performance. However, these distributed architectures relay heavily on network connectivity.

The Data Center Interconnection (DCI) is a wide area architecture between data centers. It ensures that data is consistent, it allows virtualized workloads to be moved quickly, and it makes for an easier deployment of high availability solutions between different geographical locations.

DCI enables the bridging of Layer 2 services between multiple locations across existing Layer 3 IP networks. Virtual Extensible LAN (VXLAN) provides a high availability DCI framework for connecting two or more data centers. It does not require specialized hardware and it is deployable using any network devices that support VXLAN. For more details about VXLAN, see "VXLAN" on page 695.

Figure 44 shows an overview of how traffic flows between different virtual networks across distinct data center locations.

Figure 44. *DCI Traffic Flow*



Host traffic entering the Lenovo VXLAN gateway is encapsulated using VXLAN based on the VXLAN Network ID (VNI). The VXLAN encapsulated traffic is transmitted across the DCI tunnel to the corresponding VXLAN Tunnel Endpoint (VTEP). The VTEP decapsulates the received traffic and then forwards it to the host with the corresponding VNI.

Packet Flow Overview

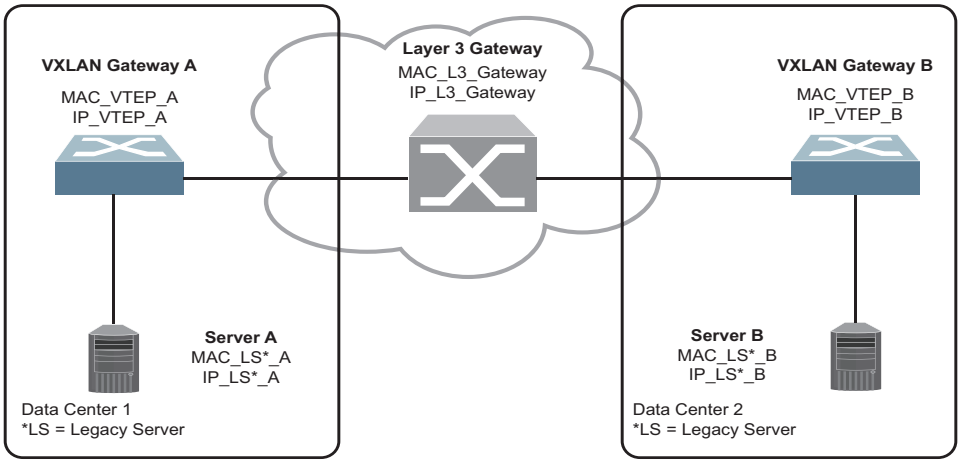
In order for packet flow to occur between the servers behind various VXLAN gateways on a given VNID, all of the server MAC addresses are learned by the VXLAN gateway and associated with the VNI to VLAN mapping on the corresponding VTEP.

When a server wants to talk to another server, it needs to know the MAC address of the other server before it can establish a unicast connection. The first packet is an ARP broadcast from the server, that is sent to all the VTEPs within the same VNI domain.

The initial ARP broadcast is:

Server A to VXLAN Gateway A to VXLAN Gateway B to Server B.

Figure 45. DCI Topology Diagram



On VXLAN Gateway B, the ASIC receives the broadcast packet that contains the source IP (VXLAN Gateway B IP). The MAC inner source is the Server A MAC. This way, the ASIC Layer 2 learns the Server A MAC with source VPORT of VXLAN Gateway A. VXLAN Gateway B associates the newly learned Server A MAC to the VNI and the VTEP that encapsulated the original packet.

When the packet arrives at VXLAN Gateway B, ASIC performs learning based on:

MAC A (MAC inner packet = Server A MAC) - VNID A - Source VPORT of Remote VXLAN Gateway.

Server B receives the ARP broadcast and responds. This is a unicast response to Server A which originated the broadcast. Once the ARP response from Server B reaches Server A, it programs the ARP entry in its cache and from that point on the communication works in both directions.

A Broadcast Unknown/Unicast Multicast (BUM) packet received on the access vPort is broadcasted to other access vPorts and other network vPorts in the same VNI. All network vPorts of all VTEPs that receive the BUM traffic must be added.

For the following configuration:

- VTEP1 – VNI: 1000, 2000, 3000
- VTEP2 – VNI: 2000, 5000
- VTEP3 – VNI: 1000, 5000

The following traffic encapsulation and forwarding takes place:

- Access port traffic is designated for VNI 1000, BUM traffic must be sent only to the network vPort of VTEP1, VTEP3
- Access port traffic is designated for VNI 2000, BUM traffic must be sent only to the network vPort of VTEP1, VTEP2
- Access port traffic is designated for VNI 3000, BUM traffic must be sent only to the network vPort of VTEP1
- Access port traffic is designated for VNI 5000, BUM traffic must be sent only to the network vPort of VTEP2, VTEP3

Packet Format Illustration

Packets exchanged between Server A and Server B are illustrated using the typical topology of the deployment of VXLAN Gateway. The Level 3 gateway is deployed between the two VXLAN gateways to provide the routing functionality.

The VXLAN packet has the original Ethernet packet encapsulated with the outer L2/L3/UDP/VXLAN headers. Figure 45 only shows the MAC and IP which must be in the outer Layer 2 header.

UCAST Packet from Server A to Server B

1. From Server A through VTEP A, the packet is sent to Layer 3 Gateway with VNID 1000.
2. Layer 3 Gateway routes the VXLAN packet to VTEP B using the outer Layer 2 and 3 headers.
3. VTEP B decapsulates the VXLAN packet and transforms it into an Ethernet Layer 2 packet and sends it to Server B. The egress packet is the original inner packet, with VLAN 100.

Table 48. *UCAST Packets Server A to B*

STEP	SRC MAC	DST MAC	SRC IP	DST IP
1	VXLAN Outer L2 MAC_VTEP_A	VXLAN Outer L2 MAC_L3_GW	VXLAN Outer L3 IP_VTEP_A	VXLAN Outer L3 IP_VTEP_B
2	VXLAN Outer L2 MAC_L3_GW	VXLAN Outer L2 MAC_VTEP_B	VXLAN Outer L3 IP_VTEP_A	VXLAN Outer L3 IP_VTEP_B
3	Ethernet inner L2 MAC_LS_A	Ethernet inner L2 MAC_LS_B	Ethernet inner L3 IP_LS_A	Ethernet inner L3 IP_LS_B

UCAST Packet from Server B to Server A

1. Server B sends the ethernet packet to VTEP B with LAN 100.
2. VTEP B encapsulates the original Ethernet packet with the outer L2/L3/UDP/VXLAN header as a VXLAN packet. Then switches to Layer 3 Gateway with VNID 1000.
3. Layer 3 Gateway routes the VXLAN packet to Server A trough VTEP A. The MAC/IP shown in Table 49 is the outer header of the egress packet leaving from Layer 3 Gateway to VTEP A.

Table 49. *UCAST Packets Server B to A*

STEP	SRC MAC	DST MAC	SRC IP	DST IP
1	Ethernet inner L2 MAC_LS_B	Ethernet inner L2 MAC_LS_A	Ethernet inner L3 IP_LS_B	Ethernet inner L3 IP_LS_A
2	VXLAN Outer L2 MAC_VTEP_B	VXLAN Outer L2 MAC_L3_GW	VXLAN Outer L3 IP_VTEP_B	VXLAN Outer L3 IP_VTEP_A
3	VXLAN Outer L2 MAC_L3_GW	VXLAN Outer L2 MAC_VTEP_A	VXLAN Outer L3 IP_VTEP_B	VXLAN Outer L3 IP_VTEP_A

Non-UCAST Packet from Server A to Server B

1. Server A through VTEP A replicates and sends the VXLAN packet to a list of VTEPs with VNID 1000.
2. Layer 3 Gateway routes the VXLAN packet to VTEP B using the outer L2/L3 headers.
3. VTEP B decapsulates the VXLAN B packet to be an Ethernet packet with VLAN 100 and switches it to all servers that belong to VNID 1000.

Table 50. *Non-UCAST Packets Server A to B*

STEP	SRC MAC	DST MAC	SRC IP	DST IP
1	VXLAN Outer L2 MAC_VTEP_A	VXLAN Outer L2 MAC_VTEP_B	VXLAN Outer L3 IP_VTEP_A	VXLAN Outer L3 IP_VTEP_B
2	VXLAN Outer L2 MAC_L3_GW	VXLAN Outer L2 MAC_VTEP_B	VXLAN Outer L3 IP_VTEP_A	VXLAN Outer L3 IP_VTEP_B
3	Ethernet inner L2 MAC_LS_A	Ethernet inner L2 non-UCAST MAC	Ethernet inner L3 IP_LS_A	Ethernet inner L3 as in original packet

Non-UCAST Packet from Server B to Server A

1. Server B sends Ethernet packets to VTEP B with LAN 100.
2. VTEP B encapsulates the packet to be VXLAN packet and forwards it to the list of VTEPs that belong to VNID 1000 and also switches the original packet to other servers that belong to VLAN 100. Table 51 displays only the egress packet switched to the list of VTEPs and outer VXLAN packet. The egress packet switched to the list of VTEPs is sent through the Layer 3 Gateway to be routed.

3. Layer 3 Gateway routes the VXLAN packets to one of more VTEPs.

Table 51. *Non-UCAST Packets Server B to A*

STEP	SRC MAC	DST MAC	SRC IP	DST IP
1	Ethernet inner L2 MAC_LS_B	Ethernet inner L2 non-UCAST MAC	Ethernet inner L3 IP_LS_B	Ethernet inner L3 as in original packet
2	VXLAN Outer L2 MAC_VTEP_B	VXLAN Outer L2 MAC_L3_GW	VXLAN Outer L3 IP_VTEP_B	VXLAN Outer L3 IP_VTEP_A
3	VXLAN Outer L2 MAC_L3_GW	VXLAN Outer L2 MAC_VTEP_A	VXLAN Outer L3 IP_VTEP_B	VXLAN Outer L3 IP_VTEP_A

Note: If the destination IP of the encapsulated VXLAN packet ingress from the network side, and the Destination IP (DIP) is not VXLAN Gateway IP, the packet is not decapsulated. It is processed as a regular Layer 2/Layer 3 packet and switched by the outer Layer 2/Layer 3 headers.

Considering VTEPs within a DCI Domain

DCI establishes virtual connections called tunnels between specific physical devices or virtual machines over the logical network. This allow the advantage of not needing to change the physical topology of a network. The network separation is achieved through the use of software, thus making it a logical separation and not a physical one.

For example, when connecting two devices from different cloud data centers, the physical network between the hosts needs to be restructured for them to be in the same Layer 2 domain. Rather than physically altering the network, DCI provides the option of creating any virtual network topology and deploying it over the existing physical network.

To achieve this logical separation, DCI creates tunnels between the physical or virtual devices needed in a specific topology. A tunnel is created using the VXLAN protocol and it originates and terminates in a VXLAN Tunnel End Point (VTEP).

A VTEP can be created on a physical switch. Once a tunnel is set up, it gives the impression that the devices (physical or virtual) connected to its VTEPs are communicating across a Layer 2 domain. The underlying Layer 3 infrastructure is invisible to the devices communicating through the tunnel.

Static Configuration

You can statically configure all the VTEPs within the DCI domain.

After VTEP configuration, Ping can determine the health of the VTEPs before setting up the data path used for forwarding traffic. This means that the MAC addresses of the VTEPs and their attached switch interfaces are dynamically learned. You must statically configure VTEP information, VNI-to-VLAN mappings, and local physical ports that participate in the VXLAN/DCI topology. Local and remote MAC addresses are dynamically learned and associated to VTEPs.

To enable static configuration for network virtualization, use the following command:

```
Switch(config)# nwv mode static
```

To disable network virtualization on the switch, use the following command:

```
Switch(config)# no nwv mode
```

MP-BGP EVPN Configuration

Multi-protocol Border Gateway Protocol (MP-BGP) Ethernet Virtual Private Network (EVPN) is a control plane protocol used to exchange information between VTEPs. It dynamically learns and updates VTEP, VNI, and MAC entries on the devices where the VTEPs are configured.

MP-BGP EVPN distributes Layer 2 reachability information for VXLAN overlay network end hosts. Each VTEP learns MAC information from its locally attached hosts and then distributes this information to remote VTEPs using MP-BGP EVPN. This decreases network flooding when learning about end hosts and offers a better control over the distribution of end host reachability information.

To enable MP-BGP EVPN network virtualization on the switch, use the following command:

```
Switch(config)# nwv mode bgp-evpn
```

To disable network virtualization on the switch, use the following command:

```
Switch(config)# no nwv mode
```

DCI High Availability

DCI can be used together with Virtual Link Aggregation Group (vLAG) and Equal Cost Multiple Paths (ECMP) to provide a fully redundant active-active High Availability (HA) solution. For more details about vLAG and ECMP, see "Virtual Link Aggregation Groups" on page 313 and "ECMP Routes" on page 412.

In DCI HA solutions, vLAG peers are configured as a single device. The CLI commands used to configure the DCI are issued only on the primary vLAG switch and the resulting configuration is automatically synchronized with the secondary vLAG switch.

During vLAG role negotiation, the designated secondary vLAG switch deletes its DCI configuration when a new configuration is received from the primary vLAG switch. The secondary vLAG switch applies the new configuration and from this point on, you can continue to modify the DCI configuration only on the primary vLAG switch.

Configuration synchronization between the two vLAG peers is achieved as such:

- Global DCI and VXLAN configuration commands are executed only on the primary vLAG switch;
- Global and vLAG instance configuration commands relating to DCI are not accepted on the vLAG secondary switch;
- DCI commands executed on vLAG interfaces are applied on the vLAG peer on the corresponding vLAG interface;
- DCI commands executed on non-vLAG interfaces can be executed on either the primary or the secondary vLAG switch. The configuration is kept locally;
- The configuration needs to be saved on both switches, even if the configuration commands are executed only on the primary vLAG switch.

In a DCI solution, Forwarding Database (FDB) synchronization has the following behavior:

- FDB synchronization is initialized when the first vLAG interface is configured and it is stopped when all vLAG interfaces are in the `DOWN` state;
- Local MAC addresses that are learned on a vLAG interface are synchronized with the vLAG peer on the corresponding vLAG interface;
- Remote MAC addresses that are learned on network ports are synchronized with the vLAG peer - the same as within a vLAG instance;

Static Configuration

When implementing a DCI Static Configuration you must manually add the VXLAN topology information on all VTEPs within the DCI domain. Besides the local configuration (Local TEP information, VLAN-to-VNI mappings, and VXLAN enabled interfaces), you must also add the data about Remote VTEPs and Remote VTEP-to-VNI mappings.

BUM traffic within the DCI domain that is received on the access vPorts is replicated by the receiving device and sent as unicast VXLAN packets to all remote VTEPs that are part of the virtual network.

In DCI High Availability (HA) Static topologies, both the primary and the secondary vLAG switches share the same tunnel IP address, resulting in Bidirectional Forwarding Detection (BFD) to run only on one of the vLAG peers.

Only one of the vLAG switches establishes the BFD session and is considered BFD active, while its vLAG peer is considered BFD standby. The BFD standby switch only processes BFD session update messages received from the BFD active switch through the Edge Control Protocol (ECP). However, both vLAG switches receive BFD packets because of the upstream ECMP hash. BFD packets received by the BFD standby switch are forwarded to its vLAG peer across the ISL.

BFD `UP/DOWN` messages are synchronized between the vLAG switches to determine the active VTEP.

Remote VTEP health check is achieved by using BFD. A session is automatically established for every BFD enabled remote VTEP.

By default, remote VTEP health check is disabled on the switch. To enable it, use the following command:

```
Switch(config)# nwv vxlan
Switch(config-vxlan)# vtep <remote VTEP IP address> health-check
```

The following table shows the DCI tasks performed by each vLAG peer:

Table 52. *vLAG Peers DCI Tasks*

Primary vLAG switch	Secondary vLAG switch
	DCI configuration reset: During the vLAG role negotiation, the secondary vLAG switch deletes its DCI related configuration if it receives a new configuration from the primary vLAG switch.
DCI configuration synchronization	
(optional) Remote VTEP health checking	Remote VTEPs health checking: The secondary vLAG switch performs VTEP health checking only in the case of a vLAG failover

Table 52. *vLAG Peers DCI Tasks*

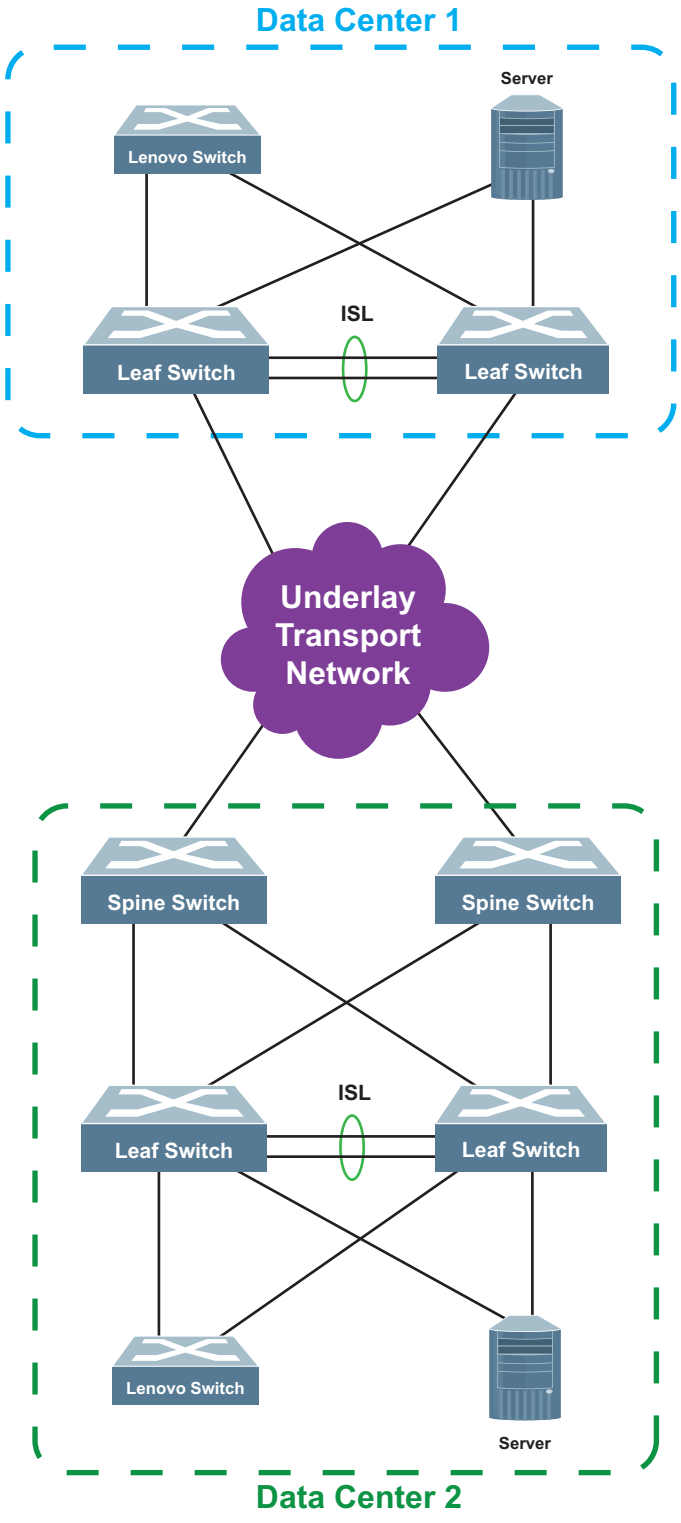
Primary vLAG switch	Secondary vLAG switch
(optional) Receive health check update notification messages	Receive health check update notification messages
MAC address learning	MAC address learning
FDB synchronization	FDB synchronization

To enable Static configuration High Availability DCI network virtualization, use the following command:

```
Switch(config)# nwv mode static ha
```

Note: vLAG ISL is automatically added as an Access Virtual Port for all VNIs.

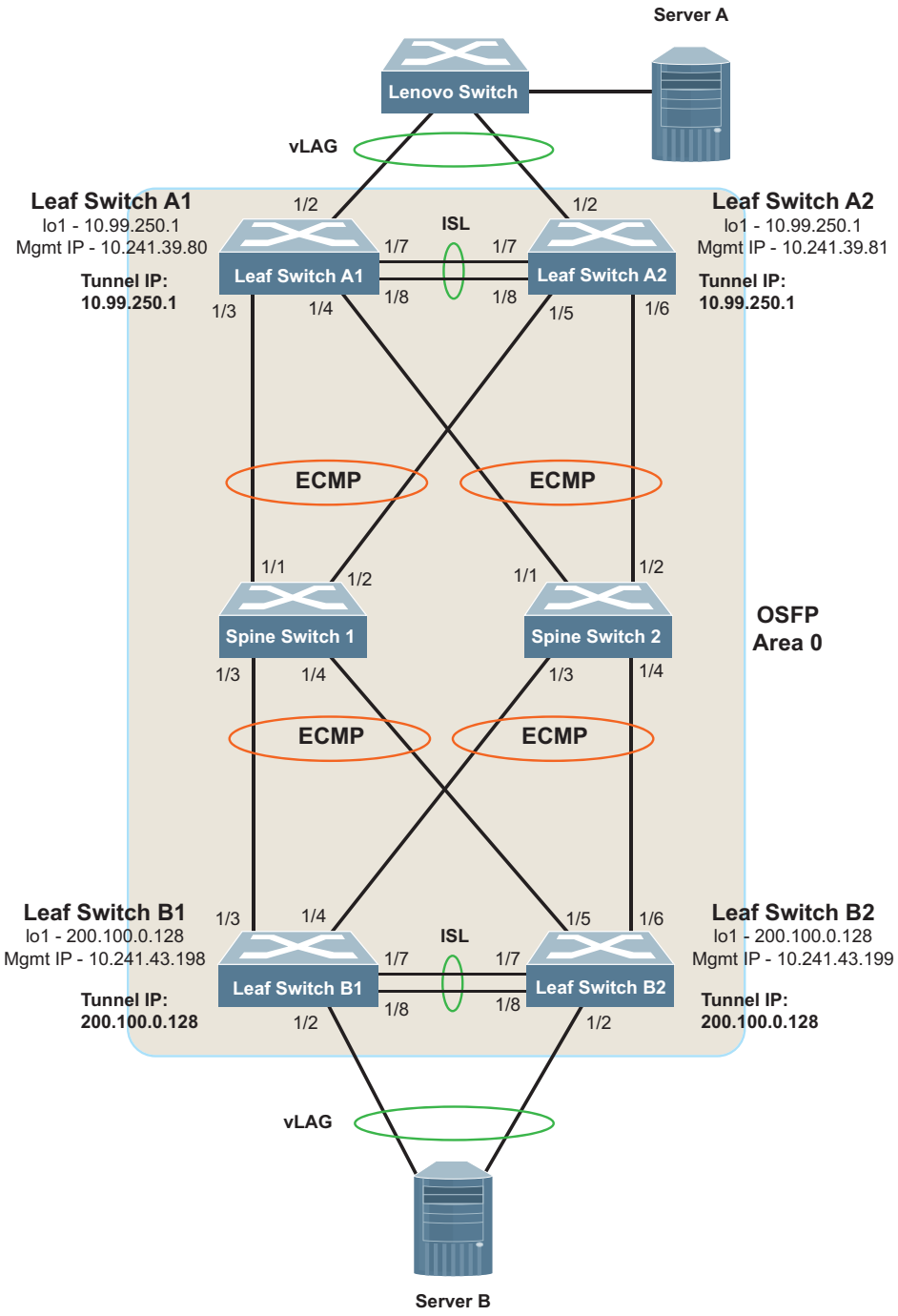
Figure 46. *DCI HA Static Topology Example*



DCI High Availability Static Configuration Example

Figure 47 is a basic example of a Lenovo CNOS DCI Static High Availability topology.

Figure 47. *DCI Static High Availability Topology Configuration Example*



Configuring Leaf Switches A1 and A2

The following steps show how to configure Leaf Switches A1 and A2 as members of the DCI High Availability solution:

vLAG Configuration

As a prerequisite for all DCI HA topologies, the vLAG configuration must be set up accordingly on both vLAG switches before proceeding with the DCI HA configuration.

As a requirement when configuring vLAG between the two leaf switches, ensure on both vLAG peers that the ISL LAG shares the same VLAN configuration. This is also required for the switch interfaces that are members of the vLAG instance.

Configure a vLAG between Leaf Switches 1 and 2. On both switches, ethernet ports 1/7 and 1/8 are used as the Inter-Switch Link (ISL) LAG 10, and ethernet ports 1/2 used for the vLAG instance in LAG 20.

For more details about vLAGs and how to configure them, see Chapter 13, "Virtual Link Aggregation Groups".

Note: The following steps need to be configured on both switches.

1. Create a static or an LACP LAG on ethernet port 1/2. For example, a static LAG:

```
Switch(config)# interface ethernet 1/2
Switch(config-if)# channel-group 501 mode on
Switch(config-if)# exit
```

2. Disable STP on the LAG used to connect the switch to Server A:

```
Switch(config)# interface port-channel 501
Switch(config-if)# spanning-tree disable
Switch(config-if)# exit
```

3. Create a LACP LAG on ethernet ports 1/7 and 1/8:

```
Switch(config)# interface ethernet 1/7-8
Switch(config-if-range)# channel-group 100 mode active
Switch(config-if-range)# exit
```

4. Configure the LAG used in the ISL between the vLAG peers:

```
Switch(config)# interface port-channel 100
Switch(config-if)# switchport mode trunk
Switch(config-if)# exit
```

5. Configure the vLAG tier ID:

```
Switch(config)# vlag tier-id 512
```

6. Configure Leaf Switch A1 as the primary vLAG switch:

```
Switch(config)# vlag priority 100
```

7. Configure Leaf Switch A2 as the secondary vLAG switch:

```
Switch(config)# vlag priority 200
```

8. Configure the vLAG ISL on the LAG which includes ethernet ports 1/7-8:

```
Switch(config)# vlag isl port-channel 100
```

9. Configure the health check IP address of the peer switch, using the management IP address of the peer switch:
   - Configure Leaf Switch A1 with the management IP address of Leaf Switch A2:

```
Switch(config)# vlag hlthchk peer-ip 10.241.39.81 vrf management
```

   - Configure Leaf Switch A2 with the management IP address of Leaf Switch A1:

```
Switch(config)# vlag hlthchk peer-ip 10.241.39.80 vrf management
```

10. Globally enable the vLAG:

```
Switch(config)# vlag enable
```

11. Configure the vLAG instance and enable it:

```
Switch(config)# vlag instance 1 port-channel 501
Switch(config)# vlag instance 1 enable
```

12. (Optional) Check the vLAG instance configuration:

```
Switch(config)# show vlag instance 1 information
```

```
Switch(config)# show vlag instance 1 configuration
```

Underlying Layer 3 Configuration

ECMP takes advantage of the available links and balances the incoming or outgoing VXLAN encapsulated traffic on Leaf Switches A1 and A2.

You need to configure the VTEP IP address on a loopback interface. Ensure that the loopback interface is correctly advertised within the routing protocol.

Note: The loopback interface configuration must be identical on both vLAG peers.

Routed interfaces can also be configured for OSPF ECMP.

1. Configure a unique OSPF router ID for each Leaf Switch:
   - Leaf Switch A1:

```
Switch(config)# router ospf 0
Switch(config-router)# router-id 210.73.40.140
Switch(config-router)# exit
```

   - Leaf Switch A2:

```
Switch(config)# router ospf 0
Switch(config-router)# router-id 210.73.50.92
Switch(config-router)# exit
```

2. Configure routed interfaces for OSPF ECMP:
   - Leaf Switch A1:

```
Switch(config)# interface Ethernet 1/3-4
Switch(config-if-range)# no switchport
Switch(config-if-range)# ip ospf network point-to-point
Switch(config-if-range)# ip router ospf 0 area 0.0.0.1
Switch(config-if-range)# mtu 9198
Switch(config-if-range)# exit

Switch(config)# interface Ethernet 1/3
Switch(config-if)# ip address 200.10.3.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/4
Switch(config-if)# ip address 200.10.4.1/24
Switch(config-if)# exit
```

- Leaf Switch A2:

```
Switch(config)# interface Ethernet 1/5-6
Switch(config-if-range)# no switchport
Switch(config-if-range)# ip ospf network point-to-point
Switch(config-if-range)# ip router ospf 0 area 0.0.0.1
Switch(config-if-range)# mtu 9198
Switch(config-if-range)# exit

Switch(config)# interface Ethernet 1/5
Switch(config-if)# ip address 200.20.5.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/6
Switch(config-if)# ip address 200.20.6.1/24
Switch(config-if)# exit
```

3. On both vLAG switches, configure a loopback interface which is used as the Tunnel IP address. This configuration must be the same on both vLAG peers:

```
Switch(config)# interface loopback 1
Switch(config-if)# no switchport
Switch(config-if)# ip address 10.99.250.1/32
Switch(config-if)# ip ospf network point-to-point
Switch(config-if)# ip router ospf 0 area 0.0.0.1
Switch(config-if)# exit
```

DCI HA Network Virtualization Configuration

The DCI HA configuration needs to be done manually. This includes all remote VTEP information, virtual network IDs, VNI-to-VLAN mappings and remote VTEP-to-VNI mappings must be configured manually by using the switch CLI.

When the vLAG is configured and the vLAG instance is formed, configuring the DCI must be done on the primary vLAG switch. The DCI configuration is automatically synchronized with the secondary vLAG switch.

Note: Once the configuration is complete, it needs to be saved on both devices.

1. Ensure you are configuring DCI on the primary vLAG switch:

```
Switch(config)# show vlag information

...
Role Information:
                  Local                       Peer
    -------------+---------------------------+-----------------------
    Admin Role   : Primary                     Secondary
    Oper Role    : Primary                     Secondary
    Priority     : 100                         200
...
```

2. On the primary vLAG switch, enter VXLAN configuration mode:

```
Switch(config)# nwx vxlan
```

3. Configure the local tunnel IP address:

```
Switch(config-vxlan)# tunnel interface ip 10.99.250.1
```

4. Configure a VNI-to-VLAN mapping:

```
Switch(config-vxlan)# vlan 10 virtual-network 1000
```

Note: Ensure that VLAN 10 is used only for VXLAN tunneling. Switch interfaces that are members of VLAN 10 and have VXLAN enabled are mapped to VNI 1000.

5. Configure a VTEP-to-VNI mapping:

```
Switch(config-vxlan)# vtep 200.100.0.128 virtual-network 1000
```

6. (Optional) Configure BFD health check for the remote VTEP:

```
Switch(config-vxlan)# vtep 200.100.0.128 health-check
Switch(config-vxlan)# exit
```

7. Enable VXLAN for LAG 501:

```
Switch(config)# interface port-channel 501
Switch(config-if)# vxlan enable
Switch(config-if)# exit
```

8. Configure the network virtualization mode to static configuration High Availability:

```
Switch(config)# nwv mode static ha
```

9. Save the current configuration as the startup configuration:

```
Switch(config)# copy running-configuration startup-configuration
```

10. Check the DCI configuration:

```
Switch(config)# show nwv vxlan information

Codes:  A - Access vPort
        N - Network vPort, M - Multicast Network vPort

Virtual Networks Count: 20
Tunnels Count: 1
Access vPorts Count: 2
Network vPorts Count: 2
Multicast vPorts Count: 2

Virtual Ports:
Interface           Mode     vPorts Count
---------           ----     ------------
po100               A        1
po501               A        1
Ethernet1/3         N/M      3
Ethernet1/4         N/M      3
```

```
Switch(config)# show nwv vxlan tunnel

Tunnel Count: 2

Tunnel IP Address     Tunnel Type    Status
-----------------     -----------    ------
10.99.250.1           Local          UP
200.100.0.128         Remote         UP
```

```
Switch(config)# show nwv vxlan virtual-network

Virtual Networks Count: 2

Local bindings:

VNID       VLAN   Interfaces              State
--------   ----   --------------------    -----------
1000       10     po100                   Enabled
                  po501                   Enabled

Remote bindings:
VNID       VTEPs              Status
--------   ----------------   --------
1000       200.100.0.128      UP
```

Configuring Spine Switches 1 and 2

The Spine Switches need to be configured to function in the Underlay Transport Network. In the example, we use OSPF.

1. Configure a unique OSPF router ID for each Spine Switch:
   - Spine Switch 1:

```
Switch(config)# router ospf 0
Switch(config-router)# router-id 220.108.140.53
Switch(config-router)# exit
```

   - Spine Switch 2:

```
Switch(config)# router ospf 0
Switch(config-router)# router-id 220.108.150.65
Switch(config-router)# exit
```

2. Configure routed interfaces for OSPF ECMP:
   - Spine Switch 1:

```
Switch(config)# interface Ethernet 1/1-2
Switch(config-if-range)# no switchport
Switch(config-if-range)# ip ospf network point-to-point
Switch(config-if-range)# ip router ospf 0 area 0.0.0.1
Switch(config-if-range)# mtu 9198
Switch(config-if-range)# exit

Switch(config)# interface Ethernet 1/1
Switch(config-if)# ip address 210.10.1.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/2
Switch(config-if)# ip address 210.10.2.1/24
Switch(config-if)# exit
```

   - Spine Switch 2:

```
Switch(config)# interface Ethernet 1/1-2
Switch(config-if-range)# no switchport
Switch(config-if-range)# ip ospf network point-to-point
Switch(config-if-range)# ip router ospf 0 area 0.0.0.1
Switch(config-if-range)# mtu 9198
Switch(config-if-range)# exit

Switch(config)# interface Ethernet 1/1
Switch(config-if)# ip address 210.20.1.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/2
Switch(config-if)# ip address 210.20.2.1/24
Switch(config-if)# exit
```

Configuring Leaf Switches B1 and B2

The following steps show how to configure leaf switches B1 and B2 as members of the DCI High Availability solution:

vLAG Configuration

As a prerequisite for all DCI HA topologies, the vLAG configuration must be set up accordingly on both vLAG switches before proceeding with the DCI HA configuration.

As a requirement when configuring vLAG between the two leaf switches, ensure on both vLAG peers that the ISL LAG shares the same VLAN configuration. This is also required for the switch interfaces that are members of the vLAG instance.

Configure a vLAG between Leaf Switches 1 and 2. On both switches, ethernet ports 1/7 and 1/8 are used as the Inter-Switch Link (ISL) LAG 10, and ethernet ports 1/2 used for the vLAG instance in LAG 20.

For more details about vLAGs and how to configure them, see Chapter 13, "Virtual Link Aggregation Groups".

Note: The following steps need to be configured on both switches.

1. Create a static or an LACP LAG on ethernet port 1/2. For example, a static LAG:

```
Switch(config)# interface ethernet 1/2
Switch(config-if)# channel-group 501 mode on
Switch(config-if)# exit
```

2. Disable STP on the LAG used to connect the switch to Server B:

```
Switch(config)# interface port-channel 501
Switch(config-if)# spanning-tree disable
Switch(config-if)# exit
```

3. Create a LACP LAG on ethernet ports 1/7 and 1/8:

```
Switch(config)# interface ethernet 1/7-8
Switch(config-if-range)# channel-group 100 mode active
Switch(config-if-range)# exit
```

4. Configure the LAG used in the ISL between the vLAG peers:

```
Switch(config)# interface port-channel 100
Switch(config-if)# switchport mode trunk
Switch(config-if)# exit
```

5. Configure the vLAG tier ID:

```
Switch(config)# vlag tier-id 256
```

6. Configure Leaf Switch B1 as the primary vLAG switch:

```
Switch(config)# vlag priority 100
```

7. Configure Leaf Switch B2 as the secondary vLAG switch:

```
Switch(config)# vlag priority 200
```

8. Configure the vLAG ISL on the LAG which includes ethernet ports 1/7-8:

```
Switch(config)# vlag isl port-channel 100
```

9. Configure the health check IP address of the peer switch, using the management IP address of the peer switch:
   a. Configure Leaf Switch B1 with the management IP address of Leaf Switch B2:

```
Switch(config)# vlag hlthchk peer-ip 10.241.43.199 vrf management
```

   b. Configure Leaf Switch B2 with the management IP address of Leaf Switch B1:

```
Switch(config)# vlag hlthchk peer-ip 10.241.43.198 vrf management
```

10. Globally enable the vLAG:

```
Switch(config)# vlag enable
```

11. Configure the vLAG instance and enable it:

```
Switch(config)# vlag instance 1 port-channel 501
Switch(config)# vlag instance 1 enable
```

12. (Optional) Check the vLAG instance configuration:

```
Switch(config)# show vlag instance 1 information
```

```
Switch(config)# show vlag instance 1 configuration
```

Underlying Layer 3 Configuration

ECMP takes advantage of the available links and balances the incoming or outgoing VXLAN encapsulated traffic on Leaf Switches B1 and B2.

You need to configure the VTEP IP address on a loopback interface. Ensure that the loopback interface is correctly advertised within the routing protocol.

Note: The loopback interface configuration must be identical on both vLAG peers.

Routed interfaces can also be configured for OSPF ECMP.

1. Configure a unique OSPF router ID for each Leaf Switch:
   - Leaf Switch B1:

```
Switch(config)# router ospf 0
Switch(config-router)# router-id 210.173.32.88
Switch(config-router)# exit
```

   - Leaf Switch B2:

```
Switch(config)# router ospf 0
Switch(config-router)# router-id 210.173.47.192
Switch(config-router)# exit
```

2. Configure routed interfaces for OSFP ECMP:
   - Leaf Switch B1:

```
Switch(config)# interface Ethernet 1/3-4
Switch(config-if-range)# no switchport
Switch(config-if-range)# ip ospf network point-to-point
Switch(config-if-range)# ip router ospf 0 area 0.0.0.1
Switch(config-if-range)# mtu 9198
Switch(config-if-range)# exit

Switch(config)# interface Ethernet 1/3
Switch(config-if)# ip address 220.10.3.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/4
Switch(config-if)# ip address 220.10.4.1/24
Switch(config-if)# exit
```

- Leaf Switch B2:

```
Switch(config)# interface Ethernet 1/5-6
Switch(config-if-range)# no switchport
Switch(config-if-range)# ip ospf network point-to-point
Switch(config-if-range)# ip router ospf 0 area 0.0.0.1
Switch(config-if-range)# mtu 9198
Switch(config-if-range)# exit

Switch(config)# interface Ethernet 1/5
Switch(config-if)# ip address 220.20.5.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/6
Switch(config-if)# ip address 220.20.6.1/24
Switch(config-if)# exit
```

3. On both vLAG switches, configure a loopback interface which is used as the Tunnel IP address. This configuration must be the same on both vLAG peers:

```
Switch(config)# interface loopback 1
Switch(config-if)# no switchport
Switch(config-if)# ip address 200.100.0.128/32
Switch(config-if)# ip ospf network point-to-point
Switch(config-if)# ip router ospf 0 area 0.0.0.1
Switch(config-if)# exit
```

DCI HA Network Virtualization Configuration

The DCI HA configuration needs to be done manually. This includes all remote VTEP information, virtual network IDs, VNI-to-VLAN mappings and remote VTEP-to-VNI mappings must be configured manually by using the switch CLI.

When the vLAG is configured and the vLAG instance is formed, configuring the DCI must be done on the primary vLAG switch. The DCI configuration is automatically synchronized with the secondary vLAG switch.

Note: Once the configuration is complete, it needs to be saved on both devices.

1. Ensure you are configuring DCI on the primary vLAG switch:

```
Switch(config)# show vlag information

...
Role Information:
                  Local                       Peer
    ------------+---------------------------+-----------------------
    Admin Role   : Primary                   Secondary
    Oper Role    : Primary                   Secondary
    Priority     : 100                       200
...
```

2. On the primary vLAG switch, enter VXLAN configuration mode:

```
Switch(config)# nwx vxlan
```

3. Configure the local tunnel IP address:

```
Switch(config-vxlan)# tunnel interface ip 200.100.0.128
```

4. Configure a VNI-to-VLAN mapping:

```
Switch(config-vxlan)# vlan 10 virtual-network 1000
```

Note: Ensure that VLAN 10 is used only for VXLAN tunneling. Switch interfaces that are members of VLAN 10 and have VXLAN enabled are mapped to VNI 1000.

5. Configure a VTEP-to-VNI mapping:

```
Switch(config-vxlan)# vtep 10.99.250.1 virtual-network 1000
```

6. (Optional) Configure BFD health check for the remote VTEP:

```
Switch(config-vxlan)# vtep 10.99.250.1 health-check
Switch(config-vxlan)# exit
```

7. Enable VXLAN for LAG 501:

```
Switch(config)# interface port-channel 501
Switch(config-if)# vxlan enable
Switch(config-if)# exit
```

8. Configure the network virtualization mode to static configuration High Availability:

```
Switch(config)# nwv mode static ha
```

9. Save the current configuration as the startup configuration:

```
Switch(config)# copy running-configuration startup-configuration
```

10. Check the DCI configuration:

```
Switch(config)# show nwv vxlan information

Codes:  A - Access vPort
        N - Network vPort, M - Multicast Network vPort

Virtual Networks Count: 20
Tunnels Count: 1
Access vPorts Count: 2
Network vPorts Count: 2
Multicast vPorts Count: 2

Virtual Ports:
Interface           Mode     vPorts Count
---------           ----     ------------
po100               A        1
po501               A        1
Ethernet1/3         N/M      3
Ethernet1/4         N/M      3
```

```
Switch(config)# show nwv vxlan tunnel

Tunnel Count: 2

Tunnel IP Address     Tunnel Type    Status
-----------------     -----------    ------
200.100.0.128         Local          UP
10.99.250.1           Remote         UP
```

```
Switch(config)# show nwv vxlan virtual-network

Virtual Networks Count: 2

Local bindings:

VNID       VLAN   Interfaces              State
--------   ----   ---------------------   -----------
1000       10     po100                   Enabled
                  po501                   Enabled

Remote bindings:
VNID       VTEPs              Status
--------   ----------------   --------
1000       10.99.250.1        UP
```

MP-BGP EVPN

Virtual Extensible LAN (VXLAN) offers the same Ethernet Layer 2 services as the VLAN protocol, but with increased flexibility and scalability. The VXLAN protocol uses an overlay mechanism to tunnel virtualized network traffic over existing Layer 2 networks.

When deploying a distributed solution for a VXLAN network, Control Plane information is exchanged between VXLAN Tunnel End Points (VTEPs) by using Multi-protocol Border Gateway Protocol (MP-BGP) Ethernet Virtual Private Network (EVPN).

MP-BGP EVPN offers a control plane through which to discover protocol based VTEP peers, and also presents a feature set that allows for optimal forwarding of both west-east traffic and south-north traffic in the VXLAN network.

Usual topologies that support MP-BGP EVPN include the following types of network devices:

- MP-BGP EVPN capable devices for IP transport

  Such devices provide IP transport for the underlaying network. They can also distribute MP-BGP EVPN routes among their peers and they can be either route reflectors or iBGP EVPN peers. IP routing is achieved only by using the outer IP address of a VXLAN encapsulated packet. These devices are not required to support VXLAN data encapsulation or decapsulation.

- VTEPs running MP-BGP EVPN

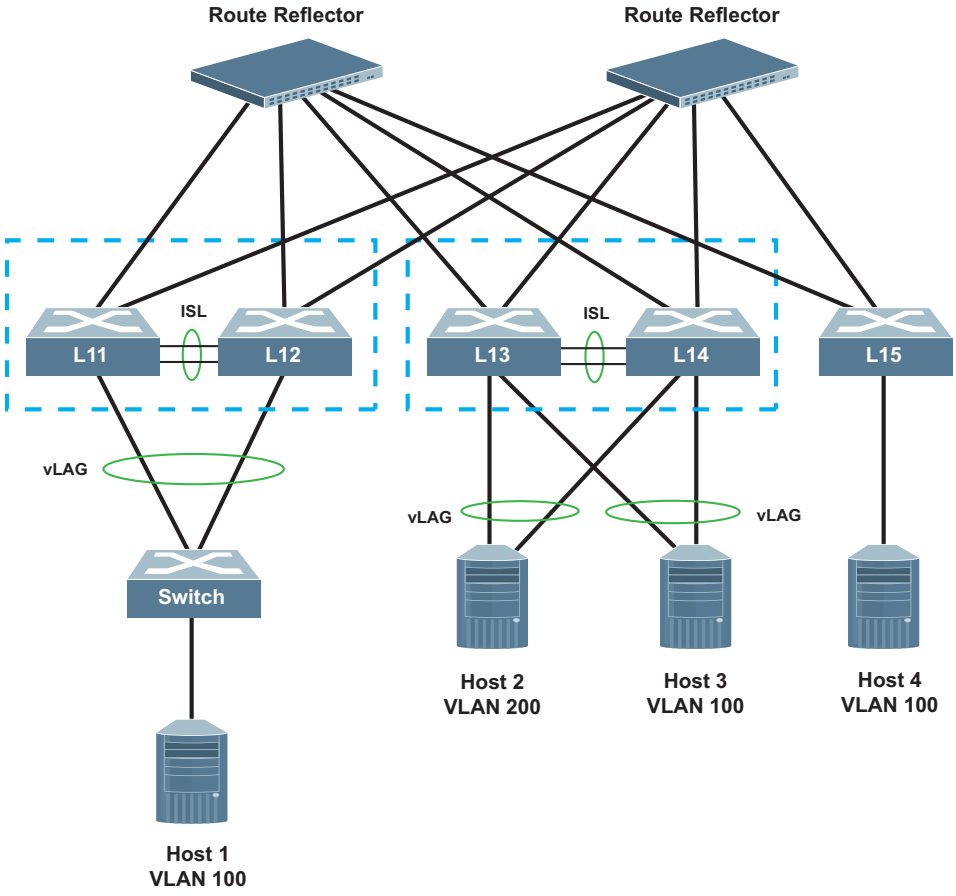
  Such VTEPs support Control Plane functions which allows them to initiate MP-BGP EVPN routes advertisement from their local hosts, and to receive updates from their peers and install EVPN routes in their tables.

  They also support data plane functions which allows them to encapsulate network traffic using VXLAN and then send the encapsulated traffic over the underlaying IP network. When receiving VXLAN encapsulated packets from other VTEPs, they decapsulate the packets, encapsulate them using native Ethernet, and then forward them to the host.

Note: The supported BGP routes IPv4/IPv6/EVPN existing in BGP is limited to a maximum of 120.000 on all existing VRFs. When the limit is exceeded, a message is displayed: Memory for route nodes exceeded. Ignoring route.

Figure 48 is an example of MP-BGP EVPN VXLAN topology, used to interconnect hosts within a data center.

Figure 48. *MP-BGP EVPN VXLAN Topology Example*



Within the EVPN VXLAN overlay network, VXLAN network identifiers (VNIs) define the Layer 2 domains and segmentation among these domains is done by denying Layer 2 traffic to cross the VNI boundaries.

The Layer 2 VPN (L2VPN) address family for EVPN uses Route Distinguishers (RDs) to differentiate between MAC-VRF tables. RDs must be set to the route distinguisher of the MAC-VRF instance that is advertising the Network Layer Reachability Information (NLRI). An Provider Edge (PE) router is a router between one network service provider's area and areas administered by other network providers. An RD must be assigned for a given MAC-VRF instance on a PE router. The assigned RD must be unique across all MAC-VRF instances on a PE router.

MP-BGP EVPN uses Route Targets (RTs) to define the policies determining how routes are advertised and distributed in the MAC-VRF instances. RTs manage the import and export of routes between them. The RT attributes for a route are distributed in the form of a BGP extended community attribute.

To make the MP-BGP EVPN DCI configuration easier, BGP Route Distinguishers and Route Targets are generated automatically. An RD for a switch is derived automatically from the local Tunnel IP address and the VNI, while an RT is generated automatically from the Autonomous System (AS) number of the local BGP instance and the VNI.

A VTEP switch inserts its own Tunnel IP address in the BGP Tunnel Encapsulation attribute when it originates MP-BGP EVPN routes for its locally learned end-hosts. Remote VTEPs use this attribute to learn the originating VTEP address and use it as the next-hop address for VXLAN encapsulation when forwarding packets across the overlaying network.

The underlaying network only provides IP reachability for all the VTEP addresses, and it does not need to learn the EVPN routes.

MP-BGP EVPN supports the following types of routes:

- Type 1 - Ethernet Auto-Discovery (A-D) Route with the two subtypes:
  - Ethernet A-D per Ethernet Segment
  - Ethernet A-D per EVPN instance route
- Type 2 - MAC/IP Advertisement route
- Type 3 - Inclusive Multicast Route

An Ethernet Segment (ES) represents the link or set of links that connect a customer site (device or network) to a Leaf switch. Each Ethernet Segment is associated an unique non-zero identifier (called Ethernet Segment Identifier).

An EVPN Instance represents a VNI.

BGP neighbors can be configured as Bidirectional Forwarding Detection (BFD) multi-hop peers. BFD provides failure detection in the forwarding path for destinations that are directly connected one hop or more away from the switch. For more details about BFD multi-hop peers, see BFD Peer Support.

To configure a BGP neighbor as a BFD multi-hop peer, use the following command:

```
Switch(config)# router bgp <AS number>
Switch(config-router)# neighbor <IP address> remote-as <AS number>
Switch(config-router-neighbor)# bfd multihop-peer
```

For example:

```
Switch(config)# router bgp 400
Switch(config-router)# neighbor 190.44.177.3 remote-as 3300
Switch(config-router-neighbor)# bfd multihop-peer
```

DCI High Availability MP-BGP EVPN

The following table shows the DCI tasks performed by each vLAG peer in a DCI High Availability (HA) MP-BGP EVPN topology:

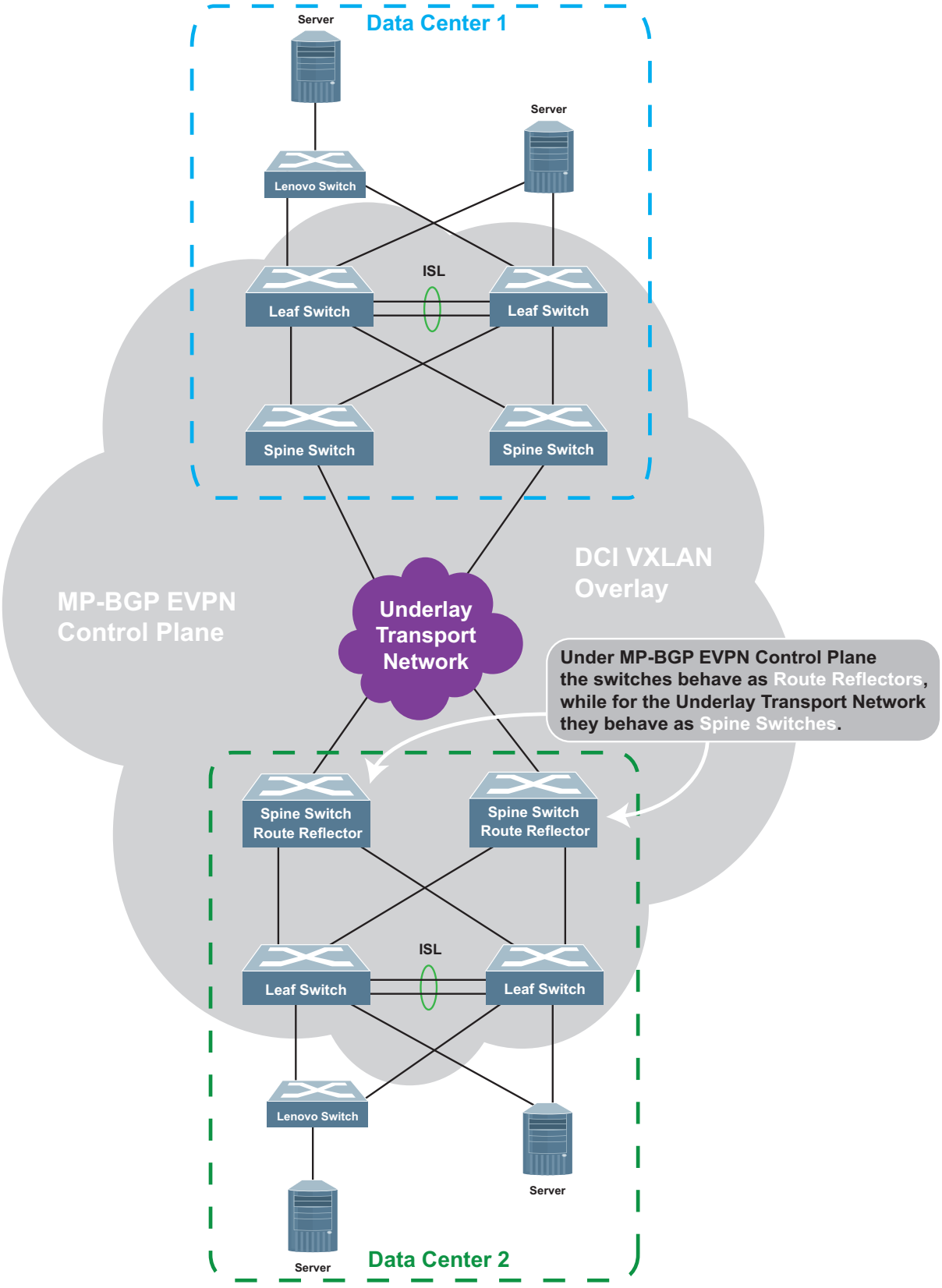
Table 53. *vLAG Peers DCI Tasks*

Primary vLAG switch	Secondary vLAG switch
	DCI configuration reset: During the vLAG role negotiation, the secondary vLAG switch deletes its DCI related configuration if it receives a new configuration from the primary vLAG switch.
DCI configuration synchronization	
MAC address learning	MAC address learning
FDB synchronization	FDB synchronization

To enable MP-BGP EVPN High Availability DCI network virtualization, use the following command:

```
Switch(config)# nwv mode bgp-evpn ha
```

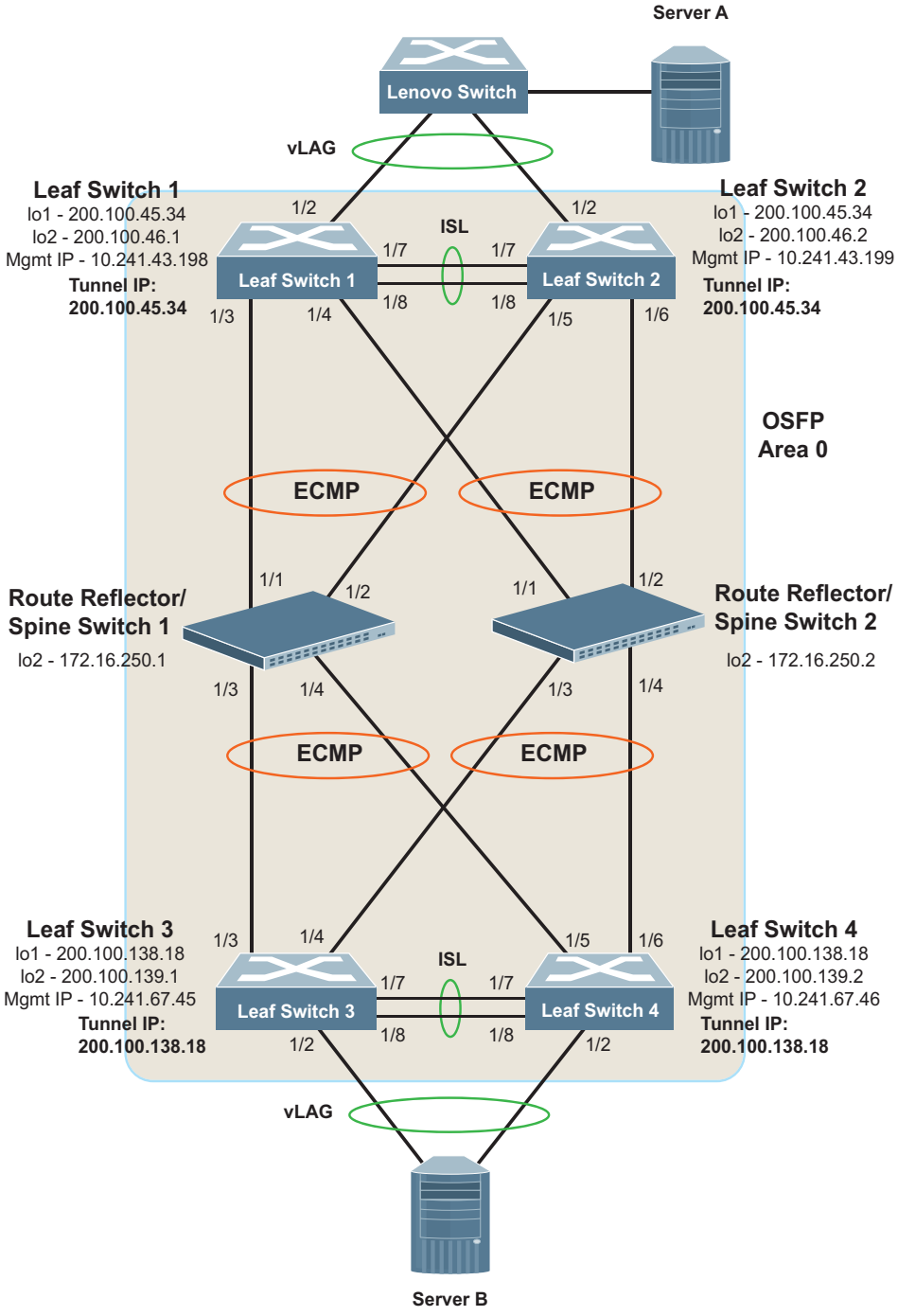
Figure 49. *DCI HA MP-BGP EVPN Topology Example*



DCI High Availability MP-BGP EVPN Configuration Example

Figure 50 is a basic example of a Lenovo CNOS DCI MP-BGP EVPN High Availability topology.

Figure 50. *DCI MP-BGP EVPN High Availability Topology Configuration Example*



vLAG Configuration

As a prerequisite for all DCI HA topologies, the vLAG configuration must be set up accordingly on vLAG switches before proceeding with the DCI HA configuration.

As a requirement when configuring vLAG between the two leaf switches, ensure on both vLAG peers that the ISL LAG shares the same VLAN configuration. This is also required for the switch interfaces that are members of the vLAG instance.

For more details about vLAGs and how to configure them, see Chapter 13, "Virtual Link Aggregation Groups".

Configure vLAG on Leaf Switches 1 and 2

Configure a vLAG between Leaf Switches 1 and 2. On both switches, ethernet ports 1/7 and 1/8 are used as the Inter-Switch Link (ISL) LAG 10, and ethernet ports 1/2 used for the vLAG instance in LAG 20.

Note: The following steps need to be configured on both switches.

1. Create the VLANs used in the configuration:

```
Switch(config)# vlan 100,200
Switch(config-vlan)# exit
```

2. Create a static or an LACP LAG on ethernet port 1/2. For example, a LACP LAG:

```
Switch(config)# interface ethernet 1/2
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 100,200
Switch(config-if)# channel-group 20 mode active
Switch(config-if)# exit
```

3. Configure the LAG used to connect the switch to Server A as an trunk port and disable STP on it:

```
Switch(config)# interface port-channel 20
Switch(config-if)# spanning-tree disable
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 100,200
Switch(config-if)# exit
```

4. Create a LACP LAG on ethernet ports 1/7 and 1/8:

```
Switch(config)# interface ethernet 1/7-8
Switch(config-if-range)# switchport mode trunk
Switch(config-if-range)# switchport trunk allowed vlan 100,200
Switch(config-if-range)# channel-group 10 mode active
Switch(config-if-range)# exit
```

5. Configure the LAG used in the ISL between the vLAG peers:

```
Switch(config)# interface port-channel 10
Switch(config-if)# switchport mode trunk
Switch(config-if)# switchport trunk allowed vlan 100,200
Switch(config-if)# lacp suspend-individual
Switch(config-if)# exit
```

6. Configure the vLAG tier ID:

```
Switch(config)# vlag tier-id 512
```

Note: If you have multiple vLAGs in the DCI MP-BGP EVPN topology, configure a different tier-id for each vLAG, from 1-255.

7. Configure the vLAG roles by setting their vLAG priorities:
   - Leaf Switch 1 as the primary vLAG switch:

```
Switch(config)# vlag priority 100
```

   - Leaf Switch 2 as the secondary vLAG switch:

```
Switch(config)# vlag priority 200
```

8. Configure the vLAG ISL on the LAG which includes ethernet ports 1/7-8:

```
Switch(config)# vlag isl port-channel 10
```

9. Configure the health check IP address of the peer switch, using the management IP address of the peer switch:
   a. Configure Leaf Switch 1 with the management IP address of Leaf Switch 2:

```
Switch(config)# vlag hlthchk peer-ip 10.241.43.199 vrf management
```

   b. Configure Leaf Switch 2 with the management IP address of Leaf Switch 1:

```
Switch(config)# vlag hlthchk peer-ip 10.241.43.198 vrf management
```

10. Globally enable the vLAG:

```
Switch(config)# vlag enable
```

11. Configure the vLAG instance and enable it:

```
Switch(config)# vlag instance 1 port-channel 20
Switch(config)# vlag instance 1 enable
```

Underlying Transport Network Configuration

ECMP takes advantage of the available links and balances the incoming or outgoing VXLAN encapsulated traffic on Leaf Switches 1 and 2.

You need to configure the VTEP IP address on a loopback interface. Ensure that the loopback interface is correctly advertised within the routing protocol.

Routed interfaces can also be configured for ECMP.

Configuring the Underlying Transport Network on Leaf Switch 1

1. Configure the OSPF router ID:

```
Switch(config)# router ospf 0
Switch(config-router)# router-id 210.173.32.80
Switch(config-router)# exit
```

2. Configure routed interfaces for ECMP:

```
Switch(config)# interface Ethernet 1/3-4
Switch(config-if-range)# no switchport
Switch(config-if-range)# ip ospf network point-to-point
Switch(config-if-range)# ip router ospf 0 area 0.0.0.1
Switch(config-if-range)# mtu 9198
Switch(config-if-range)# exit

Switch(config)# interface Ethernet 1/3
Switch(config-if)# ip address 10.137.3.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/4
Switch(config-if)# ip address 10.137.4.1/24
Switch(config-if)# exit
```

3. Configure a loopback interface which is used as the Tunnel IP address:

```
Switch(config)# interface loopback 1
Switch(config-if)# no switchport
Switch(config-if)# ip address 200.100.45.34/32
Switch(config-if)# ip ospf network point-to-point
Switch(config-if)# ip router ospf 0 area 0.0.0.1
Switch(config-if)# description DCI_VTEP (optional)
Switch(config-if)# exit
```

Notes:

- The loopback interface configuration must be identical on both Leaf Switches 1 and 2 (vLAG peers);
- While the interface description is optional, it can be useful to be able to differentiate between loopback interfaces.

4. Configure a second loopback interface to used in the MP-BGP EVPN control plane and the DCI VXLAN overlay:

```
Switch(config)# interface loopback 2
Switch(config-if)# no switchport
Switch(config-if)# ip address 200.100.46.1/32
Switch(config-if)# ip ospf network point-to-point
Switch(config-if)# ip router ospf 0 area 0.0.0.1
Switch(config-if)# description Leaf1_MP_BGP_source (optional)
Switch(config-if)# exit
```

Configuring the Underlying Transport Network on Leaf Switch 2

1. Configure the OSPF router ID:

```
Switch(config)# router ospf 0
Switch(config-router)# router-id 210.173.34.60
Switch(config-router)# exit
```

2. Configure routed interfaces for ECMP:

```
Switch(config)# interface Ethernet 1/5-6
Switch(config-if-range)# no switchport
Switch(config-if-range)# ip ospf network point-to-point
Switch(config-if-range)# ip router ospf 0 area 0.0.0.1
Switch(config-if-range)# mtu 9198
Switch(config-if-range)# exit

Switch(config)# interface Ethernet 1/5
Switch(config-if)# ip address 10.147.5.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/6
Switch(config-if)# ip address 10.147.6.1/24
Switch(config-if)# exit
```

3. Configure a loopback interface which is used as the Tunnel IP address:

```
Switch(config)# interface loopback 1
Switch(config-if)# no switchport
Switch(config-if)# ip address 200.100.45.34/32
Switch(config-if)# ip ospf network point-to-point
Switch(config-if)# ip router ospf 0 area 0.0.0.1
Switch(config-if)# description DCI_VTEP (optional)
Switch(config-if)# exit
```

Notes:

- The loopback interface configuration must be identical on both Leaf Switches 1 and 2 (vLAG peers);
- While the interface description is optional, it can be useful to be able to differentiate between loopback interfaces.

4. Configure a second loopback interface to used in the MP-BGP EVPN control plane and the DCI VXLAN overlay:

```
Switch(config)# interface loopback 2
Switch(config-if)# no switchport
Switch(config-if)# ip address 200.100.46.2/32
Switch(config-if)# ip ospf network point-to-point
Switch(config-if)# ip router ospf 0 area 0.0.0.1
Switch(config-if)# description Leaf2_MP_BGP_source (optional)
Switch(config-if)# exit
```

Configuring the Underlying Transport Network on Route Reflector 1

1. Configure the OSPF router ID:

```
Switch(config)# router ospf 0
Switch(config-router)# router-id 210.173.35.20
Switch(config-router)# exit
```

2. Configure a loopback interface to be used in the MP-BGP EVPN control plane and the DCI VXLAN overlay:

```
Switch(config)# interface loopback 2
Switch(config-if)# no switchport
Switch(config-if)# ip address 172.16.250.1/32
Switch(config-if)# ip router ospf 0 area 0
Switch(config-if)# ip ospf network point-to-point
Switch(config-if)# description Spine1_MP_BGP_source (optional)
Switch(config-if)# exit
```

While the interface description is optional, it can be useful to be able to differentiate between loopback interfaces.

3. Configure routed interfaces for OSPF ECMP:

```
Switch(config)# interface Ethernet 1/1-4
Switch(config-if-range)# no switchport
Switch(config-if-range)# ip ospf network point-to-point
Switch(config-if-range)# ip router ospf 0 area 0.0.0.1
Switch(config-if-range)# mtu 9198
Switch(config-if-range)# exit

Switch(config)# interface Ethernet 1/1
Switch(config-if)# ip address 10.107.10.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/2
Switch(config-if)# ip address 10.107.20.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/3
Switch(config-if)# ip address 10.107.30.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/4
Switch(config-if)# ip address 10.107.40.1/24
Switch(config-if)# exit
```

Configuring the Underlying Transport Network on Route Reflector 2

1. Configure the OSPF router ID:

```
Switch(config)# router ospf 0
Switch(config-router)# router-id 210.173.36.10
Switch(config-router)# exit
```

2. Configure a loopback interface to be used in the MP-BGP EVPN control plane and the DCI VXLAN overlay:

```
Switch(config)# interface loopback 2
Switch(config-if)# no switchport
Switch(config-if)# ip address 172.16.250.2/32
Switch(config-if)# ip router ospf 0 area 0
Switch(config-if)# ip ospf network point-to-point
Switch(config-if)# description Spine2_MP_BGP_source (optional)
Switch(config-if)# exit
```

   While the interface description is optional, it can be useful to be able to differentiate between loopback interfaces.

3. Configure routed interfaces for OSPF ECMP:

```
Switch(config)# interface Ethernet 1/1-4
Switch(config-if-range)# no switchport
Switch(config-if-range)# ip ospf network point-to-point
Switch(config-if-range)# ip router ospf 0 area 0.0.0.1
Switch(config-if-range)# mtu 9198
Switch(config-if-range)# exit

Switch(config)# interface Ethernet 1/1
Switch(config-if)# ip address 10.117.10.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/2
Switch(config-if)# ip address 10.117.20.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/3
Switch(config-if)# ip address 10.117.30.1/24
Switch(config-if)# exit

Switch(config)# interface Ethernet 1/4
Switch(config-if)# ip address 10.117.40.1/24
Switch(config-if)# exit
```

MP-BGP EVPN Configuration

You need to configure MP-BGP EVPN as the control plane through which to discover protocol based VTEP peers.

Configure MP-BGP EVPN on Leaf Switches 1 and 2

You need to configure local MAC address redistribution and the route reflectors as BGP neighbors.

1. Configure the BGP router ID. This configuration must be the same on both vLAG peers.

```
Switch(config)# router bgp 400
Switch(config-router)# router-id 20.45.135.178
```

Note: In HA mode, we recommend you to have the same BGP router ID on both vLAG peers (preferably manually configured).

2. Configure the redistribution of locally learned MAC addresses:

```
Switch(config-router)# address-family l2vpn evpn
Switch(config-router-af)# redistribute host-info
Switch(config-router-af)# exit
```

3. Configure the Route Reflectors as BGP neighbors. Optionally, you can also configure them as BFD multi-hop peers. This configuration must be the same on both vLAG peers:

```
Switch(config-router)# neighbor 172.16.250.1 remote-as 400
Switch(config-router-neighbor)# update-source loopback2
Switch(config-router-neighbor)# bfd multihop (optional)
Switch(config-router-neighbor)# address-family l2vpn evpn
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit

Switch(config-router)# neighbor 172.16.250.2 remote-as 400
Switch(config-router-neighbor)# update-source loopback2
Switch(config-router-neighbor)# bfd multihop (optional)
Switch(config-router-neighbor)# address-family l2vpn evpn
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

Note: After configuring the EVPN address family, the sending of extended community attributes is automatically enabled to that BGP neighbor:

```
! send-community extended
```

4. (Optional) To check the automatically generated information that contains the Route Distinguishers (RDs) and Route Targets (RTs) for each VNI, use the following command:

```
Switch(config)# show ip bgp statistics
...
EVPN vrfs configuration:
vrf context bgp100/rd 200.100.45.34:100/route-target both 1:268435556
...
```

These are generated based on the Network Virtualization Daemon (NWVD) configuration as soon as the Access Virtual Port goes up.

The Route Distinguisher (RD) is formed from the local Tunnel IP address and the virtual network identifier.

Configure MP-BGP EVPN on Route Reflector 1

1. Configure a unique BGP router ID:

```
Switch(config)# router bgp 400
Switch(config-router)# router-id 200.130.133.54
```

Note: The router IDs of the Route Reflectors must be unique and not shared with other network devices, such as leaf switches participating in a vLAG instance.

2. Configure L2VPN EVPN address family:

```
Switch(config-router)# address-family l2vpn evpn
Switch(config-router-af)# exit
```

3. Configure the Leaf Switches as BGP neighbors and enable them as route reflector clients:

   - Leaf Switch 1:

```
Switch(config-router)# neighbor 200.100.46.1 remote-as 400
Switch(config-router-neighbor)# update-source loopback2
Switch(config-router-neighbor)# bfd multihop (optional)
Switch(config-router-neighbor)# address-family l2vpn evpn
Switch(config-router-neighbor-af)# route-reflector-client
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

   - Leaf Switch 2:

```
Switch(config-router)# neighbor 200.100.46.2 remote-as 400
Switch(config-router-neighbor)# update-source loopback2
Switch(config-router-neighbor)# bfd multihop (optional)
Switch(config-router-neighbor)# address-family l2vpn evpn
Switch(config-router-neighbor-af)# route-reflector-client
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

- Leaf Switch 3:

```
Switch(config-router)# neighbor 200.100.139.1 remote-as 400
Switch(config-router-neighbor)# update-source loopback2
Switch(config-router-neighbor)# bfd multihop (optional)
Switch(config-router-neighbor)# address-family l2vpn evpn
Switch(config-router-neighbor-af)# route-reflector-client
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

- Leaf Switch 4:

```
Switch(config-router)# neighbor 200.100.139.2 remote-as 400
Switch(config-router-neighbor)# update-source loopback2
Switch(config-router-neighbor)# bfd multihop (optional)
Switch(config-router-neighbor)# address-family l2vpn evpn
Switch(config-router-neighbor-af)# route-reflector-client
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

Note: After configuring the EVPN address family, the sending of extended community attributes is automatically enabled to that BGP neighbor:

```
! neighbor 10.187.60.134 remote-as 400
!   address-family l2vpn evpn
!     route-reflector-client
!     send-community extended (this configuration line is automatically added)
```

Configure MP-BGP EVPN on Route Reflector 2

1. Configure a unique BGP router ID:

```
Switch(config)# router bgp 400
Switch(config-router)# router-id 200.130.154.90
```

Note: The router IDs of the Route Reflectors must be unique and not shared with other network devices, such as leaf switches participating in a vLAG instance.

2. Configure L2VPN EVPN address family:

```
Switch(config-router)# address-family l2vpn evpn
Switch(config-router-af)# exit
```

3. Configure the Leaf Switches as BGP neighbors and enable them as route reflector clients:

- Leaf Switch 1:

```
Switch(config-router)# neighbor 200.100.46.1 remote-as 400
Switch(config-router-neighbor)# update-source loopback2
Switch(config-router-neighbor)# bfd multihop (optional)
Switch(config-router-neighbor)# address-family l2vpn evpn
Switch(config-router-neighbor-af)# route-reflector-client
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

- Leaf Switch 2:

```
Switch(config-router)# neighbor 200.100.46.2 remote-as 400
Switch(config-router-neighbor)# update-source loopback2
Switch(config-router-neighbor)# bfd multihop (optional)
Switch(config-router-neighbor)# address-family l2vpn evpn
Switch(config-router-neighbor-af)# route-reflector-client
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

- Leaf Switch 3:

```
Switch(config-router)# neighbor 200.100.139.1 remote-as 400
Switch(config-router-neighbor)# update-source loopback2
Switch(config-router-neighbor)# bfd multihop (optional)
Switch(config-router-neighbor)# address-family l2vpn evpn
Switch(config-router-neighbor-af)# route-reflector-client
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

- Leaf Switch 4:

```
Switch(config-router)# neighbor 200.100.139.2 remote-as 400
Switch(config-router-neighbor)# update-source loopback2
Switch(config-router-neighbor)# bfd multihop (optional)
Switch(config-router-neighbor)# address-family l2vpn evpn
Switch(config-router-neighbor-af)# route-reflector-client
Switch(config-router-neighbor-af)# exit
Switch(config-router-neighbor)# exit
```

Note: After configuring the EVPN address family, the sending of extended community attributes is automatically enabled to that BGP neighbor:

```
! neighbor 10.127.210.17 remote-as 400
!   address-family l2vpn evpn
!     route-reflector-client
!     send-community extended (this configuration line is automatically added)
```

Note: Make sure the import/export (auto-generated) route targets match. They must be included in the packet (send-community-extended). If they don't mach, you must set them manually.

Check the MP-BGP EVPN Configuration

Check the configuration by displaying MP-BGP EVPN information on Leaf Switch 1 or 2:

```
Switch(config)# show ip bgp l2vpn evpn

BGP routing table information for  address family L2VPN evpn
BGP table version is 1, local router ID is 200.100.45.34
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal, l - labeled
              S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete, |- multipath

EVPN type-1 prefix: [1]:[ESI]:[EthTag]
EVPN type-2 prefix: [2]:[ESI]:[EthTag]:[MAClen]:[MAC]

    Network                                          Next Hop       Metric  LocPrf  Weight Path
Route distinguisher = 200.100.138.18:0, virtual-network default
*>i [1]:[159][01A897DC1B8100419F00]:[4294967295]    10.117.23.29           100      0        i

Route distinguisher = 200.100.138.18:10027, virtual-network 10027 Ref = 43
*>i [3]:[0]:[32][200.200.0.64]
                                                   200.100.138.18         100      0        i
* i
                                                   200.100.138.18         100      0        i
*>i [2]:[65][01A48CDB67A500964100]:[0]:[48]:[0000.aaaa.aac4]:[0][0]
                                                   200.100.138.18         100      0        i
* i
                                                   200.100.138.18         100      0        i
*>i [1]:[65][01A48CDB67A500964100]:[0]
                                                   200.100.138.18         100      0        i
* i
                                                   200.100.138.18         100      0        i
*>i [1]:[255][01A48CDB67A500FFFF00]:[0]
                                                   200.100.138.18         100      0        i
* i
                                                   200.100.138.18         100      0        i

Total number of prefixes 7
```

```
Switch(config)# show nwv vxlan information

Network Virtualization Mode: BGP-EVPN HA
Codes:  A - Access vPort
        N - Network vPort, M - Multicast Network vPort

Virtual Networks Count: 100
Remote Tunnels Count: 3
Access vPorts Count: 205
Network vPorts Count: 600
Multicast vPorts Count: 600

Virtual Ports:
Interface           Mode     vPorts  Count
---------           ----     ------- -----
po100               A        100
po501               A        50
po502               A        50
po1001              A        1
Ethernet1/49        N/M      300
Ethernet1/50        N/M      300
```

DCI HA Network Virtualization Configuration

The VXLAN protocol uses an overlay mechanism to tunnel virtualized network traffic over existing Layer 2 networks.

Configuring Network Virtualization on Leaf Switches 1 and 2

1. Configure the VLAN-to-VNI mappings on Leaf Switch 1:

```
Switch(config)# nwv vxlan
Switch(config-vxlan)# vlan 10 virtual-network 1000
```

2. Configure the local Tunnel IP address on Leaf Switch 1:

```
Switch(config-vxlan)# tunnel interface ip 200.100.45.34
Switch(config-vxlan)# exit
```

3. Configure DCI MP-BGP EVPN High Availability network virtualization on Leaf Switch 1:

```
Switch(config)# nwv mode bgp-evpn ha
```

4. Configure VXLAN on LAG 20 on the primary vLAG switch (Leaf Switch 1):

```
Switch(config)# interface port-channel 20
Switch(config-if)# vxlan enable
Switch(config-if)# exit
```

DCI Configuration Considerations and Limitations

To accommodate the overhead added by the VXLAN encapsulation, we recommend that you increase the maximum transmission unit (MTU) to at least 1,550 bytes for the interfaces of the spine switches that are part of the DCI solution and the network devices participating in the Underlay Transport Network.

To increase the MTU of a switch interface, use the following command:

```
Switch(config-if)# mtu 1550
```

DCI General Considerations and Limitations

The following limitations apply when configuring a DCI solution:

- 802.1Q (dot1q) tunnel VLAN is not used during VXLAN processing. Therefore, dot1q tunneling feature in conjunction with VXLAN is not operational;
- VXLAN routing will be supported in a future release;
- VXLAN cannot be enabled on a switch interface when:
  - the interface is configured in hybrid switchport mode;
  - Private VLAN (PVLAN) is enabled on an interface;
  - the interface is configured as ISL;
  - the interface is member of an aggregation group. (VXLAN should be enabled on the port-channel interface, not on the members).
- The switch supports only one-to-one VNI-to-VLAN mappings;
- A VLAN that is mapped to a VNI must be used only for packet switching within the associated virtual network. If VXLAN is enabled on an interface after the maximum number of virtual port is reached, the corresponding virtual ports will no longer be created;
- DCI Static supports up to 1,000 VNIs and 32,768 MACs per VTEP;
- To delete a VLAN that is mapped to a VNI, you must first disable VXLAN on all the interfaces associated with that VLAN;
- Changing the switchport mode requires VXLAN to be disabled at interface level;
- When VXLAN is enabled on a switch interface, its VLAN membership is not removed. Any Layer 2 broadcast, unknown unicast, and multicast traffic (BUM traffic) received by the VLAN is also forwarded on the VXLAN enabled port;
- Outgoing BUM traffic is not distributed across all ECMP enabled Layer 3 links;
- Asymmetric underlay routing, where traffic sent by a remote TEP arrives on a Layer 3 routed interface that does not have a route back to the source or has a route with a lower priority, is not supported;
- Asymmetric VTEP/VNI configurations do not ensure traffic isolation if the same VTEP is mapped to another VNI;
- On VTEPs, only Layer 3 routed ports are supported for the underlay network. SVI support will be added in a future release;

- VXLAN traffic on access ports do not take into consideration STP forwarding states;
- When STP is disabled on the switch, Bridge Protocol Data Units (BPDUs) are flooded back on the receiving port;
- In High Availability mode, we recommend a maximum of 32,768 local unicast MAC addresses. Exceeding this threshold, might lead MAC address synchronization between the two vLAG peers to not function properly;
- VNI mappings cannot be created on non-existent VLANs. In HA topologies, make sure that VLANs are created on both peers before proceeding with the DCI HA configuration;
- In DCI-HA topologies, the vLAG configuration must be set up accordingly on both vLAG switches before proceeding with the DCI HA configuration;
- When the switch receives MAC addresses at a very high rate, the Forwarding Database (FDB) table is not updated. However, MAC addresses are still learned in hardware and Layer 2 traffic is not impacted;
- In High Availability mode, when adding a new vLAG instance, you must first configure and enable the vLAG instance before enabling VXLAN on the switch interfaces that are part of the new vLAG instance;
- In High Availability mode, when the vLAG instance goes down on one of the vLAG switches, the MAC addresses learned on that instance are not moved to the ISL Link Aggregation Group (LAG). This causes traffic to flood on both the ISL LAG and other switch access ports. Traffic flooded on the ISL eventually reaches the vLAG instance on the vLAG peer switch, thus the traffic is not lost. However, traffic flooded on the access ports is discarded by the end hosts since it is not addressed to them;
- vLAG MAC address synchronization functions only when at least one vLAG instance has formed between the vLAG peers. In Static High Availability mode, if all vLAG instances are down, then the vLAG peers now act as standalone switches and vLAG MAC address synchronization between them is disabled;
- vLAG cannot be enabled/disabled once NWV mode static High Availability has been configured;
- vLAG instances cannot be disabled/enabled if they are VXLAN enabled;
- Port-channel interfaces cannot be removed if they are VXLAN enabled;
- Bidirectional Forwarding Detection (BFD) is not supported in a Static High Availability DCI topology over vLAG with Virtual Router Redundancy Protocol (VRRP) and with an additional Layer 3 link connecting the vLAG peers besides the ISL LAG;
- BFD sessions are not created per virtual network. When a VTEP-to-virtual network mapping is deleted, if there are other valid mappings between the two BFD peers, then the BFD session is not closed;
- In some failover/failback scenarios, BFD can flap (change between `UP` and `DOWN` states) for a short period of time until the routing protocols fully converge upstream and on both vLAG peers;
- Known Unicast Traffic (KUC) traffic is load-balanced based on the Layer 3 overlay header;

DCI BGP EVPN General Considerations and Limitations

- BGP Unnumbered is not supported with DCI BGP MP BGP EVPN;
- DCI MP-BGP EVPN with eBGP will be supported in a future release;
- DCI MP-BGP EVPN limits per VTEP: 100 VNIs and 8,000 MACs per VTEP;
- If you have multiple vLAGs in the DCI MP-BGP EVPN topology, configure a different tier-id for each vLAG, from 1-255;
- An EVPN Type 1 route (Auto-Discovery per Ethernet Segment) with more than 400 Route Targets (RTs) cannot be advertised. We recommend that you do not configure more than 400 VNIs on a single interface (identified by the Ethernet Segment Identifier - ESI);
- Losing BGP connectivity on one of the vLAG peers without loosing OSPF connectivity, may end up in loosing traffic due to fact that network ports are removed and all the ingress traffic on that vLAG peer is dropped;
- The multihomming feature is not supported;

Chapter 35. Network Policy Agent

Lenovo Cloud Network Operating System provides a network policy agent that works with Nutanix or VMware Virtual Domain Manager (VDM). Interaction between the switch and the external VDM is handled by the Lenovo VDM plug-in.

The Lenovo Network Policy Agent supports multiple VDM plug-ins to obtain updates on events in a Nutanix or VMware cluster. These updates are then used to provide the switch with a view of the virtual network and to automatically configure updated VLAN to port mappings for event changes.

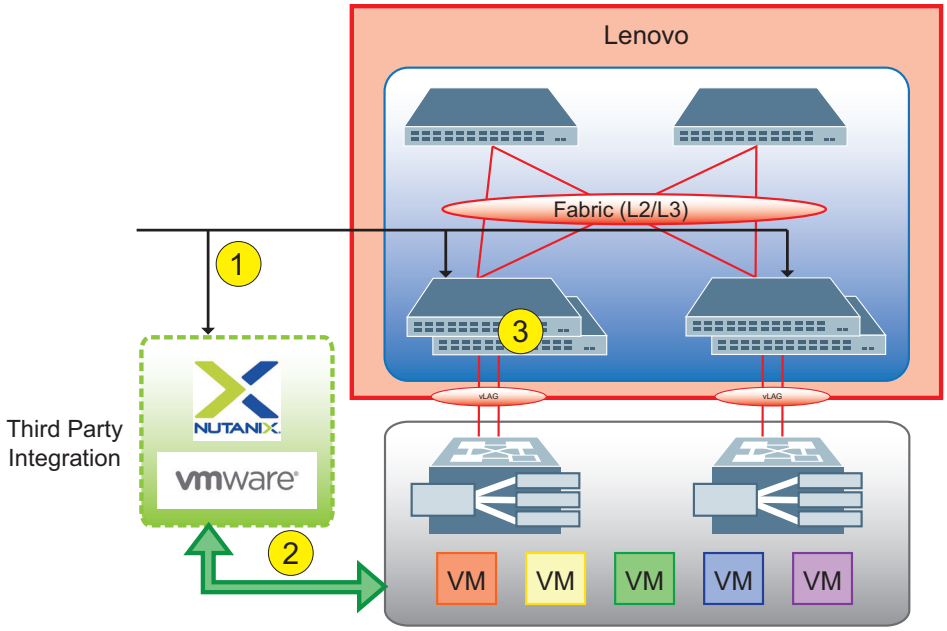
The following topics are discussed in this section:

Overview

Usually, the infrastructure administrator depends on the network administrator to provision, operate and troubleshoot network related issues. Also, the network boundary starts upwards from the server Network Interface Card (NIC). These dynamics are different in the case of Hyperconverged Infrastructure (HCI).

In a typical HCI Point of Delivery (PoD) architecture there are at least two pairs of Top-of-Rack (ToR) switches included and the infrastructure administrator manages the entire solution. Because of these reasons, it is necessary to decrease the complexity of the network language associated with the configuration of an HCI PoD architecture. While the physical network continues to exist, it needs to become invisible from a workload provisioning and operational point of view. It also needs to integrate seamlessly with the workload/cloud management system. Figure 51 shows VM workload visibility and provisioning.

Figure 51. VM Workload Visibility and Provisioning



The steps in this figure are:

1. Integration with the Virtual Management Module (VMM) for notifications and topology discovery. The following notifications happen:
   - VM and vNIC Create, Read, Update, and Delete (CRUD)
   - Virtual network CRUD
2. The VMM controls and manages the virtual network infrastructure management and VM workload and overlay provisioning.

3. The workload visibility includes VM information and overlay network information, and topology discovery associates VMs to the physical switch interface. Dynamic network provisioning occurs:

   - The physical network (Layer 2 VLAN) is provisioned based on virtual network and VM associations
   - The Network Policy Agent dynamically handles VM migrations and moves Layer 2 VLAN configurations

   The Lenovo CNOS Network Policy Agent gives increased visibility of the virtual infrastructure, including workload (VM) information and virtual network information. It also provides auto-discovery of any changes to the virtual network topology.

   The CNOS Network Policy Agent also provides automatic VM-aware provisioning. The physical network is automatically configured based on the auto-discovered topology. The agent provides ongoing, dynamic updates to the physical network configuration in response to new VMs, updated VMs, and deleted VMs, eliminating errors with manual configuration.

   Table 54 explains the advantages of using the Network Policy Agent.

Table 54. *Advantages of Using the Network Policy Agent*

Action	Without Network Policy Agent	With Network Policy Agent
Network settings update based on VM and virtual network configuration	Pending changes are communicated to Network Administrator, who manually reconfigures each physical switch connected to new VM. This process repeats each time changes in virtual network occurs.	CNOS Network Policy Agent communicates with VMM to automatically learn when VM changes occur and update switch configuration accordingly. No scheduled maintenance window or user intervention is required.
VM Live Migration	The Network Administrator must identify the new location of a VM and must configure new connectivity information. This results in network downtime.	A new VM location is detected, and the physical switch automatically updates. No network interruption occurs.
Virtual Network Visibility	Physical switch has no visibility into the virtual network and is only aware of physical host connectivity.	An unprecedented view of a virtual network's VMs, hosts, and their connectivity is now available to the physical switch.

Setting up the Nutanix VDM Plug-in

Follow the next steps to set up the switch to work with the Nutanix VDM Plug-in.

Notes:

- LLDP feature is required for Nutanix VDM Plug-in. Please make sure it is enabled on your switch.
- You must have Nutanix AOS version 5.0.2 – 5.8 or 5.9.2 – 5.10 installed for the CNOS Network Policy Agent to work properly.

Enter Interface Configuration mode for the switch interface facing the server ports. For example ethernet port 1/12:

```
Switch(config)# interface ethernet 1/12
Switch(config-if)#
```

1. Modify the LLDP transmit delay value to one:

```
Switch(config-if)# lldp transmit-delay 1
```

2. Modify the LLDP transmit interval to five seconds (default value is 30 seconds) for faster transmission of LLDP packets:

```
Switch(config-if)# lldp timer 5
```

3. Enable provisioning of virtual domain information on the interface.

   Note: Make sure the interface belongs on server facing ports, and not on uplinks of vLAG ISL ports or any port that is not controlled by the VDM Plug-in.

```
Switch(config-if)# auto-policy enable
```

   To turn off the provisioning of virtual domain information, use the following command:

```
Switch(config-if)# no auto-policy enable
```

4. Enable the REST API:

   - via HTTPS (default):

```
Switch(config)# feature restApi
```

   - via HTTP:

```
Switch(config)# feature restApi http
```

   Note: Depending on the Rest API server configuration, the subscription URLs for VM and VNETWORK on the client URL will reflect the corresponding changes.

5. Move into the Nutanix VDM context:

```
Switch(config)# vdm nutanix
```

6. Specify the IP address of the Nutanix cluster:

```
Switch(config-vdm)# ip address <IP address> vrf management
```

7. Specify the user name and password to access the Nutanix cluster:

```
Switch(config-vdm)# user <username> password <password>
```

8. Specify the switch port interfaces or aggregations on which you want to have the Nutanix cluster provision:

```
Switch(config-vdm)# add [interface ethernet <chassis number/port number>|
|port-channel <LAG number (1-4096)>]
```

9. Configure the Virtual Machine information for inbound packets:

```
Switch(config-vdm)# vm {name "<VM name>"|uuid <VM UUID>} vnic {vlan <VLAN
ID (1-4093)>|ip <IP address>|mac <MAC address>} attach security-policy <policy name>
in
```

Notes:

- As best practice, any policy must be configured before it is attached to any virtual machine.
- Virtual machine names must contain only alphanumeric characters.

10. Configure the URL for refreshing the Virtual Machine information on the switch:

```
Switch(config-vdm)# refresh-vms-url <URL>
```

This is often:

```
Switch(config-vdm)# refresh-vms-url
https://<IP address>:<port>/api/nutanix/v3/vms/list
```

11. Configure the URL for refreshing the virtual network information on the switch:

```
Switch(config-vdm)# refresh-vnet-url <URL>
```

This is often:

```
Switch(config-vdm)# refresh-vnet-url
https://<IP address>:<port>/api/nutanix/v3/networks/list
```

12. Configure the Virtual Machine information QoS policy:

```
Switch(config-vdm)# vm {name "<VM name>"|uuid <VM UUID>} vnic {vlan <VLAN
ID (1-4093)>|ip <IP address>|mac <MAC address>} attach qos-policy <policy name> in
```

Notes:

- As best practice, any policy must be configured before it is attached to any virtual machine.
- Virtual machine names must contain only alphanumeric characters.

13. The switch needs to query the topology discovery URL on each VM to get the switch, port, and VLAN information pertaining to each VM. Configure the topology discovery URL:

```
Switch(config-vdm)# topo-discovery-url <server URL> query-delay <query delay>
```

For example, to query a topology server URL with a Nutanix cluster at 10.20.30.40 with a query delay time of 10 seconds, the command would be:

```
Switch(config-vdm)# topo-discovery-url
https://10.20.30.40:9440/PrismGateway/services/rest/v1/vms query-delay 10
```

14. Configure the Virtual Machine information queueing policy:

```
Switch(config-vdm)# vm {name "<VM name>"|uuid <VM UUID>} vnic {vlan <VLAN
ID (1-4093)>|ip <IP address>|mac <MAC address>} attach queueing-policy <policy name>
in
```

Notes:

- As best practice, any policy must be configured before it is attached to any virtual machine.
- Virtual machine names must contain only alphanumeric characters.

15. To get updated LLDP information, you need to wait at least until the vLAG startup-delay expires before performing the LLDP query so that the query response can reflect the UP ports. This is called the *topology startup delay*. To configure the topology startup delay:

```
Switch(config-vdm)# topo-startup-delay <topology startup delay>
```

16. Subscribe to the Nutanix cluster for virtual machine events, via HTTPS (default) or HTTP:

```
Switch(config-vdm)# subscribe server-url <server URL> client-url <client URL>
vm
```

For example, given a Nutanix cluster at 10.20.30.40 and switch IP 10.20.30.50, the command might be:

```
Switch(config-vdm)# subscribe server-url
https://10.20.30.40:9440/api/nutanix/v3/webhooks client-url
https://10.20.30.50:443/nos/api/cfg/nutanix/vm vm
```

Note: Both HTTP and HTTPS are supported for the client URL.

17. Subscribe to the Nutanix cluster for virtual network events, via HTTPS (default) or HTTP:

```
Switch(config-vdm)# subscribe server-url <server URL> client-url <client URL>
vnetwork
```

For example, given a Nutanix cluster at 10.20.30.40 and switch IP 10.20.30.50, the command might be:

```
Switch(config-vdm)# subscribe server-url
https://10.20.30.40:9440/api/nutanix/v3/webhooks client-url
https://10.20.30.50:443/nos/api/cfg/nutanix/network vnetwork
```

Note: Both HTTP and HTTPS are supported for the server URL.

To display the running VDM configuration, enter:

```
Switch(config-vdm)# show running-config vdm
```

Note: Policies are not in effect for traffic local to the hypervisor. When the source and destination MAC or IP addresses reside on the same host, the traffic will not come out of the internal virtual switch of Nutanix.

Unsubscribing from Nutanix VDM Notifications

To stop receiving notifications of events from the Nutanix VDM:

1. To unsubscribe to the Nutanix cluster for virtual machine events, enter:

```
Switch(config-vdm)# unsubscribe server-url <server URL> client-url <client
URL> vm
```

2. To unsubscribe to the Nutanix cluster for virtual network events:

```
Switch(config-vdm)# unsubscribe server-url <server URL> client-url <client
URL> vnetwork
```

VMware VDM Plug-in

In case of VMware's Virtual Domain Manager (VDM), the Network Policy Agent uses a Simple Object Access Protocol (SOAP) client that is generated using VMware Virtual Infrastructure (VI) Software Development Kit (SDK). The SOAP client is used to connect to the vCenter for inventory retrieval and the receiving of various runtime events using the wait-for-updates mechanism.

The VI SDK offers a complete set of management interfaces to the VMware Infrastructure. Everything is centered on Web Services, a popular communication method that defines the interfaces and is supported by SOAP as the underlying communication protocol.

Topology Mapping

Host discovery and getting topology information is achieved by querying Link Layer Discovery Protocol (LLDP) or Cisco Discovery Protocol (CDP) information after Virtual Machine (VM) events, if host information is unavailable.

Using LLDP the switch transmits and receives Protocol Data Units (PDUs). If the vCenter has the required license (Enterprise-Plus), then you need to enable LLDP Receive on the distributed virtual switch (dvSwitch).

The LLDP process running on the switch is also capable of transmitting CDP packets following the configured LLDP parameters. The sending of CDP packets over switch interfaces with automatic policy provisioning enabled is a user configurable option. By default, virtual switches (vSwitches) on ESXi hosts are enabled with CDP Receive.

Since CDP is a proprietary Layer 2 protocol, it is not supported on CNOS and any received CDP packets are flooded by the switch on interfaces other than the originating port. To avoid upstream switches from transmitting CDP packets and corrupting interfaces connected to ESXi hosts, it is recommended to configure a filter than discards CDP packets on upstream ports or LAGs.

Note: You must ensure that CDP Receive is enabled on vSwitches using ESXi web interface or CLI.

Following is a configuration example that drops CDP packets on an upstream Link Aggregation Group (LAG):

1. MAC address *0100.0CCC.CCCC* is used as destination address by CDP packets. Configuring a MAC ACL that discards packets with that MAC destination address results in CDP packets not being forwarded through the upstream LAG.

```
Switch(config)# mac access-list vmware_cdp
Switch(config-mac-acl)# statistics per-entry
Switch(config-mac-acl)# 10 deny any host 0100.0CCC.CCCC
Switch(config-mac-acl)# 20 permit any any
Switch(config-mac-acl)# exit
```

2. Apply the MAC ACL to the upstream LAG:

```
Switch(config)# interface port-channel 137
Switch(config-if)# mac port access-group vmware_cdp
```

Policy Mapping

The policy mapper maintains the network policies that apply to VLAN membership, Access Control Lists (ACLs), and Quality of Service (QoS) class maps. It also interacts with the CNOS control plane to install or uninstall these policies in the data plane. Intent based policies are mapped to the CNOS control plane services.

Notes:

- Security policies configured on the switch do not affect network traffic between two virtual machines if both VMs are on the same host. This happens because the VMware vSwitch transmits the traffic locally without going through the Lenovo switch, thus the security policies cannot be applied;
- IP information for a VM's virtualized Network Interface Card (vNIC) is not propagated to the vCenter if the VM does not have installed VMware's guest tool. Therefore, vCenter notifications do not contain IP information. In this scenario, a security policy cannot be attached to a VM if the VM is identified by its IP address;
- If a VM is migrated to another host, there is a delay in receiving information about the IP migration from the vCenter. During this delay, if a security policy was attached to the VM via its IP address, traffic does not follow the configured clauses of the policy until IP information is received from the vCenter;
- When attaching a security policy to a Virtual Machine, if the VM has multiple VLAN associations, then the security policy is also attached to those VLANs.

VMware VDM Policy Configuration Examples

Following are some basic examples of configuring the Lenovo VMware VDM plug-in that cover ACLs, QoS, and queueing policies.

When multiple configured policies (ACL, QoS, or queueing) can occur for the same virtual machine, either attached to the VM by its name or by its UUID, the policy attached to the VM's UUID gets precedence over the policy attached to the VM's name. Configured policies remain in the configuration database, even if they are outweighed by other policies.

ACL Policy Configuration Example

The following example shows the configuration for Port Access Control Lists (PACLs). For more details on ACLs, see "Access Control Lists" on page 167.

Note: As best practice, any policy must be configured before it is attached to a virtual machine.

1. Create an IP PACL and configure its permit or deny clauses:

```
Switch(config)# ip access-list acl-ip-1
Switch(config-acl)# permit ip host 10.115.47.87 any
Switch(config-acl)# deny ip any 10.78.190.32/24
Switch(config-acl)# exit
```

This creates an IP PACL named *acl-ip-1*. It forwards traffic that originates from IP address `10.115.47.87`, regardless of its destination. It also drops any packets that are destined for network `10.78.190.32/24`.

2. Create a MAC PACL and configure its permit or deny clauses:

```
Switch(config)# mac access-list acl-mac-1
Switch(config-mac-acl)# permit any host 3C-97-0E-23-83-AB
Switch(config-mac-acl)# deny host 00:0A:95:9D:68:16 any
Switch(config-mac-acl)# exit
```

This creates a MAC PACL named *acl-mac-1*. It forwards any traffic that is destined for MAC address `3C-97-0E-23-83-AB`, and drops all packets that originate from the host with MAC address `00:0A:95:9D:68:16`.

3. Enter VMware VDM configuration mode and attach MAC PACL *acl-mac-1* as a security policy to a virtual machine (VM):

```
Switch(config)# vdm vmware
Switch(config-vdm)# vm uuid 52f7b088-357e-bb81-59ec-9d9389c7d89e vnic mac
001B.4411.3AB7 attach security-policy acl-mac-1 in
```

This attaches MAC PACL *acl-mac-1* as a security policy for inbound traffic to the VM with UUID `52f7b088-357e-bb81-59ec-9d9389c7d89e` for the vNIC with MAC address `001B.4411.3AB7`.

4. Attach IP PACL *acl-ip-1* as a security policy to a virtual machine (VM):

```
Switch(config-vdm)# vm name "VM-344-user1" vnic ip 23.45.167.93 attach
security-policy acl-ip-1 in
Switch(config-vdm)# exit
```

This attaches IP PACL *acl-ip-1* as a security policy for inbound packets to the VM named *VM-344-user1* for the vNIC with IP address `23.45.167.93`.

Notes:

- By specifying the VM name instead of its UUID, security policies can be statically configured for VMs that are yet to be created.
- Virtual machine names must contain only alphanumeric characters.

5. Verify the configuration by running one of the following commands:

```
Switch# show virtual-machine security-policy information
```

```
Switch# show virtual-machine security-policy information vm name
“VM-334-user1”
```

```
Switch# show virtual-machine security-policy information vm uuid
52f7b088-357e-bb81-59ec-9d9389c7d89e
```

QoS Policy Configuration Example

QoS policies are provisioned on ingress traffic for a switch ethernet port or Link Aggregation Group (LAG).

Notes:

- Only one QoS policy can be applied on a single switch interface.
- As best practice, any policy must be configured before it is attached to a virtual machine.

The following example shows the configuration for a Quality of Service (QoS) class map. For more details on QoS, see "Quality of Service" on page 347.

1. Create a QoS class map and configure its match clauses:

```
Switch(config)# class-map type qos cmap4
Switch(config-cmap-qos)# match dscp af41,af42,af43,cs4
Switch(config-cmap-qos)# exit
```

This creates a QoS class map named *cmap4*. It classifies traffic based on its DiffServ Code Points (DSCP): af41, af42, af43, cs4. For more details on DSCP, see "Using DiffServ Code Point (DSCP) Filters" on page 351.

2. Create a QoS policy map and configure its parameters:

```
Switch(config)# policy-map type qos pmap4
Switch(config-pmap-qos)# class type qos cmap4
Switch(config-pmap-c-qos)# police cir 2 mbps conform transmit
Switch(config-pmap-c-qos)# set cos 4
Switch(config-pmap-c-qos)# exit
Switch(config-pmap-qos)# exit
```

This creates a QoS policy map named *pmap4*. It filters traffic based on the class map *cmap4*. For packets that match the class map, the policy map forwards the packets limiting their traffic rate to a committed information rate (CIR) of 2 Mbps. It also configures the Class of Service (CoS) of the packets to 4.

3. Enter VMware VDM configuration mode and attach QoS policy map *pmap4* to a virtual machine (VM):

```
Switch(config)# vdm vmware
Switch(config-vdm)# vm name "VM-30-user4" vnic vlan 137 attach qos-policy
pmap4
```

This attaches QoS policy map *pmap4* as a QoS policy to the VM named *VM-30-user4* for the vNICs members of VLAN 137.

4. Verify the configuration by running one of the following commands:

```
Switch# show virtual-machine qos-policy information
```

```
Switch# show virtual-machine qos-policy information vm name "VM-30-user4"
```

Queueing Policy Configuration Example

Queueing policies are provisioned on egress traffic only for switch ethernet ports. To provision a queueing policy for a Link Aggregation Group (LAG), you must instead provision the policy on each individual ethernet port that is a member of the LAG.

Notes:

- Only one queueing policy can be applied on a single switch interface.
- As best practice, any policy must be configured before it is attached to a virtual machine.

The following example shows the configuration for a queuing class map. For more details on QoS, see "Quality of Service" on page 347.

1. Select a queuing class map and configures its match clauses:

```
Switch(config)# class-map type queuing match-any 1p7q1t-out-q3
Switch(config-cmap-que)# match cos 4
Switch(config-cmap-que)# exit
```

This configures queuing class map `1p7q1t-out-q3` to filter traffic if its Class of Service (CoS) is 4.

2. Create a queuing policy map and configure its parameters:

```
Switch(config)# policy-map type queuing pmap-que-3
Switch(config-pmap-que)# class type queuing 1p7q1t-out-q3
Switch(config-pmap-c-que)# shape percent 3
Switch(config-pmap-c-que)# exit
Switch(config-pmap-que)# exit
```

This creates a queuing policy named *pmap-que-3*. It filters traffic based on the queuing class map `1p7q1t-out-q3`. For packets that match the class map, the policy map limits the egress traffic rate to 3% of the interface's link rate.

3. Enter VMware VDM configuration mode and attach queuing policy *pmap-que-3* to a virtual machine (VM):

```
Switch(config)# vdm vmware
Switch(config-vdm)# vm name "VM-137-user8" vnic mac 001B.4411.3AB7 attach
queueing-policy pmap-que-3
```

This attaches queuing policy map *pmap-que-3* as a queueing policy to the VM named *VM-137-user8* for the vNIC with MAC address `001B.4411.3AB7`.

4. Verify the configuration by running one of the following commands:

```
Switch# show virtual-machine queueing-policy information
```

```
Switch# show virtual-machine queueing-policy information vm name
"VM-137-user8"
```

VMware VDM Configuration Example

Following is a configuration example for VMware's VDM:

1. Enable automatic policy provisioning on the switch interfaces or Link Aggregation Groups (LAGs) that need to be managed/provisioned by VMware's VDM:

```
Switch(config)# interface {ethernet <chassis number/port number>|port-channel
<LAG number (1-4096)>}
Switch(config-if)# auto-policy enable
Switch(config-if)# exit
```

   For example, enable automatic policy provisioning on ethernet ports 1/1-1/4:

```
Switch(config)# interface ethernet 1/1-4
Switch(config-if-range)# auto-policy enable
```

2. (Optional) For CDP on vSwitches or dvSwitches, enable automatic host discovery of VMware ESXi hosts on the switch interfaces that need to be managed or provisioned by VMware's VDM:

```
Switch(config-if)# auto-policy host-discovery
```

   Note: Automatic host discovery can be enabled only on ethernet ports.

3. Enter VMware VDM configuration mode and configure the IP address and Virtual Routing and Forwarding (VRF) instance for the vCenter:

```
Switch(config)# vdm vmware
Switch(config-vdm)# ip address <vCenter IP address> vrf management
```

   For example, configure vCenter with IP address `45.154.11.3`:

```
Switch(config-vdm)# ip address 45.154.11.3 vrf management
```

4. Configure the vCenter security access credentials:

```
Switch(config-vdm)# username <username> password [encrypted] <password>
```

5. Configure the cluster name of the vCenter to which the switch is connected. A vCenter can have multiple clusters in its database:

```
Switch(config-vdm)# clustername "NTNX_B_8_Broad"
```

6. Add to the VDM the switch interfaces or LAGs that have been enabled with automatic policy provisioning at Step 1:

```
Switch(config-vdm)# add interface {ethernet <chassis number/port number>|
|port-channel <LAG number (1-4096)>}
Switch(config-vdm)# exit
```

For example, add ethernet ports 1/1-1/4 to the VMware VDM:

```
Switch(config-vdm)# add interface ethernet 1/1-4
Switch(config-vdm)# exit
```

To remove a switch interface or LAG from the VDM, use the following command:

```
Switch(config-vdm)# remove interface {ethernet <chassis number/port number>|
|port-channel <LAG number (1-4096)>}
```

7. Verify the VDM configuration:

```
Switch# show vdm information vmware

Owner: vmware
Connection state of vCenter: Connected
Version: 6.5
IP Address: 45.154.11.3 vrf management
Username: administrator@vsphere.local
Clustername configured: NTNX_B_8_Broad
Events received from: specific cluster
Topology startup delay : 90 (Finished)
Virtual Machine VNIC Statistics : Enabled
Virtual Machine VNIC Statistics Interval : 300
Interfaces
     po1 po2 po3 po4 po5
     po6 po7 po8

Queueing Policies

VM Name : WinBB
   VNIC Qualifier   : VLAN 2
   Queueing Policy  : pmap-que
```

To display a list of the current provisioned virtual machines, use the following command:

```
Switch# show virtual-machine information ?

  interface  Interface name
  vm         virtual machine information
  |          Output modifiers
  >          Output redirection
  <cr>
```

For example, display the current provisioned virtual machines that are connected to ethernet port 1/1:

```
Switch# show virtual-machine information interface ethernet 1/1

Interface Ethernet1/1
uuid: 4239ca4a-09da-cf42-4664-ce0b21fd5a68
    name: VM2_94
        host_reference:
            kind: host
            uuid: 7a1462af-f883-e611-a0ee-0894ef25b0bb
        num_cores_per_vcpu: 1
        memory_size_mb: 4096
        num_vcpus: 2
        power_state: poweredOn
        nic_list:
            kind: subnet
            connected_state: connected
            network_name: USER_VLANALL
            nic_type: VMXNET 3
            mac_address: 00:50:56:B9:A3:FF

            kind: subnet
            connected_state: connected
            network_name: User_VLAN10
            nic_type: E1000
            mac_address: 00:50:56:B9:5B:48
```

Viewing Virtual Domain Information

To display virtual domain manager information, use the following command:

```
Switch# show vdm information [<VDM name>]
```

To display Nutanix virtual network information, use the following command:

```
Switch# show vnetworks [uuid <network UUID>]
```

To display Nutanix and/or VMware VDM virtual network information, use the following command:

```
Switch# show vnetworks
```

To display Nutanix and/or VMware virtual machine information, use the following command:

```
Switch# show virtual-machine information [interface {all|ethernet <chassis
number/port number>|port-channel <LAG number (1-4096)>|vm {name "<VM name>"|
|uuid <VM UUID>}]
```

To display Nutanix and/or VMware ACL policies, use the following command:

```
Switch# show virtual-machine security-policy information [vm {name
"<VM name>"|uuid <VM UUID>}]
```

To display Nutanix and/or VMware QoS policies, use the following command:

```
Switch# show virtual-machine qos-policy information [vm {name "<VM name>"
|uuid <VM UUID>}]
```

To display Nutanix and/or VMware queueing policies, use the following command:

```
Switch# show virtual-machine queueing-policy information [vm {name
"<VM name>"|uuid <VM UUID>}]
```

Dynamic VLANs and the VDM

Dynamic VLANs are VLANs provisioned by the VDM when it attaches virtual Network Interface Cards (vNICs) to powered ON virtual machines (VMs).

Dynamic VLAN Considerations

Note the following guidelines for using Dynamic VLANs with the VDM:

- Dynamic VLANs are depicted with an *(d)* symbol in the output of CLI display commands.
- The main intention of dynamic VLANs is to have VLAN provisioning controlled by the VDM and not by the switch administrator. Thus we recommend configuring the switch interfaces as switch trunk ports and add all the trunk ports to the allowed VLAN list. For more details, see "Configuring a Switch Trunk Port" on page 235.
- Dynamic VLANs work exactly like static VLANs in terms of functionality and protocol interactions. The auto-provisioning of VLANs is done when a network attach event occurs. Similarly, if there are no more VMs participating in a VLAN, then network detach events cause the non-provisioning of that VLAN. In the case of a pure dynamic VLAN, non-provisioning results in the removal of that dynamic VLAN.
- Turning off provisioning removes all dynamic VLANs.
- A static VLAN that is created and is auto-provisioned is called a *hybrid VLAN*. Turning off provisioning causes a hybrid VLAN to revert to a static VLAN. Hybrid VLANs are depicted with an *(h)* symbol in the output of CLI display commands.
- Non-auto-policy ports can be added to a dynamic VLAN only if the dynamic VLAN is converted to a static VLAN and the non-auto-policy ports are explicitly added to the static VLAN.
- Any configuration done on the dynamic VLAN is automatically removed when the dynamic VLAN is removed, whether by configuration or by not being provisioned any more.
- vLAG consistency checking is disabled for dynamic VLANs. If a vLAG consistency check is triggered for a dynamic VLAN and a switch receives a network attach event, there is a consistency check fail before the other switch receives the same event. This causes the vLAG ports to be error-disabled and leads to the VDM migrating the associated VMs. A vNIC attached to a VM on a specific host triggers network detach events on both switches. Since the same Dynamic VLAN is configured on both the switches, there is no need for a vLAG consistency check.
- If a dynamic VLAN is configured in hybrid mode, then deleting the VLAN removes the static and dynamic VLANs from the switch, and triggers a vLAG configuration consistency check which transitions the vLAG in the DOWN state.

Dynamic VLAN Commands

To view all VLANs, use the command:

```
Switch(config-vdm)# show vlan
```

To view the total number of dynamic VLANs, use the command:

```
Switch(config-vdm)# show vlan summary

  Number of existing VLANs               : 115
  Number of existing user VLANs          : 103
  Number of auto-provisioned dynamic VLANs: 12
  Number of existing reserved VLANs      : 95
```

To view VLAN status information, use the command:

```
Switch(config-vdm)# show vlan brief

Flags:
u - untagged egress traffic for this VLAN
t - tagged egress traffic for this VLAN

d - auto-provisioned VLAN
h - static and auto-provisioned VLAN
VLAN     Name                           Status  IPMC FLOOD Ports

======== ======================== ======= ========== ==================
1        default                  ACTIVE  IPv4,IPv6  po1(t)
                                                    po2(t)
                                                    po3(t)
                                                    po4(t)
                                                    po5(t)
2 (d)    VLAN0002                 ACTIVE  IPv4,IPv6
                                                    po2(t)
                                                    po7(t)
                                                    po100(t)
                                                    po202(t)
                                                    Ethernet1/2(t)
                                                    Ethernet1/7(t)
                                                    Ethernet1/50(t)
                                                    Ethernet1/51(t)
                                                    Ethernet1/53(t)
                                                    Ethernet1/54(t)
```

Note: Dynamic VLANs are marked by `(d)` and Hybrid VLANs are marked by `(h)`. In the above command output, VLAN 2 is a Dynamic VLAN and is marked with `(d)`.

To delete a VLAN from the switch, whether the VLAN is static, dynamic, or hybrid, use the command:

```
Switch(config-vdm)# no vlan <VLAN ID (1-4093)>
```

Part 8: Monitoring

The ability to monitor traffic passing through the switch can be invaluable for troubleshooting some types of networking problems. This section covers the following monitoring features:

Chapter 36. Port Mirroring

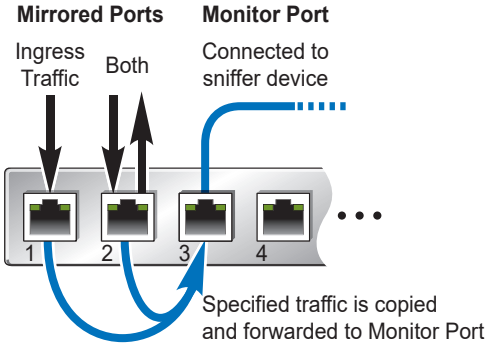
The Lenovo Cloud Network Operating System port mirroring feature allows you to mirror (copy) the packets of a target port and forward them to a monitoring port. Port mirroring functions for all layer 2 and layer 3 traffic on a port. This feature can be used as a troubleshooting tool or to enhance the security of your network. For example, an IDS server or other traffic sniffer device or analyzer can be connected to the monitoring port to detect intruders attacking the network.

The following topics are discussed in this section:

Port Mirroring Overview

The switch supports a “many to one” mirroring model. As shown in Figure 52, selected traffic for ports 1 and 2 is being monitored by port 3. In the example, both ingress traffic and egress traffic on port 2 are copied and forwarded to the monitor. However, port 1 mirroring is configured so that only ingress traffic is copied and forwarded to the monitor. A device attached to port 3 can analyze the resulting mirrored traffic.

Figure 52. Mirroring Ports



The switch supports four monitor sessions for mirroring rx or tx traffic and two monitor sessions for mirroring both rx and tx traffic. Each monitor port can receive mirrored traffic from any number of target ports.

Cloud NOS does not support “one to many” or “many to many” mirroring models where traffic from a specific port traffic is copied to multiple monitor ports. For example, port 1 traffic cannot be monitored by both port 3 and 4 at the same time, nor can port 2 ingress traffic be monitored by a different port than its egress traffic.

Ingress and egress traffic is duplicated and sent to the monitor port before processing.

SPAN Configuration

The Switched Port Analyzer (SPAN) feature selects network traffic for analysis by a network analyzer. The network analyzer can be any Remote Monitoring mechanism with the capability to perform packet captures.

The switch supports up to a maximum of 18 SPAN sessions.

Note: Only two SPAN sessions can be simultaneously active.

SPAN feature is applicable for the following types of ports:

- Ethernet ports (but not sub-interfaces);
- Link Aggregation Groups (LAGs).

Sources

SPAN sources refer to the interfaces from which traffic can be monitored. The Cloud NOS supports Ethernet and LAGs as SPAN sources. The SPAN traffic can be performed in the ingress direction, the egress direction or both directions:

- Ingress source (Rx)—Traffic entering the device through this source port is copied to the SPAN destination port.
- Egress source (Tx)—Traffic exiting the device through this source port is copied to the SPAN destination port.

The command to add or remove a source interface for the current SPAN session is as follows:

```
Switch(config)# monitor session {<1-18>|all>
Switch(config-monitor)# [no] source interface {ethernet <chassis number/port
number>|port-channel <LAG number>} {both|rx|tx}
```

Destinations

SPAN destinations refer to the interfaces that monitors source ports.

The command to add or remove a destination interface for the current SPAN session is as follows:

```
Switch(config)# monitor session {<1-18>|all>
Switch(config-monitor)# [no] destination interface {ethernet <chassis
number/port number>|port-channel <LAG number>}
```

Sessions

Lenovo N/OS supports SPAN sessions to designate sources and destinations to monitor.

The command to add or remove a SPAN session is as follows:

```
Switch(config)# [no] monitor session {<1-18>|all}
```

Configuration Example

Follow this procedure to configure SPAN feature:

1. Enter the monitor configuration mode.

```
Switch(config)# monitor session 3
Switch(config-monitor)
```

2. Configure sources and the traffic direction in which to copy packets. Source interface is Ethernet 1/1 and both incoming and outgoing traffic is mirrored.

```
Switch(config-monitor)# source interface ethernet 1/1 both
```

3. Configure a destination for copied source packets.

```
Switch(config-monitor)# destination interface ethernet 1/3
```

4. Optionally, configure a description for the session. By default, no description is defined.

```
Switch(config-monitor)# description span_session_3
```

5. Enable the SPAN session. By default, the session is created in the down state.

```
Switch(config-monitor)# no shutdown
```

6. Display the SPAN configuration.

```
Switch# show monitor session 3
```

To clear the configuration of the specified SPAN session, use the following command:

```
Switch(config)# no monitor session 3
```

ERSPAN Configuration

Lenovo N/OS supports the Encapsulated Remote Switching Port Analyser (ERSPAN) feature on both source and destination ports. ERSPAN transports mirrored traffic over an IP network. The traffic is encapsulated using generic routing encapsulation (GRE) at the source router and is transferred across the network. The packet is decapsulated at the destination router and then sent to the destination interface.

The switch supports up to a maximum of 18 ERSPAN sessions.

Note: Only two ERSPAN sessions can be simultaneously active.

ERSPAN feature is applicable for the following types of ports:

- Ethernet ports (but not sub-interfaces);
- LAGs.

Session Types

Lenovo N/OS supports two types of ERSPAN session: source sessions and destination sessions.

ERSPAN source sessions are created on a switch for which traffic needs to be monitored from a remote device across an IP network. The ERSPAN source session mirrors traffic from an interface, encapsulates that traffic and sends it across the network to the specified IPv4 address.

ERSPAN destination sessions are created on a switch to receive mirrored traffic from another switch (on which an ERSPAN source session was created) and then forward that traffic to a monitoring device for analysis. The ERSPAN destination session receives GRE encapsulated packets from an IPv4 address, decapsulates the packets and sends them to a monitoring device reachable through one of its interfaces.

ERSPAN source sessions can be configured to directly send encapsulated GRE packets to a monitoring device, if that device is reachable. If the target host is not reachable from the source switch, an ERSPAN destination session must be created on the switch to which the monitoring device is directly connected.

Creating an ERSPAN destination session is also required when the mirrored traffic needs to be received by the monitoring device without GRE/ERSPAN headers. The ERSPAN destination switch will decapsulate the packets and then forward them to the monitoring device in the same format in which they we're received on the ERSPAN source switch.

The command to select an ERSPAN session type is as follows:

```
Switch(config)# [no] monitor session <1-18> type {erspan-destination|
erspan-source}
```

To configure the global origin IPv4 address of ethernet ERSPAN sessions, use the following command:

```
Switch(config)# monitor erspan origin ip-address <IPv4 address> global
```

Sources

For ERSPAN source sessions, sources refer to the interfaces from which traffic can be monitored. The Cloud NOS supports ethernet ports and LAGs as ERSPAN sources. The ERSPAN traffic can be performed in the ingress direction, the egress direction or both directions:

- Ingress source (Rx)—Traffic entering the device through this source port is sent to the ERSPAN destination IP address.
- Egress source (Tx)—Traffic exiting the device through this source port is sent to the ERSPAN destination IP address.

In an ERSPAN source session, there is a source interface and a destination IPv4 address. Use the following commands to add or remove a source interface for the current ERSPAN source session:

```
Switch(config)# monitor session <1-18> type erspan-source
Switch(config-erspan-src)# [no] source interface {ethernet <chassis number>/
/<port number>|port-channel <LAG number>} [both|rx|tx]
```

For ERSPAN source sessions, destinations refer to the IPv4 addresses of the hosts that monitor the mirrored traffic.

In an ERSPAN source session, there is a source interface and a destination IPv4 address. Use the following commands to configure the destination IPv4 address for the current ERSPAN source session:

```
Switch(config)# monitor session <1-18> type erspan-source
Switch(config-erspan-dst)# destination ip <IP address>
```

For a detailed list of the ERSPAN source configuring commands, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

Destinations

For an ERSPAN destination session, there is a source IPv4 address and a destination interface. Use the following commands to add or remove a source IPv4 address for the current ERSPAN destination session:

```
Switch(config)# monitor session <1-18> type erspan-destination
Switch(config-erspan-dst)# [no] source ip <IP address>
```

For an ERSPAN destination session, there is a source IPv4 address and a destination interface. Use the following commands to configure the destination interface for the current ERSPAN destination session:

```
Switch(config)# monitor session <1-18> type erspan-destination
Switch(config-erspan-dst)# destination interface {ethernet <chassis number/
/port number>|port-channel <LAG number>}
```

For a detailed list of the ERSPAN destination configuring commands, see the *Lenovo Network Command Reference for Lenovo Cloud Network Operating System 10.9*.

ERSPAN Source Session Configuration Example

Follow this procedure to configure an ERSPAN source session.

1. Configure the ERSPAN global origin IP address.

```
Switch(config)# monitor erspan origin ip-address 10.1.1.1 global
```

2. Configure a monitor session of type ERSPAN source.

```
Switch(config)# monitor session 3 type erspan-source
Switch(config-erspan-src)#
```

3. Optionally, configure a description for the session. By default, no description is defined.

```
Switch(config-erspan-src)# description erspan_source_session_3
```

4. Configure the source interface and the traffic direction in which to copy packets.

```
Switch(config-erspan-src)# source interface port-channel 2 both
```

5. Configure the destination IP address (to which the traffic is mirrored) in the ERSPAN session.

   Only one destination IP address is supported per ERSPAN source session.

```
Switch(config-erspan-src)# destination ip 10.2.0.0
```

6. Enable the ERSPAN session. By default, the session is created in the shutdown state.

```
Switch(config-erspan-src)# no shutdown
```

7. Verify the ERSPAN configuration.

```
Switch# show monitor session 3
```

ERSPAN Destination Session Configuration Example

Follow this procedure to configure an ERSPAN destination session.

1. Configure a monitor session of type ERSPAN source.

```
Switch(config)# monitor session 4 type erspan-destination
Switch(config-erspan-dst)#
```

2. Optionally, configure a description for the session. By default, no description is defined.

```
Switch(config-erspan-dst)# description erspan_destination_session_4
```

3. Configure the source IPv4 address.

```
Switch(config-erspan-dst)# source ip 10.2.0.0
```

4. Configure the destination interface (to which the traffic is forwarded for monitoring) in the ERSPAN session.

```
Switch(config-erspan-dst)# destination interface ethernet 1/23
```

5. Enable the ERSPAN session. By default, the session is created in the shutdown state.

```
Switch(config-erspan-dst)# no shutdown
```

6. Verify the ERSPAN configuration.

```
Switch# show monitor session 4
```

Limitations

- Entering additional monitor session commands does not clear previously configured SPAN parameters. You must enter the **`no monitor session`** command to clear configured SPAN parameters.
- When you specify sources and do not specify a traffic direction (ingress, egress, or both), `both` is used by default.
- For LAGs, only the first 8 members are supported, if that LAG is configured as a sniffer port.
- Up to two ERSPAN sessions are allowed to run simultaneously on the switch.

Chapter 37. Sampled Flow

Sampled Flow (sFlow) a technology for monitoring traffic in networks containing switches and routers. The sFlow monitoring system consists of an sFlow Agent and a central sFlow Collector. The sFlow architecture and sampling techniques were designed for providing continuous site-wide and enterprise-wide traffic monitoring of high speed switched and routed networks.

CNOS supports sFlow version 5 technology for monitoring traffic in data networks using an embedded sFlow agent that can be configured to provide continuous monitoring information of traffic to a central sFlow analyzer.

The switch is responsible only for forwarding sFlow information. A separate sFlow analyzer is required elsewhere on the network to interpret sFlow data.

The following topics are discussed in this chapter:

Note: CNOS only supports sending sFlow datagrams to collectors with IPv4.

Configuring sFlow

You can configure the rate at which sFlow samples network traffic, the size of packets, the polling interval, and the collector address.

To enable or disable the sFlow feature, use the command:

```
Switch(config)# [no] feature sflow
```

To enable or disable sFlow on a specific interface, enter:

```
Switch(config-if)# [no] sflow enable
```

To set the sFlow analyzer IP address, enter:

```
Switch(config-if)# sflow collector ip <IPv4 address> [port <port>] [vrf <vrf>]
```

where:

Parameter	Description
IPv4 address	The IP address of the sFlow analyzer.
port	(Optional) The IP port of the sflow analyzer; default value is 6343.
vrf	(Optional) The VRF; default value is `data`.

To view the sFlow configuration, enter:

```
Switch# show sflow
```

sFlow Network Polling

You can configure the switch to send network statistics to an sFlow analyzer at regular intervals. When polling is enabled, at the end of each configured polling interval, the switch reports general port statistics and port Ethernet statistics.

To enable sFlow polling and set the polling interval, in seconds, enter:

```
Switch(config)# sflow polling-interval <seconds>
```

where *seconds* is an integer from 0-86400. The default interval is 60. Setting *seconds* to 0 disables polling.

To set the maximum size of an sFlow datagram, enter:

```
Switch(config)# sflow max-datagram-size <size>
```

where *size* is an integer from 200-9000. The default maximum datagram size is 1500.

sFlow Network Sampling

In addition to statistical counters, the switch can be configured to collect periodic samples of the traffic data received on each port. For each sample, 128 bytes are copied, UDP-encapsulated, and sent to the configured sFlow analyzer.

For all ports, the sFlow sampling rate can be configured to occur once each 4096 to 1000000000 packets with a default value of 4096. A sampling rate of 4096 means that one sample will be taken for approximately every 4096 packets received on the port. The sampling rate is statistical, however. It is possible to have slightly more or fewer samples sent to the analyzer for any specific group of packets (especially under low traffic conditions). The actual sample rate becomes most accurate over time, and under higher traffic flow.

Note: The sampling mechanism is provided by the ASIC. It can be configured on a per-port-basis by specifying a sampling rate. For a sampling rate *N*, a sample will be sent to the CPU for each *N* packets. This is, however, a statistical sampling rate. It does not mean that if you have a sampling rate of 128 (one packet out of 128), a packet will be sampled after exact 128 packets. It is possible to have two or three or no samples sent to the CPU for a burst of 128 packets. The higher the traffic, the more accurate the sampling mechanism.

To set the sFlow sampling rate, enter:

```
Switch(config)# sflow sampling-rate <rate>
```

where *rate* is an integer from 4096-1000000000. The default rate is 4096.

To set the maximum size of sFlow packets to be sampled, enter:

```
Switch(config)# sflow max-sampled-size <size>
```

where *size* is an integer from 64-256. The default maximum sampled size is 128.

sFlow Example Configuration

1. Enable the sFlow feature:

```
Switch(config)# feature sflow
```

2. Specify the location where the sFlow information will be sent:

```
Switch(config)# sflow collector <IPv4 address>   (sFlow server address)
```

   By default, the switch uses established sFlow service port 6343.

3. On a per-port basis, enable sFlow:

```
Switch(config)# interface ethernet <chassis number>/<port number>
Switch(config-if)# sflow enable
Switch(config-if)# exit
```

4. Set the statistics polling rate:

```
Switch(config)# sflow polling-interval <polling rate>   (Statistics polling rate)
```

   Specify a polling rate between 1 and 86400 seconds, or 0 to disable. By default, polling is set to 60 for each port.

5. Set the data sampling rate:

```
Switch(config)# sflow sampling-rate <sampling rate>      (Data sampling rate)
```

   Specify a sampling rate between 4096 and 1000000000 packets. By default, the sampling rate is 4096 for each port.

6. Save the configuration.

7. Display sFlow statistics:

```
Switch(config)# show sflow statistics
```

8. Clear sFlow statistics:

```
Switch(config)# clear sflow statistics
```

Part 9: Appendices

This section discusses the following topics:

Appendix A. Getting help and technical assistance

If you need help, service, or technical assistance or just want more information about Lenovo products, you will find a wide variety of sources available from Lenovo to assist you.

Use this information to obtain additional information about Lenovo and Lenovo products, and determine what to do if you experience a problem with your Lenovo system or optional device.

Note: This section includes references to IBM web sites and information about obtaining service. IBM is Lenovo's preferred service provider for the System x, Flex System, and NeXtScale System products.

Before you call, make sure that you have taken these steps to try to solve the problem yourself.

If you believe that you require warranty service for your Lenovo product, the service technicians will be able to assist you more efficiently if you prepare before you call.

- Check all cables to make sure that they are connected.
- Check the power switches to make sure that the system and any optional devices are turned on.
- Check for updated software, firmware, and operating-system device drivers for your Lenovo product. The Lenovo Warranty terms and conditions state that you, the owner of the Lenovo product, are responsible for maintaining and updating all software and firmware for the product (unless it is covered by an additional maintenance contract). Your service technician will request that you upgrade your software and firmware if the problem has a documented solution within a software upgrade.
- If you have installed new hardware or software in your environment, check the IBM ServerProven website to make sure that the hardware and software is supported by your product.
- Go to the IBM Support portal to check for information to help you solve the problem.
- Gather the following information to provide to the service technician. This data will help the service technician quickly provide a solution to your problem and ensure that you receive the level of service for which you might have contracted.
  - Hardware and Software Maintenance agreement contract numbers, if applicable
  - Machine type number (if applicable–Lenovo 4-digit machine identifier)
  - Model number
  - Serial number
  - Current system UEFI and firmware levels
  - Other pertinent information such as error messages and logs

- Start the process of determining a solution to your problem by making the pertinent information available to the service technicians. The IBM service technicians can start working on your solution as soon as you have completed and submitted an Electronic Service Request.

You can solve many problems without outside assistance by following the troubleshooting procedures that Lenovo provides in the online help or in the Lenovo product documentation. The Lenovo product documentation also describes the diagnostic tests that you can perform. The documentation for most systems, operating systems, and programs contains troubleshooting procedures and explanations of error messages and error codes. If you suspect a software problem, see the documentation for the operating system or program.

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Important Notes

Processor speed indicates the internal clock speed of the microprocessor; other factors also affect application performance.

CD or DVD drive speed is the variable read rate. Actual speeds vary and are often less than the possible maximum.

When referring to processor storage, real and virtual storage, or channel volume, KB stands for 1,024 bytes, MB stands for 1,048,576 bytes and GB stands for 1,073,741,824 bytes.

When referring to hard disk drive capacity or communications volume, MB stands for 1,000,000 bytes and GB stands for 1,000,000,000 bytes. Total user-accessible capacity can vary depending on operating environments.

Maximum internal hard disk drive capacities assume the replacement of any standard hard disk drives and population of all hard-disk-drive bays with the largest currently supported drives that are available from Lenovo.

Maximum memory might require replacement of the standard memory with an optional memory module.

Each solid-state memory cell has an intrinsic, finite number of write cycles that the cell can incur. Therefore, a solid-state device has a maximum number of write cycles that it can be subjected to, expressed as total bytes written (TBW). A device that has exceeded this limit might fail to respond to system-generated commands or might be incapable of being written to. Lenovo is not responsible for replacement of a device that has exceeded its maximum guaranteed number of program/erase cycles, as documented in the Official Published Specifications for the device.

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Some software might differ from its retail version (if available) and might not include user manuals or all program functionality.

Recycling Information

Lenovo encourages owners of information technology (IT) equipment to responsibly recycle their equipment when it is no longer needed. Lenovo offers a variety of programs and services to assist equipment owners in recycling their IT products. For information on recycling Lenovo products, go to:

http://www.lenovo.com/recycling

Particulate Contamination

Attention: Airborne particulates (including metal flakes or particles) and reactive gases acting alone or in combination with other environmental factors such as humidity or temperature might pose a risk to the device that is described in this document.

Risks that are posed by the presence of excessive particulate levels or concentrations of harmful gases include damage that might cause the device to malfunction or cease functioning altogether. This specification sets forth limits for particulates and gases that are intended to avoid such damage. The limits must not be viewed or used as definitive limits, because numerous other factors, such as temperature or moisture content of the air, can influence the impact of particulates or environmental corrosives and gaseous contaminant transfer. In the absence of specific limits that are set forth in this document, you must implement practices that maintain particulate and gas levels that are consistent with the protection of human health and safety. If Lenovo determines that the levels of particulates or gases in your environment have caused damage to the device, Lenovo may condition provision of repair or replacement of devices or parts on implementation of appropriate remedial measures to mitigate such environmental contamination. Implementation of such remedial measures is a customer responsibility..

Contaminant	Limits
Particulate	• The room air must be continuously filtered with 40% atmospheric dust spot efficiency (MERV 9) according to ASHRAE Standard 52.2[1]. • Air that enters a data center must be filtered to 99.97% efficiency or greater, using high-efficiency particulate air (HEPA) filters that meet MIL-STD-282. • The deliquescent relative humidity of the particulate contamination must be more than 60%[2]. • The room must be free of conductive contamination such as zinc whiskers.
Gaseous	• Copper: Class G1 as per ANSI/ISA 71.04-1985[3] • Silver: Corrosion rate of less than 300 Å in 30 days

[1] ASHRAE 52.2-2008 - *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

[2] The deliquescent relative humidity of particulate contamination is the relative humidity at which the dust absorbs enough water to become wet and promote ionic conduction.

[3] ANSI/ISA-71.04-1985. *Environmental conditions for process measurement and control systems: Airborne contaminants*. Instrument Society of America, Research Triangle Park, North Carolina, U.S.A.

Telecommunication Regulatory Statement

This product may not be certified in your country for connection by any means whatsoever to interfaces of public telecommunications networks. Further certification may be required by law prior to making any such connection. Contact a Lenovo representative or reseller for any questions.

Electronic Emission Notices

When you attach a monitor to the equipment, you must use the designated monitor cable and any interference suppression devices that are supplied with the monitor.

Federal Communications Commission (FCC) Statement

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference, in which case the user will be required to correct the interference at his own expense.

Properly shielded and grounded cables and connectors must be used to meet FCC emission limits. Lenovo is not responsible for any radio or television interference caused by using other than recommended cables and connectors or by unauthorized changes or modifications to this equipment. Unauthorized changes or modifications could void the user's authority to operate the equipment.

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that might cause undesired operation.

Industry Canada Class A Emission Compliance Statement

This Class A digital apparatus complies with Canadian ICES-003.

Avis de Conformité à la Réglementation d'Industrie Canada

Cet appareil numérique de la classe A est conforme à la norme NMB-003 du Canada.

Australia and New Zealand Class A Statement

Attention: This is a Class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

European Union - Compliance to the Electromagnetic Compatibility Directive

This product is in conformity with the protection requirements of EU Council Directive 2004/108/EC (until April 19, 2016) and EU Council Directive 2014/30/EU (from April 20, 2016) on the approximation of the laws of the Member States relating to electromagnetic compatibility. Lenovo cannot accept responsibility for any failure to satisfy the protection requirements resulting from a non-recommended modification of the product, including the installation of option cards from other manufacturers.

This product has been tested and found to comply with the limits for Class A equipment according to European Standards harmonized in the Directives in compliance. The limits for Class A equipment were derived for commercial and industrial environments to provide reasonable protection against interference with licensed communication equipment.

CE Lenovo, Einsteinova 21, 851 01 Bratislava, Slovakia

Warning: This is a Class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

Germany Class A Statement

Deutschsprachiger EU Hinweis:

Hinweis für Geräte der Klasse A EU-Richtlinie zur Elektromagnetischen Verträglichkeit

Dieses Produkt entspricht den Schutzanforderungen der EU-Richtlinie 2014/30/EU (früher 2004/108/EC) zur Angleichung der Rechtsvorschriften über die elektromagnetische Verträglichkeit in den EU-Mitgliedsstaaten und hält die Grenzwerte der Klasse A der Norm gemäß Richtlinie.

Um dieses sicherzustellen, sind die Geräte wie in den Handbüchern beschrieben zu installieren und zu betreiben. Des Weiteren dürfen auch nur von der Lenovo empfohlene Kabel angeschlossen werden. Lenovo übernimmt keine Verantwortung für die Einhaltung der Schutzanforderungen, wenn das Produkt ohne Zustimmung der Lenovo verändert bzw. wenn Erweiterungskomponenten von Fremdherstellern ohne Empfehlung der Lenovo gesteckt/eingebaut werden.

Deutschland:

Einhaltung des Gesetzes über die elektromagnetische Verträglichkeit von Betriebsmittein

Dieses Produkt entspricht dem „Gesetz über die elektromagnetische Verträglichkeit von Betriebsmitteln“ EMVG (früher „Gesetz über die elektromagnetische Verträglichkeit von Geräten“). Dies ist die Umsetzung der EU-Richtlinie 2014/30/EU (früher 2004/108/EC) in der Bundesrepublik Deutschland.

Zulassungsbescheinigung laut dem Deutschen Gesetz über die elektromagnetische Verträglichkeit von Betriebsmitteln, EMVG vom 20. Juli 2007 (früher Gesetz über die elektromagnetische Verträglichkeit von Geräten), bzw. der EMV EU Richtlinie 2014/30/EU (früher 2004/108/EC), für Geräte der Klasse A.

Dieses Gerät ist berechtigt, in Übereinstimmung mit dem Deutschen EMVG das EG-Konformitätszeichen - CE - zu führen. Verantwortlich für die Konformitätserklärung nach Paragraf 5 des EMVG ist die Lenovo (Deutschland) GmbH, Meitnerstr. 9, D-70563 Stuttgart.

Informationen in Hinsicht EMVG Paragraf 4 Abs. (1) 4:

Das Gerät erfüllt die Schutzanforderungen nach EN 55024 und EN 55022 Klasse A.

Nach der EN 55022: „Dies ist eine Einrichtung der Klasse A. Diese Einrichtung kann im Wohnbereich Funkstörungen verursachen; in diesem Fall kann vom Betreiber verlangt werden, angemessene Maßnahmen durchzuführen und dafür aufzukommen."

Nach dem EMVG: „Geräte dürfen an Orten, für die sie nicht ausreichend entstört sind, nur mit besonderer Genehmigung des Bundesministers für Post und Telekommunikation oder des Bundesamtes für Post und Telekommunikation betrieben werden. Die Genehmigung wird erteilt, wenn keine elektromagnetischen Störungen zu erwarten sind." (Auszug aus dem EMVG, Paragraph 3, Abs. 4). Dieses Genehmigungsverfahrenist nach Paragraph 9 EMVG in Verbindung mit der entsprechenden Kostenverordnung (Amtsblatt 14/93) kostenpflichtig.

Anmerkung: Um die Einhaltung des EMVG sicherzustellen sind die Geräte, wie in den Handbüchern angegeben, zu installieren und zu betreiben.

Japan VCCI Class A Statement

この装置は、クラス A 情報技術装置です。この装置を家庭環境で使用すると電波妨害を引き起こすことがあります。この場合には使用者が適切な対策を講ずるよう要求されることがあります。 VCCI–A

This is a Class A product based on the standard of the Voluntary Control Council for Interference (VCCI). If this equipment is used in a domestic environment, radio interference may occur, in which case the user may be required to take corrective actions.

Japan Electronics and Information Technology Industries Association (JEITA) Statement

高調波ガイドライン適合品

Japan Electronics and Information Technology Industries Association (JEITA) Confirmed Harmonics Guidelines (products less than or equal to 20 A per phase)

高調波ガイドライン準用品

Japan Electronics and Information Technology Industries Association (JEITA) Confirmed Harmonics Guidelines with Modifications (products greater than 20 A per phase).

Korea Communications Commission (KCC) Statement

이 기기는 업무용(A급)으로 전자파적합기기로
서 판매자 또는 사용자는 이 점을 주의하시기
바라며, 가정외의 지역에서 사용하는 것을 목
적으로 합니다.

This is electromagnetic wave compatibility equipment for business (Type A). Sellers and users need to pay attention to it. This is for any areas other than home.

Russia Electromagnetic Interference (EMI) Class A statement

ВНИМАНИЕ! Настоящее изделие относится к классу А.
В жилых помещениях оно может создавать радиопомехи, для
снижения которых необходимы дополнительные меры

People's Republic of China Class A electronic emission statement

中华人民共和国“A类”警告声明

声 明

此为A级产品，在生活环境中，该产品可能会造成无线电干扰。在这种情况下，
可能需要用户对其干扰采取切实可行的措施。

Taiwan Class A compliance statement

警告使用者:
這是甲類的資訊產品，在
居住的環境中使用時，可
能會造成射頻干擾，在這
種情況下，使用者會被要
求採取某些適當的對策。

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