BROADCOM®

EFOS

Administrator’s Guide

User Guide
Software Release 3.4.3

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Chapter 1: EFOS Features

This section provides a brief overview of the supported Ethernet Fabric Operating System (EFOS) features.

1.1 Management and EFOS Base Features

This section describes the management features EFOS software supports. For additional information and configuration examples for some of these features, see Section 3, Configuring Switch Management Features.

1.1.1 Management Options

You can use the following methods to manage the switch:

- Use a telnet client, SSH client, or a direct console connection to access the CLI. The CLI syntax and semantics conform as much as possible to common industry practice.
- Use a network management system (NMS) to manage and monitor the system through SNMP. The switch supports SNMP v1/v2c/v3 over the UDP/IP transport protocol.

1.1.2 Management of Basic Network Information

The DHCP client on the switch allows the switch to acquire information such as the IP address and default gateway from a network DHCP server. You can also disable the DHCP client and configure static network information. Other configurable network information includes a Domain Name Server (DNS), host name to IP address mapping, and a default domain name.

The switch also includes a DHCPv6 client for acquiring IPv6 addresses, prefixes, and other IPv6 network configuration information.

1.1.3 Dual Software Images

The switch can store up to two software images. The dual image feature allows you to upgrade the switch without deleting the older software image. You designate one image as the active image and the other image as the backup image.

1.1.4 File Management

You can upload and download files such as configuration files and system images by using FTP, TFTP, Secure FTP (SFTP), or Secure Copy (SCP). Configuration file uploads from the switch to a server are a good way to back up the switch configuration. You can also download a configuration file from a server to the switch to restore the switch to the configuration in the downloaded file.

1.1.4.1 FTP File Update

This feature adds support for file transfers using FTP protocol. FTP Transfers are supported over both IPv4 and IPv6. Upon failure of a FTP transfer operation, a LOG message is sent to the logging component, the initiating application is notified of the failure, and any partial or temporary files for the transfer are removed from persistent memory.

1.1.4.2 Malicious Code Detection

This feature provides a mechanism to detect the integrity of the image, if the software binary is corrupted or tampered with while end user attempts to download the software image to the switch. This release addresses this problem by using digital signatures to verify the integrity of the binary image. It also provides flexibility to download a digitally signed configuration script and verify the digital signature to ensure the integrity of the downloaded configuration file.

1.1.4.3 File Transfer OpEN APIs

File transfer provides the ability to download code to a switch. These APIs are used to setup and execute file transfer via TFTP, SFTP and SCP.

1.1.4.4 SCP Push

EFOS includes support for SCP push operations, which allows files to be transferred from the host device to the switch using the SCP protocol.

1.1.5 Automatic Installation of Firmware and Configuration

The Auto Install feature allows the switch to upgrade to a newer software image and update the configuration file automatically during device initialization with limited administrative configuration on the device. The switch can obtain the necessary information from a DHCP server on the network.

1.1.6 In-Service Software Upgrade

The in-service software upgrade (ISSU) feature allows users to upgrade the switch software without interrupting data forwarding through the switch.

This feature is mainly targeted for top-of-rack (TOR) switches in data center Clos topologies. The goal of ISSU is to maintain Ethernet data connectivity with the servers attached to TOR switches while the TOR switch software is being upgraded. A software upgrade that requires a reboot or a kernel upgrade is not supported via ISSU.

1.1.7 Warm Reboot

The Warm Reboot feature reduces the time it takes to reboot the switch thereby reducing the traffic disruption in the network during a switch reboot. For a typical switch, the traffic disruption is reduced from about two minutes for a cold reboot to about 20 seconds for a warm reboot.

1.1.8 SNMP Alarms and Trap Logs

The system logs events with severity codes and timestamps. The events are sent as SNMP traps to a trap recipient list.

1.1.9 CDP Interoperability Through ISDP

Industry Standard Discovery Protocol (ISDP) allows the switch to interoperate with Cisco devices running the Cisco Discovery Protocol (CDP). ISDP is a proprietary Layer 2 network protocol which inter-operates with Cisco network equipment and is used to share information between neighboring devices (routers, bridges, access servers, and switches).

1.1.10 Remote Monitoring (RMON)

RMON is a standard Management Information Base (MIB) that defines current and historical MAC-layer statistics and control objects, allowing real-time information to be captured across the entire network. The data collected is defined in the RMON MIB, RFC 2819 (32-bit counters), RFC 3273 (64-bit counters), and
RFC 3434 (High Capacity Alarm Table).

1.1.11 Statistics Application

The statistics application collects the statistics at a configurable time interval. The user can specify the port number(s) or a range of ports for statistics to be displayed. The configured time interval applies to all ports. Detailed statistics are collected between the specified time range in date and time format. The time range can be defined as having an absolute time entry and/or a periodic time. For example, a user can specify the statistics to be collected and displayed between 9:00 12 NOV 2011 (START) and 21:00 12 NOV 2011 (END) or schedule it on every MON, WED and FRI 9:00 (START) to 21:00 (END).

The user receives these statistics in a number of ways as listed below:

- User requests through CLI for a set of counters.
- User can configure the device to display statistics using syslog or email alert. The syslog or email alert messages are sent by the statistics application at END time.

The statistics are presented on the console at END time.

1.1.12 Log Messages

The switch maintains in-memory log messages as well as persistent logs. You can also configure remote logging so that the switch sends log messages to a remote log server. You can also configure the switch to send log messages to a configured SMTP server. This allows you to receive the log message in an e-mail account of your choice. Switch auditing messages, CLI command logging, and SNMP logging can be enabled or disabled.

1.1.13 Dying Gasp

The Dying-Gasp feature sends a *dying-gasp* notification through Syslog or Ethernet-OAM when the switch loses power or resets abruptly. The switch reset might be due to an unexpected software failure, a LOG_ERROR, or a user-triggered switch reload. The Dying Gasp feature also notifies dying gasp events as *SNMP trap* to the trap receiver

The ability to send Dying-Gasp notifications on loss of power depends on the platform hardware capability. The switch hardware must be able to supply back power for approximately 300 ms to send the dying gasp notification after the abrupt power loss or reset occurs.

1.1.14 System Time Management

You can configure the switch to obtain the system time and date through a remote Simple Network Time Protocol (SNTP) server, or you can set the time and date locally on the switch. You can also configure the time zone and information about time shifts that might occur during summer months.

NOTE: The manually-configured local clock settings are not retained across a system reset if the platform does not include a Real Time Clock (RTC).

1.1.15 Source IP Address Configuration

Syslog, TACACS, SNTP, sFlow, SNMP Trap, RADIUS, and DNS Clients allow the IP Stack to select the source IP address while generating the packet. This feature provides an option for the user to select an interface for the source IP address while the management protocol transmits packets to management stations. The source address is specified for each protocol.

1.1.16 Multiple Linux Routing Tables

On Linux systems, local and default IPv4 routes for the service port and network port are installed in routing tables dedicated to each management interface. Locally-originated IPv4 packets use these routing tables when the source IP address of the packet matches an address on one of these interfaces. This feature allows the Linux IP stack to use default routes for different interfaces simultaneously.

1.1.17 Core Dump

The core dump feature provides the ability to retrieve the state from a crashed box such that it can be then loaded into a debugger and have that state re-created there.

1.1.17.1 Core Dump File Handling

A core dump file can be transferred to a debugger using several methods, depending on the supported switch interfaces and capabilities:

- Via a USB connection (if supported)
- Stored locally on flash (if it is of sufficient size) and accessed from a remote system via NFS.
- Transferred via FTP to a remote FTP server.

Because the size of the core dump file can be several hundred megabytes, the file is compressed using the bzip2 compression technique available in BusyBox. Compression is enabled by default and can be enabled/disabled using the CLI.

1.1.17.2 Kernel Core Dump

The kernel core dump (kdump) feature enables the system to perform a warm reboot into a new kernel in reserved memory, allowing the current state of the operating kernel to be captured for analysis. This feature is available on all x86 platforms operating on Ubuntu and CentOS.

1.1.18 Link Debounce

In network deployments where the switch detects random spurious link flaps, network performance is affected due to the frequent unwanted re-convergence of topology for protocols like spanning tree, OSPF, and link aggregation.

The link debounce feature tries to solve this problem by delaying the link-down event notification to applications by waiting for a configurable duration of time known as the *debounce time*. During this time, the link may cycle through down-and-up states several times before it finally settles down. If the link goes down (and stays down), applications are notified after the debounce time period expires; otherwise it is ignored.

1.1.19 Chef API Integration

EFOS provides a Chef agent that allows a Chef server to configure the switch. This configuration is done via Chef Recipes. The recipes are written in Ruby and will interface to the EFOS OpEN API in order to enact configuration changes.

The following items are supported:

- The standard Chef Client (version:11.4.0), available from OpsCode (www.opscode.com).
- Creating a set of RPMs for installing Chef Client.
- Integrating the ported Chef Client with the EFOS software.
- Providing a simple Broadcom API cookbook and role to make EFOS specific configurations.

The agent and dependent RPMs require 32 MB of NVRAM (flash). The agent requires approximately 23 MB of DRAM once initialized.

1.1.20 Puppet API Integration

EFOS provides a Puppet agent that allows a Puppet server to manage patches and configure/provision the switch.

Puppet is designed to deploy system configurations. It supports the following:

- Open source based on Ruby
- Policy based
- Runs every 30 minutes
- An abstraction layer between the system administrator and the system
- Capable to run on any UNIX operating system
- The agent and dependent RPMs require 32 MB of NVRAM (flash)
- The agent requires approximately 25 MB of DRAM once initialized

The following items are supported:

- Standard Puppet Agent (version: 3.1.1), available from Puppet Labs (https://puppetlabs.com/)
- Creating a set of RPMs for installing Puppet Agent.
- Integrating the ported Puppet Agent with EFOS.
- Providing a few Broadcom Netdev Providers which uses an API to perform EFOS specific configurations.

1.1.21 Zero-Touch Provisioning

The Zero Touch Provisioning (ZTP) feature is an enhancement to the AutoInstall feature that supports installation of Chef Client or Puppet Agent at the time of device bootup. EFOS supports automatic installation of the Chef Client/Puppet Agent.

ZTP uses DHCP option 125 to download an .ini file from a TFTP server and installs the Chef Client/Puppet Agent as defined in the .ini file.

Automatic installation of Chef Client/Puppet Agent occurs when:

- The device boots with no saved configuration found in the designated storage areas.
- The device boots with a saved configuration that has AutoInstall enabled.

ZTP enables installing the device “Chef Client” or “Puppet Agent” ready without login into the device. Installing “Chef Client” or “Puppet Agent” is involved transferring necessary files (bootstrapping and RPMs) to the device and executing Linux commands on the device. The feature takes cares of retrieving necessary files and executes Linux commands automatically. However, DHCP server, HTTP Server and RPM repositories must exist in the network to perform the actions automatically.

The Zero Touch Provisioning feature on x86 platforms allows administrators to execute custom script on Broadcom devices. Upon the first boot after a successful ONIE installation of EFOS, the DHCP client requests the "Provisioning script URL" via DHCP Option 239. The provisioning script is downloaded from the URL and executed by a ZTP service. The provisioning script execution is performed only once, and the configuration mode is disabled. The script execution mode can be re-enabled by modifying a ZTP-related configuration file. The provisional script can be used to perform basic operations, including but not limited to execute Linux commands, modify Linux application configuration files.

1.1.22 Open Network Install Environment Support

Open Network Install Environment (ONIE) allows customers to install their choice of network operating system (NOS) onto an EFOS platform. When the switch boots, ONIE enables the switch to fetch a NOS stored on a remote server. The remote server can hold multiple NOS images, and the administrator can specify which NOS to load and run on the switch. ONIE support in EFOS facilitates automated data center provisioning by enabling a bare-metal network switch ecosystem.

ONIE is a small operating system. It is preinstalled as firmware and requires an ONIE-compliant boot loader (U-Boot/ BusyBox), a kernel (Linux) and the ONIE discovery and execution application provided by the ODM.

ONIE can be installed onto the EFOS platform over the network or by copying the EFOS ONIE image file into the dedicated disk partition. For more information about ONIE, refer to the *Open Network Install Environment* in Appendix A.1, References.

1.1.23 Interface Error Disable and Auto Recovery

If EFOS software detects an error condition for an interface, it places the interface in diagnostic disabled state by shutting down the interface. The error-disabled interface does not allow any traffic until it is re-enabled. The interface can be manually re-enabled by the administrator or, when the Auto Recovery feature is enabled, can be re-enabled automatically after a configurable time-out.

There are multiple reasons that may cause EFOS to place an interface in the error-disabled state. Auto Recovery can be configured to take effect if an interface is error-disabled for any reason, or for some reasons but not others.

1.1.24 BroadView Support

EFOS supports the Broadcom® BroadView™ version 3.2.02 software suite, which can help network administrators analyze and optimize their networks through the following features:

- Buffer statistics tracking (BST) provides network congestion analysis through monitoring on-chip buffers.
- Live packet tracing for LAG and ECMP provides detailed information on how a specific packet is processed through the ingress pipeline.
- Packet Drop Monitor, a sub-feature of the Packet Trace feature, allows users to monitor the packet drops and identify the reason for the packet drop.
- Black hole detection (BHD) helps get notification logs intermittently whenever packets are black-holed in the network. Because of an enhancement in the spine port list, the spine ports can be:
  - Physical Ports.
  - Physical Ports as a member of different trunk (LAG) interfaces.
  - Physical Ports as a member of ECMP groups.
  - Physical Ports as a member of trunk interfaces and these trunk interfaces are eventually a member of ECMP group.
- Storage provisioning allows switches to be configured to ensure storage traffic is recognized and classified into lossless and lossy categories. Various resources available in the Broadcom ASIC are set aside for such storage traffic upon provisioning, and statistics are reported for monitoring the resources.
- Inband Flow Analyzer (IFA) requires firmware version 4.3.7.6 and is supported only on the BCM56870 platform.

- The Flow Tracker (FT) feature requires Flow Tracker firmware version 4.3.6 and is supported only on the BCM56870 platform. Flow Tracker allows operators to configure flow-groups (5-tuples with wild cards), for which the flows should be monitored. Flow-related metrics are captured within the ASIC and are exported in IPFIX format to a remote collector at regular intervals. EFOS has an *Observation Time Stamp* field in the flow group record IPFIX message in the Flow Tracker feature.
- Optional configuration parameters `template-update-periodicity`, `flow-records-src-port`, `flow-group-records-src-port`, and `flowgroup-records-update-periodicity` in the `configure-ft-feature` API.
- Additional configuration parameter support for `ingress-ports` in the `create-ft-flowgroup` API.
- The `get-storage-statistics` response/notification message shows the `total-count` of storage statistics.
- The `get-switch-properties` response/notification message adds `IFA` (Inband Flow Analyzer feature), `STRG` (storage provisioning) and BHD (black hole detection) as supported features.
- The `version` field in the `Agent` response/notification message is incremented to 8.
- BroadView support on BCM56970 silicon.

NOTE: The Flow Tracker and Inband Flow Analyzer firmware from Broadcom are licensed separately. Both features cannot be run simultaneously because both features are dependent upon two separate firmware running the same switch core.

1.1.25 CPU Traffic Filtering

Packets to and from the switch CPU can be sent to a remote Wireshark packet analyzer. These CPU packets can also be saved in pcap format as a file, which can be uploaded to external server to view the packets. EFOS provides an option to define filters that limit the captured data to packets that match the filter criteria.

EFOS also provides a trace mechanism for packets received by CPU and matches the filter until the packet is delivered to registered application. This can help determine whether a packet was dropped or mishandled after being received by the CPU.

1.1.26 Protocol Packet Trace

The packet trace feature provides detailed information on how a specific packet is processed through the ingress pipeline. The feature allows the user to send a special visibility loopback packet into the Ingress Packet Processing Pipeline that is then processed as if it were received on one of the front-panel ports, so that internal forwarding and packet processing states can be logged. The internal forwarding and packet processing data retrieved for the packet as a part of the packet trace feature is called a trace profile. The trace profile contains data such as the lookup resolution results, lookup status, state of the ingress port, hashing info for the packet (i.e., LAG hash resolution, and ECMP route resolution). This information can be useful for detecting/diagnosing potential network problems.

1.1.27 Expandable Port Configuration

NOTE: This feature is available only on platforms that contain expandable ports, which are ports capable of being configured as a variable number of ports.

Expandable ports allow the administrator to configure:

- A 40G port in either 4×10G mode or 1×40G mode. When the 40G port is operating in 4×10G mode, the port operates as four 10G ports, each on a separate lane. This mode requires the use of a suitable 4×10G to 1×40G pigtail cable.
- A 100G port in 4×25G, 2×50G, or 1×100G mode. When the 100G port is operating in 4×25G mode, the port operates as four 25G ports, each on a separate lane. This mode requires the use of a suitable 4×25G to 1×100G pigtail cable. When the 100G port is operating in 2×50G mode, the port operates as two 50G ports, each using two lanes. This mode requires the use of a suitable 2×50G to 1×100G pigtail cable.

Expandable port capability can be enabled on the supported ports using the CLI command **[no] hardware profile portmode**. On switches based on the Broadcom BCM56850 and later devices, a change to the port mode is made effective immediately. On switches based on other chips, the mode of the expandable port takes place when the system boots, so if the mode is changed during switch operation, the change does not take effect until the next boot cycle.

1.1.28 Forward Error Correction

This feature provides a mechanism to enable/disable forward error correction (FEC) on interfaces operating at speeds of 100G, 50G and 25G, in adherence with IEEE requirements (IEEE 802.3bj -CL 91). FEC is programmed as a PHY capability in the port descriptors of ports that can operate at these speeds and is enabled by default on all such ports. FEC can be configured in three modes: FEC 100G, FEC 50G, and FEC 25G. By default, FEC is configured in the mode that corresponds to the speed of the interface. For example a 50G interface is configured in FEC 50G mode.

1.1.29 Port and Feature Licensing

Port licensing allows enabling a block of ports in a platform which already supports a higher number of ports but, by default, they are disabled. A valid license file must be purchased and installed in the system to enable such ports.

Feature licensing allows a disabled license feature to be enabled once a valid feature license file is installed.

For example, the BCM56870 IX8-B ODM platform has 48 x 25G + 8 x 100G ports. But only 16 x 25G + 2 x 100G ports are enabled by default. An additional downloadable software license is needed to enable multiples of 8 x 25G + 2 x 100G port blocks and the BroadView feature.

1.2 Security Features

This section describes the security features EFOS software supports. For additional information and configuration examples for some of these features, see Section 4, Configuring Security Features.

1.2.1 Configurable Access and Authentication Profiles

You can configure rules to limit access to the switch management interface based on criteria such as access type and source IP address of the management host. You can also require the user to be authenticated locally or by an external server, such as a RADIUS server.

1.2.2 AAA Command Authorization

This feature enables AAA Command Authorization in EFOS.

1.2.3 Task-Based Authorization

Task-based authorization allows users to have different permission levels (read, write, execute, debug) at a per-component level for the AAA, BGP, and OSPF components. Task-based authorization uses the concept of components/tasks to define permission for commands for a given user.

Users are assigned to User Groups that are, in turn, associated with Task Groups. Each Task Group is then associated with one or more tasks/components. This feature is supported only for users who are authenticated locally via the CLI interface. Users authenticated via any other mechanism (RADIUS, TACACS, etc.) will have access to all CLI commands. Permissions are set only during user login.

1.2.4 Password-Protected Management Access

Access to the CLI and SNMP management interfaces is password protected, and there are no default users on the system.

1.2.5 Strong Password Enforcement

The Strong Password feature enforces a baseline password strength for all locally administered users. Password strength is a measure of the effectiveness of a password in resisting guessing and brute-force attacks. The strength of a password is a function of length, complexity and randomness. Using strong passwords lowers overall risk of a security breach.

1.2.6 MAC-Based Port Security

The port security feature limits access on a port to users with specific MAC addresses. These addresses are manually defined or learned on that port. When a frame is seen on a locked port, and the frame source MAC address is not tied to that port, the protection mechanism is invoked.

1.2.7 VLAN MAC Locking

VLAN MAC locking allows a network administrator to secure the network by locking down allowable MAC addresses on a given VLAN. Packets with a matching source MAC address can be forwarded normally. All other packets will be discarded. VLAN MAC locking will lock the dynamic MAC entries.

If VLAN and MAC-based port security (also known as Port MAC Locking) are enabled, VLAN MAC locking will be given precedence over Port MAC locking.

1.2.8 RADIUS Client

The switch has a Remote Authentication Dial In User Service (RADIUS) client and can support up to 32 authentication and accounting RADIUS servers. The RADIUS client supports communication with either an IPv4 or IPv6 RADIUS server.

1.2.9 TACACS+ Client

The switch has a TACACS+ client. TACACS+ provides centralized security for validation of users accessing the switch. TACACS+ provides a centralized user management system while still retaining consistency with RADIUS and other authentication processes.The TACACS+ client supports communication with either an IPv4 or IPv6 TACACS+ server.

1.2.10 Dot1x Authentication (IEEE 802.1X)

Dot1x authentication enables the authentication of system users through a local internal server or an external server. Only authenticated and approved system users can transmit and receive data. Supplicants are authenticated using the Extensible Authentication Protocol (EAP). Also supported are PEAP, EAP-TTL, EAP-TTLS, and EAP-TLS.

The EFOS 802.1X implementation is based on the IEEE 802.1X 2010 standard.

1.2.11 Dynamic ACLs

When the RADIUS server authenticates a user who is connected to an IEEE 802.1X (Dot1x) port, the server sends ACL attributes based on user-configuration information on the RADIUS server. The switch applies the ACL attributes for the duration of Dot1x user session. The switch removes the ACL configuration when the session is terminated on the dot1x port. The switch does not save RADIUS-specified ACLs in the running configuration. When the port is unauthorized, the per-user ACL is removed from the port. ACL attributes can be sent using various attributes in the access-accept request, such as Cisco VSA (26) or Filter-Id (11).

1.2.12 MAC Authentication Bypass

EFOS software supports the MAC-based Authentication Bypass (MAB) feature, which provides 802.1X-unaware clients (such as printers and fax machines) controlled access to the network using the devices' MAC address as an identifier. This requires that the known and allowable MAC address and corresponding access rights be pre-populated in the authentication server. MAB can also be used to authenticate 802.1X-aware clients.

1.2.13 Microsoft Active Directory Authentication for Management

EFOS supports Microsoft Active Directory (MS AD) user authentication for EFOS management interfaces. Authentication into the Windows domain network is performed by using an LDAP simple bind operation and optionally over TLS. Authorization is done based on the *memberOf* attribute or *description* attribute carrying the vendor-specific attribute (VSA) for Cisco (cisco-av-pair) configured on the Microsoft Active Directory.

1.2.14 Authentication Manager

The Authentication Manager feature provides a means of assigning authentication methods to ports and specifying the order in which the methods are executed when an authentication method fails. This feature determines which ports use which authentication methods. It also determines the failover sequencing methods on the ports. This feature allows users or IT administrators to configure the sequence and priority of IEEE 802.1X and MAC authentication bypass (MAB).

The Authentication Manager supports RADIUS-based assignment (via 802.1X or MAB) of VLANs, including guest and unauthenticated VLANs. It also supports RADIUS-based assignment of filter IDs as well as a multi-authentication host mode, which allows multiple supplicants connected to the same port to authenticate individually. Additionally, EFOS software supports critical VLANs, which allow supplicants to authenticate on a critical VLAN when all RADIUS servers are considered dead (all RADIUS servers have stopped responding).

1.2.15 Denial of Service

The switch supports configurable Denial of Service (DoS) attack protection for many different types of attacks.

1.2.16 DHCP Snooping

DHCP Snooping is a security feature that monitors DHCP messages between a DHCP client and DHCP server. It filters harmful DHCP messages and builds a bindings database of (MAC address, IP address, VLAN ID, port) tuples that are specified as authorized. DHCP snooping can be enabled globally and on specific VLANs. Ports within the VLAN can be configured to be trusted or untrusted. DHCP servers must be reached through trusted ports. This feature is supported for both IPv4 and IPv6 packets.

1.2.17 DHCPv4 and DHCPv6 Server

DHCP is used to automatically allocate and manage TCP/ IP configurations of client nodes. DHCP conforms to the client/ server model using UDP as its transport protocol. It supports a number of features which facilitate in easy administration of the address allocation mechanism.

The EFOS switch includes support to function as a DHCP server and allocate IPv4 or IPv6 addresses and other network information to DHCP clients that make requests.

1.2.18 Dynamic ARP Inspection

Dynamic ARP Inspection (DAI) is a security feature that rejects invalid and malicious ARP packets. The feature prevents a class of man-in-the-middle attacks, where an unfriendly station intercepts traffic for other stations by poisoning the ARP caches of its unsuspecting neighbors. The malicious station sends ARP requests or responses mapping another station's IP address to its own MAC address.

1.2.19 IP Source Address Guard

IP Source Guard and Dynamic ARP Inspection use the DHCP snooping bindings database. When IP Source Guard is enabled, the switch drops incoming packets that do not match a binding in the bindings database. IP Source Guard can be configured to enforce just the source IP address or both the source IP address and source MAC address. Dynamic ARP Inspection uses the bindings database to validate ARP packets. This feature is supported for both IPv4 and IPv6 packets.

1.2.20 Management Access Control and Administration List

In order to ensure the security of the switch management features, the administrator may elect to configure a management access control list. The Management Access Control and Administration List (MACAL) component is used to ensure that only known and trusted devices are allowed to remotely manage the switch via TCP/IP.

Management ACALs can be applied only to in-band ports and cannot be applied to the service port.

1.3 Switching Features

This section describes the Layer 2 switching features EFOS software supports. For additional information and configuration examples for some of these features, see Section 5, Configuring Switching Features.

1.3.1 VLAN Support

VLANs are collections of switching ports that comprise a single broadcast domain. Packets are classified as belonging to a VLAN based on either the VLAN tag or a combination of the ingress port and packet contents. Packets sharing common attributes can be groups in the same VLAN. EFOS software is in full compliance with IEEE 802.1Q VLAN tagging.

1.3.2 Double VLANs

The Double VLAN feature (IEEE 802.1QinQ) allows the use of a second tag on network traffic. The additional tag helps differentiate between customers in the Metropolitan Area Networks (MAN) while preserving individual customer's VLAN identification when they enter their own 802.1Q domain.

1.3.3 Private VLANs

Private VLANs provide Layer 2 isolation between ports that share the same broadcast domain. In other words, a private VLAN allows a VLAN broadcast domain to be partitioned into smaller point-to-multipoint subdomains. The ports participating in a private VLAN can be located anywhere in the Layer 2 network. Each subdomain is defined (represented) by a primary VLAN and a secondary VLAN. The primary VLAN ID is the same for all subdomains that belong to a private VLAN. The secondary VLAN ID differentiates subdomains from each other and provides Layer 2 isolation between ports that are members of the same private VLAN.

1.3.4 Switchport Modes

The switchport mode feature helps to minimize the potential for configuration errors. The feature also makes VLAN configuration easier by reducing the amount of commands needed for port configuration. For example, to configure a port connected to an end user, the administrator can configure the port in Access mode. Ports connected to other switches can be configured in Trunk mode. VLAN assignments and tagging behavior are automatically configured as appropriate for the connection type.

A third switchport mode, General mode, provides no configuration restrictions and allows the administrator to configure the port with custom VLAN settings.

1.3.5 VLAN Mapping for VRF

The VLAN mapping feature enables the switch to replace a VLAN in a single-tagged packet with another VLAN ID. Based on per-port configuration, the wire VLAN is replaced with a device VLAN on ingress, and the device VLAN is replaced with the wire VLAN on egress. The VLAN tag protocol for the device VLAN and the wire VLAN is 0x8100, which the standard C-VLAN defined in the 802.1d standard.

The VLAN mapping feature simplifies VLAN ID assignment in a data center when using virtual routing and forwarding (VRF). The VRF instances require the switches in the data center to be interconnected with VLAN trunks instead of port-based routing interfaces, so the VLAN mapping feature enables the network administrator to select routing interface VLAN IDs independently on each switch instead of coordinating the VLAN ID assignment across multiple switches.

1.3.6 Spanning Tree Protocol (STP)

Spanning Tree Protocol (IEEE 802.1D) is a standard requirement of Layer 2 switches that allows bridges to automatically prevent and resolve L2 forwarding loops. The STP feature supports a variety of per-port settings including path cost, priority settings, Port Fast mode, STP Root Guard, Loop Guard, TCN Guard, and Auto Edge. These settings are also configurable per-LAG.

1.3.7 Rapid Spanning Tree

Rapid Spanning Tree Protocol (RSTP) detects and uses network topologies to enable faster spanning tree convergence after a topology change, without creating forwarding loops. The port settings supported by STP are also supported by RSTP.

1.3.8 Multiple Spanning Tree

Multiple Spanning Tree (MSTP) operation maps VLANs to spanning tree instances. Packets assigned to various VLANs are transmitted along different paths within MSTP Regions (MST Regions). Regions are one or more interconnected MSTP bridges with identical MSTP settings. The MSTP standard lets administrators assign VLAN traffic to unique paths.

The switch supports IEEE 802.1Q-2005, which is a version of corrects problems associated with the previous version, provides for faster transition-to-forwarding, and incorporates new features for a port (restricted role and restricted TCN).

1.3.9 Bridge Protocol Data Unit (BPDU) Guard

Spanning Tree BPDU Guard is used to disable the port in case a new device tries to enter the already existing topology of STP. Thus devices, which were originally not a part of STP, are not allowed to influence the STP topology.

1.3.10 BPDU Filtering

When spanning tree is disabled on a port, the BPDU Filtering feature allows BPDU packets received on that port to be dropped. Additionally, the BPDU Filtering feature prevents a port in Port Fast mode from sending and receiving BPDUs. A port in Port Fast mode is automatically placed in the forwarding state when the link is up to increase convergence time.

1.3.11 PVRSTP and PVSTP

EFOS support both Rapid Spanning Tree Per VLAN (PVRSTP) and Spanning Tree Per VLAN (PVSTP). PVRSTP is the IEEE 802.1w (RSTP) standard implemented per VLAN. A single instance of rapid spanning tree (RSTP) runs on each configured VLAN. Each RSTP instance on a VLAN has a root switch. PVSTP is the IEEE 802.1D (STP) standard implemented per VLAN.

1.3.12 Link Aggregation

Up to eight ports can combine to form a single Link Aggregated Group (LAG). This enables fault tolerance protection from physical link disruption, higher bandwidth connections and improved bandwidth granularity.

A LAG is composed of ports of the same speed, set to full-duplex operation.

1.3.13 Track LAG Member Port Flaps

This feature enables a user to track how many times a LAG member has flapped. The member flap counter show the number of times a port member is INACTIVE, either because the link is down, or the administrative state is disabled. The Link Down counter shows the number of times the LAG is down because all its member ports are INACTIVE.

1.3.14 Link Aggregate Control Protocol (LACP)

Link Aggregate Control Protocol (LACP) uses peer exchanges across links to determine, on an ongoing basis, the aggregation capability of various links, and continuously provides the maximum level of aggregation capability achievable between a given pair of systems. LACP automatically determines, configures, binds, and monitors the binding of ports to aggregators within the system.

1.3.15 Virtual Port Channel (VPC)

This feature enables a LAG to be created across two independent units, which creates a scenario where some member ports of the VPC can reside on one unit and the other members of the VPC can reside on the other unit. The partner device on the remote side can be an VPC unaware unit. For the VPC unaware unit, the VPC appears to be a single LAG connected to a single unit.

NOTE: VPC is also known as Multi-Switch Link Aggregation (MLAG).

1.3.16 Flow Control Support (IEEE 802.3x)

Flow control enables lower speed switches to communicate with higher speed switches by requesting that the higher speed switch refrains from sending packets. Transmissions are temporarily halted to prevent buffer overflows.

1.3.17 Asymmetric Flow Control

Asymmetric Flow Control can only be configured globally for all ports on XGS4 silicon based switches.

When in asymmetric flow control mode, the switch responds to PAUSE frames received from peers by stopping packet transmission, but the switch does not initiate MAC control PAUSE frames.

When the switch is configured in asymmetric flow control (or no flow control mode), the device is placed in egress drop mode. Egress drop mode maximizes the throughput of the system at the expense of packet loss in a heavily congested system, and this mode avoids head of line blocking.

Asymmetric flow control is NOT supported on Fast Ethernet platforms as the support was introduced to the physical layer with the Gigabit PHY specifications.

NOTE: In asymmetric flow control mode, the switch advertises the symmetric flow control capability, but forces the TX Pause to OFF in the MAC layer. At PHY level, Pause bit = 1, and ASM_DIR =1 have to be advertised to the peer. At Driver level, TX Pause = 0, and RX Pause = 1, as described in IEEE 802.3-2005 Table 28B-2. The operational state (MAC layer) of receive Flow Control (RX) is based on the pause resolution in IEEE 802.3-2005 Table 28B-3. The operational state (MAC layer) of Flow Control on Send side (TX) is always Off.

1.3.18 Alternate Store and Forward (ASF)

The Alternate Store and Forward (ASF) feature, which is also known as cut-through mode, reduces latency for large packets. When ASF is enabled, the memory management unit (MMU) can forward a packet to the egress port before it has been entirely received on the Cell Buffer Pool (CBP) memory.

NOTE: Support for ASF is not available on all platforms.

1.3.19 Jumbo Frames Support

Jumbo frames enable transporting data in fewer frames to ensure less overhead, lower processing time, and fewer interrupts. The maximum transmission unit (MTU) size is configurable per-port.

1.3.20 Auto-MDI/MDIX Support

Your switch supports auto-detection between crossed and straight-through cables. Media-Dependent Interface (MDI) is the standard wiring for end stations, and the standard wiring for hubs and switches is known as Media-Dependent Interface with Crossover (MDIX).

1.3.21 Unidirectional Link Detection (UDLD)

The UDLD feature detects unidirectional links physical ports by exchanging packets containing information about neighboring devices. The purpose of the UDLD feature is to detect and avoid unidirectional links. A unidirectional link is a forwarding anomaly in a Layer 2 communication channel in which a bidirectional link stops passing traffic in one direction.

1.3.22 VLAN-Aware MAC-based Switching

Packets arriving from an unknown source address are sent to the CPU and added to the Hardware Table. Future packets addressed to or from this address are more efficiently forwarded.

1.3.23 Back Pressure Support

On half-duplex links, a receiver may prevent buffer overflows by jamming the link so that it is unavailable for additional traffic. On full duplex links, a receiver may send a PAUSE frame indicating that the transmitter should cease transmission of frames for a specified period.

When flow control is enabled, the switch will observe received PAUSE frames or jamming signals, and will issue them when congested.

1.3.24 Auto Negotiation

Auto negotiation allows the switch to advertise modes of operation. The auto negotiation function provides the means to exchange information between two switches that share a point-to-point link segment, and to automatically configure both switches to take maximum advantage of their transmission capabilities.

The switch enhances auto negotiation by providing configuration of port advertisement. Port advertisement allows the system administrator to configure the port speeds that are advertised.

1.3.25 Storm Control

When Layer 2 frames are forwarded, broadcast, unknown unicast, and multicast frames are flooded to all ports on the relevant virtual local area network (VLAN). The flooding occupies bandwidth, and loads all nodes connected on all ports. Storm control limits the amount of broadcast, unknown unicast, and multicast frames accepted and forwarded by the switch.

Per-port and per-storm control type (broadcast, multicast, or unicast), the storm control feature can be configured to automatically shut down a port when a storm condition is detected on the port; or to send a trap to the system log. When configured to shut down, the port is put into a diag-disabled state. The user must manually re-enable the interface for it to be operational. When configured to send a trap, the trap is sent once in every 30 seconds. When neither action is configured, the switch rate-limits the traffic when storm conditions occur.

Refer to the *CLI Command Reference* for command examples. See Appendix A.1, References.

1.3.26 Port Mirroring

Port mirroring monitors and mirrors network traffic by forwarding copies of incoming and outgoing packets from up to four source ports to a monitoring port. The switch also supports flow-based mirroring, which allows you to copy certain types of traffic to a single destination port. This provides flexibility—instead of mirroring all ingress or egress traffic on a port the switch can mirror a subset of that traffic. You can configure the switch to mirror flows based on certain kinds of Layer 2, Layer 3, and Layer 4 information.

EFOS supports up to four monitor sessions. Port mirroring, flow based mirroring, RSPAN, and VLAN mirroring can be configured at the same time on the switch using different sessions IDs and in any combinations. Any two sessions cannot be identical. Multiple mirroring sessions are supported for all types of mirroring.

A given interface can be used as a source interface for different sessions. For example a mirroring session can be created with source interface as port A and destination interface as port B. Another session can be created with source interface as port A and destination interface as port C. An interface cannot be configured as a destination interface for more than one session.

Traffic to and from the CPU can also be mirrored by specifying the CPU as the source interface.

An IP/MAC access-list can be attached to any mirroring session or to all sessions at the same time.

1.3.27 Remote Switch Port Analyzer (RSPAN)

Along with the physical source ports, the network traffic received/transmitted on a VLAN can be monitored. A port mirroring session is operationally active if and only if both a destination (probe) port and at least one source port or VLAN is configured. If neither is true, the session is inactive. EFOS supports remote port mirroring and VLAN mirroring. Traffic from/to all the physical ports which are members of that particular VLAN is mirrored.

NOTE: The source for a port mirroring session can be either physical ports or VLAN.

For Flow-based mirroring, ACLs are attached to the mirroring session. The network traffic that matches the ACL is only sent to the destination port. This feature is supported for remote monitoring also. IP/MAC access-list can be attached to the mirroring session.

NOTE: Flow-based mirroring is supported only if the QoS feature exists in the package.

Up to four RSPAN sessions can be configured on the switch and up to four RSPAN VLANs are supported. An RSPAN VLAN cannot be configured as a source for more than one session at the same time. To configure four RSPAN mirroring sessions, you must configure four RSPAN VLANs.

1.3.28 Encapsulated Remote Switched Port Analyzer (ERSPAN)

The Encapsulated Remote Port Analyzer (ERSPAN) feature allows port-mirroring collection points to be located anywhere across a routed network. This is achieved by encapsulating L2 mirrored packets using GRE with IP delivery. After a packet has been encapsulated, it can be forwarded through the L3-routed network.

ERSPAN uses a GRE tunnel to carry traffic between switches. ERSPAN consists of an ERSPAN source session, an ERSPAN destination session, and routable ERSPAN GRE-encapsulated traffic. All participating switches must be connected at Layer 3, and the network path must support the size of the ERSPAN traffic for the egress mirroring session.

The EFOS ERSPAN implementation:

- Is supported on StrataXGS® platforms only.
- Does not support destination session termination.
- Does not support the ERSPAN header (GRE only).

1.3.29 sFlow

sFlow is the standard for monitoring high-speed switched and routed networks. sFlow technology is built into network equipment and gives complete visibility into network activity, enabling effective management and control of network resources. The switch supports sFlow version 5.

EFOS supports packet sampling in hardware on BCM56960 platforms. Packet sampling in hardware does not require the sampled packet to be copied to the CPU for processing and is, therefore, less CPU-intensive (However, the counter sampling mechanism is performed in software.)

1.3.30 Static and Dynamic MAC Address Tables

You can add static entries to the switch's MAC address table and configure the aging time for entries in the dynamic MAC address table. You can also search for entries in the dynamic table based on several different criteria.

1.3.31 Link Layer Discovery Protocol (LLDP)

The IEEE 802.1AB defined standard, Link Layer Discovery Protocol (LLDP), allows the switch to advertise major capabilities and physical descriptions. This information can help you identify system topology and detect bad configurations on the LAN.

1.3.32 Link Layer Discovery Protocol (LLDP) for Media Endpoint Devices

The Link Layer Discovery Protocol for Media Endpoint Devices (LLDP-MED) provides an extension to the LLDP standard for network configuration and policy, device location, Power over Ethernet management, and inventory management.

1.3.33 DHCP Layer 2 Relay

This feature permits Layer 3 Relay agent functionality in Layer 2 switched networks. The switch supports L2 DHCP relay configuration on individual ports, link aggregation groups (LAGs) and VLANs.

1.3.34 MAC Multicast Support

Multicast service is a limited broadcast service that allows one-to-many and many-to-many connections. In Layer 2 multicast services, a single frame addressed to a specific multicast address is received, and copies of the frame to be transmitted on each relevant port are created.

1.3.35 IGMP Snooping

Internet Group Management Protocol (IGMP) Snooping is a feature that allows a switch to forward multicast traffic intelligently on the switch. Multicast IP traffic is traffic that is destined to a host group. Host groups are identified by class D IP addresses, which range from 224.0.0.0 to 239.255.255.255. Based on the IGMP query and report messages, the switch forwards traffic only to the ports that request the multicast traffic. This prevents the switch from broadcasting the traffic to all ports and possibly affecting network performance.

1.3.35.1 Source Specific Multicasting (SSM)

This mechanism provides the ability for a host to report interest in receiving a particular multicast stream only from among a set of specific source addresses, or its interest in receiving a multicast stream from any source other than a set of specific source addresses.

1.3.35.2 Control Packet Flooding

This feature enhances the MGMD Snooping functionality to flood multicast packets with DIP=224.0.0.x to ALL members of the incoming VLAN irrespective of the configured filtering behavior. This enhancement depends on the ability of the underlying switching silicon to flood packets with DIP=224.0.0.x irrespective of the entries in the L2 Multicast Forwarding Tables. In platforms that do not have the said hardware capability, 2 ACLs (one for IPv4 and another for IPv6) would be consumed in the switching silicon to accomplish the flooding using software.

1.3.35.3 Flooding to mRouter Ports

This feature enhances the MGMD Snooping functionality to flood unregistered multicast streams to ALL mRouter ports in the VLAN irrespective of the configured filtering behavior. This enhancement depends on the ability of the underlying switching silicon to flood packets to specific ports in the incoming VLAN when there are no entries in the L2 Multicast Forwarding Tables for the specific stream. In platforms that do not have the this hardware capability, incoming multicast streams will always be flooded in the ingress VLAN when there is a L2MC-MISS in the switching silicon.

1.3.36 IGMP Snooping Querier

When Protocol Independent Multicast (PIM) and IGMP are enabled in a network with IP multicast routing, the IP multicast router acts as the IGMP querier. However, if it is desirable to keep the multicast network Layer 2 switched only, the IGMP Snooping Querier can perform the query functions of a Layer 3 multicast router.

1.3.37 Multicast VLAN Registration

The Multicast VLAN Registration (MVR) protocol, like IGMP Snooping, allows a layer-2 switch to listen to IGMP frames and forward the multicast traffic only to the receivers that request it. Unlike IGMP Snooping, MVR allows the switch to listen across different VLANs. MVR uses a dedicated VLAN, which is called the multicast VLAN, to forward multicast traffic over the layer-2 network to the various VLANs that have multicast receivers as members.

1.3.38 Management and Control Plane ACLs

This feature provides hardware-based filtering of traffic to the CPU. An optional 'management' feature is available to apply the ACL on the CPU port. Currently, control packets like BPDU are dropped because of the implicit 'deny all' rule added at the end of the list. To overcome this rule, you must add rules that allow the control packets.

Support for user-defined simple rate limiting rule attributes for inbound as well as outbound traffic is also available. This attribute is supported on all QoS capable interfaces - physical, lag, and control-plane. Outbound direction is only supported on platforms with an Egress Field Processor (EFP).

1.3.39 Link Dependency

The EFOS Link Dependency feature supports enabling/disabling ports based on the link state of other ports (i.e., making the link state of some ports dependent on the link state of others). In the simplest form, if port A is dependent on port B and switch detects link loss on B, the switch automatically brings down link on port A. When the link is restored to port B, the switch automatically restores link to port A. The link action command option determines whether link A will come up/go down, depending upon the state of link B.

1.3.40 IPv6 Router Advertisement Guard

EFOS switches support IPv6 Router Advertisement Guard (RA-Guard) to protect against attacks via rogue Router Advertisements in accordance with RFC 6105. EFOS RA Guard supports Stateless RA-Guard, where the administrator can configure the interface to allow received router advertisements and router redirect message to be processed/forwarded or dropped.

By default, RA-Guard is not enabled on any interfaces. RA-Guard is enabled/disabled on physical interfaces or LAGs. RA-Guard does not require IPv6 routing to be enabled.

1.3.41 FIP Snooping

The FCoE Initialization Protocol (FIP) is used to perform the functions of FC_BB_E device discovery, initialization, and maintenance. FIP uses a separate EtherType from FCoE to distinguish discovery, initialization, and maintenance traffic from other FCoE traffic. FIP frames are standard Ethernet size (1518 Byte 802.1q frame), whereas FCoE frames are a maximum of 2240 bytes.

FIP snooping is a frame inspection method used by FIP Snooping Bridges to monitor FIP frames and apply policies based upon the L2 header information in those frames.

FIP snooping allows for:

- Auto-configuration of Ethernet ACLs based on information in the Ethernet headers of FIP frames.
- Emulation of FC point-to-point links within the DCB Ethernet network.
- Enhanced FCoE security/robustness by preventing FCoE MAC spoofing.
- The role of FIP snooping-enabled ports on the switch falls under one of the following types:
  - Perimeter or Edge port (connected directly to a Fibre Channel end node or ENode).
  - Fibre Channel forwarder (FCF) facing port (that receives traffic from FCFs targeted to the ENodes).

NOTE: The FIP Snooping Bridge feature supports the configuration of the perimeter port role and FCF-facing port roles and is intended for use only at the edge of the switched network.

The default port role in an FCoE-enabled VLAN is as a perimeter port. FCF-facing ports are configured by the user.

1.3.42 ECN Support

Explicit Congestion Notification (ECN) is defined in RFC 3168. Conventional TCP networks signal congestion by dropping packets. A Random Early Discard scheme provides earlier notification than tail drop by dropping packets already queued for transmission. ECN marks congested packets that would otherwise have been dropped and expects an ECN capable receiver to signal congestion back to the transmitter without the need to retransmit the packet that would have been dropped. For TCP, this means that the TCP receiver signals a reduced window size to the transmitter but does not request retransmission of the CE marked packet.

EFOS implements ECN capability as part of the WRED configuration process. It is configured as parameter in the **random-detect** command. Eligible packets are marked by hardware based upon the WRED configuration. The network operator can configure any CoS queue to operate in ECN marking mode and can configure different discard thresholds for each color.

EFOS supports per-CoSq statistics like Total, Peak, Current, Average Bytes, and ECN Tx counters. The release also supports configuring WRED minimum and maximum thresholds in percentage or kBytes. Refer to the *EFOS CLI Command Reference* (see Appendix A.1, References) for information on the following commands:

- `random-detect queue-parms`
- `show interfaces random-detect`
- `show interfaces traffic`
- `class-map`
- `match protocol`
- `show class-map`

1.4 Data Center Features

This section describes the data center features EFOS software supports. For additional information and configuration examples for some of these features, see Section 6, Configuring Data Center Features.

1.4.1 Priority-based Flow Control

The Priority-based Flow Control (PFC) feature allows the user to pause or inhibit transmission of individual priorities within a single physical link. By configuring PFC to pause a congested priority (priorities) independently, protocols that are highly loss sensitive can share the same link with traffic that has different loss tolerances. Priorities are differentiated by the priority field of the 802.1Q VLAN header.

An interface that is configured for PFC is automatically disabled for 802.3x flow control.

NOTE: Support for PFC is not available on all platforms.

1.4.2 Data Center Bridging Exchange Protocol

The Data Center Bridging Exchange Protocol (DCBX) is used by data center bridge devices to exchange configuration information with directly-connected peers. The protocol is also used to detect misconfiguration of the peer DCBX devices and optionally, for configuration of peer DCBX devices.

NOTE: Support for DCBX is not available on all platforms.

1.4.3 Quantized Congestion Notification

Quantized Congestion Notification (QCN) supports congestion management of long-lived data flows within a network domain by enabling bridges to signal congestion information to end stations capable of transmission rate limiting to avoid frame loss. This mechanism enables support for higher-layer protocols that are highly loss or latency sensitive. QCN helps to allow network storage traffic, high performance computing traffic, and Internet traffic to coexist within the same network.

QCN allows the flow of traffic to increase or decrease based on the behavior of the reaction point.

NOTE: Support for QCN is not available on all platforms.

1.4.4 CoS Queuing and Enhanced Transmission Selection

The CoS Queuing feature allows the switch administrator to directly configure certain aspects of the device hardware queuing to provide the required QoS behavior for different types of network traffic. The priority of a packet arriving at an interface can be used to steer the packet to the appropriate outbound CoS queue through a mapping table. CoS queue characteristics such as minimum guaranteed bandwidth, transmission rate shaping, etc. are user configurable at the queue (or port) level.

Enhanced Transmission Selection (ETS) allows Class of Service (CoS) configuration settings to be advertised to other devices in a data center network through DCBX ETS TLVs. CoS information is exchanged with peer DCBX devices using ETS TLVs.

NOTE: Support for CoS Queuing and ETS is not available on all platforms.

1.4.5 OpenFlow

The OpenFlow feature enables the switch to be managed by a centralized OpenFlow Controller using the OpenFlow protocol. EFOS supports the OpenFlow 1.0 standard and the OpenFlow 1.3 standard. EFOS uses the OpenFlow agent from the Open vSwitch (OVS) project. EFOS release 3.2 uses OVS version 2.3.0. The Open vSwitch code is licensed under the "Apache 2" license.

The OpenFlow 1.0 standard supports a single-table data forwarding path. However, EFOS supports Open vSwitch proprietary extensions to enable the OpenFlow controller to access multiple forwarding tables.

The OpenFlow 1.3 standard enables a multi-table data forwarding path. However, as of release 3.2, EFOS supports a single-table OpenFlow 1.3 data forwarding path. Support for additional hardware tables in the OpenFlow 1.3 data path may be added in future releases.

Starting with release 3.3, the EFOS OpenFlow implementation includes support for the following:

- Port based routing interfaces
- Report counters for port based routing interfaces
- Set_queue command
- Scaling:
  - The overall number of flows that the hardware can support is more than *N* where *N* is the number of hardware entries that can be supported on a platform.
  - Support for granular, per-silicon platform constants.
- Push_vlan and pop_vlan/strip_vlan flows.

1.4.6 DCVPN Gateway

Logically segregated virtual networks in a data center are sometimes referred to as data center VPNs (DCVPNs). VXLAN and NVGRE are two realizations of a DCVPN. The EFOS DCVPN Gateway is a solution that allows VXLAN and NVGRE to communicate with another network, particularly a VLAN. It offers VXLAN Tunnel Endpoint (VTEP) functionality for VXLAN and Network Virtualization Edge (NVE) functionality for NVGRE tunnels on the switch.

Both VXLAN and NVGRE are layer-3, IP-based technologies that prepend an existing layer-2 frame with a new IP header, providing layer-3 based tunneling capabilities for layer-2 frames. This essentially enables a layer-2 domain to extend across a layer-3 boundary.

For the traffic from a VXLAN/NVGRE to use services on physical devices in a distant network, the traffic must pass through a DCVPN Gateway.

The EFOS DCVPN Gateway feature is configurable through the CLI. It also offers an Overlay API to facilitate programming from external agents.

1.4.7 MPLS

Multiprotocol Label Switching (MPLS) is a technique for forwarding data between network nodes using short MPLS-assigned path labels instead of long network addresses associated with the underlying forwarding protocol. MPLS may be deployed in data centers to enable multi-service networks, which deliver data transport services and IP routing services across the same packet-switched network infrastructure. It may also improve network reliability and performance.

The EFOS MPLS feature can initiate MPLS tunnels for IPv4 and IPv6 packets. The tunnel initiators are specified as next hops for IPv4 and IPv6 routes. The switch can prepend an MPLS header with one, two, or three MPLS labels for packets that match the route destined to an MPLS tunnel. This feature is intended for Top-of-Rack (ToR) switches, enabling Ethernet servers, which are unaware of MPLS tagging, to communicate over the MPLS core network.

1.4.8 Dynamic Topology Map and Prescriptive Topology Mapping

To easily identify ports where a network cabling error and/or other cabling complication (mis-wiring) has occurred, a CLI command can be used to light the LED for a single port or multiple ports and turn off all other port LEDs. The `port-locator enable` command is executed on individual interfaces.

In the case where a port has two LEDs, one for link and a second for activity, only the link LED is used for the port locator function. The activity LED will be turned off while the port locator is active. If a port has link and activity combined on a single LED, the LED will not blink if activity is present on the port, regardless of whether port-locator is enabled or disabled on the port.

The out-of-band port LED is not affected by this feature.

Prescriptive Topology Mapping (PTM) uses a topology file to verify the cabling on a switch. The topology file can be distributed either by Chef or Puppet, or can be provided manually to all the switches in the network to verify the entire topology. PTM relies on an open-source LLDP daemon (LLDPD) to gather information about the partner switches and their links.

1.5 Routing Features

This section describes the layer-3 routing features EFOS software supports. For additional information and configuration examples for some of these features, see Section 7, Configuring Routing.

1.5.1 IP Unnumbered

Each routing interface can be configured to borrow the IP address from the loopback interfaces and use this IP for all routing activities.

The IP Unnumbered feature was initially developed to avoid wasting an entire subnet on point-to-point serial links. Though VLSM (Variable Length Subnet Mask) or private addresses can be used instead of IP Unnumbered, neither technique can be supported by classful routing protocols such as RIPv1 and IGRP.

The IP Unnumbered feature can also be used in situations where adjacencies are transient and adjacent interfaces cannot be easily configured with IPv4 addresses in the same subnet. It also helps in reducing the configuration overhead in large scale Data-Center deployments.

Multicast routing protocols PIM-SM, PIM-DM, DVMRP, and IGMP-Proxy are supported on IP unnumbered interfaces.

1.5.2 Open Shortest Path First (OSPF)

Open Shortest Path First (OSPF) is a dynamic routing protocol commonly used within medium-to-large enterprise networks. OSPF is an interior gateway protocol (IGP) that operates within a single autonomous system.

1.5.3 Border Gateway Protocol (BGP)

BGP is an exterior routing protocol used in large-scale networks to transport routing information between autonomous systems (AS). As an interdomain routing protocol, BGP is used when AS path information is required to provide partial or full Internet routing downstream. EFOS supports BGP version 4.

The following BGP features are supported:

- Proprietary BGP MIB support for reporting status variables and internal counters.
- Additional route map support:
  - Match as-path
  - Set as-path
  - Set local-preference
  - Set metric
- Support for inbound and outbound neighbor-specific route maps.
- Handling the BGP RTO full condition.
- Supports for the `show ip bgp` command.
- Supports for the show `ip bgp traffic` command.
- Supports for the `bgp always-compare-med` command.
- Support for the maximum number of BGP neighbors: 128.
- A prefix list is supported to filter the output of the `show ip bgp` command.
- Configurable maximum length of a received AS_PATH.
- Show command to list the routes accepted from a specific neighbor.
- Show command to list the routes rejected from a specific neighbor.

- Support for BGP communities.
- Support for IPv6.
- IPv6 Transport and Prefix list
- Support for BGP peer templates to simplify neighbor configuration.
- VRF support
- Dynamic neighbor creation
- Extended communities
- Dynamic route leaking between VRF instances
- 4-byte ASN support
- Graceful restart
- Ethernet VPN (EVPN) support, including:
  - Support for EVPN route propagation when deployed as a spine node only.
  - BGP capability to negotiate an EVPN NLRI exchange.
  - Forwarding of EVPN NLRI with eBGP and iBGP peers.
  - Route reflection of EVPN NLRIs.

1.5.4 VLAN Routing

EFOS software supports VLAN routing. You can also configure the software to allow traffic on a VLAN to be treated as if the VLAN were a router port.

1.5.5 IP Configuration

The switch IP configuration settings to allow you to configure network information for VLAN routing interfaces such as IP address and subnet mask, MTU size, and ICMP redirects. Global IP configuration settings for the switch allow you to enable or disable the generation of several types of ICMP messages and enable or disable the routing mode.

1.5.6 ARP Table Management

You can create static Address Resolution Protocol (ARP) entries and manage many settings for the dynamic ARP table, such as age time for entries, retries, and cache size.

1.5.7 BOOTP/DHCP Relay Agent

The switch BOOTP/DHCP Relay Agent feature relays BOOTP and DHCP messages between DHCP clients and DHCP servers that are located in different IP subnets.

1.5.8 IP Helper and UDP Relay

The IP Helper and UDP Relay features provide the ability to relay various protocols to servers on a different subnet.

1.5.9 Router Discovery

For each interface, you can configure the Router Discovery Protocol (RDP) to transmit router advertisements. These advertisements inform hosts on the local network about the presence of the router.

1.5.10 Routing Table

The routing table displays information about the routes that have been dynamically learned. You can configure static and default routes and route preferences. A separate table shows the routes that have been manually configured.

1.5.11 Virtual Router Redundancy Protocol (VRRP) and VRRP v3

VRRP provides hosts with redundant routers in the network topology without any need for the hosts to reconfigure or know that there are multiple routers. If the primary (master) router fails, a secondary router assumes control and continues to use the virtual router IP (VRIP) address. VRRP v2 provides address redundancy for IPv4 addresses. VRRPv3 provides address redundancy for both IPv4 and IPv6 addresses. For IPv6 addresses, VRRP IP also contains the link-local IPv6 address.

VRRP Route Interface Tracking extends the capability of VRRP to allow tracking of specific route/interface IP states within the router that can alter the priority level of a virtual router for a VRRP group.

1.5.12 Bidirectional Forwarding Detection

In a network device, Bidirectional Forwarding Detection (BFD) is presented as a service to its user applications, providing them options to create and destroy a session with a peer device and reporting upon the session status. On EFOS switches, BGP and OSPF can use BFD for monitoring of their neighbors' availability in the network and for fast detection of connection faults with them.

1.5.13 VRF Lite

The Virtual Routing and Forwarding (VRF) Lite feature enables a router to function as multiple routers. Each virtual router (VR) manages its own routing domain. Specifically, each virtual router maintains its own IP routes, routing interfaces, and host entries, which enables each virtual router to make its own routing decisions, independent of other virtual routers. More than one virtual routing table may contain a route to a given destination. The network administrator can associate a subset of the router's interfaces with each virtual router. The router routes packets according to the virtual routing table associated with the packet's ingress interface. Each interface can be associated with at most one virtual router.

As part of the latest EFOS release, the OSPF, PING, BGP and Traceroute applications are VR-aware.

1.5.14 RFC 5549

EFOS software supports RFC 5549, “Advertising IPv4 Network Layer Reachability Information with an IPv6 Next Hop.” This specification enables the deployment of a mixed IPv4/IPv6 network without having to assign IPv4 addresses to transit links between switches. Instead, IPv6 interfaces are used for forwarding the IPv4 traffic.

This feature enables IPv4 routes to use IPv6 NDPs to determine the next hop. No IPv6 tunneling is needed. The IPv4 packets are routed as normal but they use next hops determined by the IPv6 protocol. RFC 5549 adds BGP extensions to insert these IPv4 routes with IPv6 next hops into the routing table.

When this feature is present in software, it is applicable to port-based and VLAN-based routing interfaces. RFC 5549 forwarding mode is enabled only when two neighbor routers use the BGP capabilities field to agree that the RFC 5549 forwarding mode is supported on the interface.

This feature enables the customers to minimize the use of IPv4 addresses. The IPv4 addresses only need to be assigned to the routing interfaces to which the IPv4 servers are connected. All the interconnect links in the network and the switch management IP addresses are IPv6.

The typical usage scenario for this feature is to interconnect IPv4 subnets at the edge of the network via IPv6 core network.

There is no user configuration associated with this feature. When used, the **show ip route** command may show some IPv4 routes with IPv6 addresses as next hops.

1.5.15 Algorithmic Longest Prefix Match (ALPM)

ALPM is a protocol used by routers to select an entry from a forwarding table. When an exact match is not found in the forwarding table, the match with the longest subnet mask, also called longest prefix match, is chosen. It is called the longest prefix match because it is also the entry where the largest number of leading address bits of the destination address match those in the table entry.

ALPM is primarily a switch silicon feature and the algorithm for this is implemented in the SDK on the chip. ALPM enables supporting for large number of routes (for BGP, 32k IPv4 routes and 24k IPv6 are supported).

Support for ALPM is platform-dependent. For platforms that support ALPM, two SDM templates, "dual-ipv4-and-ipv6 alpm-data-center" and "dual-ipv4-and-ipv6 alpm-mpls-data-center", are made available to accommodate the larger number of routes.

Starting with EFOS 3.4, ALPM routes are scaled for BCM56850 (Trident2) and BCM56960 (Tomahawk) platforms with a minimum of 4 GB RAM. ALPM routes are scaled to a maximum of 128K IPv4 routes on the BCM56960 platform. The actual number of routes depends on the platform and the feature set enabled on the switch. The maximum number of entries in the L2 table was reduced on supported platforms to accommodate additional ALPM routes.

NOTE: IPv4 and IPv6 route limits on an SDM template now give the over-subscribed maximum routes supported by the switch when only the respective route types are present on the switch. The actual maximum number of routes will be less when both IPv4 and IPv6 routes are present and will depend on the mix of these two route types. Prior to the EFOS 3.4 release, the SDM template listed the guaranteed maximum number of IPv4 and IPv6 routes.

1.5.16 Unicast Reverse Path Forwarding

Unicast reverse path forwarding (uRPF) is a powerful security tool specified in RFC 3704. It helps to limit the problems that are caused by the malformed or spoofed IP source addresses into a network by discarding IP packets that lack a verifiable IP source address. Unicast RPF deflects various denial-of-service (DoS) attacks (such as Smurf attacks, Tribe Flood Network (TFN), and forging or rapidly changing source IP addresses to cause a flood of useless packets to choke the network) by forwarding only packets that have source addresses that are valid and consistent with the IP routing table. This defensive action helps protect the network of the ISP, its customer, and the rest of the Internet.

Once enabled, the uRPF check examines all IP packets on the input path of that interface. When this mode is set in the silicon, it divides the route table in half. The first half stores the routes with destination IP address as the key (normal routing behavior), and the second half stores the routes with source IP address as the key. Both halves are programmed identically in the hardware.

1.5.17 Policy-Based Routing

To forward packets to their destination addresses, routers typically make forwarding decision based on information in routing tables. Static or dynamic routing protocols provide the information to populate the routing tables.

With policy-based routing, network administrators can define forwarding behavior based on the contents of a packet rather than relying on information in the routing table. In other words, policy-based routing overrides traditional destination-based routing behavior. EFOS supports policy-based routing for both IPv4 and IPv6.

For configuration information, see Section 7.11, Policy-Based Routing

1.5.18 IPv6 Link-local Address Configuration

The IPv6 link-local address is allowed to be manually configured on the following interface types:

- Port-based routing
- VLAN-based routing
- Loopback
- Tunnel

This capability allows administrators to assign a unique link-local address per interface that does not conflict with the link-local address of other interfaces. Configuring a link-local IPv6 address overrides the link-local address that is automatically generated for the routing interface, which implies there can be only one link-local address on an interface.

1.5.19 Class-E IPv4 Addresses

The Class-E IPv4 addresses are the IPv4 addresses in the range [240.0.0.0 to 255.255.255.255] that are reserved for future use as per the IANA standards.

The EFOS support for Class-E IPv4 addresses does not change the behavior of the protocols or packages that allow them. A Class-E IPv4 address is treated like any other valid IPv4 unicast address in the applications and in the IP stack in Linux.

All the routing protocols, management applications and switching/security applications that use IPv4 addresses work with Class-E addresses as well.

1.5.20 IP Service Level Agreements

The IP service-level agreement (SLA) feature allows users to monitor network performance between routers or from a router to a remote IP device. EFOS supports the following measurement capabilities:

- Remote IP reachability tracking.
- Round-trip-time threshold monitoring

These metrics are collected by measuring ICMP response time and connectivity. This feature is deployed mostly in Enterprise networks on multi-homed customer edge devices, where there is a need to automatically switch to the next priority ISP in case of reachability issues with the current ISP.

For configuration information, see Section 7.10, IP Service Level Agreement

1.5.21 Microsoft Network Load Balancing

The network load balancing (NLB) feature allows an EFOS router to work with Microsoft NLB clusters. EFOS replicates and (if required) routes every incoming NLB client request to the connected cluster hosts (servers). EFOS can work with all the three NLB modes: unicast, multicast, and multicast IGMP.

For configuration information, see Section 7.12, Microsoft Network Load Balancing

1.6 Layer 3 Multicast Features

For information about configuring L3 multicast features, see Section 8, Configuring IPv4 and IPv6 Multicast.

1.6.1 Distance Vector Multicast Routing Protocol

Distance Vector Multicast Routing Protocol (DVMRP) exchanges probe packets with all DVMRP-enabled routers, establishing two way neighboring relationships and building a neighbor table. It exchanges report packets and creates a unicast topology table, which is used to build the multicast routing table. This multicast route table is then used to route the multicast packets.

1.6.2 Internet Group Management Protocol

The Internet Group Management Protocol (IGMP) is used by IPv4 systems (hosts and routers) to report their IP multicast group memberships to any neighboring multicast routers. PowerConnect 7000 Series switches perform the "multicast router part" of the IGMP protocol, which means it collects the membership information needed by the active multicast router.

1.6.3 IGMP Proxy

The IGMP Proxy feature allows the switch to act as a proxy for hosts by sending IGMP host messages on behalf of the hosts that the switch discovered through standard IGMP router interfaces.

1.6.4 Protocol Independent Multicast

1.6.4.1 Dense Mode (PIM-DM)

Protocol Independent Multicast (PIM) is a standard multicast routing protocol that provides scalable inter-domain multicast routing across the Internet, independent of the mechanisms provided by any particular unicast routing protocol. The Protocol Independent Multicast-Dense Mode (PIM-DM) protocol uses an existing Unicast routing table and a Join/Prune/Graft mechanism to build a tree. PIM-DM creates source-based shortest-path distribution trees, making use of reverse path forwarding (RPF).

1.6.4.2 Sparse Mode (PIM-SM)

Protocol Independent Multicast-Sparse Mode (PIM-SM) is used to efficiently route multicast traffic to multicast groups that may span wide area networks, and where bandwidth is a constraint. PIM-SM uses shared trees by default and implements source-based trees for efficiency. This data threshold rate is used to toggle between trees.

1.6.4.3 Source Specific Multicast (PIM-SSM)

Protocol Independent Multicast—Source Specific Multicast (PIM-SSM) is a subset of PIM-SM and is used for one-to-many multicast routing applications, such as audio or video broadcasts. PIM-SSM does not use shared trees.

1.6.4.4 PIM IPv6 Support

PIM-DM and PIM-SM support IPv6 routes.

1.6.5 MLD/MLDv2 (RFC2710/RFC3810)

MLD is used by IPv6 systems (listeners and routers) to report their IP multicast addresses memberships to any neighboring multicast routers. The implementation of MLD v2 is backward compatible with MLD v1.

MLD protocol enables the IPv6 router to discover the presence of multicast listeners, the nodes that want to receive the multicast data packets, on its directly attached interfaces. The protocol specifically discovers which multicast addresses are of interest to its neighboring nodes and provides this information to the multicast routing protocol that make the decision on the flow of the multicast data packets.

1.7 Quality of Service Features

This section describes the Quality of Service (QoS) features EFOS software supports. For additional information and configuration examples for some of these features, see Section 9, Configuring Quality of Service.

1.7.1 Access Control Lists (ACL)

Access Control Lists (ACLs) ensure that only authorized users have access to specific resources while blocking off any unwarranted attempts to reach network resources. ACLs are used to provide traffic flow control, restrict contents of routing updates, decide which types of traffic are forwarded or blocked, and above all provide security for the network. The switch supports the following ALC types:

- IPv4 ACLs
- IPv6 ACLs
- MAC ACLs

For all ACL types, you can apply the ACL rule when the packet enters or exits the physical port, LAG, or VLAN interface.

1.7.1.1 ACL Remarks

Users can use ACL remarks to include comments for ACL rule entries in any MAC ACL. Remarks assist the user in understanding ACL rules easily.

1.7.1.2 ACL Rule Priority

This feature allows user to add sequence numbers to ACL rule entries and re-sequence them. When a new ACL rule entry is added, the sequence number can be specified so that the new ACL rule entry is placed in the appropriate position in the access list.

1.7.1.3 ACL Counters

For the following ACL types, EFOS provides a counter for every ACL rule applied on physical interface, LAG, and VLAN, with no additional configuration:

- IP standard ACLs
- IP extended ACLs
- IPv4 named ACLs
- IPv6 named ACLs
- MAC ACLs

These counter values can be viewed and reset using CLI `show` and `clear` commands for ACLs. You can also enable or disable the ACL counters.

1.7.2 Differentiated Services (DiffServ)

The QoS Differentiated Services (DiffServ) feature allows traffic to be classified into streams and given certain QoS treatment in accordance with defined per-hop behaviors. EFOS software supports both IPv4 and IPv6 packet classification.

1.7.3 Class of Service (CoS)

The Class Of Service (CoS) queuing feature lets you directly configure certain aspects of switch queuing. This provides the required QoS behavior for different types of network traffic when the complexities of DiffServ are not required. CoS queue characteristics, such as minimum guaranteed bandwidth and transmission rate shaping, are configurable at the queue (or port) level.

Chapter 2: Getting Started with Switch Configuration

2.1 Accessing the Switch Command-Line Interface

The command-line interface (CLI) provides a text-based way to manage and monitor the switch features. You can access the CLI by using a direct connection to the console port or by using a Telnet or SSH client.

To access the switch by using Telnet or Secure Shell (SSH), the switch must have an IP address configured on either the service port or the network interface, and the management station you use to access the device must be able to ping the switch IP address. DHCP is enabled by default on the service port. It is disabled on the network interface.

NOTE: By default, entry into Privileged EXEC mode requires a password for Telnet and SSH access methods, and if the correct password is not supplied access is denied. Because no password is configured by default, access is always denied. For information about changing the default settings for Telnet and SSH access methods, see Section 4.1.3, Configuring and Applying Authentication Profiles.

2.1.1 Connecting to the Switch Console

To connect to the switch and configure or view network information, use the following steps:

1. Using a straight-through modem cable, connect a VT100/ANSI terminal or a workstation to the console (serial) port.

   If you attached a PC, Apple, or UNIX workstation, start a terminal-emulation program, such as HyperTerminal or TeraTerm.

2. Configure the terminal-emulation program to use the following settings:
   - Baud rate: 9600 b/s
   - Data bits: 8
   - Parity: none
   - Stop bit: 1
   - Flow control: none

3. Power on the switch.

   For information about the boot process, including how to access the boot menu, see Section 2.3, Booting the Switch.

   After the system completes the boot cycle, the `User:` prompt appears.

4. At the `User:` prompt, type `admin` and press ENTER. The `Password:` prompt appears.

5. There is no default password. Press ENTER at the password prompt if you did not change the default password.

   After a successful login, the screen shows the system prompt, for example `(Routing) >`.

6. At the `(Routing) >` prompt, enter `enable` to enter the Privileged EXEC command mode.

7. There is no default password to enter Privileged EXEC mode. Press ENTER at the password prompt if you did not change the default password.

   The command prompt changes to `(Routing) #`.

8. To view service port network information, type `show serviceport` and press ENTER.

```
(Routing) #show serviceport
```

```
   Interface Status............................... Up
   IP Address..................................... 10.27.21.33
   Subnet Mask.................................... 255.255.252.0
   Default Gateway................................ 10.27.20.1
   IPv6 Administrative Mode....................... Enabled
   IPv6 Prefix is ................................ fe80::210:18ff:fe82:157c/64
   Configured IPv4 Protocol....................... DHCP
   Configured IPv6 Protocol....................... None
   IPv6 AutoConfig Mode........................... Disabled
   Burned In MAC Address.......................... 00:10:18:82:15:7C
```

By default, the DHCP client on the service port is enabled. If your network has a DHCP server, then you need only to connect the switch service port to your management network to allow the switch to acquire basic network information.

2.2 Accessing the Switch CLI Through the Network

Remote management of the switch is available through the service port or through the network interface. To use telnet, SSH, or SNMP for switch management, the switch must be connected to the network, and you must know the IP or IPv6 address of the management interface. The switch has no IP address by default. The DHCP client on the service port is enabled, and the DHCP client on the network interface is disabled.

After you configure or view network information, configure the authentication profile for telnet or SSH (see Section 4.1.3, Configuring and Applying Authentication Profiles) and physically and logically connect the switch to the network, you can manage and monitor the switch remotely. You can also continue to manage the switch through the terminal interface via the console port.

2.2.1 Using the Service Port or Network Interface for Remote Management

The service port is a dedicated Ethernet port for out-of-band management. Broadcom recommends that you use the service port to manage the switch. Traffic on this port is segregated from operational network traffic on the switch ports and cannot be switched or routed to the operational network. Additionally, if the production network is experiencing problems, the service port still allows you to access the switch management interface and troubleshoot issues. Configuration options on the service port are limited, which makes it difficult to accidentally cut off management access to the switch.

Alternatively, you can choose to manage the switch through the production network, which is known as in-band management. Because in-band management traffic is mixed in with production network traffic, it is subject to all of the filtering rules usually applied on a switched/routed port such as ACLs and VLAN tagging. You can access the in-band network management interface through a connection to any front-panel port.

2.2.1.1 Configuring Service Port Information

To disable DHCP/BOOTP and manually assign an IPv4 address, enter:

```
serviceport protocol none
serviceport ip ipaddress netmask [gateway]
```

For example, `serviceport ip 192.168.2.23 255.255.255.0 192.168.2.1`

To disable DHCP/BOOTP and manually assign an IPv6 address and (optionally) default gateway, enter:

```
serviceport protocol none
serviceport ipv6 address address/prefix-length [eui64]
serviceport ipv6 gateway gateway
```

To view the assigned or configured network address, enter:

```
show serviceport
```

To enable the DHCP client on the service port, enter:

```
serviceport protocol dhcp
```

To enable the BOOTP client on the service port, enter:

```
serviceport protocol bootp
```

2.2.1.2 Configuring the In-Band Network Interface

To use a DHCP server to obtain the IP address, subnet mask, and default gateway information, enter:

```
network protocol dhcp.
```

To use a BOOTP server to obtain the IP address, subnet mask, and default gateway information, enter:

```
   network protocol bootp.
```

To manually configure the IPv4 address, subnet mask, and (optionally) default gateway, enter:

```
   network parms ipaddress netmask [gateway],
```

For example, `network parms 192.168.2.23 255.255.255.0 192.168.2.1`

To manually configure the IPv6 address, subnet mask, and (optionally) default gateway, enter:

```
   network ipv6 address address/prefix-length [eui64]
   network ipv6 gateway gateway
```

To view the network information, enter:

```
   show network.
```

To save these changes so they are retained during a switch reset, enter the following command:

```
   copy system:running-config nvram:startup-config
```

2.2.2 DHCP Option 61

DHCP Option 61 (client Identifier) allows the DHCP server to be configured to provide an IP address to a switch based on its Media Access Control (MAC) Address or an ID entered into the system. DHCP servers use this value to index their database of address bindings. This value is expected to be unique for all clients in an administrative domain. This option allows the system to move from one part of the network to another while maintaining the same IP address.

DHCP client Identifier (Option 61) is used by DHCP clients to specify their unique identifier. The client identifier option is optional and can be specified while configuring the DHCP on the interfaces. DHCP Option 61 is enabled by default.

2.2.2.1 Configuring DHCP Option 61

Configuring the DHCP with client-id (option 61) differs depending on the port or interface. Refer to the information below:

2.2.2.1.1 Service Port:

To enable DHCP with client-id (option 61) on from the service port, issue the following command:

```
(Routing) #serviceport protocol dhcp client-id
```

2.2.2.1.2 Network Port:

To enable DHCP with client-id (option 61) on from the network port, issue the following command:

```
(Routing) #network protocol dhcp client-id
```

2.2.2.1.3 Routing Enabled Interface:

To enable DHCP with client-id (option 61) on from on the routing enabled interface, issue the following command `in` interface configuration mode.

```
(Routing) (Interface 0/1)#ip address dhcp client-id
```

Physical Interface:

To enable DHCP with client-id (option 61) on from on the physical interface, issue the commands as shown below:

```
(Routing) #config
(Routing) (Config)#interface 0/4
(Routing) (Interface 0/4)#ip address dhcp client-id
```

VLAN Interface:

To enable DHCP with client-id (option 61) on from on the VLAN interface, issue the commands as shown below:

```
(Routing) #config
(Routing) (Config)#interface vlan 10
(Routing) (Interface vlan 10)#ip address dhcp client-id
```

2.3 Booting the Switch

When the power is turned on with the local terminal already connected, the switch goes through Power-On Self-Test (POST). POST runs every time the switch is initialized and checks hardware components to determine if the switch is fully operational before completely booting.

If a critical problem is detected, the program flow stops. If POST passes successfully, a valid executable image is loaded into RAM.

POST messages are displayed on the terminal and indicate test success or failure.

To view the text that prints to the screen during the boot process, perform the following steps:

1. Make sure that the serial cable is connected to the terminal.
2. Connect the power supply to the switch.
3. Power on the switch.

   As the switch boots, the boot-up test first counts the switch memory availability and then continues to boot.
4. During boot, you can use the Utility menu, if necessary, to run special procedures. To enter the Boot menu, press **2** within the first three seconds after the following message appears.

   ```
   Select startup mode.  If no selection is made within 3 seconds,
   the EFOS Application will start automatically...

   EFOS Startup -- Main Menu

   1 - Start EFOS Application
   2 - Display Utility Menu
   Select (1, 2):
   ```

   For information about the Boot menu, see “Section 2.3.1, Utility Menu Functions."
5. If you do not start the boot menu, the operational code continues to load.

After the switch boots successfully, the User login prompt appears and you can use the local terminal to begin configuring the switch. However, before configuring the switch, make sure that the software version installed on the switch is the latest version.

2.3.1 Utility Menu Functions

NOTE: Utility menu functions vary on different platforms. The following example might not represent the options available on your platform.

You can perform many configuration tasks through the Utility menu, which can be invoked after the first part of the POST is completed.

To display the Utility menu, boot the switch observe the output that prints to the screen. After various system initialization information displays, the following message appears:

```
EFOS Startup Rev: 3.4.3

Select startup mode.  If no selection is made within 3 seconds,
the EFOS Application will start automatically...

EFOS Startup -- Main Menu
```

```
1 - Start EFOS Application
2 - Display Utility Menu
Select (1, 2):
```

Press press **2** within five seconds to start the Utility menu. If you do not press 2, the system loads the operational code.

After you press **2** the following information appears:

```
EFOS Startup -- Utility Menu

 1  - Start EFOS Application
 2  - Load Code Update Package
 3  - Load Configuration
 4  - Select Serial Speed
 5  - Retrieve Error Log
 6  - Erase Current Configuration
 7  - Erase Permanent Storage
 8  - Select Boot Method
 9  - Activate Backup Image
10  - Start Diagnostic Application
11  - Reboot
12 - Rease All Configuration Files

 Q  - Quit from EFOS Startup

Select option (1-12 or Q):
```

The following sections describe the Utility menu options.

2.3.1.1 1 – Start EFOS Application

Use option 1 to resume loading the operational code. After you enter 1, the switch exits the Startup Utility menu and the switch continues the boot process.

2.3.1.2 2 – Load Code Update Package

Use option 2 to download a new software image to the switch to replace a corrupted image or to update, or upgrade the system software.

The switch is preloaded with EFOS software, so these procedures are needed only for upgrading or downgrading to a different image.

You can use any of the following methods to download the image:

- TFTP
- XMODEM
- YMODEM
- ZMODEM

If you use TFTP to download the code, the switch must be connected to the network, and the code to download must be located on the TFTP server.

When you use XMODEM, YMODEM, or ZMODEM to download the code, the code must be located on an administrative system that has a console connection to the switch.

Use the following procedures to download an image to the switch by using TFTP:

1. From the Utility menu, select **2** and press ENTER.

   The switch creates a temporary directory and prompts you to select the download method:

   ```
   Creating tmpfs filesystem on tmpfs for download...done.
   Select Mode of Transfer (Press T/X/Y/Z for TFTP/XMODEM/YMODEM/ZMODEM) []:
   ```

2. Enter **T** to download the image from a TFTP server to the switch.
3. Enter the IP address of the TFTP server where the new image is located, for example:

   ```
   Enter Server IP []:192.168.1.115
   ```

4. Enter the IP address of the switch management interface, for example:

   ```
   Enter Host IP []192.168.1.23
   ```

NOTE: The switch uses the IP address, subnet mask, and default gateway information you specify for the TFTP download process only. The switch automatically reboots after the process completes, and this information is not saved.

5. Enter the subnet mask associated with the management interface IP address or press ENTER to accept the default value, which is 255.255.255.0.
6. Optionally, enter the IP address of the default gateway for the switch management interface, for example:

   ```
   Enter Gateway IP []192.168.1.1
   ```

7. Enter the filename, including the file path (if it is not in the TFTP root directory), of the image to download, for example:

   ```
   Enter Filename[]images/image0630.stk
   ```

8. Confirm the information you entered and enter **y** to allow the switch to contact the TFTP server.

   After the download completes, you are prompted to reboot the switch. The switch loads the image during the next boot cycle.

Use the following procedures to download an image to the switch by using XMODEM, YMODEM, or ZMODEM.

1. From the Utility menu, select **2** and press ENTER.

   The switch creates a temporary directory and prompts you to select the download method:

   ```
   Creating tmpfs filesystem on tmpfs for download...done.
   Select Mode of Transfer (Press T/X/Y/Z for TFTP/XMODEM/YMODEM/ZMODEM) []:
   ```

2. Specify the protocol to use for the download.
   - Enter **X** to download the image by using the XMODEM file transfer protocol.
   - Enter **Y** to download the image by using the YMODEM file transfer protocol.
   - Enter **Z** to download the image by using the ZMODEM file transfer protocol.
3. When you are ready to transfer the file from the administrative system, enter **y** to continue.

   ```
   Do you want to continue? Press(Y/N): y
   ```

4. From the terminal or terminal emulation application on the administrative system, initiate the file transfer.

   For example, if you use HyperTerminal, use the following procedures:

   a. From the **HyperTerminal** menu bar, click **Transfer** > **Send File**.

      The **Send File** window displays.

   b. Browse to the file to download and click **Open** to select it.

   c. From the **Protocol:** field, select the protocol to use for the file transfer.

   d. Click **Send**.

After you start the file transfer, the software is downloaded to the switch, which can take several minutes. The terminal emulation application might display the loading process progress.

5. After software downloads, you are prompted to reboot the switch. The switch loads the image during the next boot cycle.

2.3.1.3 3 – Load Configuration

Use option **3** to download a new configuration that will replace the saved system configuration file. You can use any of the following methods to download the configuration file:

- TFTP
- XMODEM
- YMODEM
- ZMODEM

Use the following procedures to download a configuration file to the switch.

1. From the Utility menu, select **3** and press ENTER.
2. Enter T to download the text-based configuration file to the switch.
3. Specify the protocol to use for the download.
4. Respond to the prompts to begin the file transfer.

   The configuration file download procedures are very similar to the software image download procedures. For more information about the prompts and how to respond, see Section 2.3.1.2, 2 – Load Code Update Package.

2.3.1.4 4 – Select Serial Speed

Use option **4** to change the baud rate of the serial interface (console port) on the switch. When you select option **4**, the following information displays:

```
1 - 2400
2 - 4800
3 - 9600
4 - 19200
5 - 38400
6 - 57600
7 - 115200
8 - Exit without change
Select option (1-8):
```

To set the serial speed, enter the number that corresponds to the required speed.

NOTE: The selected baud rate takes effect immediately.

2.3.1.5 5 – Retrieve Error Log

Use option **5** to retrieve the error log that is stored in nonvolatile memory and upload it from the switch to your ASCII terminal or administrative system. You can use any of the following methods to copy the error log to the system:

- TFTP
- XMODEM
- YMODEM
- ZMODEM

Use the following procedures to upload the error log from the switch:

1. From the Utility menu, select **5** and press ENTER.
2. Specify the protocol to use for the download.
3. Respond to the prompts to begin the file transfer.

   If you use TFTP to upload the file from the switch to the TFTP server, the prompts and procedures very similar to the steps described for the TFTP software image download. For more information about the prompts and how to respond, see Section 2.3.1.2, 2 – Load Code Update Package.

   If you use XMODEM, YMODEM, or ZMODEM to transfer the file, configure the terminal or terminal emulation application with the appropriate settings to receive the file. For example, if you use HyperTerminal, click **Transfer** > **Receive File, and then specify where to put the file and which protocol to use.**

2.3.1.6 6 – Erase Current Configuration

Use option **6** to clear changes to the startup-config file and reset the system to its factory default setting. This option is the same as executing the `clear config` command from Privileged EXEC mode. You are not prompted to confirm the selection.

2.3.1.7 7 – Erase Permanent Storage

Use option **7** to completely erase the switch software application, any log files, and any configurations. The boot loader and operating system are not erased. Use this option only if a file has become corrupt and your are unable to use option **2**, Load Code Update Package, to load a new image onto the switch. After you erase permanent storage, you must download an image to the switch; otherwise, the switch will not be functional.

2.3.1.8 8 – Select Boot Method

Use option **8** to specify whether the system should boot from the image stored on the internal flash, from an image over the network, or from an image over the serial port. By default, the switch boots from the flash image.

To boot over the network, the image must be located on a TFTP server that can be accessed by the switch. To boot from the serial port, the switch must be connected through the console port to a terminal or system with a terminal emulator. The image must be located on the connected device.

If you select option **8**, the following menu appears:

```
Current boot method: FLASH
1 - Flash Boot
2 - Network Boot
3 - Serial Boot
4 - Exit without change
Select option (1-4):
```

If you select a new boot method, the switch uses the selected method for the next boot cycle.

2.3.1.9 9 – Activate Backup Image

Use option **9** to activate the backup image. The active image becomes the backup when you select this option. When you exit the Startup Utility and resume the boot process, the switch loads the image that you activated, but Broadcom recommends that you reload the switch so it can perform an entire boot cycle with the newly active image.

After you active the backup image, the following information appears.

```
Image image1 is now active.
Code update instructions found!
Extracting kernel and rootfs from image1
Copying kernel/rootfs uimage to boot flash area
Activation complete
image1 activated -- system reboot recommended!
Reboot? (Y/N):
```

Enter **y** to reload the switch.

2.3.1.10 10 – Start Diagnostic Application

Option **10** is for field support personnel only. Access to the diagnostic application is password protected.

2.3.1.11 11 – Reboot

Use option **11** to restart the boot process.

2.3.1.12 12 – Erase All Configuration Files

Use option **12** to clear changes to the startup-config file and the factory-defaults file and reset the system to its factory default (compile-time) setting. You are not prompted to confirm the selection.

2.4 Understanding the User Interfaces

EFOS software includes a set of comprehensive management functions for configuring and monitoring the system by using one of the following methods:

- Command-Line Interface (CLI)
- Simple Network Management Protocol (SNMP)
- RESTful API Interface
- RESTCONF Interface
- NETCONF Interface

These standards-based management methods allows you to configure and monitor the components of the EFOS software. The method you use to manage the system depends on your network size and requirements, and on your preference.

NOTE: Not all features are supported on all hardware platforms, so some CLI commands and object identifiers (OIDs) might not available on your platform.

2.4.1 Using the Command-Line Interface

The command-line interface (CLI) is a text-based way to manage and monitor the system. You can access the CLI by using a direct serial connection or by using a remote logical connection with telnet or SSH.

The CLI groups commands into modes according to the command function. Each of the command modes supports specific software commands. The commands in one mode are not available until you switch to that particular mode, with the exception of the User EXEC mode commands. You can execute the User EXEC mode commands in the Privileged EXEC mode.

To display the commands available in the current mode, enter a question mark (?) at the command prompt. To display the available command keywords or parameters, enter a question mark (?) after each word you type at the command prompt. If there are no additional command keywords or parameters, or if additional parameters are optional, the following message appears in the output:

```
<cr>                     Press Enter to execute the command
```

For more information about the CLI, refer to the *EFOS CLI Command Reference*. See Appendix A.1, References.

The *EFOS CLI Command Reference* lists each command available from the CLI by the command name and provides a brief description of the command. Each command reference also contains the following information:

- The command keywords and the required and optional parameters.
- The command mode you must be in to access the command.
- The default value, if any, of a configurable setting on the device.

The `show` commands in the document also include a description of the information that the command shows.

2.4.2 Using SNMP

SNMP is enabled by default. The `show sysinfo` command displays the information you need to configure an SNMP manager to access the switch. You can configure SNMP groups and users that can manage traps that the SNMP agent generates.

EFOS uses both standard public MIBs for standard functionality and private MIBs that support additional switch functionality. All private MIBs begin with a "-" prefix. The main object for interface configuration is in -SWITCHING-MIB, which is a private MIB. Some interface configurations also involve objects in the public MIB, IF-MIB.

2.4.2.1 SNMPv3

SNMP version 3 (SNMPv3) adds security and remote configuration enhancements to SNMP. EFOS has the ability to configure SNMP server, users, and traps for SNMPv3. Any user can connect to the switch using the SNMPv3 protocol, but for authentication and encryption, you need to configure a new user profile. To configure a profile by using the CLI, refer to the SNMP section in the *EFOS CLI Command Reference* (see Appendix A.1, References).

2.4.3 Using RESTful APIs

The OpEN RESTful APIs provide a resource-oriented architecture that developers can use to remotely access and configure a switch. REST is the underlying architectural principle of the Web. It uses HTTP, which is oriented around verbs and resources. The verbs are the well-known HTTP commands: POST, GET, PUT, and DELETE (which correspond to create, read, update, and delete, or CRUD operations, respectively). The verbs are applied to EFOS resources such as VLANs, LAGs, and interfaces.

Because the APIs are based on REST principles, writing and testing applications is easy. You can use your browser to access URLs and an HTTP client in any programming language to interface with the APIs.

The OpEN RESTful APIs provides an interface to the OpEN API for Linux processes running on the same CPU to access control and status features of the main EFOS process (switchdrvr). These includes APIs for:

- Setting and getting switch user configuration
- Monitoring and changing switch operational state

An example application that uses this API is the Broadcom OpenStack Neutron ML2 plugin mechanism driver. The driver, which is written in Python and runs on the controller node in an OpenStack cluster, must be able to issue commands to the switch to create and destroy VLANs and to place and remove ports that participate in these VLANs. This core functionality is required for a basic mechanism driver that implements the ML2 L2/VLAN type driver model. The RESTful API provides the means by which this work can be done.

2.4.4 Using the RESTCONF Interface

RESTCONF is an HTTP-based network management protocol that allows the user to monitor, read status, and configure a switch programmatically. It makes use of schema described by YANG models to describe the data exposed by the device. It allows web-based applications to configure a switch, create a back-up of its running configuration, and replicate its configuration to other switches.

The configuration data and state data for RESTCONF can now be encoded with either XML or JSON.

As of EFOS release 3.2, monitoring and notification features are not implemented. These features may be added in future releases.

2.4.5 Using the NETCONF Interface

The NETCONF protocol defines a simple mechanism through which a network device can be managed, configuration data information can be retrieved, and new configuration data can be uploaded and manipulated. NETCONF uses a simple RPC-based mechanism to facilitate communication between one or more clients and a single server over a secure transport layer. The client sends an RPC-encoded configuration message in an XML document on an authenticated NETCONF session to retrieve configuration and status data or to modify the configuration. The configuration and state data that NETCONF operates upon is defined by YANG models.

A change in one session is reflected in all other existing sessions. Configuration changes done from other non-NETCONF sessions (CLI, SNMP, Web, RESTCONF) is also reflected in the NETCONF session, and vice versa.

Chapter 3: Configuring Switch Management Features

3.1 Managing Images and Files

EFOS-based switches maintain several different types of files on the flash file system. Table 1 describes the files that you can manage. You use the `copy` command to copy a source file to a destination file. The copy command may permit the following actions (depending on the file type):

- Copy a file from the switch to a remote server.
- Copy a file from a remote server to the switch.
- Overwrite the contents of the destination file with the contents of the source file.

Table 1: Files to Manage

File	Description
active	The switch software image that has been loaded and is currently running on the switch.
backup	A second software image that is currently not running on the switch.
startup-config	Contains the software configuration that loads during the boot process.
running-config	Contains the current switch configuration.
factory-defaults	Contains the software configuration that can be used to load during the boot process or after clearing the configuration.
backup-config	An additional configuration file that serves as a backup. You can copy the startup-config file to the backup-config file.
fastpath.cfg	A binary configuration file.
Configuration script	Text file with CLI commands. When you apply a script on the switch, the commands are executed and added to the running-config.
CLI Banner	Text file containing the message that displays upon connecting to the switch or logging on to the switch by using the CLI.
Log files	Trap, error, or other log files that provide Provides various information about events that occur on the switch.
SSH key files	Contains information to authenticate SSH sessions. The switch supports the following files for SSH: ■ SSH-1 RSA Key File ■ SSH-2 RSA Key File (PEM Encoded) ■ SSH-2 Digital Signature Algorithm (DSA) Key File (PEM Encoded) **NOTE:** SSH-1 is deprecated. **NOTE:** If you use the CLI to manage the switch over an SSH connection, you must copy the appropriate key files to the switch.
IAS Users	List of Internal Authentication Server (IAS) users for IEEE 802.1X authentication. You can configure the switch to use the local IAS user database for port-based authentication instead of using a remote server, such as a RADIUS server.

3.1.1 Supported File Management Methods

For most file types, you can use any of the following protocols to download files from a remote system to the switch or to upload files from the switch to a remote system:

- FTP
- TFTP
- SFTP
- SCP

- XMODEM
- YMODEM
- ZMODEM

NOTE: The IAS Users file can be copied from a remote server to the switch only by using FTP, TFTP, SFTP, or SCP.

3.1.2 Uploading and Downloading Files

To use FTP, TFTP, SFTP, or SCP for file management, you must provide the IP address of the remote system that is running the appropriate server (FTP, TFTP, SFTP, or SCP). Make sure there is a route from the switch to the remote system. You can use the `ping` command from the CLI to verify that a route exists between the switch and the remote system.

If you are copying a file from the remote system to the switch, be sure to provide the correct path to the file (if the file is **not** in the root directory) and the correct file name.

3.1.3 Managing Switch Software (Images)

The switch can maintain two software images: the active image and the backup image. When you copy a new image from a remote system to the switch, you can specify whether to save it as the active or backup image. The downloaded image overwrites the image that you specify. If you save the new image as the active image, the switch continues to operate using the current (old) image until you reload the switch. Once the switch reboots, it loads with the new image. If you download the new image as the backup image, the file overwrites the current backup image, if it exists. To load the switch with the backup image, you must first set it as the active image and then reload the switch. The image that was previously the active image becomes the backup image after the switch reloads.

If you activate a new image and reload the switch, and the switch is unable to complete the boot process due to a corrupt image or other problem, you can use the boot menu to activate the backup image. You must be connected to the switch through the console port to access the boot menu.

To create a backup copy of the firmware on the switch, copy the active image to the backup image. You can also copy an image to a file on a remote server.

3.1.4 Managing Configuration Files

Configuration files contain the CLI commands that change the switch from its default configuration. The switch can maintain three separate configuration files: startup-config, running-config, and backup-config. The switch loads the startup-config file when the switch boots. Any configuration changes that take place after the boot process completes are written to the running-config file. The backup-config file does not exist until you explicitly create one by copying an existing configuration file to the backup-config file or downloading a backup-config file to the switch.

You can also create configuration scripts, which are text files that contains CLI commands.

When you apply (run) a configuration script on the switch, the commands in the script are executed in the order in which they are written as if you were typing them into the CLI. The commands that are executed in the configuration script are added to the running-config file.

You might upload a configuration file from the switch to a remote server for the following reasons:

- To create a backup copy
- To use the configuration file on another switch
- To manually edit the file

You might download a configuration file from a remote server to the switch for the following reasons:

- To restore a previous configuration
- To load the configuration copied from another switch
- To load the same configuration file on multiple switches

Use a text editor to open a configuration file and view or change its contents.

3.1.4.1 Editing and Downloading Configuration Files

Each configuration file contains a list of executable CLI commands. The commands must be complete and in a logical order, as if you were entering them by using the switch CLI.

When you download a startup-config or backup-config file to the switch, the new file replaces the previous version. To change the running-config file, you execute CLI commands either by typing them into the CLI or by applying a configuration script with the `script apply` command.

3.1.4.2 Creating and Applying Configuration Scripts

When you use configuration scripting, keep the following considerations and rules in mind:

NOTE: If your switch is currently at EFOS software version 3.4.3 and you plan to downgrade the switch to a version previous to EFOS 3.4.3, you must uncompress the scripts so they will operate. See Section 3.1.4.2.1, Uncompressing Configuration Scripts.

- The application of scripts is partial if the script fails. For example, if the script executes four of ten commands and the script fails, the script stops at four, and the final six commands are not executed.
- Scripts cannot be modified or deleted while being applied.
- Validation of scripts checks for syntax errors only. It does not validate that the script will run.
- The file extension must be `.scr`.
- There is no limit on the maximum number of scripts files that can be stored on the switch within a given storage space limit.
- The combined size of all script files on the switch cannot exceed 2048 Kbytes. The zlib compression technique is applied to script files to decrease script file size.

You can type single-line annotations in the configuration file to improve script readability. The exclamation point (!) character flags the beginning of a comment. Any line in the file that begins with the “!” character is recognized as a comment line and ignored by the parser. Do not use a comment character anywhere in a line that contains a command.

The following example shows annotations within a file (commands are bold):

```
!Configuration script for mapping lab hosts to IP addresses
!Enter Global Config mode and map host name to address
configure
    ip host labpc1 192.168.3.56
    ip host labpc2 192.168.3.57
    ip host labpc3 192.168.3.58
    exit
! End of the script file
```

3.1.4.2.1 Uncompressing Configuration Scripts

If you plan to downgrade your switch from EFOS 3.4.3, you must use the following procedure to uncompress the scripts.

1. Upload the scripts from the switch to an external server via FTP/TFTP. During the upload process from the switch, the scripts are uncompressed.
2. Downgrade the software image on the switch.
3. Download the uncompressed script files to the switch.

3.1.4.3 Non-Disruptive Configuration Management

The Non-Disruptive Configuration feature can apply a new configuration file without disrupting the operation of features that are unchanged by the new configuration.

In the data center network, where the network administrator may manage thousands of switches, when the switch configuration is changed by uploading a new configuration file to it, the switch can gracefully resolve any differences between the running configuration and the new configuration. For example, if the switch has VLANs 10, 20, and 30 configured, and the new configuration has VLANs 10, 20, and 40, the switch deletes VLAN 30 and creates VLAN 40 without disturbing traffic forwarding on VLANs 10 and 20.

Without this feature, to upgrade to a new configuration, the administrator must either provide a new configuration file and restart the switch or upload a 'delta' configuration. Restarting the switch is disruptive, and managing delta configurations is difficult on a large scale.

The following commands can be used to apply the configuration gracefully.

- `reload configuration` — Applies the startup-config gracefully.
- `reload configuration <scriptfile>` — Applies the given script file gracefully.

On platforms where EFOS runs as an application, management tools such as Puppet/Chef use the `icos-cfg` command to copy the new configuration file to */mnt/fastpath/startup-config* and apply it. The `-n` option is added to `icos-cfg` to load the configuration gracefully, as follows:

```
root@localhost:~# icos-cfg -h
Usage: icos-cfg [options]
    -a, --apply script            apply CLI configuration script
    -d, --debug                   debug mode suppresses output, applicable for "apply",
                                "validate" and "generate"
    -g, --generate script         generate running-config and writes to file
    -s, --save                    save running-config to startup-config
    -n, --ndcm                    gracefully apply CLI configuration script
    -t, --timeout seconds         wait for EFOS process in seconds, default: 30 seconds
    -v, --validate script         validate CLI configuration script
    -h, --help                    display this message
root@localhost:~#
```

3.1.5 Saving the Running Configuration

Changes you make to the switch configuration while the switch is operating are written to the running-config. These changes are not automatically written to the startup-config. When you reload the switch, the startup-config file is loaded. If you reload the switch (or if the switch resets unexpectedly), any settings in the running-config that were not explicitly saved to the startup-config are lost. You must save the running-config to the startup-config to ensure that the settings you configure on the switch are saved across a switch reset.

To save the running-config to the startup-config from the CLI, use the `write memory` command.

3.1.6 File and Image Management Configuration Examples

3.1.6.1 Upgrading the Firmware

This example shows how to download a firmware image to the switch and activate it. The TFTP server in this example is PumpKIN, an open source TFTP server running on a Windows system.

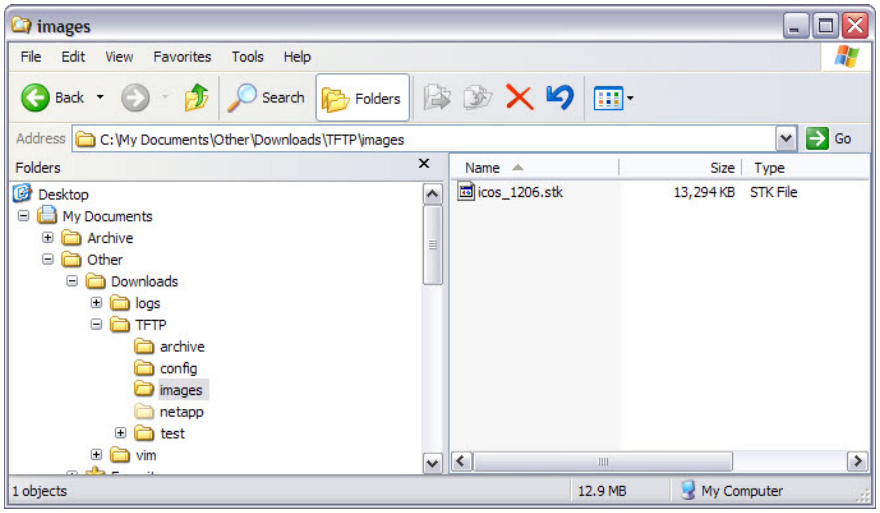
- TFTP server IP address: 10.27.65.112
- File path: \image
- File name: icos_1206.stk

Use the following steps to prepare the download, and then download and upgrade the switch image.

1. Check the connectivity between the switch and the TFTP server.

```
(Routing) #ping 10.27.65.112
 Pinging 10.27.65.112 with 0 bytes of data:

Reply From 10.27.65.112: icmp_seq = 0. time= 5095 usec.

----10.27.65.112 PING statistics----
1 packets transmitted, 1 packets received, 0% packet loss
round-trip (msec) min/avg/max = 5/5/5
```

2. Copy the image file to the appropriate directory on the TFTP server. In this example, the TFTP root directory is `C:\My Documents\Other\Downloads\TFTP`, so the file path is `images`.



Address C:\My Documents\Other\Downloads\TFTP\images

Name	Size	Type
icos_1206.stk	13,294 KB	STK File

3. View information about the current image.

```
(Routing) #show bootvar
Image Descriptions
active : default image
 backup :

 Images currently available on Flash
--------------------------------------------------------------------
 unit      active      backup     current-active        next-active
```

```
   --------------------------------------------------------------------
   1    I.12.5.1  11.21.16.52           I.12.5.1           I.12.5.1
```

4. Download the image to the switch. After you execute the `copy` command, you must verify that you want to start the download. The image is downloaded as the backup image.

```
(Routing) #copy tftp://10.27.65.112/images/icos_1206.stk backup

Mode........................................... TFTP
Set Server IP.................................. 10.27.65.112
Path........................................... images/
Filename....................................... icos_1206.stk
Data Type...................................... Code
Destination Filename........................... backup

Management access will be blocked for the duration of the transfer
Are you sure you want to start? (y/n)y
```

5. After the transfer completes, activate the new image so that it becomes the active image after the switch resets.

```
(Routing) #boot system backup
Activating image backup ..
```

6. View information about the current image.

```
(Routing) #show bootvar
Image Descriptions

 active : default image
 backup :

 Images currently available on Flash
--------------------------------------------------------------------
 unit      active    backup       current-active   next-active
--------------------------------------------------------------------
  1        I.12.5.1  11.21.16.52  I.12.5.1         I.12.6.2
```

7. Copy the running configuration to the startup configuration to save the current configuration to NVRAM.

```
(Routing) #write memory

This operation may take a few minutes.
Management interfaces will not be available during this time.

Are you sure you want to save? (y/n)y

Configuration Saved!
```

8. Reset the switch to boot the system with the new image.

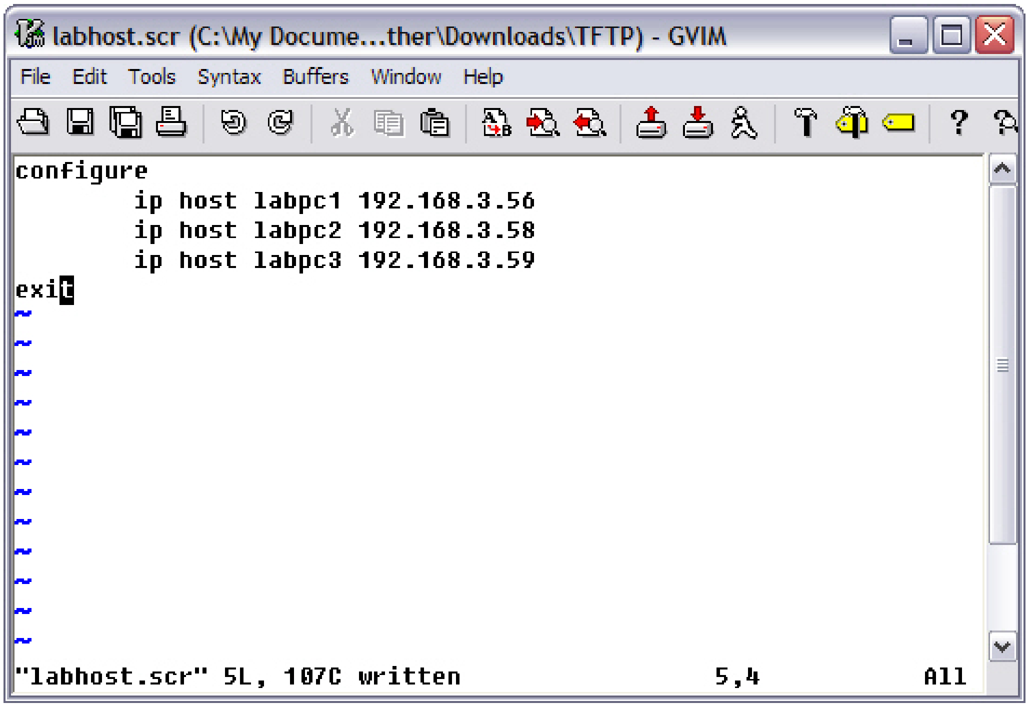
```
(Routing) #reload
Are you sure you want to continue? (y/n)y
Reloading all switches...
```

3.1.6.2 Managing Configuration Scripts

This example shows how to create a configuration script that adds three host name-to-IP address mappings to the host table.

To configure the switch:

1. Open a text editor on an administrative computer and type the commands as if you were entering them by using the CLI.


labhost.scr (C:\My Docume...ther\Downloads\TFTP) - GVIM
File Edit Tools Syntax Buffers Window Help

```
configure
        ip host labpc1 192.168.3.56
        ip host labpc2 192.168.3.58
        ip host labpc3 192.168.3.59
exit
~
~
~
~
~
~
~
~
~
~
~
~
"labhost.scr" 5L, 107C written                    5,4          All
```

2. Save the file with an *.scr extension and copy it to the appropriate directory on your TFTP server.
3. Download the file from the TFTP server to the switch.

```
(Routing) #copy tftp://10.27.65.112/labhost.scr nvram:script labhost.scr

Mode........................................... TFTP
Set Server IP.................................. 10.27.65.112
Path........................................... ./
Filename....................................... labhost.scr
Data Type...................................... Config Script
Destination Filename........................... labhost.scr

Management access will be blocked for the duration of the transfer
Are you sure you want to start? (y/n)
```

4. After you confirm the download information and the script successfully downloads, it is automatically validated for correct syntax.

```
Are you sure you want to start? (y/n) y

135 bytes transferred

Validating configuration script...
configure
exit
configure
ip host labpc1 192.168.3.56

ip host labpc2 192.168.3.58

ip host labpc3 192.168.3.59
```

```
Configuration script validated.
File transfer operation completed successfully.
```

5. Run the script to execute the commands.

```
(Routing) #script apply labhost.scr

Are you sure you want to apply the configuration script? (y/n)y

configure
exit
configure
ip host labpc1 192.168.3.56

ip host labpc2 192.168.3.58sj

ip host labpc3 192.168.3.59

Configuration script 'labhost.scr' applied.
```

6. Verify that the script was successfully applied.

```
(Routing) #show hosts
..
.
.
Configured host name-to-address mapping:
Host                      Addresses
------------------------  ------------------------
labpc1                    192.168.3.56
labpc2                    192.168.3.58
labpc3                    192.168.3.59
```

3.2 Enabling Automatic Image Installation and System Configuration

The Auto Install feature can automatically update the firmware image and obtain configuration information when the switch boots. Auto Install begins the automatic download and installation process when the switch boots and loads a saved configuration that has the persistent Auto Install mode enabled. Additionally, the switch supports a non-persistent Auto Install mode so that Auto Install can be stopped or restarted at any time during switch operation.

3.2.1 DHCP Auto Install Process

The switch can use a DHCP server to obtain configuration information from a TFTP server.

DHCP Auto Install is accomplished in three phases:

1. Assignment or configuration of an IP address for the switch
2. Assignment of a TFTP server
3. Obtaining a configuration file for the switch from the TFTP server

Auto Install is successful when an image or configuration file is downloaded to the switch from a TFTP server.

NOTE: The downloaded configuration file is not automatically saved to startup-config. You must explicitly issue a save request (`write memory`) in order to save the configuration.

3.2.1.1 Obtaining IP Address Information

DHCP is enabled by default on the service port. If an IP address has not been assigned, the switch issues requests for an IP address assignment.

A network DHCP server returns the following information:

- IP address and subnet mask to be assigned to the interface
- IP address of a default gateway, if needed for IP communication

3.2.1.2 Obtaining Other Dynamic Information

The following information is also processed and may be returned by a BOOTP or DHCP server:

- Name of configuration file (the *file* field in the DHCP header or option 67) to be downloaded from the TFTP server.
- Identification of the TFTP server providing the file. The TFTP server can be identified by name or by IP address as follows:
  - Host name: DHCP option 66 or the *sname* field in the DHCP header
  - IP address: DHCP option 150 or the *siaddr* field in the DHCP header

When a DHCP OFFER identifies the TFTP server more than once, the DHCP client selects one of the options in the following order: *sname*, option 66, option 150, *siaddr*. If the TFTP server is identified by host name, a DNS server is required to translate the name to an IP address.

The DHCP client on the switch also processes the name of the text file (option 125, the V-I vendor-specific Information option) which contains the path to the image file.

3.2.1.3 Obtaining the Image

Auto Install attempts to download an image file from a TFTP server only if the switch loads with a saved configuration file that has Auto Install enabled (the `boot host dhcp` command) or if Auto Install has been administratively activated by issuing the `boot autoinstall start` command during switch operation.

The network DHCP server returns a DHCP OFFER message with option 125. When configuring the network DHCP server for image downloads, you must include Option 125 and specify the Broadcom Enterprise Number, 4413. Within the Broadcom section of option 125, sub option 5 must specify the path and name of a file on the TFTP server. This file is not the image file itself, but rather a text file that contains the path and name of the image file. Upon receipt of option 125, the switch downloads the text file from the TFTP server, reads the name of the image file, and downloads the image file from the TFTP server.

After the switch successfully downloads and installs the new image, it automatically reboots. The download or installation might fail for one of the following reasons:

- The path or filename of the image on the TFTP server does not match the information specified in DHCP option 125.
- The downloaded image is the same as the current image.
- The validation checks, such as valid CRC Checksum, fails.

If the download or installation was unsuccessful, a message is logged.

3.2.1.4 Obtaining the Configuration File

If the DHCP OFFER identifies a configuration file, either as option 67 or in the *file* field of the DHCP header, the switch attempts to download the configuration file.

NOTE: The configuration file is required to have a file type of *.cfg.

The TFTP client makes three unicast requests. If the unicast attempts fail, or if the DHCP OFFER did not specify a TFTP server address, the TFTP client makes three broadcast requests.

If the DHCP server does not specify a configuration file or download of the configuration file fails, the Auto Install process attempts to download a configuration file with the name *fp-net.cfg*. The switch unicasts or broadcasts TFTP requests for a network configuration file in the same manner as it attempts to download a host-specific configuration file.

The default network configuration file consists of a set of IP address-to-host name mappings, using the command **ip host hostname** *address*. The switch finds its own IP address, as learned from the DHCP server, in the configuration file and extracts its host name from the matching command. If the default network configuration file does not contain the switch's IP address, the switch attempts a reverse DNS lookup to resolve its host name.

A sample `fp-net.cfg` file follows:

```
config
   ...
   ip host switch1 192.168.1.10
   ip host switch2 192.168.1.11
   ... <other hostname definitions>
exit
```

Once a host name has been determined, the switch issues a TFTP request for a file named *hostname*.cfg, where *hostname* is the first thirty-two characters of the switch's host name.

If the switch is unable to map its IP address to a host name, Auto Install sends TFTP requests for the default configuration file host.cfg.

Table 2, Configuration File Possibilities summarizes the config files that may be downloaded and the order in which they are sought.

Table 2: Configuration File Possibilities

Order Sought	File Name	Description	Final File Sought
1	bootfile.cfg	Host-specific config file, ending in a *.cfg file extension	Yes
2	fp-net.cfg	Default network config file	No
3	hostname.cfg	Host-specific config file, associated with host name.	Yes
4	host.cfg	Default config file	Yes

The following table displays the determining factors for issuing unicast or broadcast TFTP requests.

Table 3: TFTP Request Types

TFTP Server Address Available	Host-specific Switch Config Filename Available	TFTP Request Method
Yes	Yes	Issue a unicast request for the host-specific router config file to the TFTP server
Yes	No	Issue a unicast request for a default network or router config file to the TFTP server
No	Yes	Issue a broadcast request for the host-specific router config file to any available TFTP server
No	No	Issue a broadcast request for the default network or router config file to any available TFTP server

3.2.2 Monitoring and Completing the DHCP Auto Install Process

When the switch boots and triggers an Auto Install, a message is written to the buffered log. After the process completes, the Auto Install process writes a log message. You can use the `show logging buffered` command to view information about the process. The following log message indicates that the switch has broadcast a request to download the fp-net.cfg file from any TFTP server on the network.

```
<14> Jan  1 00:00:42 10.27.22.157-1 AUTO_INST[310234388]: auto_install_control.c(2427) 202 %%
AutoInstall<->TFTP : Downloading tftp://255.255.255.255/fp-net.cfg (via eth0)
```

Additionally, while the Auto Install is running, you can issue the `show autoinstall` command to view information about the current Auto Install state.

When Auto Install has successfully completed, you can execute a `show running-config` command to validate the contents of configuration.

3.2.2.1 Saving a Configuration

The Auto Install feature includes an AutoSave feature that allows the downloaded configuration to be automatically saved; however, AutoSave is disabled by default. If AutoSave has not been enabled, you must explicitly save the downloaded configuration in non-volatile memory. This makes the configuration available for the next reboot. In the CLI, this is performed by issuing a `write memory` command or `copy system:running-config nvram:startup-config` command and should be done after validating the contents of saved configuration.

3.2.2.2 Stopping and Restarting the Auto Install Process

You can terminate the Auto Install process at any time before the image or configuration file is downloaded. This is useful when the switch is disconnected from the network. Termination of the Auto Install process ends further periodic requests for a host-specific file.

3.2.2.3 Managing Downloaded Config Files

The configuration files downloaded to the switch by Auto Install are stored in the nonvolatile memory as `.scr` files. The files may be managed (viewed or deleted) along with files downloaded by the configuration scripting utility. If the Auto Install persistent mode is enabled (`boot dhcp host`) and the switch reboots, the `.scr` configuration file created by the switch in the non-volatile memory is overwritten during the Auto Install process.

To ensure that the downloaded configuration file is used during the next boot cycle, make sure that the Auto Install persistent mode is disabled (`no boot dhcp host`) and save the configuration (`write memory`).

3.2.3 DHCP Auto Install Dependencies

The Auto Install process from TFTP servers depends upon the following network services:

- A DHCP server must be configured on the network with appropriate services.
- An image file and a text file containing the image file name for the switch must be available from a TFTP server if DHCP image download is required.
- A configuration file (either from bootfile (or) option 67 option) for the switch must be available from a TFTP server.
- The switch must be connected to the network and have a Layer 3 interface that is in an UP state.
- A DNS server must contain an IP address to host name mapping for the TFTP server if the DHCP server response identifies the TFTP server by name.
- A DNS server must contain an IP address to host name mapping for the switch if a `<hostname>.cfg` file is to be downloaded.
- If a default gateway is needed to forward TFTP requests, an IP helper address for TFTP needs to be configured on the default gateway.

3.2.4 Default Auto Install Values

Table 4 describes the Auto Install defaults.

Table 4: Auto Install Defaults

Feature	Default	Description
Retry Count	3	When the DHCP or BOOTP server returns information about the TFTP server and bootfile, the switch makes three unicast TFTP requests for the specified bootfile. If the unicast attempts fail or if a TFTP server address was not provided, the switch makes three broadcast requests to any available TFTP server for the specified bootfile.
AutoSave	Disabled	If the switch is successfully auto-configured, the running configuration is not saved to the startup configuration.
AutoReboot	Enabled	After an image is successfully downloaded during the Auto Install process, the switch automatically reboots and makes the downloaded image the active image.

3.2.5 Enabling DHCP Auto Install and Auto Image Download

A network administrator is deploying three switches and wants to quickly and automatically install the latest image and a common configuration file that configures basic settings such as VLAN creation and membership and RADIUS server settings. This example describes the procedures to complete the configuration. The DHCP and TFTP servers in this example are reachable from the service port on the switch.

To use DHCP Auto Install:

1. Log on to each switch and enable persistent Auto Install mode.
   ```
   (Routing) #boot host dhcp
   ```
2. Save the running configuration to the startup configuration file.
   ```
   (Routing) #write memory
   ```
3. Create a default config file for the switches named `host.cfg`. For information about creating configuration files, see Section 3.1, Managing Images and Files.
4. Upload the `host.cfg` file to the TFTP server.
5. Upload the image file to the TFTP server.
6. Configure an address pool on the DHCP server that contains the following information:
   a. The IP address (*yiaddr*) and subnet mask (option 1) to be assigned to the interface
   b. The IP address of a default gateway (option 3)
   c. DNS server address (option 6)
   d. Name of config file for each host
   e. Identification of the TFTP server by host name (DHCP option 66 or the *sname* field in the DHCP header) or IP address (DHCP option 150 or the *siaddr* field in the DHCP header)
   f. Name of the text file (option 125, the V-I vendor-specific Information option) that contains the path to the image file.
7. Connect the service port on each switch to the management network. This network must have a route to the DHCP server and TFTP server that are used for Auto Install process.
8. Reboot each switch.
   ```
   (Routing) #reload
   ```

3.3 Using the ISSU Feature to Upgrade the Software

NOTE: The in-service software upgrade (ISSU) feature is available only on x86 platforms.

The ISSU feature allows users to upgrade the switch software without interrupting data forwarding through the switch.

This feature is mainly targeted for top-of-rack (TOR) switches in data center Clos topologies. The goal of ISSU is to maintain Ethernet data connectivity with the servers attached to TOR switches while the TOR switch software is being upgraded. A software upgrade that requires a reboot or a kernel upgrade is not supported via ISSU.

During the ISSU process, management to the switch is disrupted. After the upgrade, users must log on to the switch again and re-authenticate to resume any switch management session.

The following features support ISSU in this release

.

- SIM
- DiffServ/ACL
- ARP
- NDP Cache
- NIM
- MPLS
- Routing Interfaces
- BGP
- L2 FDB
- DOT1X
- RTO
- VRF
- DoS
- Open API Clients
- RTO6

The 802.1Q, DOT3AD, and DHCP client features have limited support for ISSU.

Any feature not listed above is ISSU unaware. This means that the feature does not distinguish between an ISSU restart and a normal restart. A feature that is not ISSU-aware tends to initialize afresh without the knowledge of previously active instance of the same and can cause traffic disruption during initialization.

To initiate ISSU, perform the following:

1. Use standard Linux utilities from the Linux shell to download the new EFOS software package to the switch. Use any Linux-supported file transfer mode to download files.
2. Enter the Linux shell as a root user. To login as root, execute the `sudo su` command.
3. Run the `icos-mgmt -s` command to prevent any configuration changes until the EFOS software saves all check pointed data to SYNCDB and to persistent storage (which contains the data from Components, USL, SDK).
4. Issue the `service icos stop` command to stop all EFOS processes.
5. Get the EFOS package name by using the `rpm/dpkg` commands

   For example:

   ```
   dpkg -l | grep icos
   rpm -qa | grep icos
   ```
6. Uninstall the old package by using the `rpm/dpkg` commands.

   For example:

   ```
   dpkg --remove <icos-package>
   rpm -e <icos-package>
   ```
7. Install the package (using `rpm` or `dpkg`, depending on the Linux distribution type the package is built for).

   For example:

   ```
   dpkg -i /path/to/deb-file
   rpm -ivh /path/to/rpm-file
   ```
8. Issue the `service icos start` command to restart the EFOS service.

9. Log on to the EFOS CLI console and wait for the # prompt.

10. Issue the `show issu status` command to view the status of the ISSU operation.

    For example:

```
(localhost) #show issu status
Last reset reason.............................. In Service Software Upgrade
Current state.................................. ISSU completed, H/W reconciliation done
Time elapsed since ISSU initiation............. 2 minutes 9 seconds
```

3.4 Downloading a Core Dump

The core dump file can be downloaded using the following methods:

- NFS
- TFTP
- FTP

On systems that have gigabytes of flash storage, the core dump file can also be copied to flash.

3.4.1 Using NFS to Download a Core Dump

Use the following commands to download a core dump file via NFS:

```
(Routing) #config
(Routing) (Config)#exception protocol nfs
(Routing) (Config)#exception dump nfs 192.168.1.10://home/nfs_test
(Routing) (Config)#show exception

Coredump file name............................. ASDF
Coredump filename uses hostname................ TRUE
Coredump filename uses time-stamp.............. TRUE
NFS mount point................................ 192.168.1.10://home/nfs_test
TFTP server IP................................. 10.27.9.99
File path...................................... ./.
Protocol....................................... nfs
Switch-chip-register...........................TRUE
(Routing) (Config)#

(Routing) #write core test

The configured protocol nfs test PASS
(Routing) #
```

3.4.2 Using TFTP or FTP to Download a Core Dump

Use the following commands to download a core dump file via TFTP. To use FTP, substitute `ftp` for `tftp` in the commands.

```
(Routing) #config
(Routing) (Config)#exception protocol tftp
(Routing) (Config)#exception dump tftp-server 192.168.1.2
(Routing) (Config)#show exception

Coredump file name............................. core
Coredump filename uses hostname................ FALSE
Coredump filename uses time-stamp.............. TRUE
TFTP server IP................................. 192.168.1.2
File path...................................... ./.
Protocol....................................... tftp
Switch-chip-register...........................FALSE
(Routing) (Config)#

(Routing) #write core test
The configured protocol tftp test PASS
(Routing) #
```

3.5 Enabling Kernel Core Dump

The kernel core dump feature enables the system to perform a warm reboot into a new kernel in reserved memory, allowing the current state of the operating kernel to be captured for post-mortem analysis. This feature involves configuring the underlying operating system to enable the Linux kexec feature. The kernel-dump feature is implemented as a set of bash scripts in either a RPM or DEB package that can be used with or without the EFOS application running. It provides a convenient method to invoke the "crash" console kernel debugging utility without requiring complex user configuration. This provides the necessary handling to allow debugging of the EFOS customized Linux kernel. This feature is available only on platforms with Intel x86-class CPUs running standard Ubuntu Linux.

The following commands can be executed in Global Config mode to enable the kernel-dump feature, which is disabled by default, and to configure the path for storing kernel-dump files:

```
(Routing) #config
(Routing) (Config)#exception kernel-dump
(Routing) (Config)#exception kernel-dump path path
```

You use the following commands in Privileged Exec mode to show kernel-dump settings, show the list of saved kernel dumps, and show the dmesg log from a particular kernel dump.

```
(Routing) #show exception kernel-dump
(Routing) #show exception kernel-dump list
(Routing) #show exception kernel-dump log record number
```

Refer to the *EFOS CLI Command Reference* for a complete list of commands (see Appendix A.1, References).

3.6 Setting the System Time

The switch uses the system clock to provide time stamps on log messages. Additionally, some show commands include the time in the command output. For example, the `show users login-history` command includes a Login Time field. The system clock provides the information for the Login Time field.

You can configure the system time manually, or you can configure the switch to obtain the time by using a Simple Network Time Protocol (SNTP) server. A network SNTP server can provide more accurate switch clock time synchronization than manually-configured time.

NOTE: The manually-configured local clock settings are not retained across a system reset if the platform does not include a Real Time Clock (RTC).

The SNTP client on the switch can request the time from an SNTP server on the network (unicast), or you can allow the switch to receive SNTP broadcasts. Requesting the time from a unicast SNTP server is more secure. Use this method if you know the IP address of the SNTP server on your network. If you allow the switch to receive SNTP broadcasts, any clock synchronization information is accepted, even if it has not been requested by the device. This method is less secure than polling a specified SNTP server.

The switch also supports the following time configuration settings:

- Time Zone —Allows you to specify the offset from Coordinated Universal Time (UTC), which is also known as Greenwich Mean Time (GMT).
- Summer Time/Daylight Saving Time (DST)— In some regions, the time shifts by one hour in the fall and spring. The switch supports manual entry of one-time or recurring shifts in the time.

3.6.1 Manual Time Configuration

The example in this section shows how to manually configure the time, date, time zone, and summer time settings for a switch in Hyderabad, India.

11. Set the time. The system clock uses a 24-hour clock, so 6:23 PM is entered as 18:23:00.

```
(Routing) #configure
(Routing) (Config)#clock set 18:23:00
```

12. Set the date. In this example, the date is April 30, 2012.

```
(Routing) (Config)#clock set 04/30/2012
```

13. Configure the time zone. In this example, the time zone is India Standard Time (IST), which is UTC/GMT +5 hours and 30 minutes.

```
(Routing) (Config)#clock timezone 5 minutes 30 zone IST
```

14. Configure the offset for a hypothetical daylight saving time. In this example, the offset is one hour. It occurs every year on Sunday in the first week of April and ends the fourth Sunday in October. The start and end times are 2:30 AM, and the time zone is India Standard Summer Time (ISST).

```
(Routing) (Config)#clock summer-time recurring 1 sun apr 02:30 4 sun oct 02:30 offset 60 zone ISST
(Routing) (Config)#exit
```

15. View the clock settings.

```
(Routing) #show clock detail

20:30:07 ISST(UTC+6:30) Apr 30 2012
No time source

 Time zone:
 Acronym is IST
 Offset is UTC+5:30

 Summertime:
 Acronym is ISST
 Recurring every year
 Begins at first Sunday of Apr at 02:30
 Ends at fourth Sunday of Oct at 02:30
 offset is 60 minutes
```

3.6.2 Configuring SNTP

This example shows how to configure the system clock for a switch in New York City, which has a UTC/GMT offset of –5 hours.

1. Specify the SNTP server the client on the switch should contact. You can configure the IP address or host name of the SNTP server.

```
(Routing) #configure
(Routing) (Config)#sntp server time1.rtp.broadcom.com
```

2. Configure the UTC/GMT offset for the location.

```
(Routing) (Config)#clock timezone -5
```

3. Configure the time offset for DST.

   ```
   (Routing) (Config)#clock summer-time recurring USA
   ```

4. Enable the SNTP client on the device in unicast mode.

   ```
   (Routing) (Config)#sntp client mode unicast
   ```

5. View the time information.

   ```
   (Routing) #show sntp

   Last Update Time:                  Apr 27 16:42:23 2012
   Last Unicast Attempt Time:         Apr 27 16:43:28 2012
   Last Attempt Status:               Success

   (Routing) #show clock

   12:47:22 (UTC-4:00) Apr 27 2012
   Time source is SNTP
   ```

3.7 Creating CPU Traffic Filters

When mirroring traffic to and from the CPU, you can create filters that match only certain packets and quickly see if there are packets to/from CPU that match the filters. Filters can be based on the protocol along with IP address, MAC address, and TCP and UPD port numbers. In lieu of a named protocol, a custom option can be used to specify the offset and data to match.

The match condition for the filter can be one or more of the following: STP, LACPDU, ARP, UDLD, BCAST, MCAST, UCAST, LLDP, IP, OSPF, BGP, DHCP, SRCIP, DSTIP, SRCMAC, DSTMAC, SRCTCP, DSTTCP, SRCUDP, DSTUDP, and custom data with offset.

EFOS supports using two software filters (one filter for TX and one for RX), and can configure the filter to match one, multiple, or all of the supported protocols in the TX or RX direction, or both directions.

CPU traffic either in the RX or TX direction is compared with the defined user-level filters. Filter statistics are updated for the packet matching the filter.

Statistics counters are available for each filter option per interface and direction. For example, if a filter is defined for STP and LACPDU packets on port-1 for RX and TX direction, then each STP or LACPDU packet received on port-1 increments STP and LACP counter statistics. Similarly, STP or LACPDU packets sent by the switch from port-1 also increment the counter statistics. The counter statistics for an interface are associated with the last updated timestamp to determine when the counter on an interface was most recently updated.

3.7.1 Configuration Example

1. Enable the feature on interface:
   ```
   (Routing) #cpu-traffic direction both interface 0/1
   ```
2. Enable a particular filter (in the following example, we are interested in packets with particular SrcIP, 10.27.9.99):
   ```
   (Routing) #cpu-traffic direction both match filter srcip
   ```
3. Configure additional parameters for the filter:
   ```
   (Routing) #cpu-traffic direction both match srcip 10.27.9.99 mask 255.255.255.255
   ```
4. Enable the feature:
   ```
   (Routing) #cpu-traffic mode
   ```
5. Use `show` commands to check the counters:
   ```
   show cpu-traffic interface 0/1 srcip
   show cpu-traffic summary
   ```

3.8 Configuring a Packet Trace

The packet trace feature can be used to trace the egressing LAG member port/ECMP route for a specified packet. This feature allows the network administrator to figure out the specific path a specified network stream may take. The feature does not need to save any configuration and is provided as a utility. On a system that has LAGs/ECMP routes set up (specific routes that the packet may take), the following steps can be used to find the egress information.

1. Specify the packet fields for the packet to be traced. Appropriate packet-trace commands can be used depending upon the type of packet to be traced. Show packet-trace packet-data can be used to dump the currently configured packet fields.

```
(Routing) #packet-trace eth src-mac 00:00:00:00:07:00 dst-mac 00:00:00:00:06:00 vlan 10

(Routing) #show packet-trace packet-data

Packet header fields
--------------------

Ethernet header fields:
Src Mac               Dst Mac              Vlan
-----------------     ----------------     ----
00:00:00:00:07:00     00:00:00:00:06:00    10

IPv4 header fields
Src IP               Dst IP               TOS
-------              -------              ---
0.0.0.0              0.0.0.0              0

IPv6 header fields
Src IP               Dst IP               TOS
------               ------               ---
::                   ::                   0

TCP/UDP header fields
Src Port     Dst Port
--------     --------
0            0
```

2. Use the `show packet-trace` *`packet-data`* command to dump the currently configured packet fields.

```
(Routing) #show packet-trace port 0/34 eth

LAG             Destination member Port
-----------     -----------------------
6               0/55

Local Interface................................ 3/6
Channel Name................................... ch6
Link State..................................... Up
Admin Mode..................................... Enabled
Type........................................... Static
Port-channel Min-links......................... 1
Load Balance Option............................ 3
(Src/Dest MAC, VLAN, EType, incoming port)

Mbr     Device/       Port      Port
Ports   Timeout       Speed     Active
------- ------------- --------- -------
0/33    actor/long    10G Full  True
```

```
        partner/long
0/35    actor/long    10G Full  True
        partner/long
0/36    actor/long    10G Full  True
        partner/long
0/53    actor/long    10G Full  True
        partner/long
0/54    actor/long    10G Full  True
        partner/long
0/55    actor/long    10G Full  True
        partner/long
0/56    actor/long    10G Full  True
        partner/long
```

Chapter 4: Configuring Security Features

4.1 Controlling Management Access

A user can access the switch management interface only after providing a valid user name and password combination that matches the user account information stored in the user database configured on the switch.

EFOS software include several additional features to increase management security and help prevent unauthorized access to the switch configuration interfaces.

4.1.1 Using RADIUS Servers for Management Security

Many networks use a RADIUS server to maintain a centralized user database that contains per-user authentication information. RADIUS servers provide a centralized authentication method for:

- Telnet Access
- Console to Switch Access
- Access Control Port (802.1X)

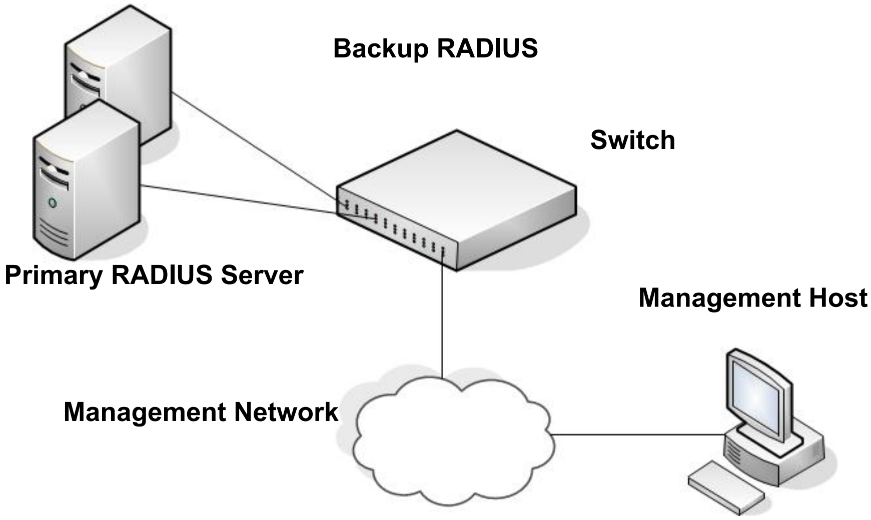
RADIUS access control utilizes a database of user information on a remote server. Making use of a single database of accessible information—as in an Authentication Server—can greatly simplify the authentication and management of users in a large network. One such type of Authentication Server supports the Remote Authentication Dial In User Service (RADIUS) protocol as defined by RFC 2865.

For authenticating users prior to access, the RADIUS standard has become the protocol of choice by administrators of large accessible networks. To accomplish the authentication in a secure manner, the RADIUS client and RADIUS server must both be configured with the same shared password or *secret*. This secret is used to generate one-way encrypted authenticators that are present in all RADIUS packets. The secret is never transmitted over the network.

RADIUS conforms to a secure communications client/server model using UDP as a transport protocol. It is extremely flexible, supporting a variety of methods to authenticate and statistically track users. RADIUS is also extensible, allowing for new methods of authentication to be added without disrupting existing functionality.

As a user attempts to connect to the switch management interface, the switch first detects the contact and prompts the user for a name and password. The switch encrypts the supplied information, and a RADIUS client transports the request to a pre-configured RADIUS server.

Figure 1: RADIUS Topology



The server can authenticate the user itself or make use of a back-end device to ascertain authenticity. In either case a response may or may not be forthcoming to the client. If the server accepts the user, it returns a positive result with attributes containing configuration information. If the server rejects the user, it returns a negative result. If the server rejects the client or the shared secrets differ, the server returns no result. If the server requires additional verification from the user, it returns a challenge, and the request process begins again.

If you use a RADIUS server to authenticate users, you must configure user attributes in the user database on the RADIUS server. The user attributes include the user name, password, and privilege level.

4.1.1.1 RADIUS Dynamic Authorization

The RADIUS Dynamic Authorization feature implements part of the Dynamic Authorization Server (DAS) functionality defined in RFC 5176 (Dynamic Authorization Extensions to Remote Authentication Dial In User Services). This feature enables a RADIUS server or any other external server to send messages to a Network Access Server (NAS) to terminate a user's session. This is desirable when a device or user session is causing problems in normal network operation.

RFC 5176 defines the DAS and Dynamic Authorization Client (DAC) and the following types of messages:

- Disconnect messages—This message from the DAC may result in terminating a user's session.
- Change of Authorization messages—This message from a DAC results in changing authorization status of the session.

As of current EFOS release, the DAS implementation handles Disconnect message only.

When EFOS DAS receives Disconnect Message from DAC, it looks for NAS identification and User Identity attributes available in the Disconnect Message. If the match for the NAS attribute and user's identify is found then it disconnect matching sessions and when successful, sends an ACK to DAC. The DAS sends a NAK with "Acct-Terminate-Cause" attribute (49) with value set to 6 if the user's session is not available or one or more sessions could not be disconnected by DAS.

The following example configures dynamic authorization on a DAC and server host.

1. Enter RADIUS dynamic authorization configuration mode:
   ```
   console(config)#aaa server radius dynamic-author
   ```
2. Configure the DAC. The server-key, if configured, overrides the global shared secret for this client only:

```
console(config-radius-da)#client 10.130.191.89 server-key lvl7india
```

3. Set the accepted authorization types (`{all | any | session-key}`) for dynamic RADIUS clients:

```
console(config-radius-da)#auth-type any
```

4. Set the port on which to listen for CoA and disconnect requests:

```
console(config-radius-da)#port 4747
console(config-radius-da)#exit
```

5. Set the network access server (NAS) IP address for the RADIUS server

```
console(config)#radius-server attribute 4 10.130.65.4
```

6. Specify a RADIUS server host and type (`{accounting | authentication}`):

```
console(config)#radius-server host auth 10.130.191.89
```

7. Configure the server host:

```
console(config-auth-radius)#name "default-radius-server"
console(config-auth-radius)#key lvl7india
```

4.1.2 Using TACACS+ to Control Management Access

TACACS+ (Terminal Access Controller Access Control System) provides access control for networked devices via one or more centralized servers. TACACS+ simplifies authentication by making use of a single database that can be shared by many clients on a large network. TACACS+ uses TCP to ensure reliable delivery and a shared key configured on the client and daemon server to encrypt all messages.

If you configure TACACS+ as the authentication method for user login and a user attempts to access the user interface on the switch, the switch prompts for the user login credentials and requests services from the TACACS+ client. The client then uses the configured list of servers for authentication, and provides results back to the switch.

You can configure the TACACS+ server list with one or more hosts defined via their network IP address. You can also assign each a priority to determine the order in which the TACACS+ client will contact them. TACACS+ contacts the server when a connection attempt fails or times out for a higher priority server.

You can configure each server host with a specific connection type, port, timeout, and shared key, or you can use global configuration for the key and timeout.

The TACACS+ server can do the authentication itself, or redirect the request to another back-end device. All sensitive information is encrypted and the shared secret is never passed over the network; it is used only to encrypt the data.

4.1.3 Configuring and Applying Authentication Profiles

A user can access the switch management interface only after providing a valid user name and password combination that matches the user account information stored in the user database configured on the switch.

EFOS software include several additional features to increase management security and help prevent unauthorized access to the CLI.

An authentication profile specifies which authentication method or methods to use to authenticate a user who attempts to access the switch management interface. The profile includes a method list, which defines how authentication is to be performed, and in which order. The list specifies the authentication method to use first, and if the first method returns an error, the next method in the list is tried. This continues until all methods in the list have been attempted. If no method can perform the authentication, then the authentication fails. A method might return an error if, for example, the authentication server is unreachable or misconfigured.

The authentication method can be one or more of the following:

- enable—Uses the enable password for authentication. If there is no enable password defined, then the enable method returns an error.
- line—Uses the Line password for authentication. If there is no line password defined for the access line, then the line method returns an error.
- local— Uses the ID and password in the Local User Database for authentication. If the user ID is not in the local database, access is denied. This method never returns an error. It always permits or denies a user.
- radius—Sends the user's ID and password a RADIUS server to be authenticated. The method returns an error if the switch is unable to contact the server.
- tacacs+— Sends the user's ID and password to a TACACS+ server to be authenticated. The method returns an error if the switch is unable to contact the server.
- ldap—Sends the user's ID and password to a LDAP server to be authenticated. The method returns an error if the switch is unable to contact the server.
- none—No authentication is used. This method never returns an error.
- deny—Access is denied. This method never returns an error.

An authentication method might require a user name and password to be supplied, a password only, or no user information. Some methods return errors when authentication fails, while other methods do not. The following table summarizes the method user name/password requirements and error behavior.

Table 5: Authentication Method Summary

Method	User Name Required	Password Required	Error Returned
Local	Yes	Yes	No
RADIUS	Yes	Yes	Yes
TACACS+	Yes	Yes	Yes
LDAP	Yes	Yes	Yes
Enable	No	Yes	Yes
Line	No	Yes	Yes
None	No	No	No
Deny	No	No	No

You can use the same Authentication Profile for all access types, or select or create a variety of profiles based on how a user attempts to access the switch management interface. Profiles can be applied to each of the following access types:

- Login—Authenticates all attempts to login to the switch.
- Enable—Authenticates all attempts to enter Privileged EXEC mode.
- Console—Authenticates access through the console port.
- Telnet—Authenticates users accessing the CLI by using telnet
- SSH—Authenticates users accessing the CLI by using an SSH client.

The following authentication profiles are configured by default:

- defaultList—Method is LOCAL, which means the user credentials are verified against the information in the local user database.
- networkList—Method is LOCAL, which means the user credentials are verified against the information in the local user database.
- enableList—Method is ENABLE, followed by NONE, which means that if the *enable* password is not configured access is granted. If the enable password is configured and user fails to authenticate then access is not granted.
- enableNetList—Method is ENABLE, followed by DENY, which means that if the *enable* password is not configured access is denied. This list is applied by default for telnet and SSH. In EFOS the enable password is not configured by default. That means that, by default, telnet and SSH users will not get access to Privileged EXEC mode. However, a console user always enters the Privileged EXEC mode without entering the enable password in the default configuration.

The methods can be changed, but the preconfigured profiles cannot be deleted or renamed.

4.1.3.1 Configuring Authentication Profiles for Port-Based Authentication

In addition to authentication profiles to control access to the management interface, you can configure an authentication profile for IEEE 802.1X port-based access control to control access to the network through the switch ports. To configure a port-based authentication profile, you specify `dot1x` as the access type, and configure `ias`, `local`, `none`, or `radius` as the authentication method. The `ias` method specifies that the 802.1X feature should use the Internal Authentication Server (IAS) database for 801X port-based authentication. The IAS database is stored locally on the switch.

4.1.4 Configuring the Primary and Secondary RADIUS Servers

The commands in this example configure primary and secondary RADIUS servers that the switch will use to authenticate access. The RADIUS servers use the same RADIUS secret.

To configure the switch:

1. Configure the primary and secondary RADIUS servers.

```
(Routing) #configure
(Routing) (Config)#radius server host auth 10.27.65.103
(Routing) (Config)#radius server host auth 10.27.65.114
```

2. Specify which RADIUS server is the primary.

```
(Routing) (Config)#radius server primary 10.27.65.103
(Routing) (Config)#radius server key auth 10.27.65.103
```

3. Configure a shared secret that the switch will use to authenticate with the RADIUS servers.

```
Enter secret (64 characters max):********

Re-enter secret:********
```

4. View the configured RADIUS servers.

```
(Routing) (Config)#exit
(Routing) #show radius servers

Cur
rent Host Address             Server Name                      Port  Type
---- ------------------------ -------------------------------- ----- ---------
     10.27.65.114             Default-RADIUS-Server            1812  Secondary
  *  10.27.65.103             Default-RADIUS-Server            1812  Primary
```

4.1.5 Configuring an Authentication Profile

The commands in this example create a new authentication profile named myList that uses the RADIUS server configured in the previous example to authenticate users who attempt to access the switch management interface by using SSH or Telnet. If the RADIUS authentication is unsuccessful, the switch uses the local user database to attempt to authenticate the users.

To configure the switch:

1. Create an access profile list that uses RADIUS as the first access method and the local user database as the second login method.

```
(Routing) #configure
(Routing) (Config)#aaa authentication login myList radius local
```

NOTE: The switch attempts to contact the primary RADIUS server that has been configured on the switch. To see an example of how to configure a RADIUS server on the switch, see Section 4.1.4, Configuring the Primary and Secondary RADIUS Servers.

2. Enter line configuration mode for Telnet and specify that any attempt to access the switch by using Telnet are authenticated using the methods defined in the profile created in the previous step.

```
(Routing) (Config)#line telnet
(Routing) (Config-telnet)#l#login authentication myList
(Routing) (Config-telnet)#l#exit
```

3. Enter line configuration mode for SSH and specify that any attempt to access the switch by using SSH are authenticated using the methods defined in the myList profile.

```
(Routing) (Config)#line ssh
(Routing) (Config-ssh)#login authentication myList
(Routing) (Config-ssh)#exit
(Routing) (Config)#exit
```

4. View the current authentication methods and profiles.

```
(Routing) #show authentication methods

Login Authentication Method Lists
---------------------------------
defaultList         :  local
networkList         :  local
myList              :  radius   local

Enable Authentication Method Lists
----------------------------------
enableList          :  enable   none

Line     Login Method List    Enable Method List
```

```
-------  -----------------    ------------------
Console  defaultList          enableList
Telnet   myList               enableList
SSH      myList               enableList
```

4.1.6 Configuring Task-Based Authorization

The task-based authorization feature allows you to define user permissions at a component level for all supported components. Users are assigned to user groups, and user groups are assigned to task groups for a given component. Each task group is associated with a set of task IDs. All CLI commands for a supported component are associated with a task ID.

The high-level steps involved in configuring task-based authorization are as follows:

- Create and configure a task group.
- Set permissions for the task group.
- Create and configure a user group.
- Associate the user group with the task group.
- Associate the user with a user group.

In this example, two users are given read-only access to the OSPF and BGP commands so that they can monitor the OSPF and BGP components. The users are not permitted to issue any CLI commands that will change the OSPF and BGP configuration on the switch. This example assumes the users, *user1* and *user2*, have already been created with the `username` command.

1. Create a task group and optionally configure a description.
   ```
   (Routing) #configure
   (Routing) (Config)#taskgroup routing-ro
   (Routing) (config-taskgroup)#description "Read-Only OSPF BGP"
   ```
2. Specify the task ID to be associated with the task group and the permissions for all CLI commands associated with the task ID. The following commands configure the OSPF and BGP component task ID permissions as read-only and associate them with the routing-ro task group.
   ```
   (Routing) (config-taskgroup)#task read ospf
   (Routing) (config-taskgroup)#task read bgp
   (Routing) (config-taskgroup)#exit
   ```
3. Create a user group.
   ```
   (Routing) (Config)#usergroup entry-level-routing
   ```
4. Associate the user group with the task group created in the first step.
   ```
   (Routing) (config-usergroup)#taskgroup routing-ro
   (Routing) (config-usergroup)#exit
   ```
5. Assign the users user1 and user2 to the user group.
   ```
   (Routing) (Config)#username user1 usergroup entry-level-routing
   (Routing) (Config)#username user2 usergroup entry-level-routing
   (Routing) (Config)#exit
   ```
6. Verify the configuration.
   ```
   (Routing) #show aaa taskgroup routing-ro

   Task group "routing-ro"

   Description : "Read-Only OSPF BGP"
   Parent taskgroups: ""

   Configured permissions:
   ```

```
Task: ospf                      : READ
Task: bgp                       : READ

Operational permission:
Task: ospf                      : READ
Task: bgp                       : READ


(Routing) #show aaa usergroup entry-level-routing

User group "entry-level-routing"

Description : ""
Parent user groups: ""

Contained task groups:
Contained task group : "routing-ro"

Operational permission:
Task: ospf                      : READ
Task: bgp                       : READ

(Routing) #show aaa userdb

User "admin"

Contained user groups:
Contained user group : "default-usergroup-name"

Operational permission:
Task: aaa                       : READ     WRITE     EXECUTE     DEBUG
Task: ospf                      : READ     WRITE     EXECUTE     DEBUG
Task: bgp                       : READ     WRITE     EXECUTE     DEBUG

User "guest"
Contained user groups: ""
Operational permission: ""

User "user1"

Contained user groups:
Contained user group : "entry-level-routing"

Operational permission:
Task: ospf                      : READ
Task: bgp                       : READ

User "user2"

Contained user groups:
Contained user group : "entry-level-routing"

Operational permission:
Task: ospf                      : READ
Task: bgp                       : READ
```

4.1.7 Using Microsoft Active Directory to Control Management Access

Many networks use a Microsoft Active Directory (MS AD) service to maintain a centralized user database that contains per-user authentication information. EFOS can use Microsoft Active Directory Service to control access to its management interface.

When a user tries to access the switch management interface and the authentication method is configured as LDAP, the EFOS LDAP client looks up the list of configured LDAP (MS AD) servers and authenticates via a simple LDAP bind operation.

This example configures the LDAP server information and authentication list to require LDAP-based authentication for a user who attempts to access the EFOS system by using SSH.

1. Enter Global Configuration mode and configure the information about the MSAD (LDAP) server and credentials for the EFOS system to use to authenticate a user on the management port.

   The command in this example configures the following information:

   - LDAP server IP address: 10.89.97.215
   - The root distinguished name (rootDN) to bind to has a common name of *admin* and domain components (DC) are *fp* and *broadcom*.
   - The rootDN password is test1234
   - The port to use to connect to the LDAP server is port 636

   ```
   (Routing) #configure
   (Routing) (Config)#ldap-server host 10.89.97.215 rootDN cn=admin,dc=fp,dc=broadcom,dc=in
   password test1234  port 636
   ```

   This configuration uses the *Search and Bind* method, which is the default method. Configuring the rootDN is optional, and it is required only where search without bind is not allowed.

   If the *Bind and Search* method is required (for example, if an LDAP search is not allowed without a valid authentication), use the `ldap authentication bind-first` command, in which case the rootDN, if configured, is not used.

2. Specify that the communication channel between the EFOS system and the LDAP server is encrypted.

   ```
   (Routing) (Config)#ldap-server host 10.89.97.215 enable-ssl
   ```

3. Download the root certificate for establishing a secured SSL channel with the server. This example uses SCP to download the *cacert.pem* file from the host with an IP address of 10.89.20.21 to the local root-ca-certs location.

   ```
   (Routing)#copy scp://testuser@10.89.20.21/cacert.pem nvram:root-ca-certs
   ```

4. Configure the LDAP search to send the search query to the server. The search query is used to fetch the user's privilege level or group membership information. This command names the query *map1* and enters the LDAP Search Map Configuration mode.

   ```
   (Routing) (Config)#ldap search-map "map1"
   ```

5. Configure the search map details for fetching the privilege level of the user. The attribute-name argument is the name of the attribute in the LDAP server that contains the privilege level information. For example the vendor specific "Cisco-AVPair" attribute can contain "shell:priv-lvl=15" which puts the authenticating user to privilege level 15.

   ```
   (Routing) (config-ldap-search-map)#userprofile attribute-name "memberOf" search-filter
   "(sAMAccountName=$userid)" base-DN dc=fp,dc=broadcom,dc=in
   ```

6. Exit to Global Config mode.

   ```
   (Routing) (config-ldap-search-map)#exit
   ```

7. Configure an authentication profile called *myList* that uses LDAP as the authentication method for logging on to the system. For more information about authentication lists, see Section 4.1.5, Configuring an Authentication Profile

   ```
   (Routing) (Config)#aaa authentication login "mylist" ldap
   ```

8. Configure myList to deny access to Privileged Exec and higher levels unless the LDAP server confirms that the user has a sufficient privilege level (15).

   ```
   (Routing) (Config)#aaa authentication enable "mylist" ldap deny
   ```

9. Enter line configuration mode for SSH and specify that any attempts to access the switch by using SSH are authenticated using the methods defined in the myList profile.

   ```
   (Routing) (Config)#line ssh
   (Routing) (Config-ssh)#login authentication myList
   (Routing) (Config-ssh)#enable authentication myList
   (Routing) (Config-ssh)#exit
   (Routing) (Config)#exit
   ```

4.2 Configuring DHCP Snooping, DAI, and IPSG

Dynamic Host Configuration Protocol (DHCP) Snooping, IP Source Guard (IPSG), and Dynamic ARP Inspection (DAI) are layer 2 security features that examine traffic to help prevent accidental and malicious attacks on the switch or network.

DHCP Snooping monitors DHCP messages between a DHCP client and DHCP server to filter harmful DHCP messages and to build a bindings database. The IPSG and DAI features use the DHCP Snooping bindings database to help enforce switch and network security.

IP Source Guard allows the switch to drop incoming packets that do not match a binding in the bindings database. Dynamic ARP Inspection allows the switch to drop ARP packets whose sender MAC address and sender IP address do not match an entry in the DHCP snooping bindings database.

4.2.1 DHCP Snooping Overview

Dynamic Host Configuration Protocol (DHCP) Snooping is a security feature that monitors DHCP messages between a DHCP client and DHCP server to accomplish the following tasks:

- Filter harmful DHCP messages
- Build a bindings database with entries that consist of the following information:
  - MAC address
  - IP address
  - VLAN ID
  - Client port

Entries in the bindings database are considered to be authorized network clients.

DHCP snooping can be enabled on VLANs, and the trust status (trusted or untrusted) is specified on individual physical ports or LAGS that are members of a VLAN. When a port or LAG is configured as untrusted, it could potentially be used to launch a network attack. DHCP servers must be reached through trusted ports.

DHCP snooping enforces the following security rules:

- DHCP packets from a DHCP server (DHCPOFFER, DHCPACK, DHCPNAK, DHCPRELEASEQUERY) are dropped if they are received on an untrusted port.
- DHCPRELEASE and DHCPDECLINE messages are dropped if the MAC addresses in the snooping database, but the binding's interface is other than the interface where the message was received.
- On untrusted interfaces, the switch drops DHCP packets with a source MAC address that does not match the client hardware address. This is a configurable option.

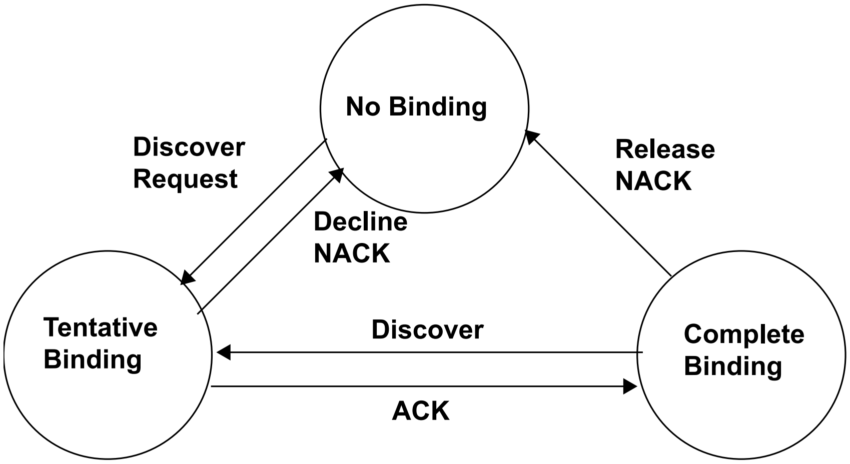
4.2.1.1 Populating the DHCP Snooping Bindings Database

The DHCP snooping application uses DHCP messages to build and maintain the binding's database. DHCP snooping creates a tentative binding from DHCP DISCOVER and REQUEST messages. Tentative bindings tie a client to a port (the port where the DHCP client message was received). Tentative bindings are completed when DHCP snooping learns the client's IP address from a DHCP ACK message on a trusted port. DHCP snooping removes bindings in response to DECLINE, RELEASE, and NACK messages. The DHCP snooping application ignores the ACK messages as a reply to the DHCP Inform messages received on trusted ports. You can also enter static bindings into the binding database.

When a switch learns of new bindings or loses bindings, the switch immediately updates the entries in the database. The switch also updates the entries in the binding file. The frequency at which the file is updated is based on a configurable delay, and the updates are batched.

If the absolute lease time of the snooping database entry expires, that entry is removed. Make sure the system time is consistent across the reboots. Otherwise, the snooping entries will not expire properly. If a host sends a DHCP release while the switch is rebooting, when the switch receives the DHCP discovery or request, the client's binding goes to the tentative binding as shown in Figure 2.

Figure 2: DHCP Binding



The binding database includes data for clients only on untrusted ports.

4.2.1.2 DHCP Snooping and VLANs

DHCP snooping forwards valid DHCP client messages received on non-routing VLANs. The message is forwarded on all trusted interfaces in the VLAN.

DHCP snooping can be configured on switching VLANs and routing VLANs. When a DHCP packet is received on a routing VLAN, the DHCP snooping application applies its filtering rules and updates the bindings database. If a client message passes filtering rules, the message is placed into the software forwarding path where it may be processed by the DHCP relay agent, the local DHCP server, or forwarded as an IP packet.

4.2.1.3 DHCP Snooping Logging and Rate Limits

The DHCP snooping application processes incoming DHCP messages. For DHCPRELEASE and DHCPDECLINE messages, the application compares the receive interface and VLAN with the client interface and VLAN in the bindings database. If the interfaces do not match, the application logs the event and drops the message. For valid client messages, DHCP snooping compares the source MAC address to the DHCP client hardware address. When there is a mismatch, DHCP snooping drops the packet and generates a log message if logging of invalid packets is enabled.

If DHCP relay co-exists with DHCP snooping, DHCP client messages are sent to DHCP relay for further processing.

To prevent DHCP packets from being used as a DoS attack when DHCP snooping is enabled, the snooping application enforces a rate limit for DHCP packets received on interfaces. DHCP snooping monitors the receive rate on each interface separately. If the receive rate exceeds a configurable limit, DHCP snooping brings down the interface. Administrative intervention is necessary to enable the port, either by using the **no shutdown** command in Interface Config mode.

4.2.2 IP Source Guard Overview

IPSG is a security feature that filters IP packets based on source ID. This feature helps protect the network from attacks that use IP address spoofing to compromise or overwhelm the network.

The source ID may be either the source IP address or a {source IP address, source MAC address} pair. You can configure:

- Whether enforcement includes the source MAC address
- Static authorized source IDs

The DHCP snooping bindings database and static IPSG entries identify authorized source IDs. IPSG can be enabled on physical and LAG ports.

If you enable IPSG on a port where DHCP snooping is disabled or where DHCP snooping is enabled but the port is trusted, all IP traffic received on that port is dropped depending on the admin-configured IPSG entries.

4.2.2.1 IPSG and Port Security

IPSG interacts with port security, also known as port MAC locking to enforce the source MAC address. Port security controls source MAC address learning in the layer 2 forwarding database (MAC address table). When a frame is received with a previously unlearned source MAC address, port security queries the IPSG feature to determine whether the MAC address belongs to a valid binding.

If IPSG is disabled on the ingress port, IPSG replies that the MAC is valid. If IPSG is enabled on the ingress port, IPSG checks the bindings database. If the MAC address is in the bindings database and the binding matches the VLAN the frame was received on, IPSG replies that the MAC is valid. If the MAC is not in the bindings database, IPSG informs port security that the frame is a security violation.

In the case of an IPSG violation, port security takes whatever action it normally takes upon receipt of an unauthorized frame. Port security limits the number of MAC addresses to a configured maximum. If the limit *n* is less than the number of stations *m* in the bindings database, port security allows only *n* stations to use the port. If $n > m$, port security allows only the stations in the bindings database.

4.2.3 Dynamic ARP Inspection Overview

Dynamic ARP Inspection (DAI) is a security feature that rejects invalid and malicious ARP packets. DAI prevents a class of man-in-the-middle attacks where an unfriendly station intercepts traffic for other stations by poisoning the ARP caches of its unsuspecting neighbors. The malicious attacker sends ARP requests or responses mapping another station's IP address to its own MAC address.

When DAI is enabled, the switch drops ARP packets whose sender MAC address and sender IP address do not match an entry in the DHCP snooping bindings database. You can optionally configure additional ARP packet validation.

When DAI is enabled on a VLAN, DAI is enabled on the interfaces (physical ports or LAGs) that are members of that VLAN. Individual interfaces are configured as trusted or untrusted. The trust configuration for DAI is independent of the trust configuration for DHCP snooping.

In EFOS, DAI supports `any` in both sender-IP and sender-MAC match criteria in ARP ACLs. A Deny rule in ARP ACLs is also supported.

4.2.3.1 Optional DAI Features

If you configure the MAC address validation option, DAI verifies that the sender MAC address equals the source MAC address in the Ethernet header. There is a configurable option to verify that the target MAC address equals the destination MAC address in the Ethernet header. This check applies only to ARP responses, since the target MAC address is unspecified in ARP requests. You can also enable IP address checking. When this option is enabled, DAI drops ARP packets with an invalid IP address. The following IP addresses are considered invalid:

- 0.0.0.0
- 255.255.255.255
- all IP multicast addresses
- all class E addresses (240.0.0.0/4)
- loopback addresses (in the range 127.0.0.0/8)

The valid IP check is applied only on the sender IP address in ARP packets. In ARP response packets, the check is applied only on the target IP address.

4.2.4 Increasing Security with DHCP Snooping, DAI, and IPSG

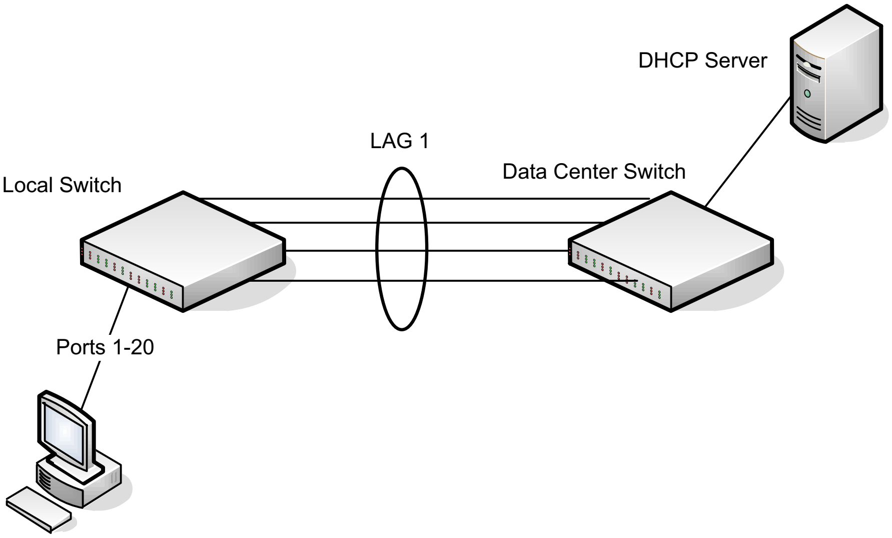
DHCP Snooping, IPSG, and DAI are security features that can help protect the switch and the network against various types of accidental or malicious attacks. It might be a good idea to enable these features on ports that provide network access to hosts that are in physically unsecured locations or if network users connect nonstandard hosts to the network.

For example, if an employee unknowingly connects a workstation to the network that has a DHCP server, and the DHCP server is enabled, hosts that attempt to acquire network information from the legitimate network DHCP server might obtain incorrect information from the rogue DHCP server. However, if the workstation with the rogue DHCP server is connected to a port that is configured as untrusted and is a member of a DHCP Snooping-enabled VLAN, the port discards the DHCP server messages.

4.2.5 Configuring DHCP Snooping

In this example, DHCP snooping is enabled on VLAN 100. Ports 1-20 connect end users to the network and are members of VLAN 100. These ports are configured to limit the maximum number of DHCP packets with a rate limit of 100 packets per second. LAG 1, which is also a member of VLAN 100 and contains ports 21-24, is the trunk port that connects the switch to the data center, so it is configured as a trusted port.

Figure 3: DHCP Snooping Configuration Topology



The commands in this example also enforce rate limiting and remote storage of the bindings database. The switch has a limited amount of storage space in NVRAM and flash memory, so the administrator specifies that the DHCP snooping bindings database is stored on an external TFTP server.

To configure the switch:

1. Enable DHCP snooping on VLAN 100.
```
(Routing) #config
(Routing) (Config)#ip dhcp snooping vlan 100
```
2. Configure LAG 1, which includes ports 21-24, as a trusted port. All other interfaces are untrusted by default.
```
(Routing) (Config)#interface 3/1
(Routing) (Interface 3/1))#ip dhcp snooping trust
(Routing) (Interface 3/1)#exit
```
3. Enter interface configuration mode for all untrusted interfaces (ports 1-20) and limit the number of DHCP packets that an interface can receive to 100 packets per second. LAG 1 is a trusted port and keeps the default value for rate limiting (unlimited).
```
(Routing) (Config)#interface 0/1-0/20
(Routing) (Interface 0/1-0/20)#ip dhcp snooping limit rate 100
(Routing) (Interface 0/1-0/20)#exit
```
4. Specify that the DHCP snooping database is to be stored remotely in a file called dsDb.txt on a TFTP server with and IP address of 10.131.11.1.
```
(Routing) (Config)#ip dhcp snooping database tftp://10.131.11.1/dsDb.txt
```
5. Enable DHCP snooping for the switch
```
(Routing) (Config)#ip dhcp snooping
(Routing) (Config)#exit
```
6. View DHCP snooping information.
```
(Routing) #show ip dhcp snooping

DHCP snooping is Enabled
DHCP snooping source MAC verification is enabled
DHCP snooping is enabled on the following VLANs:
```

```
100

 Interface    Trusted     Log Invalid Pkts
-----------  ----------   ----------------
```

4.2.6 Configuring IPSG

This example builds on the previous example and uses the same topology shown in Figure 3, DHCP Snooping Configuration Topology. In this configuration example, IP source guard is enabled on ports 1-20. DHCP snooping must also be enabled on these ports. Additionally, because the ports use IP source guard with source IP and MAC address filtering, port security must be enabled on the ports as well.

To configure the switch:

1. Enter interface configuration mode for the host ports and enable IPSG.

```
(Routing) #config
(Routing) (Config)#interface 0/1-0/20
(Routing) (Interface 0/1-0/20)#ip verify source port-security
```

2. Enable port security on the ports.

```
(Routing) (Interface 0/1-0/20)#port-security
(Routing) (Interface 0/1-0/20)#exit
(Routing) (Config)#exit
```

3. View IPSG information.

```
(Routing) #show ip verify source

Interface     Filter Type  IP Address       MAC Address         VLAN
-----------   -----------  ---------------  -----------------   -----
0/1           ip-mac       192.168.3.45     00:1C:23:55:D4:8E   100
0/2           ip-mac       192.168.3.33     00:1C:23:AA:B8:01   100
0/3           ip-mac       192.168.3.18     00:1C:23:55:1B:6E   100
0/4           ip-mac       192.168.3.49     00:1C:23:67:D3:CC   100
--More-- or (q)uit
```

Chapter 5: Configuring Switching Features

5.1 VLANs

By default, all switchports on the switch are in the same broadcast domain. This means when one host connected to the switch broadcasts traffic, every device connected to the switch receives that broadcast. All ports in a broadcast domain also forward multicast and unknown unicast traffic to the connected host. Large broadcast domains can result in network congestion, and end users might complain that the network is slow. In addition to latency, large broadcast domains are a greater security risk since all hosts receive all broadcasts.

Virtual Local Area Networks (VLANs) allow you to divide a broadcast domain into smaller, logical networks. Like a bridge, a VLAN switch forwards traffic based on the Layer 2 header, which is fast, and like a router, it partitions the network into logical segments, which provides better administration, security, and management of multicast traffic.

Network administrators have many reasons for creating logical divisions, such as department or project membership. Because VLANs enable logical groupings, members do not need to be physically connected to the same switch or network segment. Some network administrators use VLANs to segregate traffic by type so that the time-sensitive traffic, like voice traffic, has priority over other traffic, such as data. Administrators also use VLANs to protect network resources. Traffic sent by authenticated clients might be assigned to one VLAN, while traffic sent from unauthenticated clients might be assigned to a different VLAN that allows limited network access.

When one host in a VLAN sends a broadcast, the switch forwards traffic only to other members of that VLAN. For traffic to go from a host in one VLAN to a host in a different VLAN, the traffic must be forwarded by a layer 3 device, such as a router. VLANs work across multiple switches, so there is no requirement for the hosts to be located near each other to participate in the same VLAN.

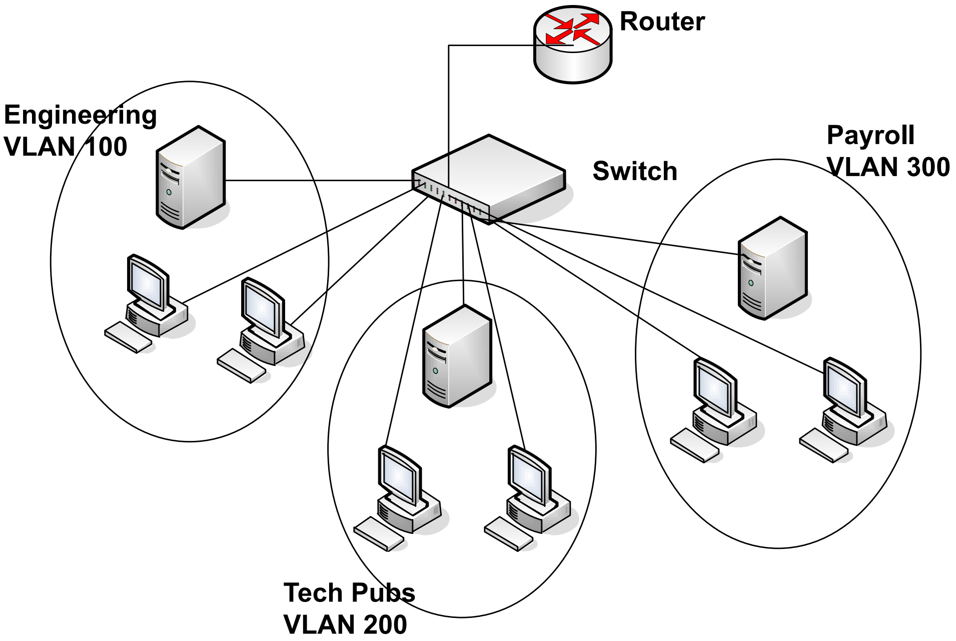
NOTE: EFOS software supports VLAN routing. When you configure VLAN routing, the switch acts as a layer 3 device and can forward traffic between VLANs. For more information, see Section 7.1.1, VLAN Routing.

Each VLAN has a unique number, called the VLAN ID. The EFOS supports a configurable VLAN ID range of 2–4093. A VLAN with VLAN ID 1 is configured on the switch by default. You can associate a name with the VLAN ID. In a tagged frame, the VLAN is identified by the VLAN ID in the tag. In an untagged frame, the VLAN identifier is the Port VLAN ID (PVID) specified for the port that received the frame. For information about tagged and untagged frames, see Section 5.1.1, VLAN Tagging.

EFOS supports adding individual ports and Link Aggregation Groups (LAGs) as VLAN members.

Figure 4, Simple VLAN Topology shows an example of a network with three VLANs that are department-based. The file server and end stations for the department are all members of the same VLAN.

Figure 4: Simple VLAN Topology



In this example, each port is manually configured so that the end station attached to the port is a member of the VLAN configured for the port. The VLAN membership for this network is port-based or static.

5.1.1 VLAN Tagging

EFOS supports IEEE 802.1Q tagging. Ethernet frames on a tagged VLAN have a 4-byte VLAN tag in the header. VLAN tagging is required when a VLAN spans multiple switches, which is why trunk ports transmit and receive only tagged frames.

Tagging may be required when a single port supports multiple devices that are members of different VLANs. For example, a single port might be connected to an IP phone, a PC, and a printer (the PC and printer are connected via ports on the IP phone). IP phones are typically configured to use a tagged VLAN for voice traffic, while the PC and printers typically use the untagged VLAN.

When a port is added to a VLAN as an untagged member, untagged packets entering the switch are tagged with the PVID (also called the *native VLAN*) of the port. If the port is added to a VLAN as an untagged member, the port does not add a tag to a packet in that VLAN when it exits the port. Configuring the PVID for an interface is useful when untagged and tagged packets will be sent and received on that port and a device connected to the interface does not support VLAN tagging.

When ingress filtering is on, the frame is dropped if the port is not a member of the VLAN identified by the VLAN ID in the tag. If ingress filtering is off, all tagged frames are forwarded. The port decides whether to forward or drop the frame when the port receives the frame.

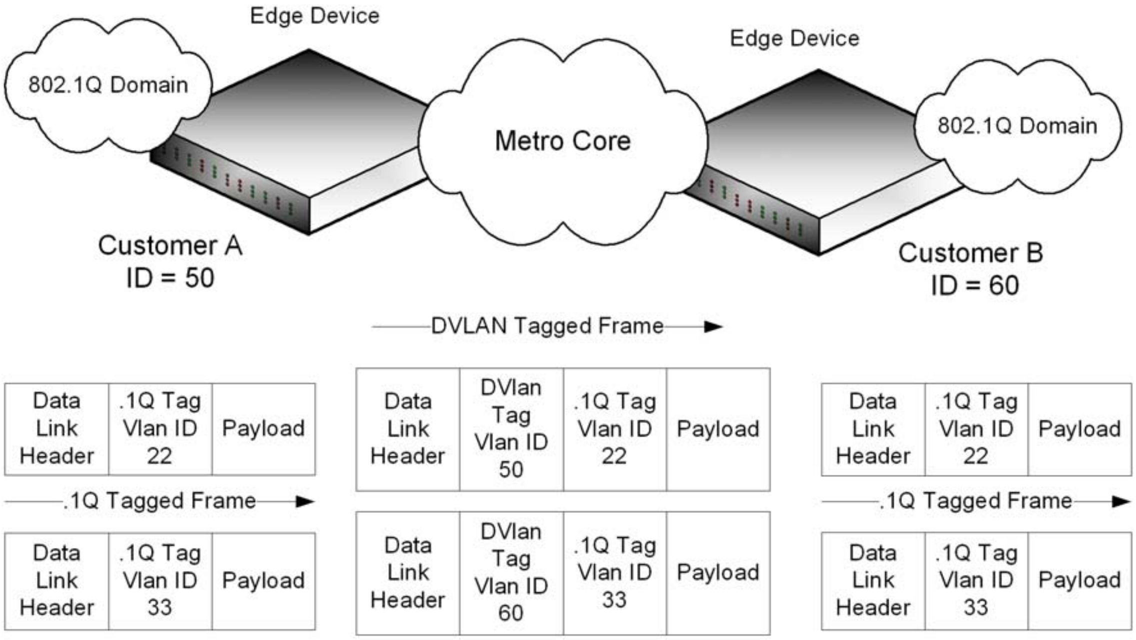
5.1.2 Double-VLAN Tagging

For trunk ports, which are ports that connect one switch to another switch, EFOS software supports double-VLAN tagging. This feature allows service providers to create Virtual Metropolitan Area Networks (VMANs). With double-VLAN tagging, service providers can pass VLAN traffic from one customer domain to another through a metro core in a simple and cost-effective manner. By using an additional tag on the traffic, the switch can differentiate between customers in the MAN while preserving an individual customer's VLAN identification when the traffic enters the customer's 802.1Q domain.

With the introduction of this second tag, customers are no longer required to divide the 4-byte VLAN ID space to send traffic on a Ethernet-based MAN. In short, every frame that is transmitted from an interface has a double-VLAN tag attached, while every packet that is received from an interface has a tag removed (if one or more tags are present).

In Figure 5, Double VLAN Tagging Network Example, two customers share the same metro core. The service provider assigns each customer a unique ID so that the provider can distinguish between the two customers and apply different rules to each. When the configurable EtherType is assigned to something different than the 802.1Q (0x8100) EtherType, it allows the traffic to have added security from misconfiguration while exiting the metro core. For example, if the edge device on the other side of the metro core is not stripping the second tag, the packet would never be classified as a 802.1Q tag, so the packet would be dropped rather than forwarded in the incorrect VLAN.

Figure 5: Double VLAN Tagging Network Example



5.1.3 Private VLANs

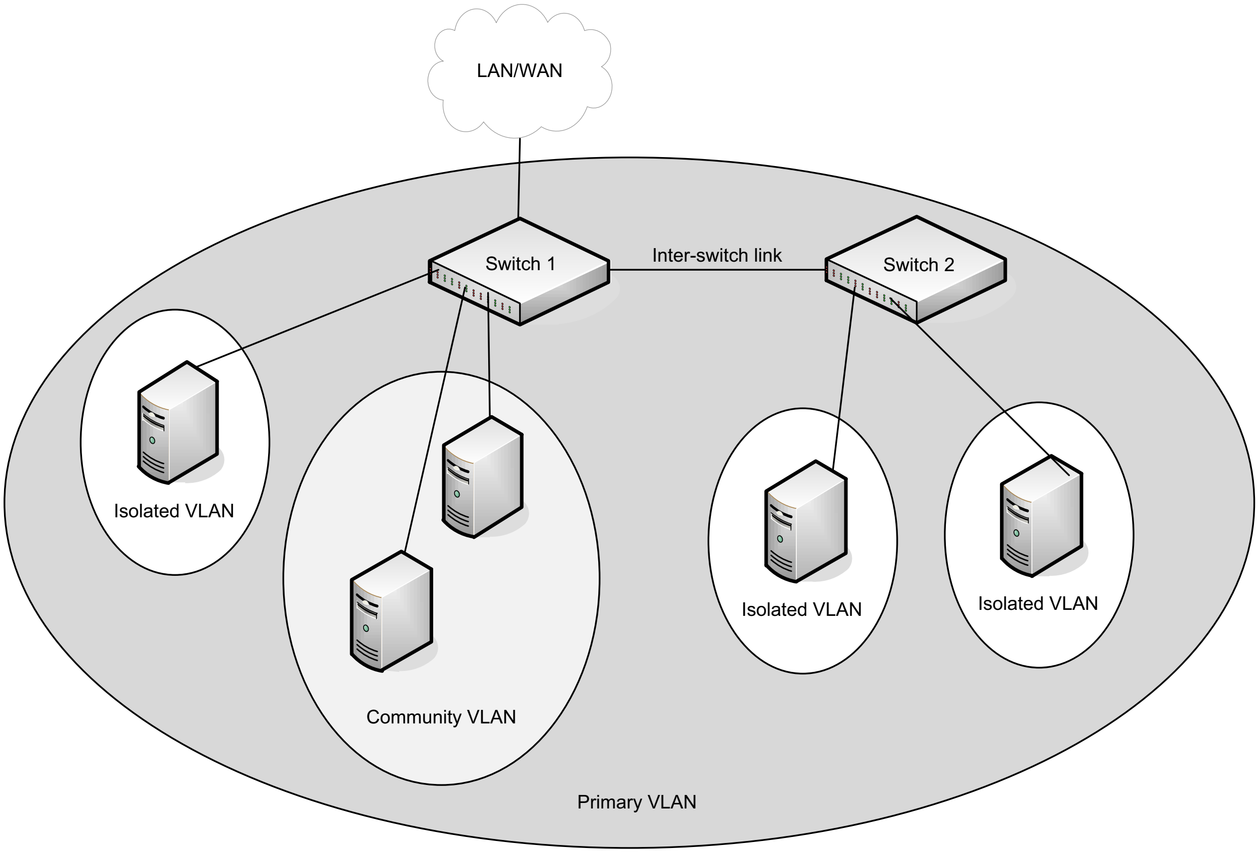
The private VLAN feature provides Layer 2 isolation between ports that share the same broadcast domain. In other words, it allows a VLAN broadcast domain to be partitioned into smaller point-to-multipoint subdomains. The ports participating in a private VLAN can be located anywhere in the Layer 2 network.

In a private VLAN (sometimes called PVLAN), a VLAN domain is separated into two or more subdomains. Each subdomain is defined (represented) by a primary VLAN and a secondary VLAN. The primary VLAN ID is the same for all subdomains that belong to a private VLAN. The secondary VLAN ID differentiates subdomains from each another and provides Layer 2 isolation between ports of the same private VLAN. The following types of VLANs can exist within a private VLAN:

- Primary VLAN—Forwards the traffic from the promiscuous ports to isolated ports, community ports, and other promiscuous ports in the same private VLAN. Only one primary VLAN can be configured per private VLAN. All ports within a private VLAN share the same primary VLAN.
- Isolated VLAN—A secondary VLAN that carries traffic from isolated ports to promiscuous ports. Only one isolated VLAN can be configured per private VLAN.
- Community VLAN—A secondary VLAN that forwards traffic between ports that belong to the same community and to the promiscuous ports. There can be multiple community VLANs per private VLAN.

Figure 6 illustrates the VLAN types that exist in a private VLAN.

Figure 6: VLAN Types in a Private VLAN



A port associated with a private VLAN can have one of the following port designations:

- Promiscuous port—Belongs to a primary VLAN and can communicate with all interfaces in the private VLAN, including other promiscuous ports, community ports, and isolated ports. An endpoint connected to a promiscuous port is allowed to communicate with any endpoint within the private VLAN. Multiple promiscuous ports can be defined for a single private VLAN domain.
- Host port—Belongs to a secondary VLAN and, depending upon the type of secondary VLAN, can either communicate with other ports in the same community (if the secondary VLAN is a community VLAN) and with the promiscuous ports or is able to communicate only with the promiscuous ports (if the secondary VLAN is an isolated VLAN). In other words, host ports can be one of two port types:
  - Community port—An endpoint connected to a community port is allowed to communicate with the endpoints within a community and can also communicate with any configured promiscuous port. The endpoints that belong to one community cannot communicate with endpoints that belong to a different community or with endpoints connected to isolated ports.
  - Isolated port—An endpoint connected to an isolated port is allowed to communicate with endpoints connected to promiscuous ports only. Endpoints connected to adjacent isolated ports cannot communicate with each other.
- Promiscuous trunk port—Carries tagged traffic of multiple primary VLANs and normal VLANs. An endpoint connected to a promiscuous trunk port is allowed to communicate with all the endpoints within the private VLAN and also with other ports participating in normal VLANs. These ports carry the traffic of multiple primary VLANs towards the upstream router and regular VLANs also.
- Isolated trunk port— Carries tagged traffic of multiple secondary (isolated) VLANs and regular VLANs to and from downstream devices that are private-VLAN unaware. Isolated trunk ports are part of multiple private VLANs.

The private VLANs can be extended across multiple switches through inter-switch links that transport primary, community, and isolated VLANs between devices.

5.1.3.1 Private VLANs in the Network

Private VLANs are typically implemented in the DMZ for security reasons. Servers are not supposed to communicate with each other, but they need to communicate with a router that (eventually) connects them to the users. Such servers are connected to host ports, and routers are attached to promiscuous ports. Then, if one of the servers is compromised, the intruder cannot use it to attack another server in the same network segment.

The same traffic isolation can be achieved by assigning each port with a different VLAN, allocating an IP subnet for each VLAN, and enabling L3 routing between them. On the other hand, in a private VLAN domain, all members can share a common address space of a single subnet that is associated with a primary VLAN. So, the advantage of the private VLAN feature is that it reduces the number of consumed VLANs, improves IP address space utilization, and helps to avoid L3 routing.

Promiscuous trunk ports are used when it is required to reduce the number of links connected to upstream devices while still being able to manage all the endpoints in a private VLAN in addition to carrying traffic of normal VLANs. These ports are used typically where the switches are connected to upstream devices that do not understand private VLANs.

Isolated trunk ports are used when an isolated VLAN is required to be extended to a downstream device that is PVLAN-unaware. The PVLAN-unaware switch is expected to use the protected ports feature (or a feature with a similar functionality) to achieve isolation among its hosts. In addition to carrying tagged traffic of isolated VLANs, these ports also carry tagged traffic of normal VLANs.

5.1.4 Default VLAN Behavior

One VLAN exists on the switch by default. The VLAN ID is 1, and all ports are included in the VLAN as access ports, which are untagged. This means when a device connects to any port on the switch, the port forwards the packets without inserting a VLAN tag. If a device sends a tagged frame to a port, the frame is dropped. Since all ports are members of this VLAN, all ports are in the same broadcast domain and receive all broadcast and multicast traffic received on any port.

When you add a new VLAN to the VLAN database, no ports are members. The configurable VLAN range is 2–4093. VLANs 4094 and 4095 are reserved.

Table 6 shows the default values or maximum values for VLAN features.

Table 6: VLAN Default and Maximum Values

Feature	Value
Default VLAN ID	1
VLAN Name	default
VLAN Range	2–4093
Frames accepted	Untagged Incoming untagged frames are classified into the VLAN whose VLAN ID is the currently configured PVID.
Frames sent	Untagged
Ingress Filtering	On
PVID	1
Double-VLAN tagging	Disabled If double-VLAN tagging is enabled, the default EtherType value is 802.1Q

5.1.5 VLAN Configuration Example

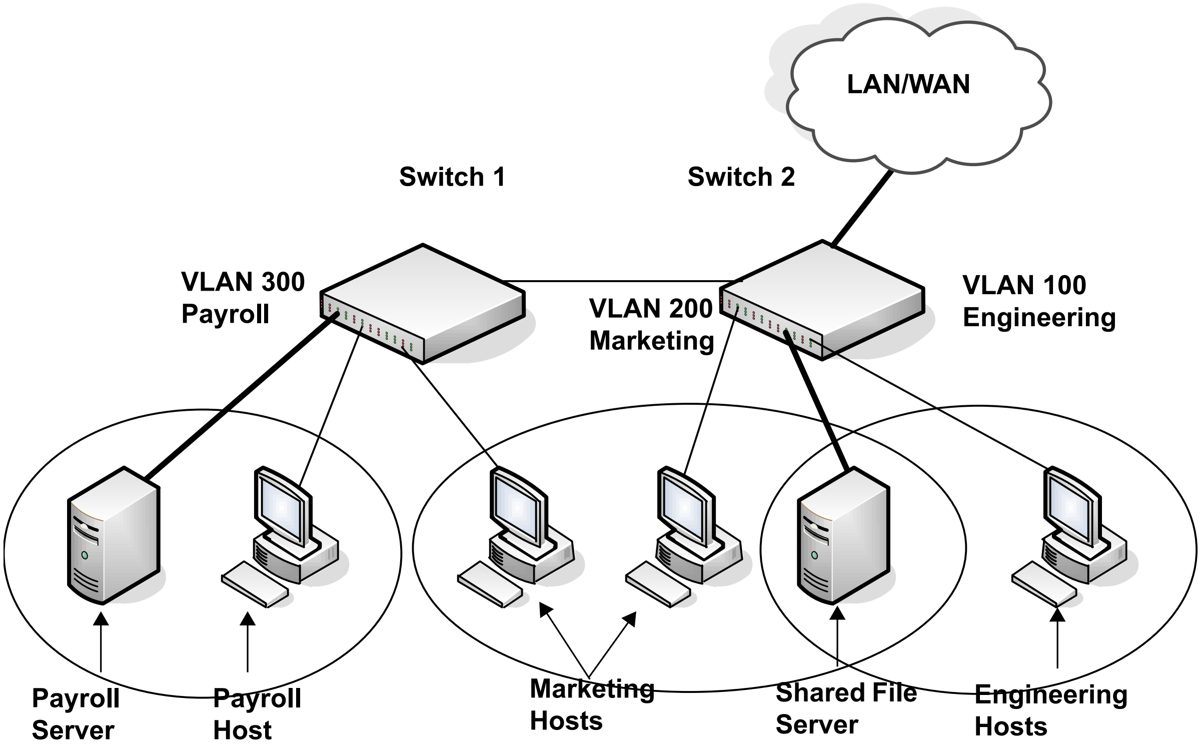
A network administrator wants to create the VLANs in Table 7, Example VLANs:

Table 7: Example VLANs

VLAN ID	VLAN Name	VLAN Type	Purpose
100	Engineering	Port-based	All employees in the Engineering department use this VLAN. Confining this department's traffic to a single VLAN helps reduce the amount of traffic in the broadcast domain, which increases bandwidth.
200	Marketing	Port-based	All employees in the Marketing department use this VLAN.
300	Payroll	Port-based	The payroll department has sensitive traffic and needs its own VLAN to help keep that traffic private.

Figure 7, Network Topology for VLAN Configuration shows the network topology for this example. As the figure shows, there are two switches, two file servers, and many hosts. One switch has an uplink port that connects it to a layer 3 device and the rest of the corporate network.

Figure 7: Network Topology for VLAN Configuration



The network in Figure 7 has the following characteristics:

- Each connection to a host represents multiple ports and hosts.
- The Payroll and File servers are connected to the switches through a LAG.
- Some of the Marketing hosts connect to Switch 1, and some connect to Switch 2.
- The Engineering and Marketing departments share the same file server.
- Because security is a concern for the Payroll VLAN, the ports and LAG that are members of this VLAN will accept and transmit only traffic tagged with VLAN 300.

Table 8 shows the port assignments on the switches.

Table 8: Switch Port Connections

Port/LAG	Function
Switch 1	
1	Connects to Switch 2
2–15	Host ports for Payroll
16–20	Host ports for Marketing
LAG1 (ports 21–24)	Connects to Payroll server
Switch 2	
1	Connects to Switch 1
2–10	Host ports for Marketing
11–30	Host ports for Engineering
LAG1 (ports 35–39)	Connects to file server

Table 8: Switch Port Connections (Continued)

Port/LAG	Function
LAG2 (ports 40–44)	Uplink to router.

5.1.5.1 Configure the VLANs and Ports on Switch 1

Use the following steps to configure the VLANs and ports on Switch 1. None of the hosts that connect to Switch 1 use the Engineering VLAN (VLAN 100), so it is not necessary to create it on that switch.

To configure Switch 1:

1. Create VLANs 200 (Marketing), 300 (Payroll), and associate the VLAN ID with the appropriate name.

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 200,300
(Routing) (Vlan)#vlan name 200 Marketing
(Routing) (Vlan)#vlan name 300 Payroll
(Routing) (Vlan)#exit
```

2. Assign ports 16–20 to the Marketing VLAN.

```
(Routing) #configure
(Routing) (Config)#interface 0/16-0/20
(Routing) (Interface 0/16-0/20)#vlan participation include 200
(Routing) (Interface 0/16-0/20)#exit
```

3. Assign ports 2–15 to the Payroll VLAN

```
(Routing) (Config)#interface 0/2-0/15
(Routing) (Interface 0/2-0/15)#vlan participation include 300
(Routing) (Interface 0/2-0/15)#exit
```

4. Assign LAG1 to the Payroll VLAN and configure the frames to always be transmitted tagged with a PVID of 300.

```
(Routing) (Config)#interface 3/1
(Routing) (Interface 3/1)#vlan participation include 300
(Routing) (Interface 3/1)#vlan tagging 300
(Routing) (Interface 3/1)#vlan pvid 300
(Routing) (Interface 3/1)#exit
```

5. Configure port 1 as a trunk port and add VLAN 200 and VLAN 300 as members. Trunk ports accept and transmits tagged frames only and have ingress filtering enabled.

```
(Routing) (Config)#interface 0/1
(Routing) (Interface 0/1)#vlan acceptframe vlanonly
(Routing) (Interface 0/1)#vlan participation include 200,300
(Routing) (Interface 0/1)#vlan participation exclude 1
(Routing) (Interface 0/1)#vlan tagging 200,300
(Routing) (Interface 0/1)#vlan ingressfilter
(Routing) (Interface 0/1)#exit
(Routing) (Config)#exit
```

6. To save the configuration so that it persists across a system reset, use the following command:

```
(Routing) #copy system:running-config nvram:startup-config
```

7. View the VLAN settings.

```
(Routing) #show vlan

VLAN ID VLAN Name                        VLAN Type
------- -------------------------------- -------------------
1       default                           Default
200     Marketing                         Static
```

```
300     Payroll                           Static

(Routing) #show vlan 300

VLAN ID: 300
VLAN Name: Payroll
VLAN Type: Static

Interface   Current   Configured   Tagging
----------  --------  -----------  --------
0/1         Include   Include      Tagged
0/2         Include   Include      Untagged
0/3         Include   Include      Untagged
0/4         Include   Include      Untagged
0/5         Include   Include      Untagged
--More-- or (q)uit
```

8. View the VLAN information for a port.

```
(Routing) #show vlan port 0/1

          Port       Port                  Ingress    Ingress
          VLAN ID    VLAN ID  Acceptable  Filtering  Filtering Default
Interface Configured Current  Frame Types Configured Current   Priority
--------- ---------- -------- ----------- ---------- --------- --------
0/1       1          1        VLAN Only   Enable     Enable       0

Protected Port .............................. False
```

5.1.5.2 Configure the VLANs and Ports on Switch 2

Use the following steps to configure the VLANs and ports on Switch 2. Many of the procedures in this section are the same as procedures used to configure Switch 1. For more information about specific procedures, see the details and figures in the previous section.

To configure Switch 2:

1. Create the Engineering, Marketing, and Payroll VLANs.

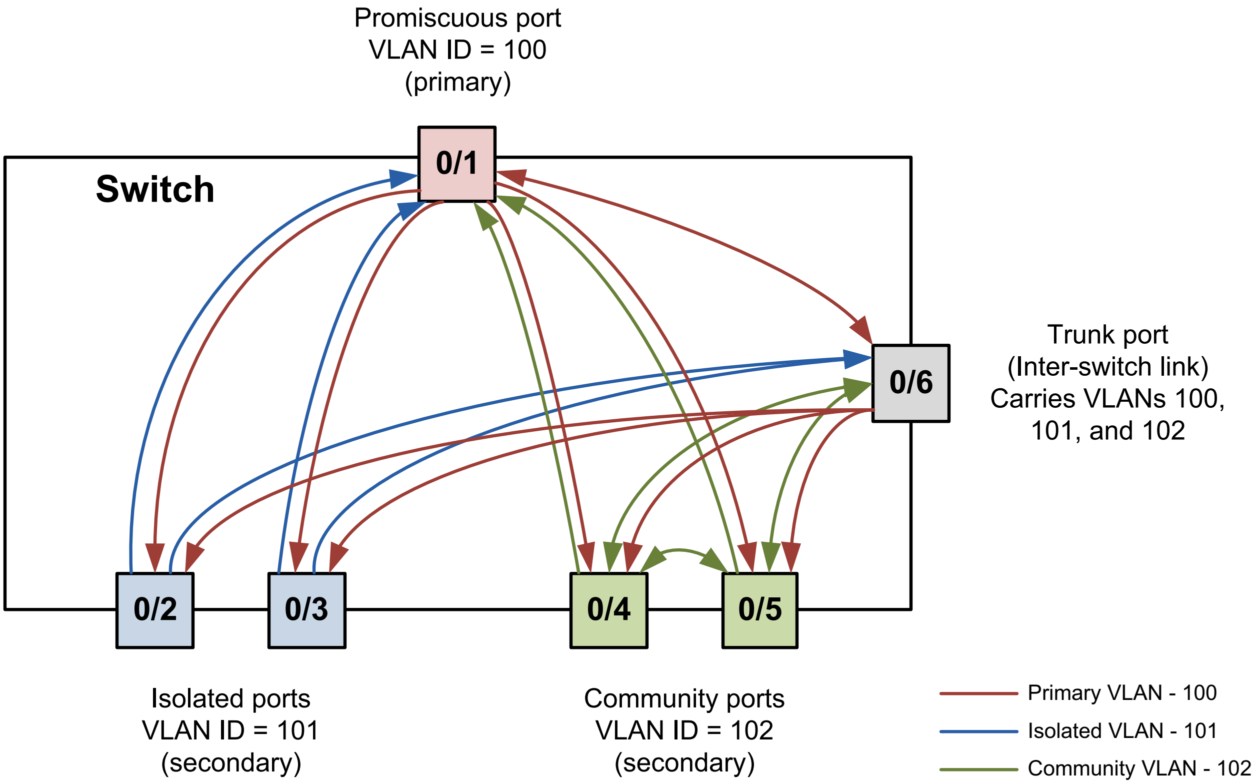
   Although the Payroll hosts do not connect to this switch, traffic from the Payroll department must use Switch 2 to reach the rest of the network and Internet through the uplink port. For that reason, Switch 2 must be aware of VLAN 300 so that traffic is not rejected by the trunk port.

2. Configure ports 2-10 to participate in VLAN 200.
3. Configure ports 11–30 to participate in VLAN 100.
4. Configure LAG 1 to participate in VLAN 100 and VLAN 200.
5. Configure port 1 and LAG 2 as participants in ports and add VLAN 100, VLAN 200, and VLAN 300 that accept and transit tagged frames only.
6. Enable ingress filtering on port 1 and LAG 2.
7. Optionally, copy the running configuration to the startup configuration.
8. View VLAN information for the switch and ports.

5.1.6 Configuring a Private VLAN

In this example, five ports on the switch shown in Figure 8, Private VLAN Configuration Example participate in a private VLAN. Port 0/1 is a promiscuous port that is associated with the primary VLAN 100. Ports 0/2 and 0/3 are the host ports that belong to the isolated VLAN 101. Ports 0/4 and 0/5 are the community ports that are associated with community VLAN 102. Port 0/6 is the inter-switch link. It is configured to transmit VLANs 100, 101 and 102. This example assumes port 0/6 is it is connected to an upstream device that does not understand private VLANs, so it is configured as a promiscuous trunk port. Colored arrows represent possible packet flow paths in the private VLAN domain.

Figure 8: Private VLAN Configuration Example



To configure the switch shown in Figure 8:

1. Create VLANs 100, 101, 102, and 105.

```
(Switch) #vlan database
(Switch) (Vlan)#vlan 100,101,102,105
(Switch) (Vlan)#exit
```

2. Configure VLAN 100 as a primary VLAN.

```
(Switch) #configure
(Switch) (Config)#vlan 100
(Switch) (Config)(Vlan 100)#private-vlan primary
```

3. Associate the secondary VLANs (VLANs 101 and 102) with the primary VLAN (VLAN 100).

```
(Switch) (Config)(Vlan 100)#private-vlan association 101,102
(Switch) (Config)(Vlan 100)#exit
```

4. Configure VLAN 101 as an isolated VLAN.

```
(Switch) #configure
(Switch) (Config)#vlan 101
(Switch) (Config)(Vlan 101)#private-vlan isolated
(Switch) (Config)(Vlan 101)#exit
```

5. Configure VLAN 102 as a community VLAN.

```
(Switch) (Config)#vlan 102
(Switch) (Config)(Vlan 102)#private-vlan community
(Switch) (Config)(Vlan 102)#exit
```

6. Configure port 0/1 as a promiscuous port and associate it with the primary VLAN (VLAN 100) and secondary VLANs (VLAN 101 and VLAN 102).

```
(Switch) (Config)#interface 0/1
(Switch) (Interface 0/1)#switchport mode private-vlan promiscuous
(Switch) (Interface 0/1)#switchport private-vlan mapping 100 101,102
(Switch) (Interface 0/1)#exit
```

7. Configure port 0/2 and 0/3 as host ports that are members of VLAN 101.

```
(Switch) (Config)#interface 0/2-0/3
(Switch) (Interface 0/2-0/3)#switchport mode private-vlan host
(Switch) (Interface 0/2-0/3)#switchport private-vlan host-association 100 101
(Switch) (Interface 0/2-0/3)#exit
```

8. Configure ports 0/4 and 0/5 as host ports that are members of VLAN 102.

```
(Switch) (Config)#interface 0/4-0/5
(Switch) (Interface 0/4-0/5)#switchport mode private-vlan host
(Switch) (Interface 0/4-0/5)#switchport private-vlan host-association 100 102
(Switch) (Interface 0/4-0/5)#exit
```

9. Configure port 0/6 as a promiscuous trunk port that is a member of VLANs 100, 101, and 102.

```
(Switch) (Config)#interface 0/6
(Switch) (Interface 0/6)#switchport mode private-vlan trunk promiscuous
(Switch) (Interface 0/6)#switchport private-vlan mapping trunk 100 101-102
```

10. Configure the native VLAN and allowed VLAN list on port 0/6. The trunk native VLAN defines the VLAN association for untagged packets. If not configured, untagged packets are dropped. The trunk allowed VLAN list specifies the list of allowed normal (non-private) VLANs on the trunk port.

```
(Switch) (Interface 0/6)#switchport private-vlan trunk native vlan 105
(Switch) (Interface 0/6)#switchport private-vlan trunk allowed vlan 100,105
(Switch) (Interface 0/6)#exit
```

11. Configure port 0/7 as an isolated trunk port that is associated with VLAN 101.

```
(Switch) (Config)#interface 0/7
(Switch) (Interface 0/7)#switchport mode private-vlan trunk secondary
(Switch) (Interface 0/7)#switchport private-vlan association trunk 100 101
(Switch) (Interface 0/7)#exit
(Switch) (Config)#exit
```

12. View private VLAN configuration information.

```
(Switch) #show vlan private-vlan

Primary VLAN Secondary VLAN Type             Ports
------------ -------------- ---------------- ----------------------------------
100          101            Isolated         0/1,0/2,0/3,0/6,0/7
100          102            Community        0/1,0/4,0/5,0/6

(Switch) #show vlan private-vlan type
```

```
VLAN   Type
-----  ---------------
100     primary
101     isolated
102     community

(Switch) #show interface ethernet 0/1 switchport

Port: 0/1
VLAN Switchport mode:Private Vlan Promiscuous
Private VLAN configured Host association:
Private VLAN configured Promiscuous VLANS: 100,101-102
Operational Private VLANS :100-102

(Switch) #show interface ethernet 0/6 switchport

Port: 0/6
VLAN Switchport mode:Private Vlan Trunk Promiscuous
Private VLAN trunk mappings:
 100,101-102
Private VLAN trunk native VLAN:  105
Private VLAN trunk allowed VLANs: 100,105

(Switch)#show interface ethernet 0/7 switchport

Port: 0/7
VLAN Switchport mode:Private Vlan Trunk Isolated
Private VLAN trunk associations:
 100 101
Private VLAN trunk native VLAN:
Private VLAN trunk allowed VLANs: 2
Operational Private VLANS :100-101
```

5.1.7 Per VLAN Statistics

Per VLAN counters are available for administratively-created VLANs. Users can enable or disable these counters:

- RxBytes
- RxFrames
- RxDiscardBytes
- RxDiscardFrames
- TxBytes
- TxFrames
- TxDiscardBytes
- TxDiscardFrames

Dynamically-created VLAN properties cannot be changed by the system administrator. However, APIs are provided for use by the components creating the VLANs to disable or enable VLAN statistics mode.

- The `vlan stats` command enables statistics collection on the VLAN list specified if the specified VLAN(s) are administratively created in the system.
- The `no vlan stats` command disables statistics collection on the VLAN list specified if the specified VLAN(s) are administratively created in the system.
- The `show vlan stats` command displays the supported per-VLAN statistics for the VLAN(s) specified.
- The `clear vlan stats` command clears the supported per-VLAN statistics for the VLAN(s) specified.

Refer to the *EFOS CLI Command Reference* for more information about the Per VLAN Statistics commands. See Appendix A, Document Resources.

5.2 Switchport Modes

You can configure each port on an EFOS switch to be in one of the following modes:

- **Access**—Access ports are intended to connect end-stations to the system, especially when the end-stations are incapable of generating VLAN tags. Access ports support a single VLAN (the PVID). Packets received untagged are processed as if they are tagged with the access port PVID. Packets received that are tagged with the PVID are also processed. Packets received that are tagged with a VLAN other than the PVID are dropped. If the VLAN associated with an access port is deleted, the PVID of the access port is set to VLAN 1. VLAN 1 may not be deleted.
- **Trunk**—Trunk-mode ports are intended for switch-to-switch links. Trunk ports can receive both tagged and untagged packets. Tagged packets received on a trunk port are forwarded on the VLAN contained in the tag if the trunk port is a member of the VLAN. Untagged packets received on a trunk port are forwarded on the native VLAN. Packets received on another interface belonging to the native VLAN are transmitted untagged on a trunk port.
- **General**—General ports can act like access or trunk ports or a hybrid of both. VLAN membership rules that apply to a port are based on the switchport mode configured for the port.

Table 21-2 shows the behavior of the three switchport modes.

Table 9: Switchport Mode Behavior

Mode	VLAN Membership	Frames Accepted	Frames Sent	Ingress Filtering
Access	One VLAN	Untagged/Tagged	Untagged	Always On
Trunk	All VLANs that exist in the system (default)	Untagged/Tagged	Tagged and Untagged	Always On
General	As many as needed	Tagged or Untagged	Tagged or Untagged	On or Off

When a port is in General mode, all VLAN features are configurable. When ingress filtering is on, the frame is dropped if the port is not a member of the VLAN identified by the VLAN ID in the tag. If ingress filtering is off, all tagged frames are forwarded. The port decides whether to forward or drop the frame when the port receives the frame.

The following example configures a port in Access mode with a single VLAN membership in VLAN 10:

```
(Routing) #config
(Routing) (Config)#interface 0/5
(Routing) (Interface 0/5)#switchport mode access
(Routing) (Interface 0/5)#switchport access vlan 10
(Routing) (Interface 0/5)#exit
```

The following example configures a port in Trunk mode. The **sw**it**chport trunk allowed vlan** command with the **add** keyword adds the list of VLANs that can receive and send traffic on the interface in tagged format when in trunking mode. Alternatively, the all keyword can be used to specify membership in all VLANs, the **remove** keyword can be used to remove membership. If this command is omitted, the port is a member of all configured VLANs. The native VLAN specifies the VLAN on which the port forwards untagged packets it receives.

```
(Routing) #config
(Routing) (Config)#interface 0/8
(Routing) (Interface 0/8)#switchport mode trunk
(Routing) (Interface 0/8)#switchport trunk allowed vlan add 10,20,30
(Routing) (Interface 0/8)#switchport trunk native vlan 100
(Routing) (Interface 0/8)#exit
```

The following commands configure a port in General mode.

```
(Routing) #config
(Routing) (Config)#interface 0/10
(Routing) (Interface 0/10)#switchport mode general
(Routing) (Interface 0/10)#exit
```

The General mode port can then be configured as a tagged or untagged member of any VLAN, as shown in Section 5.1.5, VLAN Configuration Example.

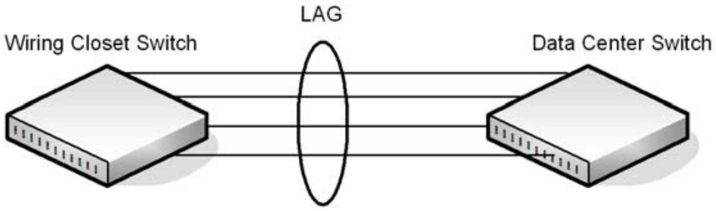
5.3 LAGs—Operation and Configuration

Link Aggregation allows one or more full-duplex (FDX) Ethernet links of the same speed to be aggregated together to form a LAG. This allows the switch to treat the LAG as if it is a single link. The primary purpose of LAGs is to increase the overall bandwidth between two switches. This is accomplished by effectively aggregating multiple ports together that act as a single, logical connection between the two switches. LAGs also provide redundancy. If a link fails, traffic is automatically redistributed across the remaining links.

EFOS software supports industry-standard LAGs that adhere to the IEEE 802.3ad specification. Both static and dynamic LAGs are supported. Each LAG can have a maximum of 32 ports as members (as long as the platform can support it). You can configure LAGs until all switch ports are assigned to a LAG.

Figure 9, LAG Configuration shows an example of a switch in the wiring closet connected to a switch in the data center by a LAG that consists of four physical 10 Gb/s links. The LAG provides full-duplex bandwidth of 40 Gb/s between the two switches.

Figure 9: LAG Configuration



5.3.1 Static and Dynamic Link Aggregation

Link aggregation can be configured as either dynamic or static. Dynamic configuration is supported using the IEEE 802.3ad standard, which is known as Link Aggregation Control Protocol (LACP). Static configuration is used when connecting the switch to an external Gigabit Ethernet switch that does not support LACP.

One advantage of LACP is that the protocol enables the switch to confirm that the external switch is also configured for link aggregation. When using static configuration, a cabling or configuration mistake involving the local switch or the external switch could go undetected and thus cause undesirable network behavior. Both static and dynamic LAGs (via LACP) can detect physical link failures within the LAG and continue forwarding traffic through the other connected links within that same LAG. LACP can also detect switch or port failures that do not result in loss of link. This provides a more resilient LAG. Best practices suggest using dynamic link aggregation instead of static link aggregation. When a port is added to a LAG as a static member, it neither transmits nor receives LACP PDUs.

5.3.2 LAG Hashing

EFOS software support configuration of hashing algorithms for each LAG interface. The hashing algorithm is used to distribute traffic load among the physical ports of the LAG while preserving the per-flow packet order.

The hashing algorithm uses various packet attributes to determine the outgoing physical port.

The switch supports the following set of packet attributes to be used for hash computation:

- Source MAC, VLAN, EtherType, and incoming port.
- Destination MAC, VLAN, EtherType, and incoming port.
- Source IP and Source TCP/UDP port numbers.

- Destination IP and Destination TCP/UDP port numbers.
- Source/Destination MAC, VLAN, EtherType, and incoming port.
- Source/Destination IP and Source/Destination TCP/UDP port numbers.
- Enhanced hashing mode

Enhanced hashing mode has following advantages:

- MODULO-N operation based on the number of ports in the LAG.
- Packet attributes selection based on the packet type. For L2 packets, Source and Destination MAC address are used for hash computation. For IP packets, Source IP, Destination IP address, TCP/UDP ports are used.
- Non-Unicast traffic and Unicast traffic is hashed using a common hash algorithm.
- Excellent load balancing performance.

5.3.2.1 Resilient Hashing

Resilient Hashing (RH) is a feature on BCM56850 (and later) switches that introduces an extra level of indirection between the hash value and the selected output port for a layer-2 LAG () or a layer-3 ECMP route. In a typical non-RH configuration, the output port can change for all flows when the number of ports changes, even if the flow was on a port that was not affected. This can cause degraded performance due to frame reordering. With RH, the hash value is used to index into a table of ports. If a port goes down, then only the entries that use that port are rewritten. Other ports are left untouched and, therefore, do not suffer degraded performance.

Resilient hashing is globally enabled on BCM56850 switch ports by default. It can be globally enabled (or disabled) in Global Config mode using the **(no) port-channel resilient-hashing** command for LAGs or the **(no) ip resilient-hashing** command for ECMP routes. The new setting takes effect after a system reboot.

5.3.2.2 Hash Prediction with ECMP and LAG

The Hash Prediction feature provides a utility to predict how packets will be forwarded over a LAG or to the next-hop device when Equal-Cost Multipath (ECMP) is the destination. Given the link aggregation method, ingress physical port, and values of various packet fields, the utility predicts an egress physical port for the packet.

An ECMP group is identified by the IP address of one of its members. By entering the IP address in the form <prefix/prefix-length>, the utility predicts the packet's physical egress port based on the destination ECMP group. To predict the an egress physical port when the egress objects are VLAN routing interfaces with LAG or port interfaces as members of the VLANs, the utility requires the PVID to be configured on the interfaces and the next hops to be fully installed in hardware.

If an ECMP group is comprised of VLAN routing interfaces and each VLAN has a LAG that contains multiple ports, the utility requires the PVID to be configured on the LAGs. In this configuration, the utility first predicts which VLAN routing interface the packet is forwarded to and finds the LAG by matching the VLAN ID of the VLAN routing interface to the PVID of the LAG. Then, it predicts which physical port in the LAG the packet is forwarded to.

To make correct prediction when LAGs are used as egress interfaces, the utility requires the enhanced hashing mode to be set on the LAGs.

Hash prediction is supported only for unicast packets on BCM56850-based platforms.

5.3.3 LAG Interface Naming Convention

LAGs are logical interfaces and follow a slot/port naming convention. The slot number is always 3, and the port number ranges from 1 to the maximum number of LAGs the switch supports. The **show port-channel brief** command provides summary information about all LAGs available on the system. In the following output, LAG 3/1 has been configured as a dynamic LAG with five member ports. No other LAGs have been configured.

```
(Routing) #show port-channel brief

Logical   Port-Channel  Min Link State Trap     Type    Mbr Ports Active Ports
Interface Name                         Flag
--------- ------------- --- ---------- -------- ------- --------- ------------
3/1       ch1             1  Down       Disabled Dynamic 0/1,0/2,
                                                         0/3,0/6,
                                                         0/7
3/2       ch2             1  Down       Disabled Static
3/3       ch3             1  Down       Disabled Static
3/4       ch4             1  Down       Disabled Static
3/5       ch5             1  Down       Disabled Static
```

5.3.4 LAG Interaction with Other Features

From a system perspective, a LAG is treated just as a physical port, with the same configuration parameters for administrative enable/disable, spanning tree port priority, path cost as may be for any other physical port.

5.3.4.1 VLAN

When members are added to a LAG, they are removed from all existing VLAN membership. When members are removed from a LAG they are added back to the VLANs that they were previously members of as per the configuration file. Note that a port's VLAN membership can still be configured when it's a member of a LAG. However this configuration is only actually applied when the port leaves the LAG.

The LAG interface can be a member of a VLAN complying with IEEE 802.1Q.

5.3.4.2 STP

Spanning tree does not maintain state for members of a LAG, but the Spanning Tree does maintain state for the LAG interface. As far as STP is concerned, members of a LAG do not exist. (Internally, the STP state of the LAG interface is replicated for the member links.)

When members are deleted from a LAG they become normal links, and spanning tree maintains their state information.

5.3.4.3 Statistics

Statistics are maintained for all LAG interfaces as they are done for the physical ports, besides statistics maintained for individual members as per the 802.3ad MIB statistics.

5.3.5 LAG Configuration Guidelines

Ports to be aggregated must be configured so that they are compatible with the link aggregation feature and with the partner switch to which they connect.

Ports to be added to a LAG must meet the following requirements:

- Interface must be a physical Ethernet link.
- Each member of the LAG must be running at the same speed and must be in full duplex mode.
- The port cannot be a mirrored port

The following are the interface restrictions

- The configured speed of a LAG member cannot be changed.
- An interface can be a member of only one LAG.

5.3.6 Link Aggregation Configuration Examples

NOTE: The examples in this section show the configuration of only one switch. Because LAGs involve physical links between two switches, the LAG settings and member ports must be configured on both switches.

5.3.6.1 Configuring Dynamic LAGs

The commands in this example show how to configure a static LAG on a switch. The LAG number is 1 (port 3/1), and the member ports are 1, 2, 3, 6, and 7.

To configure the switch:

1. Enter interface configuration mode for the ports that are to be configured as LAG members.
```
(Routing) #config
(Routing) (Config)#interface 0/1-0/3,0/6-0/7
```
2. Add the ports to LAG 1 with LACP.
```
(Routing) (Interface 0/1-0/3,0/6-0/7)#addport 3/1
(Routing) (Interface 0/1-0/3,0/6-0/7)#exit
```
3. Configure LAG 1 as dynamic.
```
(Routing) (Config)#interface 3/1
(Routing) (Interface 3/1)#no port-channel static
(Routing) (Interface 3/1)#exit
(Routing) (Config)#exit
```
4. View information about LAG 1.
```
(Routing) #show port-channel 3/1

Local Interface............................... 3/1
Channel Name.................................. ch1
Link State.................................... Down
Admin Mode.................................... Enabled
Type.......................................... Dynamic
Port-channel Min-links........................ 1
Load Balance Option........................... 3
(Src/Dest MAC, VLAN, EType, incoming port)

Mbr    Device/       Port      Port
Ports  Timeout       Speed     Active
------ ------------- --------- -------
0/1    actor/long    Auto      False
       partner/long
0/2    actor/long    Auto      False
       partner/long
0/3    actor/long    Auto      False
       partner/long
```

```
0/6    actor/long    Auto      False
       partner/long
0/7    actor/long    Auto      False
       partner/long
```

5.3.6.2 Configuring Static LAGs

The commands in this example show how to configure a static LAG on a switch. The LAG number is 3 (interface 1/3), and the member ports are 10, 11, 14, and 17.

To configure the switch:

1. Enter interface configuration mode for the ports that are to be configured as LAG members.

```
(Routing) (Config)#interface 0/10-0/12,0/14,0/17
```

2. Add the ports to LAG 2 without LACP.

```
(Routing) (Interface 0/10-0/12,0/14,0/17)#addport 1/3
(Routing) (Interface 0/10-0/12,0/14,0/17)#exit
(Routing) (Config)#exit
```

3. View information about LAG 2.

```
(Routing) #show port-channel 3/3

Local Interface................................ 1/3
Channel Name................................... ch3
Link State..................................... Up
Admin Mode..................................... Enabled
Type........................................... Static
Port-channel Min-links......................... 1
Load Balance Option............................ 3
(Src/Dest MAC, VLAN, EType, incoming port)

Mbr    Device/       Port      Port
Ports  Timeout       Speed     Active
------ ------------- --------- -------
0/10   actor/long    Auto      True
       partner/long
0/11   actor/long    Auto      False
       partner/long
0/12   actor/long    Auto      False
       partner/long
0/14   actor/long    Auto      False
       partner/long
0/17   actor/long    Auto      False
       partner/long
--More-- or (q)uit
```

5.4 Virtual Port Channel—Operation and Configuration

5.4.1 Overview

In a typical layer-2 network, the Spanning Tree Protocol (STP) is deployed to avoid packet storms due to loops in the network. To perform this function, STP sets ports into either a forwarding state or a blocking state. Ports in the blocking state do not carry traffic. In the case of a topology change, STP reconverges to a new loop-free network and updates the port states. STP is relatively successful mitigating packet storms in the network, but redundant links in the network are blocked from carrying traffic by the spanning tree protocol.

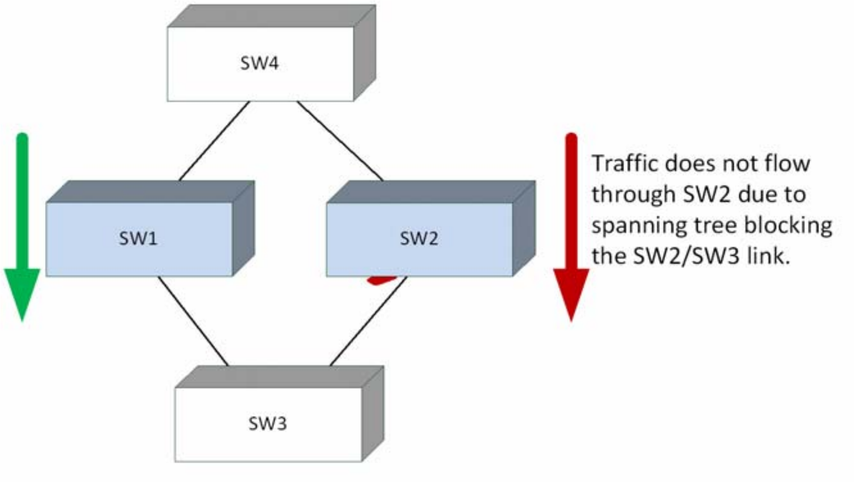
In some network deployments, redundant links between two switches are bundled together in a Link Aggregation Group (LAG) and appear as a single link in the spanning tree topology. The advantage is that all LAG member links can be in the forwarding state and a link failure can be recovered in milliseconds. This allows the bandwidth on the redundant links to be utilized. However, LAGs are limited to connecting multiple links between two partner switches, which leaves the switch as a single point of failure in the topology.

EFOS VPC extends the LAG bandwidth advantage across multiple EFOS switches connected to a LAG partner device. The LAG partner device is oblivious to the fact that it is connected over a LAG to two peer EFOS switches; instead, the two switches appear as a single switch to the partner with a single MAC address. All links can carry data traffic across a physically diverse topology and in the case of a link or switch failure, traffic can continue to flow with minimal disruption.

5.4.1.1 Deployment Scenarios

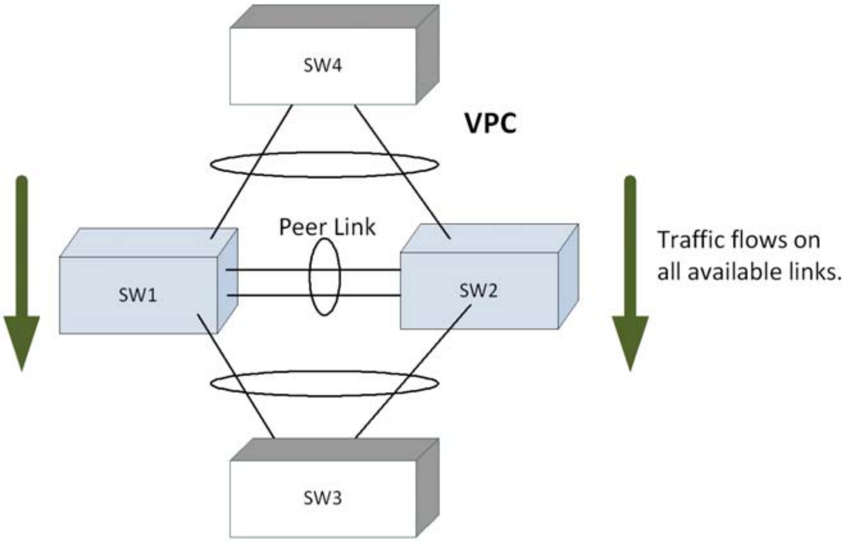
VPC is intended to support higher bandwidth utilization in scenarios where a redundant layer-2 network is needed. In such scenarios the effects of STP on link utilization are profound. Large percentages of links do not carry data because they are blocked and only a single path through the network carries traffic.

Figure 10: STP Blocking


SW4
SW1
SW2
SW3
Traffic does not flow through SW2 due to spanning tree blocking the SW2/SW3 link.

VPC reduces some of the bandwidth shortcomings of STP in a layer-2 network. It provides a reduced convergence period when a port-channel link goes down and provides more bandwidth because all links can forward traffic. In the figure below, if SW1 and SW2 form an VPC with SW3 and SW4, none of the links are blocked, which means traffic can flow over both links from SW4 through to SW1 and SW2 over both links from SW1 and SW2 to SW3.

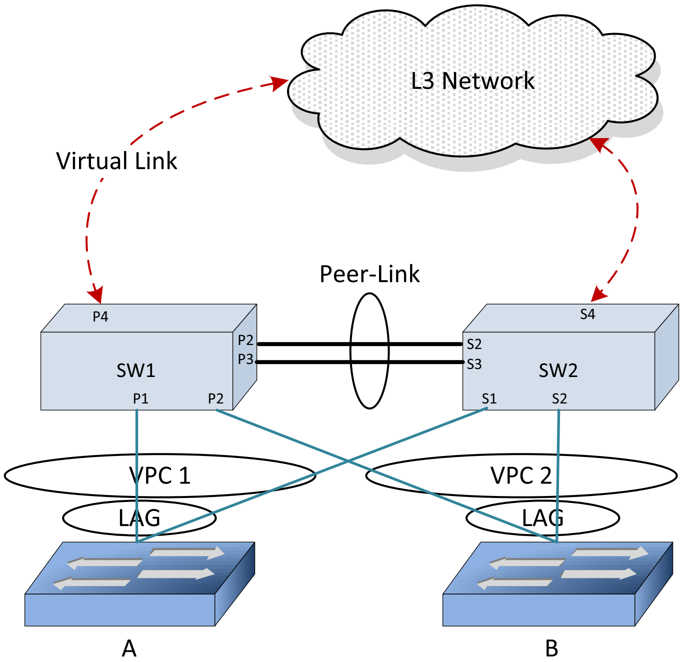
Figure 11: VPC in a Layer-2 Network



5.4.1.2 Definitions

Refer to Figure 12, VPC Components for the definitions that follow.

Figure 12: VPC Components



VPC switches: VPC-aware switches running EFOS switch firmware. No more than two VPC aware switches can pair to form one end of the LAG. Stacked switches do not support VPCs. In the above figure, SW1 and SW2 are VPC peer switches. These two switches form a single logical end point for the VPC from the perspective of switch A.

VPC interfaces: VPC functionality is a property of LAGs. LAGs configured as VPCs are called VPC interfaces. Administrators can configure multiple instances of VPC interfaces on the peer VPC switches. LAG limitations and capabilities such as min-links and maximum number of ports supported per LAG also apply to VPC interfaces.

VPC member ports: Ports on the peer VPC switches that are part of the VPC interface (P1 on SW1 and S1 on SW2).

Non-redundant ports: Ports on either of the peer switches that are not part of the VPC (ports P4 and S4). VPC interfaces and non-redundant ports cannot be members of the same VLAN, i.e. a VLAN may contain VPC interfaces or a VLAN may contain non-redundant ports, but not both.

VPC peer-link: A link between the two VPC peer switches (ports P2,P3,S2,S3). Only one peer-link can be configured per device. The peer-link is crucial for the operation of the VPC component. A LAG must be configured as the peer-link. All VLANs configured on VPC interfaces must be configured on the peer-link as well.

VPC Dual Control Plane Detection link: A virtual link that is used to advertise the Dual Control Plane Detection protocol (DCPDP) packets between the two VPC switches (ports P4, S4). This protocol is optional. The protocol indicates the presence of the peer switch in the network. The DCPDP protocol should not be configured on MLAG interfaces.

5.4.1.3 Configuration Consistency

VPC is operational only if the VPC domain ID, VPC system MAC address, and VPC system priority are the same on both the VPC peer switches.

NOTE: Configuring a VPC domain ID is mandatory; the VPC system MAC address and VPC system priority are optional (these values are auto generated if not configured).

The administrator must ensure that the neighboring devices connected to VPC switches perceive the two switches as a single spanning tree and Link Aggregation Control Protocol (LACP) entity. To achieve this end, the following configuration settings must be identical for VPC links on the VPC peer switches:

1. Link aggregation
   - Hashing mode
   - Minimum links
   - Static/dynamic LAG
   - LACP parameters
     – Actor parameters
     – Admin key
     – Collector max-delay
     – Partner parameters
2. STP

   The default STP mode for EFOS switches is RSTP. VLANs cannot be configured to contain both VPC ports and non-VPC (non-redundant) ports. Only RSTP or MSTP are supported with VPC. STP-PV and RSTP-PV are not supported with VPC. The following STP configuration parameters must be the identical on both VPC peers.
   - Bpdufilter
   - Bpduflood
   - Auto-edge
   - TCN-guard
   - Cost

- Edgeport
- Loop guard
- Root guard
- PVSTP/PVRSTP global configuration (FastUplink mode, FastUplink maximum update rate, FastBackbone mode, hello time, forward time, maximum age time, priority)
- PVSTP/PVRSTP per-port configuration (VLAN membership, STP port-priority, per-VLAN port priority, cost)
- STP Version
- STP MST VLAN configuration
- STP MST instance configuration (MST instance ID/port priority/port cost/mode)

3. LAG (port-channel) interface

   The following LAG attributes must be identical for VPC LAGs:

   - LAG mode
   - Link speed
   - Duplex mode
   - MTU
   - Bandwidth
   - VLAN configuration

   The administrator should also ensure that the following are identical before enabling VPC:

   - FDB entry aging timers
   - Static MAC entries.
   - ACL configuration

4. Interface Configuration
   - PFC configuration
   - CoS queue assignments

5. VLAN configuration
   - VPC VLANs must span the VPC topology and be configured on both VPC peers. This means that every VPC VLAN must connect to two partner LAGs.
   - VLAN termination of an VPC VLAN on an VPC peer is not supported.

6. Switch firmware versions

   Except during firmware upgrade, the peer switch firmware versions must be identical, as subtle differences between versions may cause instability.

The administrator must ensure that the above configuration items are configured identically on the VPC interfaces on both of the VPC peers before enabling the VPC feature. If the configuration settings are not in sync, the VPC behavior is undefined. Once the above configuration is in place and consistent, the two switches will form an VPC that operates in the intended manner. The VPC may form even if the configuration is not consistent, however, it may not operate consistently in all situations.

5.4.2 VPC Fast Failover

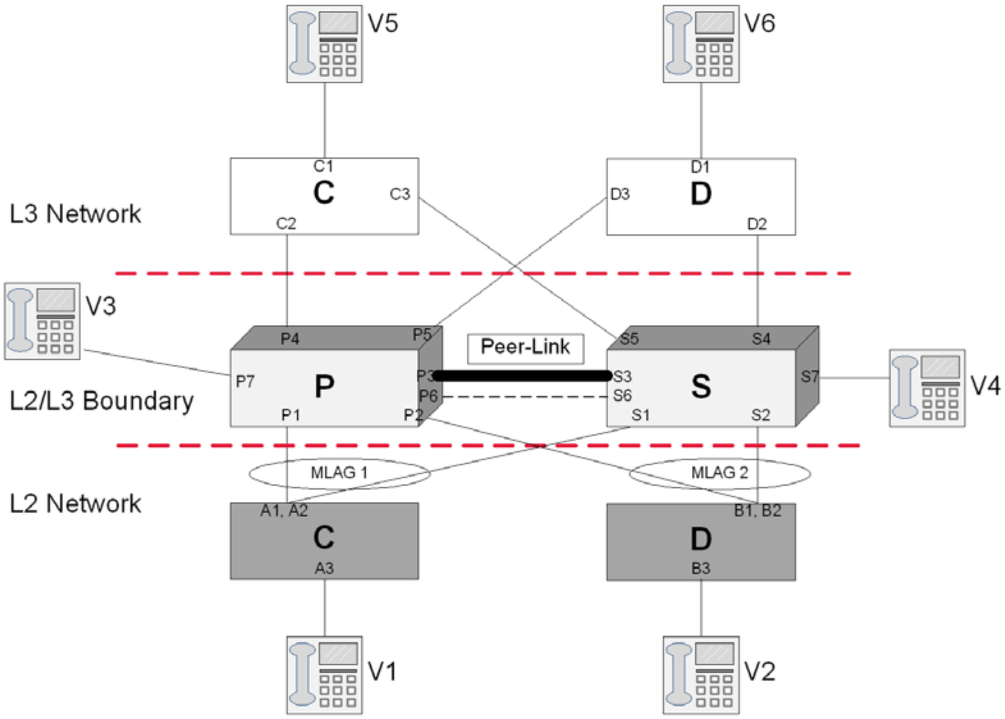
Prior to EFOS release 3.0, when the primary switch fails, secondary switch restarts the LACP protocol on its VPC member ports. STP is also restarted on secondary device's VPC member ports. Until the LACP and STP reconverges, the partner device is disconnected from the VPC domain.

With fast failover support, neither LACP reconvergence nor STP reconvergence occurs, and minimal traffic loss is observed when primary device fails. During the failover, traffic that is being forwarded using the links connected to primary device will failover to links connected to the secondary device. The traffic disruption is limited to the time required for the partner devices dual-attached to the VPC domain to detect the link down (links connected to primary device) and redistribute the traffic using the links connected to the secondary device.

Spanning tree modes should be configured the same on both the VPC peers. The following modes are supported for fast-failover: STP, RSTP, MSTP, PVST, and Rapid-PVST.

For voice VLAN, VoIP phones can be connected to the partner devices and cannot be connected as VPC partner devices. Figure 13 shows an example of VoIP phone connectivity in a VPC topology.

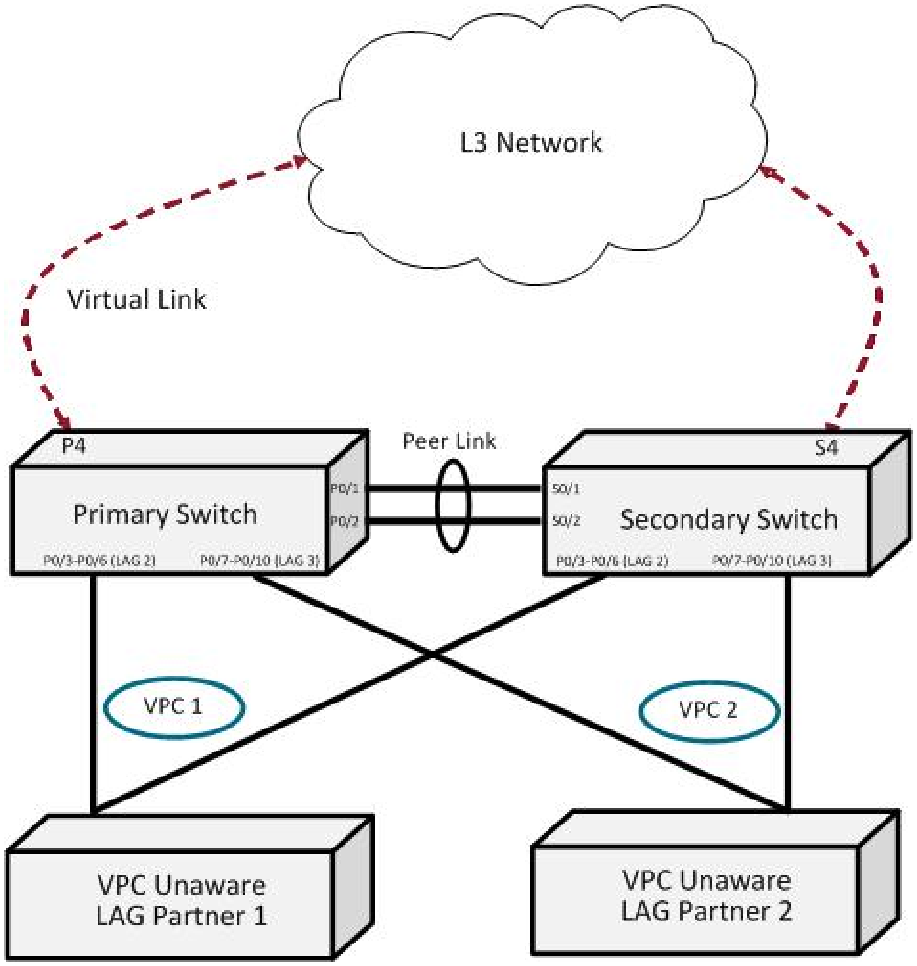
Figure 13: VOIP Phones in a VPC Topology



5.4.3 VPC Configuration

Refer to Figure 14 for a visual overview of the VPC configuration steps.

Figure 14: VPC Configuration Diagram



To configure VPC:

1. Enter VLAN database mode and create the VPC VLANs.
```
(Routing) #vlan database
(Routing) (Vlan) #vlan 2-99
```
2. Create the VLAN routing interface that will be used for the Dual Control Plane detection Protocol.
```
(Routing) (Vlan) #vlan 100
(Routing) (Vlan) #vlan routing 100
(Routing) (Vlan) #exit
```
3. Enable the VPC feature.
```
(Routing) #config
(Routing) (Config)#feature vpc
```
4. Create the VPC domain ID. The domain ID configured on both the VPC peer switches should be same. In a two-tier VPC topology, each pair should have different domain ID.
```
(Routing) (Config)#vpc domain 1
```
5. Configure the VPC system MAC address and/or VPC system priority (optional).
```
(Routing) (Config-VPC 1)#system-mac 00:01:85:48:E0:0F
```

```
(Routing) (Config-VPC 1)#system-priority 1000
```

6. Enable the keepalive protocol.

```
(Routing) (Config-VPC 1)#peer-keepalive enable
```

7. Configure the VPC role priority (optional).

```
(Routing) (Config)#vpc domain 1
(Routing) (Config-VPC 1)#role priority 10
```

8. Create LAG 1.

```
(Routing) (Config)#interface lag 1
(Routing) (Interface lag 1)#description "VPC-Peer-Link"
```

9. Allow the LAG to participate in all VLANs and accept and send tagged frames only. This is similar to configuring a port in trunk mode.

```
(Routing) (Interface lag 1)#vlan participation include 1-99
(Routing) (Interface lag 1)#vlan tagging 1-99
(Routing) (Interface lag 1)#vlan acceptframe vlanonly
(Routing) (Interface lag 1)#vpc peer-link
(Routing) (Interface lag 1)#exit
```

10. Create the peer link.

```
(Routing) (Config)#interface 0/1-0/2
(Routing) (Interface 0/1-0/2)#addport lag 1
(Routing) (Interface 0/1-0/2)#description "VPC-Peer-Link"
```

11. Enable UDLD (if required).

```
(Routing) (Interface 0/1-0/2)#udld enable
(Routing) (Interface 0/1-0/2)#udld port aggressive
(Routing) (Interface 0/1-0/2)#exit
```

12. Configure Dual Control Plane detection Protocol Configuration (if required):

    a. Configure a VLAN routing interface and assign a local IP address (independent form the peer address).

    ```
    (Routing) (Config)#interface vlan 100
    ```

    b. This command configures the IP address of the source device on the VLAN routing interface. This configuration is used by the dual control plane detection protocol (DCPDP) on the VPC switches.

    ```
    (Routing) (Interface vlan 100)#ip address 192.168.0.2 255.255.255.0
    (Routing) (Interface vlan 100)#exit
    ```

    c. Configure the keepalive source and destination IP address.

    ```
    (Routing) #config
    (Routing) #vpc domain 1
    (Routing) (Config-VPC 1)#peer-keepalive destination 192.168.0.1 source 192.168.0.2
    ```

    The UDP port on which the VPC switch listens to the DCPDP messages can also be configured with this command. The configurable range for the UDP port 1 to 65535 (Default is 60000).

    d. Configure the DCPDP transmission interval and reception timeout values (optional).

    ```
    (Routing) (Config-VPC 1)#peer detection interval 600 timeout 2000
    ```

    e. Enable Peer Detection mode. The mode starts running if VPC is globally enabled.

    ```
    (Routing) (Config-VPC 1)#peer detection enable
    ```

13. Configure a LAG as VPC interface. The configurable range for the VPC ID is 1 to L7_MAX_NUM_VPC.

```
(Routing) (Config)#interface 0/3-0/6
(Routing) (Interface 0/3-0/6)#addport lag 2
(Routing) (Interface 0/3-0/6)#exit
(Routing) (Config)#interface 0/7-0/10
(Routing) (Interface 0/7-0/10)#addport lag 3
(Routing) (Interface 0/7-0/10)#exit
```

```
(Routing) (Config)#interface lag 2
(Routing) (Interface lag 2)#vlan participation include 1-99
(Routing) (Interface lag 2)#vlan tagging 1-99
(Routing) (Interface lag 2)#vlan acceptframe vlanonly
(Routing) (Interface lag 2)#vpc 1
(Routing) (Interface lag 2)#exit
(Routing) (Config)#interface lag 3
(Routing) (Interface lag 3)#vlan participation include 1-99
(Routing) (Interface lag 3)#vlan tagging 1-99
(Routing) (Interface lag 3)#vlan acceptframe vlanonly
(Routing) (Interface lag 3)#vpc 2
(Routing) (Interface lag 3)#exit
```

The administrator must ensure that the port channel configurations on both devices are in sync before enabling VPC. After the VPC interfaces are enabled, the VPC interfaces are operationally shut down. The VPC component exchanges information regarding the port members that constitute the LAG on each device. Once this information is populated on both devices, the VPC interfaces are operationally up and traffic forwarding on VPC interfaces is allowed. LAGs must be configured on both devices as VPC interfaces for the VPC interface to be enabled. Also, the port-channel-number:VPC-Id pair must be the same on both the primary and secondary devices.

Member ports can be added or removed from the VPC interface. If a port is added as a port member to a VPC interface, the Primary allows the port member if the maximum criteria is satisfied. When a port member is removed from the VPC interface, the Primary decides if the minimum criteria is satisfied. If it is not, it will shut down the VPC interface on both the devices. Shutting down the VPC interface on the Secondary is not allowed. The VPC interface can only be shut down on the Primary.

FDB entries learned on VPC interfaces are synced between the two devices. In the case where all VPC member ports are UP, data traffic does not traverse the peer link.

5.5 Unidirectional Link Detection (UDLD)

The UDLD feature detects unidirectional links on physical ports. UDLD must be enabled on the both sides of the link in order to detect an unidirectional link. The UDLD protocol operates by exchanging packets containing information about neighboring devices.

The purpose of UDLD feature is to detect and avoid unidirectional links. A unidirectional link is a forwarding anomaly in a Layer 2 communication channel in which a bidirectional link stops passing traffic in one direction.

5.5.1 UDLD Modes

The UDLD supports two modes: normal and aggressive.

In normal mode, a port's state is classified as *undetermined* if an anomaly exists. An anomaly might be the absence of its own information in received UDLD messages or the failure to receive UDLD messages. An *undetermined* state has no effect on the operation of the port. The port is not disabled and continues operating. When operating in UDLD normal mode, a port will be put into a disabled state (D-Disable) only in the following situations:

- The UDLD PDU received from a partner does not have its own details (echo).
- When there is a loopback, and information sent out on a port is received back exactly as it was sent.

When operating in UDLD aggressive mode, a port is put into a disabled state for the same reasons that it occurs in normal mode. Additionally, a port in UDLD aggressive mode can be disabled if the port does not receive any UDLD echo packets even *after* bidirectional connection was established. If a bidirectional link is established, and packets suddenly stop coming from partner device, the UDLD aggressive-mode port assumes that link has become unidirectional.

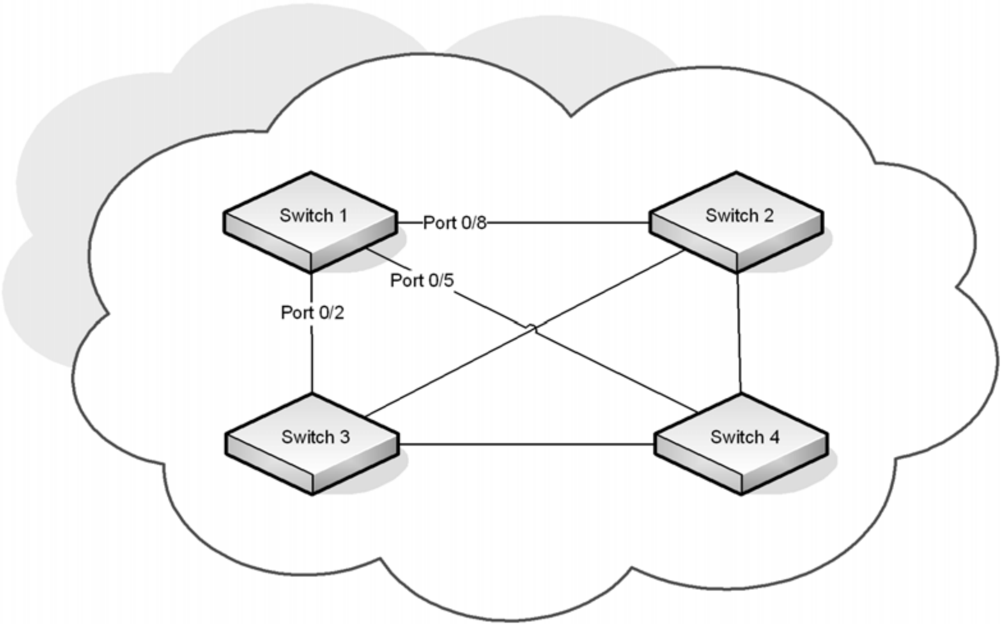
5.5.2 UDLD and LAG Interfaces

UDLD is supported on individual physical ports that are members of a LAG. If any of the aggregated links becomes unidirectional, UDLD detects it and disables the individual link, but not the entire LAG. This improves the fault tolerance of the LAG.

5.5.3 Configuring UDLD

A network administrator decides to use the UDLD feature while building a loop-free topology with the use of STP. The administrator configures the ports on both side of the link to use UDLD in aggressive mode to ensure that ports with unidirectional links will be shut down, and no loops will be introduced into topology. This example shows the steps to configure UDLD on Switch 1 only. The same configuration must be performed on all ports that form partner links with the ports on Switch 1.

Figure 15: UDLD Configuration Example



To configure the ports on Switch 1:

14. Globally enable UDLD on the switch.

```
(Routing) #configure
(Routing) (Config)#udld enable
```

15. Enter interface configuration mode for the ports that are connected to other switches and enable UDLD on the ports.

```
(Routing) (Config)#interface 0/8,0/11,0/20
(Routing) (Interface 0/8,0/11,0/20)#udld enable
```

16. Configure the UDLD mode on the ports to be aggressive.

```
(Routing) (Interface 0/8,0/11,0/20)#udld port aggressive
(Routing) (Interface 0/8,0/11,0/20)#exit
(Routing) (Config)#exit
```

17. After configuring UDLD on Switch 2, Switch, 3, and Switch 4, view the UDLD status for the ports.

```
(Routing) #show udld all

Port       Admin Mode   UDLD Mode      UDLD Status
-----      ----------   -----------    --------------
0/1        Disabled     Normal         Not Applicable
0/8        Enabled      Aggressive     Bidirectional
0/3        Disabled     Normal         Not Applicable
0/4        Disabled     Normal         Not Applicable
0/8        Enabled      Aggressive     Bidirectional
0/6        Disabled     Normal         Not Applicable
0/7        Disabled     Normal         Not Applicable
0/8        Enabled      Aggressive     Bidirectional
0/9        Disabled     Normal         Not Applicable
--More-- or (q)uit
```

NOTE: If a port has become disabled by the UDLD feature and you want to re-enable the port, use the `udld reset` command in Privileged EXEC mode.

5.6 Port Mirroring

Port mirroring is used to monitor the network traffic that a port sends and receives. The Port Mirroring feature creates a copy of the traffic that the source port handles and sends it to a destination port. The source port is the port that is being monitored. The destination port is monitoring the source port. The destination port is where you would connect a network protocol analyzer to learn more about the traffic that is handled by the source port.

A port monitoring session includes one or more source ports that mirror traffic to a single destination port. EFOS software supports a single port monitoring session. LAGs (port channels) cannot be used as the source or destination ports.

For each source port, you can specify whether to mirror ingress traffic (traffic the port receives, or RX), egress traffic (traffic the port sends, or TX), or both ingress and egress traffic.

The packet that is copied to the destination port is in the same format as the original packet on the wire. This means that if the mirror is copying a received packet, the copied packet is VLAN tagged or untagged as it was received on the source port. If the mirror is copying a transmitted packet, the copied packet is VLAN tagged or untagged as it is being transmitted on the source port.

After you configure the port mirroring session, you can enable or disable the administrative mode of the session to start or stop the probe port from receiving mirrored traffic.

5.6.1 Configuring Port Mirroring

In this example, traffic from ports 1 and 4 is mirrored to probe port 10.

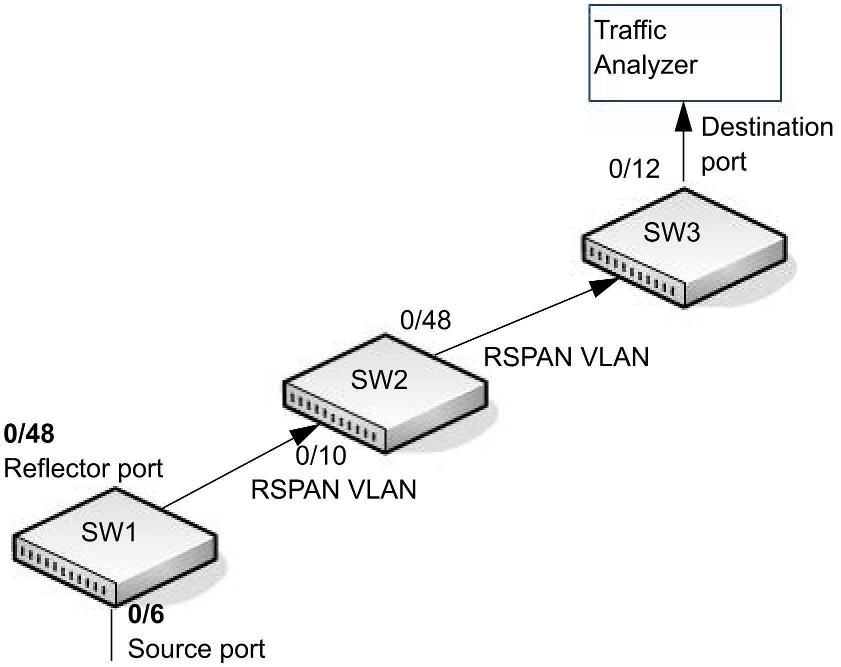
1. Configure the source ports. Traffic received and transmitted on by these ports will be mirrored.
```
(Routing) #configure
(Routing) (Config)#monitor session 1 source interface 0/1
(Routing) (Config)#monitor session 1 source interface 0/4
```
2. Configure the destination (probe) port.
```
(Routing) (Config)#monitor session 1 destination interface 0/10
```
3. Enable port mirroring on the switch.
```
(Routing) (Config)#monitor session 1 mode
(Routing) (Config)#exit
```
4. View summary information about the port mirroring configuration.
```
(Routing) #show monitor session 1

Session Admin   Probe   Src  Mirrored Ref.    Src   Dst   Type  IP      MAC
ID      Mode    Port    VLAN Port     Port    RVLAN RVLAN       ACL     ACL
------- ------- ------- ---- -------- ------- ----- ----- ----  ------- -------
1       Enable  0/10         0/1                          Rx,Tx
                             0/4                          Rx,Tx
```

5.6.2 Configuring RSPAN

This example mirrors traffic from port 6 on a source switch (SW1) to a probe port on a remote switch (port 12 on SW3). The mirrored traffic is carried in the RSPAN VLAN and VLAN 100, which traverses an intermediate switch (SW2). The commands in this example show how to configure port mirroring on the source, intermediate, and destination switches.

Figure 16 provides a visual overview of the RSPAN configuration example.

Figure 16: RSPAN Configuration Example



5.6.2.1 Configuration on the Source Switch (SW1)

To configure the source switch:

1. Access the VLAN configuration mode and create VLAN 100, which will be the RSPAN VLAN.
```
(Routing) #vlan database
(Routing) (Vlan)#vlan 100
(Routing) (Vlan)#exit
```
2. Configure VLAN 100 as the RSPAN VLAN.
```
(Routing) #configure
(Routing) (Config)#vlan 100
(Routing) (Config) (vlan 100)#remote-span
(Routing) (Config) (vlan 100)#exit
```
3. Configure the RSPAN VLAN as the destination port and the reflector port as port 0/48.
```
(Routing) #configure
(Routing) (Config)#monitor session 1 destination remote vlan 100 reflector-port 0/48
```
4. Configure the source interface port as port 0/6.
```
(Routing) (Config)#monitor session 1 source interface 0/6
```
5. Enable the port mirroring session on the switch.
```
(Routing) (Config)#monitor session 1 mode
```

```
(Routing) #exit
```

5.6.2.2 Configuration on the Intermediate Switch (SW2)

To configure the intermediate switch:

1. Access the VLAN configuration mode and create VLAN 100.
   ```
   (Routing) #vlan database
   (Routing) (Vlan)#vlan 100
   (Routing) (Vlan)#exit
   ```
2. Enable RSPAN on vlan 100.
   ```
   (Routing) #configure
   (Routing) (Config)#vlan 100
   (Routing) (Config) (vlan 100)#remote-span
   (Routing) (Config) (vlan 100)#exit
   ```
3. Configure VLAN participation so the interface is always a member of the VLAN.
   ```
   (Routing) (Config)#vlan participation include 100
   (Routing) (Config)#interface 0/10
   ```
4. Enable VLAN tagging on the interface.
   ```
   (Routing) (Config)#vlan tagging 100
   (Routing) (Config)#exit
   ```
5. Configure VLAN participation so the interface is always a member of the VLAN.
   ```
   (Routing) (Config)#vlan participation include 100
   (Routing) (Config)#interface 0/48
   (Routing) (Config)#exit
   ```

5.6.2.3 Configuration on the Destination Switch (SW3)

To configure the destination switch:

1. Access the VLAN configuration mode and create VLAN 100.
   ```
   (Routing) #vlan database
   (Routing) (Vlan)#vlan 100
   (Routing) (Vlan)#exit
   ```
2. Enable RSPAN on vlan 100.
   ```
   (Routing) #configure
   (Routing) (Config)#vlan 100
   (Routing) (Config) (vlan 100)#remote-span
   (Routing) (Config) (vlan 100)#exit
   ```
3. Configure the RSPAN VLAN as the source interface for the port mirroring session.
   ```
   (Routing) #configure
   (Routing) (Config)#monitor session 1 source remote vlan 100
   ```
4. Configure the destination port as port 0/12. This is the probe port that is attached to a network traffic analyzer.
   ```
   (Routing) (Config)#monitor session 1 destination interface 0/12
   ```
5. Enable the port mirroring session on the switch.
   ```
   (Routing) (Config)#monitor session 1 mode
   (Routing) (Config)#exit
   ```

5.6.3 VLAN-Based Mirroring

In this example, traffic from all ports that are members of VLAN 10 is mirrored to port 0/18.

To configure VLAN based mirroring:

1. Access VLAN Database mode and create VLAN 10.

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 10
(Routing) (Vlan)#exit
```

2. Configure the destination interface port as port 0/18.

```
(Routing) #configure
(Routing) (Config)#monitor session 1 destination interface 0/18
```

3. Configure VLAN 10 as the source interface for the port mirroring session.

```
(Routing) (Config)#monitor session 1 source vlan 10
```

4. Enable the port mirroring session on the switch.

```
(Routing) (Config)#monitor session 1 mode
(Routing) (Config)#exit
```

5.6.4 Flow-Based Mirroring

In this example, traffic from port 1 is mirrored to port 18 if it matches the criteria defined in the IP ACL or MAC ACL that are associated with the port mirroring session.

To configure flow based mirroring:

1. Create the extended IP access list IPACL.

```
(Routing) #configure
(Routing) (Config)#ip access-list IPACL
(Routing) (Config)#permit ip 1.1.1.1 0.0.0.0 any
(Routing) (Config)#exit
```

2. Create the mac access list MACL.

```
(Routing) #configure
(Routing) (Config)#mac access-list extended MACL
(Routing) (Config)#permit 00:00:00:00:00:11 00:00:00:00:00:00 any
(Routing) (Config)#exit
```

3. Configure the destination port as port 0/18.

```
(Routing) #monitor session 1 destination interface 0/18
```

4. Configure the source port as port 0/2.

```
(Routing) #monitor session 1 source interface 0/2
```

5. Enable the port mirroring session.

```
(Routing) #monitor session 1 mode
```

6. To filter L3 traffic so only flows that match the rules in the IP ACL called IPACL are mirrored to the destination port, add the IPACL ACL.

```
(Routing) #monitor session 1 filter ip access-group IPACL
```

7. To filter L2 traffic so only flows that match the rules in the MAC-based ACL called MACL are mirrored to the destination port, add the MACL ACL.

```
(Routing) #monitor session 1 filter mac access-group MACL
(Routing) #exit
```

5.6.5 Configuring ERSPAN

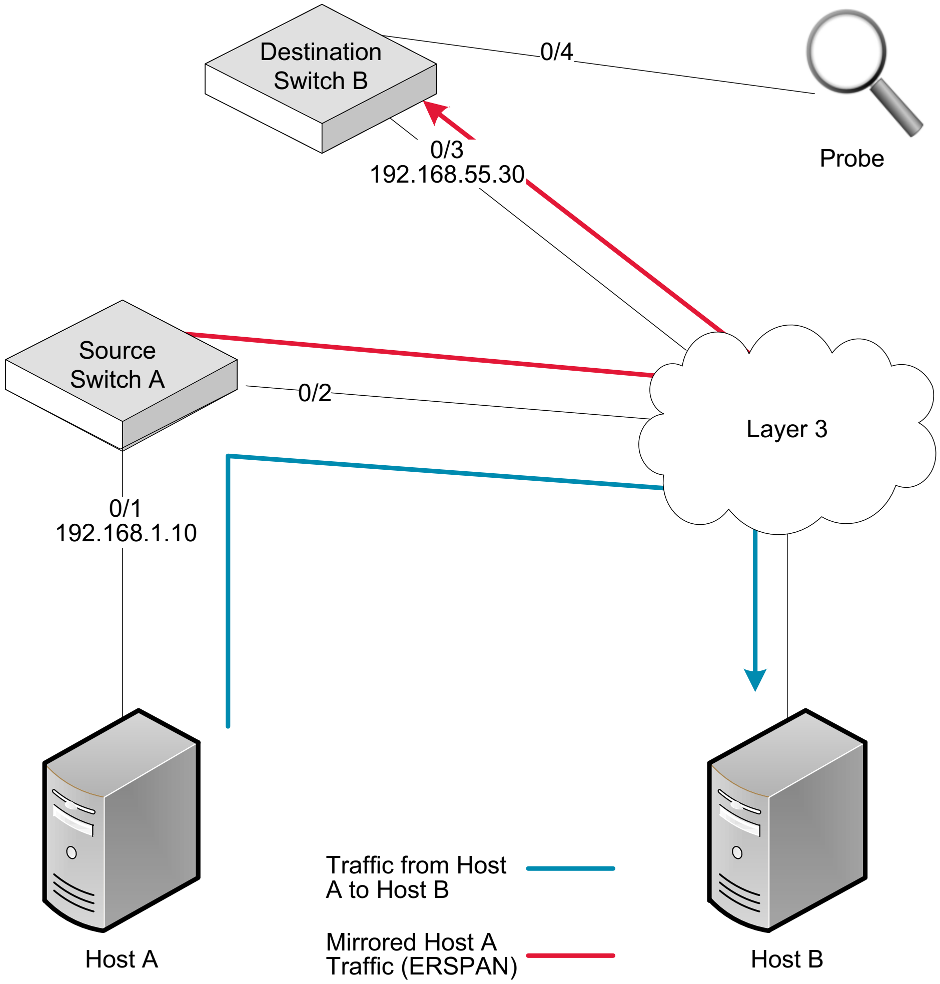
The Encapsulated Remote Port Analyzer (ERSPAN) feature allows mirroring collection points to be located anywhere across a routed network. This is achieved by encapsulating L2 mirrored packets using the Generic Routing Encapsulation (GRE) protocol with IP delivery. After a packet has been encapsulated, it can be forwarded throughout the L3-routed network.

Figure 17 illustrates an example ERSPAN, where Host A sends traffic to Host B.

This traffic will simply be captured, encapsulated in GRE by Source Switch A and routed over Layer 3 domain to Destination Switch B. A sniffing station on Destination Switch B attached to 0/4 will see the captured packets.

Any intermediate devices in the mirror path will merely forward the packet as normal, and no packet modification will occur.

Figure 17: ERSPAN Configuration Example



The following parameters are configured on Source Switch A:

- Source ports (i.e. the traffic on this port is mirrored)
- ERSPAN destination IPv4 address
- ERSPAN origin IPv4 address
- ERSPAN session ID

- ERSPAN reflector port

The following parameters are configured on Destination Switch B:

- ERSPAN destination IPv4 address (as source)
- ERSPAN session ID
- Probe port

NOTE: Note the following:

- The ERSPAN mirrored packet is encapsulated with an IPv4 GRE tunnel and with a dedicated ERSPAN encapsulation header by the source device.
- StrataXGS platforms do not support decapsulation of the IP/GRE header. StrataXGS platforms do not add the dedicated ERSPAN encapsulation header to the mirrored packet.

5.6.5.1 Configuring Source Switch A

The commands in this example show how to configure Source Switch A with the settings shown in Figure 17, ERSPAN Configuration Example.

To configure the switch:

1. Configure the ERSPAN source session number with a session ID of 1 and enter ERSPAN Source Session Configuration mode.
```
(Switch)# configure
(Switch) (Config)#monitor session 1 type erspan-source
```
2. Configure port 0/1 on Source Switch A as the source port. The traffic on this port is mirrored to the probe port connected to Destination Switch B. Traffic on this port in both the TX and RX direction is mirrored.
```
(Switch) (config-erspan-src)#source interface 0/1
```
3. Enter the ERSPAN Source Session Destination Configuration mode and configure the ERSPAN destination IPv4 address. The ERSPAN destination IPv4 address is the IP address of port 0/3 on Destination Switch B.
```
(Switch) (config-erspan-src)#destination
(Switch) (config-erspan-src-dst)#ip address 192.168.55.30
```
4. Configure the IP address associated with port 0/1 on Source Switch A as the ERSPAN origin IPv4 address.
```
(Switch) (config-erspan-src-dst)#origin ip address 192.168.1.10
```
5. Configure the ERSPAN session ID, which is the flow ID number used by the source and destination sessions to identify the ERSPAN traffic. In this example, the ID is 100.
```
(Switch) (config-erspan-src-dst)#erspan-id 100
```
6. Configure port 2 as the reflector port.
```
(Switch) (config-erspan-src-dst)#reflector-port 0/2
```
7. Exit to Global Config mode and administratively enable the ERSPAN port mirroring session on Source Switch A.
```
(Switch) (config-erspan-src-dst)#exit
(Switch) (config-erspan-src)#exit
(Switch) (Config)#monitor session 1 mode
```
8. Exit to Privileged Exec mode and view the current configuration for the port monitoring session.
```
(Switch) (Config)#exit

(Switch) #show monitor session 1

Session ID..................................... 1
Admin Mode..................................... Enable
```

```
Probe Port....................................
Remove RSPAN Tag..............................
Source VLAN...................................
Mirrored Port(s).............................. 0/1(Rx,Tx)
Reflector Port................................ 0/2
Source RSPAN VLAN.............................
Destination RSPAN VLAN........................
Source ERSPAN Flow ID.........................
Source ERSPAN IP Address......................
Destination ERSPAN Flow ID.................... 100
Destination ERSPAN IP Address................. 192.168.55.30
Destination ERSPAN Origin IP.................. 192.168.1.10
Destination ERSPAN IP TTL..................... 64
Destination ERSPAN IP DSCP.................... 0
Destination ERSPAN IP Precedence.............. 0
IP ACL........................................
MAC ACL.......................................
```

5.6.5.2 Configuring Destination Switch B

The commands in this example show how to configure Destination Switch B with the settings shown in Figure 17, ERSPAN Configuration Example.

To configure the switch:

1. Configure the ERSPAN destination session number with a session ID of 1 and enter ERSPAN Destination Session Configuration mode.
```
(Switch)# configure
(Switch) (Config)#monitor session 1 type erspan-destination
```
2. Configure port 0/4 as the destination interface (probe port) for the ERSPAN monitor session.
```
(Switch) (config-erspan-dst)#destination interface 0/4
```
3. Enter the ERSPAN Destination Session Source Configuration mode and configure the IP address associated with port 0/3 as the ERSPAN destination IPv4 address (as source). This interface is the source of traffic that an ERSPAN destination session sends to the destination.
```
(Switch) (config-erspan-dst)#source
(Switch) (config-erspan-dst-src)#ip address 192.168.55.30
```
4. Configure the ERSPAN session ID, which is the flow ID number used by the source and destination sessions to identify the ERSPAN traffic. In this example, the ID is 100.
```
(Switch) (config-erspan-dst-src)#erspan-id 100
```
5. Exit to Global Config mode and administratively enable the ERSPAN port mirroring session on Destination Switch B.
```
(Switch) (config-erspan-dst-src)#exit
(Switch) (config-erspan-dst)#exit
(Switch) (Config)#monitor session 1 mode
```
6. Exit to Privileged Exec mode and view the current configuration for the port monitoring session.
```
(Switch) (Config)#exit

(Switch) #show monitor session 1

Session ID.................................... 1
Admin Mode.................................... Enable
Probe Port.................................... 0/4
Remove RSPAN Tag.............................. False
Source VLAN...................................
```

```
Mirrored Port(s)...............................
Reflector Port.................................
Source RSPAN VLAN..............................
Destination RSPAN VLAN.........................
Source ERSPAN Flow ID.......................... 100
Source ERSPAN IP Address....................... 192.168.55.30
Destination ERSPAN Flow ID.....................
Destination ERSPAN IP Address..................
Destination ERSPAN Origin IP...................
Destination ERSPAN IP TTL......................
Destination ERSPAN IP DSCP.....................
Destination ERSPAN IP Precedence...............
IP ACL.........................................
MAC ACL........................................
```

5.7 Spanning Tree Protocol

Spanning Tree Protocol (STP) is a layer 2 protocol that provides a tree topology for switches on a bridged LAN. STP allows a network to have redundant paths without the risk of network loops. STP uses the spanning-tree algorithm to provide a single path between end stations on a network.

EFOS software supports Classic STP, Multiple STP, and Rapid STP.

5.7.1 Classic STP, Multiple STP, and Rapid STP

Classic STP provides a single path between end stations, avoiding and eliminating loops. Multiple Spanning Tree Protocol (MSTP) is specified in IEEE 802.1s and supports multiple instances of Spanning Tree to efficiently channel VLAN traffic over different interfaces. Each instance of the Spanning Tree behaves in the manner specified in IEEE 802.1w, Rapid Spanning Tree (RSTP), with slight modifications in the working but not the end effect (chief among the effects, is the rapid transitioning of the port to Forwarding). The difference between the RSTP and the traditional STP (IEEE 802.1D) is the ability to configure and recognize full-duplex connectivity and ports which are connected to end stations, resulting in rapid transitioning of the port to the Forwarding state and the suppression of Topology Change Notifications.

MSTP is compatible to both RSTP and STP. It behaves appropriately to STP and RSTP bridges. A MSTP bridge can be configured to behave entirely as a RSTP bridge or a STP bridge.

5.7.2 STP Operation

The switches (bridges) that participate in the spanning tree elect a switch to be the root bridge for the spanning tree. The root bridge is the switch with the lowest bridge ID, which is computed from the unique identifier of the bridge and its configurable priority number. When two switches have an equal bridge ID value, the switch with the lowest MAC address is the root bridge.

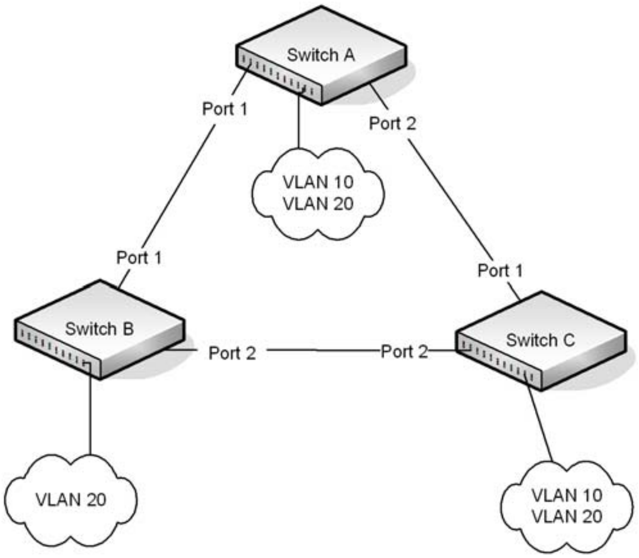
After the root bridge is elected, each switch finds the lowest-cost path to the root bridge. The port that connects the switch to the lowest-cost path is the root port on the switch. The switches in the spanning tree also determine which ports have the lowest-path cost for each segment. These ports are the designated ports. Only the root ports and designated ports are placed in a forwarding state to send and receive traffic. All other ports are put into a blocked state to prevent redundant paths that might cause loops.

To determine the root path costs and maintain topology information, switches that participate in the spanning tree use Bridge Protocol Data Units (BPDUs) to exchange information.

5.7.2.1 MSTP in the Network

In the following diagram of a small 802.1D bridged network, STP is necessary to create an environment with full connectivity and without loops.

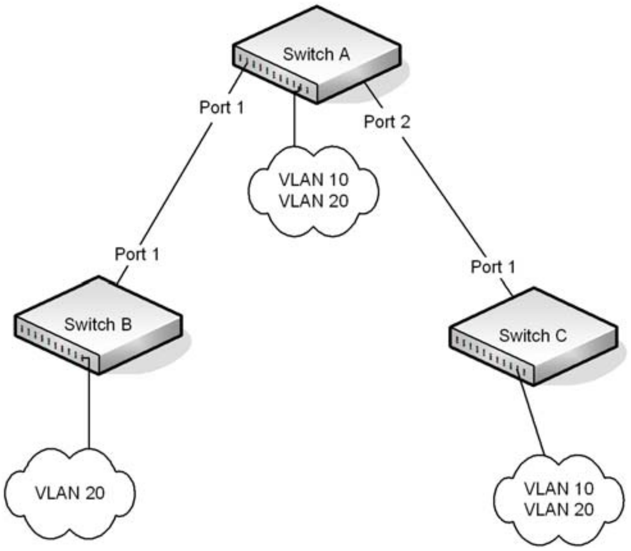
Figure 18: STP in a Small Bridged Network



Assume that Switch A is elected to be the Root Bridge, and Port 1 on Switch B and Switch C are calculated to be the root ports for those bridges, Port 2 on Switch B and Switch C would be placed into the Blocking state. This creates a loop-free topology. End stations in VLAN 10 can talk to other devices in VLAN 10, and end stations in VLAN 20 have a single path to communicate with other VLAN 20 devices.

Figure 19 shows the logical single STP network topology.

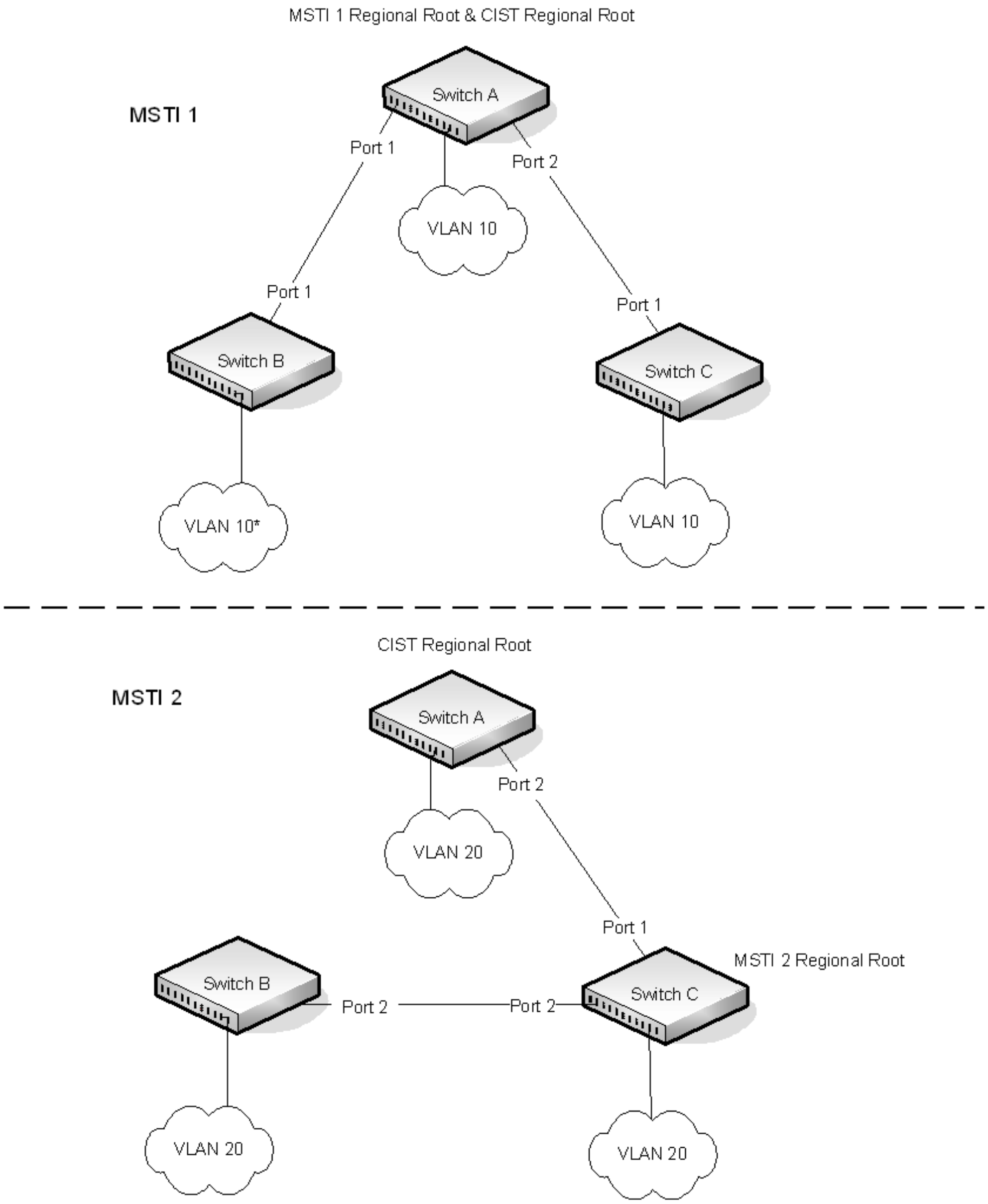
Figure 19: Single STP Topology



For VLAN 10 this single STP topology is fine and presents no limitations or inefficiencies. On the other hand, VLAN 20's traffic pattern is inefficient. All frames from Switch B will have to traverse a path through Switch A before arriving at Switch C. If the Port 2 on Switch B and Switch C could be used, these inefficiencies could be eliminated. MSTP does just that, by allowing the configuration of MSTIs based upon a VLAN or groups of VLANs. In this simple case, VLAN 10 could be associated with Multiple Spanning Tree Instance (MSTI)1 with an active topology similar to Figure 20, Logical MSTP Environment and VLAN 20 could be associated with MSTI 2 where Port 1 on both Switch A and Switch B begin discarding and all others forwarding. This simple modification creates an active topology with a better distribution of network traffic and an increase in available bandwidth.

The logical representation of the MSTP environment for these three switches is shown in Figure 20.

Figure 20: Logical MSTP Environment



For MSTP to correctly establish the different MSTIs as above, some additional changes are required. For example, the configuration would have to be the same on each and every bridge. That means that Switch B would have to add VLAN 10 to its list of supported VLANs (shown in Figure 20, Logical MSTP Environment with a *). This is necessary with MSTP to allow the formation of Regions made up of all switches that exchange the same MST Configuration Identifier. It is within only these MST Regions that multiple instances can exist. It will also allow the election of Regional Root Bridges for each instance. One common and internal spanning tree (CIST) Regional Root for the CIST and an MSTI Regional Root Bridge per instance will enable the possibility of alternate paths through each Region. Above Switch A is elected as both the MSTI 1 Regional Root and the CIST Regional Root Bridge, and after adjusting the Bridge Priority on Switch C in MSTI 2, it would be elected as the MSTI 2 Regional Root.

To further illustrate the full connectivity in an MSTP active topology, the following rules apply:

1. Each Bridge or LAN is in only one Region.
2. Every frame is associated with only one VID.
3. Frames are allocated either to the IST or MSTI within any given Region.
4. The internal spanning tree (IST) and each MSTI provides full and simple connectivity between all LANs and Bridges in a Region.
5. All Bridges within a Region reach a consistent agreement as to which ports interconnect that Region to a different Region and label those as Boundary Ports.
6. At the Boundary Ports, frames allocated to the CIST or MSTIs are forwarded or not forwarded alike.
7. The CIST provides full and simple connectivity between all LANs and Bridges in the network.

5.7.3 Optional STP Features

EFOS software supports the following optional STP features:

- BPDU flooding
- Edge Port
- BPDU filtering
- Root guard
- Loop guard
- BPDU protection

5.7.3.1 BPDU Flooding

The BPDU flooding feature determines the behavior of the switch when it receives a BPDU on a port that is disabled for spanning tree. If BPDU flooding is configured, the switch will flood the received BPDU to all the ports on the switch which are similarly disabled for spanning tree.

5.7.3.2 Edge Port

The Edge Port feature reduces the STP convergence time by allowing ports that are connected to end devices (such as a desktop computer, printer, or file server) to transition to the forwarding state without going through the listening and learning states.

5.7.3.3 BPDU Filtering

Ports that have the Edge Port feature enabled continue to transmit BPDUs. The BPDU filtering feature prevents ports configured as edge ports from sending BPDUs.

If BPDU filtering is configured globally on the switch, the feature is automatically enabled on all operational ports where the Edge Port feature is enabled. These ports are typically connected to hosts that drop BPDUs. However, if an operational edge port receives a BPDU, the BPDU filtering feature disables the Edge Port feature and allows the port to participate in the spanning-tree calculation.

Enabling BPDU filtering on a specific port prevents the port from sending BPDUs and allows the port to drop any BPDUs it receives.

5.7.3.4 Root Guard

Enabling root guard on a port ensures that the port does not become a root port or a blocked port. When a switch is elected as the root bridge, all ports are designated ports unless two or more ports of the root bridge are connected together. If the switch receives superior STP BPDUs on a root-guard enabled port, the root guard feature moves this port to a root-inconsistent STP state, which is effectively equal to a listening state. No traffic is forwarded across this port. In this way, the root guard feature enforces the position of the root bridge.

When the STP mode is MSTP, the port may be a designated port in one MSTI and an alternate port in the CIST, etc. Root guard is a per port (not a per port per instance command) configuration, so all the MSTP instances this port participates in should not be in a root role.

5.7.3.5 Loop Guard

Loop guard protects a network from forwarding loops induced by BPDU packet loss. The reasons for failing to receive packets are numerous, including heavy traffic, software problems, incorrect configuration, and unidirectional link failure. When a non-designated port no longer receives BPDUs, the spanning-tree algorithm considers that this link is loop free and begins transitioning the link from blocking to forwarding. Once in forwarding state, the link may create a loop in the network.

Enabling loop guard prevents such accidental loops. When a port is no longer receiving BPDUs and the max age timer expires, the port is moved to a *loop-inconsistent blocking state*. In the loop-inconsistent blocking state, traffic is not forwarded so the port behaves as if it is in the blocking state. The port will remain in this state until it receives a BPDU. It will then transition through the normal spanning tree states based on the information in the received BPDU.

NOTE: Loop Guard should be configured only on non-designated ports. These include ports in alternate or backup roles. Root ports and designated ports should not have loop guard enabled so that they can forward traffic.

5.7.3.6 BPDU Protection

When the switch is used as an access layer device, most ports function as edge ports that connect to a device such as a desktop computer or file server. The port has a single, direct connection and is configured as an edge port to implement the fast transition to a forwarding state. When the port receives a BPDU packet, the system sets it to non-edge port and recalculates the spanning tree, which causes network topology flapping. In normal cases, these ports do not receive any BPDU packets. However, someone may forge BPDU to maliciously attack the switch and cause network flapping.

BPDU protection can be enabled in RSTP to prevent such attacks. When BPDU protection is enabled, the switch disables an edge port that has received BPDU and notifies the network manager about it.

5.7.4 PVRSTP

EFOS software supports both Rapid Spanning Tree Per VLAN (PVRSTP) and Spanning Tree Per VLAN (PVSTP) with a high degree of interoperability with other vendor implementations, such as Cisco's PVST+ and RPVST+. PVRSTP is the IEEE 802.1w (RSTP) standard implemented per VLAN. A single instance of rapid spanning tree (RSTP) runs on each configured VLAN. Each RSTP instance on a VLAN has a root switch. The PVRSTP protocol state machine, port roles, port states, and timers are similar to those defined for RSTP. PVRSTP embeds the DRC and IndirectLink Fast Rapid Convergence (IRC) features, which cannot be disabled.

PVSTP is the IEEE 802.1D (STP) standard implemented per VLAN. The PVSTP-related state machine, roles, and timers are similar to those defined for STP. PVSTP does not have the DirectLink Rapid Convergence (DRC) or IndirectLink Rapid Convergence (IRC) features enabled by default. These features can be enabled by the switch administrator.

The switch spanning tree configuration is global in nature. Enabling PVRSTP disables other spanning tree modes on the switch. The switch cannot operate with some ports configured to operate in standard spanning tree mode and others to operate in PVRSTP mode. However, PVRSTP has fallback modes for compatibility with standards-based versions of spanning tree.

Access Ports—For an access port, normal IEEE BPDUs will be received and sent, though PVSTP or PVRSTP is enabled on the switch. BPDUs received on the access port will be associated with the CST instance.

Trunk Ports—If the native VLAN on an IEEE 802.1Q trunk is VLAN 1:

- VLAN 1 STP BPDUs are sent to the IEEE STP MAC address (0180.c200.0000), untagged.
- VLAN 1 STP BPDUs are also sent to the SSTP MAC address, untagged.
- Non-VLAN 1 STP BPDUs are sent to the SSTP MAC address (also called the Shared Spanning Tree Protocol [SSTP] MAC address, 0100.0ccc.cccd), tagged with a corresponding IEEE 802.1Q VLAN tag.

If the native VLAN on an IEEE 802.1Q trunk is not VLAN 1:

- VLAN 1 STP BPDUs are sent to the SSTP MAC address, tagged with a corresponding IEEE 802.1Q VLAN tag.
- VLAN 1 STP BPDUs are also sent to the IEEE STP MAC address on the Native VLAN of the IEEE 802.1Q trunk, untagged.
- Non-VLAN 1 STP BPDUs are sent to the SSTP MAC address, tagged with a corresponding IEEE 802.1Q VLAN tag.

Per port counters are provided for PVSTP and PVRSTP. In PVSTP mode, per port counters are incremented for STP BPDUs received and transmitted. In addition to these, existing per port counters for STP BPDU reception and transmission are also incremented as STP BPDUs are received and transmitted for the native VLAN. Counters accounted are per port only, not per-port per-VLAN. There is a provision to clear these counters, either per port or for all ports at once. When the counters reach the maximum value, they roll over for the next BPDU processed. To view the PVSTP and PVRSTP counters for an interface, use the `show interface ethernet slot/port` command.

Only IEEE STP BPDUs are used for convergence on VLAN 1, hence the STP BPDUs received counter is not incremented for VLAN 1.

5.7.4.1 DirectLink Rapid Convergence

The DirectLink Rapid Convergence (DRC) feature is designed for an access-layer switch that has redundant blocked uplinks. It operates on ports blocked by spanning tree. DRC can be configured for the entire switch; it cannot be enabled for individual VLANs.

The DRC feature is based on the concept of an uplink group. An uplink group consists of all the ports that provide a path to the root bridge (the root port and any blocked ports). If the root port fails, the blocked port with next lowest cost from the uplink group is selected and immediately put in the forwarding state without going through the standard spanning tree listening and learning states.

To accelerate convergence time once DRC has switched over to a new root port, the switch transmits dummy packets out the new root port, with the source MAC addresses taken from its forwarding table. The destination address is an SSTP MAC address that ensures that the packet is flooded on the whole network. The packets update the forwarding tables on the other upstream switches. The rate at which the dummy multicasts are sent can be configured by the administrator.

5.7.4.1.1 DRC and Link Up Events

In the event of failure of the primary uplink, a replacement uplink is immediately selected from the uplink group and put into the forwarding state. If another port is enabled that, in accordance with STP rules, should become the primary uplink (root port), the switch delays migrating to the new port for twice the forwarding delay. The purpose of this delay is two-fold:

- Stability—If the primary uplink is flapping, re-enabling the link immediately can introduce additional instability into the network.
- Reduced Traffic Loss—DRC moves a port into the forwarding state as soon as it is up, but the connected port obeys the usual STP rules; i.e. it goes through the listening and learning stages, which take 15 seconds each by default. Delaying the switchover allows the connected port to go to through the listening and learning states while the switch is still transmitting packets on the original uplink.

The optimal behavior is to keep the current uplink active and hold the new port in the blocked state for twice the forwarding delay.

5.7.4.2 IndirectLink Rapid Convergence Feature

To handle indirect link failure, the RSTP standard requires that a switch passively wait for "max_age" seconds once a topology change has been detected. IndirectLink Rapid Convergence (IRC) handles these failures in two phases:

- Rapid detection of an indirect link failure. Tracking the inferior BPDUs that a designated bridge detects when it transmits a direct link failure indicates that a failure has occurred elsewhere in the network.
- Performing an immediate check if the BPDU information stored on a port is still valid. This is implemented with a new protocol data unit (PDU) and the Root Link Query message (RLQ).

Receiving an inferior BPDU on a port from the designated bridge indicates that one of the following has occurred on the designated bridge:

- The path to the root has been lost and the switch starts to advertise a root with a numerically higher bridge ID (worse root) than the local switch.
- The path cost to the root has increased above the path cost of the local switch.

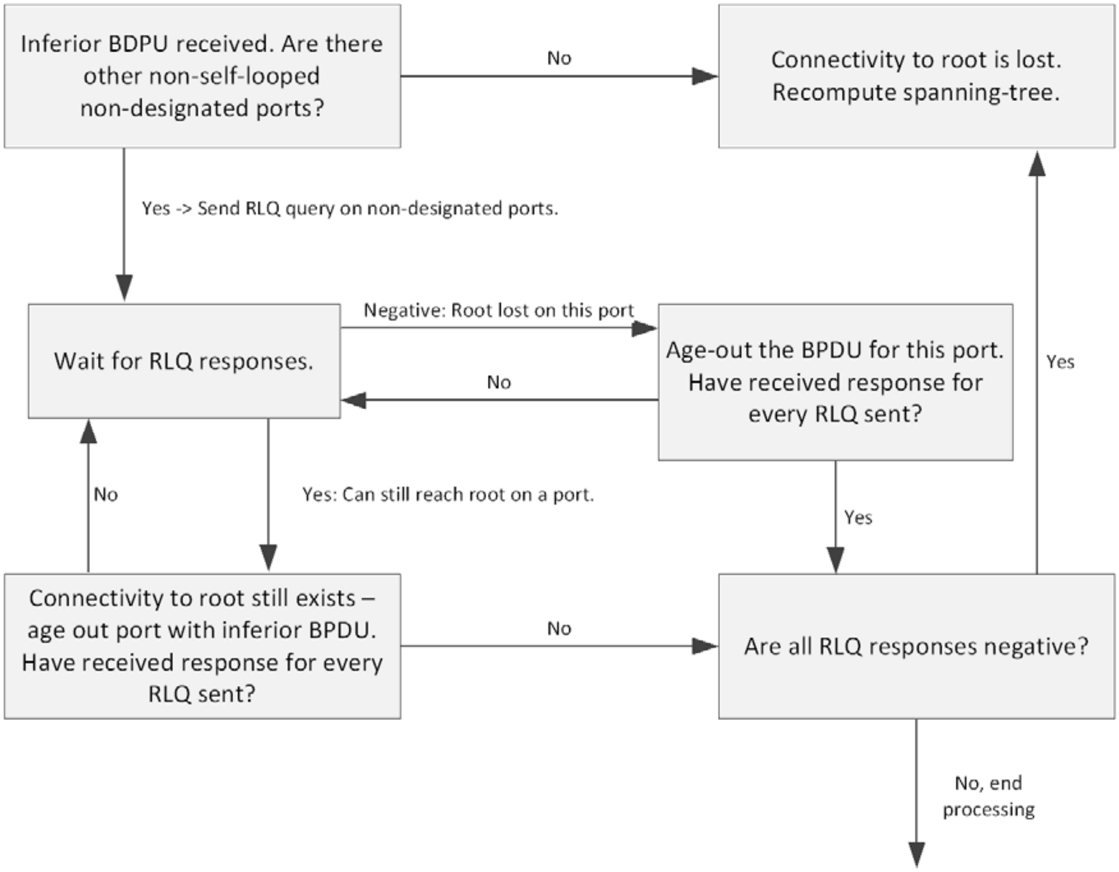
IEEE 802.1D behavior is to ignore inferior BPDUs. IRC retains the inferior BPDUs sent by the designated bridge and processes them to determine if a failure has occurred on the path to the root. In this case, it must age-out at least one port. This process occurs only in the case that a bridge in the network detects a direct link failure.

The switch tracks inferior BPDUs sent by the designated bridge only, since this is the BPDU that is stored for the port. If, for instance, a newly inserted bridge starts to send inferior BPDUs, it does not start the IRC feature.

5.7.4.2.1 Reacting to Indirect Link Failures

When an inferior BPDU is received on a non-designated port, phase 2 of IRC processing starts. An RLQ PDU is transmitted on all non-designated ports except the port where the inferior BPDU was received and self-looped ports. This action is intended to verify that the switch can still receive from the root on ports that should have a path to the root. The port where the switch received the inferior BPDU is excluded because it already failed; self-looped and designated ports are eliminated as they do not have a path to the root.

Figure 21: IRC Flow


Inferior BDPU received. Are there other non-self-looped non-designated ports?
No
Connectivity to root is lost. Recompute spanning-tree.
Yes -> Send RLQ query on non-designated ports.
Wait for RLQ responses.
Negative: Root lost on this port
Age-out the BPDU for this port. Have received response for every RLQ sent?
No
Yes
No
Yes: Can still reach root on a port.
Yes
Connectivity to root still exists – age out port with inferior BPDU. Have received response for every RLQ sent?
No
Are all RLQ responses negative?
No, end processing

Upon receiving a negative RLQ response on a port, the port has lost connection to the root and the switch ages-out its BPDU. If all other non-designated ports received a negative answer, the switch has lost the root and restarts the STP calculation.

If the response confirms the switch can still access the root bridge via a particular port, it immediately ages-out the port on which the inferior BPDU was received.

If the switch only received responses with a root different from the original root, it has lost the root port and restarts the STP calculation immediately.

5.7.4.3 Interoperability Between PVSTP and PVRSTP Modes

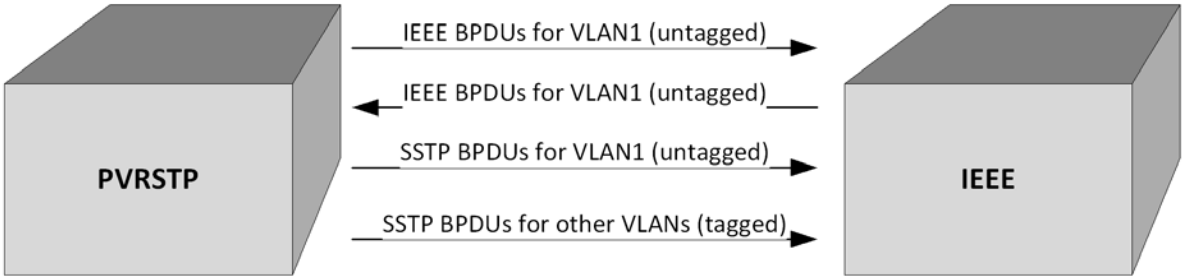
PVSTP is derived from 802.1D and PVRSTP is derived from 802.1w. The fallback mechanism is the same as between a standard 802.1D switch and a standard 802.1w switch. When a lower protocol version BPDU is received on a switch that runs a higher protocol version, the latter falls back to the lower version after its migration delay timer expires.

For example, an PVRSTP switch, when connected to PVSTP switch, falls back to the PVSTP protocol after the migration delay timer expires.

5.7.4.4 Interoperability With IEEE Spanning Tree Protocols

When a switch configured with PVRSTP receives IEEE standard RSTP BPDUs on a port, it responds with two versions of BPDUs on the port: SSTP formatted BPDUs and IEEE standard STP BPDUs. The IEEE standard BPDUs are processed by the peer switch running MSTP/RSTP, and the SSTP format BPDUs are flooded across the MSTP/RSTP domain.

Figure 22: PVRSTP and IEEE Spanning Tree Interoperability


PVRSTP
IEEE BPDUs for VLAN1 (untagged)
IEEE BPDUs for VLAN1 (untagged)
SSTP BPDUs for VLAN1 (untagged)
SSTP BPDUs for other VLANs (tagged)
IEEE

5.7.4.4.1 Common Spanning Tree

There are differences between the ways that MSTP and PVRSTP map spanning tree instances to VLANs: PVRSTP creates a spanning tree instance for each VLAN, and MSTP maps one or more VLANs to each MST instance. Where an PVRSTP region is connected to an MSTP region, the set of PVRSTP instances does not generally match the set of MST instances. Therefore, the PVRSTP region and the MSTP region communicate with each other on a single common spanning tree instance.

For the MSTP region, the MSTP instance communicates to the PVRSTP region using the CIST. For the PVRSTP region, switches use the VLAN 1 PVRSTP instance as the common spanning tree. On the link between the PVRSTP region and the MSTP region, the PVRSTP switch sends VLAN1 BPDUs in IEEE standard format, so they can be interpreted by the MSTP peers. Similarly, the PVRSTP switch processes incoming MSTP BPDUs as though they were BPDUs for the VLAN 1 PVRSTP instance.

If the PVRSTP switch ports connected to the MSTP switches are configured with a native VLAN, the PVRSTP switches are able to detect IEEE standard format BPDUs arriving from peer switches, incorporate them into the common spanning tree that operates in the native VLAN (VLAN 1), and transmit untagged STP or RSTP packets to the STP/RSTP peers, in addition to the SSTP format BPDUs.

5.7.4.4.2 SSTP BPDUs Flooding Across MST (CST) Regions

In addition to the IEEE standard RSTP or STP BPDUs that the PVRSTP switch sends to the MSTP (or RSTP or STP) region, the switch sends SSTP format BPDUs for VLAN 1, untagged. The MSTP switch does not interpret the SSTP BPDUs as standard BPDUs because they do not use the standard destination MAC address, so it makes no spanning tree decisions based on them. Instead, it floods the SSTP BPDUs over all ports in the corresponding VLAN. These SSTP BPDUs may be multicast over the MSTP region to other PVRSTP switches, which use them to maintain the VLAN 1 spanning tree topology across the MSTP (non-PVRSTP) switches.

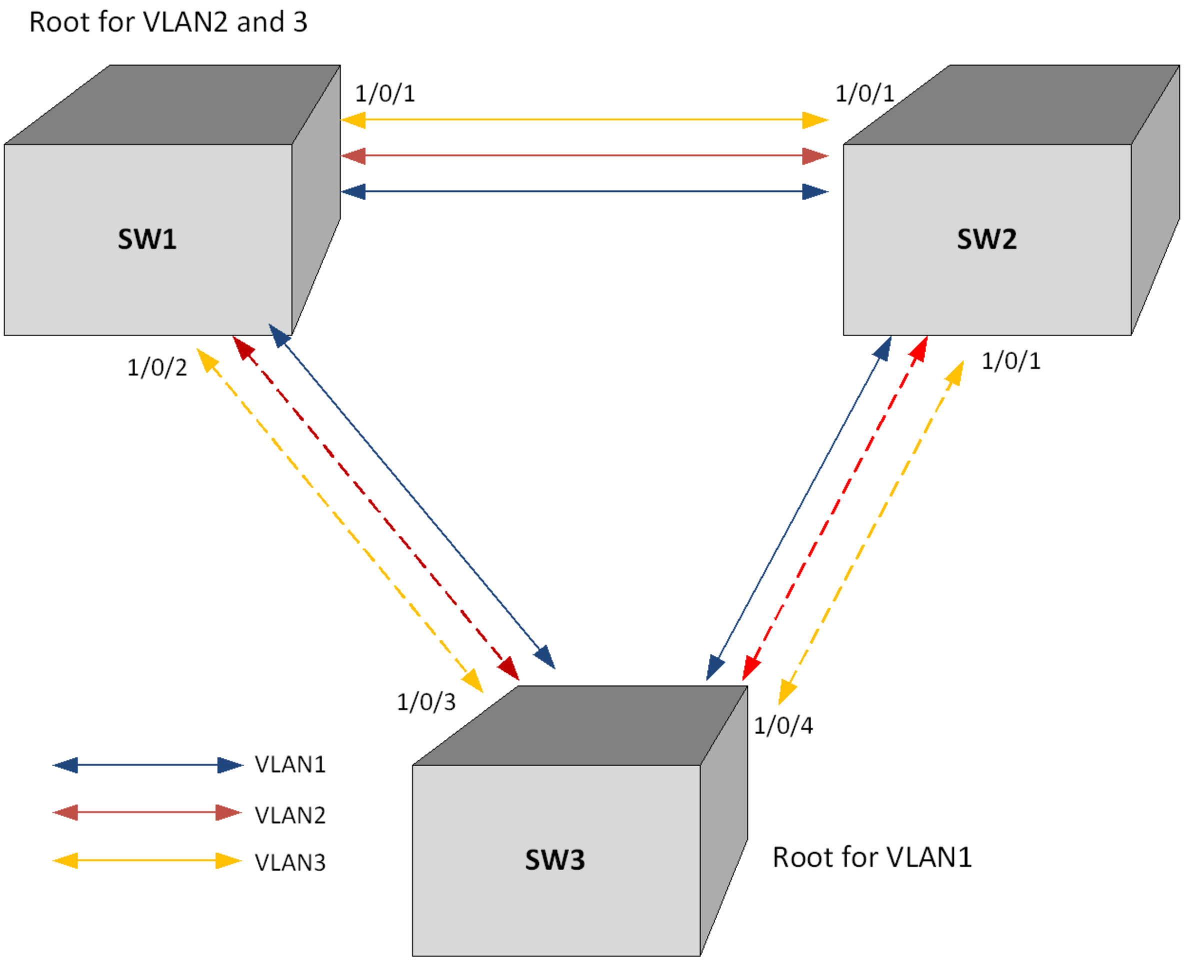
The PVRSTP switches also send SSTP format BPDUs for the other (non-VLAN 1) PVRSTP instances into the MSTP region, tagged with the VID of their associated VLANs. These SSTP packets are also be multicast by the switches in the MSTP region, and will reach any other PVRSTP regions connected to the MSTP region. The switches in the remote PVRSTP regions receive and process them as normal PVRSTP BPDUs. Thus, PVRSTP instances are transparently expanded across the MSTP region and their spanning trees span the MSTP region. For PVRSTP, the MSTP region is treated as a single hub.

5.7.4.4.3 Interoperability with RSTP

In Figure 23, PVRSTP and RSTP Interoperability:

- SW1 and SW2 are EFOS switches running PVRSTP with default bridge priority 32768.
- SW3 is an EFOS switch running RSTP with default bridge priority 32768.

Figure 23: PVRSTP and RSTP Interoperability



SW3 sends IEEE STP BPDUs to the IEEE multicast MAC address as untagged frames. These BPDUs are processed by the VLAN 1 STP instance on the PVRSTP switch as part of the VLAN 1 STP instance.

The PVRSTP side sends IEEE STP BPDUs corresponding to the VLAN 1 STP to the IEEE MAC address as untagged frames across the link. At the same time, SSTP BPDUs are sent as untagged frames. IEEE switches simply flood the SSTP BPDUs throughout VLAN 1. This facilitates PVRSTP connectivity in case there are other PVRSTP switches connected to the IEEE STP domain.

For non-native VLANs (VLANs 2–4093), the PVRSTP switch sends SSTP BPDUs, tagged with their VLAN number. The VLAN STP instances are multicast across the RSTP region, as if it were a hub switch.

The VLAN 1 STP instance of SW1 and SW2 are joined with the STP instance running in SW3. VLANs 2 and 3 consider the path across SW3 as another segment linking SW1 and SW2, and their SSTP information is multicast across SW3.

The bridge priority of SW1 and SW2 for VLAN1 instance is 32769 (bridge priority + VLAN identifier).

The bridge priority of SW3 is 32768, per the IEEE 802.w standard.

SW3 is selected as Root Bridge for the VLAN1 instance that is CST, and SW1 is selected as Root Bridge for VLAN2 and VLAN3 (based on the low MAC address of SW1).

5.7.4.4.4 Interoperability with MSTP

PVRSTP runs an individual RSTP instance for each VLAN. MSTP maps VLANs to MSTIs, so one-to-one mapping between VLAN and STP instance is not possible.

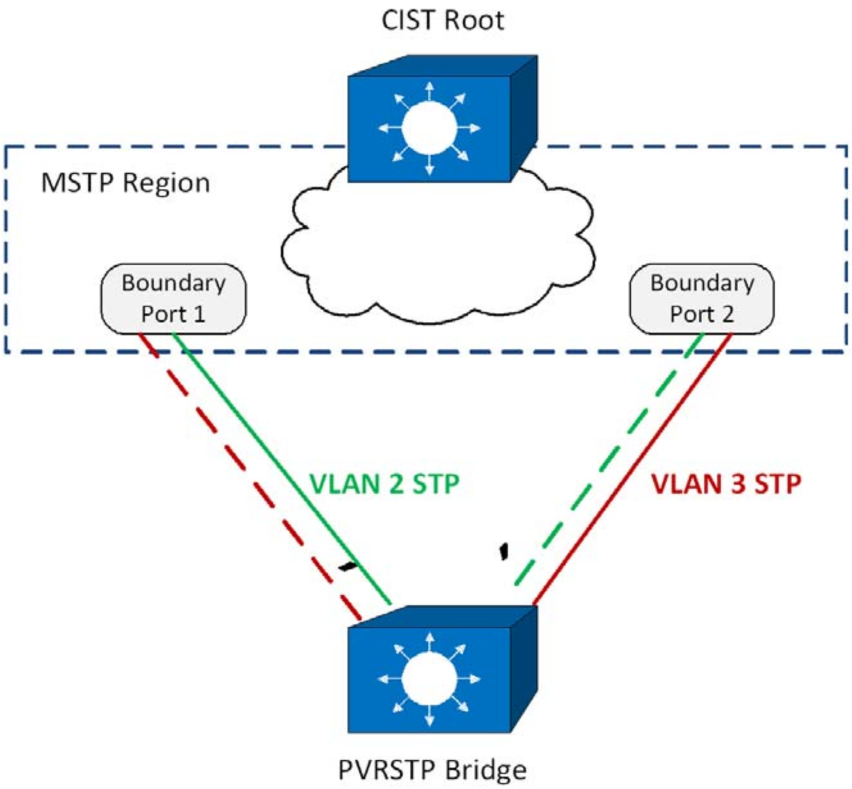
MSTP runs multiple MSTIs inside a region and maps them to the CIST on the border ports. The interoperability model must ensure that internal MSTIs are aware of changes to any of the PVRSTP trees. Therefore, the simplest way to ensure the correct behavior is to join ALL PVRSTP trees to the CST.

Connecting PVRSTP trees to the CST ensures that changes in any of the PVRSTP STP instances will affect the CST and all MSTIs. This approach ensures that no changes go unnoticed and no black holes occur in a single VLAN. As with IEEE STP, every tree in the PVRSTP domain views the MSTP regions as virtual bridges with multiple boundary ports. A topology change in any of PVRSTP trees will affect the CST and propagate through every MSTI instance in all MSTP regions. This behavior, consequently, makes the MSTP topology less stable.

The MSTP implementation simulates PVRSTP by replicating CIST BPDUs on the link facing the PVRSTP domain and sending those BPDUs on ALL VLANs active on the trunk. The MSTP switch processes IEEE STP VLAN 1 BPDUs received from the PVRSTP domain using the CIST instance. The PVRSTP+ domain interprets the MSTP domain as an PVRSTP bridge with all per-VLAN instances claiming the CIST Root as the root of their individual spanning tree. For the common STP Root elected between MSTP and PVRSTP, two options are possible:

- The MSTP domain contains the root bridge for ALL VLANs. This implies that the CIST Root Bridge ID is configured to be better than any PVRSTP STP root Bridge ID. If there is only one MSTP region connected to the PVRSTP domain, then all boundary ports on the virtual-bridge will be unblocked and used by PVRSTP. This is the only supported topology, as the administrator can manipulate uplink costs on the PVRSTP side and obtain optimal traffic engineering results. In Figure 24, MSTP and PVRSTP Interoperability, VLANs 2 and 3 have their STP costs configured to select different uplinks connected to the MSTP region's boundary ports. Since the CIST Root is inside the MSTP region, both boundary ports are non-blocking designated and the load balancing scheme operates as expected.

Figure 24: MSTP and PVRSTP Interoperability



- The alternative is that the PVRSTP domain contains the root bridges for ALL VLANs. This is only true if all PVRSTP root bridges’ Bridge IDs for all VLANs are better than the MSTP CIST Root Bridge ID. This is not a supported topology, because all MSTIs map to CIST on the border link, and it is not possible to load-balance the MSTIs as they enter the PVRSTP domain.

The EFOS software PVRSTP implementation does not support the second option. The MSTP domain must contain the bridge with the best Bridge ID to ensure that the CIST Root is also the root for all PVRSTP trees. In any other case, the MSTP border switch will place the ports that receive superior BPDUs from the PVRSTP region in the root-inconsistent state. To resolve this issue, ensure that the PVRSTP domain does not have any bridges with Bridge IDs better than the CIST Root Bridge ID.

5.7.4.4.5 Native VLAN Inconsistent State

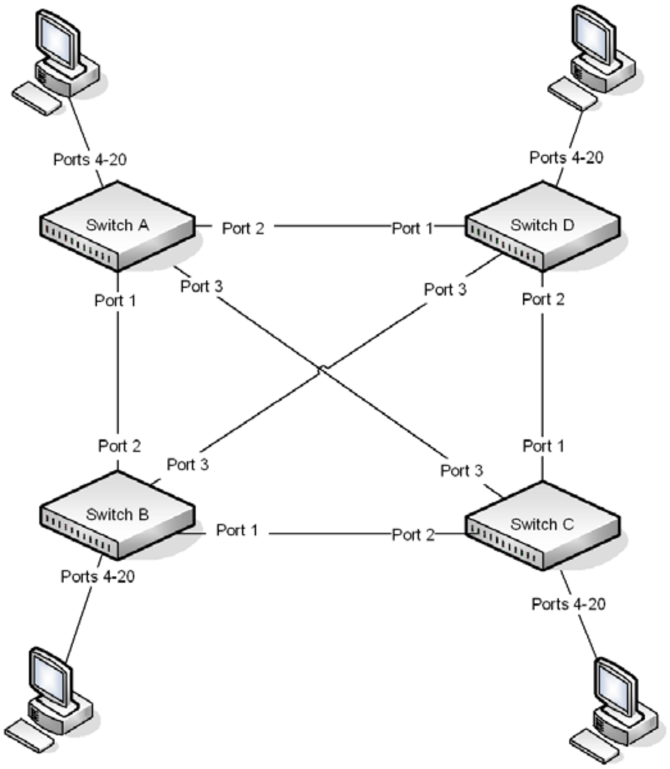
This occurs if a trunk port receives an untagged SSTP BPDU with a VLAN type, length, value (TLV) that does not match the VLAN where the BPDU was received. In this case, the port transitions to the blocked state.

5.7.5 STP Configuration Examples

5.7.5.1 Configuring STP

This example shows a LAN with four switches. On each switch, ports 1, 2, and 3 connect to other switches, and ports 4–20 connect to hosts (in Figure 25, STP Example Network Diagram, each PC represents 17 host systems).

Figure 25: STP Example Network Diagram



Of the four switches in Figure 25, the administrator decides that Switch A is the most centrally located in the network and is the least likely to be moved or redeployed. For these reasons, the administrator selects it as the root bridge for the spanning tree. The administrator configures Switch A with the highest priority and uses the default priority values for Switch B, Switch C, and Switch D.

For all switches, the administrator also configures ports 4–17 in Port Fast mode because these ports are connected to hosts and can transition directly to the Forwarding state to speed up the connection time between the hosts and the network.

The administrator also configures Port Fast BPDU filtering and Loop Guard to extend STP's capability to prevent network loops. For all other STP settings, the administrator uses the default STP values.

To configure the switch:

1. Connect to Switch A and configure the priority to be higher (a lower value) than the other switches, which use the default value of 32768.
   ```
   (Routing) #config
   (Routing) (Config)#spanning-tree mst priority 0 8192
   ```
2. Configure ports 4–20 to be in Edge Port mode.
   ```
   (Routing) (Config)#interface 0/4-0/20
   (Routing) (Interface 0/4-0/20)#spanning-tree edgeport
   (Routing) (Interface 0/4-0/20)#exit
   ```
3. Enable Loop Guard on ports 1–3 to help prevent network loops that might be caused if a port quits receiving BPDUs.
   ```
   (Routing) (Config)#interface 0/1-0/3
   (Routing) (Interface 0/1-0/3)#spanning-tree guard loop
   (Routing) (Interface 0/1-0/3)#exit
   ```

4. Enable Port Fast BPDU Filter. This feature is configured globally, but it affects only access ports that have the Edge Port feature enabled.

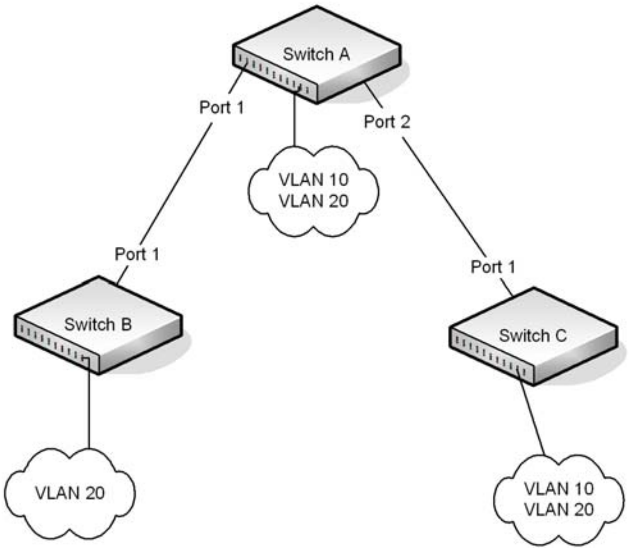
```
(Routing) (Config)#spanning-tree bpdufilter default
```

5. Repeat Step 2 through Step 4 on Switch B, Switch C, and Switch D to complete the configuration.

5.7.5.2 Configuring MSTP

This example shows how to configure IEEE 802.1s Multiple Spanning Tree (MST) protocol on the switches shown in Figure 26.

Figure 26: MSTP Configuration Example



To make multiple switches be part of the same MSTP region, make sure the STP operational mode for all switches is MSTP. Also, make sure the MST region name and revision level are the same for all switches in the region.

To configure the switches:

1. Create VLAN 10 (Switch A and Switch B) and VLAN 20 (all switches).

NOTE: Even Switch B does not have any ports that are members of VLAN 10, this VLAN must be created to allow the formation of MST regions made up of all bridges that exchange the same MST Configuration Identifier. It is only within these MST Regions that multiple instances can exist.

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 10,20
(Routing) (Vlan)#exit
```

2. Set the STP operational mode to MSTP.

```
(Routing) #config
(Routing) (Config)#spanning-tree forceversion 802.1s
```

3. Create MST instance 10 and associate it to VLAN 10.

```
(Routing) (Config)#spanning-tree mst instance 10
(Routing) (Config)#spanning-tree mst vlan 10 10
```

4. Create MST instance 20 and associate it to VLAN 20.

```
(Routing) (Config)#spanning-tree mst instance 20
```

```
(Routing) (Config)#spanning-tree mst vlan 20 20
```

5. Change the region name so that all the bridges that want to be part of the same region can form the region.

```
(Routing) (Config)#spanning-tree configuration name broadcom
```

6. (Switch A only) Make Switch A the Regional Root for MSTI 1 by configuring a higher priority for MST ID 10.

```
(Routing) (Config)#spanning-tree mst priority 10 12288
```

7. (Switch A only) Change the priority of MST ID 20 to ensure Switch C is the Regional Root bridge for this MSTI.

```
(Routing) (Config)#spanning-tree mst priority 20 61440
```

8. (Switch C only) Change the priority of port 1 to force it to be the root port for MST 20.

```
(Routing) (Config)#interface 0/1
(Routing) (Interface 0/1)#spanning-tree mst 20 port-priority 64
(Routing) (Interface 0/1)#exit
(Routing) (Config)#exit
```

5.7.5.3 Configuring PVRSTP

5.7.5.3.1 PVRSTP Access Switch Configuration Example

In this configuration, ports 0/3-0/48 are presumed to be connected to host machines, and ports 0/1 and 0/2 are uplink ports are connected to an aggregation-layer switch with a total L2 network diameter of 4. The aggregation-layer switch can be a single switch or multiple switches, running either PVRSTP or MSTP. For fastest convergence during failover scenarios, it is recommended that the uplink switches be configured in PVRSTP mode.

Three VLANs are configured in addition to VLAN 1. Interface 0/1 is configured to be the primary uplink port and 0/2 is configured to be the backup uplink.

1. Configure VLANs 2 through 4.

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 2-4
(Routing) (Vlan) (Vlan2-4)#exit
```

2. Enable PVRSTP.

```
(Routing) #config
(Routing) (Config)#spanning-tree mode rapid-pvst
```

3. Configure for a maximum network diameter of 4.

```
(Routing) (Config)#spanning-tree vlan 1-4 max-age 16
```

4. Configure access and trunk ports.

```
(Routing) (Config)#interface 0/3-0/48
(Routing) (Interface 0/3-0/48)#switchport mode access
(Routing) (Interface 0/3-0/48)#exit

(Routing) (Config)#interface 0/1-0/2
(Routing) (Interface 0/1-0/2)#switchport mode trunk
(Routing) (Interface 0/1-0/2)#exit
```

5. Configure interface 0/1 as the preferred uplink.

```
(Routing) (Config)#interface 0/1
(Routing) (Inteface 0/1)#spanning-tree port-priority 112
(Routing) (Inteface 0/1)#exit
```

6. Assign ports to VLANs.

```
(Routing) (Config)#interface 0/3-0/12
(Routing) (Interface 0/3-0/12)#switchport access vlan 1
```

```
(Routing) (Interface 0/3-0/12)#exit
(Routing) (Config)#interface 0/13-0/24
(Routing) (Interface 0/13-0/24)#switchport access vlan 2
(Routing) (Interface 0/13-0/24)#exit
(Routing) (Config)#interface 0/25-0/36
(Routing) (Interface 0/25-0/36)#switchport access vlan 3
(Routing) (Interface 0/25-0/36)#exit
(Routing) (Config)#interface 0/37-0/48
(Routing) (Interface 0/37-0/48)#switchport access vlan 4
(Routing) (Interface 0/37-0/48)#exit
```

5.7.5.3.2 PVRSTP Aggregation Layer Switch Configuration Example

In this configuration example, two aggregation-layer switches are configured. Ports 1–4 are configured in a LAG connecting the two aggregation-layer switches. Ports 12–24 are configured as down-links to twelve access layer switches configured as in the previous example. Down-links to the access-layer switches have physical diversity; there is one downlink to each of the twelve access-layer switches from each of the paired aggregation-layer switches.

The uplink ports to the network core are configured as LAGs to provide link redundancy. It is presumed that the core links connect to a router running PVRSTP. The configuration for the two aggregation-layer switches is identical, except for the diversity configuration noted below.

For forwarding diversity, the even numbered switch is made the root for the even-numbered VLANs. The odd numbered switch is made the root for the odd-numbered VLANs.

1. Create VLANs 2 through 4:

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 2-4
(Routing) (Vlan)#exit
```

2. Enable PVRSTP:

```
(Routing) #Config
(Routing) (Config)#spanning-tree mode rapid-pvst
```

3. Configure for a max network diameter of 4:

```
(Routing) (Config)#spanning-tree vlan 1-4 max-age 16
```

4. Configure one downlink trunk port per downlink switch:

```
(Routing) (Config)#interface 0/12-0/24
(Routing) (Interface 0/12-0/24)#switchport mode trunk
(Routing) (Interface 0/12-0/24)#exit
```

5. Configure forwarding diversity for the even numbered switches:

```
(Routing) (Config)#spanning-tree vlan 2,4 root primary
(Routing) (Config)#spanning-tree vlan 1,3 root secondary
```

6. Configure forwarding diversity for the odd numbered switches:

```
(Routing) (Config)#spanning-tree vlan 1,3 root primary
(Routing) (Config)#spanning-tree vlan 2,4 root secondary
```

7. Configure two uplink ports per uplink switch:

```
(Routing) (Config)#interface 0/1-0/2
(Routing) (Interface 0/1-0/2)#channel-group 1 mode active
(Routing) (Interface 0/1-0/2)#exit
```

8. Configure peer switch links:

```
(Routing) (Config)#interface 0/5-0/8
(Routing) (Interface 0/5-0/8)#channel-group 2 mode    active
```

```
(Routing) (Interface 0/5-0/8)#exit
```

9. Configure the uplinks into a port channel:

```
(Routing) (Config)#interface lag 1
(Routing) (Interface lag 1)#switchport mode trunk
(Routing) (Interface lag 1)#exit
```

10. Configure the peer links into a port channel and prefer to go to the core router or access switches directly, i.e., block the peer link unless it is needed:

```
(Routing) (Config)#interface lag 1
(Routing) (Interface lag 1)#switchport mode trunk
(Routing) (Interface lag 1)#spanning-tree port-priority 144
(Routing) (Interface lag 1)#exit
```

5.8 IGMP Snooping

IGMP Snooping is a layer 2 feature that allows the switch to dynamically add or remove ports from IP multicast groups by listening to IGMP join and leave requests. By "snooping" the IGMP packets transmitted between hosts and routers, the IGMP Snooping feature enables the switch to forward IP multicast traffic more intelligently and help conserve bandwidth.

Based on the IGMP query and report messages, the switch forwards traffic only to the ports that request the multicast traffic. This prevents the switch from broadcasting the traffic to all ports and possibly affecting network performance. The switch uses the information in the IGMP packets as they are being forwarded throughout the network to determine which segments should receive packets directed to the group address.

5.8.1 IGMP Snooping Querier

When PIM and IGMP are enabled in a network with IP multicast routing, the IP multicast router acts as the IGMP querier. However, if the IP-multicast traffic in a VLAN needs to be Layer 2 switched only, an IP-multicast router is not required. The IGMP Snooping Querier can perform the IGMP snooping functions on the VLAN.

Without an IP-multicast router on a VLAN, you must configure another switch as the IGMP querier so that it can send queries.

When the IGMP snooping querier is enabled, the IGMP snooping querier sends out periodic IGMP queries that trigger IGMP report messages from the switch that wants to receive IP multicast traffic. The IGMP snooping feature listens to these IGMP reports to establish appropriate forwarding.

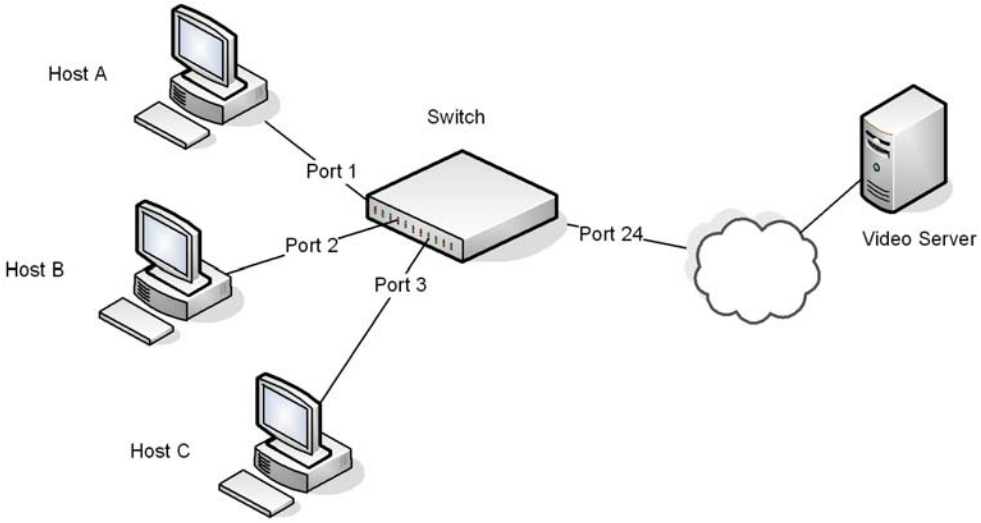
5.8.2 Configuring IGMP Snooping

This example configures IGMP snooping on the switch to limit multicast traffic and to allow L2 multicast forwarding on a single VLAN. The IP-multicast traffic in VLAN 100 needs to be Layer 2 switched only, so the IGMP snooping querier is enabled on the switch to perform the IGMP snooping functions on the VLAN, if necessary. The switch can send queries even if it is not the IGMP snooping querier and will use 0.0.0.0 as the source IP address. This will not cause any disruption to the operation of external querier.

In this configuration, an IP-multicast router is not required.

The three hosts in Figure 27, Switch with IGMP Snooping are connected to ports that enabled for IGMP snooping and are members of VLAN 100. Port 24 is a trunk port and connects the switch to the data center, where the L3 multicast router is located.

Figure 27: Switch with IGMP Snooping



To configure the switch:

1. Enable IGMP snooping globally.
```
(Routing) #configure
(Routing) (Config)#set igmp
```
2. Enable the IGMP snooping querier on the switch. If there are no other IGMP snooping queriers, this switch will become the IGMP snooping querier for the local network. If an external querier is discovered, this switch will not be a querier.
```
(Routing) (Config)#set igmp querier
```
3. Create VLAN 100
```
(Routing) #vlan database
(Routing) (Vlan)#vlan 100
```
4. Enable IGMP snooping on VLAN 100.
```
(Routing) (Vlan)#set igmp 100
```
5. Enable the IGMP snooping querier on VLAN 100.
```
(Routing) (Vlan)#set igmp querier 100
```
6. Enable VLAN routing on VLAN 100.
```
(Routing) (Vlan)#vlan routing 150
(Routing) (Vlan)#exit
```
7. View the VLAN routing interface information.
```
(Routing) #show ip interface brief

Interface    State  IP Address      IP Mask         Method
----------   -----  --------------- --------------- -------
4/1          Down   0.0.0.0         0.0.0.0         None
```
8. Configure an IP address for VLAN 100. This address will be used as the IGMP snooping querier address if this switch becomes the querier.
```
(Routing) #configure
```

```
(Routing) (Config)#interface 4/1
(Routing) (Interface 4/1)#ip address 192.168.10.2 255.255.255.0
(Routing) (Interface 4/1)#exit
```

9. Specify the address to use as the source address for IGMP queries sent from any interface. The global querier address is the IP address of VLAN 100.

```
(Routing) (Config)#set igmp querier address 192.168.10.2
```

10. Enable IGMP snooping on ports 1–3.

```
(Routing) (Config#interface 0/1-0/3
(Routing) (Interface 0/1-0/3)#set igmp
```

11. Configure ports 1–3 as members of VLAN 100.

```
(Routing) (Interface 0/1-0/3)#vlan participation include 100
(Routing) (Interface 0/1-0/3)#exit
```

12. Enable IGMP on port 24, and configure the port as a trunk port that connects to the data center switch.

```
(Routing) (Config)#interface 0/24
(Routing) (Interface 0/24)#set igmp
(Routing) (Interface 0/24)#vlan participation include 100
(Routing) (Interface 0/24)#vlan tagging 100
(Routing) (Interface 0/24)#exit
(Routing) (Config)#exit
```

13. Verify the IGMP snooping configuration.

```
(Routing) #show igmpsnooping

Admin Mode..................................... Enable
Multicast Control Frame Count.................. 0
IGMP Router-Alert check........................ Disabled
Interfaces Enabled for IGMP Snooping........... 0/1
                                                0/2
                                                0/3
                                            0/24
VLANs enabled for IGMP snooping................ 100



(Routing) #show igmpsnooping querier vlan 100

VLAN 100 :   IGMP Snooping querier status
----------------------------------------------
IGMP Snooping Querier VLAN Mode................ Enable
Querier Election Participate Mode.............. Disable
Querier VLAN Address........................... 0.0.0.0
Operational State.............................. Querier
Operational version............................ 2
Operational Max Resp Time...................... 10
```

After performing the configuration in this example, Host A sends a join message for multicast group 225.1.1.1. Host B sends a join message for group 225.1.1.2. Because IGMP snooping is enabled on the switch and on VLAN 100, the switch listens to the messages and dynamically adds Ports 1 and 2 to the multicast address table. Port 3 did not send a join message, so it does not appear in the table, as the following `show` command indicates.

```
(Routing) #show mac-address-table multicast

                                                                   Fwd
VLAN ID MAC Address        Source  Type    Description     Interface Interface
------- ----------------   ------- ------- --------------- --------- ---------
```

```
100     01:00:5E:01:01:01  IGMP   Dynamic  Network Assist 0/1       0/1
100     01:00:5E:01:01:02  IGMP   Dynamic  Network Assist 0/2       0/2
```

When the video server sends multicast data to group 225.1.1.1, Port 1 participates and receives multicast traffic, but Port 2 does not participate because it is a member of a different multicast group. Without IGMP snooping, all ports that are members of VLAN 100 would be flooded with traffic for all multicast groups, which would greatly increase the amount of traffic on the switch.

5.8.3 IGMPv3/SSM Snooping

IGMPv3 adds support for source filtering, which is the ability for a system to report interest in receiving packets **only** from specific source addresses, or from **all but** specific source addresses sent to a particular multicast address. This information is used by snooping switches to avoid delivering multicast packets from specific sources to networks where there are no interested receivers.

No additional configuration is required to enable IGMPv3/SSM snooping. It is enabled or disabled when snooping is enabled on a VLAN/interface. The forwarding database built using IGMPv3 reports is based on the Source IP address, the Multicast Group address, and VLAN. Consider the above configuration example. When Host A sends IGMPv3 IS_IN a report for Group 225.1.1.1 and Sources 192.168.10.1 and 192.168.20.1. As snooping is enabled globally on the switch and also on VLAN 100, two entries are added to MFDB so that multicast traffic with group IP = 225.1.1.1 and if Source Ip=192.168.10.1 or 192.168.20.1 is forwarded to port 1. All other multicast traffic destined to group 225.1.1.1 is dropped. The following command is used to display the SSM forwarding database.

```
(Routing) #show igmpsnooping ssm entries

VLAN                                                    Source
ID    Group                  Source Ip              Filter Mode Interfaces
----  ---------------------- ---------------------- ----------- --------------
100   225.1.1.1              192.168.10.1           include     0/1
100   225.1.1.1              192.168.20.1           include     0/1
```

5.9 Multicast VLAN Registration Configuration

5.9.1 Overview

Multicast VLAN Registration (MVR), like IGMP Snooping protocol, allows a layer-2 switch to listen to the IGMP frames.

IGMP is a layer-3 protocol widely used for IPv4 networks multicasting. In layer-2 networks, IGMP protocol uses resources inefficiently. For example, a layer-2 switch broadcasts any multicast traffic to all the ports even when there are only several receivers connected to several ports. The IGMP Snooping protocol was developed to address this issue. But the problem still appears when receivers are in different VLANs.

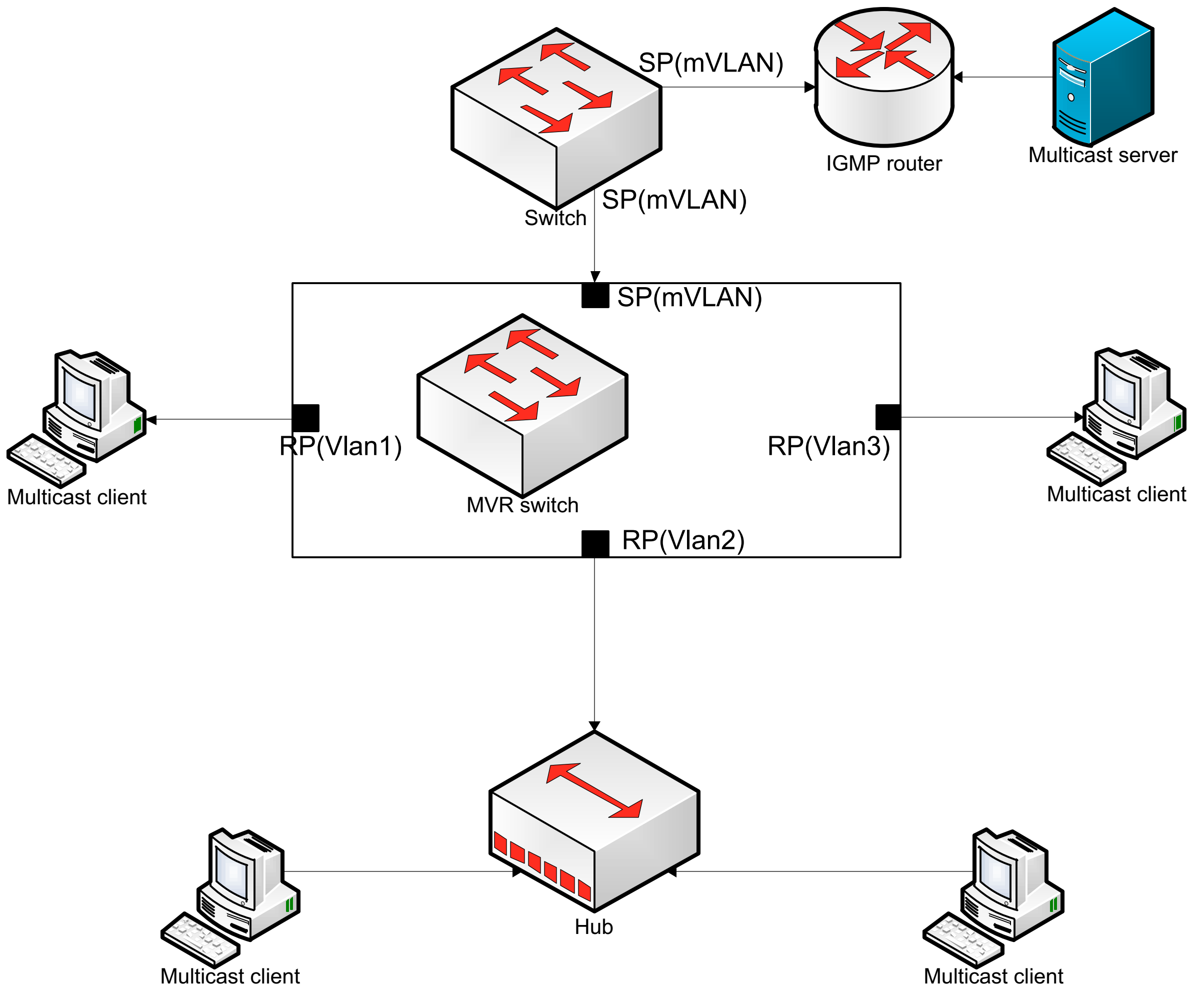
The purpose of MVR is to solve the problem when receivers are in different VLANs. It uses dedicated VLAN, called a multicast VLAN, to forward multicast traffic over a layer-2 network. Only one multicast VLAN can be configured per switch.

Ports can be configured as MVR source ports or receiver ports.

- The source port is the port where multicast traffic is flowing to. It must be the member of the multicast VLAN.
- The receiver port is the port where the listening host is connected to the switch. It can be a member of any VLAN except the multicast VLAN.

The multicast VLAN is configured for all the source ports over the network. It is the VLAN that is used to transfer multicast traffic over the network avoiding duplication of multicast streams for clients in different VLANs. Figure 28, MVR-Enabled Network shows a network configured to use MRV. SP is the source port and RP is the receiver port.

Figure 28: MVR-Enabled Network



MVR and IGMP snooping operate independently and can both be enabled on an interface. When both MVR and IGMP snooping are enabled, MVR listens to the IGMP join and report messages for static multicast group information, and IGMP snooping manages dynamic multicast groups.

Parsing the IGMP packets generated by router and hosts, MVR fills its own membership group database to track hosts interested in specific multicast traffic. There are two types of group entries in this database, static and dynamic. Static entries are configured by administrator, but dynamic are learned by MVR on the source ports.

There are two configured learning modes of the MVR operation, dynamic and compatible.

- In Dynamic mode, MVR learns source ports membership from IGMP queries. The protocol forwards Joins and Leaves from the hosts to the router. The multicast traffic is forwarded only to receiver ports that joined the group, either by IGMP Joins or by MVR static configuration.
- In Compatible mode, MVR does not learn source ports membership, but all source ports are members of all groups by default. The protocol does not forward Joins and Leaves from the hosts to the router. The multicast traffic is forwarded only to receiver ports that joined the group, either by IGMP Joins or by MVR static configuration.

To enable multicast traffic flow over the multicast VLAN only, MVR does the following with the IGMP control packets and multicast streams:

- MVR intercepts the IGMP reports from hosts that are connected to the receiver ports, puts the Multicast VLAN tag and forwards them to the IGMP router from the source ports.
- MVR intercepts multicast stream on the source ports of the layer-2 switch and forwards it to the receiver ports where clients are connected, removing the multicast VLAN tag.

The MVR has two modes of operating with the IGMP Leave messages, Normal Leave and Immediate Leave.

- In normal Leave mode, when a Leave is received, the General IGMP query is sent from the layer-2 switch to the receiver port where the leave was received. Then, reports are received from other interested hosts that are connected to that port too, for example, using a hub.
- In Immediate Leave mode, when a Leave is received, the switch is immediately reconfigured to not forward a specific multicast stream to the port where message is received. This mode is used only for the ports where only one client may be connected.

MVR processes the IGMP messages according to its type the following way:

- When MVR receives a General group query on the source port, MVR forwards it to all receiver ports. Timers are started for each port in each membership group. If the timer expires for a port, its number is removed from the particular group entry. If it is the last port in the group, the group entry is removed.
- When MVR receives a Group specific query, MVR forwards it to the receiver ports that are interested in the particular group. Timers are started for each port in this membership group. If the timer is expired for a port, its number is removed from the group's entry. If it is the last port in the group, the group entry is removed.
- When MVR receives a Report, MVR forwards it to the source ports of the specific membership group only if it is the first reply to the query for the particular group. The switch is reconfigured to forward packets to the port, if this was not already configured.
- When MVR receives a Leave message, MVR forwards it to the source port of the specific membership group only if it is the last port for this particular membership group. The switch is reconfigured to not forward packets to this port.

5.9.2 MVR Configuration Example

The following example configures MVR.

1. Enable MVR globally and specify a multicast VLAN (VLAN 10) is configured:
   ```
   (Routing) #configure
   (Routing) (Config)#mvr
   (Routing) (Config)#mvr vlan 10
   ```
2. Set the MVR query response time in units of tenths of a second. The query time is the maximum time to wait for an IGMP membership report on a receiver port before removing the port from the multicast group. The query time only applies to receiver ports and is specified in tenths of a second.
   ```
   (Routing) (Config)#mvr querytime 10
   ```
3. Specify the MVR mode of operation, which can be dynamic or compatible.
   ```
   (Routing) (Config)#mvr mode dynamic
   ```
4. Add an MVR membership group by specifying the group IP multicast address.
   ```
   (Routing) (Config)#mvr group 225.5.23.2
   ```
5. Enter Interface Config mode for the port to be configured as a receiver. Enable MVR and assign the port type as receiver.

   The following commands also configure the port to participate in the specified MVR group by specifying the multicast VLAN and multicast group IP address. This step also sets the leave mode to **immediate**.
   ```
   (Routing) (Config)##interface 0/3
   (Routing) (Interface 0/3)#mvr
   (Routing) (Interface 0/3)#mvr type receiver
   ```

```
(Routing) (Interface 0/3)#mvr immediate
(Routing) (Interface 0/3)#mvr 10 group 225.5.23.2
```

6. Enter Interface Config mode for the port to be configured as a source port. Enable MVR and assign the port type. Do not make the port a member of the multicast VLAN.

```
(Routing) (Interface 0/10)#interface 0/5
(Routing) (Interface 0/10)#mvr
(Routing) (Interface 0/10)#mvr type source
```

You can use the **show mvr [***members***]** command to view information about the administrative mode, MVR groups and members and the **show mvr interface** *interface* command to view MVR port configuration information. To view information on IGMP traffic in the MVR table, use the **show mvr traffic** command.

5.10 LLDP and LLDP-MED

LLDP is a standardized discovery protocol defined by IEEE 802.1AB. It allows stations residing on an 802 LAN to advertise major capabilities physical descriptions, and management information to physically adjacent devices allowing a network management system (NMS) to access and display this information.

LLDP is a one-way protocol; there are no request/response sequences. Information is advertised by stations implementing the transmit function, and is received and processed by stations implementing the receive function. The transmit and receive functions can be enabled/disabled separately on each switch port.

LLDP-MED is an extension of the LLDP standard. LLDP-MED uses LLDP's organizationally-specific Type- Length-Value (TLV) extensions and defines new TLVs that make it easier for a VoIP deployment in a wired or wireless LAN/MAN environment. It also makes mandatory a few optional TLVs from LLDP and recommends not transmitting some TLVs.

The TLVs only communicate information; these TLVs do not automatically translate into configuration. An external application may query the MED MIB and take management actions in configuring functionality.

LLDP and LLDP-MED are used primarily in conjunction with network management tools to provide information about network topology and configuration, and to help troubleshoot problems that occur on the network. The discovery protocols can also facilitate inventory management within a company.

LLDP and the LLDP-MED extension are vendor-neutral discovery protocols that can discover devices made by numerous vendors. LLDP-MED is intended to be used on ports that connect to VoIP phones. Additional applications for LLDP-MED include device location (including for Emergency Call Service/E911) and Power over Ethernet management.

5.10.1 LLDP and Data Center Applications

DCBX uses TLV information elements over LLDP to exchange information, so LLDP must be enabled on the port to enable the information exchange.

5.10.2 Configuring LLDP

This example shows how to configure LLDP settings for the switch and to allow port 0/3 to transmit all LLDP information available.

To configure the switch:

1. Configure the transmission interval, hold multiplier, and reinitialization delay for LLDP PDUs sent from the switch.
   ```
   (Routing) #configure
   (Routing) (Config)#lldp timers interval 60 hold 5 reinit 3
   ```
2. Enable port 0/3 to transmit and receive LLDP PDUs.
   ```
   (Routing) (Config)#interface 0/3
   (Routing) (Interface 0/3)#lldp transmit
   (Routing) (Interface 0/3)#lldp receive
   ```
3. Enable port 0/3 to transmit management address information in the LLDP PDUs and to send topology change notifications if a device is added or removed from the port.
   ```
   (Routing) (Interface 0/3)#lldp transmit-mgmt
   (Routing) (Interface 0/3)#lldp notification
   ```
4. Specify the TLV information to be included in the LLDP PDUs transmitted from port 0/3.
   ```
   (Routing) (Interface 0/3)#lldp transmit-tlv sys-name sys-desc sys-cap port-desc
   ```

5. Set the port description to be transmitted in LLDP PDUs.

```
(Routing) (Interface 0/3)#description “Test Lab Port”
```

6. Exit to Privileged EXEC mode.

```
(Routing) (Interface 0/3)# <CTRL + Z>
```

7. View global LLDP settings on the switch.

```
(Routing) #show lldp

LLDP Global Configuration

Transmit Interval..................... 60 seconds
Transmit Hold Multiplier.............. 5
Reinit Delay.......................... 3 seconds
Notification Interval................. 5 seconds
```

8. View summary information about the LLDP configuration on port 0/3.

```
(Routing) #show lldp interface 0/3
LLDP Interface Configuration

Interface  Link    Transmit  Receive   Notify    TLVs     Mgmt
---------  ------  --------  --------  --------  -------  ----
0/3        Down    Enabled   Enabled   Enabled   0,1,2,3  Y

TLV Codes: 0- Port Description,   1- System Name
           2- System Description, 3- System Capabilities
```

9. View detailed information about the LLDP configuration on port 0/3.

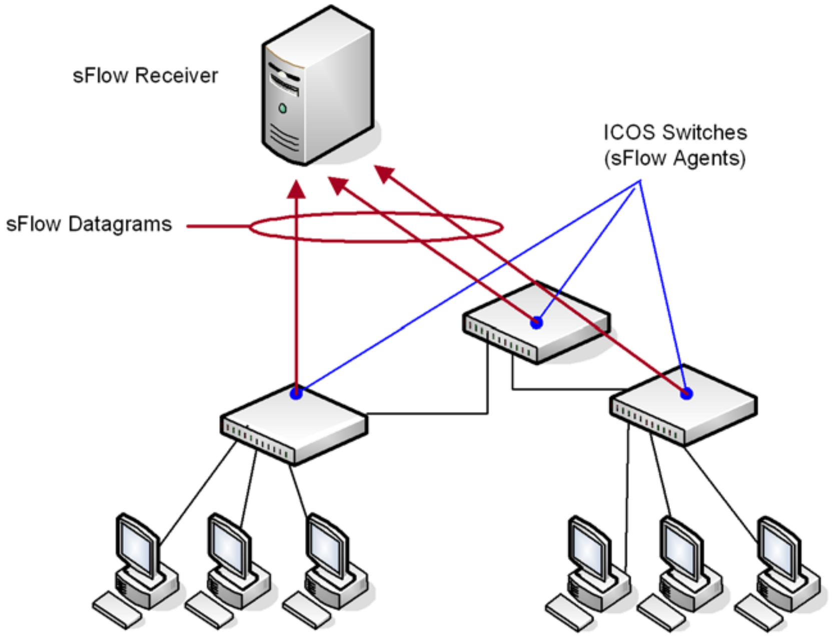
```
(Routing) #show lldp local-device detail 0/3

LLDP Local Device Detail

Interface: 0/3

Chassis ID Subtype: MAC Address
Chassis ID: 00:10:18:82:15:7B
Port ID Subtype: MAC Address
Port ID: 00:10:18:82:15:7D
System Name:
System Description: Broadcom Triumph2 56634 Development System - 48 GE, 4 TENGIG, I.12.5.1, Linux
2.6.27.47
Port Description: Test Lab Port
System Capabilities Supported: bridge, router
System Capabilities Enabled: bridge
Management Address:
    Type: IPv4
    Address: 10.27.22.149
```

5.11 sFlow

sFlow is an industry standard technology for monitoring high-speed switched and routed networks. EFOS software has a built-in sFlow agent that can monitor network traffic on each port and generate sFlow data to an sFlow receiver (also known as a collector). sFlow helps to provide visibility into network activity, which enables effective management and control of network resources. sFlow is an alternative to the NetFlow network protocol, which was developed by Cisco Systems. The switch supports sFlow version 5.

As illustrated in Figure 29, sFlow Architecture, the sFlow monitoring system consists of sFlow Agents (such as EFOS-based switch) and a central sFlow receiver. sFlow Agents use sampling technology to capture traffic statistics from monitored devices. sFlow datagrams forward sampled traffic statistics to the sFlow Collector for analysis. You can specify up to eight different sFlow receivers to which the switch sends sFlow datagrams.

Figure 29: sFlow Architecture



The advantages of using sFlow are:

- It is possible to monitor all ports of the switch continuously, with no impact on the distributed switching performance.
- Minimal memory is required. Samples are not aggregated into a flow-table on the switch; they are forwarded immediately over the network to the sFlow receiver.
- The sFlow system is tolerant to packet loss in the network because statistical modeling means the loss is equivalent to a slight change in the sampling rate.
- sFlow receiver can receive data from multiple switches, providing a real-time synchronized view of the whole network.
- The receiver can analyze traffic patterns based on protocols found in the headers (e.g., TCP/IP, IPX, Ethernet, AppleTalk…). This alleviates the need for a layer 2 switch to decode and understand all protocols.

5.11.1 sFlow Sampling

The sFlow Agent in the EFOS software uses two forms of sampling:

- Statistical packet-based sampling of switched or routed Packet Flows

- Time-based sampling of counters

Packet Flow Sampling and Counter Sampling are performed by sFlow Instances associated with individual Data Sources within an sFlow Agent. Both types of samples are combined in sFlow datagrams. Packet Flow Sampling creates a steady, but random, stream of sFlow datagrams that are sent to the sFlow Collector. Counter samples may be taken opportunistically to fill these datagrams.

To perform Packet Flow Sampling, an sFlow Sampler Instance is configured with a Sampling Rate. Packet Flow sampling results in the generation of Packet Flow Records. To perform Counter Sampling, an sFlow Poller Instance is configured with a Polling Interval. Counter Sampling results in the generation of Counter Records. sFlow Agents collect Counter Records and Packet Flow Records and send them as sFlow datagrams to sFlow Collectors.

BCM56960 silicon offers the capability to perform packet sampling in hardware, which is less CPU-intensive because it does not require sampled packets to be copied to CPU for processing. EFOS supports sFlow packet sampling in hardware on the BCM56960-based platforms.

5.11.1.1 Packet Flow Sampling

The Packet Flow Sampling mechanism carried out by each sFlow instance ensures that any packet observed at a Data Source has an equal chance of being sampled, irrespective of the Packet Flow(s) to which it belongs.

Packet Flow Sampling is accomplished as follows:

- A packet arrives on an interface.
- The Network Device makes a filtering decision to determine whether the packet should be dropped.
- If the packet is not filtered (dropped), a decision is made on whether or not to sample the packet.
- A decision is made on whether or not to sample the packet.

  The mechanism involves a counter that is decremented with each packet. When the counter reaches zero a sample is taken.
- When a sample is taken, the counter indicating how many packets to skip before taking the next sample is reset. The value of the counter is set to a random integer where the sequence of random integers used over time is the Sampling Rate.

5.11.1.1.1 Sampling in Hardware

On platforms where sFlow packet sampling is supported in hardware, the hardware can send sampled packets to a configured remote-agent and can copy the sampled packet to the CPU (local agent). The hardware-sampled packets are encapsulated in custom format (MAC, IPv4, UDP, sFlow shim headers) and sent to the configured reachable remote agent. A remote agent must be available in the network to receives the custom packets. The remote agent can extract the sampled packets and send them within standard sFlow datagrams to sFlow receivers.

A configuration parameter can be configured to determine whether sFlow processes the packets in hardware or copies the sampled packets to software. sFlow in hardware supports three types of packet sampling: Ingress, Flex, and Egress packet sampling. The Ingress and Flex sampled packets can be processed by either hardware or software. The hardware also maintains statistics of the Ingress and Flex sampling counters, (sample pool, sample count, etc.). Flex sampling is enabled based on the ingress filtering policy (IFP). Egress-sampled packets must always be processed in software, as this is not supported in hardware. If egress sampling enabled and when the packet random-number-generated value is less than or equal to the threshold value, the packet is egress sampled and sent to the host CPU.

The sFlow shim header sent by silicon does not contain information about sampling rate, sampling counters, etc. Thus, the sFlow application sends the configured sampling rate and sampling counter values information to the remote agent at a regular interval (every 10 seconds by default; a different value have been specified at compile time). The remote agent might use this information while preparing an sFlow standard datagram and send to sFlow receiver/collector.

NOTE: Software Egress sampling (i.e., egress-sampled packets sent to CPU) works only for known unicast packets. The software provides the correct destination port information. For broadcast and multicast packets, the destination port information cannot be known. The software identifies the destination port by VLAN ID, so the sFlow application cannot create the sample packet.

5.11.1.2 Counter Sampling

The primary objective of Counter Sampling is to efficiently, periodically export counters associated with Data Sources. A maximum Sampling Interval is assigned to each sFlow instance associated with a Data Source.

Counter Sampling is accomplished as follows:

- sFlow Agents keep a list of counter sources being sampled.
- When a Packet Flow Sample is generated the sFlow Agent examines the list and adds counters to the sample datagram, least recently sampled first. Counters are only added to the datagram if the sources are within a short period, 5 seconds say, of failing to meet the required Sampling Interval.
- Periodically, say every second, the sFlow Agent examines the list of counter sources and sends any counters that must be sent to meet the sampling interval requirement.

The set of counters is a fixed set.

5.11.1.3 Configuring sFlow in Software

This example shows how to configure the switch so that ports 10-15 and port 23 send sFlow datagrams to an sFlow receiver at the IP address 192.168.20.34. The receiver owner is receiver1, and the timeout is 100000 seconds. A counter sample is generated on the ports every 60 seconds (polling interval), and 1 out of every 8192 packets is sampled.

To configure the switch:

1. Configure information about the sFlow receiver.

```
(Routing) #configure
(Routing) (Config)#sflow receiver 1 ip 192.168.20.34
(Routing) (Config)#sflow receiver 1 owner receiver1 timeout 100000
```

2. Configure the polling and sampling information for ports 10–15.

```
(Routing) (Config)#interface 0/10-0/15
(Routing) (Interface 0/10-0/15)#sflow poller 1
(Routing) (Interface 0/10-0/15)#sflow poller interval 60
(Routing) (Interface 0/10-0/15)#sflow sampler 1
(Routing) (Interface 0/10-0/15)#sflow sampler rate 8192
(Routing) (Interface 0/10-0/15)#exit
```

3. Configure the polling and sampling information for port 23.

```
(Routing) (Config)#interface 0/23
(Routing) (Interface 0/23)#sflow poller 1
(Routing) (Interface 0/23)#sflow poller interval 60
(Routing) (Interface 0/23)#sflow sampler 1
(Routing) (Interface 0/23)#sflow sampler rate 8192
(Routing) (Interface 0/23)#exit
```

4. Verify the configured information.

```
(Routing) #show sflow receivers 1

Receiver Index................................ 1
Owner String.................................. receiver1
Time out...................................... 99400
IP Address:................................... 192.168.20.34
Address Type.................................. 1
Port.......................................... 6343
Datagram Version.............................. 5
Maximum Datagram Size......................... 1400

(Routing) #show sflow pollers

 Poller        Receiver  Poller
 Data Source   Index     Interval
 -----------   -------   -------
 0/10          1         60
 0/11          1         60
 0/12          1         60
 0/13          1         60
 0/14          1         60
 0/15          1         60
 0/23          1         60

(Routing) #show sflow samplers

 Sampler      Receiver  Packet          Max Header
 Data Source  Index     Sampling Rate   Size
 -----------  -------   -------------   ----------
 0/10         1         8192            128
 0/11         1         8192            128
 0/12         1         8192            128
 0/13         1         8192            128
 0/14         1         8192            128
 0/15         1         8192            128
 0/23         1         8192            128
```

5.11.1.4 Configuring sFlow in Hardware

This example shows how to configure the switch so that ports 10–15 and port 23 send sFlow datagrams to an sFlow remote agent at the IP address 192.168.20.34 using port 22 as destination interface. A sample is generated on the ports for 1 out of every 8192 packets and is mirrored to port 22.

To configure the switch:

1. Configure information for the sFlow receiver:

```
(Routing) #configure
(Routing) (Config)#sflow remote-agent 1 ip 192.168.20.34
(Routing) (Config)# sflow remote-agent 1 monitor-session 1 destination Interface 0/22
```

2. Configure the polling and sampling information for ports 10–15:

```
(Routing) (Config)#interface 0/10-0/15
(Routing) (Interface 0/10-0/15)#sflow sampler remote-agent 1
(Routing) (Interface 0/10-0/15)#sflow sampler rate 8192
(Routing) (Interface 0/10-0/15)#exit
```

3. Configure the polling and sampling information for port 23:

```
(Routing) (Config)#interface 0/23
(Routing) (Interface 0/23)#sflow sampler remote-agent 1
(Routing) (Interface 0/23)#sflow sampler rate 8192
(Routing) (Interface 0/23)#exit
```

4. Verify the configured information:

```
(Routing) #show sflow remote-agents 1

Remote Agent Index............................ 1
IP Address:................................... 0.0.0.0
Port.......................................... 16343
Monitor Session Id............................ 2
Destination port ............................. 0/22
```

(continued on next page)

```
(Routing) #show sflow samplers
Sampler  Receiver  Remote  Ingress   Flow      Egress    Max     IP        MAC
Data     Index     Agent   Sampling  Sampling  Sampling  Header  ACL       ACL
Source             Index   Rate      Rate      Rate      Size
-------  --------  ------  --------  --------  --------  ------  --------  --------
   0/10             1       8192      0         0         128
  0/11             1       8192      0         0         128
  0/12             1       8192      0         0         128
  0/13             1       8192      0         0         128
  0/14             1       8192      0         0         128
  0/15             1       8192      0         0         128
  0/23             1       8192      0         0         128

(Routing) #show monitor session 1

Session AdminProbeSrc   Mirrored     Ref.   Src    Dst    Type   IP     MAC
ID  Mode    Port  VLAN    Port         Port   RVLAN  RVLAN         ACL    ACL
------- ------- -------- ------ ------------ ------- ----- ----- - ---------  -------
1       Reserve   0/22  0/10                              Rx,Tx
        (sflow)
                        0/11                              Rx,Tx
                        0/12                              Rx,Tx
                        0/13                              Rx,Tx
                        0/14                              Rx,Tx
                        0/15                              Rx,Tx
                        0/23                              Rx,Tx
```

5.12 Link Dependency

The following commands configure a link-dependency group.

1. Create a link dependency group with group ID 100. This command also configures whether the downstream interfaces should mirror or invert the status of upstream interfaces. The **action up** command causes the downstream interfaces to be up when no upstream interfaces are down.

```
(Routing) #configure
(Routing) (Config)#link state group 100 action down
```

2. Configure ports as link-dependency group members. Port 0/8 is configured as an upstream member of the group and ports 0/3 and 0/5 are configured as downstream members. The state of downstream members is dependent on the state of the upstream member.

Circular dependencies are not allowed. An interface that is defined as an upstream interface cannot also be defined as a downstream interface in the same link state group. An interface that is defined as an upstream interface cannot also be defined as a downstream interface in a different link state group, when such configuration creates a circular dependency between groups.

CAUTION! Adding an interface as a downstream port brings the interface down until an upstream interface is added to the group. The link status will then follow the interface specified in the upstream command. To avoid bringing down interfaces, configure the upstream port prior to configuring the downstream ports.

```
(Routing) (Config)#interface 0/8
(Routing) (Interface 0/8)#link state group 100 upstream
(Routing) (Interface 0/8)#exit

(Routing) (Config)#interface 0/3, 0/5
(Routing) (Interface 0/3,0/5)#link state group 100 downstream
(Routing) (Interface 0/3,0/5)#exit
```

To view link dependency settings for all groups or for the specified group, along with the group state, use the commands **show link state group [***group_id***]** and **show link state group** *group-id* **detail**.

5.13 RA Guard

The following example configures IPv6 RA Guard on a host connected port. The policy drops all incoming RA and router redirect messages received on the port.

```
(Switching)#config
(Switching)(config)#interface 0/1
(Switching)(Interface 0/1)#ipv6 nd raguard attach-policy

(Switching) (Interface 0/1)#show ipv6 nd raguard policy
Ipv6 RA-Guard Configured Interfaces
Interface         Role
--------------- -------
0/1             Host
```

5.14 FIP Snooping

FIP snooping is a frame inspection method used by the EFOS FIP Snooping Bridge to monitor FIP frames and apply policies based on the L2 header information in those frames, following recommendations in Annex C of FC_BB_5 Rev 2.00.

FIP Snooping enables the following features:

- Auto-configuration of Ethernet ACLs based on information in the Ethernet headers of FIP frames.
- Emulation of fibre channel (FC) point-to-point links within the DCB Ethernet network.
- Enhanced FCoE security/robustness by preventing FCoE MAC spoofing.

The FIP Snooping Bridge solution in EFOS is intended for use only at the edge or perimeter of the switched network and not on an interior switch.

To configure FIP snooping:

1. For ports connected to CNAs/ENodes, enable LLDP and DCBX and configure them as DCBX *auto-down* ports. In this example, the ports connected to the CNAs/ENodes are ports 0/9 and 0/10.

```
(Routing) #config
(Routing) (Config)#interface 0/9-0/10
(Routing) (Interface 0/9-0/10)#lldp transmit
(Routing) (Interface 0/9-0/10)#lldp receive
(Routing) (Interface 0/9-0/10)#lldp dcbx port-role auto-down
(Routing) (Interface 0/9-0/10)#exit
```

2. For ports connected to the FCoE Forwarders (FCFs, Cisco Nexus 5010/5548), enable LLDP and DCBX and configure these ports as DCBX *auto-up* ports. In this example, the port connected to the FCF is port 0/11.

```
(Routing) (Config)#interface 0/11
(Routing) (Interface 0/11)#lldp transmit
(Routing) (Interface 0/11)#lldp receive
(Routing) (Interface 0/11)#lldp dcbx port-role auto-up
(Routing) (Interface 0/11)#exit
```

3. In Global Config mode, configure one-to-one global dot1p mapping.

```
(Routing) (Config)#classofservice dot1p-mapping 0 0
(Routing) (Config)#classofservice dot1p-mapping 1 1
(Routing) (Config)#classofservice dot1p-mapping 2 2
(Routing) (Config)#classofservice dot1p-mapping 3 3
(Routing) (Config)#classofservice dot1p-mapping 4 4
(Routing) (Config)#classofservice dot1p-mapping 5 5
(Routing) (Config)#classofservice dot1p-mapping 6 6
```

```
(Routing) (Config)#exit
```

4. Create the FCoE VLAN. In this example, FCoE VLAN ID is 1000.

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 1000
(Routing) (Vlan)#exit
```

5. Add VLAN 1000 membership to the ports connected to CNAs and FCF. Enable VLAN tagging on these ports for FCoE VLAN using below interface commands.

```
(Routing) #config
(Routing) (Config)#interface 0/9-0/11
(Routing) (Interface 0/9-0/11)#vlan participation include 1000
(Routing) (Interface 0/9-0/11)#vlan tagging 1000
(Routing) (Interface 0/9-0/11)#exit
(Routing) (Config)#exit
```

6. Enable FIP snooping in FCoE VLAN 1000. Also enable FIP snooping in VLAN 1 to allow FIP VLAN discovery to happen in untagged mode.

```
(Routing) #configure
(Routing) (Config)#feature fip-snooping
(Routing) (Config)#vlan 1,1000
(Routing) (Config)(Vlan 1,1000)#fip-snooping enable
(Routing) (Config)(Vlan 1,1000)#exit
(Routing) (Config)#exit
```

7. Configure FCF facing ports using below interface command. By default, FIP snooping ports are configured as host/ENode mode.

```
(Routing) #configure
(Routing) (Config)#interface 0/11
(Routing) (Interface 0/11)#fip-snooping port-mode fcf
(Routing) (Interface 0/11)#exit
(Routing) (Config)#exit
```

The following code sample shows the configuration script for the FIP snooping switch configured in the example. Two interfaces (0/9 and 0/10) are connected to CNAs, and 0/11 is connected to CISCO Nexus 5010 FCF.

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 1000
(Routing) (Vlan)#exit

(Routing) #configure

(Routing) (Config)#feature fip-snooping
(Routing) (Config)#vlan 1,1000
(Routing) (Config)(Vlan 1,1000)#fip-snooping enable
(Routing) (Config)(Vlan 1,1000)#exit

(Routing) (Config)#classofservice dot1p-mapping 0 0
(Routing) (Config)#classofservice dot1p-mapping 1 1
(Routing) (Config)#classofservice dot1p-mapping 2 2
(Routing) (Config)#classofservice dot1p-mapping 3 3
(Routing) (Config)#classofservice dot1p-mapping 4 4
(Routing) (Config)#classofservice dot1p-mapping 5 5
(Routing) (Config)#classofservice dot1p-mapping 6 6

(Routing) (Config)#interface 0/9
(Routing) (Interface 0/9)#description 'Brocade CNA'
(Routing) (Interface 0/9)#vlan participation include 1000
(Routing) (Interface 0/9)#vlan tagging 1000
(Routing) (Interface 0/9)#vlan priority 3
(Routing) (Interface 0/9)#lldp transmit
(Routing) (Interface 0/9)#lldp receive
(Routing) (Interface 0/9)#lldp dcbx port-role auto-down
(Routing) (Interface 0/9)#exit

(Routing) (Config)#interface 0/10
(Routing) (Interface 0/10)#description 'Broadcom CNA'
(Routing) (Interface 0/10)#vlan participation include 1000
(Routing) (Interface 0/10)#vlan tagging 1000
(Routing) (Interface 0/10)#vlan priority 3
(Routing) (Interface 0/10)#lldp transmit
(Routing) (Interface 0/10)#lldp receive
(Routing) (Interface 0/10)#lldp dcbx port-role auto-down
(Routing) (Interface 0/10)#exit

(Routing) (Config)#interface 0/11
(Routing) (Interface 0/11)#description 'CISCO Nx5010-FCF Facing'
(Routing) (Interface 0/11)#vlan participation include 1000
(Routing) (Interface 0/11)#vlan tagging 1000
(Routing) (Interface 0/11)#vlan priority 3
(Routing) (Interface 0/11)#fip-snooping port-mode fcf
(Routing) (Interface 0/11)#lldp transmit
(Routing) (Interface 0/11)#lldp receive
(Routing) (Interface 0/11)#lldp dcbx port-role auto-up
(Routing) (Interface 0/11)#exit

(Routing) (Config)#exit
```

5.15 ECN

Explicit Congestion Notification (ECN) is defined in RFC 3168. Conventional TCP networks signal congestion by dropping packets. A Random Early Discard scheme provides earlier notification than a tail drop scheme by dropping packets already queued for transmission. ECN marks congested packets that would otherwise have been dropped and expects an ECN-capable receiver to signal congestion back to the transmitter without the need to retransmit the packet that would have been dropped. For TCP, this means that the TCP receiver signals a reduced window size to the transmitter but does not request retransmission of the CE marked packet.

ECN uses the two least significant bits of the DiffServ field (TOS octet in IPv4/Traffic Class octet in IPv6) and codes them as follows:

00: Non ECN-Capable Transport – Non-ECT
10: ECN Capable Transport – ECT(0)
01: ECN Capable Transport – ECT(1)
11: Congestion Encountered – CE

ECN-capable hosts communicate support for ECN via two flags in the TCP header:

- ECN-Echo (ECE)
- Congestion Window Reduced (CWR)

EFOS WRED considers packets for early discard only when the number of packets queued for transmission on a port exceeds the relevant minimum WRED threshold. The green, yellow, red thresholds operate on TCP packets. The fourth threshold operates on non-TCP packets.

When ECN is enabled and congestion is experienced, TCP packets that are marked ECN Capable that are queued for transmission and are selected for discarded by WRED, are instead marked CE and transmitted. This includes packets that exceed the WRED upper threshold. If the switch experiences severe congestion (no buffers available), then packets are discarded.

WRED considers packets for early discard only when the number of packets queued for transmission on a port exceeds the relevant minimum WRED threshold. Four thresholds are available for configuration. The green, yellow, and red thresholds operate on TCP packets. The fourth threshold operates on non-TCP packets.

When ECN is enabled and congestion is experienced, packets that are marked ECN-capable, are queued for transmission, and are randomly selected for discard by WRED are instead marked CE and are transmitted rather than dropped. This includes packets that exceed the WRED upper threshold. If the switch experiences severe congestion (no buffers available), then packets are discarded.

EFOS implements ECN capability as part of the WRED configuration process. Eligible packets are marked by hardware based on the WRED configuration. The network operator can configure any CoS queue to operate in ECN marking mode and can configure different discard thresholds for each color.

5.15.1 Enabling ECN in Microsoft Windows

On many current Windows implementations, ECN capability is enabled via the **netsh** command as follows:

```
netsh int tcp set global ecncapability=enabled
```

The capability can be verified with the following command:

```
netsh int tcp show global.
```

An example is shown below:

```
C:\Users\user1>Netsh int tcp set global ecncapability=enabled
Ok.
C:\Users\user1>netsh int tcp show global
Querying active state...

TCP Global Parameters
----------------------------------------------
Receive-Side Scaling State : enabled
Chimney Offload State : automatic
NetDMA State : enabled
Direct Cache Acess (DCA) : disabled
Receive Window Auto-Tuning Level : normal
Add-On Congestion Control Provider : none
ECN Capability : enabled
RFC 1323 Timestamps : disabled
```

In Windows Server 2012, DCTCP is self-activating based on the RTT of TCP packets. No user management is required. Use the PowerShell cmdlet **Get-NetTcpConnection** to verify DCTCP operation.

5.15.2 Example 1: SLA Example

The following example configures simple meter and a trTCM meter in support of a network SLA. The SLA classes are segregated by CoS class.

1. Define a class-map so that all traffic will be in the set of traffic “cos-any”.
   ```
   (Routing) (Config)#class-map match-all cos-any ipv4
   (Routing) (Config-classmap)#match any
   (Routing) (Config-classmap)#exit
   ```
2. Define a class-map such that all traffic with a Cos value of 1 will be in the set of traffic “cos1”. This will be used as a conform-color class map. Conform-color class maps must be one of CoS, secondary CoS, DSCP, or IP precedence.
   ```
   (Routing) (Config)#class-map match-all cos1 ipv4
   (Routing) (Config-classmap)#match cos 1
   (Routing) (Config-classmap)#exit
   ```
3. Define a class-map such that all IPv4 traffic with a CoS value of 0 will be in the set of traffic “cos0”. This will be used as a conform-color class map. Conform-color class maps must be one of CoS, secondary CoS, DSCP, or IP precedence.
   ```
   (Routing) (Config)#class-map match-all cos0 ipv4
   (Routing) (Config-classmap)#match cos 0
   (Routing) (Config-classmap)#exit
   ```
4. Define a class-map such that all TCP will be in the set of traffic “TCP”. This will be used as a base color class for metering traffic.
   ```
   (Routing) (Config)#class-map match-all tcp ipv4
   (Routing) (Config-classmap)#match protocol tcp
   (Routing) (Config-classmap)#exit
   ```
5. Define a policy-map to include packets matching class “cos-any” (IPv4). Ingress IPv4 traffic arriving at a port participating in this policy will be assigned red or green coloring based on the metering.
   ```
   (Routing) (Config)#policy-map simple-policy in
   (Routing) (Config-policy-map)#class cos-any
   ```

6. Create a simple policer in color blind mode. Packets below the committed information rate (CIR) or committed burst size (CBS) are assigned drop precedence "green". Packets that exceed the CIR (in Kb/s) or CBS (in Kbytes) are colored "red". Both the conform and violate actions are set to transmit as WRED is used to drop packets when congested.

```
(Routing) (Config-policy-classmap)#police-simple 10000000 64 conform-action transmit violate-
action transmit
(Routing) (Config-policy-classmap)#exit
(Routing) (Config-policy-map)#exit
```

7. Define a policy-map in color aware mode matching class "cos-any" (IPv4). Ingress IPv4 traffic arriving at a port participating in this policy will be assigned green, yellow, or red coloring based on the meter.

```
(Routing) (Config)#policy-map two-rate-policy in
(Routing) (Config-policy-map)#class tcp
```

8. Create a two-rate policer per RFC 2698. The CIR value is 800 Kb/s and the CBS is set to 96 Kbytes. The PIR is set to 950 Kb/s and the PBS is set to 128 Kbytes. Color-aware processing is enabled via the **conform-color** command (i.e., any packets not in cos 0 or 1 are pre-colored "red." Packets in cos 0 are pre-colored yellow. Packets in cos 1 are pre-colored green. Pre-coloring gives greater bandwidth to cos 1 packets, as they are initially subject to the CIR/CBS limits. Packets in CoS 0 are subject to the PIR limits. Based on the CIR/CBD, the PIR/PBS, and the conform, exceed, and violate actions specified below.

   TCP packets with rates less than or equal to the CIR/CBS in class cos 1 are conforming to the rate (green). These packets will be dropped randomly at an increasing rate between 0–3% when the outgoing interface is congested between 80 and 100%.

   TCP packets with rates above the CIR/CBS and less than or equal to PIR/PBS in either class cos 1 or class cos 2 are policed as exceeding the CIR (yellow). These packets will be dropped randomly at an increasing rate between 0–5% when the outgoing interface is congested between 70 and 100%. TCP packets with rates higher than the PIR/PBS or which belong to neither class cos 1 nor class cos 2 are violating the rate (red).

   These packets will be dropped randomly at an increasing rate between 0–10% when the outgoing interface is congested between 50 and 100%.

   Non-TCP packets in CoS queue 0 or 1 will be dropped randomly at an increasing rate between 0–15% when the outgoing interface is congested between 50 and 100%.

```
(Routing) (Config-policy-classmap)#police-two-rate 800 96 950 128 conform-action transmit
exceedaction transmit violate-action transmit conform-color cos1 exceed-color cos0
(Routing) (Config-policy-classmap)#exit
(Routing) (Config-policy-map)#exit
```

9. Enable WRED drop on traffic classes 0 and 1.

```
(Routing) (Config)#cos-queue random-detect 0 1
```

10. Set the exponential-weighting-constant. The exponential weighting constant smooths the result of the average queue depth calculation by the function:

    average depth = (previous queue depth * (1-1/2^n)) + (current queue depth * 1/2^n).

    The average depth is used in calculating the amount of congestion on a queue. Because the instantaneous queue depth fluctuates rapidly, larger values of the weighting constant cause the average queue depth value to respond to changes more slowly than smaller values.

```
(Routing) (Config)#random-detect exponential-weighting-constant 4
```

11. Configure the queue parameters for traffic class 0 and 1. We set the minimum threshold and maximum thresholds to 80–100% for green traffic, 70–100% for yellow traffic, and 50–100% for red traffic. Non-TCP traffic drops in the 50–100% congestion range. Green traffic is dropped at a very low rate to slowly close the TCP window. Yellow and red traffic are dropped more aggressively.

```
   (Routing) (Config)#random-detect queue-parms 0 1 min-thresh 80 70 50 50 max-thresh 100 100 100 100
   drop-prob-scale 3 5 10 15
```

12. Assign the color policies to ports. The metering policies are applied on ingress ports.

```
   (Routing) (Config)#interface 0/22
   (Routing) (Interface 0/22)#service-policy in simple-policy
   (Routing) (Interface 0/22)#exit
   (Routing) (Config)#interface 0/23
   (Routing) (Interface 0/23)#service-policy in two-rate-policy
   (Routing) (Interface 0/23)#exit
```

5.15.3 Example 2: Data Center TCP (DCTCP) Configuration

This example globally configures an EFOS switch to utilize ECN marking of green packets queued for egress on CoS queues 0 and 1, using the DCTCP threshold as it appears in "DCTCP: Efficient Packet Transport for the Commoditized Data Center" (Alizadeh, Greenberg, Maltz, Padhye, Patel, Prabhakar, Sengupta, and Sridharan, 2010.)

In the first line of the following configuration, the first integer after the **minthresh** keyword configures green-colored Congestion Enabled TCP packets in CoS queues 0 and 1 that exceed the WRED threshold (13% or ~38 Kbytes) to mark packets as Congestion Experienced. The first integer after the **max-thresh** parameter configures the upper threshold for green-colored TCP packets to the same value as the **min-thresh** threshold. This causes the switch to mark all ECN-capable queued packets as Congestion Experienced when the threshold is reached or exceeded. TCP packets without ECN capability bits set are dropped according to the normal WRED processing when the threshold is exceeded. Packets on other CoS queues are handled in the standard manner (i.e., are tail-dropped) when insufficient buffer is available.

Yellow and red packet configuration (second and third threshold parameters) are kept at the defaults, as no metering to reclassify packets from green to yellow or red is present. The last threshold parameter configures non-TCP packets in CoS queues 0 and 1 to be processed with the WRED defaults. The **ecn** keyword enables ECN marking of ECN-capable packets on CoS queues 0 and 1. The weighting constant is set to 0 in the second line of the configuration, as described in the DCTCP paper cited above. Finally, CoS queues 0 and 1 are configured for WRED in the last line of the configuration.

```
(Routing) #config
(Routing) (Config)#random-detect queue-parms 0 1 min-thresh 13 30 20 100 max-thresh 13 90 80 100
   drop-prob-scale 100 10 10 10 ecn
(Routing) (Config)#random-detect exponential-weighting-constant 0
(Routing) (Config)#cos-queue random-detect 0 1
```

Chapter 6: Configuring Data Center Features

6.1 Data Center Technology Overview

NOTE: The Data Center features and commands in this section are platform-dependent.

EFOS software supports Data Center Bridging (DCB) features to increase the reliability of Ethernet-based networks in the data center. The Ethernet enhancements that DCB provides are well suited for Fibre Channel over Ethernet (FCoE) environments.

Table 10, DCB Features provides a summary of the features this section describes.

Table 10: DCB Features

Feature	Description
PFC	Provides a way to distinguish which traffic on a physical link is paused when congestion occurs based on the priority of the traffic. See Section 6.2, Priority-Based Flow Control.
DCBX	Allows DCB devices to exchange configuration information, using type-length-value (TLV) information elements over LLDP, with directly connected peers. See Section 6.3, Data Center Bridging Exchange Protocol.
CoS Queuing	Allows the switch administrator to directly configure certain aspects of device queuing to provide the required QoS behavior for different types of network traffic when the complexities of DiffServ are not required. See Section 6.4, CoS Queuing.
ETS	Supports the ETS configuration and Application Priority TLVs, which are accepted from auto-upstream devices and propagated to auto-downstream devices. See Section 6.5, Enhanced Transmission Selection.
QCN	Manages end-to-end congestion by enabling bridges to signal congestion information to end stations capable of transmission rate limiting to avoid frame loss. VLAN tag-encoded priority values are allocated to segregate frames subject to congestion control, allowing simultaneous support for both congestion control and other higher layer protocols This feature is not supported on all platforms. See Section 6.6, Quantized Congestion Notification (QCN).
OpenFlow	The OpenFlow feature enables the switch to be managed by a centralized OpenFlow Controller using the OpenFlow protocol. See Section 6.7, OpenFlow Operation and Configuration.
DCVPN Gateway	Enables VXLAN and NVGRE network virtualization technologies to communicate with another network, particularly a VLAN. It offers VTEP functionality for VXLAN and NVE functionality for NVGRE tunnels on the switch. See Section 6.8, DCVPN Gateway Operation and Configuration.
MPLS	Provides a technique for forwarding data between network nodes using short MPLS-assigned path labels instead of long network addresses associated with the underlying forwarding protocol. MPLS may be deployed in data centers to enable multi-service networks, which deliver data transport services and IP routing services across the same packet-switched network infrastructure. Section 6.9, MPLS Operation and Configuration.

6.2 Priority-Based Flow Control

Ordinarily, when flow control is enabled on a physical link, it applies to all traffic on the link. When congestion occurs, the hardware sends pause frames that temporarily suspend traffic flow to help prevent buffer overflow and dropped frames.

PFC provides a means of pausing individual priorities within a single physical link. By pausing the congested priority or priorities independently, protocols that are highly loss-sensitive can share the same link with traffic that has different loss tolerances.

This feature is used in networks where the traffic has differing loss tolerances. For example, Fibre Channel traffic is highly sensitive to traffic loss. If a link contains both loss-sensitive data and other less loss-sensitive data, the loss-sensitive data should use a no-drop priority that is enabled for flow control.

Priorities are differentiated by the priority field of the IEEE 802.1Q VLAN header, which identifies an IEEE 802.1p priority value. These priority values must be mapped to internal class-of-service (CoS) values.

The PFC feature allows you to specify the CoS values that should be paused (due to greater loss sensitivity) instead of dropped when congestion occurs on a link. Unless configured as no-drop, all CoS priorities are considered non-pausable ("drop") when priority-based flow control is enabled until no-drop is specifically turned on.

6.2.1 PFC Operation and Behavior

PFC uses a new control packet defined in IEEE 802.1Qbb and therefore is not compatible with IEEE 802.3 Annex 31B flow control. An interface that is configured for PFC will be automatically disabled for flow control. When PFC is disabled on an interface, the flow control configuration for the interface becomes active. Any flow control frames received on a PFC configured interface are ignored.

Each priority is configured as either *drop* or *no-drop*. If a priority that is designated as no-drop is congested, the priority is paused. Drop priorities do not participate in pause. You must configure the same no-drop priorities across the network in order to ensure end-to-end lossless behavior.

Operator configuration of PFC is used only when the port is configured in a manual role. When interoperating with other equipment in a manual role, the peer equipment must be configured with identical PFC priorities and VLAN assignments. Interfaces not enabled for PFC ignore received PFC frames. Ports configured in auto-upstream or auto-downstream roles receive their PFC configuration from the configuration source and ignore any manually-configured information.

NOTE: This feature is configurable on physical full duplex interfaces only. To enable PFC on a LAG interface, the member interfaces must have the same configuration.

When PFC is disabled, the interface defaults to the IEEE 802.3 flow control setting for the interface. PFC is disabled by default.

If you enable priority-based flow control for a particular priority value on an interface, make sure 802.1p priority values are mapped to CoS values (see Section 9.2, CoS).

6.2.2 Configuring PFC

The network in this example handles standard data traffic and traffic that is time sensitive (such as voice and video). The time-sensitive traffic requires a higher priority than standard data traffic. All time-sensitive traffic is configured to use VLAN 100 and has an 802.1p priority of 5, which is mapped to hardware queue 4. The hosts that frequently send and receive the time-sensitive traffic are connected to ports 3, 5, and 10, so PFC is enabled on these ports with 802.1p priority 5 traffic as no-drop. The configuration also enables VLAN tagging so that the 802.1p priority is identified. This example assumes that VLAN 100 has already been configured.

CAUTION! All ports may be briefly shutdown when modifying either flow control or PFC settings. PFC uses a control packet defined in 802.1Qbb and is not compatible with 802.3x FC.

1. Map 802.1p priority 5 to traffic class 4. For more information about traffic classes, see Section 9.2, CoS.

   ```
   (Routing) #configure
   (Routing) (Config)#classofservice dot1p-mapping 5 4
   ```

2. Enter Interface Configuration mode for ports 3, 5, and 10.

```
(Routing) (Config)#interface 0/3,0/5,0/10
```

3. Enable PFC and configure traffic marked with 802.1p priority 5 to be paused rather than dropped when congestion occurs.

```
(Routing) (Interface 0/3,0/5,0/10)#datacenter-bridging
(Routing) (Config-if-dcb)#priority-flow-control mode on
(Routing) (Config-if-dcb)#priority-flow-control priority 5 no-drop
```

4. Enable VLAN tagging on the ports so the 802.1p priority is identified.

```
(Routing) (Interface 0/3,0/5,0/10)#vlan participation include 100
(Routing) (Interface 0/3,0/5,0/10)#vlan tagging 100
(Routing) (Interface 0/3,0/5,0/10)#exit
```

6.3 Data Center Bridging Exchange Protocol

The Data Center Bridging Exchange Protocol (DCBX) is used by DCB devices to exchange configuration information with directly connected peers. DCBX uses type-length-value (TLV) information elements over LLDP to exchange information, so LLDP must be enabled on the port to enable the information exchange. By default, LLDP is enabled on all ports. For more information, see Section 5.10, LLDP and LLDP-MED.

The main objective of DCBX is to perform the following operations:

- **Discovery of DCB capability in a peer**: DCBX is used to learn about the capabilities of the peer device. It is a means to determine if the peer device supports a particular feature such as PFC.
- **DCB feature misconfiguration detection**: DCBX can be used to detect misconfiguration of a feature between the peers on a link. Misconfiguration detection is feature-specific because some features may allow asymmetric configuration.
- **Peer configuration of DCB features**: DCBX can be used by a device to perform configuration of DCB features in its peer device if the peer device is willing to accept configuration.

DCBX is expected to be deployed in Fibre Channel over Ethernet (FCoE) topologies in support of lossless operation for FCoE traffic. In these scenarios, all network elements are DCBX enabled. In other words, DCBX is enabled end-to-end.

The DCBX protocol supports the propagation of configuration information for the following features:

- Enhanced Transmission Selection (ETS)
- Priority-based Flow Control (PFC)
- Application Priorities

These features use DCBX to send and receive device configuration and capability information to the peer DCBX device.

The Application Priorities information is simply captured from the peer and potentially propagated to other peers by the DCBX component.

6.3.1 Interoperability with IEEE DCBX

To be interoperable with legacy industry implementations of DCBX protocol, EFOS software uses a hybrid model to support both the IEEE version of DCBX (IEEE 802.1Qaz) and legacy DCBX versions.

EFOS software automatically detects if a peer is operating with either of the two CEE DCBX versions or the IEEE standard DCBX version. This is the default mode. You can also configure DCBX to manually select one of the legacy versions or IEEE standard mode. In auto-detect mode, the switch starts operating in IEEE DCBX mode on a port, and if it detects a legacy DCBX device based on the OUI of the organization TLV, then the switch changes its DCBX mode on that port to support the version detected. There is no timeout mechanism to move back to IEEE mode. Once the DCBX peer times out, multiple peers are detected, the link is reset (link down/up) or as commanded by the operator, DCBX resets its operational mode to IEEE.

The interaction between the DCBX component and other components remains the same irrespective of the operational mode it is executing. For instance DCBX component interacts with PFC to get needed information to pack the TLVs to be sent out on the interface. Based on the operational control mode of the port, DCBX packs it in the proper frame format.

6.3.2 DCBX and Port Roles

Each port's behavior is dependent on the operational mode of that port and of other ports in the switch. The port mode is a DCBX configuration item that is passed to the DCBX clients to control the processing of their configuration information. There are four port roles:

- Manual
- Auto-Upstream
- Auto-Downstream
- Configuration Source

Ports operating in the manual role do not have their configuration affected by peer devices or by internal propagation of configuration. These ports have their operational mode, traffic classes, and bandwidth information specified explicitly by the operator. These ports advertise their configuration to their peer if DCBX is enabled on that port. Incompatible peer configurations are logged and counted with an error counter.

The default operating mode for each port is manual. A port that is set to manual mode sets the willing bit for DCBX client TLVs to false. Manually- configured ports never internally propagate or accept internal or external configuration from other ports, in other words, a manual configuration discards any automatic configuration. Manually-configured ports may notify the operator of incompatible configurations if client configuration exchange over DCBX is enabled. Manually- configured ports are always operationally enabled for DCBX clients, regardless of whether DCBX is enabled. Operationally enabled means that the port reports that it is able to operate using the current configuration.

A port operating in the auto-upstream role advertises a configuration, but it is also willing to accept a configuration from the link-partner and propagate it internally to the auto-downstream ports as well as receive configuration propagated internally by other auto-upstream ports. Specifically, the willing parameter is enabled on the port and the recommendation TLV is sent to the peer and processed if received locally. The first auto-upstream port to successfully accept a compatible configuration becomes the configuration source. The configuration source propagates its configuration to other auto-upstream and auto-downstream ports. Only the configuration source may propagate configuration to other ports internally. Auto-upstream ports that receive internally propagated information ignore their local configuration and utilize the internally propagated information.

Peer configurations received on auto-upstream ports other than the configuration source result in one of two possibilities. If the configuration is compatible with the configuration source, then the DCBX client becomes operationally active on the upstream port. If the configuration is not compatible with the configuration source, then a message is logged indicating an incompatible configuration, an error counter is incremented, and the DCBX client is operationally disabled on the port. The expectation is that the network administrator configures the upstream devices appropriately so that all such devices advertise a compatible configuration.

A port operating in the auto-downstream role advertises a configuration but is not willing to accept one from the link partner. However, the port will accept a configuration propagated internally by the configuration source. Specifically, the willing parameter is disabled on auto-downstream. By default, auto-downstream ports have the recommendation TLV parameter enabled. Auto-downstream ports that receive internally propagated information ignore their local configuration and utilize the internally propagated information. Auto-downstream ports propagate PFC, ETS, and application priority information received from the configuration source.

In the Configuration Source role, the port has been manually selected to be the configuration source. Configuration received over this port is propagated to the other auto-configuration ports, however, no automatic election of a new configuration source port is allowed. Events that cause selection of a new configuration source are ignored. The configuration received over the configuration source port is maintained until cleared by the operator (set the port to the manual role).

6.3.3 Configuration Source Port Selection Process

When an auto-upstream or auto-downstream port receives a configuration from a peer, the DCBX client first checks if there is an active configuration source. If there is a configuration source already selected, the received configuration is checked against the local port operational values as received from the configuration source, and if compatible, the client marks the port as operationally enabled. If the configuration received from the peer is determined to not be compatible, a message is logged, an error counter is incremented and the DCBX clients become operationally disabled on the port. Operationally disabled means that PFC will not operate over the port. The port continues to keep link up and exchanges DCBX packets. If a compatible configuration is later received, the DCBX clients will become operationally enabled.

If there is no configuration source, a port may elect itself as the configuration source on a first-come, first-serve basis from the set of eligible ports. A port is eligible to become the configuration source if the following conditions are true:

- No other port is the configuration source.
- The port role is auto-upstream.
- The port is enabled with link up and DCBX enabled.
- The port has negotiated a DCBX relationship with the partner.
- The switch is capable of supporting the received configuration values, either directly or by translating the values into an equivalent configuration.

Whether or not the peer configuration is compatible with the configured values is NOT considered.

The newly elected configuration source propagates DCBX client information to the other ports and is internally marked as being the port over which configuration has been received. Configuration changes received from the peer over the configuration source port are propagated to the other auto-configuration ports. Ports receiving auto-configuration information from the configuration source ignore their current settings and utilize the configuration source information.

When a configuration source is selected, all auto-upstream ports other than the configuration source are marked as willing disabled.

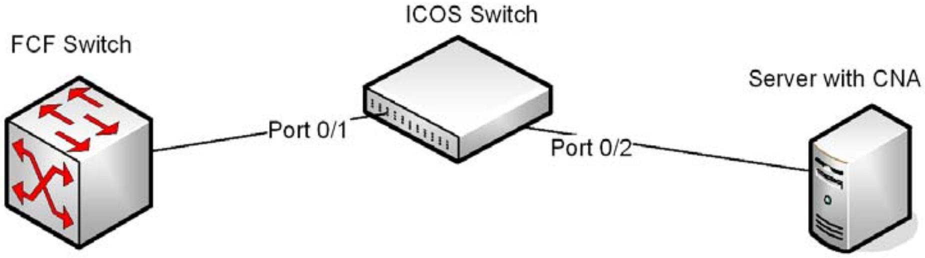
To reduce flapping of configuration information, if the configuration source port is disabled, disconnected or loses LLDP connectivity, the system clears the selection of configuration source port (if not manually selected) and enables the willing bit on all auto-upstream ports. The configuration on the auto-configuration ports is not cleared (configuration holdover). If the user wishes to clear the configuration on the system in this scenario, the user can put the configuration source port into manual mode.

When a new port is selected as configuration source, it is marked as the configuration source, the DCBX configuration is refreshed on all auto-configuration ports and each port may begin configuration negotiation with their peer again (if any information has changed).

6.3.4 Configuring DCBX

In this example, port 0/1 on the EFOS switch connects to a FCoE-facing (FCF) switch. This port is designated as default DCBX auto-upstream ports. Port 0/2 on the EFOS switch is directly connected to a Converged Network Adapter (CNA) on a network server. The configuration advertised by the FCF is distributed from port 0/1 to port 0/2. In order to reduce configuration flapping, ports that obtain configuration information from a configuration source port will maintain that configuration for 2× the LLDP timeout, even if the configuration source port becomes operationally disabled.

Figure 30: DCBX Configuration



1. Map 802.1p priority 3 to traffic class 3. For more information about traffic classes, see Section 9.2, CoS.
   ```
   (Routing) #configure
   (Routing) (Config)#classofservice dot1p-mapping 3 3
   ```
2. Enter Interface Configuration mode for port 1.
   ```
   (Routing) (Config)#interface 0/1
   ```
3. Enable the LLDP transmit and receive capability on the port.
   ```
   (Routing) (Interface 0/1)#lldp transmit
   (Routing) (Interface 0/1)#lldp receive
   ```
4. Enable the port as the configuration source. This port is connected to a trusted FCF. Configuration received over this port is propagated to the other auto-configuration ports.
   ```
   (Routing) (Interface 0/1)#lldp dcbx port-role configuration-source
   (Routing) (Interface 0/1)#exit
   ```
5. Enter Interface Configuration mode for port 2.
   ```
   (Routing) (Config)#interface 0/2
   ```
6. Enable the LLDP transmit and receive capability on the port.
   ```
   (Routing) (Interface 0/2)#lldp transmit
   (Routing) (Interface 0/2)#lldp receive
   ```
7. Configure the LLDP port role as *auto-down*, which means the port advertises a configuration but is not willing to accept one from the link partner. However, the port will accept a configuration propagated internally by the configuration source (port 0/1).
   ```
   (Routing) (Interface 0/2)#lldp dcbx port-role auto-down
   (Routing) (Interface 0/2)#exit
   ```

6.4 CoS Queuing

In a typical switch or router, each physical port consists of one or more queues for transmitting packets on the attached network. Multiple queues per port are often provided to give preference to certain packets over others based on user-defined criteria. When a packet is queued for transmission in a port, the rate at which it is serviced depends on how the queue is configured—and possibly the amount of traffic present in the other queues of the port. If a delay is necessary, packets are held in the queue until the scheduler authorizes the queue for transmission. As queues become full, packets have no place to be held for transmission and get dropped by the device.

The drop precedence of a packet is an indication of whether the packet is more or less likely to be dropped during times of queue congestion. Often referred to as packet coloring, a low drop precedence (green) allows the packet to be transmitted under most circumstances, a higher drop precedence (yellow) subjects the packet to dropping when bursts become excessive, while the highest drop precedence (red) discards the packet whenever the queue is congested. In some hardware implementations, the queue depth can be managed using tail dropping or a weighted random early discard, or WRED, technique. These methods often use customizable threshold parameters that are specified on a per-drop-precedence basis.

The EFOS QoS package contains Differentiated Services (DiffServ) support that allows traffic to be classified into streams and given certain QoS treatment in accordance with defined per-hop behaviors. However, the DiffServ feature does not offer direct configuration of the hardware COS queue resources.

The COS Queuing feature allows the switch administrator to directly configure certain aspects of device queuing to provide the required QoS behavior for different types of network traffic when the complexities of DiffServ are not required. The priority of a packet arriving at an interface can be used to steer the packet to the appropriate outbound COS queue through a mapping table. With the CoS queuing feature, COS queue characteristics such as minimum guaranteed bandwidth, transmission rate shaping, etc. can be configured at the queue (or port) level.

For platforms that support the multistage scheduling architecture, the COS queue feature provides a method to configure Traffic Class Groups (TCGs) to extend the COS queue management. Multiple COS queues can be mapped to a single TCG. Each TCG can have a configured minimum guaranteed bandwidth allocation and a scheduling algorithm similar to the COS queue configuration. The TCG scheduling and bandwidth enforcement occurs after the COS queue scheduling and bandwidth enforcement is performed. Therefore all COS queues mapped to the same TCG share the scheduling and bandwidth properties of the TCG.

6.4.1 CoS Queuing Function and Behavior

Like CoS mapping, CoS queuing uses the concept of trusted and untrusted ports. CoS queuing builds on includes user-configurable settings that affect hardware queue operation.

6.4.1.0.1 Trusted Port Queue Mappings

A trusted port is one that takes at face value a certain priority designation within arriving packets. Specifically, a port may be configured to trust one of the following packet fields:

- 802.1p User Priority
- IP Precedence
- IP DSCP

Packets arriving at the port ingress are inspected and their trusted field value is used to designate the COS queue that the packet is placed when forwarded to the appropriate egress port. A mapping table associates the trusted field value with the required COS queue.

6.4.1.0.2 Un-trusted Port Default Priority

Alternatively, a port may be configured as un-trusted, whereby it does not trust any incoming packet priority designation and uses the port default priority value instead. All packets arriving at the ingress of an un-trusted port are directed to a specific COS queue on the appropriate egress port(s) in accordance with the configured default priority of the ingress port. This process is also used for cases where a trusted port mapping is unable to be honored, such as when a non-IP packet arrives at a port configured to trust the IP precedence or IP DSCP value.

6.4.1.0.3 Queue Configuration

Queue configuration involves setting the following hardware port egress queue configuration parameters:

- Scheduler type: strict vs. weighted
- Minimum guaranteed bandwidth
- Maximum allowed bandwidth (i.e. shaping)
- Queue management type: tail-drop vs. WRED
- Tail drop parameters: threshold
- WRED parameters: minimum threshold, maximum threshold, drop probability

Defining these settings on a per-queue basis allows the user to create the required service characteristics for different types of traffic. The tail drop and WRED parameters are specified individually for each supported drop precedence level.

In addition, the following settings can be specified on a per-interface basis:

- Queue management type: tail drop vs. WRED (only if per-queue configuration is not supported)
- WRED decay exponent

6.4.1.0.4 Traffic Class Groups

In EFOS platforms that support multiple levels of egress scheduling, the Traffic Class Groups (TCGs) extend the egress queuing to make use of multiple levels of scheduling. A TCG defines a collection of egress COS Queues. The configuration parameters for the TCG specify the class of service characteristics applied to the aggregated traffic from the associated COS queues. This involves setting the following configuration parameters to each TCG.

- Map one or more COS queues to the TCG.
- Set the scheduling type for each TCG: Strict vs. WDRR
- Set the weight percentages for each TCG.
- Set the minimum guaranteed bandwidth for each TCG. The minimum bandwidth is specified in terms of the percentage of the total link bandwidth.
- Set the maximum allowed bandwidth for each TCG. The maximum bandwidth is specified in terms of the percentage of the total link bandwidth.

TCG configuration parameters are similar to that of COS queues. That is, the configuration of scheduling attributes such as minimum bandwidth, maximum bandwidth, and scheduling algorithm also apply to TCG. The behavior of a TCG with respect to scheduling algorithm and bandwidth allocation configuration is the same as that of COS Queues.

Each TCG is associated with a weight percentage which defines the priority of the TCG to be serviced when WDRR is configured as the scheduling type of the TCG. The weight of the TCG is used only after the minimum guaranteed bandwidth of each of the TCG is met and after all the strict priority TCGs are serviced. The weight of the TCG is then used to prioritize the TCGs among the TCGs that are configured for WDRR.

6.4.2 Configuring CoS Queuing and ETS

This example shows the manual configuration of the CoS queuing feature in a network where traffic needs to be prioritized based on the protocol frame-loss tolerance. For example, FCoE traffic is highly sensitive to traffic loss. If a port has both loss-sensitive data and other less loss-sensitive data, then the loss-sensitive data is categorized into the same TCG to provide control over the bandwidth allocation and scheduling for the loss-sensitive traffic.

In this example, loss-sensitive traffic is sent with an 801.p priority value of 4, and less loss-sensitive traffic is sent with an 801.p priority value priority of 1. The following steps show how to configure the switch to prioritize the traffic.

1. Configure one to one mapping between 802.1p priority and COS Queue on the ingress port. Frames with 802.1p priority 1 are assigned to COS 1 queue and similarly frames with 802.1p priority 2 are assigned to COS2 and so on.
   ```
   (Routing) (Config)#classofservice dot1p-mapping 0 0
   (Routing) (Config)#classofservice dot1p-mapping 1 1
   (Routing) (Config)#classofservice dot1p-mapping 2 2
   (Routing) (Config)#classofservice dot1p-mapping 3 3
   (Routing) (Config)#classofservice dot1p-mapping 4 4
   (Routing) (Config)#classofservice dot1p-mapping 5 5
   (Routing) (Config)#classofservice dot1p-mapping 6 6
   (Routing) (Config)#classofservice dot1p-mapping 7 7
   ```
2. Enable 802.1p Trust mode on all the ports.
   ```
   (Routing) (Config)#interface 0/1-0/16
   (Routing) (Interface 0/1-0/16)#classofservice trust dot1p
   (Routing) (Interface 0/1-0/16)#exit
   ```
3. Configure the mapping between COS queues and Traffic Classes Groups. Configure the Traffic Class Group that such 802.1p priority 4 is assigned to TCG1 and 802.1p priority 1 is assigned to TCG2 so that less loss sensitive traffic does not starve the loss sensitive traffic even during traffic bursts. Assign 802.1p priority 7 traffic to TCG0.
   ```
   (Routing) (Config)#classofservice traffic-class-group 4 1
   (Routing) (Config)#classofservice traffic-class-group 1 2
   (Routing) (Config)#classofservice traffic-class-group 7 0
   ```
4. Enable VLAN tagging on the ports so the 802.1p priority is identified. The interfaces in this example are members of VLAN 100, which has been previously configured.
   ```
   (Routing) (Config)#interface 0/1-0/16
   (Routing) (Interface 0/1-0/16)#vlan participation include 100
   (Routing) (Interface 0/1-0/16)#vlan tagging 100
   (Routing) (Interface 0/1-0/16)#exit
   ```
5. Configure the weight percentage of TCG0 to 10%, and the weights of TCG1 and TCG2 to 45% each.
   ```
   (Routing) (Config)#traffic-class-group weight 10 45 45
   ```
6. Associate weighted round robin scheduling with TCG1 and TCG2.
   ```
   (Routing) (Config)#no traffic-class-group strict 1 2
   ```
7. Configure TCG0 for strict priority scheduling.
   ```
   (Routing) (Config)#traffic-class-group strict 0
   ```
8. Associate TCG0 with CoS queue 7 so that it serves the high priority internal control traffic with CoS 7.
   ```
   (Routing) (Config)#classofservice traffic-class-group 7 0
   ```
9. Configure the minimum bandwidth percentage for all the TCGs to be zero.
   ```
   (Routing) (Config)#traffic-class-group min-bandwidth 0 0 0
   ```

After performing Step 1–Step 9, the data traffic with an 802.1p priority is sent through TCG1, and 45% of the bandwidth (excluding TCG0 bandwidth) is reserved for TCG1. This protects the TCG1 traffic from traffic that is transmitted on TCG2. Any burst in traffic being transmitted in TCG2 does not affect traffic in TCG1. If TCG2 is not being utilized to the full potential then TCG1 can still use that bandwidth for transmitting TCG1 traffic.

With the configuration in this example, TCG0 with strict priority gets highest priority and can consume the full bandwidth of the pipeline. TCG1 and TCG2 share the remaining bandwidth after TCG0 consumes its share of the pipeline.

Based on this configuration, when the switch sends the configuration ETS TLVs to the peer, the values that are given to DCBX are as follows:

- **Willing Bit**—This bit is set to TRUE for auto-upstream interfaces if there is no configuration source or FALSE if there is a configuration source, and FALSE for auto-downstream and manual ports.
- **Credit-based Shaper support and Max TC**—These are platform-specific values.
- **Priority Assignment Table**—Table 11, 802.1p-to-TCG Mapping contains the default values advertised by DCBX to the peer DCBX device. If available, the mapping translated from the configuration source is used. This table defines the mapping between the egress Traffic Class Group and ingress 802.1p priority.

Table 11: 802.1p-to-TCG Mapping

802.1p Priority	Traffic Class
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0

- **TC Bandwidth And TSA Assignment Table**—Table 12, TCG Bandwidth and Scheduling contains the default values advertised by DCBX to the peer DCBX device. If available, the assignments translated from the configuration source is used. This table defines the bandwidth allocated to each Traffic Class Group and the respective scheduling algorithm for each TCG; the scheduling algorithm is enumerated in the IEEE 802.1Q specification.

Table 12: TCG Bandwidth and Scheduling

Traffic Class	Bandwidth percentage	Scheduling Algorithm
0	10	strict priority (tail-drop) (0)
1	45	strict priority (tail-drop) (0)
2	45	strict priority (tail-drop) (0)

6.5 Enhanced Transmission Selection

Enhanced Transmission Selection (ETS) enables the sharing and redistribution of network bandwidth between various protocols. To support ETS, EFOS software accepts the ETS traffic class group and bandwidth information Application Priority TLV from auto-upstream devices and propagates it to auto-downstream devices. EFOS software supports the reception and propagation of ETS information in the automatic configuration port roles. On EFOS platforms that support hierarchical scheduling, bandwidth allocation and traffic class groups can be configured by ETS TLVs. Platforms that do not support hierarchical scheduling do not use the ETS information to configure traffic class groups or bandwidth allocations.

6.5.1 ETS Operation and Dependencies

Using priority-based processing and bandwidth allocations, different Traffic Class Groups (TCGs) within different types of traffic such as LAN, SAN and Management can be configured to provide bandwidth allocation or best effort transmit characteristics.

For ETS to be operational, the following dependency the following three configuration steps need to occur:

10. Configure COS queues to Traffic Class Group mapping for the egress ports.
11. Configure weight percentage (bandwidth allocation) for each TCG.
12. Enable appropriate scheduling algorithm for each TCG.

CoS information is exchanged with peer DCBX devices using ETS TLVs. As part of the ETS TLV, by default, DCBX advertises the following parameters, which are populated on per port basis.

- Mapping between ingress ports 802.1p priority to Traffic Class Group (TCG).
- Bandwidth percentage (weight percentage) of each Traffic Class Group.
- Scheduling algorithm for each Traffic Class Group.

The mapping between the ingress ports 802.1p priority and TCG is not direct. The mapping depends upon:

- The COS map defining the COS queue that a packet is egress forwarded for the ingress 802.1p priority.
- Traffic Class Group map defining the COS queue to TCG mapping.

The indirect mapping between the 802.1p priorities and the associated TCG mapping is advertised by DCBX as part of the ETS TLVs. For this indirect mapping to be valid, the following two parameters must be configured (in addition to the configuration of the TCGs):

1. Configure 8021.p priority to COS mapping for the ingress ports.
2. Enable Trust mode on the ingress ports to trust the 802.1p priority present in the frames.

See Section 6.4.2, Configuring CoS Queuing and ETS for a configuration example.

6.6 Quantized Congestion Notification (QCN)

NOTE: QCN is not available on all platforms.

QCN is a critical protocol for data center networks in which Ethernet is the common platform, to address the issues of congestion control. In data center networks, factors like flow control, lossless behavior, and latency are extremely important.

The QCN feature attempts to push the network congestion from the heart of core networks to the edges toward end stations. QCN avoids congestion spread by slowing down the end-hosts causing the congestion. QCN works across a single layer-2 domain. As soon as the traffic crosses a router (or an FCoE switch), it enters a different QCN domain.

The QCN congestion-point algorithm is implemented on queues where congestion is expected. Once enabled, it follows following three steps to rectify congestion:

- Congestion Detection—Monitoring the queue size and performing some calculations so that the algorithm can detect congestion as soon as possible.
- Culprit Flow Detection—Identifying the sender end station that is causing the congestion
- Congestion Notification—Issuing a Congestion Notification Message (CNM) to the culprit sender.

QCN operates between Congestion Points (CP), which detect and notify of congestion in the network, and Reaction Points (RP), which originate traffic into the congestion-managed network and receive/process the congestion notifications. The EFOS switch acts a Congestion Point in the network. More specifically, each EFOS switch consists of a set of Congestion points, one per port for each congestion-managed queue.

6.7 OpenFlow Operation and Configuration

The OpenFlow feature enables the switch to be managed by a centralized OpenFlow Controller using the OpenFlow protocol. EFOS supports the OpenFlow 1.0 and OpenFlow 1.3 standards.

6.7.1 Enabling and Disabling OpenFlow

The OpenFlow feature can be enabled or disabled by the network administrator. Although this feature is administratively enabled, it is not operational until the switch has an IP address. A separate operational state indicates whether the OpenFlow feature is operational. If the feature is not operational, then another state indicates the reason for the feature to be disabled.

After administratively disabling the feature, the network administrator must wait until the OpenFlow Feature is operationally disabled before re-enabling the feature. The OpenFlow feature can be administratively disabled at any time.

The administrator can allow the switch to automatically assign an IP address to the OpenFlow feature or can manually select the address. The administrator can also configure the OpenFlow feature to always use the service port.

If the address is assigned automatically and the interface with the assigned address goes offline, the switch selects another active interface if one is available. The OpenFlow feature becomes operationally disabled and re-enabled when a new IP address is selected. If the address is assigned statically, the OpenFlow feature becomes operational only when a switch interface with the matching IP address becomes active.

The automatic IP addresses selection is done in the following order of preference.

1. The loopback interfaces.
2. The routing interfaces.
3. The network interface.
4. The service port interface.

EFOS currently supports only IPv4 addresses for connecting to the OpenFlow controller.

If routing is enabled, the Network interface cannot be used as the OpenFlow interface.

Once the IP address is selected, it is used until the interface goes offline, the feature is disabled, or, in the case of automatic address selection, a more preferred interface becomes available.

If a service port is manually selected as the OpenFlow IP address, the Open Flow feature is enabled immediately, even if there is no IP address assigned to the service port.

The selected IP address is used as the end-point of SSL connections and the end-point of the IP connections to the OpenFlow controllers.

When the OpenFlow feature is operationally disabled, the switch drops connections with the OpenFlow controllers. The switch also purges all flows programmed by the controllers.

If the administrator changes the OpenFlow variant while the OpenFlow feature is enabled, the switch automatically disables and re-enables the OpenFlow feature causing all flows to be deleted and connections to the controllers to be dropped.

If the administrator changes the default hardware table for OpenFlow 1.0 and if the switch is currently operating in OpenFlow 1.0 variant, the OpenFlow feature is automatically disabled and re-enabled.

6.7.2 OpenFlow Scenarios

The OpenFlow feature is mainly used in a data center network where devices are located in different parts of the network and require layer-2 connectivity. Using OpenFlow helps to avoid scaling problems and loops associated with the layer-2 network.

The OpenFlow feature can also be used in a research environment, but there are two limitations that make the "research" use case less attractive. First, there is only one OpenFlow dataplane instance, meaning that concurrent experiments are not supported unless concurrency is handled at the controller level. Second, the OpenFlow controller has complete access to all ports and VLANs, meaning that using the switch for mixed production and experimental traffic is not advisable.

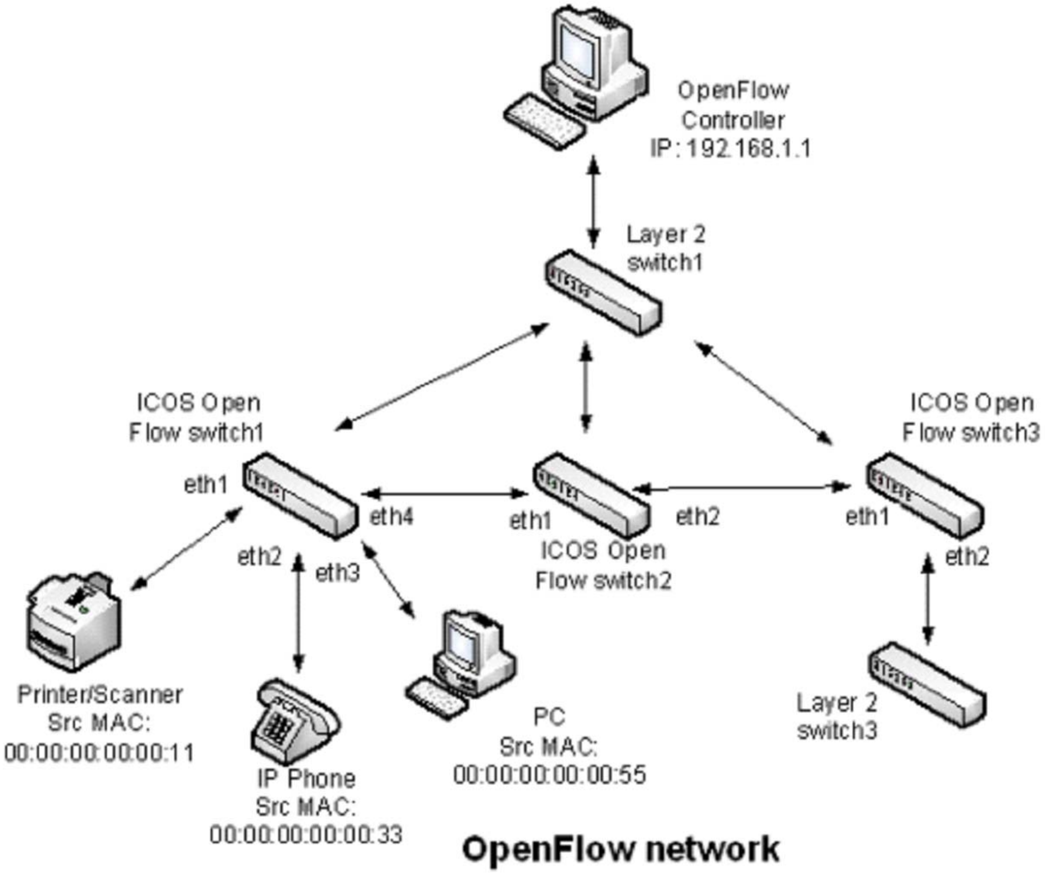
6.7.3 OpenFlow Interaction with Other Functions

The OpenFlow component interacts with multiple EFOS components by either communicating with these components or sharing common resources with the components.

6.7.4 Configuring OpenFlow

The following example uses the network interface's IP address. All EFOS switches shown in Figure 31, OpenFlow Network Example have the same OpenFlow configuration.

Figure 31: OpenFlow Network Example



Use the following commands to configure an OpenFlow network:

1. Configure the network protocol as DHCP with the following command:
   ```
   (Routing) #network protocol dhcp
   ```
2. Since the controller IP address in this example is configured from the Switch CLI, set the OpenFlow variant mode to **openflow1.0** with the following command:
   ```
   Routing) (Config)# openflow variant openflow10
   ```
3. Set the controller IP address with the following command:
   ```
   (Routing) (Config)#openflow controller 192.168.1.1 6633 tcp
   ```
4. To insert the flow into the **OpenFlow 1.0** match table which can match on all OpenFlow 1.0 fields, set the OpenFlow default flow table to **Full-Match** with the following command:
   ```
   (Routing) (Config)# openflow default-table full-match
   ```
5. Enable OpenFlow on the switch with the following command:
   ```
   (Routing) (Config)# openflow enable
   ```
6. Verify the OpenFlow configuration with the following command:
   ```
   (Routing) #show openflow

   Administrative Mode............................ Enable
   Operational Status............................. Disabled
   Disable Reason................................. No-Suitable-IP-Interface
   IP Address..................................... 192.168.1.1
   IP Mode........................................ Auto
   Static IP Address.............................. 0.0.0.0
   OpenFlow Variant............................... OpenFlow 1.0
   Default Table.................................. full-match
   Passive Mode....................................Enable

     OpenFlow Manager IP:port Addresses
   --------------------------------------


   (Routing) #show openflow configured controller

   IP Address       IP Port          Connection Mode   Role
   ---------------  ---------------  ---------------   ----
   192.168.1.1      6633             tcp               Master
   ```

7. The controller installs rules in the EFOS switches. In this example, the following rules have been installed:

   EFOS Switch 1

   - Forward any traffic with ingress port 0/1 with Source MAC 00:00:00:00:00:11 to egress port 0/4
   - Forward any traffic with ingress port 0/1 with Source MAC 00:00:00:00:00:33 to egress port 0/4
   - Forward any traffic with ingress port 0/1 with Source MAC 00:00:00:00:00:55 to egress port 0/4

   EFOS Switch 2

   - Forward any traffic with ingress port 0/1 with Source MAC 00:00:00:00:00:11 to egress port 0/2
   - Forward any traffic with ingress port 0/1 with Source MAC 00:00:00:00:00:33 to egress port 0/2
   - Forward any traffic with ingress port 0/1 with Source MAC 00:00:00:00:00:55 to egress port 0/2

   EFOS Switch 3

   - Forward any traffic with ingress port 0/1 with Source MAC 00:00:00:00:00:11 to egress port 0/2

- Forward any traffic with ingress port 0/1 with Source MAC 00:00:00:00:00:33 to egress port 0/2
- Forward any traffic with ingress port 0/1 with Source MAC 00:00:00:00:00:55 to egress port 0/2

8. To verify the installed flows for EFOS Switch 1, use the following command:

```
(Routing) #show openflow installed flows

Flow 0C9E0D00 type "1DOT0"

Match criteria:
Flow table              24 : Priority             32768
Ingress port           0/1 : Src MAC  00:00:00:00:00:11
Actions:
Egress port            0/4
Status:
Duration                 7 : Idle                     5 : installed in hardware    1

Flow F6880900 type "1DOT0"

Match criteria:
Flow table              24 : Priority             32768
Ingress port           0/2 : Src MAC  00:00:00:00:00:33
Actions:
Egress port            0/4
Status:
Duration                11 : Idle                     9 : installed in hardware    1

Flow 36370100 type "1DOT0"

Match criteria:
Flow table              24 : Priority             32768
Ingress port           0/3 : Src MAC  00:00:00:00:00:55
Actions:
Egress port            0/4
Status:
Duration              1121 : Idle                  1119 : installed in hardware    1
```

9. To verify the installed flows for EFOS Switch 2, use the following command:

```
(Routing) #show openflow installed flows

Flow 0C9E0D00 type "1DOT0"

Match criteria:
Flow table              24 : Priority             32768
Ingress port           0/1 : Src MAC  00:00:00:00:00:11
Actions:
Egress port            0/2
Status:
Duration                 7 : Idle                     5 : installed in hardware    1

Flow F6880900 type "1DOT0"

Match criteria:
Flow table              24 : Priority             32768
Ingress port           0/1 : Src MAC  00:00:00:00:00:33
Actions:
Egress port            0/2
Status:
```

```
Duration                11 : Idle                    9 : installed in hardware    1

Flow 36370100 type "1DOT0"

Match criteria:
Flow table              24 : Priority            32768
Ingress port           0/1 : Src MAC  00:00:00:00:00:55
Actions:
Egress port            0/2
Status:
Duration              1121 : Idle                 1119 : installed in hardware    1
```

10. To verify the installed flows for EFOS Switch 3, use the following command:

```
(Routing) #show openflow installed flows

Flow 0C9E0D00 type "1DOT0"

Match criteria:
Flow table              24 : Priority            32768
Ingress port           0/1 : Src MAC  00:00:00:00:00:11
Actions:
Egress port            0/2
Status:
Duration                 7 : Idle                    5 : installed in hardware    1

Flow F6880900 type "1DOT0"

Match criteria:
Flow table              24 : Priority            32768
Ingress port           0/1 : Src MAC  00:00:00:00:00:33
Actions:
Egress port            0/2
Status:
Duration                11 : Idle                    9 : installed in hardware    1

Flow 36370100 type "1DOT0"

Match criteria:
Flow table              24 : Priority            32768
Ingress port           0/1 : Src MAC  00:00:00:00:00:55
Actions:
Egress port            0/2
Status:
Duration              1121 : Idle                 1119 : installed in hardware    1
```

6.8 DCVPN Gateway Operation and Configuration

6.8.1 Overview

Logically segregated virtual networks in a data center are sometimes referred to as data center VPNs (DCVPNs). VXLAN and NVGRE are two realizations of a DCVPN. Others include E-VPNs, IP VPNs, TRILL, and VPLS.

The encapsulation and decapsulation required by DCVPNs is done by devices called Virtual Tunnel Endpoints (VTEPs) or NVEs. VTEPs/NVEs are most commonly implemented within a virtualized server. However, there are cases where it is necessary to implement the VTEP/NVE in a stand-alone networking device. This section describes the functional behavior of the EFOS implementation of a hardware-based VXLAN or NVGRE gateway service and provides configuration scenarios.

This document uses the term *DCVPN gateway* to refer to both VXLAN and NVGRE gateways when the discussion applies to both protocols.

6.8.1.1 VXLAN

VXLAN is one method of creating tenant networks on a common network infrastructure. VXLAN encapsulates Ethernet frames in IP packets, thus enabling the network to provide the illusion that hosts connected to arbitrary access routers are attached to a common layer-2 networks. The VXLAN encapsulation includes a 24-bit virtual network ID (VNID). Hosts can be associated to a VNID and restricted to communicate only with hosts associated to the same VNID. This association segregates communities of interest, or tenants, into different virtual networks. VXLAN allows a public or private data center operator to use a common network infrastructure to provide virtual private network service to multiple tenants while distributing any given tenant's compute and storage resources anywhere in the network infrastructure.

In a data center, VXLAN encapsulation and decapsulation of tenant packets is normally done by a virtual switch within a virtualized server; however, not all tenant systems are virtualized. Non-virtualized tenant systems can participate in a VXLAN by using a VXLAN gateway. A VXLAN gateway is a networking device that does VXLAN encapsulation and decapsulation. A server's first-hop router, often referred to as a top-of-rack (ToR) device, can be a VXLAN gateway.

With VXLAN, the inner Ethernet header can optionally include an incoming VLAN tag. The DCVPN application always strips the inner VLAN information from the incoming Ethernet packet during encapsulation. The inner payload in the VXLAN encapsulated packet does not contain the incoming VLAN tag information in it, which enables flexibility in mapping available VLANs to VNIDs.

The allowed range of VNID values is 1–16777214. VNID 16777215 is reserved for internal purposes.

6.8.1.2 NVGRE

NVGRE is similar to VXLAN. NVGRE differs from VXLAN in several ways. NVGRE uses standard GRE encapsulation (RFC 2784 and RFC 2890). NVGRE defines a 24-bit Virtual Subnet Identifier (VSID) that serves the same purpose as the VXLAN VNID. The VSID is included in the GRE header. With NVGRE, the inner Ethernet header never includes a VLAN tag.

The allowed range of VSID values is 1–16777214. VSID 16777215 is reserved for internal purposes.

6.8.2 Functional Description

6.8.2.1 Switch Overlay Mode

A DCVPN-capable switch can support either VXLAN or NVGRE, or both. On the switches that support both types, only one can be configured at a time (to prevent contention for hardware resources). The switch must be configured with the preferred overlay type before DCVPNs of the preferred type are created. Only DCVPNs matching the configured overlay type can be created. To configure DCVPNs of the other overlay type, the preferred overlay type configuration must be changed. When the preferred overlay type on the switch is reset or disabled, the entire existing configuration of the disabled overlay type is cleared from the running configuration; i.e, all DCVPN configuration is removed for that type.

6.8.2.2 VTEP to VN Association

The operator must configure switches that are to serve as DCVPN gateways. A gateway may serve one or more DCVPNs. For each DCVPN, the operator specifies the virtual network ID (VNID), the type of network (VXLAN or NVGRE), and a method for identifying which incoming native packets belong to the VPN. The ingress VLAN ID can be used as this classifier. Only one VLAN ID can be associated with a specific VNID on a given router. However, the VLAN ID used has no significance beyond that router, and so the same ID can be used on other routers. In this case the number of tenant networks is not limited to VLAN ID space (i.e., 4096). All ingress ports that are members of specified VLAN ID are treated as access ports for the VPN identified by VNID. This defines the access port set for the specified VPN. The access port set for the DCVPN can be altered by updating the VLAN membership configuration. All incoming VLAN traffic is translated to virtual network traffic identified by VNID. A VLAN ID that is already used or configured for routing is not allowed to be configured as an access VLAN for DCVPN.

A source IP address (local VTEP) must be specified for each configured DCVPN. The valid source IP interface is either a loopback interface or a routing interface (port-based or VLAN-based) on the router. It is recommended that a loopback interface be dedicated for DCVPN gateway purposes and configured with the intended source IP configuration before associating it with any DCVPN. If the configured source IP interface is down or has no IP address, all remote VTEPs in the VPN are considered unreachable. No traffic flows to the remote VTEPs.

Note that the configured source IP address must correspond to an IP address configured on each remote VTEP. Otherwise, the remote VTEPs will discard the gateway's packets.

6.8.2.3 Configuration of Remote VTEPs

Each gateway VTEP must know the set of VTEPs other than itself in each DCVPN. This knowledge is necessary because tenant systems can send broadcast and multicast Ethernet frames. For example, ARP requests are generally broadcast. Also, a VTEP may receive a packet for a destination MAC address it has not learned yet. Such a packet is called an unknown frame. The VTEP must send the packet to all other remote VTEPs configured in the DCVPN, since the destination may be accessed through any one of them.

VXLAN and NVGRE handle broadcast, multicast, and unknown frames by encapsulating the packet in an IP packet whose destination IP address is an IP multicast group configured for the VN. Each VTEP sends Join messages to join the VN's multicast group. There can be difficulties in using IP multicast to deliver broadcast and unknown frames, the main difficulty being that the data center networks that would be used as underlays often do not enable IP multicast because it does not scale to the size of large public cloud networks. Because of this limitation, DCVPN implementation requires user configuration of the remote VTEPs associated with a particular VPN.

Because VMs may be created, deleted or moved rapidly within the data center, the set of VTEPs within a VN may be very dynamic. When this is the case, it is not feasible to manually provision VTEP membership. Instead, VTEP membership must be provisioned through automation. When an orchestration system creates, deletes, or moves a tenant VM, the orchestration system may update the VTEP membership for the VM's virtual network. If one of the VTEPs in the virtual network is a gateway, the orchestration system can use an Overlay OpEN API to update the gateway's configuration.

Dynamic VTEP learning through IP multicast is not currently supported.

When a gateway receives a broadcast, multicast, or unknown packet on an access port, it makes a copy of each packet for each of the other VTEP's in the VN, setting the outer IP address to the unicast IP address of the remote VTEP, and setting the outer MAC address to the unicast MAC address of the next hop to the VTEP. The hardware does this packet replication. In this mode, the gateway can still learn L2 entries from packets it decapsulates and, thus, is able to unicast to a single VTEP most of the time.

For each remote VTEP, the operator must specify the following parameters:

- The associated virtual network (specified by VNID).
- The VTEP's IP address. This address is an IP address in the underlay.

The source IP address is inherited from the DCVPN configuration. The system creates overlay tunnels to all configured remote VTEPs in hardware as they become reachable. The system removes the tunnel configuration from hardware when the VTEPs are not reachable.

DCVPNs with matching tunnel configuration (i.e., a pair of VTEPs {source or gateway IP address, remote VTEP IP address}) share the same hardware tunnel. Each hardware tunnel has unicast packet and unicast byte counters in either direction (TX/RX). When the tunnel is removed from hardware, counters are reset to 0.

If the gateway receives a packet for an unknown VNID or for a known VNID from a VTEP IP address that has not been configured, the gateway drops the packet.

6.8.2.4 VTEP Next-Hop Resolution

A remote VTEP is considered reachable if the gateway has a non-default route to the VTEP's IP address. The DCVPN application determines the reachability of the VTEP's address and registers with the routing table manager for changes in the route to that IP address. When there is a route to the VTEP, the DCVPN application copies the next hops of the best route and uses them as the next hop for the packets forwarded to that VTEP. The DCVPN application creates a tunnel in the hardware for each reachable VTEP. The gateway may use multiple next hops to a VTEP, hashing a given flow to an individual next hop as is done in layer-3 routing. The number of next hops to a VTEP and, thus, the number of next hops for a tunnel, is limited only by the ECMP limit of the platform (or the active SDM template). It is recommended that SDM template *dcvpn-data-center* for DCVPN-capable StrataXGS® V platforms.

The DCVPN application registers with the routing table manager for next-hop resolution changes for each VTEP's remote IP address. When DCVPN receives a next-hop resolution change event, it queries the routing table manager for the new best route and updates the set of next hops to the VTEP. If the VTEP is unreachable, DCVPN deletes the corresponding tunnel in the hardware.

NOTE: If the hardware tunnel is shared by another DCVPN, then the hardware tunnel is removed only when its reference count becomes 0.

A VTEP cannot be resolved by a default route. The presence of a default route does not provide any confidence that the VTEP is actually reachable.

NOTE: Any physical interface or LAG that has tenant access ports configured cannot be configured as the next-hop interface for the tunnel. Similarly, a physical interface or LAG that is configured as a next-hop interface on the switch cannot be configured as an access interface for any tenant. A physical port or LAG cannot be shared or be part of both an access port configuration and a tunnel next-hop configuration. This configuration leads to errors and the system generating the following log message:

```
<15> Aug 26 23:37:26 10.18.36.41-1 DCVPN[dcVpnTask]: broad_l2ol3tunnel.c(1038) 216 %%
hapiBroadL2oL3PortCfgFindAdd():1038 Error> Error: Incorrect configuration detected. Port 1.3.0
(lport=0xC000000) is already configured in Access mode. Same physical/LAG port cannot be
configured in Network/Tunnel mode.
```

6.8.2.5 VXLAN UDP Destination Port

The VXLAN standard defines 4789 as the standard UDP destination port to be used for encapsulation and termination. Switches that supported earlier draft versions used custom defined UDP port numbers. To be compatible with those switches, DCVPN supports switch-level VXLAN UDP destination port configuration. By default, the VXLAN UDP destination port is set to 4789 on the switch. The switch terminates incoming VXLAN traffic when the UDP destination port in the VXLAN header matches 4789 and encapsulates VXLAN tenant traffic by putting 4789 in the UDP destination port field in the VXLAN frame.

Users can modify how VXLANs are terminated or encapsulated by changing the default VXLAN UDP destination port configuration on the switch. When the VXLAN UDP destination port is modified, all existing tunnels are modified in the hardware to encapsulate using new VXLAN UDP destination port information. The switch is also configured to terminate VXLAN traffic using the new configuration. There is no or very minimal traffic disruption during this operation.

NOTE: By default, the switch is configured to generate a source port (in the outer UDP header of the VXLAN frame) that is a hash of the inner Ethernet frame's headers. This is to enable a level of entropy for ECMP/load balancing of the VM to VM traffic across the VXLAN overlay.

6.8.2.6 Tunnels

The DCVPN application creates a tunnel in hardware for each configured and reachable remote VTEP. To create a tunnel in hardware, the application must provide the following tunnel parameters:

- A local IP address. This is the source IP address configured for the DCVPN. The hardware sets the source IP address of the outer IPv4 header to this value.
- The remote IP address. This is the IP address of the VTEP. The hardware sets the destination IP address of the outer IPv4 header to this value.
- A local MAC address, which the hardware uses as the outer source MAC address when encapsulating and sending packets on the tunnel. This MAC address is the MAC address of the originating local routing interface MAC address.
- For VXLAN tunnel, UDP destination port to use in VXLAN header while encapsulation.
- The tunnel VLAN ID. This is the VLAN associated with the outgoing interface in the underlay. If the outgoing interface is a port-based routing interface, this is the VLAN ID assigned internally to the port-based routing interface. If the outgoing interface is a VLAN routing interface, the tunnel VLAN ID is set to the VLAN ID of this routing interface.
- The next hops in the underlay network. Each next hop is specified as the combination of the following parameters:
  - The internal interface number of the outgoing routing interface in the underlay network.
  - The MAC addresses corresponding to the next hop IP address. The hardware uses this as the destination MAC address of the outer Ethernet header.

6.8.2.7 MAC Learning and Aging

The hardware does MAC learning for DCVPNs. Normal MAC learning associates a MAC address with a VLAN and interface. For DCVPNs, the hardware learns MAC entries associated with both access ports and network ports. The forwarding entries are learned in the VPN. The VLAN ID field in the entry is replaced by a VPN field. For network-side entries associated with VTEPs, the interface is the hardware tunnel identifier. The MAC address in network-side entries is the MAC address of a tenant system behind a remote VTEP. For access-side entries, the associated interface is the physical or LAG interface who are members of the configured DCVPN VLAN. The MAC address in access-side entries is the MAC address of a tenant system behind the local interface (physical or LAG interface).

DCVPN MAC entries are not listed in the **show mac-addr-table** command output. They can be listed using **show vxlan *vnid* tenant-systems**. Both access and network-side entries are listed in the show command output.

The maximum age of a DCVPN MAC entry is the same as normal L2 entries. The user cannot configure a different maximum age for DCVPN MAC entries than for normal L2 entries.

DCVPN performs aging of learned entries in software when the virtual port channel (VPC) feature is present in the build package. DCVPN handles entries those are learned in configured VPNs only. It would not handle MAC entries learned in VLANs or listed in the **show mac-addr-table** command output. For packages without the VPC component, DCVPN relies on hardware aging for MAC entries learned in configured VPNs.

6.8.2.8 Host Configuration

An operator may wish to statically configure host MAC-to-VTEP mappings. Doing so eliminates the initial flooding of packets on all tunnels when the MAC-to-VTEP mapping is unknown. So for each remote VTEP, an operator can optionally configure the MAC addresses of the tenant systems reachable through the VTEP. The maximum allowed static host MAC-to-VTEP binding (or remote tenant systems MAC entries) per tenant is 600. Once this limit is reached, configuring new MAC-to-VTEP bindings for the tenant results in failure. The system generates a log message that describes the reason for failure.

Overall, the system has a maximum allowed limit of 4096 static host MAC-to-VTEP bindings. At any point in time, the sum of all tenants static host MAC-to-VTEP mappings must be less than or equal to the system limit. Once this limit is reached, configuring new MAC-to-VTEP bindings for any tenant results in failure and a log message is generated.

The operator may optionally configure host MAC-to-access port entries as well. The maximum allowed static host MAC-to-interface bindings (or local tenant system MAC entries) per interface (physical or LAG) is 24. Once this limit is reached, configuring new MAC-to-interface bindings for any tenant results in failure and a log message is generated.

6.8.2.9 ECMP

A tunnel may have multiple next hops when the underlay has multiple next hops to the tunnel's remote endpoint. Many data center designs make heavy use of ECMP. To get good traffic distribution within the underlay, it is important that encapsulated packets hash well.

VXLAN encapsulation includes a UDP header. Switches can include the source and destination UDP port in ECMP hash computations. The hardware offers an option for the source VTEP to set the source UDP port to a variable value (hash based on incoming packet Ethernet header) to ensure good ECMP hashing. DCVPN enables this option in hardware by default.

NOTE: At VXLAN initiation, payload fields are used for hashing at the egress and also to generate the entropy into the UDP source port which becomes part of VXLAN tunnel information. This UDP source port can be used by transit switches for hashing purposes.

NVGRE encapsulation is GRE-over-IP. There are no layer-4 ports to include when computing an ECMP hash; StrataXGS V platforms offer an option to introduce a hash value into the 8-bit Flow ID field. However, these fields are at a different offset than the L4 port number. Router hardware in the underlay would have to be updated to include these fields (8-bit flow ID) in the ECMP hash. NVGRE proponents contend that such hardware will emerge. Until then, all packets between a pair of NVEs follow the same path in the underlay, potentially causing severe utilization imbalances on underlay links.

6.8.2.10 MTU

VXLAN encapsulation adds 50 bytes of overhead. NVGRE encapsulation adds 46 bytes. This additional overhead can cause an encapsulated packet to exceed the MTU of the outgoing port. The gateway does no IP fragmentation while tunneling a packet and is by default configured to set DF=1 in the outer IPv4 header. If an encapsulated packet exceeds the L2 MTU of the outgoing port, the hardware drops it. To avoid this problem, operators must ensure that the L2 MTU on gateway ports to the underlay and underlay network be configured at least 46 bytes larger (for NVGRE) or 50 bytes larger (for VXLAN) than the MTU on ports on the access side.

The hardware may also enforce an IP MTU. In most cases, network-side ports will be configured as port-based routing interfaces. The IP MTU of these routing interfaces will automatically be adjusted to match the L2 MTU. Therefore, if the administrator adjusts the L2 MTU as described above, the hardware should not drop packets because of an IP MTU limitation. If, however, network-side ports are VLAN routing interfaces, the administrator will need to also increase the IP MTU on each network-side routing interface.

6.8.2.11 TTL and DSCP/TOS

By default, the switch is configured to behave as follows:

- The TTL in the outer IPv4 header during tunnel encapsulation is set to 255.
- For incoming IPv4 packets, the DSCP/TOS value from the incoming IPv4 header is copied into the outer IPv4 header's DCSP/TOS field during encapsulation. Otherwise, the DSCP/TOS value is set to 0.

6.8.2.12 Packet Forwarding

The gateway forwards all packets in hardware. There is no software forwarding.

6.8.3 Usage Scenarios

6.8.3.1 VXLAN Gateway With Single Tunnel

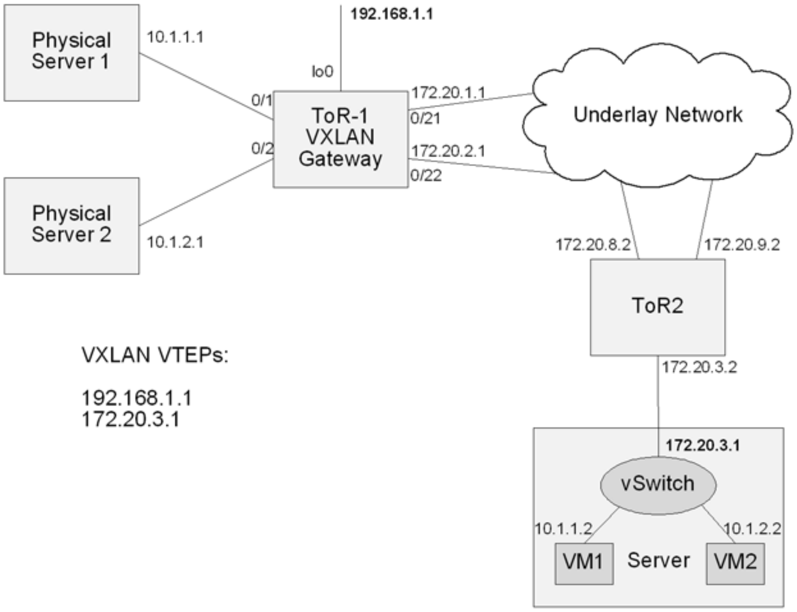
Figure 32, VXLAN Gateway—One Tunnel Between a Pair of VTEPs shows a ToR-1 router configured as a VXLAN gateway that connects two physical servers to their VXLANs. Ports attached to physical servers are configured in respective access VLANs on the ToR-1.

Server 1 and VM1 are part of the Tenant Red, which are on the VXLAN-identified by VNID=1. Server 1 is VLAN-unaware and can send and receive with no VLAN tag. Tenant Red on the switch uses VLAN 10 for defining its access ports.

Server 2 and VM2 are part of the Tenant Blue, which are on the VXLAN identified by VNID=2. Server 2 is VLAN-aware and is configured to send and receive VLAN 20 tagged frames. Tenant Blue must use VLAN 20 to define its access ports.

Each server communicates with a peer VM on a remote virtualized server.

Figure 32: VXLAN Gateway—One Tunnel Between a Pair of VTEPs



ToR 1 is configured as follows:

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 10
(Routing) (Vlan)#vlan 20
(Routing) (Vlan)#exit

(Routing) #config
(Routing) #ip routing


(Routing) (Config)#interface 0/1
(Routing) (Interface 0/1)#vlan participation include 10
(Routing) (Interface 0/1)#vlan participation exclude 1
(Routing) (Interface 0/1)#vlan pvid 10
(Routing) (Interface 0/1)#exit

(Routing) (Config)#interface 0/2
(Routing) (Interface 0/2)#vlan participation include 20
(Routing) (Interface 0/2)#vlan participation exclude 1
(Routing) (Interface 0/2)#ingressfilter
(Routing) (Interface 0/2)#vlan tagging 20
(Routing) (Interface 0/2)#exit

(Routing) (Config)#interface 0/21
(Routing) (Interface 0/21)#routing
(Routing) (Interface 0/21)#ip address 172.20.1.1 255.255.255.0
(Routing) (Interface 0/21)#ip ospf area 0
(Routing) (Interface 0/21)#exit

(Routing) (Config)#interface 0/22
(Routing) (Interface 0/22)#routing
```

```
(Routing) (Interface 0/22)#ip address 172.20.2.1 255.255.255.0
(Routing) (Interface 0/21)#ip ospf area 0
(Routing) (Interface 0/22)#exit

(Routing) (Config)#interface loopback 0
(Routing) (Interface loopback 0)#ip address 192.168.1.1 255.255.255.0
(Routing) (Interface loopback 0)#ip ospf area 0
(Routing) (Interface loopback 0)#exit

(Routing) (Config)#router ospf
(Routing) (Config-router)#router-id 1.1.1.1
(Routing) (Config-router)#exit

(Routing) (Config)#vxlan enable

!! Tenent Red
(Routing) (Config)#vxlan 1 vlan 10
(Routing) (Config)#vxlan 1 source-ip 192.168.1.1
(Routing) (Config)#vxlan 1 vtep 172.20.3.1

!! Tenant Blue
(Routing) (Config)#vxlan 2 vlan 20
(Routing) (Config)#vxlan 2 source-ip 192.168.1.1
(Routing) (Config)#vxlan 2 vtep 172.20.3.1

(Routing) (Config)#exit
```

To initiate communication with VM1, physical server 1 originates an ARP request with target 10.1.1.2. The hardware at ToR1 recognizes the incoming packet as arriving on a VLAN 10 that is assigned to VXLAN 1. The gateway encapsulates the ARP request, setting the VNID in the VXLAN header to 1. A copy of the packet is sent to each access port and VTEP in VXLAN 1. In this case, a single copy is sent to 172.20.3.1. The outer source IP address is set to the IP address of the loopback 0, i.e., 192.168.1.1.

The vSwitch decapsulates the received VXLAN packet on 172.20.3.1 and delivers the ARP request to VM1, which unicasts an ARP reply with its MAC address to the source IP address in the ARP request, 10.1.1.1. The virtual switch encapsulates the ARP reply and sends it to 192.168.1.1 over VXLAN 1.

The encapsulated ARP reply arrives at TOR- 1. The hardware recognizes the packet to have arrived on a VXLAN network port, terminates the VXLAN, identifies that the packet is intended for VXLAN 1 hosts, and forwards the inner Ethernet frame to Server 1 through the access port on interface 0/1. This packet is sent untagged to Server 1 based on the interface 0/1 configuration. The hardware also learns that VM1's MAC address is behind the VTEP at 172.20.3.1. Future packets to VM1's MAC address are encapsulated and sent only to this VTEP.

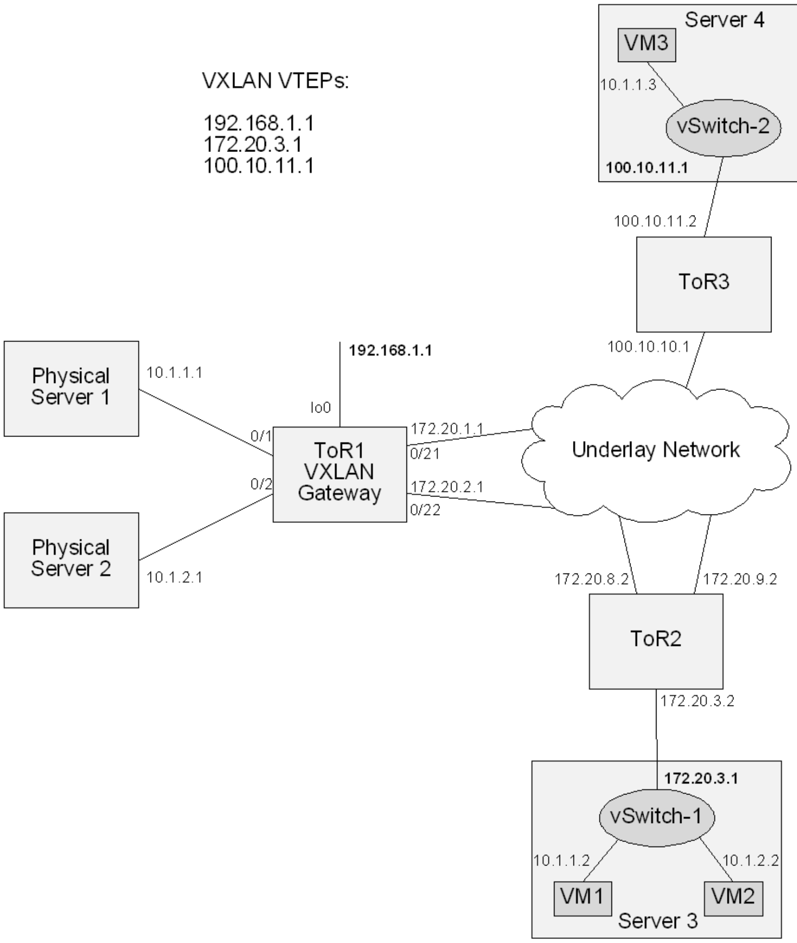
Similarly, when Server 2 communicates with VM2, it sends out packets with VLAN 20 tagged. Based on the incoming VLAN tag, ToR-1 associates it to Tenant Blue. This frame is then encapsulated and sent on VXLAN 2. When the response arrives on VXLAN 2, the gateway terminates the VXLAN 2 and forwards the inner frame with VLAN 20 tagged on port 0/2. Server 2 is able to process the VLAN 20 tagged frames and is unaware of VM2 being on a remote network.

6.8.3.2 VXLAN Gateway With Multiple Tunnels

Figure 33, VXLAN Gateway—Multiple Tunnels shows a ToR router configured as a VXLAN gateway that connects two physical servers to their VXLANs spanning two different VTEPs. Server 1, VM1, and VM3 are part of the Tenant Red using VXLAN 1. Server 2 and VM2 are part of the Tenant Blue using VXLAN 2.

Each server connected to the ToR-1 communicates with VM/s in remote virtualized servers. Server 2 communicates with VM2 on Server 3 using a single VXLAN tunnel to 172.20.3.1. Server 1 communicates with VM1 on Server 3 and also with VM3 on Server 4 using two different VXLAN tunnels. Server 1 and Server 2 are VLAN-aware.

Figure 33: VXLAN Gateway—Multiple Tunnels



TOR 1 is configured as follows:

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 10
(Routing) (Vlan)#vlan 20
(Routing) (Vlan)#exit

(Routing) #config
(Routing) (Config)#ip routing

(Routing) (Config)#interface 0/1
(Routing) (Interface 0/1)#vlan participation include 10
(Routing) (Interface 0/1)#vlan participation exclude 1
(Routing) (Interface 0/1)#vlan ingressfilter
(Routing) (Interface 0/1)#vlan tagging 10
(Routing) (Interface 0/1)#exit

(Routing) (Config)#interface 0/2
(Routing) (Interface 0/2)#vlan participation include 20
(Routing) (Interface 0/2)#vlan participation exclude 1
(Routing) (Interface 0/2)#vlan ingressfilter
(Routing) (Interface 0/2)#vlan tagging 20
(Routing) (Interface 0/2)#exit

(Routing) (Config)#interface 0/21
(Routing) (Interface 0/21)#routing
(Routing) (Interface 0/21)#ip address 172.20.1.1 255.255.255.0
(Routing) (Interface 0/21)#ip ospf area 0
(Routing) (Interface 0/21)#exit

(Routing) (Config)#interface 0/22
(Routing) (Interface 0/22)#routing
(Routing) (Interface 0/22)#ip address 172.20.2.1 255.255.255.0
(Routing) (Interface 0/22)#ip ospf area 0
(Routing) (Interface 0/22)#exit

(Routing) (Config)#interface loopback 0
(Routing) (Interface loopback 0)#ip address 192.168.1.1 255.255.255.255
(Routing) (Interface loopback 0)#ip ospf area 0
(Routing) (Interface loopback 0)#exit

(Routing) (Config)#router ospf
(Routing) (Config-router)#router-id 1.1.1.1
(Routing) (Config-router)#exit

(Routing) (Config)#vxlan enable

!! Tenant Red access VLAN
(Routing) (Config)#vxlan 1 vlan 10

!! Tenant Red VXLAN gateway
(Routing) (Config)#vxlan 1 source-ip 192.168.1.1

!! First tunnel to Server 3
(Routing) (Config)#vxlan 1 vtep 172.20.3.1


!! Second tunnel to Server 4
```

```
(Routing) (Config)#vxlan 1 vtep 100.10.11.1

!! Tenant Blue
(Routing) (Config)#vxlan 2 vlan 20
(Routing) (Config)#vxlan 2 source-ip 192.168.1.1
(Routing) (Config)#vxlan 2 vtep 172.20.3.1
(Routing) (Config)#exit
```

6.9 MPLS Operation and Configuration

6.9.1 Overview

This feature is targeted towards data center customers deploying EFOS-based switches in leaf-and-spine or other popular data center network topologies. These types of switches with MPLS capabilities are typically known as Provider ("P") switches that perform the Label Switch Router (LSR) functionality. The switches support MPLS-tagged packet reception and MPLS-tagged packet transmission. The switches do not convert between MPLS and non-MPLS traffic, except for stripping the last MPLS tag on transmitted packets when the label action is "last-pop".

The MPLS feature is enabled on the BCM56850 platforms using the SDM template "mpls-data-center".

When the MPLS package included in EFOS and the SDM template is enabled, all VLANs enabled for routing and all port-based routing interfaces are enabled for MPLS packet switching. Also, any VLANs specified as egress VLANs in the layer-2 static LFDB entries are enabled for MPLS packet switching (see Section 6.9.2.1, Static Layer-2 MPLS Labels). VLANs that are not enabled for MPLS packet switching forward the MPLS packets using the standard Ethernet bridging rules.

The non-MPLS packet forwarding works as usual on VLANs enabled for MPLS switching. The non-MPLS packets can be bridged or routed as configured by the network administrator.

The EFOS MPLS switches can be programmed with a static Label-Switched Path (LSP) using CLI commands. The EFOS MPLS switches can also automatically program the label path using the BGP protocol label distribution extension defined in RFC 3107.

A key feature of the EFOS MPLS automatic label distribution protocol is the use of a global label for each subnet in the routing domain. The global labels are statically assigned by the system administrator to the subnets that need to be distributed. Each subnet must be assigned a network-unique MPLS label. The same global label is used by all switches in the routing domain to represent this subnet.

6.9.2 EFOS MPLS Features

To use MPLS-related features supported in EFOS, the switch must be configured to use the MPLS SDM template. For example:

```
(Routing) #configure
(Routing) (Config)#sdm prefer dual-ipv4-and-ipv6 mpls-data-center
```

The switch must be rebooted after executing this command. To see the currently active template issue the command:

```
(Routing) #show sdm prefer
```

6.9.2.1 Static Layer-2 MPLS Labels

The static layer-2 MPLS labels enable the network administrator to configure the switch to forward packets received with a specified label to the specified port. The network administrator must specify the ingress label, the action to take on the label, and the egress interface.

The supported label actions are to pop the label and to swap a new label. The new label must be specified for the **swap** command. The push label action is not currently supported.

The egress interface configuration requires three parameters: the egress port number, the egress VLAN ID, and the egress MAC address to set in the packets transmitted on the egress port.

Only one egress interface can be specified in the static layer-2 label. The equal-cost multipath functionality is not supported for the static layer-2 labels.

The egress interface may be a layer-2 port, a LAG, or a port-based routing interface. If the egress interface is a port-based routing interface, the VLAN configuration is ignored and the MPLS packets are always sent without a VLAN tag to the egress port.

The Label Forwarding Database (LFDB) is indexed by the ingress label. If the configuration command is issued for a label that already exists in the database, the command returns an error. The old label must be deleted before a new label is added.

The static layer-2 labels may be used exclusively to program all the LSPs in the network, or they may be used in conjunction with the BGP-distributed labels to specify the last-hop for the MPLS packets.

The egress VLANs specified in the static layer-2 LFDB entries are automatically enabled for MPLS packet switching. This means that a frame received on any port explicitly or implicitly tagged with one of the egress VLANs, is subject to MPLS switching.

If the network is set up so that devices attached to the ports do not accept MPLS labeled packets, then the label action should be configured as “last-pop”. MPLS packets arriving with only one MPLS label that hit the “last-pop” action are stripped of the MPLS tag and forwarded to the target port. Only IPv4 and IPv6 packets can be forwarded by the “last-pop” action. The non-IP packets are dropped.

6.9.2.1.1 Static Layer-2 MPLS Label Configuration Examples

Example 1:

The following command creates a new layer-2 entry in the MPLS label forwarding database. The ingress label is 100. Note that there is no need to specify the ingress interface or the ingress VLAN. The packets received with MPLS label 100 on any routing interface or any layer-2 port with VLAN enabled for MPLS switching are affected by the forwarding entry.

The command replaces MPLS label 100 with MPLS label 101 and forwards the packet on port 0/10 with VLAN 1 and with DA MAC set to 00:01:01:00:00:05.

Note that the source MAC address of the transmitted MPLS packets will be the router MAC address. This MAC address can be displayed using the **show mplsd** command.

```
(Routing) #configure
(Routing) (Config)#mplsd lfdb layer-2 100 swap 101 0/10 1 00:01:01:00:00:05
```

Example 2:

The following command creates a rule to receive a packet with label 65, pop the label 65 from the packet and forward the packet on interface 0/11 with VLAN 2 and DA MAC 00:01:01:00:00:06. Note that the egress port 0/11 should be added to VLAN 2 and the appropriate tagging mode set for the port.

```
(Routing) #configure
(Routing) (Config)#mplsd lfdb layer-2 65 pop 0/11 2 00:01:01:00:00:05
```

Example 3:

The following command deletes a static entry for label 100 from the LFDB. The dynamic entries cannot be deleted using this command. The dynamic entries can only be removed by the protocols that added the entry.

```
(Routing) #configure
(Routing) (Config)#no mplsd lfdb 100
```

6.9.2.2 Static Layer-3 MPLS Labels

The static layer-3 labels enable the network administrator to associate an MPLS label with an IPv4 or IPv6 subnet or host. Once this association is established, the switch automatically detects and programs the MPLS labels into the hardware when a route pointing to the specified subnet is learned by the switch or an ARP/NDP entry is created for the host.

The switch applies the label into the hardware only if it learns a route that exactly matches the specified subnet. For example, if the specified subnet is 10.1.0.0/16 and the learned route is 10.0.0.0/8 then the MPLS label is NOT programmed into the hardware. This implies that route summarization must be disabled in the routing protocols when the layer-3 MPLS labels are in use.

The IP addresses that refer to hosts must be specified with a 32-bit mask for IPv4 and 128-bit mask for IPv6.

The layer-3 static labels support ECMP. The MPLS packets egress on the same equal-cost multipath interfaces as are applicable for the route. The MPLS packet ECMP distribution is based on hashing the top three MPLS labels in the stack. For packets with three or fewer labels, the switch also uses the IPv4 or IPv6 addresses to hash the packets. For packets with more than three MPLS labels, the switch uses only the top three MPLS labels to hash the packets.

The layer-3 static entries can take the action to “pop” or “swap” the label. The “swap” operation does not require an egress label specification because the egress label is always the same as the ingress label, due to the global subnet/label association. The layer-3 static labels do not support the “push” operation. Also the “pop” operation is supported only on non-ECMP paths. The ECMP paths ignore the “pop” action and perform only the “swap” action.

The layer-3 non-ECMP static entries can also be configured with the “last-pop” action, which strips the last MPLS tag in IPv4 or IPv6 packets and forwards the packet to the specified route or host.

When the layer-3 static label is added to the database, the **mplsd lfdb** command checks whether an entry exists with the same label or the same subnet. If the same label or subnet is already present in the database, then the **mplsd lfdb** command fails. The switch generates syslog messages when attempts are made to add a label with a duplicate subnet. The label/subnet associations must be one-to-one and must be unique in the network.

Typically, only remotely attached subnets are added to the LFDB. However, in some networks it may be desirable to provide the same configuration file containing definitions for all mapped subnets to all switches. Some of the subnets may be locally attached and are added to the LFDB, but are never inserted into the hardware. The labels for local subnets are not inserted into the hardware because there is no destination router MAC address to which to send the MPLS packets. The static layer-2 LFDB entries or host-specific static layer-3 entries must be used to direct the frames to their last hop.

The LFDB entry status commands show whether the layer-3 entries are inserted or not inserted into the hardware and the reason for not inserting the entry.

6.9.2.2.1 Static Layer-3 MPLS Label Configuration Example

Example 1:

The following command adds an IPv4 static label entry. The subnet is 10.27.33.0/24 and the label is 100. The packet is sent to the destination router with label 100.

MPLS packets received with label 100 on any interface and on any VLAN are subject to the forwarding entry. The egress packet is also sent with label 100 and with the VLAN and MAC address of the appropriate next-hop router.

```
(Routing) #configure
(Routing) (Config)#mplsd lfdb ipv4 100 swap 10.27.33.0/24
```

Example 2:

The following command adds an IPv6 static label entry. The subnet is 2001:aa10::0/64 and the label is 200. The label 200 is removed from the label stack before the frame is sent to the egress router.

```
(Routing) #configure
(Routing) (Config)#mplsd lfdb ipv6 200 pop 2001:aa10::0/64
```

Example 3:

The following command deletes the static layer-3 label entry for label 100 from the LFDB.

```
(Routing) #configure
(Routing) (Config)#no mplsd lfdb 100
```

6.9.2.3 MPLS Status and Statistics

The content of the label forwarding database can be examined using the **show mplsd lfdb** command. The global status of the MPLS feature is displayed using the **show mplsd** command. Refer to the *EFOS CLI Command Reference* for parameter and output descriptions (see Appendix A.1, References).

6.9.2.4 MPLS Label Distribution with BGP

When the MPLS feature is included in the build, the switch automatically enables MPLS label distribution in BGP. The BGP protocol advertises the capability to distribute labels and distributes the labels only to partner routers that advertise the same capability. BGP implements RFC 3107 to distribute the MPLS labels.

The administrator can optionally disable BGP from advertising MPLS labels by using the **no mplsd bgp-advertise** command.

MPLS labels are distributed for IPv4 and IPv6 subnets. The switch does not automatically generate labels for the subnets. Instead, the administrator statically configures the labels for each subnet to be distributed. A network-unique label identifier must be configured for each subnet.

BGP must be specifically configured to distribute subnet information about locally attached interfaces. Distributing local subnets is a prerequisite for distributing labels associated with the local subnets.

Note that in most large-scale leaf/spine deployment scenarios, only one subnet—typically the loopback interface on which the BGP protocols is running—must be configured with the MPLS label. Also, only the switches at the edge of the network require the subnet MPLS label. The spine switches typically do not have any servers, so would never be targets of MPLS traffic.

The EFOS BGP protocol implements two methods to distribute labels. The "per-switch" label method and the "per-interface" method. Both methods can be enabled at the same time.

6.9.2.4.1 "Per-Switch" Label BGP Distribution

The per-switch labels are associated with the loopback interfaces. See Section 6.9.3, EFOS MPLS Use Cases for information on how to configure the BGP protocol in a typical Clos network. When using the per-switch labels, the network administrator must configure at least one loopback interface and assign an MPLS label to that loopback interface.

It is possible to assign MPLS labels to multiple loopback interfaces, but that defeats the scaling benefits of the per-switch labels, since more resources are needed on the switch to distribute multiple labels.

The command to configure the per-switch MPLS label distributed by BGP for the IPv4 address on the loopback 0 interface is:

```
(Routing) #configure
(Routing) (Config)#interface loopback 0
(Routing) (Interface loopback 0)#mplsd bgp-mpls-label 100
```

To disable label distribution for the loopback interface issue the command **no mplsd bgp-mpls-label**.

To see the BGP per-switch label assigned to the loopback 0 interface issue the command **show mplsd interface loopback 0**.

When BGP distributes MPLS labels for the loopback interface it includes the "Implicit NULL" label in the advertised label stack along with the configured label. The "Implicit NULL" is a special label with the label ID of 3, which indicates to the upstream router that the LFDB entry for this label should pop the label stack before sending the packet to the downstream router.

Popping the label in the upstream switch means that the downstream switch must have static layer-2 or static layer-3 MPLS entries configured in the switch to take action on the next label in the MPLS label stack.

In theory it is possible not to use the layer-2 or layer-3 static labels to send the MPLS packets to their final destination. This requires connecting the EFOS switch with another vendor's switch that supports Provider Edge capabilities and also supports BGP label distribution. The third party switch must also respect the global label assignment model, where each subnet is assigned a unique label. Such switches are not likely to be available in the near future.

6.9.2.4.2 Per Interface Label BGP Distribution

The per-interface MPLS labels are associated with IPv4 and IPv6 routing interfaces. The VLAN routing interfaces and the port-based routing interfaces can be assigned one per-interface label for IPv4 and one per-interface label for IPv6. The labels are associated with the primary IP address of that routing interface. The IPv4 and IPv6 MPLS labels can be assigned at the same time.

The MPLS label identifiers must be network-unique. EFOS rejects assigning duplicate label IDs on the same switch, but it is up to the administrator to ensure network-unique label assignment. The switch does generate syslog messages and keeps a counter in the LFDB entry if the same label is attempted to be inserted multiple times by the BGP protocol or a static assignment.

For example to assign a BGP label to the IPv4 port-based interface 0/1 issue the commands:

```
(Routing) #configure
(Routing) (Config)#interface 0/1
(Routing) (Config)#mplsd bgp-mpls-label 1000
```

To assign a label to the IPv6 VLAN routing interface on VLAN 100, issue the following commands:

```
(Routing) #configure
(Routing) (Config)#interface vlan 100
(Routing) (Interface vlan 10)#ipv6 mplsd bgp-mpls-label 1001
```

The per-interface label distribution can be disabled for the interface using the **no mplsd bgp-mpls-label** command.

When BGP is configured to export the local interface network which has a label, the label is also distributed to the BGP neighbors. The labels are distributed over eBGP and iBGP sessions. However, the MPLS feature is not validated in conjunction with iBGP, so the iBGP should not be used when MPLS is enabled.

In contrast to the per-switch label, the BGP does not include implicit NULL label in the label stack, so the upstream switches do not strip the interface label before sending the packet to the downstream switch.

To forward the labeled packet, the switch must define a static LFDB entry for the label. The **mplsd bgp-mpls-label** command does not actually create any labels in the LFDB, but only configures BGP to distribute the label.

In the previous example, therefore, where labels 1000 and 1001 are distributed with BGP, the switch is likely to have LFDB rules that look something like the following:

```
(Routing) #config
(Routing) (Config)#mplsd lfdb ipv4 1000 last-pop 20.0.0.1/32
(Routing) (Config)#mplsd lfdb ipv6 1001 last-pop 77:88::1/128
```

The advantage of the per-interface label distribution mode over the per-switch distribution mode is that the traffic originator only needs to impose one label on the MPLS label stack. Some devices cannot impose multiple labels. Another advantage is that BGP neighbors can learn about all labels used in the network via the RFC 3107 label exchange.

On the other hand, distributing multiple per-interface labels from each switch consumes more hardware resources than distributing one per-switch label. The hardware resources required for distributing labels include route entries, next hop entries, and ECMP groups. Therefore, the per-interface labels are not scalable to the large spine-leaf data center networks.

6.9.2.5 Bidirectional Forwarding Detection

In the current release the MPLS-BFD protocol is not supported.

The switch does support the BFD protocol over IP sessions. The BGP protocol can use BFD to detect peer switch failures. Therefore, the MPLS labels distributed by the RFC 3107 BGP extension are affected by the BFD failure detection.

6.9.2.6 MPLS-Ping and MPLS-Traceroute

In the current release the MPLS-Ping and the MPLS-Traceroute protocols are not supported.

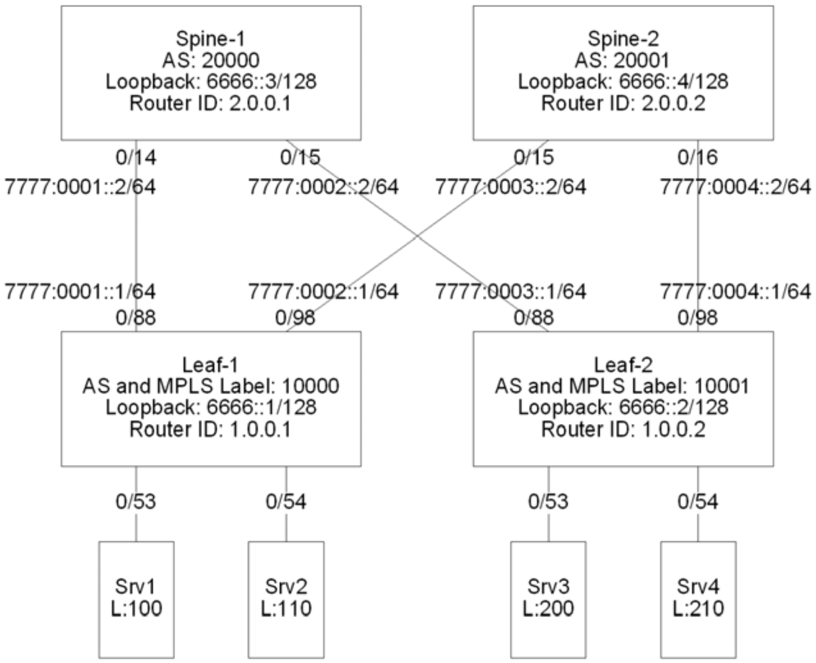
6.9.3 EFOS MPLS Use Cases

This section shows several example configurations of MPLS network with EFOS switches.

6.9.3.1 IPv6 Clos Network

This example configures four EFOS switches to form the IPv6 network shown in Figure 34, IPv6 Clos Network Example:

Figure 34: IPv6 Clos Network Example



The network consists of four switches: Spine-1, Spine-2, Leaf-1, and Leaf-2. The switches are connected in a Clos topology. The network also has four servers: Srv1, Srv2, Srv3, and Srv4. The switch and server MAC addresses are not shown in the diagram, but this example uses the following values:

- Spine-1: 60:eb:69:6f:20:d0
- Spine-2: c8:0a:a9:9e:14:56
- Leaf-1: 00:86:90:23:13:63
- Leaf-2: 00:90:00:10:FF:FF
- Srv1: 00:00:00:00:01:01
- Srv2: 00:00:00:00:01:02
- Srv3: 00:00:00:00:02:01
- Srv4: 00:00:00:00:02:02

The servers are devices such as hypervisors with multiple virtual machines that send MPLS-tagged traffic to other servers through the data center network. The MPLS label stack which needs to be used to switch the packet between the source and destination is programmed into the servers externally, such as via some Software Defined Networking mechanism.

The switches are running eBGP. The BGP Autonomous System identifier is indicated by the "AS" value. Each switch is assigned its own AS. There are no routing protocols running between the servers and the switches.

The Leaf switches are statically assigned an MPLS label, which they distribute along with the loopback interface subnet to the BGP peers. In this example the MPLS label is configured to have the same value as the AS identifier.

6.9.3.1.1 Switch Configuration

The following is the output of **show running-config** on the four switches. Comments are added to the leaf-1 configuration to explain some of the commands.

leaf-1:

```
(Routing) #hostname "leaf-1"

! Enable IPv6 routing
(Routing) #configure
(leaf-1) (Config)#ipv6 unicast-routing
(leaf-1) (Config)#ip routing

! Create static labels that enable traffic to go to the Srv1 and Srv2 devices.
! The commands implicitly enable MPLS on VLAN 1, which allows traffic from
! these servers to go into the network.
(leaf-1) (Config)#mplsd lfdb layer-2 100 pop 0/53 1 00:00:00:00:01:01
(leaf-1) (Config)#mplsd lfdb layer-2 110 pop 0/54 1 00:00:00:00:01:02

! Prevent serial console from timing out.
(leaf-1) (Config)#line console
(leaf-1) (Config-line)#serial timeout 0
(leaf-1) (Config-line)#exit

(leaf-1) (Config)#line telnet
(leaf-1) (Config-telnet)#exit


! Create the loopback interface for which to distribute the per-switch label.
(leaf-1) (Config)#interface loopback 0
(leaf-1) (Interface loopback 0)#ipv6 address 6666::1/128
(leaf-1) (Interface loopback 0)#ipv6 enable
! Configure the switch to distribute label 10000 via BGP for the loopback interface 0.
(leaf-1) (Config)#ipv6 mplsd bgp-mpls-label 10000
(leaf-1) (Config)#exit

! Assuming that the servers use the standard 1518 frame size, setting the MTU to 2000
! enables the switch to forward 1518 byte frames with a reasonable size MPLS
! label stack.
(leaf-1) (Config)#interface 0/53,0/54
(leaf-1) (Interface 0/53,0/54)#mtu 2000
(leaf-1) (Interface 0/53,0/54)#exit

! Configure interfaces 0/88 and 0/98 as port-based routing interfaces with IPv6 addresses.
(leaf-1) (Config)#interface 0/88
(leaf-1) (Interface 0/88)#routing
(leaf-1) (Interface 0/88)#ipv6 address 7777:1::1/64
(leaf-1) (Interface 0/88)#ipv6 enable
(leaf-1) (Interface 0/88)#exit

(leaf-1) (Config)#interface 0/98
(leaf-1) (Interface 0/89)#mtu 2000
(leaf-1) (Interface 0/89)#routing
(leaf-1) (Interface 0/89)#ipv6 address 7777:3::1/64
(leaf-1) (Interface 0/89)#ipv6 enable
(leaf-1) (Interface 0/89)#exit
```

```
! For convenience set the BGP system ID to be the same as the distributed MPLS label.
! The system ID can be different from the MPLS label if desired.
(leaf-1) (Config)#router bgp 10000

! The router ID is specified in IPv4 address format as per RFC. This address is not
! used for sending or receiving packets, so it is safe in IPv6-only networks.
(leaf-1) (Config-router)#bgp router-id 1.0.0.1

! To help debugging connectivity issues enable logging of BGP adjacency changes.
(leaf-1) (Config-router)#bgp log-neighbor-changes

! Define eBGP peer switches. All directly connected spine switches must be defined as
! BGP peers for the leaf switch.
(leaf-1) (Config-router)#neighbor 7777:1::2 remote-as 20000
(leaf-1) (Config-router)#neighbor 7777:3::2 remote-as 20001

! Enter IPv6 configuration mode.
(leaf-1) (Config-router)#address-family ipv6

! Enable BGP to support 16 ECMP neighbors. If you get an error on this command
! then you are probably using the wrong SDM template. Check the current settings by
! using the "show sdm prefer" command. The appropriate template for IPv6 network
! can be set using the "sdm prefer dual-ipv4-and-ipv6 data-center" command.
(leaf-1) (Config-router-af)#maximum-paths 16

! Tell BGP to export the route for the loopback interface. This is necessary in order to
! distribute the MPLS label associated with this switch. Note that the port-based
! routing interfaces are not distributed, which reduces the routing table size.
(leaf-1) (Config-router-af)#network 6666::1/128
(leaf-1) (Config-router-af)#neighbor 7777:1::2 activate
(leaf-1) (Config-router-af)#neighbor 7777:3::2 activate
(leaf-1) (Config-router-af)#exit
(leaf-1) (Config-router)#exit
(leaf-1) (Config)#exit
```

leaf-2:

```
(Routing) #hostname "leaf-2"

(leaf-2) #configure
(leaf-2) (Config)#ipv6 unicast-routing
(leaf-2) (Config)#ip routing
(leaf-2) (Config)#mplsd lfdb layer-2 200 pop 0/53 1 00:00:00:00:02:01
(leaf-2) (Config)#mplsd lfdb layer-2 210 pop 0/54 1 00:00:00:00:02:02
(leaf-2) (Config)#line console
(leaf-2) (Config-line)#serial timeout 0
(leaf-2) (Config-line)#exit

(leaf-2) (Config)#line telnet
(leaf-2) (Config-telnet)#exit

(leaf-2) (Config)#line ssh
(leaf-2) (Config-ssh)#exit

(leaf-2) (Config)#interface loopback 0
(leaf-2) (Interface loopback 0)#ipv6 address 6666::2/128
```

```
(leaf-2) (Interface loopback 0)#ipv6 enable
(leaf-2) (Interface loopback 0)#ipv6 mplsd bgp-mpls-label 10001
(leaf-2) (Interface loopback 0)#exit

(leaf-2) (Config)#interface 0/53
(leaf-2) (Interface 0/53)#mtu 2000
(leaf-2) (Interface 0/53)#exit

(leaf-2) (Config)#interface 0/54
(leaf-2) (Interface 0/54)#mtu 2000
(leaf-2) (Interface 0/54)#exit

(leaf-2) (Config)#interface 0/88
(leaf-2) (Interface 0/54)#mtu 2000
(leaf-2) (Interface 0/54)#routing
(leaf-2) (Interface 0/54)#ipv6 address 7777:2::1/64
(leaf-2) (Interface 0/54)#ipv6 enable
(leaf-2) (Interface 0/54)#exit

(leaf-2) (Config)#interface 0/98
(leaf-2) (Interface 0/98)#mtu 2000
(leaf-2) (Interface 0/98)#routing
(leaf-2) (Interface 0/98)#ipv6 address 7777:4::1/64
(leaf-2) (Interface 0/98)#ipv6 enable
(leaf-2) (Interface 0/98)#exit

(leaf-2) (Config)#router ospf
(leaf-2) (Config-router)#exit
(leaf-2) (Config)#ipv6 router ospf
(leaf-2) (Config-rtr)#exit
(leaf-2) (Config)#router bgp 10001
(leaf-2) (Config-router)#bgp router-id 1.0.0.2
(leaf-2) (Config-router)#bgp log-neighbor-changes
(leaf-2) (Config-router)#neighbor 7777:2::2 remote-as 20000
(leaf-2) (Config-router)#neighbor 7777:4::2 remote-as 20001
(leaf-2) (Config-router)#address-family ipv6
(leaf-2) (Config-router-af)#maximum-paths 16
(leaf-2) (Config-router-af)#network 6666::2/128
(leaf-2) (Config-router-af)#neighbor 7777:2::2 activate
(leaf-2) (Config-router-af)#neighbor 7777:4::2 activate
(leaf-2) (Config-router-af)#exit
(leaf-2) (Config-router)#exit
(leaf-2) (Config)#exit
```

spine-1:

```
(Routing) #hostname "spine-1"

(spine-1) #configure
(spine-1) (Config)#ipv6 unicast-routing
(spine-1) (Config)#ip routing
(spine-1) (Config)#line console
(spine-1) (Config-line)#serial timeout 0
(spine-1) (Config-line)#exit

(spine-1) (Config)#line telnet
```

```
(spine-1) (Config-telnet)#exit

(spine-1) (Config)#line ssh
(spine-1) (Config-ssh)#exit

(spine-1) (Config)#interface loopback 0
(spine-1) (Interface loopback 0)#ipv6 address 6666::3/128
(spine-1) (Interface loopback 0)#ipv6 enable
(spine-1) (Interface loopback 0)#exit

(spine-1) (Config)#interface 0/14
(spine-1) (Interface 0/14)#mtu 2000
(spine-1) (Interface 0/14)#routing
(spine-1) (Interface 0/14)#ipv6 address 7777:1::2/64
(spine-1) (Interface 0/14)#ipv6 enable
(spine-1) (Interface 0/14)#exit

(spine-1) (Config)#interface 0/15
(spine-1) (Interface 0/15)#mtu 2000
(spine-1) (Interface 0/15)#routing
(spine-1) (Interface 0/15)#ipv6 address 7777:2::2/64
(spine-1) (Interface 0/15)#ipv6 enable
(spine-1) (Interface 0/15)#exit

(spine-1) (Config)#router ospf
(spine-1) (Config-router)#exit
(spine-1) (Config)#ipv6 router ospf
(spine-1) (Config-rtr)#exit
(spine-1) (Config)#router bgp 20000
(spine-1) (Config-router)#bgp router-id 2.0.0.1
(spine-1) (Config-router)#bgp log-neighbor-changes
(spine-1) (Config-router)#neighbor 7777:1::1 remote-as 10000
(spine-1) (Config-router)#neighbor 7777:2::1 remote-as 10001
(spine-1) (Config-router)#address-family ipv6
(spine-1) (Config-router-af)#maximum-paths 16
(spine-1) (Config-router-af)#network 6666::3/128
(spine-1) (Config-router-af)#neighbor 7777:1::1 activate
(spine-1) (Config-router-af)#neighbor 7777:2::1 activate
(spine-1) (Config-router-af)#exit
(spine-1) (Config-router)#exit
(spine-1) (Config)#exit
```

spine-2:

```
(Routing) #hostname "spine-2"

(spine-2) #configure
(spine-2) (Config)#ipv6 unicast-routing
(spine-2) (Config)#ip routing
(spine-2) (Config)#line console
(spine-2) (Config-line)#serial timeout 0
(spine-2) (Config-line)#exit

(spine-2) (Config)#line telnet
(spine-2) (Config-telnet)#exit
```

```
(spine-2) (Config)#line ssh
(spine-2) (Config-ssh)#exit

(spine-2) (Config)#interface loopback 0
(spine-2) (Interface loopback 0)#ipv6 address 6666::4/128
(spine-2) (Interface loopback 0)#ipv6 enable
(spine-2) (Interface loopback 0)#exit

(spine-2) (Config)#interface 0/15
(spine-2) (Interface 0/15)#mtu 2000
(spine-2) (Interface 0/15)#routing
(spine-2) (Interface 0/15)#ipv6 address 7777:3::2/64
(spine-2) (Interface 0/15)#ipv6 enable
(spine-2) (Interface 0/15)#exit

(spine-2) (Config)#interface 0/16
(spine-2) (Interface 0/16)#mtu 2000
(spine-2) (Interface 0/16)#routing
(spine-2) (Interface 0/16)#ipv6 address 7777:4::2/64
(spine-2) (Interface 0/16)#ipv6 enable
(spine-2) (Interface 0/16)#exit

(spine-2) (Config)#router bgp 20001
(spine-2) (Config-router)#bgp router-id 2.0.0.2
(spine-2) (Config-router)#bgp log-neighbor-changes
(spine-2) (Config-router)#neighbor 7777:3::1 remote-as 10000
(spine-2) (Config-router)#neighbor 7777:4::1 remote-as 10001
(spine-2) (Config-router)#address-family ipv6
(spine-2) (Config-router-af)#maximum-paths 16
(spine-2) (Config-router-af)#network 6666::4/128
(spine-2) (Config-router-af)#neighbor 7777:3::1 activate
(spine-2) (Config-router-af)#neighbor 7777:4::1 activate
(spine-2) (Config-router-af)exit
(spine-2) (Config-router)#exit
(spine-2) (Config)#exit
```

6.9.3.1.1.1 Verifying Configuration

The following commands are used to verify the network configuration. These commands are issued on the Leaf-1 switch.

Example 1:

Verify that IPv6 interfaces are created with the appropriate IP addresses:

```
(leaf-1) #show ipv6 interface brief

           Oper.
Interface  Mode     IPv6 Address/Length
---------- -------- ---------------------------------
0/88       Enabled  fe80::210:18ff:fe99:f7ae/64
                    7777:1::1/64
0/98       Enabled  fe80::210:18ff:fe99:f7ae/64
                    7777:3::1/64
loopback 0 Enabled  fe80::210:18ff:fe99:f7ab/64
                    6666::1/128

(leaf-1) #
```

Example 2:

Verify that BGP formed connections with neighbors.

```
(leaf-1) #show bgp ipv6 summary

IPv6 Routing ................................. Enable
BGP Admin Mode ............................... Enable
BGP Router ID ................................ 1.0.0.1
Local AS Number .............................. 10000
Number of Network Entries .................... 4
Number of AS Paths ........................... 3

Neighbor           ASN  MsgRcvd  MsgSent         State   Up/Down Time  Pfx Rcvd
---------------- ----- -------- -------- ------------- ------------- ---------
7777:1::2        20000       71       68   ESTABLISHED     0:00:27:24         3
7777:3::2        20001       73       69   ESTABLISHED     0:00:27:24         3


(leaf-1) #
```

Example 3:

Verify that routes have been installed. Note that there is an ECMP route to the loopback subnet 6666::2/128 on Leaf-2.

```
(leaf-1) #show ipv6 route

IPv6 Routing Table - 6 entries

Codes: C - connected, S - static, 6To4 - 6to4 Route, B - BGP Derived
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF Ext 1, OE2 - OSPF Ext 2
       ON1 - OSPF NSSA Ext Type 1, ON2 - OSPF NSSA Ext Type 2

C    6666::1/128 [0/0]
      via ::,   loopback 0
B    6666::2/128 [20/0]
      via fe80::62eb:69ff:fe6f:20d3,   00h:28m:26s,  0/1
      via fe80::ca0a:a9ff:fe9e:1459,   00h:28m:26s,  0/2
B    6666::3/128 [20/0]
      via fe80::62eb:69ff:fe6f:20d3,   00h:28m:26s,  0/1
B    6666::4/128 [20/0]
      via fe80::ca0a:a9ff:fe9e:1459,   00h:28m:26s,  0/2
C    7777:1::/64 [0/0]
      via ::,   0/1
C    7777:3::/64 [0/0]
      via ::,   0/2

(leaf-1) #
```

Example 4:

Verify connectivity from leaf-1 to leaf-2. The **ping** and the **traceroute** commands must be issued with the **source loopback 0** qualifier. The **source** command option forces the switch to use the loopback subnet as the source IP address for the ping requests. Without the **source** option, the source IP is the egress interface 7777:0003::2, which is not configured to be advertised by the BGP. Therefore, the ping reply will fail without the **source** option.

Also note that the **ping** command for IPv6 blocks for 3 seconds and does not show intermediate ping replies. The successful completion is indicated by the non-zero value in the "Receive count".

```
(leaf-1) #
(leaf-1) #ping ipv6 6666::2 source loopback 0
 Pinging 6666::2 with 0 bytes of data:


Send count=3, Receive count=3 from 6666::2
Average round trip time = 1.00 ms

(leaf-1) #

(leaf-1) #traceroute ipv6 6666::2 source loopback 0

Tracing route over a maximum of 30 hops

 1                                 7777:1::2     1 ms         1 ms         1 ms
 2                                   6666::2     1 ms         1 ms         1 ms


Hop Count = 2 Last TTL = 2 Test attempt = 6 Test Success = 6


(leaf-1) #
```

Example 5:

View the content of the LFDB database.

```
(leaf-1) #show mplsd lfdb all

Label:100  Protocol:Static  Type:Layer-2  Subnet:N/A
     Egress Label Action:pop  Egress Label:N/A
     Egress Interface Port:0/53  Vlan:1  MAC:00:00:00:00:01:01
     Hardware Status:Inserted  Not Inserted Reason:N/A
     Byte Count:0  Packet Count:0
     Duplicate Insertion Attempts:0

Label:110  Protocol:Static  Type:Layer-2  Subnet:N/A
     Egress Label Action:pop  Egress Label:N/A
     Egress Interface Port:0/54  Vlan:1  MAC:00:00:00:00:01:02
     Hardware Status:Inserted  Not Inserted Reason:N/A
     Byte Count:9115455237924  Packet Count:5711438119
     Duplicate Insertion Attempts:0

Label:10001  Protocol:BGP  Type:ipv6  Subnet:6666::2/128
     Egress Label Action:swap  Egress Label:N/A
     Egress Interface Port:N/A  Vlan:N/A  MAC:N/A
     Hardware Status:Inserted  Not Inserted Reason:N/A
     Byte Count:0  Packet Count:0
     Duplicate Insertion Attempts:0

(leaf-1) #
```

6.9.3.1.2 Traffic Forwarding Examples

To switch packets through the network, the packets must be MPLS-tagged on ingress and egress.

Example 1:

In this example the packet is switched from Srv1 to Srv2. Since the packet does not traverse multiple switches, the top MPLS label in the packet must be the label of Serv2, which is 110. The packet must also have a second label in the stack, which identifies a virtual machine, or has some other local meaning in Srv2. In this example, the second label is 2222.

The destination MAC is the MAC of Leaf-1. The packet is sent untagged, which internally in the switch Leaf-1 maps to VLAN1.

The packet transmitted from the Srv1 to Srv2 has the following addressing information:

- DA MAC: 00:86:90:23:13:63
- SA MAC: 00:00:00:00:01:01
- Label Stack: 110 2222

The Leaf-1 switch receives the packet on port 6 and MPLS-switches the packet because it is configured with Static L2 label 110. The label action for 110 is to pop the label and send the packet on port 7. The Leaf-1 switch transmits the packet on port 7, without a VLAN tag, with the following addressing information:

- DA MAC: 00:00:00:00:01:02
- SA MAC: 00:86:90:23:13:63
- Label Stack: 2222

Example 2:

In this example, the packet is switched from Srv1 to Srv3. Since the packet traverses multiple switches, the top label in the MPLS label stack must be the label of the switch to which the Srv3 is attached. In this example, the Srv3 is attached to Leaf-2, which distributes the label 10001. The Srv3 is assigned the label 200 and, in this example, internally in Srv3 the MPLS label is 3005.

The packet transmitted from Srv1 to Srv3 has the following addressing information:

- DA MAC: 00:86:90:23:13:63
- SA MAC: 00:00:00:00:01:01
- Labels Stack: 10001 200 3005

The Leaf-1 receives the packet on port 6 and MPLS-switches the packet because label 10001 has been distributed via BGP and programmed into the Leaf-1 Label Forwarding Database (LFDB). The action for label 10001 is to send the packet on an ECMP path towards Leaf-2. The packet may egress Leaf-2 either on port 1 or port 2. The action for the label 10001 is to swap with label 10001, which effectively preserves the same label at the top of the stack.

Assuming the frame exits Leaf-1 on port 1 towards Spine-1, the following addressing information is in the packet:

- DA MAC: 60:eb:69:6f:20:d0
- SA MAC: 00:86:90:23:13:63
- Label Stack 10001 200 3005

The Spine-1 switch receives the packet because label 10001 is distributed by BGP from Leaf-2. Because the subnet associated with label 10001 is locally attached to Leaf-2 the action for label 10001 is to pop the label stack and send the packet on port 2.

The frame exits Spine-1 on port 2 with the following addressing information:

- DA MAC: 00:90:00:10:FF:FF
- SA MAC: 60:eb:69:6f:20:d0
- Label Stack: 200 3005

The packet is received by Leaf-2 on port 1 because label 200 is statically programmed into the LFDB on Leaf-2. The label action for label 200 is pop, and the egress port is 6.

The Leaf-2 transmits the packet on port 6 with the following addressing information:

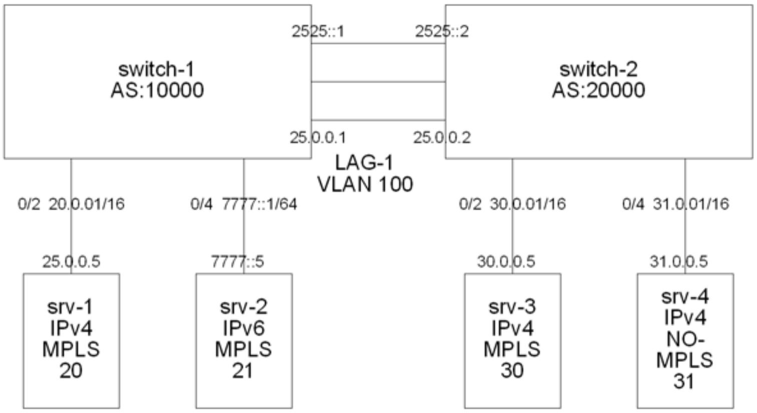
- DA MAC: 00:00:00:00:02:01
- SA MAC: 00:90:00:10:FF:FF
- Label Stack: 3005

6.9.3.2 IPv4 Network with IPv6 Subnets, VLANs, and LAGs

This example demonstrates the use of per-interface MPLS labels in an IPv4/IPv6 network that also uses LAGs and VLAN routing interfaces.

The EFOS BGP protocol can distribute IPv6 routes over IPv4 BGP peer sessions. The IPv4 routes cannot be distributed over IPv6 peer sessions. Therefore, when running the network in a mixed IPv4 and IPv6 environment, the BGP is configured to run over IPv4. Customers who do not need IPv6 can simply ignore the IPv6-related configuration in the following example.

Figure 35: MPLS Labels in IPv4/IPv6 Network with LAGs and VLAN Routing



The network consists of two switches: switch-1 and switch-2. The switches are connected to each other via a LAG. The LAG is a member of VLAN 100. Both switches have routing interfaces on VLAN 100 with IP addresses 25.0.0.1 and 25.0.0.2. The VLAN routing interface is also enabled for IPv6 with addresses 2525::1/64 and 2525::2/64.

The network also has four servers: srv-1, srv-2, srv-3, and srv-4. The switch and server MAC addresses are not shown in the diagram, but the following values are used for this example:

- switch-1: 00:10:18:7f:f9:8e
- switch-2: 00:10:18:99:f6:7a
- srv-1: 00:00:00:00:01:01
- srv-2: 00:00:00:00:01:02
- srv-3: 00:00:00:00:02:01
- srv-4: 00:00:00:00:02:02

The servers 1, 2, and 3 are devices such as hypervisors with multiple virtual machines that send MPLS-tagged traffic to other servers through the data center network. The MPLS label stack which needs to be used to switch the packet between the source and destination is programmed into the servers externally, such as via some Software Defined Networking mechanism.

In this example the server 4 is an IPv4 device that does not support MPLS tagging. The srv-4 sends traffic into the switch without the MPLS tags. The switch routes the traffic from srv-4 using the IP routing tables. Any MPLS packets destined to srv-4 are stripped of the MPLS tag.

All the servers are attached to the switches via port-based routing interfaces with the IP addresses shown above. The srv-1 is an IPv6 device.

The switches are running eBGP. The BGP Autonomous System identifier is indicated by the "AS" value. Each switch is assigned its own AS. There are no routing protocols running between the servers and the switches.

The servers 1, 2, and 3 are assigned MPLS labels. The labels are statically configured in the switch as "per-interface" labels and are distributed by BGP to the peer switch.

6.9.3.2.1 Switch Configuration

The following is the output of "show running-config" on the two switches. Comments are added to the configuration to explain some of the commands.

switch-1:

```
(Routing) #hostname "switch-1"

! Create a VLAN for the VLAN routing interface.
!
(switch-1) #vlan database
(switch-1) (Vlan)#vlan 100
(switch-1) (Vlan)#vlan routing 100 1
(switch-1) (Vlan)#exit

(switch-1) #configure
! Enable IPv4 and IPv6 routing.
!
(switch-1) (Config)#ipv6 unicast-routing
(switch-1) (Config)#ip routing

! Create LFDB entries associated with IPv4 host 20.0.0.5 and IPv6 host 7777::5.
! The MAC addresses for the hosts are automatically picked up from the
! ARP/Neighbor tables.
!
(switch-1) (Config)#mplsd lfdb ipv4 20 swap 20.0.0.5/32
(switch-1) (Config)#mplsd lfdb ipv6 21 swap 7777::5/128
(switch-1) (Config)#line console
(switch-1) (Config-line)#serial timeout 0
(switch-1) (Config-line)#exit

(switch-1) (Config)#line telnet
(switch-1) (Config-telnet)#exit

! Add ports 0/23, 0/24, 0/25 to LAG-1
!
(switch-1) (Config)#interface 0/23
(switch-1) (Interface 0/23)#addport 3/1
(switch-1) (Interface 0/23)#exit
(switch-1) (Config)#interface 0/24
(switch-1) (Interface 0/24)#addport 3/1
```

```
(switch-1) (Interface 0/24)#exit
(switch-1) (Config)#interface 0/25
(switch-1) (Interface 0/25)#addport 3/1
(switch-1) (Interface 0/25)#exit

(switch-1) (Config)#interface 0/2
! Increase the port MTU to enable support for standard 1518-byte frames with
! reasonable size MPLS header.
!
(switch-1) (Interface 0/2)#mtu 2000
(switch-1) (Interface 0/2)#routing
(switch-1) (Interface 0/2)#ip address 20.0.0.1 255.255.0.0

! Tell BGP to export MPLS label 20 for this interface.
!
(switch-1) (Interface 0/2)#mplsd bgp-mpls-label 20
(switch-1) (Interface 0/2)#exit

! Enable this interface for IPv6.
!
(switch-1) (Config)#interface 0/4
(switch-1) (Interface 0/4)#mtu 2000
(switch-1) (Interface 0/4)#routing
(switch-1) (Interface 0/4)#ipv6 address 7777::1/64
(switch-1) (Interface 0/4)#ipv6 enable
(switch-1) (Interface 0/4)#ipv6 mplsd bgp-mpls-label 21
(switch-1) (Interface 0/4)#exit

(switch-1) (Config)#interface lag 1
(switch-1) (Interface lag 1)#mtu 2000
(switch-1) (Interface lag 1)#vlan participation include 100
(switch-1) (Interface lag 1)#vlan tagging 100
(switch-1) (Interface lag 1)#exit

! The VLAN routing interface carries both, IPv4 and IPv6 traffic.
! Therefore the interface must have IPv4 and IPv6 addresses.
!
(switch-1) (Config)#interface vlan 100
(switch-1) (Interface vlan 100)#routing
(switch-1) (Interface vlan 100)#ip address 25.0.0.1 255.255.0.0
(switch-1) (Interface vlan 100)#ipv6 address 2525::1/64
(switch-1) (Interface vlan 100)#ipv6 enable
(switch-1) (Interface vlan 100)#exit

(switch-1) (Config)#router bgp 10000
(switch-1) (Config-router)#bgp router-id 1.0.0.1
(switch-1) (Config-router)#maximum-paths 16
(switch-1) (Config-router)#bgp log-neighbor-changes
(switch-1) (Config-router)#neighbor 25.0.0.2 remote-as 10001

! Instruct BGP to advertise local subnets and per-interface MPLS labels to the
! neighbors.
!
(switch-1) (Config-router)#redistribute connected
(switch-1) (Config-router)#address-family ipv6
(switch-1) (Config-router-af)#maximum-paths 16
(switch-1) (Config-router-af)#redistribute connected
! In IPv4/IPv6 mixed mode the IPv6 route information is carried over IPv4 sessions.
```

```
!
(switch-1) (Config-router-af)#neighbor 25.0.0.2 activate
(switch-1) (Config-router-af)#exit
(switch-1) (Config-router)#exit
! The static ARP and Neighbor table entries are normally not necessary. These values
! are learned dynamically via the ARP or NDP protocols. The configuration is present
! here in order to simplify testing with the traffic generator.
!
(switch-1) (Config)#arp 20.0.0.5 00:00:00:00:01:01
(switch-1) (Config)#ipv6 neighbor 7777::5 0/4 00:00:00:00:01:02
(switch-1) (Config)#exit
```

switch-2:

```
(Routing) #hostname "switch-2"
(switch-2) #vlan database
(switch-2) (Vlan)#vlan 100
(switch-2) (Vlan)#vlan routing 100 1
(switch-2) (Vlan)#exit

(switch-2) #configure
(switch-2) (Config)#ipv6 unicast-routing
(switch-2) (Config)#ip routing
(switch-2) (Config)#mplsd lfdb ipv4 30 swap 30.0.0.5/32
! This LFDB entry strips the last MPLS tag from the IPv4 and IPv6 packets.
!
(switch-2) (Config)#mplsd lfdb ipv4 31 last-pop 31.0.0.5/32
(switch-2) (Config-line)#line console
(switch-2) (Config-line)#serial timeout 0
(switch-2) (Config-line)#exit

(switch-2) (Config)#line telnet
(switch-2) (Config-telnet)#exit

(switch-2) (Config)#interface 0/23
(switch-2) (Interface 0/23)#addport 3/1
(switch-2) (Interface 0/23)#aexit
(switch-2) (Config)#interface 0/24
(switch-2) (Interface 0/24)#aaddport 3/1
(switch-2) (Interface 0/24)#exit
(switch-2) (Config)#interface 0/25
(switch-2) (Interface 0/25)#addport 3/1
(switch-2) (Interface 0/25)#exit

(switch-2) (Config)#interface 0/2
(switch-2) (Interface 0/2)#mtu 2000
(switch-2) (Interface 0/2)#routing
(switch-2) (Interface 0/2)#ip address 30.0.0.1 255.255.0.0
(switch-2) (Interface 0/2)#mplsd bgp-mpls-label 30
(switch-2) (Interface 0/2)#exit

(switch-2) (Config)#interface 0/4
(switch-2) (Interface 0/4)#routing
(switch-2) (Interface 0/4)#ip address 31.0.0.1 255.255.0.0
(switch-2) (Interface 0/4)#mplsd bgp-mpls-label 31
(switch-2) (Interface 0/4)#exit
```

```
(switch-2) (Config)#interface lag 1
(switch-2) (Interface lag 1)#mtu 2000
(switch-2) (Interface lag 1)#vlan participation include 100
(switch-2) (Interface lag 1)#vlan tagging 100
(switch-2) (Interface lag 1)#exit

(switch-2) (Config)#interface vlan 100
(switch-2) (Interface vlan 100)#routing
(switch-2) (Interface vlan 100)#ip address 25.0.0.2 255.255.0.0
(switch-2) (Interface vlan 100)#ipv6 address 2525::2/64
(switch-2) (Interface vlan 100)#ipv6 enable
(switch-2) (Interface vlan 100)#exit

(switch-2) (Config)#router rip
(switch-2) (Config-router)#exit
(switch-2) (Config)#router ospf
(switch-2) (Config-router)#exit
(switch-2) (Config)#ipv6 router ospf
(switch-2) (Config-rtr)#exit
(switch-2) (Config)#router bgp 10001
(switch-2) (Config-router)#bgp router-id 1.0.0.2
(switch-2) (Config-router)#maximum-paths 16
(switch-2) (Config-router)#bgp log-neighbor-changes
(switch-2) (Config-router)#neighbor 25.0.0.1 remote-as 10000
(switch-2) (Config-router)#redistribute connected
(switch-2) (Config-router)#address-family ipv6
(switch-2) (Config-router-af)#maximum-paths 16
(switch-2) (Config-router-af)#redistribute connected
(switch-2) (Config-router-af)#neighbor 25.0.0.1 activate
(switch-2) (Config-router-af)#exit
(switch-2) (Config-router)#exit
(switch-2) (Config)#arp 30.0.0.5 00:00:00:00:02:01
(switch-2) (Config)#arp 31.0.0.5 00:00:00:00:02:02
(switch-2) (Config)#exit
```

6.9.3.2.1.1 Verifying Configuration

The following commands are used to verify the network configuration. These commands are issued on switch-2.

Example 1:

Verify that IPv4 and IPv6 interfaces are created with the appropriate IP addresses:

```
(switch-2) #show ip interface brief

Interface    State  IP Address      IP Mask         Method
----------   -----  --------------- --------------- -------
0/2          Up     30.0.0.1        255.255.0.0     Manual
0/4          Up     31.0.0.1        255.255.0.0     Manual
4/1          Up     25.0.0.2        255.255.0.0     Manual

(switch-2) #
(switch-2) #show ipv6 interface brief

           Oper.
Interface  Mode     IPv6 Address/Length
---------- -------- ---------------------------------
0/2        Disabled fe80::210:18ff:fe99:f67a/64                        [TENT]
```

```
0/4        Disabled fe80::210:18ff:fe99:f67a/64                        [TENT]
4/1        Enabled  fe80::210:18ff:fe99:f67a/64
                    2525::2/64

(switch-2) #
```

Example 2:

Verify that BGP formed connections with neighbors for exchanging IPv4 and IPv6 routes.

```
(switch-2) #show ip bgp summary

IPv4 Routing .................................. Enable
BGP Admin Mode ................................ Enable
BGP Router ID ................................. 1.0.0.2
Local AS Number ............................... 10001
Number of Network Entries ..................... 4
Number of AS Paths ............................ 1
Dynamic Neighbors Current/High/Limit........... 1/1/100

Neighbor           ASN  MsgRcvd  MsgSent         State   Up/Down Time  Pfx Rcvd
---------------- ----- -------- -------- ------------- ------------- ---------
25.0.0.1         10000     2341     2346   ESTABLISHED     0:16:33:11         2
*100.20.1.7      30           0      7   OPEN SENT                          0


(switch-2) #show bgp ipv6 summary

IPv6 Routing .................................. Enable
BGP Admin Mode ................................ Enable
BGP Router ID ................................. 1.0.0.2
Local AS Number ............................... 10001
Number of Network Entries ..................... 2
Number of AS Paths ............................ 1

Neighbor           ASN  MsgRcvd  MsgSent         State   Up/Down Time  Pfx Rcvd
---------------- ----- -------- -------- ------------- ------------- ---------
25.0.0.1         10000     2342     2346   ESTABLISHED     0:16:33:18         1
```

Example 3:

Verify that IPv4 and IPv6 routes have been installed.

```
(switch-2) #show ip route

Route Codes: R - RIP Derived, O - OSPF Derived, C - Connected, S - Static
       B - BGP Derived, IA - OSPF Inter Area
       E1 - OSPF External Type 1, E2 - OSPF External Type 2
       N1 - OSPF NSSA External Type 1, N2 - OSPF NSSA External Type 2
       S U - Unnumbered Peer

B      20.0.0.0/16 [20/0] via 25.0.0.1,   16h:35m:00s,  4/1
C      25.0.0.0/16 [0/1] directly connected,   4/1
C      30.0.0.0/16 [0/1] directly connected,   0/2
C      31.0.0.0/16 [0/1] directly connected,   0/4
```

```
(switch-2) #show ipv6 route

IPv6 Routing Table - 2 entries

Codes: C - connected, S - static, 6To4 - 6to4 Route, B - BGP Derived
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF Ext 1, OE2 - OSPF Ext 2
       ON1 - OSPF NSSA Ext Type 1, ON2 - OSPF NSSA Ext Type 2

C    2525::/64 [0/0]
      via ::,   4/1
B    7777::/64 [20/0]
      via fe80::210:18ff:fe7f:f98e,   16h:35m:06s,  4/1

(switch-2) #
```

Example 4:

Verify IPv4 and IPv6 connectivity between switch-2 and switch-1.

Note that the **ping** command for IPv6 blocks for 3 seconds and does not show intermediate ping replies. The successful completion is indicated by the non-zero value in the “Receive count”.

```
(switch-2) #ping 20.0.0.1
 Pinging 20.0.0.1 with 0 bytes of data:

Reply From 20.0.0.1: icmp_seq = 0. time= 2 msec.
Reply From 20.0.0.1: icmp_seq = 1. time= 2 msec.
Reply From 20.0.0.1: icmp_seq = 2. time= 2 msec.

----20.0.0.1 PING statistics----
3 packets transmitted, 3 packets received, 0% packet loss
round-trip (msec) min/avg/max = 2/2/2

(switch-2) #ping ipv6 7777::1
 Pinging 7777::1 with 0 bytes of data:


Send count=3, Receive count=3 from 7777::1
Average round trip time = 2.00 ms

(switch-2) #
```

Example 5:

View the content of the LFDB Database.

```
(switch-2) #show mplsd lfdb all

Label:20  Protocol:BGP  Type:ipv4  Subnet:20.0.0.0/16
     Egress Label Action:swap  Egress Label:N/A
     Egress Port:N/A  Vlan:N/A  MAC:N/A
     Hardware Status:Inserted  Not Inserted Reason:N/A
     Byte Count:0  Packet Count:0
     Duplicate Insertion Attempts:0

Label:21  Protocol:BGP  Type:ipv6  Subnet:7777::/64
```

```
     Egress Label Action:swap  Egress Label:N/A
     Egress Port:N/A  Vlan:N/A  MAC:N/A
     Hardware Status:Inserted  Not Inserted Reason:N/A
     Byte Count:0  Packet Count:0
     Duplicate Insertion Attempts:0

Label:30  Protocol:Static  Type:ipv4  Subnet:30.0.0.5/32
     Egress Label Action:swap  Egress Label:N/A
     Egress Port:N/A  Vlan:N/A  MAC:N/A
     Hardware Status:Inserted  Not Inserted Reason:N/A
     Byte Count:0  Packet Count:0
     Duplicate Insertion Attempts:0

Label:31  Protocol:Static  Type:ipv4  Subnet:31.0.0.5/32
     Egress Label Action:last-pop  Egress Label:N/A
     Egress Port:N/A  Vlan:N/A  MAC:N/A
     Hardware Status:Inserted  Not Inserted Reason:N/A
     Byte Count:0  Packet Count:0
     Duplicate Insertion Attempts:0

(switch-2) #
```

6.9.3.2.2 Traffic Forwarding Examples

To switch packets through the network using MPLS, the packets must be MPLS-tagged on ingress. It is possible to use the MPLS-tagged and regular IP traffic concurrently.

Example 1:

In this example the packet is switched from srv-1 to srv-2. The top MPLS label in the packet must be the label of srv-2, which is: 21. Depending on the server 2 operation, the packet may or may not have another MPLS label. In this example, a second label is not necessary.

The destination MAC is the MAC of switch-1. The packet is sent without a VLAN tag, which internally in the switch-1 maps to VLAN 1.

The packet transmitted from the srv-1 to srv-2 has the following addressing information:

- DA MAC: 00:10:18:7f:f9:8e
- SA MAC: 00:00:00:00:01:01

Label Stack: 21

The switch-1 receives the packet on port 2. The action for label 21 is to swap the label and send the packet to srv-2. The switch has an ARP entry that associates the srv-2 with port 4 and MAC 00;00:00:00:01:02. The switch-1 transmits the packet on port 4, without a VLAN tag, with the following addressing information:

- DA MAC: 00:00:00:00:01:02
- SA MAC: 00:10:18:7f:f9:8e
- Label Stack: 21

Example 2:

In this example the packet is switched from srv-1 to srv-3. The top MPLS label in the packet must be the label of srv-3, which is: 30. Depending on the server 3 operation, the packet may or may not have another MPLS label. In this example, a second label is not necessary.

The destination MAC is the MAC of switch-1. The packet is sent without a VLAN tag, which internally in the switch-1 maps to VLAN 1.

The packet transmitted from the srv-1 to srv-3 has the following addressing information:

- DA MAC: 00:10:18:7f:f9:8e
- SA MAC: 00:00:00:00:01:01
- Label Stack: 30

The switch-1 receives the packet on port 2 and performs MPLS switching on the packet because label 30 has been distributed via BGP and programmed into the switch-1 Label Forwarding Database (LFDB). The action for label 30 is to send the packet on the VLAN routing interface towards switch-2 and to swap the label, which effectively preserves the same label at the top of the label stack.

The following addressing information is in the packet when it is sent to switch-2:

- DA MAC: 00:10:18:99:f6:7a
- SA MAC: 00:10:18:7f:f9:8e
- VLAN Tag: 100
- Label Stack: 30

The switch-2 receives the packet and MPLS-switches the packet because label 30 is statically programmed into the LFDB and points to the srv-3.

The frame exits switch-2 on port 4 with the following addressing information:

- DA MAC: 00:00:00:00:02:01
- SA MAC: 00:10:18:99:f6:7a
- Label Stack: 30

Example 3:

The MPLS traffic from serv-1 to serv-4 is very similar to the previous example except that the destination MPLS label is 31.

When switch-2 receives the packet with label 31, it strips the last MPLS tag from the packet and sends it untagged to serv-4.

Example 4:

The traffic from serv-4 to serv-1 is not MPLS tagged because serv-4 does not support the MPLS tagging. The packet is simply routed based on the IPv4 routing tables in the switches.

6.9.4 MPLS Device Connectivity Diagnostics and Debugging

This section describes the diagnostic facilities that EFOS provides to help debug MPLS connectivity issues.

6.9.4.1 LFDB Lookup Failure Packet Trace

The MPLS packets that fail hardware LFDB lookup are automatically sent to the CPU. In order to avoid CPU congestion the packets are rate limited at 64 Kb/s.

The received MPLS LFDB lookup failure packets are logged in the syslog. EFOS limits the LFDB Lookup Failure log entries at one entry every 5 seconds.

The packets can be examined using the command **show logging buffered**. The most recent entry is shown first. The log can be cleared using the command **clear logging buffered**.

The following is an example log entry for a packet that failed the LFDB lookup:

```
<14> Jan  1 05:44:58 10.27.22.145-1 MPLSD[dtlTask]: mpls.c(839) 1224 %% Lookup Failure USP:1.0.31 Msg
Size:64 Labels:1000/200/- TTL:64/64/- EXP:0x0/0x0/- BOS:0/1/- VLAN:1 DA MAC: 70:72:cf:a3:c6:e2
Packet(0..63):70:72:cf:a3:c6:e2:00:00:01:00:01:00:81:00:00:01:88:47:00:3e:80:40:00:0c:81:40:00:01:02
:03:04:05:06:07:08:09:0a:0b:0c:0d:0e:0f:10:11:12:13:14:15:16:17:18:19:1a:1b:1c:1d:1e:1f:20:21:22:23:
24:25:
```

The "USP" is the ingress port for this packet. The "Msg Size" is the number of bytes in the received packet. The "Labels" are the first three labels in the MPLS label stack. The "TTL", "EXP", and "BOS" are the parsed values from the top three labels. The DA MAC and VLAN are the destination MAC address and VLAN for which this packet was received.

The rest of the message shows the first 64 bytes of the packet. Note that the VLAN tag is always present in the packet, even if the original packet was sent untagged.

The following issues can cause the packet to fail the hardware LFDB lookup.

Label is not in the Hardware Database:

Verify that the label is in the database using the **show mpls lfdb label** *label-id* command. If the label is not in the database or the Hardware Status is not *Inserted*, then there some issue with the switch configuration.

Destination MAC does not match the MPLS MAC address of the switch:

The switch does not perform hardware LFDB lookup if the destination MAC address does not match the MPLS MAC address of the switch. The switch MPLS MAC address can be seen using the **show mplsd** command.

The VLAN is not enabled for MPLS:

This issue typically impacts the layer-2 MPLS entries. At least one layer-2 entry must be created for a VLAN in order for that VLAN to be enabled for MPLS. For example the following command enables MPLS on VLAN 1 and also sends packets with label 100 to port 0/53:

```
mplsd lfdb layer-2 200 pop 0/53 1 00:00:00:00:02:01.
```

If the VLAN is not enabled for MPLS, then the MPLS packets received on this VLAN fail the LFDB lookup even if the destination label is in the hardware.

The VLANs associated with the port-based and VLAN-based routing interfaces are automatically enabled for MPLS.

6.9.4.2 MPLS and Port Counters

The switch maintains the following counters that are useful for debugging MPLS connectivity issues:

Per Label Received Packets and Bytes:

The number of packets and bytes that have been received for a particular label can be seen using the **show mplsd lfdb all** command. Note that for some packets the switch may increment the per-label counter but drop the packet.

The following are some reasons that a packet can be counted and dropped:

1. Ingress or Egress port MTU is smaller than the packet size. The MTU is set using the **mtu** command in the interface configuration mode.
2. The TTL field in the MPLS label may be zero.

3. The egress port specified in the layer-2 label entry has not been added to the egress VLAN specified for that label.

The counters can be reset to zero using the **clear counters mplsd** command.

LFDB Lookup Failure Packets:

This counter can be seen using the **show mplsd** command in the line labeled *LFDB lookup failure packets*.

The counter represents the number of MPLS packets that failed hardware label lookup. The network administrator may monitor this counter to detect network issues. The counter might increment temporarily when there are network topology changes.

The counter is reset to zero with the **clear counters mplsd** command.

Port-Based Counters:

The port counters can be used to help with analyzing configuration or connectivity issues. There are no MPLS-specific port counters, but some general port counters can be useful. For example to see counters for port 0/54 issue the command:

```
show interface ethernet 0/54
```

The "Total Received Packets Not Forwarded" counter is of particular interest because it may indicate a port MTU error or a VLAN configuration error.

The port counters are reset to zero using the command:

```
clear counters 0/54
```

6.9.4.3 MPLS Packet Capture

To help further diagnose MPLS connectivity issues EFOS provides a debug command:

```
debug mplsd packet-capture {USP | “any-port”} {“mpls” | “any-packet-type'} [label-1] [label-2] [label-
3]
```

This command installs a hardware rule that matches MPLS packets with the specified ingress interface and packet type. The matched packets are sent to the CPU. The packets show up in the syslog and can also be redirected to a remote pcap-compatible capture device using the EFOS packet capture feature. The EFOS packet capture feature is controlled with the **capture** command.

In the current release, the MPLS label matching for the first label is done in hardware. The matching for label-1 and label-2 is done in software. If a lot of packets match the capture criteria then the packets with the required labels may be lost. The packets are rate limited to the CPU at about 3000 packets per second.

The most encompassing format for this command is:

```
debug mplsd packet-capture any-port any-packet-type
```

This command copies all packets received on any interface to the CPU.

The following command copies MPLS packets with the top MPLS label 100 received on any interface to the CPU.

```
debug mplsd packet-capture any-port mpls 100
```

The following command copies the packets received on port 0/54 with the top label set to 10000 and the second label set to 100 to the CPU:

```
debug mplsd packet-capture 0/54 mpls 10000 100
```

The following command captures all packets received on interface 0/54. Note that when **any-packet-type** is used, the MPLS labels cannot be specified.

```
debug mplsd packet-capture 0/54 any-packet-type
```

Only one active packet capture session can be in progress at a time. The most recent invocation of the **debug mplsd packet-capture** command overrides the previous capture setting.

The packet tracing can be stopped with the **no debug mplsd packet-capture** command.

For security and system stability reasons the MPLS packet capture settings are not saved in the configuration file, so the packet capture command needs to be re-issued if the switch is rebooted.

6.9.5 Restrictions and Limitations

The BCM56850 chip and EFOS software impose various limits on how many label paths can be created by the switch. The following are the key limitations:

- Maximum number of MPLS labels = 14K. The hardware limit is 16K, but there is an additional restriction in the device driver and EFOS limiting the maximum number of labels to 14K.
- Maximum number of ECMP MPLS labels = 1020. This limits the size of a Leaf/Spine network to about 1020 switches in one routing domain. The limit is imposed by the hardware 1K ECMP group table, which is shared with the routing component.
- Maximum number of ECMP uplinks = 16. In the ECMP Leaf/Spine topology this limits the maximum ECMP uplinks from a leaf switch to 16. The limit is imposed by the hardware table that keeps track of ECMP uplinks for each ECMP group. The size of this table is 16K, which is enough to hold 1K groups multiplied by 16 uplinks.
- Maximum number of edge devices = 512. This limit determines how many different MAC addresses can be specified by the MPLS labels installed on the switch. Note that in a typical spine/leaf topology, most MPLS labels point to the same MAC address, which is the upstream router. This is a hardware limit imposed by the size of the egr_mac_da_profile table.
- Maximum number of MPLS "swap" next hops = 16K. This limit puts a constraint on the number of MPLS labels with the swap action. This constraint comes into play when ECMP is in use. For example in a Leaf/Spine network with 1000 ECMP labels and 16 uplinks the hardware uses 16000 next hops. This means that only 384 additional non-ECMP labels with the swap rule can be installed on the switch. This is a hardware limit imposed by the size of the egr_mpls_vc_and_swap_label_table.
- Maximum number of ICAP rules = 4K. The ICAP is the ingress classifier engine. The MPLS component requires one rule for every ECMP entry and one rule for every last-hop action. Normally, the ICAP is not a limiting factor in determining the MPLS network size because the maximum number of ECMPs plus the maximum number of last-pop actions tends to be less than 2K. However the ICAP is also used for various features such as system rules, ACLs, and DiffServ. The network administrator should avoid creating too many ACL/DiffServ policies when using MPLS.
- Maximum number of routes = 4k for IPv6 and 8K for IPv4. The number of layer-3 LFDB entries is limited by the number of routes supported in the system.

Chapter 7: Configuring Routing

7.1 Basic Routing and Features

EFOS software runs on multilayer switches that support static and dynamic routing. Table 13 describes some of the general routing features that you can configure on the switch. The table does not list supported routing protocols.

Table 13: IP Routing Features

Feature	Description
ICMP message control	You can configure the type of ICMP messages that the switch responds to as well as the rate limit and burst size.
Default gateway	The switch supports a single default gateway. A manually configured default gateway is more preferable than a default gateway learned from a DHCP server.
ARP table	The switch maintains an ARP table that maps an IP address to a MAC address. You can create static ARP entries in the table and manage various ARP table settings such as the aging time of dynamically-learned entries.
Routing table entries	You can configure the following route types in the routing table: ■ Default: The default route is the route the switch will use to send a packet if the routing table does not contain a longer matching prefix for the packet's destination. ■ Static: A static route is a route that you manually add to the routing table. ■ Static Reject: Packets that match a reject route are discarded instead of forwarded. The router may send an ICMP Destination Unreachable message.
Route preferences	The common routing table collects static, local, and dynamic (routing protocol) routes. When there is more than one route to the same destination prefix, the routing table selects the route with the best (lowest) route preference.

7.1.1 VLAN Routing

VLANs divide a single physical network (broadcast domain) into separate logical networks. To forward traffic across VLAN boundaries, a layer 3 device, such as router, is required. A switch running EFOS software can act as layer 3 device when you configure VLAN routing interfaces. VLAN routing interfaces make it possible to transmit traffic between VLANs while still containing broadcast traffic within VLAN boundaries. The configuration of VLAN routing interfaces makes inter-VLAN routing possible.

For each VLAN routing interface you can assign a static IP address, or you can allow a network DHCP server to assign a dynamic IP address.

When a port is enabled for bridging (L2 switching) rather than routing, which is the default, all normal bridge processing is performed for an inbound packet, which is then associated with a VLAN. Its MAC Destination Address (MAC DA) and VLAN ID are used to search the MAC address table. If routing is enabled for the VLAN, and the MAC DA of an inbound unicast packet is that of the internal router interface, the packet is routed. An inbound multicast packet is forwarded to all ports in the VLAN, plus the internal bridge-router interface, if it was received on a routed VLAN.

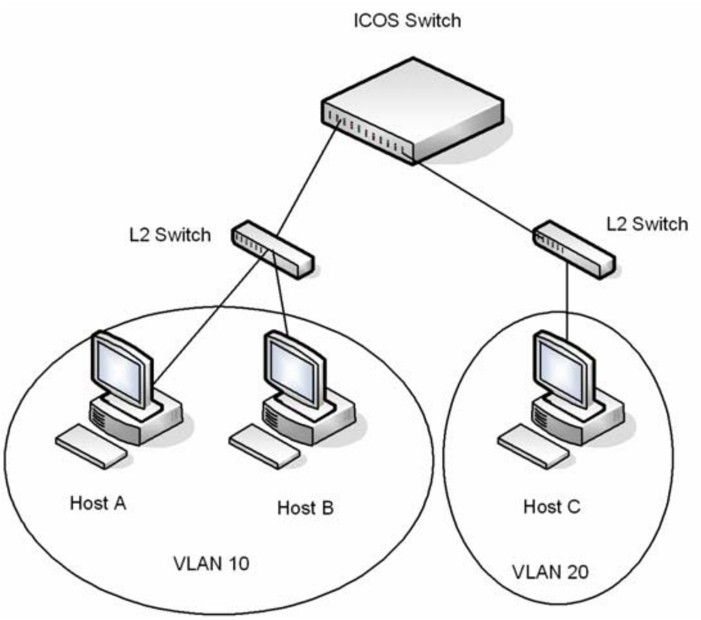
Since a port can be configured to belong to more than one VLAN, VLAN routing might be enabled for all of the VLANs on the port or for only some of the VLANs on the port. VLAN Routing can be used to allow more than one physical port to reside on the same subnet. It could also be used when a VLAN spans multiple physical networks, or when additional segmentation or security is required.

7.1.1.1 When to Configure VLAN Routing

VLAN routing is required when the switch is used as a layer 3 device. VLAN routing must be configured to allow the switch to forward IP traffic between subnets and allow hosts in different networks to communicate.

In Figure 36, Inter-VLAN Routing the EFOS switch is configured as an L3 device and performs the routing functions for hosts connected to the L2 switches. For Host A to communicate with Host B, no routing is necessary. These hosts are in the same VLAN. However, for Host A in VLAN 10 to communicate with Host C in VLAN 20, the switch must perform inter-VLAN routing.

Figure 36: Inter-VLAN Routing

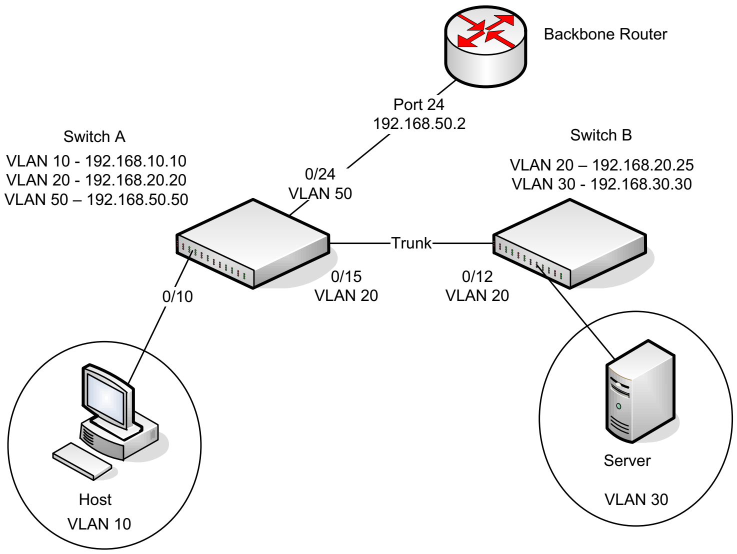


7.1.2 IP Routing Configuration Example

In this example, the switches are L3 switches with VLAN routing interfaces. VLAN routing is configured on Switch A and Switch B. This allows the host in VLAN 10 to communicate with the server in VLAN 30. A static route to the VLAN 30 subnet is configured on Switch A. Additionally, a default route is configured on Switch A so that all traffic with an unknown destination is sent to the backbone router through port 24, which is a member of VLAN 50. A default route is configured on Switch B to use Switch A as the default gateway. The hosts use the IP address of the VLAN routing interface as their default gateway.

This example assumes that all L2 VLAN information, such as VLAN creation and port membership, has been configured.

Figure 37: IP Routing Example Topology



7.1.2.1 Configuring Switch A

To configure Switch A.

1. Create the VLANs.

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 10,20,30,50
```

2. Configure the VLANs for routing and assign the interface port numbers.

```
(Routing) (Vlan)#vlan routing 10 10
(Routing) (Vlan)#vlan routing 20 20
(Routing) (Vlan)#vlan routing 30 30
(Routing) (Vlan)#vlan routing 50 50
(Routing) (Vlan)#exit
```

3. View the interface names assigned to the VLAN routing interfaces.

```
(Routing) #show ip vlan

MAC Address used by Routing VLANs:   00:10:18:82:15:7E

           Logical
VLAN ID   Interface     IP Address       Subnet Mask
-------  -------------  ---------------  ---------------
10       4/10           0.0.0.0          0.0.0.0
20       4/20           0.0.0.0          0.0.0.0
30       4/30           0.0.0.0          0.0.0.0
50       4/50           0.0.0.0          0.0.0.0
```

4. Enable routing on the switch.

```
(Routing) #configure
(Routing) (Config)#ip routing
```

5. Assign an IP address to VLAN 10. This command also enables IP routing on the VLAN.

```
(Routing) (Config)#interface 4/10
(Routing) (Interface 4/10)#ip address 192.168.10.10 255.255.255.0
(Routing) (Interface 4/10)#exit
```

6. Assign an IP address to VLAN 20.
   ```
   (Routing) (Config)#interface 4/20
   (Routing) (Interface 4/20)#ip address 192.168.20.20 255.255.255.0
   (Routing) (Interface 4/20)#exit
   ```
7. Assign an IP address to VLAN 50.
   ```
   (Routing) (Config)#interface 4/50
   (Routing) (Interface 4/50)#ip address 192.168.50.50 255.255.255.0
   (Routing) (Interface 4/50)#exit
   ```
8. Configure a static route to the network that VLAN 30 is in, using the IP address of the VLAN 20 interface on Switch B as the next hop address.
   ```
   (Routing) (Config)#ip route 192.168.30.0 255.255.255.0 192.168.20.25
   ```
9. Configure the backbone router interface as the default gateway.
   ```
   (Routing) (Config)#ip route default 192.168.50.2
   ```

7.1.2.2 Configuring Switch B

To configure Switch B:

1. Create the VLANs.
   ```
   (Routing) #vlan database
   (Routing) (Vlan)#vlan 20,30
   ```
2. Configure the VLANs for routing.
   ```
   (Routing) (Vlan)#vlan routing 20 20
   (Routing) (Vlan)#vlan routing 30 30
   (Routing) (Vlan)#exit
   ```
3. View the interface names assigned to the VLAN routing interfaces.
   ```
   (Routing) #show ip vlan

   MAC Address used by Routing VLANs:   00:10:18:82:15:7E

              Logical
   VLAN ID   Interface        IP Address       Subnet Mask
   -------  --------------  ---------------  ---------------
   20       4/20            0.0.0.0          0.0.0.0
   30       4/30            0.0.0.0          0.0.0.0
   ```
4. Enable routing on the switch.
   ```
   (Routing) #configure
   (Routing) (Config)#ip routing
   ```
5. Assign an IP address to VLAN 20. This command also enables IP routing on the VLAN.
   ```
   (Routing) (Config)#interface 4/20
   (Routing) (Interface 4/20)#ip address 192.168.20.25 255.255.255.0
   (Routing) (Interface 4/20)#exit
   ```
6. Assign an IP address to VLAN 30. This command also enables IP routing on the VLAN.
   ```
   (Routing) (Config)#interface 4/30
   (Routing) (Interface 4/30)#ip address 192.168.30.30 255.255.255.0
   (Routing) (Interface 4/30)#exit
   ```

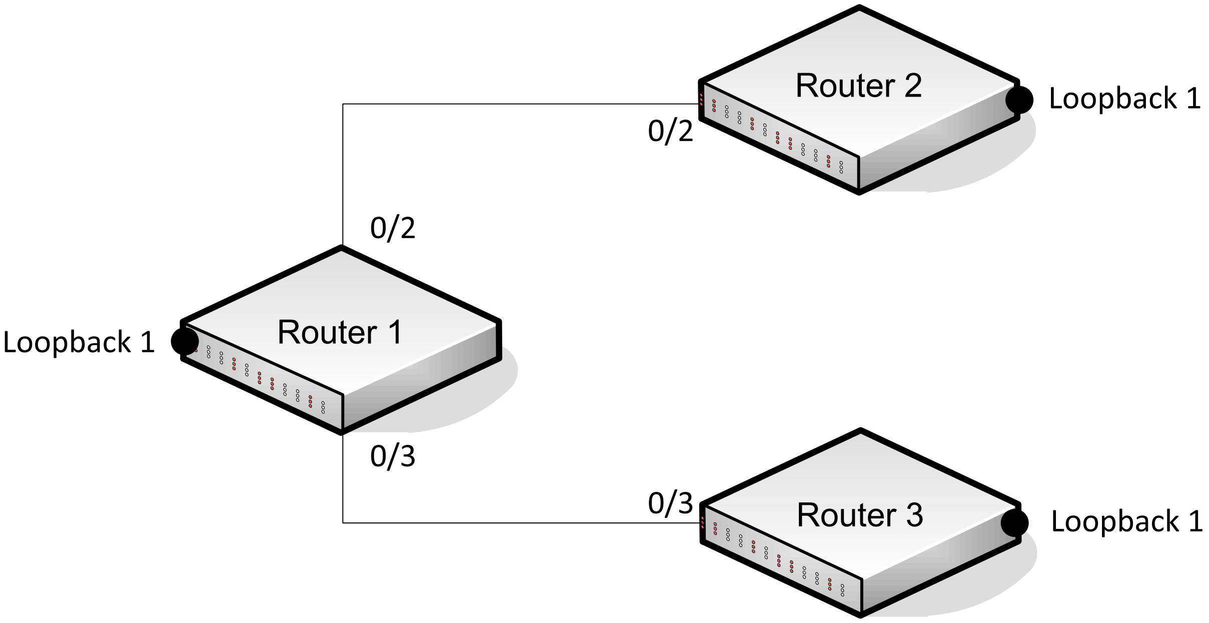
7. Configure the VLAN 20 routing interface on Switch A as the default gateway so that any traffic with an unknown destination is sent to Switch A for forwarding.

```
(Routing) (Config)#ip route default 192.168.20.20
```

7.1.3 IP Unnumbered Configuration Example

This IP unnumbered configuration example shows how the same IP is used on two different unnumbered interfaces on router 1 so it can communicate with router 2 and router 3.

Figure 38: IP Unnumbered Configuration Example



To configure the router 1:

1. Enable routing on the switch.

```
(Routing) #configure
(Routing) (Config)#ip routing
```

2. Configure the loopback interface.

```
(Router_1) (Config)#interface loopback 1
(Router_1) (Interface loopback 1)#ip address 1.0.0.1 /24
(Router_1) (Interface loopback 1)#exit
```

3. Configure port 0/2.

```
(Router_1) (Config)#interface 0/2
(Router_1) (Interface 0/2)#routing
(Router_1) (Interface 0/2)#ip unnumbered loopback 1
(Router_1) (Interface 0/2)#exit
```

4. Configure port 0/3.

```
(Router_1) (Interface 0/3)#routing
(Router_1) (Interface 0/3)#ip unnumbered loopback 1
(Router_1) (Interface 0/3)#exit
(Router_1) (Config)#
```

To configure the router 2:

1. Enable routing on the switch.

   ```
   (Routing) #configure
   (Routing) (Config)#ip routing
   ```

2. Configure the loopback interface.

   ```
   (Router_1) (Config)#interface loopback 1
   (Router_1) (Interface loopback 1)#ip address 2.0.0.2 /24
   (Router_1) (Interface loopback 1)#exit
   ```

3. Configure port 0/2.

   ```
   (Router_1) (Config)#interface 0/2
   (Router_1) (Interface 0/2)#routing
   (Router_1) (Interface 0/2)#ip unnumbered loopback 1
   (Router_1) (Interface 0/2)#exit
   ```

4. Configure port 0/3.

   ```
   (Router_1) (Interface 0/3)#routing
   (Router_1) (Interface 0/3)#ip unnumbered loopback 1
   (Router_1) (Interface 0/3)#exit
   (Router_1) (Config)#
   ```

To configure the router 3:

1. Enable routing on the switch.

   ```
   (Routing) #configure
   (Routing) (Config)#ip routing
   ```

2. Configure the loopback interface.

   ```
   (Router_1) (Config)#interface loopback 1
   (Router_1) (Interface loopback 1)#ip address 3.0.0.3 /24
   (Router_1) (Interface loopback 1)#exit
   ```

3. Configure port 0/2.

   ```
   (Router_1) (Config)#interface 0/2
   (Router_1) (Interface 0/2)#routing
   (Router_1) (Interface 0/2)#ip unnumbered loopback 1
   (Router_1) (Interface 0/2)#exit
   ```

4. Configure port 0/3.

   ```
   (Router_1) (Interface 0/3)#routing
   (Router_1) (Interface 0/3)#ip unnumbered loopback 1
   (Router_1) (Interface 0/3)#exit
   (Router_1) (Config)#
   ```

When you have completed the configuration instructions above, try to ping 2.0.0.2 and 3.0.0.3 from router 1.

7.1.4 Configuring Class-E IPv4 Addresses

Class-E IPv4 addresses are in the range [240.0.0.0 – 255.255.255.255] and are reserved by the IANA authority for future purposes according to RFC 1112, Section 4. In large data center deployments that do not use IPv6 addresses, it is possible for the standard IPv4 address space to run out. Where there is scarcity of unicast IPv4 addresses, the reserved Class-E address space can be used for address assignments. To support such deployments, all EFOS features accept the Class-E address range.

The L3 tables in switch device (Longest Prefix Match and ARP tables) treat the Class-E addresses like other unicast IPv4 addresses. The lookup mechanism, forwarding rules and hit bit updates remain same for Class-E destinations.

NOTE: Partner switches from other vendors and end hosts may not accept the Class-E addresses as valid addresses. In such scenarios, administrators should use the Class-E addresses cautiously; else interoperating with those switches/hosts may create network problems.

The Class-E addresses can be used like any other unicast IPv4 address. The following example shows how to configure interface 0/12 with the Class-E IP address 245 and enable routing on the interface.

```
(Switch) #configure
(Switch) (Config)#interface 0/12
(Switch) (Interface 0/12)#ip address 245.10.10.120 255.255.255.0
(Switch) (Interface 0/12)#routing
(Switch) (Interface 0/12)#exit
(Switch) (Interface 0/12)#routing
(Switch) (Interface 0/12)#exit
(Switch) (Config)#exit

(Switch) #show ip interface 0/12

Routing interface status....................... Up
Primary IP address............................. 245.10.10.120/255.255.255.0
Method......................................... Manual
Routing Mode................................... Enable
Administrative Mode............................ Enable
Forward Net Directed Broadcasts................ Disable
Proxy ARP...................................... Enable
Local Proxy ARP................................ Disable
Active State................................... Inactive
Link Speed Data Rate........................... 10000 Full
MAC address.................................... 00:10:18:D4:B2:76
Encapsulation Type............................. Ethernet
IP MTU......................................... 1500
Bandwidth...................................... 10000000 kbps
Destination Unreachables....................... Enabled
ICMP Redirects................................. Enabled
Interface Suppress Status...................... Unsuppressed
Unicast Reverse Path Forwarding Mode........... Disabled
Unicast Reverse Path Forwarding Allow-Default.. False
```

7.2 OSPF

OSPF is an Interior Gateway Protocol (IGP) that performs dynamic routing within a network. The top level of the hierarchy of an OSPF network is known as an OSPF domain. The domain can be divided into areas. Routers within an area must share detailed information on the topology of their area, but require less detailed information about the topology of other areas. Segregating a network into areas enables limiting the amount of route information communicated throughout the network.

Areas are identified by a numeric ID in IP address format n.n.n.n (note, however, that these are not used as actual IP addresses). For simplicity, the area can be configured and referred to in normal integer notation. For example, Area 20 is identified as 0.0.0.20 and Area 256 as 0.0.1.0. The area identified as 0.0.0.0 is referred to as Area 0 and is considered the OSPF backbone. All other OSPF areas in the network must connect to Area 0 directly or through a virtual link. The backbone area is responsible for distributing routing information between non-backbone areas.

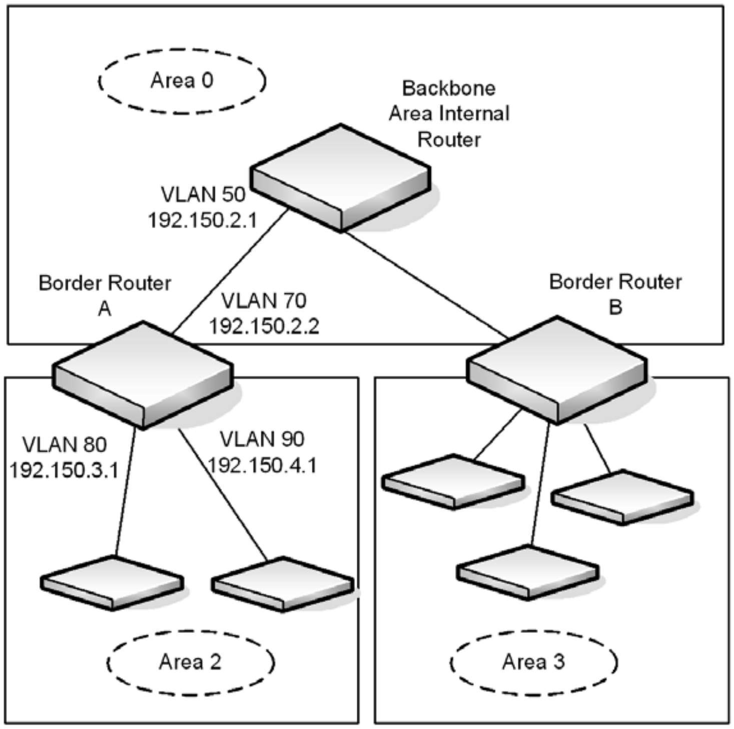
A virtual link can be used to connect an area to Area 0 when a direct link is not possible. A virtual link traverses an area between the remote area and Area 0.

A stub area is an area that does not accept external LSAs (LSAs generated by redistributing routes) that were learned from a protocol other than OSPF or were statically configured. These routes typically send traffic outside the AS. Therefore, routes from a stub area to locations outside the AS use the default gateway. A virtual link cannot be configured across a stub area. A Not So Stubby Area can import limited external routes only from a connected ASBR.

7.2.1 Configuring an OSPF Border Router and Setting Interface Costs

This example shows how to configure the EFOS-based switch as an OSPF border router. The commands in this example configure the areas and interfaces on Border Router A shown in Figure 39, OSPF Area Border Router.

Figure 39: OSPF Area Border Router



To Configure Border Router A:

1. Enable routing on the switch.

```
(Routing) #configure
(Routing) (Config)#ip routing
```

2. Create VLANS 70, 80, and 90.

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 70,80,90
```

3. Configure the VLANs for routing and assign the interface port numbers.

```
(Routing) (Vlan)#vlan routing 70 70
(Routing) (Vlan)#vlan routing 80 80
(Routing) (Vlan)#vlan routing 90 90
(Routing) (Vlan)#exit
```

4. Enable routing on the switch.

```
(Routing) #configure
(Routing) (Config)#ip routing
```

5. Assign IP addresses for VLANs 70, 80 and 90.

```
(Routing) (Config)#interface vlan 4/70
(Routing) (Interface 4/70)#ip address 192.150.2.2 255.255.255.0
(Routing) (Interface 4/70)#exit

(Routing) (Config)#interface 4/80
(Routing) (Interface 4/80)#ip address 192.150.3.1 255.255.255.0
(Routing) (Interface 4/80)#exit

(Routing) (Config)#interface 4/90
(Routing) (Interface 4/90)#ip address 192.150.4.1 255.255.255.0
(Routing) (Interface 4/90)#exit
```

6. Enable OSPF on the switch and specify a router ID.

```
(Routing) (Config)#router ospf
(Routing) (Config-router)#router-id 192.150.9.9
(Routing) (Config-router)#exit
```

7. Configure the OSPF area ID and cost for each interface.

NOTE: OSPF is globally enabled by default. To make it operational on the router, you configure OSPF for particular interfaces and identify which area the interface is associated with.

```
(Routing) (Config)#interface 4/70
(Routing) (Interface 4/70)#ip ospf area 0.0.0.0
(Routing) (Interface 4/70)#ip ospf cost 32
(Routing) (Interface 4/70)#exit

(Routing) (Config)#interface 4/80
(Routing) (Interface 4/80)#ip ospf area 0.0.0.2
(Routing) (Interface 4/80)#ip ospf cost 64
(Routing) (Interface 4/80)#exit

(Routing) (Config)#interface 4/90
(Routing) (Interface 4/90)#ip ospf area 0.0.0.2
(Routing) (Interface 4/90)#ip ospf cost 64
(Routing) (Interface 4/90)#exit
```

7.3 VRRP and VRRPv3

The Virtual Router Redundancy (VRRP) protocol is designed to handle default router (L3 switch) failures by providing a scheme to dynamically elect a backup router. VRRP can help minimize black hole periods due to the failure of the default gateway router during which all traffic directed towards it is lost until the failure is detected. EFOS supports both VRRPv2 and VRRPv3. VRRPv2 provides address redundancy for IPv4 addresses. VRRPv3 provides address redundancy for both IPv4 and IPv6 addresses.The EFOS implementation of VRRPv3 does not interoperate with VRRPv2.

7.3.1 VRRP Operation in the Network

VRRP eliminates the single point of failure associated with static default routes by enabling a backup router to take over from a master router without affecting the end stations using the route. The end stations will use a virtual IP address that will be recognized by the backup router if the master router fails. Participating routers use an election protocol to determine which router is the master router at any given time. A given port may appear as more than one virtual router to the network, also, more than one port on a switch may be configured as a virtual router. Either a physical port or a routed VLAN may participate.

With VRRP, a virtual router is associated with one or more IP addresses that serve as default gateways. In the event that the VRRP router controlling these IP addresses (formally known as the master) fails, the group of IP addresses and the default forwarding role is taken over by a Backup VRRP Router.

7.3.1.1 VRRP Router Priority

The VRRP router priority is a value from 1–255 that determines which router is the master. The greater the number, the higher the priority. If the virtual IP address is the IP address of a VLAN routing interface on one of the routers in the VRRP group, the router with IP address that is the same as the virtual IP address is the interface owner and automatically has a priority of 255. By default, this router is the VRRP master in the group.

If no router in the group owns the VRRP virtual IP address, the router with the highest configured priority is the VRRP master. If multiple routers have the same priority, the router with the highest IP address becomes the VRRP master.

If the VRRP master fails, other members of the VRRP group will elect a master based on the configured router priority values. For example, router A is the interface owner and master, and it has a priority of 255. Router B is configured with a priority of 200, and Router C is configured with a priority of 190. If Router A fails, Router B assumes the role of VRRP master because it has a higher priority.

7.3.1.2 VRRP Preemption

If preempt mode is enabled and a router with a higher priority joins the VRRP group, it takes over the VRRP master role if the current VRRP master is not the owner of the virtual IP address. The preemption delay controls how long to wait to determine whether a higher priority Backup router preempts a lower priority Master. In certain cases, for example, during periods of network congestion, a backup router might fail to receive advertisements from the master. This could cause members in the VRRP group to change their states frequently, i.e. flap. The problem can be resolved by setting the VRRP preemption delay timer to a non-zero value.

7.3.1.3 VRRP Accept Mode

The accept mode allows the switch to respond to pings (ICMP Echo Requests) sent to the VRRP virtual IP address. The VRRP specification (RFC 3768) indicates that a router may accept IP packets sent to the virtual router IP address only if the router is the address owner. In practice, this restriction makes it more difficult to troubleshoot network connectivity problems. When a host cannot communicate, it is common to ping the host's default gateway to determine whether the problem is in the first hop of the path to the destination. When the default gateway is a virtual router that does not respond to pings, this troubleshooting technique is unavailable. In the EFOS-based switch VRRP feature, you can enable Accept Mode to allow the system to respond to pings that are sent to the virtual IP address.

This capability adds support for responding to pings, but does not allow the VRRP Master to accept other types of packets. The VRRP Master responds to both fragmented and un-fragmented ICMP Echo Request packets. The VRRP Master responds to Echo Requests sent to the virtual router's primary address or any of its secondary addresses.

Members of the virtual router who are in backup state discard ping packets destined to VRRP addresses, just as they discard any Ethernet frame sent to a VRRP MAC address.

When the VRRP master responds with an Echo Reply, the source IPv4 address is the VRRP address and source MAC address is the virtual router's MAC address.

7.3.1.4 VRRP Route and Interface Tracking

The VRRP Route/Interface Tracking feature extends VRRP capability to allow tracking of specific routes and interface IP states within the router that can alter the priority level of a virtual router for a VRRP group.

VRRP interface tracking monitors a specific interface IP state within the router. Depending on the state of the tracked interface, the feature can alter the VRRP priority level of a virtual router for a VRRP group.

NOTE: An exception to the priority level change is that if the VRRP group is the IP address owner, its priority is fixed at 255 and cannot be reduced through the tracking process.

With standard VRRP, the backup router takes over only if the router goes down. With VRRP interface tracking, if a tracked interface goes down on the VRRP master, the priority decrement value is subtracted from the router priority. If the master router priority becomes less than the priority on the backup router, the backup router takes over. If the tracked interface becomes up, the value of the priority decrement is added to the current router priority. If the resulting priority is more than the backup router priority, the original VRRP master resumes control.

VRRP route tracking monitors the reachability of an IP route. A tracked route is considered up when a routing table entry exists for the route and the route is accessible. When the tracked route is removed from the routing table, the priority of the VRRP router will be reduced by the priority decrement value. When the tracked route is added to the routing table, the priority will be incremented by the same.

7.3.1.5 VRRP and Bidirectional Forwarding Detection

EFOS supports managing a VRRP Group priority by tracking an interface using Bidirectional Forwarding Detection (BFD). VRRP Group’s priority is decremented or incremented based on the BFD session event tracking the Uplink Gateway Router. This can result in faster failover in a sub-seconds time interval to the new VRRP Master on BFD Down event. The same BFD session can be tracked by one or more VRRP Groups.

The BFD Uplink tracking feature is supported for both the IPv4 and IPv6 VRRP Groups. Only on the transition of the tracked BFD session state from UP to DOWN due to reachability issue, does the corresponding VRRP Group(s) decrement the priority. In all other cases, the VRRP Group priority is not decremented.

NOTE: This feature works with VRRPv3 only and is not supported in VRRPv2 mode.

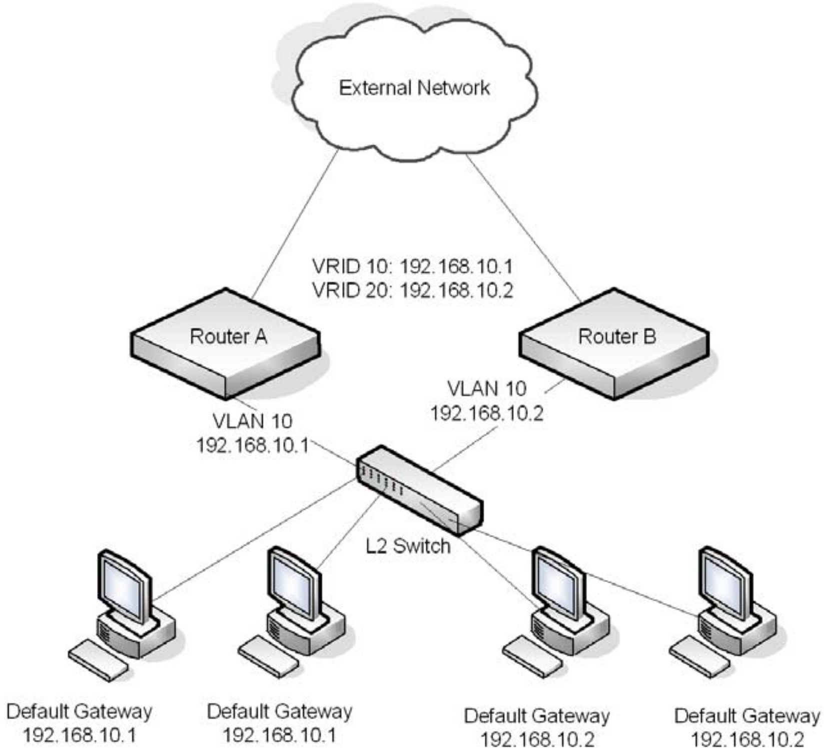
7.3.2 VRRP Configuration Example

This section contains VRRP examples.

7.3.2.1 VRRP with Load Sharing

In Figure 40, VRRP with Load Sharing Network Diagram, two L3 switches are performing the routing for network clients. Router A is the default gateway for some clients, and Router B is the default gateway for other clients.

Figure 40: VRRP with Load Sharing Network Diagram



This example configures two VRRP groups on each router. Router A is the VRRP master for the VRRP group with VRID 10 and the backup for VRID 20. Router B is the VRRP master for VRID 20 and the backup for VRID 10. If Router A fails, Router B will become the master of VRID 10 and will use the virtual IP address 192.168.10.1. Traffic from the clients configured to use Router A as the default gateway will be handled by Router B.

To configure Router A:

1. Create and configure the VLAN routing interface to use as the default gateway for network clients. This example assumes all other routing interfaces, such as the interface to the external network, have been configured.
   ```
   (Routing) #vlan database
   (Routing) (Vlan)#vlan 10
   (Routing) (Vlan)#vlan routing 10
   (Routing) (Vlan)#exit
   (Routing) #config
   (Routing) (Config)#interface 4/1
   (Routing) (Interface 4/1)#ip address 192.168.10.1 255.255.255.0
   (Routing) (Interface 4/1)#exit
   ```
2. Enable routing for the switch.
   ```
   (Routing) (Config)#ip routing
   ```
3. Enable VRRP for the switch.
   ```
   (Routing) (Config)#ip vrrp
   ```
4. Assign a virtual router ID to the VLAN routing interface for the first VRRP group.
   ```
   (Routing) (Config)#interface 4/1
   (Routing) (Interface 4/1)#ip vrrp 10
   ```
5. Specify the IP address that the virtual router function will use. The router is the virtual IP address owner (the routing interface has the same IP address as the virtual IP address for the VRRP group), so the priority value is 255.
   ```
   (Routing) (Interface 4/1)#ip vrrp 10 ip 192.168.10.1
   ```
6. Assign a virtual router ID to the VLAN routing interface for the second VRRP group.
   ```
   (Routing) (Interface 4/1)#ip vrrp 20
   ```
7. Specify the IP address that the virtual router function will use.
   ```
   (Routing) (Interface 4/1)#ip vrrp 20 ip 192.168.10.2
   ```
8. Enable the VRRP groups on the interface.
   ```
   (Routing) (Interface 4/1)#ip vrrp 10 mode
   (Routing) (Interface 4/1)#ip vrrp 20 mode
   (Routing) (Interface 4/1)#exit
   (Routing) (Config)#exit
   ```

The only difference between the Router A and Router B configurations is the IP address assigned to VLAN 10. On Router B, the IP address of VLAN 10 is 192.168.10.2. Because this is also the virtual IP address of VRID 20, Router B is the interface owner and VRRP master of VRRP group 20.

To configure Router B:

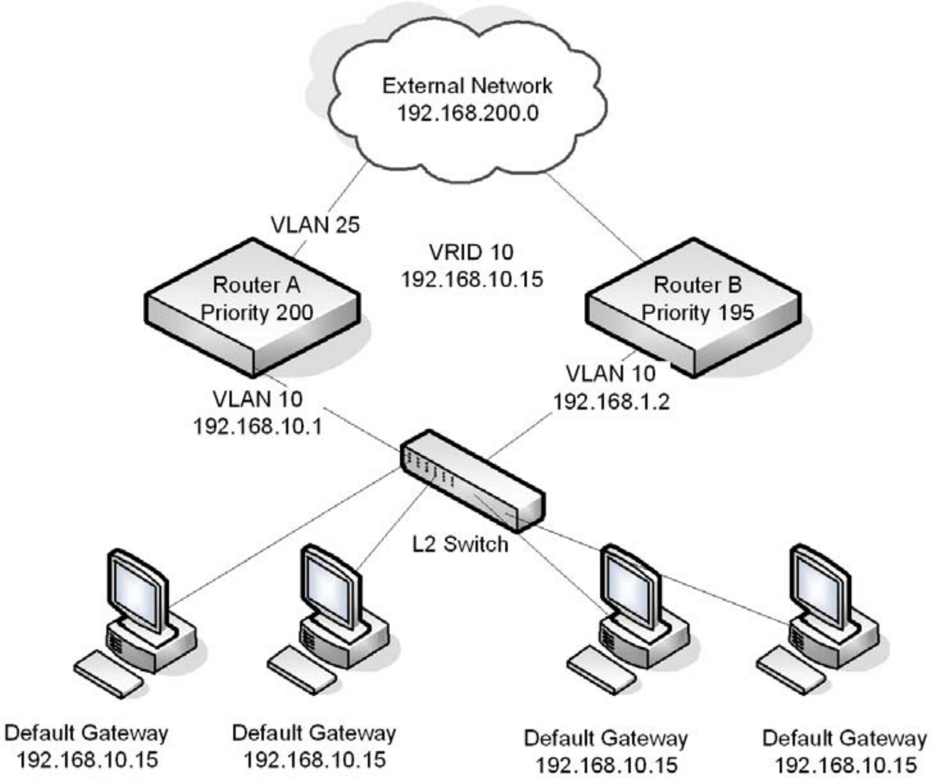
1. Enable routing for the switch.
```
(Routing) #config
(Routing) (Config)#ip routing
(Routing) (Config)#exit
```
2. Create and configure the VLAN routing interface to use as the default gateway for network clients. This example assumes all other routing interfaces, such as the interface to the external network, have been configured.
```
(Routing) #vlan database
(Routing) (Vlan)#vlan 10
(Routing) (Vlan)#vlan routing 10
(Routing) (Vlan)#exit
(Routing) (Config)#interface 4/1
(Routing) (Interface 4/1)#ip address 192.168.10.2 255.255.255.0
(Routing) (Interface 4/1)#exit
```
3. Enable VRRP for the switch.
```
(Routing) (Config)#ip vrrp
```
4. Assign a virtual router ID to the VLAN routing interface for the first VRRP group.
```
(Routing) (Config)#interface 4/1
(Routing) (Interface 4/1)#ip vrrp 10
```
5. Specify the IP address that the virtual router function will use.
```
(Routing) (Interface 4/1)#ip vrrp 10 ip 192.168.10.1
```
6. Configure an optional description to help identify the VRRP group.
```
(Routing) (Interface 4/1)#ip vrrp 10 description master
```
7. Assign a virtual router ID to the VLAN routing interface for the second VRRP group.
```
(Routing) (Interface 4/1)#ip vrrp 20
```
8. Specify the IP address that the virtual router function will use.

   The router is the virtual IP address owner of this address, so the priority value is 255 by default.
```
(Routing) (Interface 4/1)#ip vrrp 20 ip 192.168.10.2
```
9. Configure an optional description to help identify the VRRP group.
```
(Routing) (Interface 4/1)#ip vrrp 20 description backup
```
10. Enable the VRRP groups on the interface.
```
(Routing) (Interface 4/1)#ip vrrp 10 mode
(Routing) (Interface 4/1)#ip vrrp 20 mode
(Routing) (Interface 4/1)#exit
(Routing) (Config)#exit
```

7.3.2.2 VRRP with Route and Interface Tracking

In Figure 41, VRRP with Tracking Network Diagram, the VRRP priorities are configured so that Router A is the VRRP master, and Router B is the VRRP backup. Router A forwards IP traffic from clients to the external network through the VLAN 25 routing interface. The clients are configured to use the virtual IP address 192.168.10.15 as the default gateway.

Figure 41: VRRP with Tracking Network Diagram



Without VRRP interface or route tracking, if something happened to VLAN 25 or the route to the external network, as long as Router A remains up, it will continue to be the VRRP master even though traffic from the clients does not have a path to the external network. However, if the interface and/or route tracking features are configured, Router A can decrease its priority value when the problems occur so that Router B becomes the master.

To configure Router A:

1. Enable routing for the switch.

```
(Routing) #config
(Routing) (Config)#ip routing
(Routing) (Config)#exit
```

2. Configure the VLAN routing interface to use as the default gateway for network clients. This example assumes all other routing interfaces, such as the interface to the external network, have been configured.

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 10
(Routing) (Vlan)#vlan routing 10
(Routing) (Vlan)#exit
(Routing) #config
(Routing) (Config)#interface 4/1
(Routing) (Interface 4/1)#ip address 192.168.10.1 255.255.255.0
(Routing) (Interface 4/1)#exit
```

3. Enable VRRP for the switch.

```
(Routing) (Config)#ip vrrp
```

4. Assign a virtual router ID to the VLAN routing interface for the VRRP group.

```
(Routing) (Config)#interface 4/1
(Routing) (Interface 4/1)#ip vrrp 10
```

5. Specify the IP address that the virtual router function will use.

```
(Routing) (Interface 4/1)#ip vrrp 10 ip 192.168.10.15
```

6. Configure the router priority.

```
(Routing) (Interface 4/1)#ip vrrp 10 priority 200
```

7. Enable preempt mode so that the router can regain its position as VRRP master if its priority is greater than the priority of the backup router.

```
(Routing) (Interface 4/1)#ip vrrp 10 preempt
```

8. Enable the VRRP groups on the interface.

```
(Routing) (Interface 4/1)#ip vrrp 10 mode
(Routing) (Interface 4/1)#exit
```

9. Track the routing interface VLAN 25 on VRID 10 so that if it goes down, the priority of VRID 10 on Router A is decreased by 10, which is the default decrement priority value.

```
(Routing) (Interface 4/1)#ip vrrp 10 track interface vlan 25
```

10. Track the route to the 192.168.200.0 network. If it becomes unavailable, the priority of VRID 10 on Router A is decreased by 10, which is the default decrement priority value.

```
(Routing) (Interface 4/1)#ip vrrp 10 track ip route 192.168.200.0/24
(Routing) (Interface 4/1)#exit
```

Router B is the backup router for VRID 10. The configured priority is 195. If the VLAN 25 routing interface or route to the external network on Router A go down, the priority of Router A will become 190 (or 180, if both the interface and router are down). Because the configured priority of Router B is greater than the actual priority of Router A, Router B will become the master for VRID 10. When VLAN 25 and the route to the external network are back up, the priority of Router A returns to 200, and it resumes its role as VRRP master.

To configure Router B:

1. Enable routing for the switch.
   ```
   (Routing) #config
   (Routing) (Config)#ip routing
   (Routing) (Config)#exit
   ```
2. Create and configure the VLAN routing interface to use as the default gateway for network clients. This example assumes all other routing interfaces, such as the interface to the external network, have been configured.
   ```
   (Routing) #vlan database
   (Routing) (Vlan)#vlan 10
   (Routing) (Vlan)#vlan routing 10
   (Routing) (Vlan)#exit
   (Routing) (Config)#interface 4/1
   (Routing) (Interface 4/1)#ip address 192.168.10.2 255.255.255.0
   (Routing) (Interface 4/1)#exit
   ```
3. Enable VRRP for the switch.
   ```
   (Routing) (Config)#ip vrrp
   ```
4. Assign a virtual router ID to the VLAN routing interface for the VRRP group.
   ```
   (Routing) (Config)#interface 4/1
   (Routing) (Interface 4/1)#ip vrrp 10
   ```
5. Specify the IP address that the virtual router function will use.
   ```
   (Routing) (Interface 4/1)#ip vrrp 10 ip 192.168.10.15
   ```
6. Configure the router priority.
   ```
   (Routing) (Interface 4/1)#ip vrrp 10 priority 195
   ```
7. Enable preempt mode so that the router can regain its position as VRRP master if its priority is greater than the priority of the backup router.
   ```
   (Routing) (Interface 4/1)#ip vrrp 10 preempt
   ```
8. Enable the VRRP groups on the interface.
   ```
   (Routing) (Interface 4/1)#ip vrrp 10 mode
   (Routing) (Interface 4/1)#exit
   (Routing) (Config)#exit
   ```

7.3.3 VRRPv3 in an IPv6 Network

Generally the end hosts in an IPv4 or IPv6 network do not run dynamic routing protocols. They depend on a DHCP server or the Router Discovery protocol for procuring the default router or default gateway details.

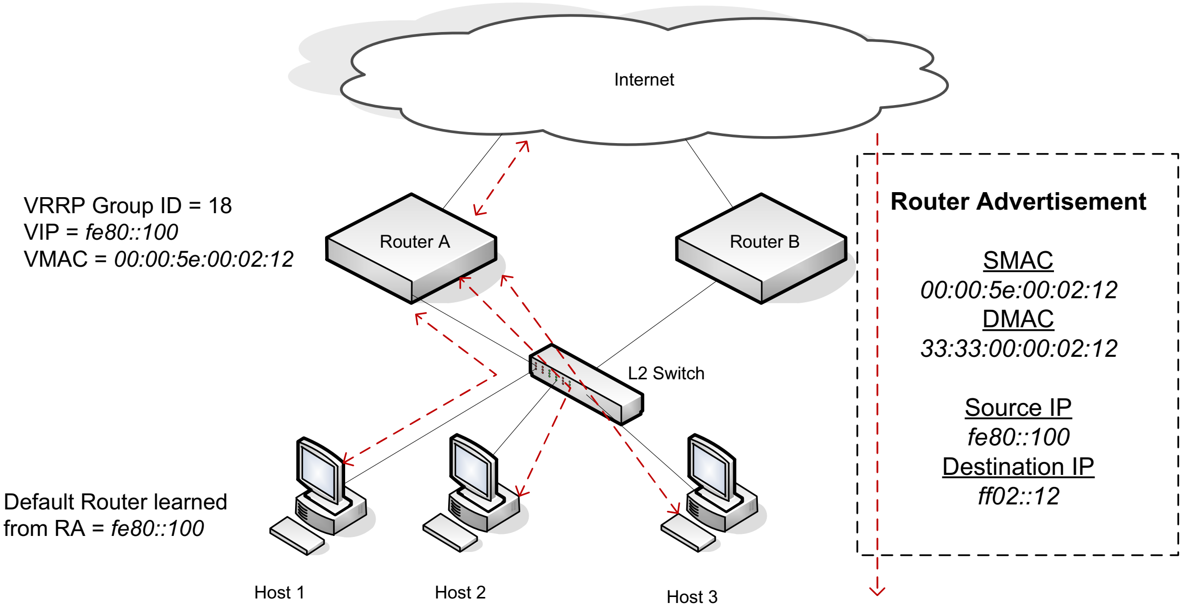
VRRP provides higher availability of the gateway address to the end hosts in the VLAN.

Figure 42, VRRPv3 for IPv6 shows an example of how VRRP operates in an IPv6 network.

- The VRRP group ID is configured to be 18.
- The link-local virtual IPv6 address is configured manually to be fe80::100.
- Router A is elected as VRRP Master (for example, because it booted first and has higher physical IPv6 address).

- Once Router A becomes the VRRP master, it sends unsolicited NA with the VRIP/VMAC information to update the MAC address table on the intermediate L2 switch.
- Router A also periodically advertises the RA messages with the VRRP IP and VRRP MAC {fe80::100 / 00:00:5e:00:02:12}.
- The end hosts update their IPv6 routing tables with default router details.

Figure 42: VRRPv3 for IPv6



This configuration example assumes IPv6 routing is already configured and that the VLAN 100 has been configured as a VLAN routing interface on Router A with an IPv6 address.

1. Enable VRRP on the switch.
   ```
   (Routing) # configure
   (Routing) (Config)#ip vrrp
   ```
2. Enable global IPv6 routing
   ```
   (Routing) (Config)#ipv6 unicast-routing
   ```
3. Enable VRRPv3 mode on the switch:
   ```
   (Routing) (Config)#fhrp version vrrp v3
   ```
4. Change to Interface Configuration mode for VLAN 100 and enable routing and IPv6 mode on the interface.
   ```
   (Routing) (Config)#interface vlan 100
   (Routing) (Interface vlan 100)#routing
   (Routing) (Interface vlan 100)#ipv6 enable
   ```
5. Create VRRPv3 group 18, and enter VRRPv3 group configuration mode.
   ```
   (Routing) (Interface vlan 100)#vrrp 18 address-family ipv6
   ```
6. Specify the primary IPv6 address that the VRRPv3 router will use.
   ```
   (Routing) (config-if-vrrp)#address fe80::100 primary
   ```
7. Enable VRRPv3 administrative mode on the interface.
   ```
   (Routing) (config-if-vrrp)#no shutdown
   ```
8. View the VRRPv3 configuration information on the switch.
   ```
   (Routing) (config-if-vrrp)#show vrrp ipv6

   Admin Mode..................................... Enable


   vlan100 - VRID 18 - Address-Family IPv6

   Virtual IP address............................. fe80::100
   Secondary IP Address(es).......................
   Virtual MAC Address............................ 00:00:5e:00:02:12
   Priority....................................... 0
   Configured Priority............................ 100
   Advertisement Interval......................... 100 centisec
   Pre-empt Mode.................................. Enable
   Accept Mode.................................... Enable
   Administrative Mode............................ Enable
   State.......................................... Master
   Master Router IP / Priority.................... 1001::1 (local) / 100
   Master Advertisement interval.................. 100 centisec
   Master Down interval........................... 300 centisec
   ```
9. Repeat the VRRPv3 configuration on Router B.

7.4 IP Helper

The IP Helper feature provides the ability for a router to forward configured UDP broadcast packets to a particular IP address. This allows applications to reach servers on non-local subnets. This is possible even when the application is designed to assume a server is always on a local subnet or when the application uses broadcast packets to reach the server (with the limited broadcast address 255.255.255.255, or a network directed broadcast address).

You can configure relay entries globally and on routing interfaces. Each relay entry maps an ingress interface and destination UDP port number to a single IPv4 address (the helper address). Multiple relay entries may be configured for the same interface and UDP port, in which case the relay agent relays matching packets to each server address. Interface configuration takes priority over global configuration. If the destination UDP port for a packet matches any entry on the ingress interface, the packet is handled according to the interface configuration. If the packet does not match any entry on the ingress interface, the packet is handled according to the global IP helper configuration.

You can configure discard relay entries. Discard entries are used to discard packets received on a specific interface when those packets would otherwise be relayed according to a global relay entry. Discard relay entries may be configured on interfaces, but are not configured globally.

Additionally, you can configure which UDP ports are forwarded. Certain UDP port numbers can be specified by name in the CLI, but you can also configure a relay entry with any UDP port number. You may configure relay entries that do not specify a destination UDP port. The relay agent assumes that these entries match packets with the UDP destination ports listed in Table 14 (the list of default ports).

Table 14: Default Ports - UDP Port Numbers Implied By Wildcard

Protocol	UDP Port Number
IEN-116 Name Service	42
DNS	53
NetBIOS Name Server	137
NetBIOS Datagram Server	138
TACACS Server	49
Time Service	37
DHCP	67
Trivial File Transfer Protocol	69

The system limits the number of relay entries to four times the maximum number of routing interfaces (512 relay entries). There is no limit to the number of relay entries on an individual interface, and no limit to the number of servers for a given {interface, UDP port} pair.

Certain configurable DHCP relay options do not apply to relay of other protocols. You may optionally set a maximum hop count or minimum wait time using the `bootpdhcprelay maxhopcount` and `bootpdhcprelay minwaittime` commands.

The relay agent relays DHCP packets in both directions. It relays broadcast packets from the client to one or more DHCP servers, and relays packets to the client that the DHCP server unicasts back to the relay agent. For other protocols, the relay agent only relays broadcast packets from the client to the server. Packets from the server back to the client are assumed to be unicast directly to the client. Because there is no relay in the return direction for protocols other than DHCP, the relay agent retains the source IP address from the original client packet. The relay agent uses a local IP address as the source IP address of relayed DHCP client packets.

When a switch receives a broadcast UDP packet on a routing interface, the relay agent verifies that the interface is configured to relay to the destination UDP port. If so, the relay agent unicasts the packet to the configured server IP addresses. Otherwise, the relay agent verifies that there is a global configuration for the destination UDP port. If so, the relay agent unicasts the packet to the configured server IP addresses. Otherwise the packet is not relayed.

NOTE: If the packet matches a discard relay entry on the ingress interface, the packet is not forwarded, regardless of the global configuration.

The relay agent relays packets that meet only the following conditions:

- The destination MAC address must be the all-ones broadcast address (FF:FF:FF:FF:FF:FF).
- The destination IP address must be the limited broadcast address (255.255.255.255) or a directed broadcast address for the receive interface.
- The IP time-to-live (TTL) must be greater than 1.
- The protocol field in the IP header must be UDP (17).
- The destination UDP port must match a configured relay entry.

Table 15 shows the most common protocols and their UDP port numbers and names that are relayed.

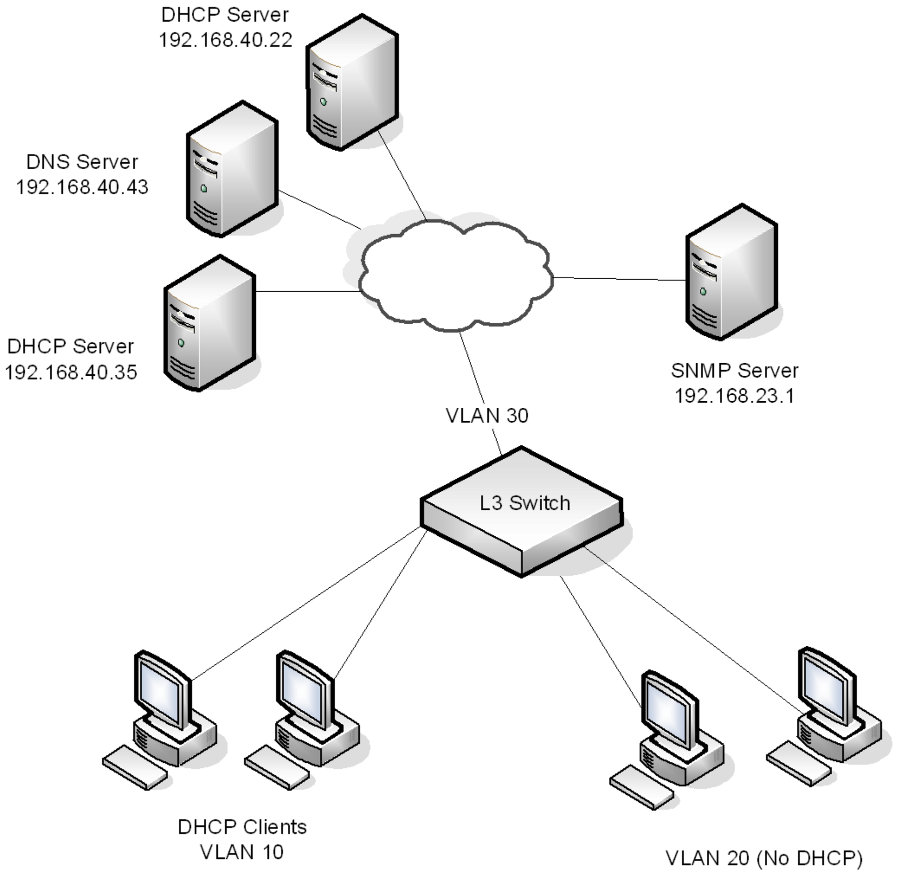
Table 15: UDP Port Allocations

UDP Port Number	Acronym	Application
7	Echo	Echo
11	SysStat	Active User
15	NetStat	NetStat
17	Quote	Quote of the day
19	CHARGEN	Character Generator
20	FTP-data	FTP Data
21	FTP	FTP
37	Time	Time
42	NAMESERVER	Host Name Server
43	NICNAME	Who is
53	DOMAIN	Domain Name Server
69	TFTP	Trivial File Transfer
111	SUNRPC	Sun Microsystems Rpc
123	NTP	Network Time
137	NetBiosNameService	NT Server to Station Connections
138	NetBiosDatagramService	NT Server to Station Connections
139	NetBios	SessionServiceNT Server to Station Connections
161	SNMP	Simple Network Management
162	SNMP-trap	Simple Network Management Traps
513	who	Unix Rwho Daemon
514	syslog	System Log
525	timed	Time Daemon

7.4.1 Relay Agent Configuration Example

The example in this section shows how to configure the L3 relay agent (IP helper) to relay and discard various protocols.

Figure 43: L3 Relay Network Diagram



This example assumes that multiple VLAN routing interfaces have been created and configured with IP addresses.

To configure the switch:

1. Enable IP helper on the switch.
```
(Routing) #config
(Routing) (Config)#ip helper enable
```
2. Relay DHCP packets received on VLAN 10 to 192.168.40.35
```
(Routing) (Config)#interface 4/1
(Routing) (Interface 4/1)#ip helper-address 192.168.40.35 dhcp
```
3. Relay DNS packets received on VLAN 10 to 192.168.40.43
```
(Routing) (Interface 4/1)#ip helper-address 192.168.40.35 domain
(Routing) (Interface 4/1)#exit
```
4. Relay SNMP traps (port 162) received on VLAN 20 to 192.168.23.1
```
(Routing) (Config)#interface 4/2
(Routing) (interface 4/2)#ip helper-address 192.168.23.1 162
```
5. The clients on VLAN 20 have statically-configured network information, so the switch is configured to drop DHCP packets received on VLAN 20
```
(Routing) (Interface 4/2)#ip helper-address discard dhcp
(Routing) (Interface 4/2)#exit
```

6. Configure the switch so that DHCP packets received from clients in any VLAN other than VLAN 10 and VLAN 20 are relayed to 192.168.40.22.

NOTE: The following command is issued in Global Configuration mode, so it applies to all interfaces except VLAN 10 and VLAN 20. IP helper commands issued in Interface Configuration mode override the commands issued in Global Configuration Mode.

```
(Routing) (Config)#ip helper-address 192.168.40.22 dhcp
(Routing) (Config)#exit
```

7. Verify the configuration.

```
(Routing) #show ip helper-address

IP helper is enabled

Interface               UDP Port    Discard  Hit Count     Server Address
-------------------- ----------- ---------- ---------- ------------------
4/1                       domain         No          0      192.168.40.35
4/1                         dhcp         No          0      192.168.40.35
4/2                         dhcp        Yes          0
4/2                          162         No          0       192.168.23.1
Any                         dhcp         No          0      192.168.40.22
```

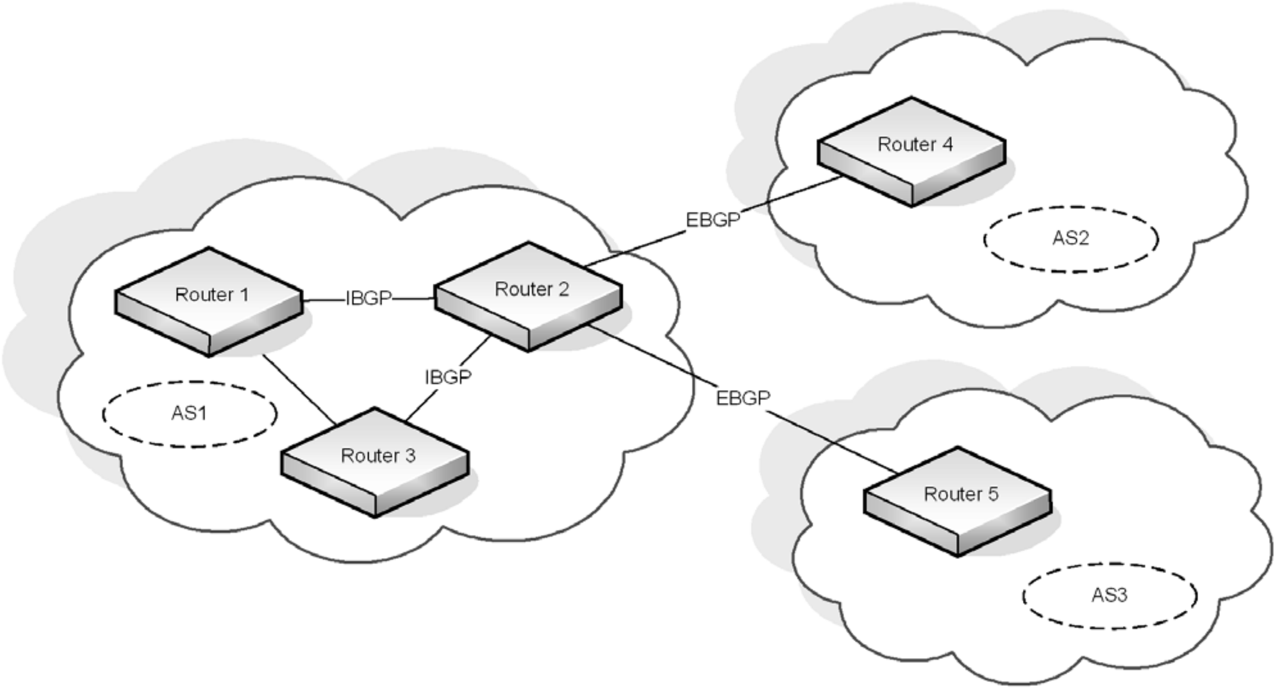
7.5 Border Gateway Protocol (BGP)

BGP is an exterior routing protocol that maintains routing tables, transmits routing updates, and bases routing decisions on routing metrics through exchanges of Network Layer Reachability Information (NLRI) with network peers (known as neighbors) via TCP/IP sessions. BGP relies on the local route table, which is populated by IGP routing protocols, in order to establish connectivity for routes contained within NLRI definitions. For routes with established connectivity, BGP determines the best route among those learned from one or more peers and then installs those routes to the local route table as well as advertises those routes to its other peers. Local policy configuration is commonly used to filter NLRIs inbound and outbound, as well as for modifying the attributes of NLRIs that are advertised to peers.

7.5.1 BGP Topology

BGP maintains routing information between routers within different Autonomous Systems (AS), where each AS typically encapsulates a single IGP routing domain. BGP peers exchange NLRIs that contain an AS path, which is an ordered set of AS values that describe the autonomous systems that must be traversed to reach a network destination. Using a distance vector algorithm, BGP uses the AS path to determine the relative distance to a network destination, and detects any potential routing loops. BGP has two types of relationships with its network peers: External BGP peering (EBGP) and Internal BGP peering (IBGP).

Figure 44: Example BGP Network



7.5.1.1 External BGP Peering

EBGP peering occurs between two or more BGP routers in different AS's. Peer routers in these different AS's use BGP to maintain a consistent view of the inter-network topology. External BGP peers exchange NLRIs, which contain reachable network destinations along with BGP specific attributes such as AS path information and various metrics. These BGP attributes along with local policy configuration, which is used to filter and/or modify the BGP NLRIs, are used by BGP to determine optimal routes to these network destinations within the Internet. An illustration of the above scenario can be observed in the figure1 between routers R2 and R4.

7.5.1.2 Internal BGP Peering

IBGP peering occurs between two or more BGP routers located within the same AS. Internal BGP peers are mainly responsible for distributing BGP NLRIs, which have been acquired via External BGP peers, to all other Internal BGP peers within the AS. The BGP protocol requires that all IBGP peers within an AS are logically connected as a “full mesh.” Thus, all BGP routers within the AS can have a consistent view of the inter-network destinations. An illustration of the above scenario can be observed in the figure1 between routers R1 and R2.

7.5.1.3 Advertising Network Layer Reachability Information

In addition to NLRIs exchanged between BGP peers, a BGP router may originate NLRIs for advertisement to its peers due to local configuration of “locally-originated” routes or “redistribution” policy. In this scenario, the configuration of locally-originated routes or redistribution policy maps to routes installed in the local router's forwarding table by IGP routing protocols on the local router. These routes typically define reachability to network destinations within the local AS. In this manner, BGP is used to advertise NLRIs that define reachability to network destinations within its own AS to BGP peers outside of the local AS.

7.5.2 BGP Behavior

BGP systems form a TCP/IP connection between one another to exchange NLRIs. First, they exchange messages to open and confirm the connection parameters. The initial data flow is the entire BGP routing table. Incremental updates are sent as the routing tables change. BGP does not require periodic refresh of the entire BGP routing table because it relies on the reliable transport provided by TCP. Therefore, a BGP speaker must retain the current version of the entire BGP routing tables of all of its peers for the duration of the connection. Keepalive messages are sent periodically to ensure that connection is active. Notification messages are sent in response to errors or special conditions. If a connection encounters an error condition, a notification message is sent and the connection is closed.

Routes are advertised between a pair of BGP speakers in UPDATE messages, where the network destinations are the systems whose IP addresses are reported in the NLRI field, and the AS path for those destinations is part of the information reported in the path attributes fields of the same UPDATE message, along with various other BGP attributes. Routes are stored in local Routing Information Bases (RIBs). Logically, all routes learned from a particular BGP peer are kept in a local Adj-RIB-In, and all routes learned from all BGP peers are held in a Loc-RIB, which serves as the central database for BGP to determine the *best* path to a particular network destination. Additionally, local policy configuration may filter or modify the BGP attributes of NLRIs that are received from BGP peers.

Once BGP has chosen the *best* path to a network destination based on the BGP attributes given in an NLRI (also known as the *decision process*), it must determine if there is connectivity to the destination defined by the BGP *nexthop* attribute from the *best* NLRI. Here, BGP performs *nexthop resolution* by referencing the local router's forwarding table, which is populated with routes installed by IGP protocols. If connectivity to the BGP nexthop is found (i.e. resolved), then the corresponding BGP route can be installed to the local router's forwarding table, using the *real* nexthop information from the IGP route that was used to resolve the BGP nexthop.

Finally, BGP routes that have been installed in the local router's forwarding table are eligible to be advertised to connected BGP peers. BGP advertises these routes to each connected peer, typically resetting the BGP nexthop attribute to be the local IP address for the BGP peer connection. Additionally, local policy configuration may filter or modify the NLRIs that are advertised to these BGP peers.

For a more detailed and comprehensive description of BGP protocol behavior, refer to the BGP-4 Protocol Specification (RFC1771/draft-ietf-idr-bgp4-26).

7.5.2.1 BGP Route Selection

EFOS BGP uses the following route selection rules:

1. Prefer the route with the higher local preference
2. Prefer a locally-originated route over a non-locally originated route
3. Prefer the route with the shorter AS Path
4. Prefer the route with the lower ORIGIN. IGP is better than EGP is better than INCOMPLETE.
5. Prefer the route with the lower MED. By default, MEDs are only compared for routes from the same AS, but a configuration option allows comparison of MEDs from different ASs. A route with no MED is considered to have a MED of 0.
6. Prefer an eBGP route to an iBGP route
7. Prefer the route with the lower IGP cost to the BGP NEXT HOP
8. Prefer the route learned from the peer with the lower router ID
9. Prefer the route learned from the peer with the lower peer IP address

7.5.3 BGP Dynamic Neighbors

BGP neighbors can be dynamically created whenever connection requests from peers are received from a configured IP address range. Creating neighbors dynamically avoids explicit configuration by the administrator when forming peering with neighbors, irrespective of the subnet to which the IP addresses belong.

The administrator specifies the address range to listen on, and the neighbors properties are inherited from a peer template. As a result, all dynamically created neighbors inherit the properties from the template.

The number of configurable listen address ranges in the system is limited to 10. The number of dynamic peers created as a result of this feature are also limited by the total number of peers allowed in the system.

7.5.4 BGP Extended Communities

EFOS BGP supports standard extended communities as defined in RFC 4360. EFOS supports extended community lists for matching routes based on the extended community and supports matching and setting extended communities in route maps. EFOS also supports selective export and import of routes using export and import maps.

The extended community attribute provides a mechanism for labeling routes carried in BGP-4. These labels are then used to control the distribution of the routes among VRFs.

A BGP route can carry both standard and extended communities attributes. It can also carry multiple community attributes through the use of the additive keyword (in the case of standard communities) and through the use of route-maps when exporting the VRF routes (in the case of extended communities).

BGP recognizes the following well-known extended community attributes (RFC 4360): and Route origin community:

- Route target community: This community identifies one or more routers that may receive a set of routes (attached with this community) carried by BGP. This community is transitive across the Autonomous System boundary.
- Route origin community: This community identifies one or more routers that inject a set of routes (attached with this community) carried by BGP. This community is transitive across the Autonomous System boundary.

  The Route Origin Community is used to prevent routing loops when a site is multi-homed to the MPLS/VPN backbone, and in addition that site uses the AS-Override feature. This is used to identify the site from where the routes are learned, based on its Origin, so that is not re-advertised back to that Site from a PE-Router somewhere else in the MPLS/VPN backbone.

7.5.5 VPNv4/VRF Route Distribution via BGP

EFOS BGP supports Virtual Routing and Forwarding (VRF) awareness. (See Section 7.7, VRF Lite Operation and Configuration for more information about VRF). See Section 7.5.6.2, BGP with VRF for a configuration example.

7.5.5.1 Overview

Management Customer Edge (MCE) routers use BGP to distribute VPN routes to each other. Each VRF has its own address space, meaning that the same address can be used in any number of VRFs, whereas in each VRF, the address specifies a different system. But a BGP speaker can install and distribute only one route to a given address prefix. EFOS allows BGP to install and distribute multiple routes to a single IP address prefix. Also it is recommended that the administrator use a policy to determine which sites can use which routes; given that several such routes are installed by BGP, only one such route must appear in any particular per-site VRF route table. We achieve this by the use of a new address family, as described in the following section.

7.5.5.2 VPNv4 Address Family

Multiprotocol BFP (MP-BGP) allows BGP to carry routes from different address families. To allow BGP to carry and distribute overlapping address routes, each address/route is made unique. To achieve this, a new VPNv4 address family is introduced. A VPN-IPv4 address is a 12-byte quantity, beginning with an 8-byte Route Distinguisher (RD) followed by a 4-byte IPv4 address.

If two VRFs use the same IPv4 address prefix, the MCE translates these into unique VPN-IPv4 address prefixes by prepending the RD (configured per VRF) to the address. The purpose of the RD is only to allow the creation of unique routes to a common IPv4 address prefix. The structuring of RD provides no semantics. When BGP compares two such addresses, it ignores the RD structure completely and just compares it as a 12-byte entity.

An MCE is configured to associate routes that belong to a particular VRF instance with a particular RD. When BGP redistributes these routes, the MCE router prepends the configured RD value (for that CE) to the routes and carries them to the other PE as VPNv4 routes. The PE router that receives these VPNv4 routes installs them in the global BGP table along with the RD. If two routes have the same address prefix but different RD values, only the first route is installed to the RTO table of the CE that imports the route; the rest are ignored.

7.5.5.3 Controlling Route Distribution

This section describes the method in which the VPNv4 route distribution is controlled.

7.5.5.3.1 The Route Target Attribute (RT)

A Route Target attribute identifies a set of sites. Associating a particular Route Target attribute with a route allows that route to be placed in the per-site (CE) VRF tables. Every per-site (CE) VRF is associated with one or more “Route Target” attributes.

When a VPNv4 route is created by an MCE router, it is associated with one or more “Route Target” attributes. These are carried in BGP as attributes of that route.

Any route associated with Route Target attribute RT1 must be distributed to every PE router that has a VRF associated with Route Target RT1. When such a route is received by a PE/MCE router, (depending on the BGP decision process) it is installed in each of the PE/MCE's VRF tables that are associated with Route Target RT1.

When an MCE router receives a route from one of its CE routers, it attaches to the route one or more Export Route Target attributes (as configured for that CE VRF). The route is then carried via MP-BGP to the other PE router. The PE router that receives the route compares it with the Import Route Target attributes configured for one or multiple VRFs and, depending on the match, installs the route in that matching VRF table.

The Export Route Target attributes and the Import Route Target attributes are two distinct sets and may or may not be the same. Only when they are same is the route is allowed to be installed in that particular VRF table.

A BGP route can only have one RD but can have multiple Route Targets.

Route Target attribute helps in route leaking among multiple VRFs in a PE/MCE. The route leaking between VRFs can be achieved without any BGP adjacencies in the VRF instances, but with only the import and export Route Target statements. See route leaking examples on Section 7.7.2.1, Route Leaking.

7.5.5.3.2 The Site of Origin Attribute (SoO)

A VPNv4 route may optionally carry a Origin attribute that uniquely identifies a set of sites. This attribute identifies the corresponding route as having come from one of the sites.

The SoO attribute is used to identify the specific site from which the PE learns the route and is used in the identification and prevention of routing loops. The SoO extended community is a BGP extended community attribute used to identify routes that have originated from a site so that the re-advertisement of that prefix back to the source site can be prevented, thus preventing routing loops.

SoO enables filtering of traffic based on the site from which it was originated. SoO filtering manages traffic and prevents routing loops from occurring in complex and mixed-network topologies in which the customer sites might possess backdoor links between sites.

SoO is one of the attributes a PE router assigns to a prefix prior to redistributing any VPNv4 prefixes. All prefixes learned from a particular site must be assigned the same SoO attribute, even if the site is multiply connected to a single PE or connected to multiple PEs.

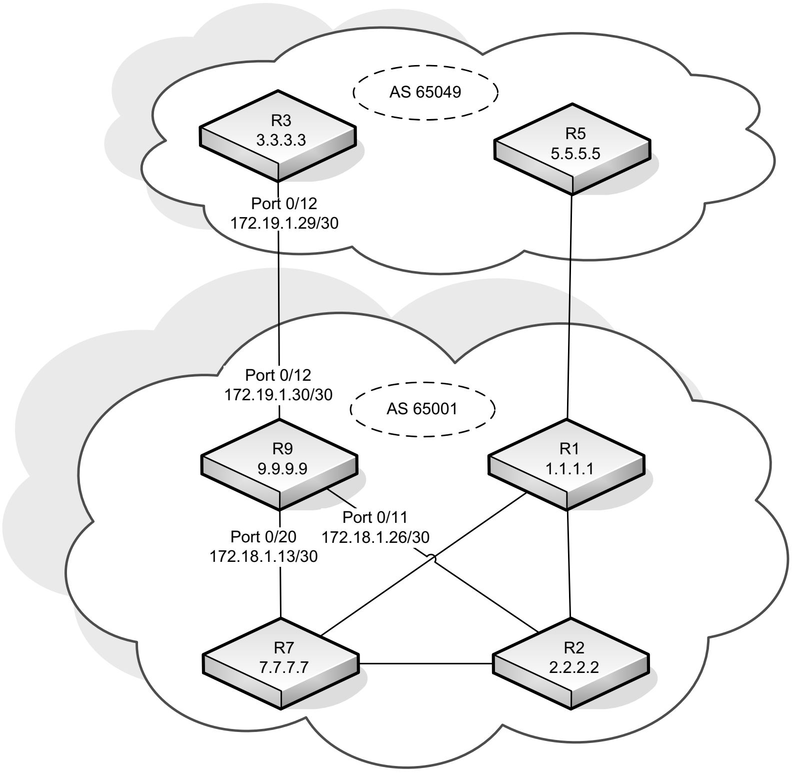
EFOS allows configuration of the SoO attribute using IP Extended community lists in association with inbound/outbound route maps.

7.5.6 BGP Configuration Examples

7.5.6.1 Two Autonomous Systems in a Network

Figure 45, BGP Configuration Example shows the topology of a large network that includes two autonomous systems. The commands in this example configure Router 3 (R3) in AS 65049 and Router 9 in AS 65001.

Figure 45: BGP Configuration Example



Configuring BGP on Router 9

To configure R9 as shown in Figure 45:

1. To make it easier to determine which device is being configured, set the name of router (R9) as the system prompt.
```
(Routing) #set prompt R9
```
2. Enter Global Config mode and enable routing on the system.
```
(R9) #configure
(R9) (Config)#ip routing
```
3. Enter Interface Config mode for port 0/11. This interface is connected to R2, which is part of the same AS. Assign an IP address to the interface, and enable routing on the interface.
```
(R9) (Config)#interface 0/11
(R9) (Interface 0/11)#ip address 172.18.1.26 255.255.255.252
(R9) (Interface 0/11)#routing
```
4. Configure the OSPF timers. The hello interval should be the same on all routers attached to a common network. Likewise, the dead interval timers should be the same across all routers on the network.

```
(R9) (Interface 0/11)#ip ospf hello-interval 3
(R9) (Interface 0/11)#ip ospf dead-interval 12
```

5. Configure OSPF to treat the interface as a point-to-point link.

```
(R9) (Interface 0/11)#ip ospf network point-to-point
(R9) (Interface 0/11exit
```

6. Enter Interface Config mode for port 0/12. This is the interface that is connected to R3, which is in a different AS. Assign an IP address to the interface, and enable routing on the interface.

```
(R9) (Interface 0/12)#interface 0/12
(R9) (Interface 0/12)#ip address 172.19.1.30 255.255.255.252
(R9) (Interface 0/12)#routing
(R9) (Interface 0/12)#exit
```

7. Enter Interface Config mode for port 0/20. This interface is connected to R7, which is part of the same AS. Assign an IP address to the interface, and enable routing on the interface.

```
(R9) (Interface 0/20)#interface 0/20
(R9) (Interface 0/20)#ip address 172.18.1.13 255.255.255.252
(R9) (Interface 0/20)#routing
```

8. Configure the OSPF timers.

```
(R9) (Interface 0/20)#ip ospf hello-interval 3
(R9) (Interface 0/20)#ip ospf dead-interval 12
```

9. Configure OSPF to treat the interface as a point-to-point link.

```
(R9) (Interface 0/20)#ip ospf network point-to-point
(R9) (Interface 0/20)#exit
```

10. Enter Interface Config mode for loopback interface 0 and assign an IP address to the interface.

```
(R9) (Config)#interface loopback 0
(R9) (Interface loopback 0)#ip address 192.168.0.9 255.255.255.255
```

11. Configure the OSPF area ID that the loopback interface belongs to.

```
(R9) (Interface loopback 0)#ip ospf area 0
(R9) (Interface loopback 0)#exit
```

12. Configure the OSPF settings for the router.

```
(R9) (Config)#router ospf
(R9) (Config-router)#router-id 9.9.9.9
(R9) (Config-router)#network 172.19.1.0 0.0.0.255 area 0
(R9) (Config-router)#network 172.18.1.0 0.0.0.255 area 0
(R9) (Config-router)#passive-interface 0/12
(R9) (Config-router)#timers spf 3 5
(R9) (Config-router)#max-metric router-lsa summary-lsa on-startup 90
(R9) (Config-router)#exit
```

13. Enable BGP and identify the autonomous system (AS) number of the router.

```
(R9) (Config-router)#router bgp 65001
```

14. Configure the BGP router ID.

```
(R9) (Config-router)#bgp router-id 9.9.9.9
```

15. Specify the maximum number of next hops BGP may include in an Equal Cost Multipath (ECMP) route derived from paths received from neighbors *outside* the local autonomous system.

```
(R9) (Config-router)#maximum-paths 24
```

16. Set the maximum number of next hops BGP may include in an ECMP route derived from paths received from neighbors *within* the local autonomous system.

```
(R9) (Config-router)#maximum-paths ibgp 24
```

17. Enable the logging of adjacency state changes.

```
(R9) (Config-router)#bgp log-neighbor-changes
```

18. Allow the aggregation of routes with different MED attributes.

```
(R9) (Config-router)#bgp aggregate-different-meds
```

19. Configure the keepalive and hold times that BGP uses for all of its neighbors.

```
(R9) (Config-router)#timers bgp 4 12
```

20. Configure the summary addresses for BGP.

```
(R9) (Config-router)#aggregate-address 172.16.1.0 255.255.255.0 summary-only
(R9) (Config-router)#aggregate-address 172.17.1.0 255.255.255.0 summary-only
(R9) (Config-router)#aggregate-address 172.18.1.0 255.255.255.0 summary-only
(R9) (Config-router)#aggregate-address 172.19.1.0 255.255.255.0 summary-only
```

21. Configure the networks that are attached to AS 65001.

```
(R9) (Config-router)#network 172.18.1.12 mask 255.255.255.252
(R9) (Config-router)#network 172.18.1.16 mask 255.255.255.252
(R9) (Config-router)#network 172.18.1.20 mask 255.255.255.252
(R9) (Config-router)#network 172.18.1.24 mask 255.255.255.252
(R9) (Config-router)#network 172.17.1.4 mask 255.255.255.252
(R9) (Config-router)#network 172.17.1.8 mask 255.255.255.252
(R9) (Config-router)#network 172.17.1.12 mask 255.255.255.252
(R9) (Config-router)#network 172.19.1.28 mask 255.255.255.252
(R9) (Config-router)#network 172.19.1.32 mask 255.255.255.252
```

22. Configure the loopback addresses of routers in AS 65001.

```
(R9) (Config-router)#network 192.168.0.1 mask 255.255.255.255
(R9) (Config-router)#network 192.168.0.2 mask 255.255.255.255
(R9) (Config-router)#network 192.168.0.9 mask 255.255.255.255
(R9) (Config-router)#network 192.168.0.11 mask 255.255.255.255

(R9) (Config-router)#neighbor 192.168.0.11 remote-as 65001
(R9) (Config-router)#neighbor 192.168.0.11 description R7
(R9) (Config-router)#neighbor 192.168.0.11 next-hop-self
(R9) (Config-router)#neighbor 192.168.0.11 update-source loopback 0

(R9) (Config-router)#neighbor 192.168.0.1 remote-as 65001
(R9) (Config-router)#neighbor 192.168.0.1 description R1
(R9) (Config-router)#neighbor 192.168.0.1 next-hop-self
(R9) (Config-router)#neighbor 192.168.0.1 update-source loopback 0

(R9) (Config-router)#neighbor 192.168.0.2 remote-as 65001
(R9) (Config-router)#neighbor 192.168.0.2 description R2
(R9) (Config-router)#neighbor 192.168.0.2 next-hop-self
(R9) (Config-router)#neighbor 192.168.0.2 update-source loopback 0

(R9) (Config-router)#neighbor 172.19.1.29 remote-as 65049
(R9) (Config-router)#neighbor 172.19.1.29 description R3
(R9) (Config-router)#exit
(R9) (Config)#exit
```

Configuring BGP on Router 3

To configure R3 as shown in Figure 45, BGP Configuration Example:

1. To make it easier to determine which device is being configured, set the name of router (R3) as the system prompt.

```
(Routing) #set prompt R3
```

2. Enter Global Config mode and enable routing on the system.

```
(R3) #configure
(R3) (Config)#ip routing
```

3. Enter Interface Config mode for port 0/12. This is the interface that is connected to R3, which is in a different AS. Assign an IP address to the interface, and enable routing on the interface.

```
(R3) (Interface 0/12)#interface 0/12
(R3) (Interface 0/12)#ip address 172.19.1.29 255.255.255.252
(R3) (Interface 0/12)#routing
(R3) (Interface 0/12)#exit
```

4. Enter Interface Config mode for loopback interface 0 and assign an IP address to the interface.

```
(R3) (Config)#interface loopback 0
(R3) (Interface loopback 0)#ip address 192.168.2.3 255.255.255.255
(R3) (Interface loopback 0)#exit
```

5. Enable BGP and identify the autonomous system (AS) number of the router.

```
(R3) (Config-router)#router bgp 65049
```

6. Configure the BGP router ID.

```
(R3) (Config-router)#bgp router-id 3.3.3.3
```

7. Specify the maximum number of next hops BGP may include in an ECMP route derived from paths received from neighbors outside the local autonomous system.

```
(R3) (Config-router)#maximum-paths 4
```

8. Enable the logging of adjacency state changes.

```
(R3) (Config-router)#bgp log-neighbor-changes
```

9. Configure BGP to advertise connected routes with a metric value of 100.

```
(R3) (Config-router)#redistribute connected metric 100
```

10. Configure the keepalive and hold times that BGP uses for all of its neighbors.

```
(R3) (Config-router)#timers bgp 4 12
```

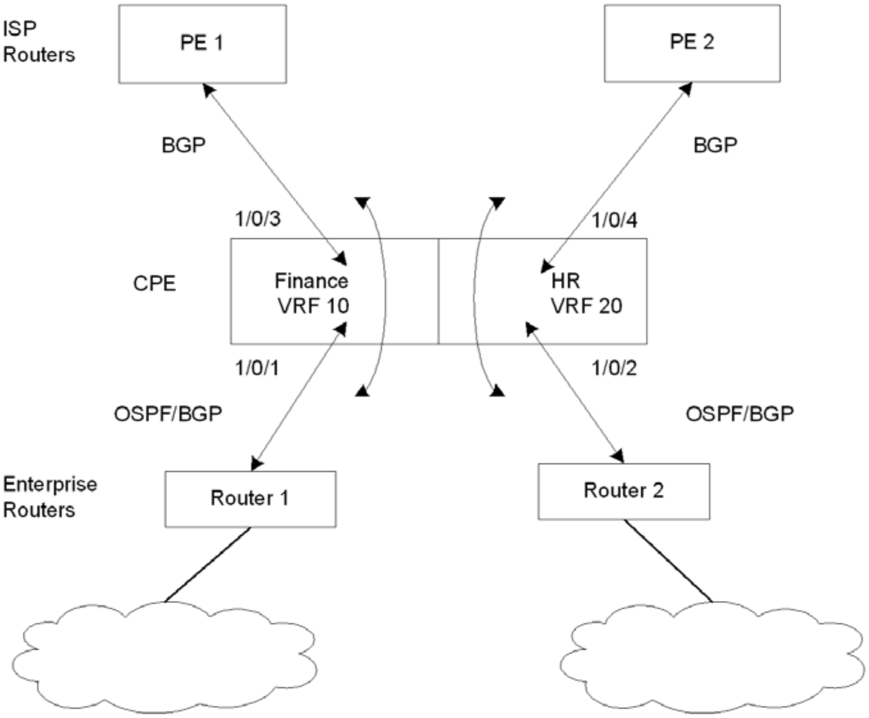
11. Configure the loopback addresses of routers in AS 65049.

```
(R3) (Config-router)#network 192.168.2.3 mask 255.255.255.255
(R3) (Config-router)#neighbor 172.19.1.30 remote-as 65001
(R3) (Config-router)#neighbor 172.19.1.30 description R9
(R3) (Config-router)#exit
(R3) (Config)#exit
```

7.5.6.2 BGP with VRF

In the following is a sample configuration, the BGP instances running in each VR are independent of each other and no leaking of routes happens between the BGP instances using this feature.

Figure 46: BGP with Virtual Routers



```
(Routing) #configure
(Routing) (Config)#ip routing

(Routing) (Config)#ip vrf finance
(Routing) (Config-vrf-finance)#exit
(Routing) (Config)#ip vrf hr
(Routing) (Config-vrf-hr)#exit

(Routing) (Config)# #interface 1/0/1
(Routing) (Interface 1/0/1)#ip vrf forwarding finance
(Routing) (Interface 1/0/1)#ip address 1.1.1.1 /24
(Routing) (Interface 1/0/1)#ip ospf area 0
(Routing) (Interface 1/0/1)#exit

(Routing) (Config)# #interface 1/0/2
(Routing) (Interface 1/0/2)#ip vrf forwarding hr
(Routing) (Interface 1/0/2)#ip address 2.2.2.2 /24
(Routing) (Interface 1/0/2)#ip ospf area 0
(Routing) (Interface 1/0/2)#exit

(Routing) (Config)# #interface 1/0/3
(Routing) (Interface 1/0/3)#ip vrf forwarding finance
(Routing) (Interface 1/0/3)#ip address 3.3.3.3 /24
(Routing) (Interface 1/0/3)#ip ospf area 0
(Routing) (Interface 1/0/3)#exit

(Routing) (Config)# #interface 1/0/4
(Routing) (Interface 1/0/4)#ip vrf forwarding hr
(Routing) (Interface 1/0/4)#ip address 4.4.4.4 /24
```

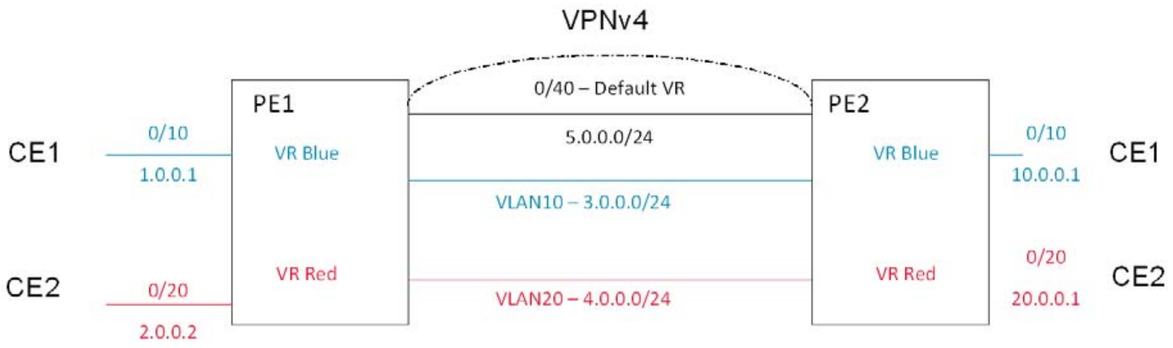
```
(Routing) (Interface 1/0/4)#ip ospf area 0
(Routing) (Interface 1/0/4)#exit

(Routing) (Config)# #router ospf vrf finance
(Routing) (Config-router)#router-id 1.1.1.1
(Routing) (Config-router)#exit

(Routing) (Config)# #router ospf vrf hr
(Routing) (Config-router)#router-id 2.2.2.2
(Routing) (Config-router)#exit

(Routing) (Config)# #router bgp 100
(Config-router)#bgp router-id 1.1.1.1

(Config-router)#address-family ipv4 vrf finance
(Config-router)#neighbor 3.3.3.4 remote-as 200
(Config-router)#neighbor 3.3.3.4 activate
(Config-router)#network 6.6.6.0 255.255.255.0
(Config-router)#redistribute ospf
(Config-router)#redistribute connected
(Config-router)#exit

(Config-router)#address-family ipv4 vrf hr
(Config-router-af)#neighbor 4.4.4.5 remote-as 300
(Config-router-af)#neighbor 4.4.4.5 activate
(Config-router-af)#network 8.8.8.0 255.255.255.0
(Config-router-af)#redistribute ospf
(Config-router-af)#redistribute connected
(Config-router-af)#exit
```

7.5.6.2.1 Route Leaking Between VRFs

The following two configuration examples demonstrate route leaking between VRFs.

- Route leaking from a global routing table into a VPN routing/forwarding instance (VRF) and route leaking from a VRF into a global routing table in a VPNv4 deployment topology.

Figure 47: Route Leaking From Global Routing Table Into a VRF



PE1

```
(Routing) #configure
```

```
(Routing) (Config)#ip routing

(Routing) (Config)#ip extcommunity-list 1    permit   rt 100:1
(Routing) (Config)#ip extcommunity-list 2    permit   rt 200:1

(Routing) (Config)#route-map test 10
(Routing) (route-map)#match extcommunity 1
(Routing) (route-map)#set ip next-hop 3.0.0.1
(Routing) (route-map)#exit

(Routing) (Config)#route-map test 20
(Routing) (route-map)#match extcommunity 2
(Routing) (route-map)#set ip next-hop 4.0.0.1
(Routing) (route-map)#exit

(Routing) (Config)#ip vrf "blue"
(Routing) (config-vrf-blue)#ip routing
(Routing) (config-vrf-blue)#rd 100:1
(Routing) (config-vrf-blue)#route-target both 100:1
(Routing) (config-vrf-blue)#route-target import 100:2
(Routing) (config-vrf-blue)#exit

(Routing) (Config)#ip vrf "red"
(Routing) (config-vrf-red)#rd 200:1
(Routing) (config-vrf-red)#ip routing
(Routing) (config-vrf-red)#route-target both 200:1
(Routing) (config-vrf-red)#route-target import 200:2
(Routing) (config-vrf-red)#exit

(Routing) (Config)#interface 0/10
(Routing) (Interface 0/10)#routing
(Routing) (Interface 0/10)#ip address 1.0.0.1 255.255.0.0
(Routing) (Interface 0/10)#ip vrf forwarding "blue"
(Routing) (Interface 0/10)#exit

(Routing) (Config)#interface 0/20
(Routing) (Interface 0/20)#routing
(Routing) (Interface 0/20)#ip address 2.0.0.1 255.255.0.0
(Routing) (Interface 0/20)#ip vrf forwarding "red"
(Routing) (Interface 0/20)#exit

(Routing) (Config)#interface vlan 10
(Routing) (interface vlan 10)#routing
(Routing) (interface vlan 10)#ip address 3.0.0.1 255.255.0.0
(Routing) (interface vlan 10)#ip vrf forwarding "blue"
(Routing) (interface vlan 10)#exit

(Routing) (Config)#interface vlan 20
(Routing) (interface vlan 20)#routing
(Routing) (interface vlan 20)#ip address 4.0.0.1 255.255.0.0
(Routing) (interface vlan 20)#ip vrf forwarding "red"
(Routing) (interface vlan 20)#exit

!VPNv4 neighborship
(Routing) (Config)#interface 0/40
(Routing) (Interface 0/40)#routing
(Routing) (Interface 0/40)#ip address 5.0.0.1 255.255.0.0
(Routing) (Interface 0/40)#exit
```

```
(Routing) (Config)#router bgp 100
(Routing) (Config-router)#bgp router-id 1.1.1.1
(Routing) (Config-router)#neighbor 5.0.0.2 remote-as 100
(Routing) (Config-router)#neighbor 5.0.0.2 route-map test out

(Routing) (Config-router)#address-family ipv4 vrf blue
(Routing) (Config-router-af)#neighbor 1.0.0.2 remote-as 200
(Routing) (Config-router-af)#exit
(Routing) (Config-router)#address-family ipv4 vrf red
(Routing) (Config-router-af)#neighbor 2.0.0.2 remote-as 300
(Routing) (Config-router-af)#exit
(Routing) (Config-router)#address-family vpnv4 unicast
(Routing) (Config-router-af)#neighbor 5.0.0.2 activate
(Routing) (Config-router-af)#exit
(Routing) (Config-router)#exit
```

PE2

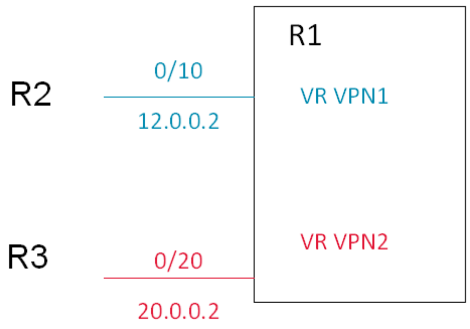
```
(Routing) #configure
(Routing) (Config)#ip routing

(Routing) (Config)#ip extcommunity-list 1 permit rt 100:2
(Routing) (Config)#ip extcommunity-list 2 permit rt 200:2

(Routing) (Config)#route-map test 10
(Routing) (route-map)#match extcommunity 1
(Routing) (route-map)#set ip next-hop 3.0.0.2
(Routing) (route-map)#exit

(Routing) (Config)#route-map test 20
(Routing) (route-map)#match extcommunity 2
(Routing) (route-map)#set ip next-hop 4.0.0.2
(Routing) (route-map)#exit

(Routing) (Config)#ip vrf "blue"
(Routing) (config-vrf-blue)#ip routing
(Routing) (config-vrf-blue)#rd 100:2
(Routing) (config-vrf-blue)#route-target both 100:2
(Routing) (config-vrf-blue)#route-target import 100:1
(Routing) (config-vrf-blue)#exit

(Routing) (Config)#ip vrf "red"
(Routing) (config-vrf-red)#ip routing
(Routing) (config-vrf-red)#rd 200:2
(Routing) (config-vrf-red)#route-target both 200:2
(Routing) (config-vrf-red)#route-target import 200:1
(Routing) (config-vrf-red)#exit

(Routing) (Config)#interface 0/10
(Routing) (Interface 0/10)#routing
(Routing) (Interface 0/10)#ip address 10.0.0.1 255.255.0.0
(Routing) (Interface 0/10)#ip vrf forwarding "blue"
(Routing) (Interface 0/10)#exit

(Routing) (Config)#interface 0/20
(Routing) (Interface 0/20)#routing
```

```
(Routing) (Interface 0/20)#ip address 20.0.0.1 255.255.0.0
(Routing) (Interface 0/20)#ip vrf forwarding "red"
(Routing) (Interface 0/20)#exit

(Routing) (Config)#interface vlan 10
(Routing) (interface vlan 10)#routing
(Routing) (interface vlan 10)#ip address 3.0.0.2 255.255.0.0
(Routing) (interface vlan 10)#ip vrf forwarding "blue"
(Routing) (interface vlan 10)#exit

(Routing) (Config)#interface vlan 20
(Routing) (interface vlan 20)#routing
(Routing) (interface vlan 20)#ip address 4.0.0.2 255.255.0.0
(Routing) (interface vlan 20)#ip vrf forwarding "red"
(Routing) (interface vlan 20)#exit


!VPNv4 neighborship
(Routing) (Config)#interface 0/40
(Routing) (Interface 0/40)#routing
(Routing) (Interface 0/40)#ip address 5.0.0.2 255.255.0.0
(Routing) (Interface 0/40)#exit

(Routing) (Config)#router bgp 100
(Routing) (Config-router)#bgp router-id 1.1.1.2
(Routing) (Config-router)#neighbor 5.0.0.1 remote-as 100
(Routing) (Config-router)#neighbor 5.0.0.1 route-map test out

(Routing) (Config-router)#address-family ipv4 vrf blue
(Routing) (Config-router-af)#neighbor 10.0.0.2 remote-as 400
(Routing) (Config-router-af)#exit
(Routing) (Config-router)#address-family ipv4 vrf red
(Routing) (Config-router-af)#neighbor 20.0.0.2 remote-as 500
(Routing) (Config-router-af)#exit
(Routing) (Config-router)#address-family vpnv4 unicast
(Routing) (Config-router-af)#neighbor 5.0.0.1 activate
(Routing) (Config-router-af)#exit
(Routing) (Config-router)#exit
```

- **Route leaking between different VRFs**

  This configuration describes route leaking between two different VRFs of a router as shown in the topology shown in Figure 48.

Figure 48: Routing Leaking Between Different VRFs of a Router



The following configuration is used:

```
(Routing) #configure
(Routing) (Config)#ip routing

(Routing) (Config)#ip vrf "vpn1"
(Routing) (Config-vrf-vpn1)#rd 1000:1
(Routing) (Config-vrf-vpn1)#route-target export 1000:1
(Routing) (Config-vrf-vpn1)#route-target import 2000:1
(Routing) (Config-vrf-vpn1)#route-target import 3000:1
(Routing) (Config-vrf-vpn1)#exit

(Routing) (Config)#ip vrf "vpn2"
(Routing) (Config-vrf-vpn2)#rd 2000:1
(Routing) (Config-vrf-vpn2)#route-target export 2000:1
(Routing) (Config-vrf-vpn2)#route-target import 1000:1
(Routing) (Config-vrf-vpn2)#route-target import 4000:1
(Routing) (Config-vrf-vpn2)#exit

(Routing) (Config)#interface 0/10
(Routing) (Interface 0/10)#routing
(Routing) (Interface 0/10)#ip vrf forwarding "vpn1"
(Routing) (Interface 0/10)#ip address 12.0.0.2 255.255.255.0
(Routing) (Interface 0/10)#exit

(Routing) (Config)#interface 0/20
(Routing) (Interface 0/20)#routing
(Routing) (Interface 0/20)#ip vrf forwarding "vpn2"
(Routing) (Interface 0/20)#ip address 20.0.0.2 255.255.255.0
(Routing) (Interface 0/20)#exit

(Routing) (Config)#router bgp 500
(Routing) (Config-router)#bgp router-id 5.5.5.5
(Routing) (Config-router)#address-family ipv4 vrf "vpn1"
(Routing) (Config-router-af)#redistribute connected
(Routing) (Config-router-af)#exit
(Routing) (Config-router)#address-family ipv4 vrf "vpn2"
(Routing) (Config-router-af)#redistribute connected
(Routing) (Config-router-af)#exit
(Routing) (Config-router)#exit
(Routing) (Config)#exit
```

7.5.6.3 BGP Dynamic Neighbors

BGP dynamic neighbors are configured using a range of IP addresses and BGP peer groups. Each range can be configured as a subnet IP address. After a subnet range is configured for a BGP peer group, and a TCP session is initiated for an IP address in the subnet range, a new BGP neighbor is dynamically created.

Use the `bgp listen` command to create an IPv4 listen range and associate it with specified peer template. The command also activates the IPv4 BGP dynamic neighbors feature. The `limit` keyword and *`max-number`* argument define the global maximum number of IPv4 BGP dynamic neighbors that can be created.

The following commands limit the maximum dynamic neighbors to 10, and create a listen range (with subnet/mask of 10.12.0.0/16) with a template (named ABC be inherited with dynamically created BGP neighbors:

```
(Routing) #configure
```

```
(Routing) (Config)#router bgp 100
(Routing) (Config-router)#bgp listen limit 10
(Routing) (Config-router)#bgp listen range 10.12.0.0/16
(Routing) (Config-router)#bgp listen range 10.27.0.0/16 inherit peer ABC
```

Dynamic neighbors and listening range information are indicated when the `show ip bgp neigbhors` command is used to show IP neighbor information:

```
(routing) #show ip bgp neighbors 10.12.0.100
Description: spine 1 router 1

Remote Address ................................ 10.12.0.100
Remote AS ..................................... 100
Peer ID ....................................... 14.3.0.1
Peer Admin Status ............................. START
Peer State .................................... ESTABLISHED
Peer Type ..................................... DYNAMIC
Listen Range .................................. 10.12.0.0/16
Local Interface Address ....................... 10.12.0.2
Local Port .................................... 179
.
.
.
-----------------
```

The `show ip bgp summary` command shows the configured dynamic neighbor limits, and the dynamically learned neighbors are indicated by an asterisk:

```
(switch-2) #show ip bgp summary

IPv4 Routing .................................. Enable
BGP Admin Mode ................................ Enable
BGP Router ID ................................. 1.0.0.2
Local AS Number ............................... 10001
Number of Network Entries ..................... 4
Number of AS Paths ............................ 1
Dynamic Neighbors Current/High/Limit........... 1/1/100

Neighbor           ASN  MsgRcvd  MsgSent         State   Up/Down Time  Pfx Rcvd
---------------- ----- -------- -------- ------------- -------------- ---------
25.0.0.1         10000     2341     2346   ESTABLISHED     0:16:33:11         2
*100.20.1.7      30           0      7   OPEN SENT                          0
.
.
.
---------------------
```

7.5.6.4 Configuring BGP Graceful Restart

EFOS supports the Graceful Restart (GR) functionality as specified in RFC 4724. The EFOS router can be configured to work as a GR-aware router or GR-enabled router, or both. Enabling GR-enabled functionality implicitly enables the GR-aware functionality (Graceful Restart Helper) on the router.

The Graceful Restart capability on an EFOS router is advertised in the BGP OPEN message sent to the peer only when the router is enabled for GR-aware or GR-enabled functionalities or both. With GR functionality enabled, the EFOS router also sends an End-of-RIB marker to ensure faster convergence after a graceful restart occurs. The GR functionality is supported only for planned restarts.

The following command sequence enters BGP configuration mode and enables the EFOS router for Graceful Restart and Graceful Restart Helper functionality.

```
(Routing) (Config)#router bgp 100
(Routing) (Config-router)# graceful-restart
```

7.6 Bidirectional Forwarding Detection

7.6.1 Overview

In a network device, Bidirectional Forwarding Detection (BFD) is presented as a service to its user applications, providing them options to create and destroy a session with a peer device and reporting upon the session status. On EFOS switches, OSPF and BGP can use BFD for monitoring of their neighbors' availability in the network and for fast detection of connection faults with them.

BFD uses a simple 'hello' mechanism that is similar to the neighbor detection components of some well-known protocols. It establishes an operational session between a pair of network devices to detect a two-way communication path between them and serves information regarding it to the user applications. The pair of devices transmits BFD packets between them periodically, and if one stops receiving peer packets within detection time limit it considers the bidirectional path to have failed. It then notifies the application protocol using its services.

BFD allows each device to estimate how quickly it can send and receive BFD packets to agree with its neighbor upon how fast detection of failure could be done.

BFD can operate between two devices on top of any underlying data protocol (network layer, link layer, tunnels, etc.) as payload of any encapsulating protocol appropriate for the transmission medium. The EFOS implementation works with IPv4 and IPv6 networks and supports IPv4/v6 address-based encapsulations.

7.6.2 BFD Support for Static Routes

BFD support for static routes provides a liveliness detection mechanism that can be utilized to detect the failures in the path to the next hop gateway, including the interfaces and the data link.

The static route configured with a tracked BFD neighbor creates a new BFD session, if a matching session is not already in use. If a matching session already exists, the same session is used for tracking. The BFD parameters (multiplier, echo mode etc) set for the interface are used in creating this session. The source IP address used for creating the tracked BFD session is the interface IP address that matches the subnet of the BFD neighbor. In case there is no matching subnet on the interface (pre-configuration), the first active IP address is used as the source IP address for creating the BFD session.

All static routes with the next-hop matching with the destination of the BFD session will be tracked by the BFD Session. Only if the tracked BFD session transitions to DOWN state from UP state owing to the L3 reachability failure, does the Static route tracking it gets removed from the Route table. In rest of the scenarios, the Static route is not removed from the Route table.

7.6.3 Configuring BFD

The following command sequence enables BFD and configures session parameters:

1. First, globally enable BFD:

```
(Router)#configure
(Routing) (Config)# feature bfd
```

2. Configure session settings. These can be configured globally or on a per-interface basis.

```
(Routing) (Config)#bfd interval 100 min_rx 200 multiplier 5
(Routing) (Config)#bfd slow-timer 1000
```

   - The argument **interval** refers to the minimum transmit interval, the minimum interval that the user wants to use while transmitting BFD control packets (in ms).

- The argument **min_rx** refers to the required minimum receive interval, the minimum interval at which the system can receive BFD control packets (in ms).
- The argument **multiplier** specifies the number of BFD control packets to be missed in a row to declare a session down.
- The **slow-timer** command sets up the BFD required echo receive interval preference value (in ms). This value determines the interval the asynchronous sessions use for BFD control packets when the echo function is enabled. The slow-timer value is used as the new control packet interval, while the echo packets use the configured BFD intervals.

3. Configure BGP to use BFD for fast detection of faults between neighboring devices.

```
(Routing) (Config)#router bgp
(Routing) (Config-router)# neighbor 172.16.11.6 fall-over bfd
(Routing) (Config-router)# exit
```

4. Enable BFD globally for OSPF:

```
(Routing) (Config)#router ospf
(Routing) (Config-router)# bfd
(Routing) (Config-router)# exit
```

5. Configure OSPF to use BFD on the interface:

```
(Routing) #configure
(Routing) (Config)#interface 0/9
(Routing) (Interface 0/9)#ip ospf bfd
(Routing) (Interface 0/9)#exit
```

7.7 VRF Lite Operation and Configuration

7.7.1 Overview

The Virtual Routing and Forwarding feature enables a router to function as multiple routers. Each virtual router (VR) manages its own routing domain, with its own IP routes, routing interfaces, and host entries. Each virtual router makes its own routing decisions, independent of other virtual routers. More than one virtual routing table may contain a route to a given destination. The network administrator can configure a subset of the router's interfaces to be associated with each virtual router. The router routes packets according to the virtual routing table associated with the packet's ingress interface. Each interface can be associated with at most one virtual router.

For definitions of terms and acronyms used in this section, see Appendix A.2, Terms and Acronyms.

7.7.2 VRF Functionality

Each virtual router behaves like an independent router. Virtual routers can be created and destroyed dynamically. The fault domains of virtual routers are isolated. Bringing down a virtual router does not impact another virtual router. Each virtual router has its own instances of routing protocols and routing applications. EFOS supports a maximum of 64 Virtual Routers. The total number of routes or host entries is still limited by the hardware capacities on the physical router, but the routes and host entries are distributed across the virtual routing domains based on the user configuration. The maximum number routes in a particular virtual router can be optionally reserved.

IP prefixes can overlap between two VR instances. The same IP address can be configured on two interfaces that are a part of different VR instances. A packet is routed based on the route table look up result in the corresponding VR instance. The VR instance is derived based on the ingress interface. There are situations, however, that require support for inter-VR routing, such as providing access to shared services syslog server, DHCP server, the Internet, etc. These cases are handled through “route leaking”.

In the standard EFOS Routing build, the VRF component must be selected to support VRF. By default, all the standard routing software and functions are in the default router (VRID 0), which is created on startup and cannot be deleted by the user. The non-VRF routing user does not experience any disruption in using the CLI commands or in router functionality as a result of VRF configuration. Configuration migration for a system running an earlier build is supported.

The EFOS Virtual Routing feature depends on the “Network Name Space” feature in Linux. EFOS supports this feature in the 3.x and later Linux kernels. There is no impact on the routing feature for EFOS running pre-3.x kernels except that the VRF feature is not supported on them. The CLI commands for VRF are disabled in the EFOS builds running pre-3.x kernels.

The user manages the VRF functionality through CLI commands. There is no separate user interface for every VR instance. The user manages all the VR instances from a single CLI. The in-band management is supported through one of the interfaces on the default VR only. EFOS CLI does not currently support managing VRF instances, although they work in the default VR instance. Syslog is enhanced to support logging from different Linux processes. VRF supports logging for all the events that are already supported.

7.7.2.1 Route Leaking

Route leaking is the ability to install a route in one VRF that allows traffic to flow to another VRF. Although this mechanism breaks the isolation between VRFs, it is sometimes used to provide access to common services for devices inside the different VRFs. EFOS supports route leaking between the global default routing table and a VR, but not across VRs. EFOS supports route leaking only through static routes. EFOS does not support inter-VRF packet forwarding by connecting a wire between ports belonging to different VR instances.

7.7.2.1.1 Adding Leaked Routes

Connected routes in one router that are leaked into another VR are referred to as leaked host routes. To add leaked host routes, specify the next-hop interface but not the next-hop address. For leaked routes that are not directly connected (static or dynamic routes), the next-hop address must to be specified in addition to the next-hop interface. The next-hop interface is specified to identify the outgoing VR interface. If the next-hop interface is unspecified, the route is treated as an internal route to the VR.

Internal routes within a router that are added with only a next-hop interface value (and no next-hop address value) are supported only over unnumbered interfaces.

7.7.2.1.2 Using Leaked Routes

The line rate forwarding continues to work the same for leaked route destinations in a router as for the internal routes in the router. For bidirectional traffic to work between VRs using leaked routes, the corresponding routes should be leaked between the VRs.

7.7.2.1.3 CPU-Originated Traffic

For CPU-originated traffic from different applications (ping, traceroute, syslog, IP helper) that may use the leaked routes to access the destination or shared service, the following conditions are required to ensure proper operation:

1. The source IP address in the originated packets must be mentioned with the source IP option (e.g., ping with source option).
2. In the router where the CPU traffic originates, the route for the source option matching network must be leaked into the virtual router where the next-hop belongs so that the return traffic is directed to the traffic-originating router.

7.7.3 VRF and EFOS Feature Support

Table 16 lists EFOS features and details how they are supported by VRF Lite:

Table 16: VRF and EFOS Feature Support

Feature	VRF Support
Network Management	Network management includes the ability to manage the switch via CLI and SNMP. EFOS Network management is supported only via the default router. Administrators cannot log into the switch and manage the switch via one of the IP addresses on the non-default VR. The Service Port and the Network Port are always associated with the default router, so the customers are able to manage the switch via these interfaces.
SNMP Management	Only the default router can be managed via SNMP.
AAA	The Authentication, Authorization, and Accounting protocols include services such as the RADIUS client and the TACACS+ client. EFOS supports these services only on the default router.
Network Services	The Ping and the Trace Route clients are supported in the Virtual Router context. Other protocols are supported only in the default router. These include the SNTP client, DNS client, sFlow, RPCAP, and Auto Install.
Loopback and Tunnel Interfaces	Loopback interfaces with IPv4 prefixes are supported in the Virtual Router. Loopback interfaces with IPv6 addresses can be configured only in the default router. The number of Loopback interfaces in builds containing the VRF package is increased to 64. The loopback interfaces are shared across VR instances in the system and there is no restriction on the maximum supported per VR. Tunnel interfaces are not supported in the Virtual Router.

Table 16: VRF and EFOS Feature Support (Continued)

Feature	VRF Support
IP unnumbered interfaces	IP unnumbered interface cannot be part of non-default VRF instance. This feature is supported only in the default router.
OSPFv2	The OSPFv2 protocol is supported in the Virtual Router. As of the current release, a crash in the OSPFv2 protocol does not cause the switch to reboot. All OSPF features including graceful restart and NSF are supported for OSPFv2 in each VR instance.
OSPFV3	The OSPFv3 protocol is supported only in the default router.
RIP	RIP is not currently supported in the Virtual Router.
VRRP	The Virtual Routing Redundancy Protocol is a fault-tolerance feature that enables two or more routers to appear as one router to the IP clients. If one of the VRRP routers fails, another router can take over the data forwarding with minimum interruption to client traffic. The VRRP protocol is supported in the Virtual Router context. The VRRP protocol enables two or more virtual routers running on different physical switches to form a VRRP group. The Virtual Routers running on the same physical switch cannot form a VRRP group with each other.
BGP	The Border Gateway Protocol is intended to be used by the Customer Edge (CE) switch to communicate with other CE switches and PE switches across the Provider Network. This typical VRF-Lite deployment is described in Section 7.7.4, VRF Lite Deployment Scenarios. The BGP protocol runs in the Default Router context and is aware of the Virtual Routers. BGP is used to: 1. Redistribute VPN routes from Virtual Routers on the CE switch to the attached PE in the Provider Network. 2. Leak routes dynamically between different Virtual Routers on the same physical switch. This requires support for BGP extended communities and route targets. In the current EFOS implementation, BGP does not support either of the above mentioned functionalities.
IPv6	The current EFOS release supports VRF-Lite only for IPv4. IPv6 data forwarding and protocols are not currently supported.
IP Multicast	The current EFOS Virtual Routing release supports only IPv4 unicast routing.
Policy Based Routing	PBR is a routing policy feature useful in overriding routing decisions with programmable rules. PBR is supported only in the default router in the current release.
DHCP Server	DHCP Server is not VR-aware in the current release.
DHCP Snooping	The IP Source Guard (IPSG) feature uses DHCP snooping to allow only packets from known sources. IPSG uses DHCP Snooping to snoop the DHCP addresses allocated to connected hosts. The tuple (IP, MAC, VLAN, Interface) uniquely identifies a host. DHCP Snooping is a layer-2 feature and is VRF-agnostic. It works in layer-2 of any VLAN irrespective of whether it belongs to a default router or any virtual router. It applies to all protocols working at L2.
IP Helper	IP Helper relays the broadcast packets received on a Routing interface in the VRF context to the configured server address. The server is looked up in the RTO specific to that VR only. Relay across VRs is not supported.
OpEN API	The applications using existing OpEN APIs are not affected by the VRF feature.
Layer-2 Features	The VRF feature does not affect the switch layer-2 features such as virtual port channels (VPC). However, if VPC is planned to be used on VRF-enabled switches, the VPC ports need to be configured to be in the same routing domain.

7.7.4 VRF Lite Deployment Scenarios

The following are two likely deployment scenarios for the VRF-Lite solution:

1. In the Customer edge (CE) devices that interface with the PE (Provider edge) device in the service provider backbone network to provide VPN connectivity for the Enterprise network sites spread across different geographical locations across the Internet backbone.

   In this scenario, the BGP protocol must be running on the device to support feature extensions required to support:

   a. Dynamic route leaking locally between the VRFs to leak the routes to shared services using Route Targets.

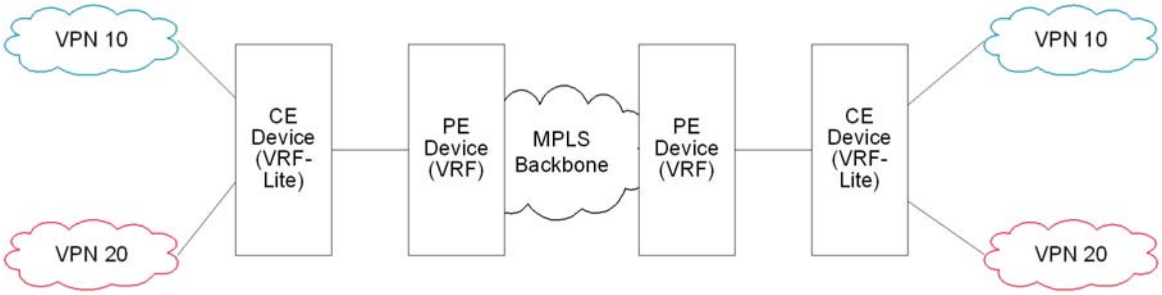
   b. Exchange the VPN related route information per VR with PE device using extended communities.

2. The internal Routers in the Enterprise networks to provide isolation of different departments/offices at layer-3 or routing domain.

   This scenario does not mandate that the BGP protocol be running on the device. It can still be run in this scenario to achieve dynamic route leaking only. The IGP protocol (OSPF or RIP) running in the VR instance communicates route information with corresponding peers in the same VR on other CE devices or internal Routers.

VRF scenarios are shown in Figure 49.

Figure 49: VRF Scenarios

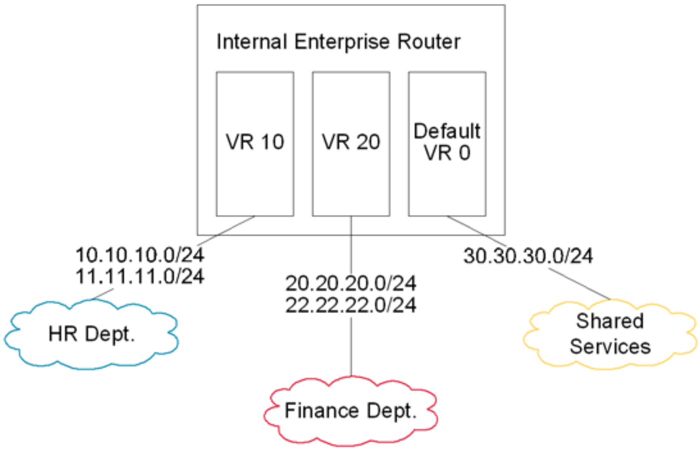


The default global routing table is also referred to as VR 0.

In the following example, subnetworks 10.10.10.0/24 and 11.11.11.0/24 belong to the virtual routing domain "HR Dept" and subnetworks 20.20.20.0/24 and 22.22.22.0/24 belong to virtual routing domain "Finance Dept". Hence, the hosts in networks 10.10.10.0/24 can communicate only with other network 11.11.11.0/24 via the router and the hosts in networks 20.20.20.0/24 can communicate only with other network 22.22.22.0/24 via the router.

If there is a shared service printer @30.30.30.30 in the default global routing domain "Shared Services", we would want the HR and Finance domains to have access to it. Therefore, we statically leak a 30.30.30.0/24 route from global routing table to VR 10 and VR 20. At the same time, we statically leak the routes 10.10.10.0/24 and 11.11.11.0/24 from VR 10 to global table (the same applies to VR 20).

Figure 50: VRF Routing With Shared Services



The route tables in both the VRs and the global domain look like the following:

```
(Routing) #show ip route vrf HR
Route Codes: R - RIP Derived, O - OSPF Derived, C - Connected, S - Static
       B - BGP Derived, IA - OSPF Inter Area
       E1 - OSPF External Type 1, E2 - OSPF External Type 2
       N1 - OSPF NSSA External Type 1, N2 - OSPF NSSA External Type 2
   L - Leaked Route
C      10.10.10.0/24 [0/1] directly connected,   vlan 10
C      11.11.11.0/24 [0/1] directly connected,   vlan 11
S L    30.30.30.0/24 [1/1] directly connected,  vlan 30
S L    50.50.50.0/24 [1/1] via 30.30.30.2,   02d:22h:15m,  vlan 30

(Routing) #show ip route vrf Finance
Route Codes: R - RIP Derived, O - OSPF Derived, C - Connected, S - Static
       B - BGP Derived, IA - OSPF Inter Area
       E1 - OSPF External Type 1, E2 - OSPF External Type 2
       N1 - OSPF NSSA External Type 1, N2 - OSPF NSSA External Type 2
   L - Leaked Route

C      20.20.20.0/24 [0/1] directly connected,   vlan 20
C      22.22.22.0/24 [0/1] directly connected,   vlan 22
S L    30.30.30.0/24 [1/1] directly connected,  vlan 30
S L    50.50.50.0/24 [1/1] via 30.30.30.2,   02d:22h:15m,  vlan 30

(Routing) #show ip route
Route Codes: R - RIP Derived, O - OSPF Derived, C - Connected, S - Static
       B - BGP Derived, IA - OSPF Inter Area
       E1 - OSPF External Type 1, E2 - OSPF External Type 2
       N1 - OSPF NSSA External Type 1, N2 - OSPF NSSA External Type 2
   L - Leaked Route

C      30.30.30.0/24 [0/1] directly connected,   vlan 30
S L    10.10.10.0/24 [1/1] directly connected,  vlan 10
S L    11.11.11.0/24 [1/1] directly connected,  vlan 11
S L    20.20.20.0/24 [1/1] directly connected,  vlan 20
S L    22.22.22.0/24 [1/1] directly connected,  vlan 22
```

7.7.5 VRF Configuration Example

1. Create virtual router instances. The following commands create and name two instances and enter VRF Configuration mode for each.

   In VRF Configuration mode for each VR, a description is added and the maximum number of routes allowed in each virtual instance is configured. On the "Red" instance, the number of routes above which a warning message is issued is also configured.

   The **ip routing** command enables routing in each VR instance:

```
(Routing) #configure
(Routing) (Config)#ip vrf Red
(Routing) (Config-vrf-Red)#description "finance department"
(Routing) (Config-vrf-Red)#maximum routes 2048
(Routing) (Config-vrf-Red)#maximum routes warn 80
(Routing) (Config-vrf-Red)#ip routing
(Routing) (Config-vrf-Red)#exit

(Routing) (Config)#ip vrf Blue
(Routing) (Config-vrf-Blue)#description "human resources department"
(Routing) (Config-vrf-Blue)#maximum routes 4096
(Routing) (Config-vrf-Blue)#ip routing
(Routing) (Config-vrf-Blue)#exit
```

2. In Interface Config mode, assign interfaces to each virtual router:

```
(Routing) (Config)#interface 0/1
(Routing) (Interface 0/1)#ip vrf forwarding Red
Warning: routing interface moved from Default router instance to "Red" router instance.
(Routing) (Interface 0/1)#exit

(Routing) (Config)#interface 0/2
(Routing) (Interface 0/2)#ip vrf forwarding Blue
Warning: routing interface moved from Default router instance to "Blue" router instance.
(Routing) (Interface 0/2)#exit
```

3. Create static leaked routes as needed in the VR instances.

   In the following example, subnetwork 9.0.0.0/24 is a connected subnetwork in the global route table and subnet 56.6.6.0/24 is reachable via a gateway 9.0.0.2 in the global route table. Subnet 8.0.0.0/24 is a connected subnetwork in virtual router Red.

   The two routes are leaked from the global route table into the Red VR and the connected subnet 8.0.0.0/24 is leaked from the Red VR to the global route table.

   The following commands also add a non-leaked static route for the 56.6.6.0/24 subnetwork scoped to the domain of Red VR.

```
(Routing) (Config)#ip routing
(Routing) (Config)#interface 0/27
(Routing) (Interface 0/27)#routing
(Routing) (Interface 0/27)#ip vrf forwarding Red
Warning: routing interface moved from Default router instance to "Red" router in
stance.
(Routing) (Interface 0/27)#ip address 8.0.0.1 /24

(Routing) (Interface 0/27)#interface 0/26
(Routing) (Interface 0/26)#routing
(Routing) (Interface 0/26)#ip address 9.0.0.1 /24
(Routing) (Interface 0/26)#exit

(Routing) (Config)#ip route 56.6.6.0 255.255.255.0 9.0.0.2
```

4. To leak routes from the global routing table to the VRF route table, use the following example:

   ```
   (Routing) (Config)#ip route vrf Red 9.0.0.2 255.255.255.255 9.0.0.2 0/26
   (Routing) (Config)#ip route vrf Red 56.6.6.0 255.255.255.0 9.0.0.2 0/26
   ```

   To leak routes from the VRF's routing table to the global routing table, use the following example:

   ```
   (Routing) (Config)#ip route 8.0.0.2 255.255.255.255 0/27
   ```

   To leak routes (non-leaked) internal to the VRF's route table, use the following example:

   ```
   (Routing) (Config)#ip route vrf Red 66.6.6.0 255.255.255.0 8.0.0.2
   ```

7.8 IPv6 Routing

IPv6 is the next generation of the Internet Protocol. With 128-bit addresses, versus 32-bit addresses for IPv4, IPv6 solves the address depletion issues seen with IPv4 and removes the requirement for Network Address Translation (NAT), which is used in IPv4 networks to reduce the number of globally unique IP addresses required for a given network.

In the EFOS software, IPv6 coexists with IPv4. As with IPv4, IPv6 routing can be enabled on loopback and VLAN interfaces. Each L3 routing interface can be used for IPv4, IPv6, or both. IP protocols running over L3 (for example, UDP and TCP) are common to both IPv4 and IPv6.

7.8.1 IPv6 Compared with IPv4

There are many conceptual similarities between IPv4 and IPv6 network operation. Addresses still have a network prefix portion (network) and a device interface specific portion (host). While the length of the network portion is still variable, most users have standardized on using a network prefix length of 64 bits. This leaves 64 bits for the interface specific portion, called an Interface ID in IPv6. Depending upon the underlying link addressing, the Interface ID can be automatically computed from the link (e.g., MAC address). Such an automatically computed Interface ID is called an EUI-64 identifier, which is the interface MAC address with ff:fe inserted in the middle.

IPv6 packets on the network are of an entirely different format than traditional IPv4 packets and are also encapsulated in a different EtherType (86DD rather than 0800 which is used with IPv4). The details for encapsulating IPv6 in Ethernet frames are described in RFC4862.

Unlike IPv4, IPv6 does not have broadcasts. There are two types of IPv6 addresses — unicast and multicast. Unicast addresses allow direct one-to-one communication between two hosts, whereas multicast addresses allow one-to-many communication. Multicast addresses are used as destinations only. Unicast addresses will have 00 through fe in the most significant octets and multicast addresses will have ff in the most significant octets.

7.8.2 Configuring IPv6 Interfaces

In the EFOS software, IPv6 coexists with IPv4. As with IPv4, IPv6 routing can be enabled on VLAN interfaces. Each L3 routing interface can be used for IPv4, IPv6, or both simultaneously.

Neighbor Discovery (ND) protocol is the IPv6 replacement for Address Resolution Protocol (ARP) in IPv4. The IPv6 Neighbor Discovery protocol is described in detail in RFC4861. Router advertisement is part of the Neighbor Discovery process and is required for IPv6. As part of router advertisement, PowerConnect 7000 Series switch software supports stateless auto configuration of end nodes. The switch supports both EUI-64 interface identifiers and manually configured interface IDs.

While optional in IPv4, router advertisement is mandatory in IPv6. Router advertisements specify the network prefix(es) on a link which can be used by receiving hosts, in conjunction with an EUI-64 identifier, to autoconfigure a host’s address. Routers have their network prefixes configured and may use EUI-64 or manually configured interface IDs. In addition to zero or more global addresses, each IPv6 interface also has an autoconfigured “link-local” address which is:

- fe80::/10, with the EUI-64 address in the least significant bits.
- Reachable only on the local VLAN — link-local addresses are never routed.
- Not globally unique.

Next hop addresses computed by routing protocols are usually link-local addresses.

During the period of transitioning the Internet to IPv6, a global IPv6 Internet backbone may not be available. One transition mechanism is to tunnel IPv6 packets inside IPv4 to reach remote IPv6 islands. When a packet is sent over such a link, it is encapsulated in IPv4 in order to traverse an IPv4 network and has the IPv4 headers removed at the other end of the tunnel.

7.8.3 IPv6 Link Local Addresses

EFOS supports the configuration of IPv6 link-local addresses (FE80::/16) on interfaces. All IPv6 routing interfaces share a single fixed IPv6 link-local address which is automatically generated using FE80::/10 and the interface identifier (MAC address) in the EUI-64 format.

Manually configuring an IPv6 link local address is allowed on the following interface types:

- Port-based routing
- VLAN-based routing
- Loopback
- Tunnel

With this feature, administrators can assign a unique link-local address per interface that does not conflict with link-local address of other interfaces. Configuring a link-local IPv6 address overrides the link-local address that is automatically generated for the routing interface, which implies there can be only one link-local address on an interface.

This feature is most commonly used on top-of-rack (TOR) switches in data center deployments. The servers attached to the TOR switches are configured with an IPv6 default gateway value that is fixed and is not changed whenever the TOR switches are replaced. Without this feature, the link-local address of the TOR switch changes (based on the MAC address) on switch replacement, and as a result there is an extra overhead of re-configuring the IPv6 default gateway on the attached servers whenever the link-local address of the TOR changes.

To avoid such situations, the link-local address on the TOR switch is manually configured to a unique fixed value that is saved in the configuration and remains the same across TOR replacements.

7.8.4 Default IPv6 Routing Values

Table 17 shows the default values for the IP routing features this section describes.

Table 17: IPv6 Routing Defaults

Parameter	Default Value
IPv6 Unicast Routing Mode	Disabled
IPv6 Hop Limit	Unconfigured
ICMPv6 Rate Limit Error Interval	1000 milliseconds
ICMPv6 Rate Limit Burst Size	100 messages
Interface IPv6 Mode	Disabled
IPv6 Router Route Preferences	Local—0 Static—1 OSPFv3 Intra—110 OSPFv3 Inter—110 OSPFv3 External—110 BGP External—20 BGP Internal—200 BGP Local —200

Table 18 shows the default IPv6 interface values after a VLAN routing interface has been created.

Table 18: IPv6 Interface Defaults

Parameter	Default Value
IPv6 Mode	Disabled
DHCPv6 Client Mode	Disabled
Stateless Address AutoConfig Mode	Disabled
Routing Mode	Enabled
Interface Maximum Transmit Unit	1500
Router Duplicate Address Detection Transmits	1
Router Advertisement NS Interval	Not configured
Router Lifetime Interval	1800 seconds
Router Advertisement Reachable Time	0 seconds
Router Advertisement Interval	600 seconds
Router Advertisement Managed Config Flag	Disabled
Router Advertisement Other Config Flag	Disabled
Router Advertisement Suppress Flag	Disabled
IPv6 Destination Unreachables	Enabled

7.8.5 Configuring IPv6 Routing Features

This section provides information about the commands you use to configure IPv6 routing on in the EFOS software.

7.8.5.1 Configuring Global IP Routing Settings

Use the following commands to configure various global IP routing settings for the EFOS software.

Table 19: Global IP Routing Settings

Command	Purpose
`configure`	Enter global configuration mode.
`sdm prefer dual-ipv4-and-ipv6 {data-center | dual-ipv4-and-ipv6 alpm-data-center | dual-ipv4-and-ipv6 alpm-mpls-data-center | default}`	Select a Switch Database Management (SDM) template to enable support for both IPv4 and IPv6. Changing the SDM template requires a system reload.
`ipv6 unicast-routing`	Globally enable IPv6 routing on the switch.
`ipv6 hop-limit limit`	Set the TTL value for the router. The valid range is 0 to 255.
`ipv6 icmp error-interval burst-interval [burst-size]`	Limit the rate at which IPv4 ICMP error messages are sent. ■ `burst-interval` — How often the token bucket is initialized (Range: 0–2147483647 milliseconds). ■ `burst-size` — The maximum number of messages that can be sent during a burst interval (Range: 1–200).
`exit`	Exit to Privileged EXEC mode.
`ipv6 redirects`	This is an Interface level command to configure to send Router Advertisements with unspecified Hop Limit value.
`ipv6 nd ra hop-limit unspecified`	This command configures the router to send Router Advertisements on an interface with unspecified (0) Current Hop Limit value. This will tell the hosts on that link to ignore the Hop Limit from this Router.

Table 19: Global IP Routing Settings (Continued)

Command	Purpose
`show ipv6 protocols`	This command lists a summary of the configuration and status for each of the active IPv6 routing protocols. If a protocol is selected on the command line, the display will be limited to that protocol.

7.8.5.2 Configuring IPv6 Interface Settings

Use the following commands to configure IPv6 settings for VLAN, tunnel, or loopback interfaces.

Table 20: IPv6 Interface settings

Command	Purpose
`configure`	Enter Global Configuration mode.
`interface {vlan | tunnel | loopback} interface-id`	Enter Interface Configuration mode for the specified VLAN, tunnel, or loopback interface.
`ipv6 enable`	Enable IPv6 on the interface. Configuring an IPv6 address will automatically enable IPv6 on the interface.
`ipv6 address {autoconfig | dhcp | prefix/prefix-length` [link-local] `[eui64]}`	Configure the IPv6 address and network prefix length. Setting an IPv6 address enables IPv6 on the interface. You can also use the **ipv6 enable command** to enable IPv6 on the interface without setting an address. Multicast, IPv4-compatible, and IPv4-mapped addresses are not allowed to be configured. Include the **link-local** keyword to configure the specified IPv6 address as the link-local address on an interface. Configuring the link-local address overwrites the automatically generated link-local address on an interface. Include the **EUI-64** keyword to have the system add the 64-bit interface ID to the address. You must use a network prefix length of 64 in this case. For VLAN interfaces, use the **dhcp** keyword to enable the DHCPv6 client and obtain an IP address form a network DHCPv6 server.
`ipv6 mtu`	(VLAN interfaces only) Set the IPv6 Maximum Transmission Unit (MTU) on a routing interface. The IPv6 MTU is the size of the largest IPv6 packet that can be transmitted on the interface without fragmentation. The range is 1280–12270 bytes.
`ipv6 traffic-filter ACL name`	Add an access-list filter to this interface.
`ipv6 unreachables`	(VLAN interfaces only) Allow the interface to send ICMPv6 Destination Unreachable messages. The no ipv6 unreachables command suppresses the ICMPv6 unreachable messages for this interface.
`exit`	Exit the interface configuration mode.
`ipv6 address` *`prefix/ prefix_length`* `[eui64]`	

7.8.5.3 Configuring IPv6 Neighbor Discovery

Use the following commands to configure IPv6 Neighbor Discovery settings.

Table 21: IPv6 Neighbor Discovery Settings

Command	Purpose
`ipv6 nd prefix prefix/ prefix-length [{valid-lifetime| infinite} {preferred-lifetime| infinite}] [no-autoconfig] [off-link]`	Configure parameters associated with network prefixes that the router advertises in its Neighbor Discovery advertisements. ■ **ipv6-prefix**—IPv6 network prefix. ■ ***prefix-length***—IPv6 network prefix length. ■ ***valid-lifetime***—Valid lifetime of the router in seconds. (Range: 0–4294967295 seconds.) ■ **infinite**—Indicates lifetime value is infinite. ■ ***preferred-lifetime***—Preferred-lifetime of the router in seconds. (Range: 0–4294967295 seconds.) ■ **no-autoconfig**—Do not use the prefix for auto configuration. ■ **off-link**—Do not use the prefix for onlink determination.
`ipv6 nd ra-interval maximum minimum`	Set the transmission interval between router Neighbor Discovery advertisements. ■ ***maximum*** — The maximum interval duration (Range: 4–1800 seconds). ■ ***minimum*** — The minimum interval duration (Range: 3 – (0.75 * maximum) seconds).
`ipv6 nd ra-lifetime seconds`	■ Set the value that is placed in the Router Lifetime field of the router Neighbor Discovery advertisements sent from the interface. ■ The *seconds* value must be zero, or it must be an integer between the value of the router advertisement transmission interval and 9000 seconds. A value of zero means this router is not to be used as the default router. (Range: 0-9000).
`ipv6 nd suppress-ra`	■ Suppress router advertisement transmission on an interface.
`ipv6 nd dad attempts value`	■ Set the number of duplicate address detection probes transmitted while doing Neighbor Discovery. ■ The range for *value* is 0–600.
`ipv6 nd ns-interval milliseconds`	■ Set the interval between router advertisements for advertised neighbor solicitations. The range is 1000 to 4294967295 milliseconds.
`ipv6 nd other-config-flag`	■ Set the *other stateful configuration* flag in router advertisements sent from the interface.
`ipv6 nd managed-config-flag`	■ Set the *managed address configuration* flag in router advertisements. When the value is true, end nodes use DHCPv6. When the value is false, end nodes automatically configure addresses.
`ipv6 nd reachable-time milliseconds`	■ Set the router advertisement time to consider a neighbor reachable after neighbor discovery confirmation.
ipv6 data-traffic rate-limit rate-in-pps	■ Configures the rate in packets-per-second for the number of IPv6 data packets trapped to CPU when the packet fails to be forwarded in the hardware due to unresolved hardware address of the destined IPv6 node. The rate ranges from 50 pps to 1024 pps.
ipv6 neighbors dynamicrenew	■ Enables/disables the periodic NUD (neighbor unreachability detection) to be run on the existing IPv6 neighbor entries based on the activity of the entries in the hardware. If the setting is disabled, only those entries that are actively used in the hardware are triggered for NUD at the end of STALE timeout of 1200 seconds. If the setting is enabled, periodically every 40 seconds a set of 300 entries are triggered for NUD irrespective of their usage in the hardware.
ipv6 nud max-unicast-solicits	■ Configures the maximum number of unicast Neighbor Solicitations sent during neighbor resolution or during NUD (neighbor unreachability detection). The value ranges from 3 to 10.
ipv6 nud max-multicast-solicits	■ Configures the maximum number of multicast Neighbor Solicitations sent during neighbor resolution or during NUD (neighbor unreachability detection). The value ranges from 3 to 255.
ipv6 nud backoff-multiple	■ Configures the exponential backoff multiple to be used in the calculation of the next timeout value for Neighbor Solicitation transmission during NUD (neighbor unreachability detection) following the exponential backoff algorithm. The value ranges from 1 to 5. The next timeout value is limited to a maximum value of 60 seconds if the value with exponential backoff calculation is greater than 60 seconds.

7.8.5.4 Configuring IPv6 Route Table Entries and Route Preferences

Use the following commands to configure IPv6 Static Routes.

Table 22: IPv6 Static Routes

Command	Purpose
`configure`	Enter global configuration mode.
`ipv6 route ipv6-prefix/prefix-length {next-hop-address | interface-type interface-number next-hop-address } [preference]`	Configure a static route.Use the keyword **null** instead of the next hop router IP address to configure a static reject route. ■ ***prefix/prefix-length***—The IPv6 network prefix and prefix length that is the destination of the static route. Use the ::/0 form (unspecified address and zero length prefix) to specify a default route. ■ ***interface-type interface-number***—Must be specified when using a link-local address as the next hop. The interface-type can be **vlan** or **tunnel**. ■ ***next-hop-address*** —The IPv6 address of the next hop that can be used to reach the specified network. A link-local next hop address must have a prefix length of 128. The next hop address cannot be an unspecified address (all zeros), a multicast address, or a loopback address. If a link local next hop address is specified, the interface (VLAN or tunnel), must also be specified. ■ ***preference***—Also known as Administrative Distance, a metric the router uses to compare this route with routes from other route sources that have the same network prefix. (Range: 1-255). Lower values have precedence over higher values. The default preference for static routes is 1. Routes with a preference of 255 are considered as "disabled" and will not be used for forwarding. Routes with a preference metric of 254 are used by the local router but will never be advertised to other neighboring routers.
`ipv6 route ipv6-prefix/prefix-length null [preference]`	Configure a static reject route. IPv6 packets matching the reject route will be silently discarded.
`ipv6 route distance integer`	Set the default distance (preference) for static IPv6 routes. Lower route preference values are preferred when determining the best route. The default distance (preference) for static routes is 1.
`exit`	Exit to Global Config mode.
serviceport ipv6 neighbor ipv6_neighbor mac_address	Configures a static IPv6 neighbor with the given IPv6 address and MAC address on the service port.
network ipv6 neighbor ipv6_neighbor mac_address	Configures a static IPv6 neighbor with the given IPv6 address and MAC address on the network port.
ipv6 neighbor ipv6_neighbor if_name mac_address	Configures a static IPv6 neighbor if_name with the given IPv6 address and MAC address on the network port.
show serviceport ipv6 neighbors	This command displays the information about the IPv6 neighbor entries cached on the service port. The information is updated to show the type of the entry.
show network ipv6 neighbors	This command displays the information about the IPv6 neighbor entries cached on the network port. The information is updated to show the type of the entry.

7.8.5.5 IPv6 Show Commands

Use the following commands to view IPv6 configuration status and related data.

Table 23: IPv6 Configuration Status

Command	Purpose
`show sdm prefer`	Show the currently active SDM template.
`show sdm prefer dual-ipv4-and-ipv6 {date-center | default}`	Show parameters for the SDM template.

Table 23: IPv6 Configuration Status (Continued)

Command	Purpose
`show ipv6 dhcp interface vlan vlan-id`	View information about the DHCPv6 lease acquired by the interface.
`show ipv6 interface {vlan | tunnel | loopback} interface-id`	View the IP interface configuration information for the specified IPv6 routing interface.
`show ipv6 brief`	View the global IPv6 settings for the switch.
`show ipv6 route [ipv6-address | ipv6-prefix/prefix-length | protocol | interface-type interface-number] [best]`	View the routing table. ■ ***ipv6-address***—Specifies an IPv6 address for which the best-matching route would be displayed. ■ ***protocol***—Specifies the protocol that installed the routes. Is one of the following keywords: **connected**, **ospf**, **static**. ■ ***ipv6-prefix/ prefix-length***—Specifies an IPv6 network for which the matching route would be displayed. ■ ***interface-type interface-number***—Valid IPv6 interface. Specifies that the routes with next hops on the selected interface be displayed. ■ **best**—Specifies that only the best routes are displayed. If the connected keyword is selected for protocol, the best option is not available because there are no best or non-best connected routes.
`show ipv6 route summary`	View summary information about the IPv6 routing table.
`show ipv6 route preferences`	View detailed information about the IPv6 route preferences.

7.9 ECMP Hash Selection

Users can choose the load balancing/sharing algorithm used for selecting the final ECMP route. The management interfaces enable choosing various combinations of IP header fields, including the inner or outer IP headers in tunneled packets. IPv4 and IPv6 are supported. The field selectors remain the same for all packet types. The following list shows available hash field selection algorithms. The list may vary depending upon the platform.

- Source IP address of the packet.
- Destination IP address of the packet.
- Source and Destination IP address of the packet.
- Source IP address and Source TCP/UDP Port field associated with the packet.
- Destination IP address and Destination TCP/UDP Port field associated with the packet.
- Source, Destination IP address and Source, Destination TCP/UDP Port field associated with the packet.

For tunneled packets, the user also must select whether the inner or the outer IP header should be used.

EFOS also supports a configuration option to enable hashing on the Security Parameters Index (SPI) field in IPsec packets.

IPsec packets are IPv4 and IPv6 packets with the following IP protocols:

- IP protocol 50—Encapsulating Security Payload (ESP)
- IP protocol 51—Authentication Header (AH).

The ESP and AH protocols do not employ the IP source and destination port numbers, so the hardware does not use the IP port numbers for hashing the packets. The ESP and AH packet headers contain the SPI field, which is associated with packet flows and can be used for hashing IPsec packets. Note that the SPI field is located in different places in the ESP and AH headers.

For configuration information, refer to the **ip load-sharing** and **ip ipsec-load-sharing spi** commands in the *EFOS CLI Command Reference* (see Appendix A.1, References). To view information about the ECMP load balancing and hashing configuration on the switch, use the **show ip load-sharing command.**

7.10 IP Service Level Agreement

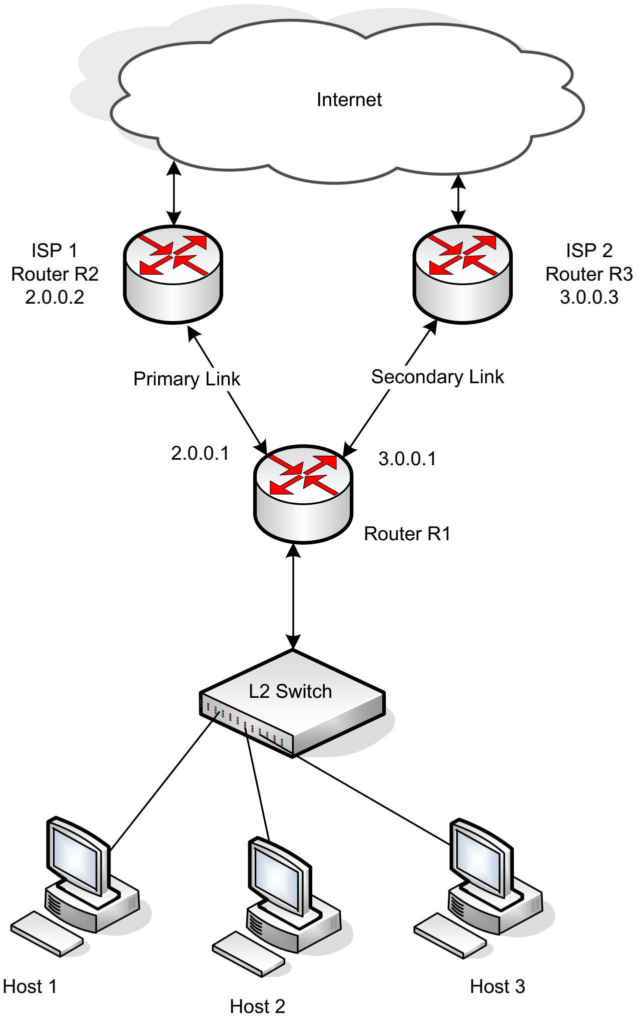
In a network environment, redundancy is one of the most important aspects, whether its on the LAN side or on the WAN side. For WAN redundancy with multiple WAN links terminating on a single router, the best and simplest way is to use reliable static backup routes with IP service-level agreement (SLA) reachability tracking.

The IP SLA feature enables network performance monitoring between routers or from a router to a remote IP device. EFOS supports the following measurement capabilities:

- Remote IP reachability tracking
- Round-trip-time threshold monitoring

Reachability tracking and threshold monitoring are performed by measuring ICMP response time and connectivity. A key application of this feature is in Enterprise networks on multi-homed customer edge devices, where there is a need to automatically switch to the next priority ISP in case of reachability issues with the current ISP.

Figure 51: IP SLA Reachability Tracking and Auto Route Failover



In Figure 51, IP SLA Reachability Tracking and Auto Route Failover, the Router R1 is connected to two WAN links ISP1 and ISP2. Generally in a scenario like this, the default routes are configured on the router R1 pointing to the respective next hop IP addresses s as shown below:

```
R1(config)# ip route 0.0.0.0 0.0.0.0 2.0.0.2
R1(config)# ip route 0.0.0.0 0.0.0.0 3.0.0.3 10
```

Here, the point to note is that the administrative distance for the secondary route pointing to ISP2 is increased to 10 so that it becomes the backup link.

The configuration shown in Figure 51 with just two floating static routes partially accomplishes our requirement as it will work only in the scenario where the router interfaces connected to the WAN link are in an up/down or down/down status. But in a lot of situations, even though the links remain up, it is not possible to reach the gateway. This type of reachability issue usually happens when the issue is at the ISP side.

In such scenarios, IP SLAs reachability tracking becomes very useful by providing a more reliable automatic failover option.

Using IP SLA, the router gets the ability to use Internet Control Message Protocol (ICMP) pings to identify when a WAN link goes down at the remote end, and hence allows the initiation of a backup connection from an alternative port. The reliable static routing backup using the object tracking feature can ensure reliable backup in the case of several catastrophic events, such as an Internet circuit failure or peer device failure.

The IP SLA is configured to ping a target, such as a publicly routable IP address, a target inside the corporate network, or the next-hop IP on the ISP's router. The pings are routed from the primary interface only.

The following example shows a sample configuration of an IP SLA to generate an ICMP ping targeted at the ISP1s next-hop IP.

```
R1(config)# ip sla 1
R1(config-ip-sla)# icmp-echo 2.0.0.2
R1(config-icmp-echo)# timeout 1000
R1(config-icmp-echo)# frequency 4
R1(config-icmp-echo)# exit
R1(config-ip-sla)# exit

R1(config)# ip sla schedule 1
```

This configuration example defines and starts an IP SLA probe.

The ICMP echo probe sends an ICMP echo packet to the next-hop IP 2.0.0.2 every four seconds, as specified by the `frequency` configuration parameter.

The `timeout` parameter sets the amount of time (in milliseconds) that the router's IP SLAs operation waits for a response for its request packet.

After defining the IP SLA operation, the next step is to define an object that tracks the SLA probe. This can be accomplished by configuring the *track object* feature as shown in the following command:

```
R1(config)# track 1 ip sla 1 reachability
```

This command configures tracking of the state of the IP SLA operation. If there are no ping responses from the next-hop IP, the track goes down, and it comes up when the IP SLA operation starts receiving ping responses.

To verify the track status use the use the `show track` command as shown below:

```
R1# show track

Track 1
IP SLA 1 reachability
Reachability is Down
1 change, last change 00:02:38
Latest operation return code: Unknown
```

The `show track` output shows that the track status is down. Every IP SLA operation maintains an operation return-code value. This return code is interpreted by the tracking process. The return code may return OK, OverThreshold, and Timeout.

Table 24 shows the track states as per the IP SLA return code.

Table 24: IP SLA Return Code Track States

Tracking	Return Code	Track State
Reachability	OK or OverThreshold	Up
	Timeout	Down

The Last step in the IP SLA reliable static route configuration is to add the track statement to the default routes pointing to the ISP routers as shown below:

```
R1(config)# ip route 0.0.0.0 0.0.0.0 2.0.0.2 track 1
R1(config)# ip route 0.0.0.0 0.0.0.0 3.0.0.3 10
```

The track number keyword and argument combination specifies that the static route will be installed only if the state of the configured track object is up. Hence, if the track status is down, the secondary route will be used to forward all the traffic.

7.11 Policy-Based Routing

Unlike standard routing, which uses a routing table to forward packets to their destination addresses, policy-based routing allows network administrators to define forwarding behavior based on the contents of a packet. Policy-based routing uses configured criteria to override traditional destination-based routing behavior that is determined by static or dynamic routing protocols. EFOS supports policy-based routing for both IPv4 and IPv6.

The policy-based routing feature can match and forward packets based on any of the following packet criteria:

- Packet size
- Protocol of the payload (protocol field in IP header)
- Source MAC address
- Source IP address
- Destination IP address
- VLAN ID
- Priority (802.1p priority)
- Source IPv6 address

The route-map statement should contain eligible match/set conditions for policy-based routing in order to be applied to hardware. IPv4 route maps can have the following match/set conditions:

- Valid match conditions: `match ip address acl`, `match mac-list`, `match length`
- Valid set conditions: `set ip next-hop`, `set ip default next-hop`, `set ip precedence`

IPv6 route maps can have the following match/set conditions:

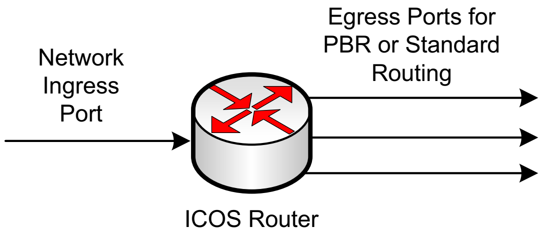
- Valid match conditions: `match ipv6 address acl, match mac-list, match length`
- Valid set conditions: `set ipv6 next-hop`, `set ipv6 default next-hop`, `set ipv6 precedence`

A route-map statement should contain at least one match condition and one set condition as specified above for it to be eligible to be applied to hardware. If not, the route-map is not applied to hardware.

7.11.1 Configuring Policy-Based Routing on a Physical Interface

This example includes the commands required to configure IPv4 and IPv6 policy-based routing (PBR) on a physical interface.

Figure 52: PBR Configuration Example



1. Enable routing.

```
configure
ipv6 unicast-routing
ip routing
```

2. Create an IPv4 named access control list (ACL).

```
ip access-list acl4
permit ip host 192.168.40.2 any
exit
```

3. Create an IPv6 ACL.

   ```
   ipv6 access-list acl6
   permit ipv6 host 4001::2 any
   exit
   ```

4. Create a MAC ACL.

   ```
   mac access-list extended m1
   permit any any
   exit
   ```

5. Create a route-map that matches the IPv4 ACL configured in Step 2 and sets the next-hop behavior for any packet that matches the ACL.

   ```
   route-map rm4 permit 10
   match ip address acl4
   set ip next-hop 192.168.30.2 192.168.20.2
   exit
   ```

6. Create a route-map that matches the IPv6 ACL configured in Step 3 and sets the next-hop forwarding behavior for a packet that matches the ACL.

   ```
   route-map rm6 permit 10
   match ipv6 address acl6
   set ipv6 next-hop 3001::2 2001::2
   exit
   ```

7. Create a route-map that matches the IPv6 ACL configured in Step 3 and sets the default next-hop forwarding behavior for a packet that matches the ACL.

   ```
   route-map rmdef permit 10
   match ipv6 address acl6
   set ipv6 default next-hop 2002::2 1001::2
   exit
   ```

8. Create a route-map that matches based on the Layer 3 packet length and sets the default next-hop forwarding behavior and also sets the precedence in the IPv6 packet header.

   ```
   route-map rmlen permit 100
   match length 500 1200
   set ipv6 default next-hop 2002::2 1001::2
   set ipv6 precedence 5
   exit
   ```

9. Configure the ingress interface as a routing interface with IPv4 and IPv6 addresses, and then attach the route maps to this interface.

   When a packet that matches the route-map match clause arrives on this interface, the port routes the packet to the egress interface specified by the set clause in the route-map. If the packet does not match the match clause in any of the associated route-maps, the packet is forwarded to an egress interface by using traditional routing.

   ```
   interface 0/21
   routing
   ip address 192.168.40.1 255.255.255.0
   ipv6 address 4001::1/64
   ipv6 enable
   ipv6 policy route-map rmdef
   ip policy route-map rm4
   exit
   ```

10. Configure the three egress interfaces.

```
interface 0/17
routing
ip address 192.168.10.1 255.255.255.0
ipv6 address 1001::1/64
ipv6 enable
exit

interface 0/31
routing
ip address 192.168.20.1 255.255.255.0
ipv6 address 2001::1/64
ipv6 enable
exit

interface 0/27
routing
ip address 192.168.30.1 255.255.255.0
ipv6 address 3001::1/64
ipv6 enable
exit
```

11. Enable routing protocols on the system.

```
router rip
exit
router ospf
exit
ipv6 router ospf
exit
exit
```

12. View the configured route maps.

```
(Router) #show route-map

route-map rm6 permit 10
     Match clauses:
       ipv6 address (access-lists) : acl6
     Set clauses:
       ipv6 next-hop 3001::2 2001::2
Policy routing matches: 0 packets, 0 bytes

route-map rm4 permit 10
     Match clauses:
       ip address (access-lists) : acl4
     Set clauses:
       ip next-hop 192.168.30.2 192.168.20.2
Policy routing matches: 0 packets, 0 bytes

route-map rmdef permit 10
     Match clauses:
       ipv6 address (access-lists) : acl6
     Set clauses:
       ipv6 default next-hop 2002::2 1001::2
Policy routing matches: 0 packets, 0 bytes

route-map rmlen permit 100
     Match clauses:
       length 500 1200
```

```
      Set clauses:
        ipv6 default next-hop 2002::2 1001::2
        ipv6 precedence 5
Policy routing matches: 0 packets, 0 bytes
```

13. View the IPv4 and IPv6 route maps used for policy-based routing on the interfaces.

```
(Router) #show ipv6 policy

Interface            Route-Map
------------  -----------------------------------------
0/21            rmdef

(dhcp-10-27-23-217) #show ip policy

Interface            Route-Map
------------  -----------------------------------------
0/21            rm4
```

7.11.2 Configuring Policy-Based Routing on a VLAN Interface

This example shows how to configure IPv4 and IPv6 PBR on a VLAN interface.

1. Create the VLANs, and enable the VLANS for VLAN routing.

```
vlan database
vlan 10,20,30,4093
vlan routing 10 1
vlan routing 20 2
vlan routing 30 3
vlan routing 4093 4
exit
```

2. Enable IP/IPv6 routing on the system.

```
configure
ipv6 unicast-routing
ipv6 route ::/0 interface 0/3/3 fe80::200:33ff:fe4d:d395
ip routing
```

3. Create the ACLs and route-maps.

```
ip access-list acl4
permit ip host 192.168.40.2 any
exit

ipv6 access-list acl6
permit tcp host 4001::2 any
exit

route-map rm6 permit 10
match ipv6 address acl6
set ipv6 next-hop 3001::2 2001::2
exit
route-map rm4 permit 10
match ip address acl4
set ip next-hop 192.168.20.2
exit
```

4. Provision the interfaces and apply the route-map.

```
interface 0/17
vlan pvid 10
vlan participation exclude 1
vlan participation include 10
exit

interface 0/21
vlan pvid 4093
vlan participation exclude 1
vlan participation include 4093
exit

interface 0/27
vlan pvid 30
vlan participation exclude 1
vlan participation include 30
exit

interface 0/31
vlan pvid 20
vlan participation exclude 1
vlan participation include 20
exit

interface vlan 10
routing
ip address 192.168.10.1 255.255.255.0
ipv6 address 1001::1/64
ipv6 enable
exit

interface vlan 20
routing
ip address 192.168.20.1 255.255.255.0
ipv6 address 2001::1/64
ipv6 enable
exit

interface vlan 30
routing
ip address 192.168.30.1 255.255.255.0
ipv6 address 3001::1/64
ipv6 enable
exit

interface vlan 4093
routing
ip address 192.168.40.1 255.255.255.0
ipv6 address 4001::1/64
ip policy route-map rm4
ipv6 policy route-map rm6
ipv6 enable
exit
```

7.12 Microsoft Network Load Balancing

The network load balancing (NLB) feature allows an EFOS router to work with Microsoft NLB clusters. EFOS replicates and (if required) routes every incoming NLB client request to the connected cluster hosts (servers). EFOS can work with all the three NLB modes: unicast, multicast, and multicast IGMP.

7.12.1 Configuring NLB on EFOS

This section describes how to provision a switch to route NLB traffic for various use cases. The following requirements apply to all use cases:

- The EFOS router should be able to resolve the cluster IP address to its cluster MAC through ARP.
- A static MAC filter/IGMP snooping entry must exist for the cluster MAC to specify the cluster destination ports.

7.12.1.1 Configuring NLB for Unicast Mode

In unicast mode, the cluster IP gets resolved to the cluster MAC through ARP dynamically. Alternatively, a static ARP entry can also be installed. The user must configure the static MAC filter entry for the cluster MAC.

7.12.1.2 Configuring NLB for Multicast Mode

For multicast mode:

- Add a static ARP entry mapping the cluster IP to the multicast cluster MAC.
- Add a static MAC filter entry for the cluster MAC specifying cluster destination ports.

7.12.1.3 Configuring NLB for IGMP Mode

For IGMP mode:

- Add a static ARP entry mapping the cluster IP to the multicast cluster MAC.
- Enable IGMP snooping.

Chapter 8: Configuring IPv4 and IPv6 Multicast

8.1 L3 Multicast Overview

IP Multicasting enables a network host (or multiple hosts) to send an IP datagram to multiple destinations simultaneously. The initiating host sends each multicast datagram only once to a destination multicast group address, and multicast routers forward the datagram only to hosts who are members of the multicast group. Multicast enables efficient use of network bandwidth because each multicast datagram needs to be transmitted only once on each network link, regardless of the number of destination hosts. Multicasting contrasts with IP unicasting, which sends a separate datagram to each recipient host. The IP routing protocols can route multicast traffic, but the IP multicast protocols handle the multicast traffic more efficiently with better use of network bandwidth.

Applications that often send multicast traffic include video or audio conferencing, Whiteboard tools, stock distribution tickers, and IP-based television (IP/TV).

8.1.1 IP Multicast Traffic

IP multicast traffic is traffic that is destined to a host group. Host groups are identified by class D IP addresses, which range from 224.0.0.0 to 239.255.255.255. When a packet with a broadcast or multicast destination IP address is received, the switch will forward a copy into each of the remaining network segments in accordance with the IEEE MAC Bridge standard. Eventually, the packet is made accessible to all nodes connected to the network.

This approach works well for broadcast packets that are intended to be seen or processed by all connected nodes. In the case of multicast packets, however, this approach could lead to less efficient use of network bandwidth, particularly when the packet is intended for only a small number of nodes. Packets will be flooded into network segments where no node has any interest in receiving the packet. The L3 multicast features on the switch help to ensure that only the hosts in the multicast group receive the multicast traffic for that group.

Multicast applications send one copy of a packet, and address it to a group of receivers (Multicast Group Address) rather than to a single receiver (unicast address). Multicast depends on the network to forward the packets to only those networks and hosts that need to receive them.

8.1.2 Multicast Protocol Switch Support

Multicast protocols are used to deliver Multicast packets from one source to multiple receivers. Table 25 summarizes the multicast protocols that the switch supports.

Table 25: Multicast Protocol Support Summary

Protocol	IPv4 or IPv6	For Communication Between
IGMP	IPv4	Host-to-L3 switch/router
MLD	IPv6	Host-to-L3 switch (router)
PIM-SM	IPv4 or IPv6	L3-switch/router-to-L3 switch/router
PIM-DM	IPv4 or IPv6	L3-switch/router-to-L3 switch/router
DVMRP	IPv4	L3-switch/router-to-L3 switch/router

8.1.3 Multicast Protocol Roles

Hosts must have a way to identify their interest in joining any particular multicast group, and routers must have a way to collect and maintain group memberships. These functions are handled by the IGMP protocol in IPv4. In IPv6, multicast routers use the Multicast Listener Discover (MLD) protocol to maintain group membership information.

Multicast routers must also be able to construct a multicast distribution tree that enables forwarding multicast datagrams only on the links that are required to reach a destination group member. Protocols such as DVMRP, and PIM handle this function.

IGMP and MLD are multicast group discovery protocols that are used between the clients and the local multicast router. PIM-SM, PIM-DM, and DVMRP are multicast routing protocols that are used across different subnets, usually between the local multicast router and remote multicast router.

8.1.4 L3 Multicast Switch Requirements

You use the IPv4/IPv6 multicast feature on the switch to route multicast traffic between VLANs on the switch. If all hosts connected to the switch are on the same subnet, there is no need to configure the IP/IPv6 multicast feature. If the switch does not handle L3 routing, you can use IGMP snooping or MLD snooping to manage port-based multicast group membership. For more information, see Section 1.3.35, IGMP Snooping. If the local network does not have a multicast router, you can configure the switch to act as the IGMP querier. For more information, see Section 1.3.36, IGMP Snooping Querier.

If the switch is configured as a L3 switch and handles inter-VLAN routing through static routes or OSPF and multicast traffic is transmitted within the network, enabling and configuring L3 multicast routing on the switch is recommended.

8.1.5 Determining Which Multicast Protocols to Enable

IGMP is recommended on any switch that participates in IPv4 multicasting. MLD is recommended on any switch that participates in IPv6 multicasting. PIM-DM, PIM-SM, and DVMRP are multicast routing protocols that help determine the best route for IP (PIM and DVMRP) and IPv6 (PIM) multicast traffic. For more information about when to use PIM-DM, see Section 8.1.10.2, Using PIM-DM as the Multicast Routing Protocol. For more information about when to use PIM-SM, see Section 8.1.10.1, Using PIM-SM as the Multicast Routing Protocol. For more information about when to configure DVMRP, see Section 8.1.11.2, Using DVMRP as the Multicast Routing Protocol.

8.1.6 Multicast Routing Tables

Multicast capable/enabled routers forward multicast packets based on the routes in the Multicast Routing Information Base (MRIB). These routes are created in the MRIB during the process of building multicast distribution trees by the Multicast Protocols running on the router. Different IP Multicast routing protocols use different techniques to construct these multicast distribution trees.

8.1.7 Multicast Tunneling

If Multicast traffic is to be routed through a part of a network that does not support multicasting (routers which are not multicast capable) then the multicast packets are encapsulated in an IP datagram and sent as a unicast packet. When the multicast router at the remote end of the tunnel receives the packet, the router strips off the IP encapsulation and forwards the packet as an IP Multicast packet. This process of encapsulating multicast packets in IP is called tunneling.

8.1.8 IGMP

The Internet Group Management Protocol (IGMP) is used by IPv4 systems (hosts, L3 switches, and routers) to report their IP multicast group memberships to any neighboring multicast routers. The switch performs the multicast router role of the IGMP protocol, which means it collects the membership information needed by the active multicast routing protocol.

The switch supports IGMP Version 3. Version 3 adds support for source filtering, which is the ability for a system to report interest in receiving packets only from specific source addresses, as required to support Source-Specific Multicast [SSM], or from all but specific source addresses, sent to a particular multicast address. Version 3 is designed to be interoperable with Versions 1 and 2.

8.1.8.1 IGMP Proxy

IGMP proxy enables a multicast router to learn multicast group membership information and forward multicast packets based upon the group membership information. The IGMP Proxy is capable of functioning only in certain topologies that do not require Multicast Routing Protocols (i.e., DVMRP, PIM-DM, and PIM-SM) and have a tree-like topology, as there is no support for features like reverse path forwarding (RPF) to correct packet route loops.

The proxy contains many downstream interfaces and a unique upstream interface explicitly configured. It performs the host side of the IGMP protocol on its upstream interface and the router side of the IGMP protocol on its downstream interfaces.

The IGMP proxy offers a mechanism for multicast forwarding based only on IGMP membership information. The router must decide about forwarding packets on each of its interfaces based on the IGMP membership information. The proxy creates the forwarding entries based on the membership information and adds it to the multicast forwarding cache (MFC) in order not to make the forwarding decision for subsequent multicast packets with same combination of source and group.

8.1.9 MLD Protocol

Multicast Listener Discovery (MLD) protocol enables IPv6 routers to discover the presence of multicast listeners, the hosts that wish to receive the multicast data packets, on its directly-attached interfaces. The protocol specifically discovers which multicast addresses are of interest to its neighboring nodes and provides this information to the active multicast routing protocol that makes decisions on the flow of multicast data packets.

The Multicast router sends General Queries periodically to request multicast address listeners information from systems on an attached network. These queries are used to build and refresh the multicast address listener state on attached networks. Multicast listeners respond to these queries by reporting their multicast addresses listener state and their desired set of sources with Current-State Multicast address Records in the MLD2 Membership Reports. The Multicast router also processes unsolicited Filter-Mode-Change records and Source-List-Change Records from systems that want to indicate interest in receiving or not receiving traffic from particular sources.

The EFOS implementation of MLD v2 supports the multicast router portion of the protocol (i.e., not the listener portion). It is backward-compatible with MLD v1.

8.1.10 PIM Protocol

The Protocol Independent Multicast protocol is a simple, protocol-independent multicast routing protocol. PIM uses an existing unicast routing table and a Join/Prune/Graft mechanism to build a tree. PIM switches support two types of PIM: sparse mode (PIM-SM) and dense mode (PIM-DM).

PIM-SM is most effective in networks with a sparse population of multicast receivers. In contrast, PIM-DM is most effective in networks with densely populated multicast receivers. In other words, PIM-DM can be used if the majority of network hosts request to receive a multicast stream, while PIM-SM might be a better choice in networks in which a small percentage of network hosts, located throughout the network, wish to receive the multicast stream.

8.1.10.1 Using PIM-SM as the Multicast Routing Protocol

PIM-SM is used to efficiently route multicast traffic to multicast groups that may span wide area networks where bandwidth is a constraint.

PIM-SM uses shared trees by default and implements source-based trees for efficiency; it assumes that no hosts want the multicast traffic unless they specifically ask for it. It creates a shared distribution tree centered on a defined rendezvous point (RP) from which source traffic is relayed to the receivers. Senders first send the multicast data to the RP, which in turn sends the data down the shared tree to the receivers.

Shared trees centered on an RP do not necessarily provide the shortest, most optimal path. In such cases, PIM-SM provides a means to switch to more efficient source-specific trees. A data threshold rate is configured to determine when to switch from shared-tree to source-tree.

PIM-SM uses a Bootstrap Router (BSR), which advertises information to other multicast routers about the RP. In a given network, a set of routers can be administratively enabled as candidate bootstrap routers. If it is not apparent which router should be the BSR, the candidates flood the domain with advertisements. The router with the highest priority is elected. If all the priorities are equal, then the candidate with the highest IP address becomes the BSR.

Only one RP address can be used at a time within a PIM domain. You can configure a static RP on the switch. However, if the PIM domain uses the BSR to dynamically learn the RP, configuring a static RP is not required. By default the RP advertised by the BSR is used, but you can specify that the static RP to override any dynamically learned RP from the BSR.

If an interface on a switch configured with PIM-SM neighbors another PIM-SM domain, the PIM BSR messages should not flood into the neighboring PIM domain because the neighbor domain might not share the same set of RPs, candidate RPs, BSR, and candidate BSRs. The switch software allows you to configure an interface that borders the PIM boundary prevent transmission (sending and receiving) of PIM BSR messages. PIM-SM is defined in RFC 4601.

8.1.10.2 Using PIM-DM as the Multicast Routing Protocol

Unlike PIM-SM, PIM-DM creates source-based shortest-path distribution trees that make use of reverse-path forwarding (RPF). PIM-DM assumes that when a sender starts sending data, all downstream routers and hosts want to receive a multicast datagram. PIM-DM initially floods multicast traffic throughout the network. Routers that do not have any downstream neighbors prune back the unwanted traffic. In addition to PRUNE messages, PIM-DM makes use of graft and assert messages. Graft messages are used whenever a new host wants to join the group. Assert messages are used to shutoff duplicate flows on the same multi-access network.

There are two versions of PIM-DM. Version 2 does not use the IGMP message; instead, it uses a message that is encapsulated in IP package, with protocol number 103. In Version 2, a Hello message is introduced in place of a query message.

PIM-DM is appropriate for:

- Densely distributed receivers
- Few senders-to-many receivers (due to frequent flooding)
- High volume of multicast traffic
- Constant stream of traffic

To minimize the repeated flooding of datagrams and subsequent pruning associated with a particular source-group (S,G) pair, PIM-DM uses a State Refresh message. This message is sent by the router(s) directly connected to the source and is propagated throughout the network. When received by a router on its RPF interface, the State Refresh message causes an existing prune state to be refreshed. State Refresh messages are generated periodically by the router directly attached to the source.

8.1.11 DVMRP

DVMRP is an interior gateway protocol that is suitable for routing multicast traffic within an autonomous system (AS). DVMRP should not be used between different autonomous systems due to limitations with hop count and scalability.

NOTE: In addition to DVMRP, the switch supports the Protocol-Independent Multicast (PIM) sparse-mode (PIM-SM) and dense-mode (PIM-SM) routing protocol. Only one multicast routing protocol can be operational on the switch at any time. If you enable DVMRP, PIM must be disabled. Similarly, if PIM is enabled, DVMRP must be disabled.

DVMRP exchanges probe packets with all its DVMRP-enabled routers, it establishes two-way neighboring relationships, and it builds a neighbor table. DVMRP exchanges report packets and creates a unicast topology table, with which it builds the multicast routing table. This table is used to route the multicast packets. Since every DVMRP router uses the same unicast routing protocol, routing loops are avoided.

8.1.11.1 Understanding DVMRP Multicast Packet Routing

DVMRP is based on RIP; it forwards multicast datagrams to other routers in the AS and constructs a forwarding table based on information it learns in response. More specifically, it uses this sequence.

- A new multicast packet is forwarded to the entire multicast network, with respect to the time-to-live (TTL) of the packet.
- The TTL restricts the area to be flooded by the message.
- All routers that do not have members on directly-attached subnetworks send back *Prune messages* to the upstream router.
- The branches that transmit a prune message are deleted from the delivery tree.
- The delivery tree which is spanning to all the members in the multicast group, is constructed in the form of a DVMRP forwarding table.

8.1.11.2 Using DVMRP as the Multicast Routing Protocol

DVMRP is used to communicate multicast information between L3 switches or routers. If a switch handles inter-VLAN routing for IP traffic, including IP multicast traffic, multicast routing might be required on the switch.

DVRMP is best suited for small networks where the majority of hosts request a given multicast traffic stream. DVMRP is similar to PIM-DM in that it floods multicast packets throughout the network and prunes branches where the multicast traffic is not wanted. DVMRP was developed before PIM-DM, and it has several limitations that do not exist with PIM-DM. You might use DVMRP as the multicast routing protocol if it has already been widely deployed within the network.

8.2 Default L3 Multicast Values

IP and IPv6 multicast is disabled by default. Table 26 shows the default values for L3 multicast and the multicast protocols.

Table 26: L3 Multicast Defaults

Parameter	**Default Value**
IPv4 Multicast Defaults	
L3 Multicast Admin Mode	Disabled
Maximum Multicast Routing Table Entries	2048
Static Multicast Routes	None configured
Interface TTL Threshold	1
IGMP Defaults	
IGMP Admin Mode	Disabled globally and on all interfaces
IGMP Version	v3
IGMP Robustness	2
IGMP Query Interval	125 seconds
IGMP Query Max Response Time	10 seconds
IGMP Startup Query Interval	31 seconds
IGMP Startup Query Count	2
IGMP Last Member Query Interval	1 second
IGMP Last Member Query Count	2
IGMP Proxy Interface Mode	Disabled
IGMP Proxy Unsolicited Report Interval	1 second
MLD Defaults	
MLD Admin Mode	Disabled globally and on all interfaces
MLD Version	v2
MLD Query Interval	125 seconds
MLD Query Max Response Time	10,000 milliseconds
MLD Last Member Query Interval	1000 milliseconds
MLD Last Member Query Count	2
MLD Proxy Interface Mode	Disabled
MLD Proxy Unsolicited Report Interval	1 second
PIM Defaults	
PIM Protocol	Disabled globally and on all interfaces
PIM-SM Data Threshold Rate	0 Kb/s
PIM-SM Register Threshold Rate	0 Kb/s
PIM Hello Interval	30 seconds (when enabled on an interface)
PIM-SM Join/Prune Interval	60 seconds (when enabled on an interface)
PIM-SM BSR Border	Disabled
PIM-SM DR Priority	1 (when enabled on an interface)
PIM Candidate Rendezvous Points (RPs)	None configured
PIM Static RP	None configured
PIM Source-Specific Multicast (SSM) Range	None configured. Default SSM group address is 232.0.0.0/8 for IPv4 multicast and ff3x::/32 for IPv6 multicast.
PIM BSR Candidate Hash Mask Length	30 (IPv4) 126 (IPv6)

Table 26: L3 Multicast Defaults (Continued)

Parameter	Default Value
PIM BSR Candidate Priority	0
DVMRP Defaults	
DVMRP Admin Mode	Disabled globally and on all interfaces
DVMRP Version	3
DVMRP Interface Metric	1

8.3 L3 Multicast Configuration Examples

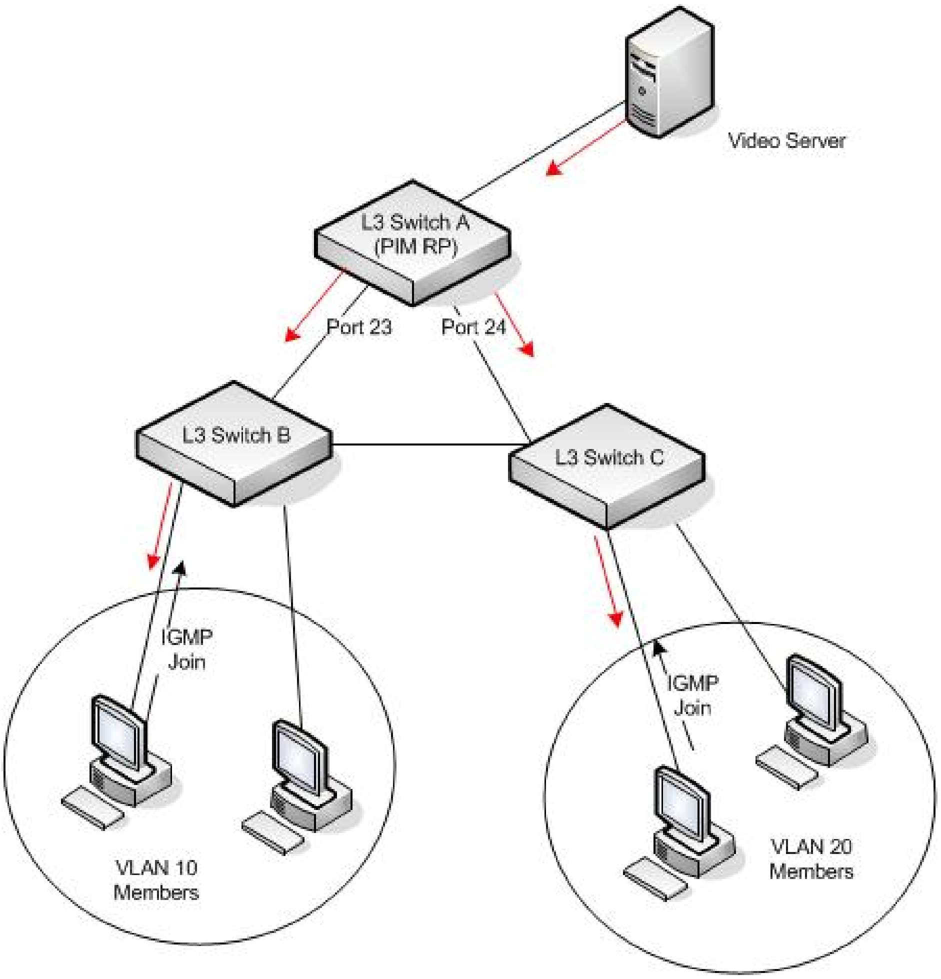
8.3.1 Configuring Multicast VLAN Routing With IGMP and PIM-SM

This example describes how to configure a switch with two VLAN routing interfaces that route IP multicast traffic between the VLANs. PIM and IGMP are enabled on the switch and interfaces to manage the multicast routing. IGMP snooping is enabled on the VLAN interfaces to control the multicast subscriptions within each VLAN. VLAN 10 is statically configured as the RP for the multicast group.

NOTE: PIM does not require OSPF specifically; static routing could also be configured for unicast routing.

The configuration in this example takes place on L3 switch A shown in Figure 53, Multicast VLAN Routing with IGMP and PIM-SM Example. The red arrows indicate the path that multicast traffic takes. L3 Switch A is configured as the RP for the PIM domain, so it is in charge of sending the multicast stream to L3 Switch B and L3 Switch C, and these switches forward the multicast data to the hosts that have requested to receive the data.

Figure 53: Multicast VLAN Routing with IGMP and PIM-SM Example



In addition to multicast configuration, this example includes commands to configure STP and OSPF on L3 Switch A. STP is configured on the ports that connects the switch to other switches. OSPF is configured to route unicast traffic between the VLANs.

To configure the switch:

1. Create two VLANs and configure them as routing VLANs.

```
(Routing) #vlan database
(Routing) (Vlan)#vlan 10,20
(Routing) (Vlan)#vlan routing 10
(Routing) (Vlan)#vlan routing 20
```

2. While in VLAN Database mode, enable IGMP snooping on the VLANs.

```
(Routing) (Vlan)#set igmp 10
(Routing) (Vlan)#set igmp 20
(Routing) (Vlan)#exit
```

3. Add VLANs to interfaces 0/23 and 0/24.

```
(Routing) (Config)#interface 0/23
(Routing) (Interface 0/23)#vlan participation include 20
```

```
(Routing) (Interface 0/23)#exit

(Routing) (Config)#interface 0/24
(Routing) (Interface 0/24)#vlan participation include 10
(Routing) (Interface 0/24)#exit
```

4. Enable routing on the switch and configure the OSPF router ID.

```
(Routing) (Config)#ip routing
(Routing) (Config)#router ospf
(Routing) (Config-router)#router-id 3.3.1.1
(Routing) (Config-router)#exit
```

5. Configure VLAN 10 as a VLAN routing interface and specify the OSPF area. When you assign an IP address to the VLAN, routing is automatically enabled.

```
(Routing) (Config)#interface vlan 10
(Routing) (interface vlan 10)#ip address 192.168.10.4 255.255.255.0
(Routing) (interface vlan 10)#ip ospf area 0
```

6. Enable IGMPv2 and PIM-SM on the VLAN routing interface.

```
(Routing) (interface vlan 10)#ip igmp
(Routing) (interface vlan 10)#ip igmp version 2
(Routing) (interface vlan 10)#ip pim
(Routing) (interface vlan 10)#exit
```

7. Configure VLAN 20 as a VLAN routing interface and specify the OSPF area.

```
(Routing) (Config)#interface vlan 20
(Routing) (interface vlan 20)#ip address 192.168.20.4 255.255.255.0
(Routing) (interface vlan 20)#ip ospf area 0
```

8. Enable IGMPv2 and PIM-SM on the VLAN routing interface.

```
(Routing) (interface vlan 20)#ip igmp
(Routing) (interface vlan 20)#ip igmp version 2
(Routing) (interface vlan 20)#ip pim
(Routing) (interface vlan 20)#exit
```

9. Globally enable IGMP snooping, IP multicast, IGMP, and PIM-SM on the switch.

```
(Routing) (Config)#set igmp
(Routing) (Config)#ip multicast
(Routing) (Config)#ip igmp
(Routing) (Config)#ip pim sparse
```

10. Configure VLAN 10 as the RP and specify the range of multicast groups for PIM-SM to control.

```
(Routing) (Config)#ip pim rp-address 192.168.10.4 225.0.0.0 240.0.0.0
```

8.3.2 Configuring DVMRP

The following example configures two DVMRP interfaces on the switch to enable inter-VLAN multicast routing.

To configure the switch:

1. Globally enable IP routing and IP multicast.

```
(Routing) #configure
(Routing) (Config)#ip routing
(Routing) (Config)#ip multicast
```

2. Globally enable IGMP so that this L3 switch can manage group membership information for its directly-connected hosts. Enabling IGMP is not required if there are no directly-connected hosts.

```
(Routing) (Config)#ip igmp
```

3. Globally enable DVMRP.

```
(Routing) (Config)#ip dvmrp
```

4. Enable DVMRP and IGMP on VLAN routing interfaces 10 and 20.

```
(Routing) (Config)#interface vlan 10
(Routing) (interface vlan 10)#ip address 192.168.10.1 255.255.255.0
(Routing) (interface vlan 10)#ip dvmrp
(Routing) (interface vlan 10)#ip igmp
(Routing) (interface vlan 10)#exit

(Routing) (Config)#interface vlan 20
(Routing) (interface vlan 20)#ip address 192.168.20.1 255.255.255.0
(Routing) (interface vlan 20)#ip dvmrp
(Routing) (interface vlan 20)#ip igmp
(Routing) (interface vlan 20)#exit
```

Chapter 9: Configuring Quality of Service

9.1 ACLs

Access Control Lists (ACLs) are a collection of permit and deny conditions, called rules, that provide security by blocking unauthorized users and allowing authorized users to access specific resources.

ACLs can also provide traffic flow control, restrict contents of routing updates, and decide which types of traffic are forwarded or blocked. ACLs can reside in a firewall router, a router connecting two internal networks, or a Layer 3 switch.

EFOS software supports ACL configuration in both the ingress and egress direction. Egress ACLs provide the capability to implement security rules on the egress flows (traffic leaving a port) rather than the ingress flows (traffic entering a port). Ingress and egress ACLs can be applied to any physical port, LAG, or VLAN routing port.

Depending on whether an ingress or egress ACL is applied to a port, when the traffic enters (ingress) or leaves (egress) a port, the ACL compares the criteria configured in its rules, in order, to the fields in a packet or frame to check for matching conditions. The ACL forwards or blocks the traffic based on the rules.

NOTE: Every ACL is terminated by an implicit **deny all** rule, which covers any packet not matching a preceding explicit rule

You can set up ACLs to control traffic at Layer 2, Layer 3, or Layer 4. MAC ACLs operate on Layer 2. IP ACLs operate on Layers 3 and 4. EFOS supports both IPv4 and IPv6 ACLs.

9.1.1 MAC ACLs

MAC ACLs are Layer 2 ACLs. You can configure the rules to inspect the following fields of a packet:

- Source MAC address
- Source MAC mask
- Destination MAC address
- Destination MAC mask
- VLAN ID
- Class of Service (CoS) (802.1p)
- EtherType

L2 ACLs can apply to one or more interfaces. Multiple access lists can be applied to a single interface; sequence number determines the order of execution. You can assign packets to queues using the assign queue option.

9.1.2 IP ACLs

IP ACLs classify for Layers 3 and 4 on IPv4 or IPv6 traffic.

Each ACL is a set of up to ten rules applied to inbound traffic. Each rule specifies whether the contents of a given field should be used to permit or deny access to the network, and may apply to one or more of the following fields within a packet:

- Destination IP with wildcard mask
- Destination L4 Port
- Every Packet
- IP DSCP
- IP Precedence

- IP TOS
- Protocol
- Source IP with wildcard mask
- Source L4 port
- IPv4 fragmented packets
- TCP flags
- IGMP type
- ICMP type
- ICMP code
- ICMP message
- Time-to-Live (TTL) field

9.1.3 ACL Redirect Function

The redirect function allows traffic that matches a permit rule to be redirected to a specific physical port or LAG instead of processed on the original port. The redirect function and mirror function are mutually exclusive. In other words, you cannot configure a given ACL rule with mirror and redirect attributes.

9.1.4 ACL Mirror Function

ACL mirroring provides the ability to mirror traffic that matches a permit rule to a specific physical port or LAG. Mirroring is similar to the redirect function, except that in flow-based mirroring a copy of the permitted traffic is delivered to the mirror interface while the packet itself is forwarded normally through the device. You cannot configure a given ACL rule with both mirror and redirect attributes.

Using ACLs to mirror traffic is considered to be flow-based mirroring since the traffic flow is defined by the ACL classification rules. This is in contrast to port mirroring, where all traffic encountered on a specific interface is replicated on another interface.

9.1.5 ACL Logging

ACL Logging provides a means for counting the number of matches against an ACL rule. When you configure ACL Logging, you augment the ACL deny rule specification with a *log* parameter that enables hardware hit count collection and reporting. The switch uses a fixed five minute logging interval, at which time trap log entries are written for each ACL logging rule that accumulated a non-zero hit count during that interval. You cannot configure the logging interval.

9.1.6 Time-Based ACLs

The time-based ACL feature allows the switch to dynamically apply an explicit ACL rule within an ACL for a predefined time interval by specifying a time range on a per-rule basis within an ACL, so that the time restrictions are imposed on the ACL rule.

With a time-based ACL, you can define when and for how long an individual rule of an ACL is in effect. To apply a time to an ACL, first you define a specific time interval and then apply it to an individual ACL rule so that it is operational only during the specified time range, for example, during a specified time period or on specified days of the week.

A time range can be absolute (specific time) or periodic (recurring). If an absolute and periodic time range entry are defined within the same time range, the periodic timer is active only when the absolute timer is active.

NOTE: Adding a conflicting periodic time range to an absolute time range will cause the time range to become inactive. For example, consider an absolute time range from 8:00 AM Tuesday March 1st 2011 to 10 PM Tuesday March 1st 2011. Adding a periodic entry using the 'weekend' keyword will cause the time-range to become inactive because Tuesdays are not on the weekend.

A named time range can contain up to 10 configured time ranges. Only one absolute time range can be configured per time range. During the ACL configuration, you can associate a configured time range with the ACL to provide additional control over permitting or denying a user access to network resources.

Benefits of using time-based ACLs include:

- Providing more control over permitting or denying a user access to resources, such as an application (identified by an IP address/mask pair and a port number).
- Providing control of logging messages. Individual ACL rules defined within an ACL can be set to log traffic only at certain times of the day so you can simply deny access without needing to analyze many logs generated during peak hours.

9.1.7 ACL Rule Remarks

ACL remarks can be added to ACLs rule to assist users in understanding the rules. Users can add up to 10 remarks per rule, up to 100 characters each (including alphanumeric characters and special characters such as space, hyphen, and underscore. One or more remarks are associated with the rule that is created immediately after the remarks are created and are deleted when the associated rule is deleted. They can be viewed using the **show running-config** command but do not display using the **show access-lists** commands.

9.1.8 ACL Rule Priority

A sequence number cab be added to ACL rule entries to facilitate resequence them. When a new ACL rule entry is added, a unique sequence number can be specified so that the new ACL rule entry is placed in the appropriate position in the access list.

If no sequence number is specified, then the rule is assigned a sequence number that is 10 greater than the highest existing sequence number for the rule (that is, it is made the lowest-priority rule); or, if the rule is the first one created for the ACL, it is assigned sequence number 10.

9.1.9 ACL Limitations

The following limitations apply to ingress and egress ACLs.

- Maximum of 100 ACLs.
- Maximum number configurable rules per list is 1023.
- Maximum ACL rules (system-wide) is 16384.
- You can configure mirror or redirect attributes for a given ACL rule, but not both.
- The switch hardware supports a limited number of counter resources, so it may not be possible to log every ACL rule. You can define an ACL with any number of logging rules, but the number of rules that are actually logged cannot be determined until the ACL is applied to an interface. Furthermore, hardware counters that become available after an ACL is applied are not retroactively assigned to rules that were unable to be logged (the ACL must be un-applied then re-applied). Rules that are unable to be logged are still active in the ACL for purposes of permitting or denying a matching packet. If console logging is enabled and the severity is set to Info (6) or a lower severity, a log entry may appear on the screen.
- The order of the rules is important: when a packet matches multiple rules, the first rule takes precedence. Also, once you define an ACL for a given port, all traffic not specifically permitted by the ACL is denied access.

9.1.10 ACL Configuration Process

To configure ACLs, follow these steps:

1. Create a MAC ACL by specifying a name.
2. Create an IP ACL by specifying a number.
3. Add new rules to the ACL.
4. Configure the match criteria for the rules.
5. Apply the ACL to one or more interfaces.

9.1.11 Preventing False ACL Matches

Be sure to specify ACL access-list, permit, and deny rule criteria as fully as possible to avoid false matches. This is especially important in networks with protocols such as FCoE that have newly-introduced EtherType values. For example, rules that specify a TCP or UDP port value should also specify the TCP or UDP protocol and the IPv4 or IPv6 EtherType. Rules that specify an IP protocol should also specify the EtherType value for the frame.

In general, any rule that specifies matching on an upper-layer protocol field should also include matching constraints for each of the lower-layer protocols. For example, a rule to match packets directed to the well-known UDP port number 22 (SSH) should also include matching constraints on the IP protocol field (protocol=0x11 or UDP) and the EtherType field (EtherType=0x0800 or IPv4). Table 27 lists commonly-used EtherType numbers:

Table 27: Common EtherType Numbers

EtherType	Protocol
0x0800	Internet Protocol version 4 (IPv4)
0x0806	Address Resolution Protocol (ARP)
0x0842	Wake-on LAN Packet
0x8035	Reverse Address Resolution Protocol (RARP)
0x8100	VLAN tagged frame (IEEE 802.1Q)
0x86DD	Internet Protocol version 6 (IPv6)
0x8808	MAC Control
0x8809	Slow Protocols (IEEE 802.3)
0x8870	Jumbo frames
0x888E	EAP over LAN (EAPOL – 802.1X)
0x88CC	Link Layer Discovery Protocol
0x8906	Fibre Channel over Ethernet
0x8914	FCoE Initialization Protocol
0x9100	Q in Q

Table 28 lists commonly-used IP protocol numbers:

Table 28: Common IP Protocol Numbers

IP Protocol Number	Protocol
0x00	IPv6 Hop-by-hop option
0x01	ICMP

Table 28: Common IP Protocol Numbers (Continued)

IP Protocol Number	Protocol
0x02	IGMP
0x06	TCP
0x08	EGP
0x09	IGP
0x11	UDP

9.1.12 IPv6 ACL Qualifiers

IPv6 ACLs support the following additional qualifiers:

- Qualify fragmented IPv6 packets (packets that have the next header field set to 44).
- Qualify routed IPv6 packets (packets that have a routing extension header (next header field set to 43)).

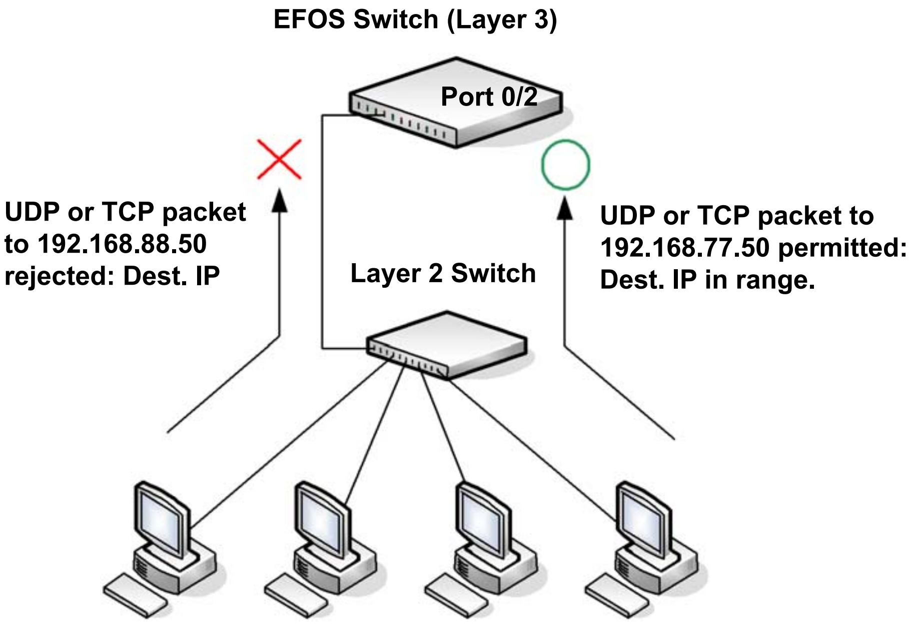
Depending upon the underlying switching silicon, IP ACLs can be applied on ingress and egress interfaces/VLANs of a switch/router.

9.1.13 ACL Configuration Examples

9.1.13.1 Configuring an IP ACL

The commands in this example set up an IP ACL that permits hosts in the 192.168.77.0/24 subnet to send TCP and UDP traffic only to the host with an IP address of 192.168.77.50. The ACL is applied to port 2 on the switch. This example also shows how to enable the ACL hit counters for all ACL types. ACL counters are enabled by default.

Figure 54: IP ACL Example Network Diagram


EFOS Switch (Layer 3)
Port 0/2
UDP or TCP packet to 192.168.88.50 rejected: Dest. IP
Layer 2 Switch
UDP or TCP packet to 192.168.77.50 permitted: Dest. IP in range.

To configure the switch:

1. Create an extended ACL and configure a rule for the ACL that permits packets carrying TCP traffic that matches the specified Source IP address (192.168.77.0/24), and sends these packets to the specified Destination IP address (192.168.77.50).

```
(Routing) #config
(Routing) (Config)#access-list 100 permit tcp 192.168.77.0 0.0.0.255 192.168.77.50 0.0.0.0
```

2. Define the rule to set similar conditions for UDP traffic as for TCP traffic.

```
(Routing) (Config)#access-list 100 permit udp 192.168.77.0 0.0.0.255 192.168.77.3 0.0.0.255
```

3. Apply the rule to inbound (ingress) traffic on port 2. Only traffic matching the criteria will be accepted on this port.

```
(Routing) (Config)#interface 0/2
(Routing) (Interface 0/2)#ip access-group 100 in
(Routing) (Interface 0/2)#exit
```

4. Ensure ACL counters are enabled.

```
(Routing) (Config)#access-list counters enable
```

5. Verify the configuration.

```
(Routing) (Config)#exit
(Routing) #show ip access-lists 100

ACL ID: 100
ACL Counters: Enabled
Inbound Interface(s): 0/2


Sequence Number: 10
Action........................................ permit
Match All..................................... False
Protocol...................................... 6(tcp)
Source IP Address............................. 192.168.77.0
Source IP Wildcard Mask....................... 0.0.0.255
Destination IP Address........................ 192.168.77.50
Destination IP Wildcard Mask.................. 0.0.0.0
ACL Hit Count................................. 0

Sequence Number: 20
Action........................................ permit
Match All..................................... False
Protocol...................................... 17(udp)
Source IP Address............................. 192.168.77.0
Source IP Wildcard Mask....................... 0.0.0.255
Destination IP Address........................ 192.168.77.3
Destination IP Wildcard Mask.................. 0.0.0.255
ACL Hit Count................................. 0
```

9.1.13.2 Configuring a MAC ACL

The following example creates a MAC ACL named mac1 that denies all IPX traffic on all ports. All other types of traffic are permitted.

To configure the switch:

1. Create a MAC Access List named mac1

```
(Routing) #config
(Routing) (Config)#mac access-list extended mac1
```

2. Configure a rule to deny all IPX traffic, regardless of the source or destination MAC address. Before creating the rule, add a remark that identifies the rule.

```
(Routing) (Config-mac-access-list)#remark “Denies all IPX traffic from for any source-dest MAC”
(Routing) (Config-mac-access-list)#deny any any ipx
```

3. Configure a rule to permit all other types of traffic, regardless of the source or destination MAC address.

```
(Routing) (Config-mac-access-list)#permit any any
(Routing) (Config-mac-access-list)#exit
```

4. Bind the ACL to all ports.

```
(Routing) (Config)#mac access-group mac1 in
(Routing) (Config)#exit
```

5. View information about the configured ACL.

```
(Routing) #show mac access-lists

ACL Counters: Enabled
Current number of all ACLs: 2  Maximum number of all ACLs: 100

MAC ACL Name                     Rules  Direction  Interface(s)     VLAN(s)
-------------------------------  -----  ---------  --------------   ----------
mac1                             2      inbound    0/1, 0/2,
                                                   0/3, 0/4,
                                                   0/5, 0/6,
                                                   0/7, 0/8,
                                                   0/9, 0/10,
--More-- or (q)uit

(Routing) #show mac access-lists mac1

ACL Name: mac1
ACL Counters: Enabled
Inbound Interface(s): 0/1, 0/2, 0/3, 0/4, 0/5, 0/6, 0/7, 0/8, 0/9, 0/10, 0/11, 0/12, 0/13, 0/14,
0/15, 0/16, 0/17, 0/18, 0/19, 0/20, 0/21, 0/22, 0/23, 0/24, 0/25, 0/26, 0/27, 0/28, 0/29, 0/30, 0/
31, 0/32, 0/33, 0/34, 0/35, 0/36, 0/37, 0/38, 0/39, 0/40, 0/41, 0/42, 0/43, 0/44, 0/45, 0/46, 0/
47, 0/48, 0/49, 0/50, 0/51, 0/52, 3/1, 3/2, 3/3, 3/4, 3/5, 3/6, 3/7, 3/8, 3/9, 3/10, 3/11, 3/12,
3/13, 3/14, 3/15, 3/16, 3/17, 3/18, 3/19, 3/20, 3/21, 3/22, 3/23, 3/24, 3/25, 3/26, 3/27, 3/28, 3/
29, 3/30, 3/31, 3/32, 3/33, 3/34, 3/35, 3/36, 3/37, 3/38, 3/39, 3/40, 3/41, 3/42, 3/43, 3/44, 3/
45, 3/46, 3/47, 3/48, 3/49, 3/50, 3/51, 3/52, 3/53, 3/54, 3/55, 3/56, 3/57, 3/58, 3/59, 3/60, 3/
61, 3/62, 3/63, 3/64


Sequence Number: 10
Action......................................... deny
Ethertype...................................... ipx
ACL Hit Count.................................. 0

Sequence Number: 20
Action......................................... permit
Match All...................................... TRUE
ACL Hit Count.................................. 0
```

9.1.13.3 Configuring a Time-Based ACL

The following example configures an ACL that denies HTTP traffic from 8:00 pm to 12:00 pm and 1:00 pm to 6:00 pm on weekdays and from 8:30 am to 12:30 pm on weekends. The ACL affects all hosts connected to ports that are members of VLAN 100. The ACL permits VLAN 100 members to browse the Internet only during lunch and after hours.

To configure the switch:

1. Create a time range called *work-hours*.
   ```
   (Routing) #config
   (Routing) (Config)#time-range work-hours
   ```
2. Configure an entry for the time range that applies to the morning shift Monday through Friday.
   ```
   (Routing) (Config-time-range)#periodic weekdays 8:00 to 12:00
   ```
3. Configure an entry for the time range that applies to the afternoon shift Monday through Friday.
   ```
   (Routing) (Config-time-range)#periodic weekdays 13:00 to 18:00
   ```
4. Configure an entry for the time range that applies to Saturday and Sunday.
   ```
   (Routing) (Config-time-range)#periodic weekend 8:30 to 12:30
   (Routing) (Config-time-range)#exit
   ```
5. Create an extended ACL that denies HTTP traffic during the *work-hours* time range.
   ```
   (Routing) (Config)#access-list 101 deny tcp any any eq http time-range work-hours
   ```
6. Apply the ACL to ingress traffic in VLAN 100.
   ```
   (Routing) (Config)#ip access-group 101 vlan 100 in
   (Routing) (Config)#exit
   ```
7. Verify the configuration.
   ```
   (Routing) #show ip access-lists 101

   ACL ID: 101
   ACL Counters: Enabled
   Inbound VLAN ID(s): 100

   Sequence Number: 10
   Action........................................ deny
   Match All..................................... False
   Protocol...................................... 6(tcp)
   Destination L4 Port Keyword................... 80(www/http)
   Time Range Name............................... work-hours
   Rule Status................................... inactive
   ACL Hit Count................................. 0
   ```

9.2 CoS

The CoS feature lets you give preferential treatment to certain types of traffic over others. To set up this preferential treatment, you can configure the ingress ports, the egress ports, and individual queues on the egress ports to provide customization that suits your environment.

The level of service is determined by the egress port queue to which the traffic is assigned. When traffic is queued for transmission, the rate at which it is serviced depends on how the queue is configured and possibly the amount of traffic present in other queues for that port. Some traffic is classified for service (i.e., packet marking) before it arrives at the switch. If you decide to use these classifications, you can map this traffic to egress queues by setting up a CoS Mapping table.

Each ingress port on the switch has a default priority value (set by configuring VLAN Port Priority in the Switching sub-menu) that determines the egress queue its traffic gets forwarded to. Packets that arrive without a priority designation, or packets from ports you’ve identified as “untrusted,” get forwarded according to this default.

9.2.1 Trusted and Untrusted Port Modes

Ports can be configured in *trusted* mode or *untrusted* mode with respect to ingress traffic.

Ports in Trusted Mode: When a port is configured in trusted mode, the system accepts at face value a priority designation encoded within packets arriving on the port. You can configure ports to trust priority designations based on one of the following fields in the packet header:

- 802.1 Priority: values 0–7
- IP DSCP: values 0–63

A mapping table associates the designated field values in the incoming packet headers with a traffic class priority (actually a CoS traffic queue).

Ports in Untrusted Mode: If you configure an ingress port in untrusted mode, the system ignores any priority designations encoded in incoming packets, and instead sends the packets to a traffic queue based on the ingress port's default priority.

9.2.2 Traffic Shaping on Egress Traffic

For slot/port interfaces, you can specify a traffic shaping rate for the port (in Kb/s) for egress traffic. The traffic shaping rate specifies an upper limit of the transmission bandwidth used.

9.2.3 Defining Traffic Queues

For each queue, you can specify:

- Minimum bandwidth guarantee: A percentage of the port's maximum negotiated bandwidth reserved for the queue.
- Scheduler type – strict/weighted:
  - Strict priority scheduling gives an absolute priority, with traffic in the highest priority queues always sent first, and traffic in the lowest priority queues always sent last.
  - Weighted scheduling requires a specification of priority for each queue relative to the other queues, based on their minimum bandwidth values.

9.2.3.1 Supported Queue Management Methods

The switch supports the following methods, configurable per-interface-queue, for determining which packets are dropped when the queue is full:

- Taildrop: Any packet forwarded to a full queue is dropped regardless of its importance.
- Weighted Random Early Detection (WRED) drops packets selectively based their drop precedence level. For each of four drop precedence levels on each WRED-enabled interface queue, you can configure the following parameters:
  - Minimum Threshold: A percentage of the total queue size below which no packets of the selected drop precedence level are dropped.
  - Maximum Threshold: A percentage of the total queue size above which all packets of the selected drop precedence level are dropped.
  - Drop Probability: When the queue depth is between the minimum and maximum thresholds, this value provides a scaling factor for increasing the number of packets of the selected drop precedence level that are dropped as the queue depth increases.

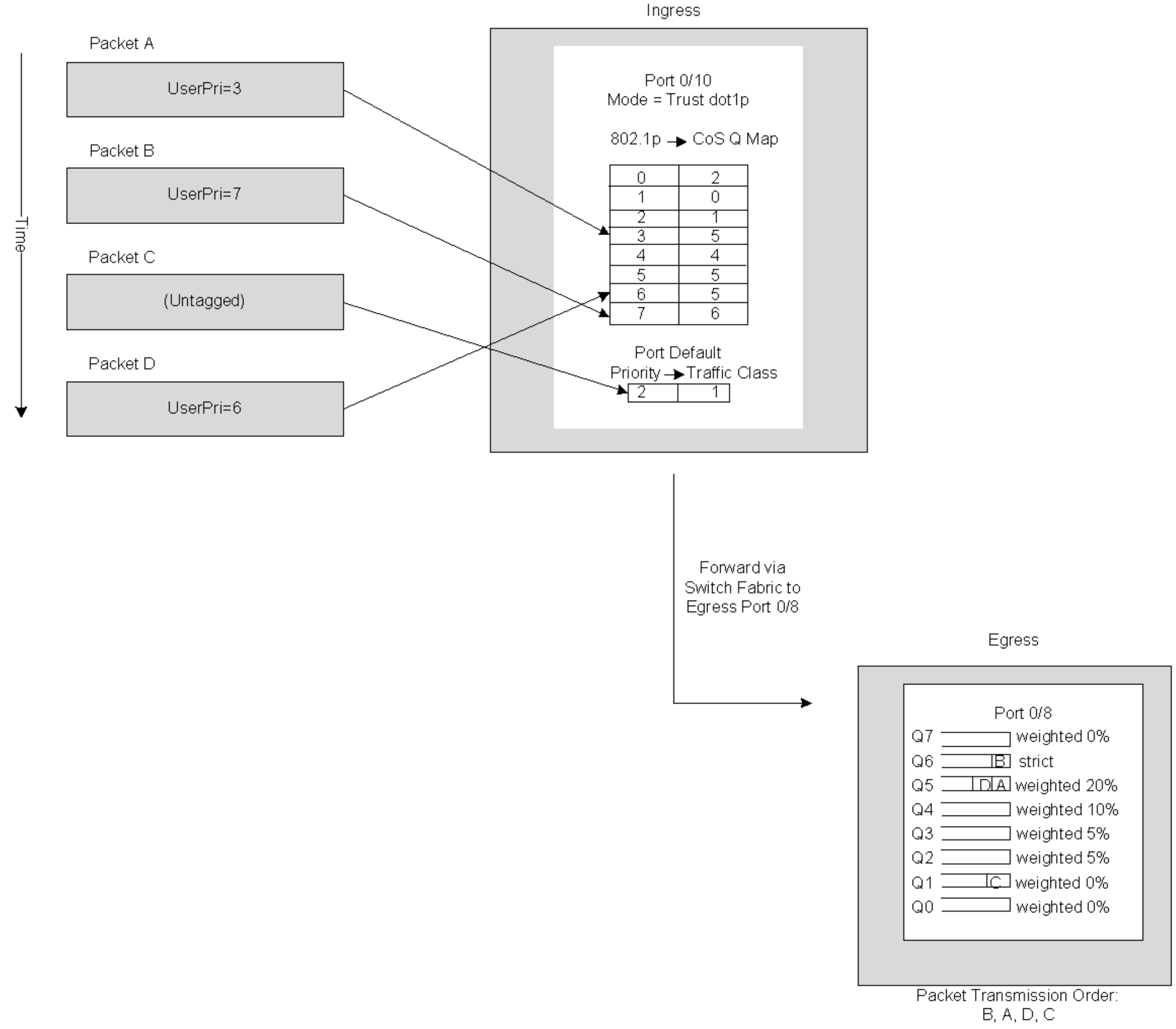
9.2.4 CoS Configuration Example

Figure 55 illustrates the network operation as it relates to CoS mapping and queue configuration.

Four packets arrive at the ingress port 0/10 in the order A, B, C, and D. Port 0/10 is configured to trust the 802.1p field of the packet, which serves to direct packets A, B, and D to their respective queues on the egress port. These three packets utilize the 802.1p to CoS Mapping Table for port 0/10.

In this example, the 802.1p user priority 3 is configured to send the packet to queue 5 instead of the default queue 3. Since packet C does not contain a VLAN tag, the 802.1p user priority does not exist, so Port 0/10 relies on its default port priority (2) to direct packet C to egress queue 1.

Figure 55: CoS Mapping and Queue Configuration



Continuing this example, the egress port 0/8 is configured for strict priority on queue 6, and a weighted scheduling scheme is configured for queues 5-0. Assuming queue 5 has a higher weighting than queue 1 (relative weight values shown as a percentage, with 0% indicating the bandwidth is not guaranteed), the queue service order is 6 followed by 5 followed by 1. Assuming each queue unloads all packets shown in the diagram, the packet transmission order as seen on the network leading out of Port 0/8 is B, A, D, C. Thus, packet B, with its higher user precedence than the others, is able to work its way through the device with minimal delay and is transmitted ahead of the other packets at the egress port.

The following commands configure port 10 (ingress interface) and Port 8 (egress interface).

1. Configure the Trust mode for port 10.
   ```
   (Routing) #config
   (Routing) (Config)#interface 0/10
   (Routing) (Interface 0/10)#classofservice trust dot1p
   ```
2. For port 10, configure the 802.1p user priority 3 to send the packet to queue 5 instead of the default queue (queue 3).
   ```
   (Routing) (Interface 0/10)#classofservice dot1p-mapping 3 5
   ```
3. For port 10, specify that untagged VLAN packets should have a default priority of 2.
   ```
   (Routing) (Interface 0/10)#vlan priority 2
   (Routing) (Interface 0/10)#exit
   ```
4. For Port 8, the egress port, configure a weighted scheduling scheme for queues 5–0.
   ```
   (Routing) (Config)#interface 0/8
   (Routing) (Interface 0/8)#cos-queue min-bandwidth 0 0 5 5 10 20 40 0
   ```
5. Configure Port 8 to have strict priority on queue 6.
   ```
   (Routing) (Interface 0/8)#cos-queue strict 6
   ```
6. View the configuration.
   ```
   (Routing) #show interfaces cos-queue 0/8

   Interface..................................... 0/8
   Interface Shaping Rate........................ 0
   WRED Decay Exponent........................... 9

   Queue Id   Min. Bandwidth   Scheduler Type   Queue Management Type
   --------   --------------   --------------   ---------------------
   0          0                Weighted         Tail Drop
   1          0                Weighted         Tail Drop
   2          5                Weighted         Tail Drop
   3          5                Weighted         Tail Drop
   4          10               Weighted         Tail Drop
   5          20               Weighted         Tail Drop
   6          40               Strict           Tail Drop
   7          0                Weighted         Tail Drop
   ```

9.3 DiffServ

Standard IP-based networks are designed to provide *best effort* data delivery service. Best effort service implies that the network delivers the data in a timely fashion, although there is no guarantee that it will. During times of congestion, packets may be delayed, sent sporadically, or dropped. For typical Internet applications, such as email and file transfer, a slight degradation in service is acceptable and in many cases unnoticeable. Conversely, any degradation of service has undesirable effects on applications with strict timing requirements, such as voice or multimedia.

9.3.1 DiffServ Functionality and Switch Roles

How you configure DiffServ support in EFOS software varies depending on the role of the switch in your network:

- **Edge device**: An edge device handles ingress traffic, flowing towards the core of the network, and egress traffic, flowing away from the core. An edge device segregates inbound traffic into a small set of traffic classes, and is responsible for determining a packet's classification. Classification is primarily based on the contents of the Layer 3 and Layer 4 headers, and is recorded in the Differentiated Services Code Point (DSCP) added to a packet's IP header.
- **Interior node**: A switch in the core of the network is responsible for forwarding packets, rather than for classifying them. It decodes the DSCP in an incoming packet, and provides buffering and forwarding services using the appropriate queue management algorithms.

Before configuring DiffServ on the switch, you must determine the QoS requirements for the network as a whole. The requirements are expressed in terms of rules, which are used to classify inbound or outbound traffic on a particular interface.

9.3.2 Elements of DiffServ Configuration

During configuration, you define DiffServ rules in terms of classes, policies, and services:

- **Class**: A class consists of a set of rules that identify which packets belong to the class. Inbound traffic is separated into traffic classes based on Layer 2, Layer 3, and Layer 4 header data. The class type **all** is supported; this specifies that every match criterion defined for the class must be true for a match to occur. The class type **any** is also supported; this specifies a match condition whereby all packets are considered to belong to the class.
- **Policy**: A policy defines the QoS attributes for one or more traffic classes. An attribute identifies the action taken when a packet matches a class rule. An example of an attribute is to mark a packet. The switch supports the ability to assign traffic classes to output CoS queues, and to mirror incoming packets in a traffic stream to a specific egress interface (physical port or LAG).

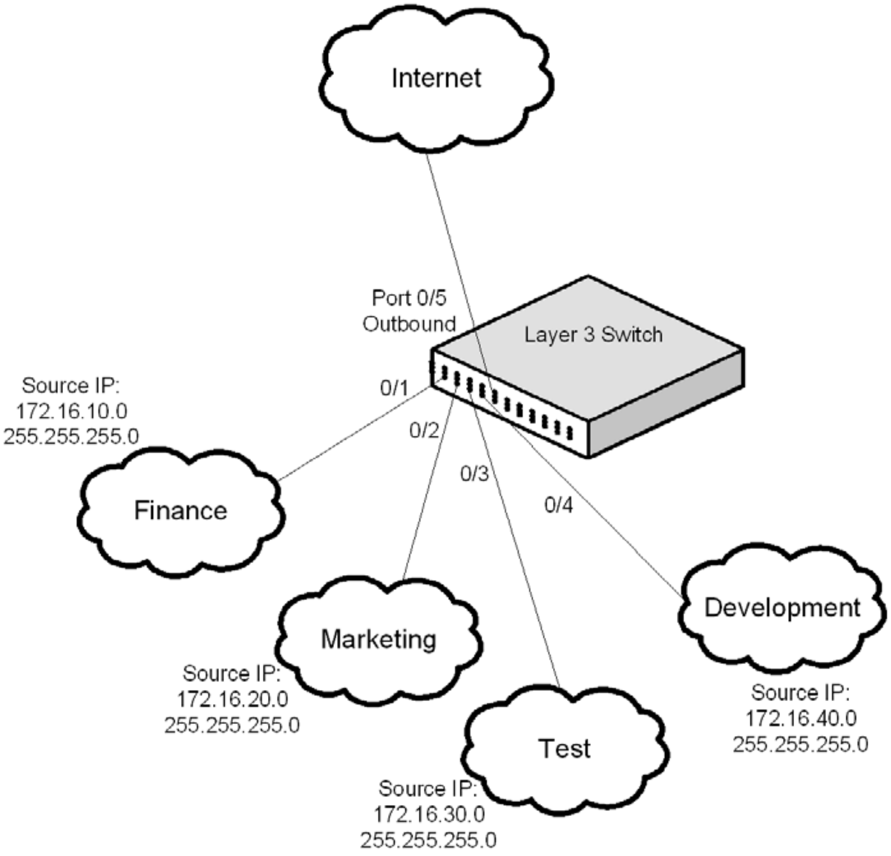
  EFOS software supports the **Traffic Conditioning Policy** type which is associated with an inbound traffic class and specifies the actions to be performed on packets meeting the class rules:

  - Marking the packet with a given DSCP, IP precedence, or CoS value. Traffic to be processed by the DiffServ feature requires an IP header if the system uses IP Precedence or IP DSCP marking.
  - Policing packets by dropping or re-marking those that exceed the class's assigned data rate.
  - Counting the traffic within the class.
- **Service:** Assigns a policy to an interface for inbound traffic.

9.3.3 Configuring DiffServ to Provide Subnets Equal Access to External Network

This example shows how a network administrator can provide equal access to the Internet (or other external network) to different departments within a company. Each of four departments has its own Class B subnet that is allocated 25% of the available bandwidth on the port accessing the Internet.

Figure 56: DiffServ Internet Access Example Network Diagram



The following commands show how to configure the DiffServ example depicted in Figure 56, DiffServ Internet Access Example Network Diagram.

1. Enable DiffServ operation for the switch.

```
(Routing) #config
(Routing) (Config)#diffserv
```

2. Create a DiffServ class of type *all* for each of the departments, and name them. Also, define the match criteria—Source IP address—for the new classes.

```
(Routing) (Config)#class-map match-all finance_dept
(Routing) (Config-classmap)#match srcip 172.16.10.0 255.255.255.0
(Routing) (Config-classmap)#exit

(Routing) (Config)#class-map match-all marketing_dept
(Routing) (Config-classmap)#match srcip 172.16.20.0 255.255.255.0
(Routing) (Config-classmap)#exit

(Routing) (Config)#class-map match-all test_dept
(Routing) (Config-classmap)#match srcip 172.16.30.0 255.255.255.0
(Routing) (Config-classmap)#exit

(Routing) (Config)#class-map match-all development_dept
(Routing) (Config-classmap)#match srcip 172.16.40.0 255.255.255.0
(Routing) (Config-classmap)#exit
```

3. Create a DiffServ policy for inbound traffic named *internet_access*, adding the previously created department classes as instances within this policy. This policy uses the assign-queue attribute to put each department's traffic on a different egress queue. This is how the DiffServ inbound policy connects to the CoS queue settings established below.

```
(Routing) (Config)#policy-map internet_access in
(Routing) (Config-policy-map)#class finance_dept
(Routing) (Config-policy-classmap)#assign-queue 1
(Routing) (Config-policy-classmap)#exit

(Routing) (Config-policy-map)#class marketing_dept
(Routing) (Config-policy-classmap)#assign-queue 2
(Routing) (Config-policy-classmap)#exit

(Routing) (Config-policy-map)#class test_dept
(Routing) (Config-policy-classmap)#assign-queue 3
(Routing) (Config-policy-classmap)#exit

(Routing) (Config-policy-map)#class development_dept
(Routing) (Config-policy-classmap)#assign-queue 4
(Routing) (Config-policy-classmap)#exit
(Routing) (Config-policy-map)#exit
```

4. Attach the defined policy to interfaces 0/1 through 0/4 in the inbound direction

```
(Routing) (Config)#interface 0/1-0/4
(Routing) (Interface 0/1-0/4)#service-policy in internet_access
(Routing) (Interface 0/1-0/4)#exit
```

5. Set the CoS queue configuration for the (presumed) egress interface 0/1 such that each of queues 1, 2, 3 and 4 get a minimum guaranteed bandwidth of 25%. All queues for this interface use weighted round robin scheduling by default. The DiffServ inbound policy designates that these queues are to be used for the departmental traffic through the assign-queue attribute. It is presumed that the switch will forward this traffic to interface 0/1 based on a normal destination address lookup for Internet traffic.

```
(Routing) (Config)#interface 0/5
(Routing) (Interface 0/5)#cos-queue min-bandwidth 0 25 25 25 25 0 0 0
(Routing) (Interface 0/5)#exit
(Routing) (Config)#exit
```

Appendix A: Document Resources

A.1 References

The references in this section may be used in conjunction with this document.

NOTE: Broadcom provides customer access to technical documentation and software through its Customer Support Portal (CSP) and Downloads and Support site.

For Broadcom documents, replace the “xx” in the document number with the largest number available in the repository to ensure that you have the most current version of the document.

Document (or Item) Name	Document Number	Source
EFOS CLI Command Reference	EFOS3.X-SWUM2xx	Broadcom CSP
EFOS Functional Specification	EFOS3.X-PG1xx	Broadcom CSP
EFOS Getting Started Guide	EFOS3.X-PG2xx	Broadcom CSP
EFOS Release Notes	EFOS3.X-RN3xx	Broadcom CSP
EFOS Scaling Parameters and Values	EFOS3.X-RM1xx	Broadcom CSP
Open Network Install Environment	2013.11.00	http://onie.github.io/onie

A.2 Terms and Acronyms

Term	Definition
Access port	A port where native (i.e. unencapsulated) packets are associated with a DCVPN. May be a physical port or a LAG.
ACL	Access Control List
Adj-RIB-In	The collection of routing information received from peers
AS	Autonomous System
BFD	Bidirectional Forwarding Detection
BGP	Border Gateway Protocol
BPDU	Bridge Protocol Data Unit
CBS	Committed Burst Size
CIR	Committed Information Rate
CLI	Command Line Interface
CN	Congestion Notification, IEEE 802.1Qau
CoA	Change of Authorization
CoS	Class of Service
CS	Class Selector (as in PHB)
DAC	Dynamic Authorization Client
DAS	Dynamic Authorization Server
DCB	Data Center Bridging
DCPDP	Dual Control Plane Detection Protocol
DCVPN	Data center virtual private network. This term can refer to the overall data center L2 over L3 tunneling feature, realized through VXLAN or NVGRE. This term may also be used to refer to the DC L2 over L3 tunnel application in EFOS.

Term	Definition
DCVPN Gateway	A VXLAN or NVGRE gateway
Default Router	The legacy router. When the Virtual Routing feature is disabled only the Default Router is operational. When the Virtual Routing feature is enabled the Default Router supports all routing protocols and features, while the Virtual Routers support only a subset of features. Also the default router is configured via CLI without specifying the “vrf” keyword.
802.3ad	IEEE Std for Link Aggregation
DSCP	Differentiated Services Code Point
eBGP	Exterior Border Gateway Protocol
ECMP	Equal-Cost Multipath
ECN	Explicit Congestion Notification
EFOS	Ethernet Fabric Operating System
ENode	FCoE End Node
ETS	Enhanced Transmission Selection, IEEE 802.1Qaz
FC	Fibre Channel
FCF	FCoE Forwarder
FCoE	Fibre Channel Over Ethernet
FDB	Forwarding Database
FIP	Fibre Channel Initialization Protocol
iBGP	Interior Border Gateway Protocol
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IP Interface	An interface configured as an IP interface rather than a layer 2 switching interface. An IP interface must be assigned one more IP addresses.
LACP	Link Aggregation Control Protocol
LAG	Link aggregation
LFDB	Label Forwarding Database
LSP	Label Switched Path
MAC	Media Access Control
MFDB	Multicast Forwarding Database
MIB	Management Information Base
VPC partner switch	DUT that is VPC unaware and forms one end of the LAG (with VPC aware switches on the other end)
VPC peer switches	DUTs that are VPC aware and pair to form one end of the LAG
VPC peer-link	Peer-Link between two MLAG peer switches
MAB	MAC Authentication Bypass. This feature provides 802.1x-unaware clients (such as printers and fax machines) controlled access to the network using the devices' MAC address as an identifier.
MPLS	Multi-Protocol Label Switching
MVR	Multicast VLAN Registration
NAS	Network Access Server
Network port (in DCVPN)	A port where DCVPN tunnels originate or terminate.
Non-redundant ports	Ports on the VPC aware switch that do not participate in VPC.
NSF	Non-stop forwarding
NVE	Network Virtualization Edge. NVGRE term for a device or software module that bridges between the overlay and underlay networks. Synonym for VTEP.

Term	Definition
NVGRE	Network Virtualization using Generic Routing Encapsulation
PBS	Peak Burst Size
PDU	Protocol data unit
PFC	Priority-based Flow Control,
PIR	Peak Information Rate
QoS	Quality of Service
RADIUS	Remote Authentication Dial In User Services
RED	Random Early Discard
RFC	Request For Comments
Route Leaking	The ability to inject routes belonging to one VR instance into another.
RTO	Routing Table Object. The common routing table, or “RIB”, which collects routes from all sources (local, static, dynamic) and determines the most preferred route to each destination.
SDM	Switch Database Management
SNMP	Simple Network Management Protocol
STP	Spanning Tree Protocol
TCP	Transmission Control Protocol
Tenant	An organization for which one or more virtual networks has been provisioned.
Tenant System	A physical or virtual resource, such as a compute or storage device, that is assigned to a specific tenant.
TRILL	Transparent Interconnect of Lots of Links
UDP	User Datagram Protocol
UI	User Interface
Underlay network	IP network that carries tunnel encapsulated traffic from one VTEP/NVE to another.
VLAN	Virtual Local Area Network
VM	Virtual Machine. A virtualized end host.
VN	Virtual Network. The set of tunnels, VTEPs, and tenant systems forming a closed user group. For VXLAN, all traffic in a VN carries the same VNID. This document uses VN interchangeably with DCVPN.
VNID	Virtual network identifier. A 24-bit value that uniquely identifies a VXLAN segment.
VoIP	Voice over Internet Protocol
VPC	Virtual Port Channel
VR	Virtual Router
VR-aware	Whether the feature is aware of and works independently in each Virtual Router
VR instance	An instance of the virtual router
VRF	Virtual Routing and Forwarding (unless otherwise specified, VRF refers to VRF Lite solution in EFOS.
VRF Lite	VRF Without MPLS
VRID	Virtual Router Identifier
VRRP	Virtual Router Redundancy Protocol
VSID	Virtual Segment Subnet IdentifierD.ID. A 24-bit value used as a Virtual network identifier in NVGRE.
VTEP	Virtual Tunnel End Point. A device or module that does VXLAN tunnel initiation and termination. Synonym for NVE.
VXLAN	Virtual Extensible Local Area Network
WRED	Weighted Random Early Discard

Term	Definition
ZTP	Zero-Touch Provisioning. This feature enables automatic installation of the Chef Client/Puppet Agent to support Auto Install functionality upon switch bootup.

Revision History

EFOS3.X-SWUM100; November 21, 2018

Initial release

BROADCOM®