BROCADE

CONFIGURATION GUIDE

Brocade SLX-OS Layer 2 Configuration Guide, 17s.1.00

Supporting the Brocade SLX 9140 and SLX 9240 Switches

53-1004968-01
31 March 2017

Contents

Preface

Document conventions

The document conventions describe text formatting conventions, command syntax conventions, and important notice formats used in Brocade technical documentation.

Notes, cautions, and warnings

Notes, cautions, and warning statements may be used in this document. They are listed in the order of increasing severity of potential hazards.

NOTE
A Note provides a tip, guidance, or advice, emphasizes important information, or provides a reference to related information.

ATTENTION
An Attention statement indicates a stronger note, for example, to alert you when traffic might be interrupted or the device might reboot.

CAUTION
A Caution statement alerts you to situations that can be potentially hazardous to you or cause damage to hardware, firmware, software, or data.

DANGER
A Danger statement indicates conditions or situations that can be potentially lethal or extremely hazardous to you. Safety labels are also attached directly to products to warn of these conditions or situations.

Text formatting conventions

Text formatting conventions such as boldface, italic, or Courier font may be used to highlight specific words or phrases.

Format	Description
bold text	Identifies command names.
	Identifies keywords and operands.
	Identifies the names of GUI elements.
	Identifies text to enter in the GUI.
italic text	Identifies emphasis.
	Identifies variables.
	Identifies document titles.
`Courier font`	Identifies CLI output.

Format	Description
	Identifies command syntax examples.

Command syntax conventions

Bold and italic text identify command syntax components. Delimiters and operators define groupings of parameters and their logical relationships.

Convention	Description
bold text	Identifies command names, keywords, and command options.
italic text	Identifies a variable.
value	In Fibre Channel products, a fixed value provided as input to a command option is printed in plain text, for example, **--show** WWN.
[ ]	Syntax components displayed within square brackets are optional. Default responses to system prompts are enclosed in square brackets.
{ **x** | **y** | **z** }	A choice of required parameters is enclosed in curly brackets separated by vertical bars. You must select one of the options. In Fibre Channel products, square brackets may be used instead for this purpose.
x | **y**	A vertical bar separates mutually exclusive elements.
< >	Nonprinting characters, for example, passwords, are enclosed in angle brackets.
...	Repeat the previous element, for example, *member*[*member*...].
\	Indicates a "soft" line break in command examples. If a backslash separates two lines of a command input, enter the entire command at the prompt without the backslash.

Brocade resources

Visit the Brocade website to locate related documentation for your product and additional Brocade resources.

White papers, data sheets, and the most recent versions of Brocade software and hardware manuals are available at www.brocade.com. Product documentation for all supported releases is available to registered users at MyBrocade.

Click the **Support** tab and select **Document Library** to access product documentation on MyBrocade or www.brocade.com. You can locate documentation by product or by operating system.

Release notes are bundled with software downloads on MyBrocade. Links to software downloads are available on the MyBrocade landing page and in the Document Library.

Document feedback

Quality is our first concern at Brocade, and we have made every effort to ensure the accuracy and completeness of this document. However, if you find an error or an omission, or you think that a topic needs further development, we want to hear from you. You can provide feedback in two ways:

- Through the online feedback form in the HTML documents posted on www.brocade.com
- By sending your feedback to documentation@brocade.com

Provide the publication title, part number, and as much detail as possible, including the topic heading and page number if applicable, as well as your suggestions for improvement.

Contacting Brocade Technical Support

As a Brocade customer, you can contact Brocade Technical Support 24x7 online or by telephone. Brocade OEM customers should contact their OEM/solution provider.

Brocade customers

For product support information and the latest information on contacting the Technical Assistance Center, go to www.brocade.com and select **Support**.

If you have purchased Brocade product support directly from Brocade, use one of the following methods to contact the Brocade Technical Assistance Center 24x7.

Online	Telephone
Preferred method of contact for non-urgent issues: • Case management through the MyBrocade portal. • Quick Access links to Knowledge Base, Community, Document Library, Software Downloads and Licensing tools	Required for Sev 1-Critical and Sev 2-High issues: • Continental US: 1-800-752-8061 • Europe, Middle East, Africa, and Asia Pacific: +800-AT FIBREE (+800 28 34 27 33) • Toll-free numbers are available in many countries. • For areas unable to access a toll-free number: +1-408-333-6061

Brocade OEM customers

If you have purchased Brocade product support from a Brocade OEM/solution provider, contact your OEM/solution provider for all of your product support needs.

- OEM/solution providers are trained and certified by Brocade to support Brocade® products.
- Brocade provides backline support for issues that cannot be resolved by the OEM/solution provider.
- Brocade Supplemental Support augments your existing OEM support contract, providing direct access to Brocade expertise. For more information, contact Brocade or your OEM.
- For questions regarding service levels and response times, contact your OEM/solution provider.

About This Document

What's new in this document

This document is the first version of the *Brocade SLX-OS Layer 2 Configuration Guide* for the Brocade SLX-OS 17s.1.00 release.

Supported hardware and software

In those instances in which procedures or parts of procedures documented here apply to some devices but not to others, this guide identifies exactly which devices are supported and which are not.

Although many different software and hardware configurations are tested and supported by Brocade Communications Systems, Inc. for SLX-OS Release 17s.1.00, documenting all possible configurations and scenarios is beyond the scope of this document.

The following hardware platforms are supported by this release:

- Brocade SLX 9140 switch
- Brocade SLX 9240 switch

NOTE
Some of the commands in this document use a slot/port designation. Because the Brocade SLX 9140 switch and the Brocade SLX 9240 switch do not contain line cards, the slot designation must always be "0" (for example, 0/1 for port 1).

To obtain information about other Brocade OS versions, refer to the documentation specific to that version.

Link Aggregation

Link aggregation overview

Link aggregation allows you to bundle multiple physical Ethernet links to form a single logical trunk providing enhanced performance and redundancy. The aggregated trunk is referred to as a Link Aggregation Group (LAG). The LAG is viewed as a single link by connected devices, the Spanning Tree Protocol, IEEE 802.1Q VLANs, and so on. When one physical link in the LAG fails, the other links stay up. A small drop in traffic is experienced when the link carrying the traffic fails.

To configure links to form a LAG, the physical links must be of the same speed. Link aggregation can be done by statically configuring the LAG, or by dynamically configuring the LAG using the IEEE 802.1AX Link Aggregation Control Protocol (LACP).

When queuing traffic from multiple input sources to the same output port, all input sources are given the same weight, regardless of whether the input source is a single physical link or a trunk with multiple member links.

NOTE
The LAG or LAG interface is also referred to as a *port-channel* in the Brocade SLX 9140 and Brocade SLX 9240 platforms.

The benefits of link aggregation are summarized as follows:

- Increased bandwidth (The logical bandwidth can be dynamically changed as the demand changes.)
- Increased availability
- Load sharing
- Rapid configuration and reconfiguration

Each LAG consists of the following components:

- A MAC address that is different from the MAC addresses of the LAG's individual member links.
- An interface index for each link to identify the link to the neighboring devices.
- An administrative key for each link. Only the links with the same administrative key value can be aggregated into a LAG. On each link configured to use LACP, LACP automatically configures an administrative key value equal to the port-channel identification number.

The Brocade SLX 9140 and Brocade SLX 9240 platforms support the following LAG types:

- Static LAG— In static link aggregation, links are added into a LAG without exchanging any control packets between the partner systems. The distribution and collection of frames on static links is determined by the operational status and administrative state of the link.
- Dynamic, standards-based LAG using LACP—Dynamic link aggregation uses LACP to negotiate with links that can be added and removed from a LAG. Typically, two partner systems sharing multiple physical Ethernet links can aggregate a number of those physical links using LACP. LACP creates a LAG on both partner systems and identifies the LAG by the LAG ID. All links with the same administrative key, and all links that are connected to the same partner switch become members of the LAG. LACP continuously exchanges LACPDUs to monitor the health of each member link.

The Brocade SLX 9140 and Brocade SLX 9240 platforms support the following trunk type:

- Static and standards-based LAG

The Brocade SLX 9140 and Brocade SLX 9240 platforms support the following LAG scalability configuration:

- The Brocade SLX 9140 supports 72 LAGs with each containing up to 64 ports.
- The Brocade SLX 9240 supports 128 LAGs with each containing up to 64 ports.

LAG load balancing

This feature allows you to configure the load-balancing feature on a node, to forward traffic. To distribute the traffic among the possible paths, you can configure the load-balancing flavor. Available flavors are listed below.

TABLE 1 Load balancing flavors

Flavor	Definition
dst-mac-vid	Distribution based on Destination MAC address and VLAN ID. (Note that the outer VID is considered).
src-mac-vid	Distribution based on source MAC address and VLAN ID.
src-dst-mac-vid	Distribution based on source and destination MAC address and VLAN ID.
src-dst-ip	Distribution based on source and destination IP address.
src-dst-ip-mac-vid	Distribution based on source and destination IP and MAC addresses including the VID.
src-dst-ip-port	Distribution based on source and destination IP addresses and TCP port.
src-dst-ip-mac-vid-port	Distribution based on source and destination IP, MAC address, VLAN, and port.

Load balancing flavor is unique per node and it can be configured at the global configuration mode.

> **NOTE**
> The default load-balancing flavor is src-dst-ip-mac-vid-port and is applied for all the port channels.

The following example sets the flavor to "destination MAC address and VID-based load balancing."

```
device(config)# load-balance dst-mac-vid
device(config)# exit
device# show running-config load-balance
load-balance dst-mac-vid
device# show port-channel load-balance
 Destination MAC address and VID based load balancing
```

Link Aggregation Control Protocol

Link Aggregation Control Protocol (LACP) is an IEEE 802.1AX standards-based protocol that allows two partner systems to dynamically negotiate attributes of physical links between them to form logical trunks. LACP determines whether a link can be aggregated into a LAG. If a link can be aggregated into a LAG, LACP puts the link into the LAG. All links in a LAG inherit the same administrative characteristics.

LACP operates in two modes:

- *Active mode*— LACP initiates the LACPDU exchange regardless of whether the partner system sends LACPDUs.
- *Passive mode* — LACP responds to Link Aggregation Control Protocol Data Units (LACPDUs) initiated by its partner system but does not initiate the LACPDU exchange.

LAG distribution process and conditions

The LAG aggregator is associated with the collection and distribution of Ethernet frames. The collection and distribution process is required to guarantee the following:

- Inserting and capturing control PDUs.
- Restricting the traffic of a given conversation to a specific link.
- Load balancing between individual links.
- Handling dynamic changes in LAG membership.

On each port, link aggregation control does the following:

- Maintains configuration information to control port aggregation.
- Exchanges configuration information with other devices to form LAGs.
- Attaches ports to and detaches ports from the aggregator when they join or leave a LAG.
- Enables or disables an aggregator's frame collection and distribution functions.

LAG configuration guidelines:

- Each link in the Brocade SLX 9140 and Brocade SLX 9240 hardware can be associated with a LAG; a link cannot be associated with more than one LAG. The process of adding and removing links to and from a LAG is controlled statically or dynamically (through LACP).
- Interfaces configured as switchport interfaces cannot be aggregated into a LAG. However, a LAG can be configured as a switchport.

Configuring and managing Link Aggregation

The following sections discuss working with the Link Aggregation on Brocade devices.

Configuring a new port channel interface

Follow this procedure to create a new port channel interface at the global configuration mode.

1. Enter the **configure terminal** command to access global configuration mode.

```
device# configure terminal
```

2. Enter the **interface port-channel** command to create a new port channel interface at the global configuration level.

```
device(config)# interface port-channel 30
```

NOTE
The port-channel interface ranges from 1 to 1024.

The following example creates a new port channel interface of 30.

```
device# configure terminal
device(config)# interface port-channel 30
```

Deleting a port channel interface

Follow this procedure to delete a port channel interface and all member interfaces from the specified LAG at the global configuration mode.

1. Enter the **configure terminal** command to access global configuration mode.

```
device# configure terminal
```

2. Enter the **no interface port-channel** command to delete an existing port channel interface at the global configuration level.

```
device(config)# no interface port-channel 30
```

NOTE
The port-channel interface ranges from 1 to 1024.

The following example deletes the existing port channel interface 30.

```
device# configure terminal
device(config)# no interface port-channel 30
```

Adding a member port to a port channel

Follow this procedure to add a port to a specific port channel interface at the interface configuration level. If the port channel is not created, the **channel-group** command creates the port channel and also adds a port to the port channel.

1. Enter the **configure terminal** command to access global configuration mode.

```
device# configure terminal
device(config)#
```

2. Enter the **interface port-channel** command to add a port channel interface at the global configuration level.

```
device(config)# interface port-channel 30
device(conf-Port-channel-30)#
```

3. Configure the **interface ethernet** command to enable the interface.

```
device(conf-Port-channel-30)# interface ethernet 0/5
device(conf-if-eth-0/5)#
```

4. Add a port to the port channel interface as static.

```
device(conf-if-eth-0/5)# channel-group 30 mode on
```

5. Add a port to the port channel interface as a dynamic (using LACP), active or passive mode.

```
device(conf-if-eth-0/5)# channel-group 30 mode active

device(conf-if-eth-0/5)# channel-group 30 mode passive
```

The following example is for a static LAG configuration with the mode ON.

```
device# configure terminal
device(config)# interface port-channel 30
device(conf-Port-channel-30)# interface ethernet 0/5
device(conf-if-eth-0/5)# channel-group 30 mode on
```

The following example adds a port 0/5 to the existing dynamic port channel interface 30 with the mode active.

```
device# configure terminal
device(config)# interface port-channel 30
device(conf-Port-channel-30)# interface ethernet 0/5
device(conf-if-eth-0/5)# channel-group 30 mode active
```

The following example adds a port 0/5 to the existing dynamic port channel interface 30 with the mode passive.

```
device# configure terminal
device(config)# interface port-channel 30
device(conf-Port-channel-30)# interface ethernet 0/5
device(conf-if-eth-0/5)# channel-group 30 mode passive
```

Deleting a member port from a port channel

Follow this procedure to delete a member port from a port channel interface at the interface configuration level.

Delete a port from the port channel interface.

```
device(conf-if-eth-0/5)# no channel-group
```

The following example deletes a port 0/5 from the existing port channel interface 30.

```
device# configure terminal
device(config)# interface ethernet 0/5
device(conf-if-eth-0/5)# no channel-group
```

Configuring the minimum number of LAG member links

Follow this procedure to configure the minimum number of LAG member links that should be functional so that the port-channel interface is operationally up.

This configuration allows a port-channel to operate at a certain minimum bandwidth at all times. If the bandwidth of the port-channel drops below the minimum number, then the port-channel is declared operationally DOWN even though it has operationally UP members.

1. Enter the **configure terminal** command to access global configuration mode.

   ```
   device# configure terminal
   device(config)#
   ```

2. Enter the **interface port-channel** command at the global configuration level.

   ```
   device(config)# interface port-channel 30
   device(conf-Port-channel-30)#
   ```

3. Configure the minimum number of LAG member links at the port-channel interface configuration mode.

   ```
   device(conf-Port-channel-30)# minimum-links 5
   ```

   NOTE
   The number of links ranges from 1 to 64. The default minimum links is 1.

The following example sets min-link 5 to the existing port channel interface 30.

```
device# configure terminal
device(config)# interface port-channel 30
device(conf-Port-channel-30)# minimum-links 5
```

Configuring the LACP system priority

You configure the LACP system priority on each switch running LACP. LACP uses the system priority with the switch MAC address to form the system ID and also during negotiation with other switches.

The system priority value must be a number in the range of 1 through 65535. The higher the number, the lower the priority. The default priority is 32768.

To configure the global LACP system priority, perform the following steps:

1. Enter the **configure terminal** command to access global configuration mode.

   ```
   device# configure terminal
   ```

2. Specify the LACP system priority.

   ```
   device(config)# lacp system-priority 25000
   ```

3. To reset the system priority to the default value.

   ```
   device(config)# no lacp system-priority
   ```

Configuring the LACP port priority

Follow this procedure to configure the LACP port priority of a member port of a specific port-channel interface.

1. Enter the **configure terminal** command to access global configuration mode.

   ```
   device# configure terminal
   device(config)#
   ```

2. Enter the **interface port-channel** command to add a port channel interface at the global configuration level.

   ```
   device(config)# interface port-channel 30
   device(conf-Port-channel-30)#
   ```

3. Configure the **interface ethernet** command and add the port to the port-channel interface.

   ```
   device(conf-Port-channel-30)# interface ethernet 0/5
   device(conf-if-eth-0/5)#channel-group 30 mode active
   ```

4. Configure the LACP port priority 12 for the member port.

   ```
   device(conf-if-eth-0/5)# lacp port-priority 12
   ```

   NOTE

   The LACP port priority value ranges from 1 to 65535. The default value is 32768.

5. To rest the configured port priority to the default value.

   ```
   device(conf-if-eth-0/5)# no lacp port-priority
   ```

The example sets the port priority as 12.

```
device# configure terminal
device(config)# interface port-channel 30
device(conf-Port-channel-30)# interface ethernet 0/5
device(conf-if-eth-0/5)# channel-group 30 mode active
device(conf-if-eth-0/5)# lacp port-priority 12
```

Configuring the LACP timeout period

The LACP timeout period indicates how long LACP waits before timing out the neighboring device. The **short** timeout period is 3 seconds and the **long** timeout period is 90 seconds. The default is **long**. The **short** timeout period specifies that the PDU is sent every second and the port waits three times this long (three seconds) before invalidating the information received earlier on this PDU. The **long** timeout period specifies that the PDU is sent once in 30 seconds and the port waits three times this long (90 seconds) before invalidating the information received earlier on this PDU.

To configure the LACP timeout period on an interface, perform the following steps:

1. Enter the **configure terminal** command to access global configuration mode.
2. Enter the **interface** command, specifying the interface type and the slot/port.

   ```
   device(config)# interface ethernet 0/1
   ```

3. Enter the **no shutdown** command to enable the interface.
4. Specify the LACP timeout short period for the interface.

   ```
   device(conf-if-eth 0/1)# lacp timeout short
   ```

5. Specify the LACP timeout long period for the interface.

   ```
   device(conf-if-eth 0/1)# lacp timeout long
   ```

Configuring LACP default Up

Follow this procedure to activate an LACP link even in the absence of PDUs.

Consider the following when using the **lacp default-up** command:

- The command is available only if the configured interface is a dynamic member of a port-channel interface.
- The command is not supported on static LAGs.
- The command is not supported on port-channel interfaces.

1. Enter the **configure terminal** command to access global configuration mode.
2. Enter the **interface** command, specifying the interface type and the slot/port.

   ```
   device(config)# interface ethernet 0/1
   ```

3. Specify LACP default-up for the interface.

   ```
   device(conf-if-eth-0/1)# lacp default-up
   ```

4. Enter the no form of the command to disable the configuration.

   ```
   device(conf-if-eth-0/1)#  no lacp default-up
   ```

Displaying port-channel information

Various show commands are used to display information for a specific port-channel interface.

Before displaying the port-channel information, you should have created a port-channel interface to generate details.

1. Use the **show port-channel summary** command to display brief information of all port-channels.

```
device# show port-channel summary
Flags:  D - Down               P - Up in port-channel (members)
        U - Up (port-channel)  * - Primary link in port-channel
        S - Switched
        M - Not in use. Min-links not met
===== ============== ========== ===============
Group Port-channel    Protocol   Member ports
===== ============== ========== ===============
1     Po 1    (D)     None       Eth 0/2  (D)
                                 Eth 0/26 (D)
2     Po 2    (D)     None       Eth 0/27 (D)
                                 Eth 0/28 (D)
10    Po 10   (U)     LACP       Eth 0/4  (P)
                                 Eth 0/18 (P)
100   Po 100  (U)     None       Eth 0/10 (P)
                                 Eth 0/11 (P)
```

2. Use the **show port-channel detail** command to display detailed information of all the port-channels.

```
device# show port-channel detail
 Static Aggregator: Po 1
 Aggregator type: Standard
 Number of Ports: 2
 Member ports:
   Eth 0/25
   Eth 0/26


 Static Aggregator: Po 2
 Aggregator type: Standard
 Number of Ports: 2
 Member ports:
   Eth 0/27
   Eth 0/28


 Static Aggregator: Po 100
 Aggregator type: Standard
 Number of Ports: 2
 Member ports:
   Eth 0/10
   Eth 0/11


 LACP Aggregator: Po 10
Aggregator type: Standard
  Actor System ID - 0x8000,76-8e-f8-0a-98-00
  Admin Key: 0010 - Oper Key 0010
  Receive link count: 2 - Transmit link count: 2
  Individual: 0 - Ready: 1
  Partner System ID - 0x8000,76-8e-f8-0a-68-00
  Partner Oper Key 0010
 Number of Ports: 2
 Member ports:
   Link: Eth 0/4 (0x18820016) sync: 1
   Link: Eth 0/18 (0x18890084) sync: 1
```

3. Use the **show port-channel num** command to display detailed information of a specific port-channel interface

```
device# show port-channel 10
LACP Aggregator: Po 10
 Aggregator type: Standard
  Admin Key: 0010 - Oper Key 0010
  Partner System ID - 0x8000,76-8e-f8-0a-68-00
  Partner Oper Key 0010
 Number of Ports: 2
 Member ports:
   Link: Eth 0/4 (0x18820016) sync: 1
   Link: Eth 0/18 (0x18890084) sync: 1
```

Displaying LACP system-id information

Follow this procedure to display LACP system ID and priority information.

Enter the **show lacp sys-id** command to display LACP information for the system ID and priority.

```
device# show lacp sys-id
System ID: 0x8000,76-8e-f8-0a-98-00
```

Displaying LACP statistics

Follow this procedure to display LACP statistics for a port-channel interface or for all port-channel interfaces.

Before displaying the LACP port-channel information, it is recommended that you create a port-channel interface in a LAG to generate details.

Enter the **show lacp counters** command to display LACP statistics for a port-channel.

```
device# show lacp counter
Traffic statistics
Port     LACPDUs   Marker   Pckt err Sent  Recv  Sent  Recv  Sent  Recv Aggregator
Eth 0/6   110                        0        0     0        0     0         Po 3
```

Clearing LACP counter statistics on a LAG

This topic describes how to clear LACP counter statistics on a single LAG.

To clear LACP counter statistics on a LAG, use the following command:

Enter the **clear lacp** *LAG_group_number* **counters** command to clear the LACP counter statistics for the specified LAG group number.

```
device# clear lacp 42 counters
```

Clearing LACP counter statistics on all LAG groups

This topic describes how to clear the LACP counter statistics for all LAG groups.

To clear LACP counter statistics on all LAG groups, use the following command:

Enter the **clear lacp counter** command to clear the LACP counter statistics for all LAG groups.

```
device# clear lacp counter
```

Troubleshooting LACP

To troubleshoot problems with your LACP configuration, use the following troubleshooting tips.

If a standard IEEE 802.1AX-based dynamic trunk is configured on a link and the link is not able to join the LAG, do the following:

- Make sure that both ends of the link are configured as **standard** for the trunk type.
- Make sure that both ends of the link are *not* configured for **passive** mode. They must be configured as **active** /**active**, **active** / **passive**, or **passive** /**active**.
- Make sure that the port-channel interface is in the administrative "up" state by ensuring that the **no shutdown** command was entered on the interface on both ends of the link.
- Make sure that the links that are part of the LAG are connected to the same neighboring switch.
- Make sure that the system ID of the switches connected by the link is unique. You can verify this by entering the **show lacp sys-id** command on both switches.
- Make sure that LACPDUs are being received and transmitted on both ends of the link and that there are no error PDUs. You can verify this by entering the **show lacp counters** *number* command and looking at the receive mode (rx) and transmit mode (tx) statistics. The statistics should be incrementing and should not be at zero or a fixed value. If the PDU rx count is not incrementing, check the interface for possible CRC errors by entering the **show interface** *link-name* command on the neighboring switch. If the PDU tx count is not incrementing, check the operational status of the link by entering the **show interface** *link-name* command and verifying that the interface status is "up."

When a link has problem, the **show port-channel** command displays the following message:

```
Mux machine state: Deskew not OK.
```

If a static trunk is configured on a link and the link is not able to join the LAG, do the following:

- Make sure that both ends of the link are configured as **standard** for trunk type and verify that the mode is "on."
- Make sure that the port-channel interface is in the administrative "up" state by ensuring that the **no shutdown** command was entered on the interface on both ends of the link.

VLANs

802.1Q VLAN overview

IEEE 802.1Q VLANs provide the capability to overlay the physical network with multiple virtual networks. VLANs allow you to isolate network traffic between virtual networks and reduce the size of administrative and broadcast domains.

A VLAN contains end stations that have a common set of requirements that are independent of physical location. You can group end stations in a VLAN even if they are not physically located in the same LAN segment. VLANs are typically associated with IP subnetworks and all the end stations in a particular IP subnet belong to the same VLAN. Traffic between VLANs must be routed. VLAN membership is configurable on a per-interface basis.

Configuring VLANs

The following sections discuss working with VLANs on Brocade devices.

Configuring a VLAN

Follow this procedure to configure a VLAN in the Brocade device at the global configuration level.

1. Enter the **configure terminal** command to access global configuration mode.

```
device# configure terminal
```

2. Enter the **vlan** command to create a topology group at the global configuration level.

```
device(config)# vlan 5
device(config-vlan-5)#
```

NOTE

The **no vlan** command removes the existing VLAN instance from the device.

Configuring a switchport interface

Follow this procedure to configure a switchport interface in the device to send and receive data packets.

1. Enter the **configure terminal** command to access global configuration mode.

```
device# configure terminal
```

2. Enter the **interface ethernet** command to configure the interface mode.

```
device(config)# interface ethernet 0/1
```

3. Enter the **switchport** command to configure a switchport interface.

```
device(conf-if-eth-0/1)# switchport
```

Configuring the switchport interface mode

Do the following to set the switchport interface as access or trunk. This configuration works only when the interface is set as switchport.

1. Enter the **configure terminal** command to access global configuration mode.

```
device# configure terminal
```

2. Enter the **interface ethernet** command to configure the interface mode.

```
device(config)# interface ethernet 0/1
```

3. Enter the **switchport** command to set the interface as switchport.

```
device(conf-if-eth-0/1)# switchport
```

4. Enter the **switchport mode** command to configure the switchport interface in trunk mode.

```
device(conf-if-eth-0/1)# switchport mode trunk
```

NOTE
The default mode is access. Enter the **switchport mode access** command to set the mode as *access*.

Configuring the switchport access VLAN type

Do the following to change the switchport access VLAN type. This configuration works only when the interface is set as switchport.

Ensure that reserved VLANs are not used. Use the **no switchport access vlan** command to set the default VLAN as the access VLAN.

1. Enter the **configure terminal** command to access global configuration mode.

```
device# configure terminal
```

2. Enter the **interface ethernet** command to specify an Ethernet interface.

```
device(config)# interface ethernet 0/1
```

3. Enter the **switchport** command to set the interface as switchport.

```
device(conf-if-eth-0/1)# switchport
```

4. Enter the **switchport access vlan** command to set the mode of the interface to *access* and specify a VLAN.

```
device(conf-if-eth-0/1)# switchport access vlan 10
```

This example sets the mode of a specific port-channel interface to *trunk*.

```
device# configure terminal
device(config)# interface port-channel 35
device(config-port-channel-35)# switchport mode trunk
```

Configuring a VLAN in trunk mode

Do the following to add or remove VLANs on a Layer 2 interface in trunk mode. The configuration is also used to configure the VLANs to send and receive data packets.

Ensure that reserved VLANs are not used.

1. Enter the **configure terminal** command to access global configuration mode.

```
device# configure terminal
```

2. Enter the **interface ethernet** command to specify an Ethernet interface.

```
device(config)# interface ethernet 0/1
```

3. Enter the **switchport** command to set the interface as switchport.

```
device(conf-if-eth-0/1)# switchport
```

4. Enter the **switchport trunk allowed vlan** command to set the mode of the interface to *trunk* and add a VLAN.

```
device(conf-if-eth-0/1)# switchport trunk allowed vlan add 5
```

The example sets the mode of the Ethernet interface to *trunk*.

```
device# configure terminal
device(config)# interface ethernet 0/1
device(conf-if-eth-0/1)# switchport mode trunk
```

The example sets the mode of a port-channel interface to *trunk* and allows all VLANs.

```
device# configure terminal
device(config)# interface port-channel 35
device(config-Port-channel-35)# switchport trunk allowed vlan all
```

Configuring a native VLAN on a trunk port

Do the following to set native VLAN characteristics on a trunk port for classifying the untagged traffic data packets.

Ensure that reserved VLANs are not used.

1. Enter the **configure terminal** command to access global configuration mode.

```
device# configure terminal
device(config)#
```

2. Enter the **interface ethernet** command to configure the interface mode.

```
device(config)# interface ethernet 0/1
```

3. Enter the **switchport** command to set the interface as switchport.

```
device(conf-if-eth-0/1)# switchport
```

4. Enter the **switchport trunk native-vlan** command to set native VLAN characteristics to *access* and specify a VLAN.

```
device(conf-if-eth-0/1)# switchport trunk native-vlan 300
```

This example removes the configured native VLAN on the Ethernet interface.

```
device# configure terminal
device(config)# interface ethernet 0/1
device(conf-if-eth-0/1)# no switchport trunk native-vlan 300
```

Enabling VLAN tagging for native traffic

Do the following to enable tagging for native traffic on a specific interface.

Ensure that reserved VLANs are not used.

1. Enter the **configure terminal** command to access global configuration mode.

   ```
   device# configure terminal
   ```

2. Enter the **interface ethernet** command to configure the interface mode.

   ```
   device(config)# interface ethernet 0/1
   ```

3. Enter the **switchport** command to set the interface as switchport.

   ```
   device(conf-if-eth-0/1)# switchport
   ```

4. Enter the **switchport trunk tag native-vlan** command to enable tagging for native traffic data VLAN characteristics on a specific interface.

   ```
   device(conf-if-eth-0/1)# switchport trunk tag native-vlan
   ```

This example enables tagging for native traffic data on a specific Ethernet interface.

```
device# configure terminal
device(config)# interface ethernet 0/1
device(conf-if-eth-0/1)# switchport trunk tag native-vlan
```

This example disables the native VLAN tagging on a port-channel.

```
device# configure terminal
device(config)# interface port-channel 35
device(config-Port-channel-35)# no switchport trunk tag native
```

Displaying the status of a switchport interface

Do the following to display detailed Layer 2 information for all switchport interfaces.

Enter the **show interface switchport** to display the detailed Layer 2 information for all interfaces.

```
device# show interface switchport
 Interface name          : Eth 0/1
 Switchport mode         : access
 Ingress filter          : enable
 Acceptable frame types  : all
 Default Vlan            : 1
 Active Vlans            : 1
 Inactive Vlans          : -
 Interface name          : Port-channel 5
 Switchport mode         : access
 Ingress filter          : enable
 Acceptable frame types  : all
 Default Vlan            : 1
 Active Vlans            : 1
```

Displaying the switchport interface type

Do the following to display detailed Layer 2 information for a specific interface.

Enter the **show interface switchport** to display the detailed Layer 2 information for a specific interface.

```
device# show interface ethernet 0/1 switchport
 Interface name          : ethernet 0/1
 Switchport mode         : trunk
 Fcoeport enabled        : no
 Ingress filter          : enable
 Acceptable frame types  : vlan-tagged only
 Native Vlan             : 1
 Active Vlans            : 1,5-10
 Inactive Vlans          : -
```

The example displays the detailed Layer 2 information for a port-channel interface.

```
device# show interface port-channel 5 switchport
 Interface name          : Port-channel 5
 Switchport mode         : access
 Fcoeport enabled        : no
 Ingress filter          : enable
 Acceptable frame types  : vlan-untagged only
 Default Vlan            : 1
 Active Vlans            : 1
 Inactive Vlans          : -
```

Verifying a switchport interface running configuration

Do the following to display the running configuration information for the Layer 2 properties for a specific interface.

Enter the **show running-config interface** to display the running configuration information for a specific interface.

```
device# show running-config interface ethernet 0/1 switchport
interface interface Eth 0/1
 switchport
 switchport mode trunk
 switchport trunk allowed vlan add 5-10
 switchport trunk tag native-vlan
```

This example displays the running configuration information for a port-channel interface.

```
device# show running-config interface port-channel 5 switchport
interface Port-channel 5
 switchport
 switchport mode access
 switchport access vlan 1
```

Displaying VLAN information

Do the following to display information about a specific VLAN.

Enter the **show vlan** to display information about VLAN 1.

```
device# show vlan 1
VLAN Name State Ports
(u)-Untagged, (t)-Tagged
(c)-Converged
==========================================================
1 default ACTIVE Eth 0/1(t) Eth 0/4(t) Eth 0/5(t) Eth 0/8(t)
```

VLAN statistics

Devices gather statistics for all ports and port channels on configured VLANs.

Use the **statistics** command in the VLAN configuration mode to enable statistics on a VLAN.

> NOTE
> Statistics has to be manually enabled for a specific VLAN, since it is not enabled by default for VLANs.

Please note that:

- The statistics reported are not real-time statistics since they depend upon the load on the system.
- Statistics has to be manually enabled for a specific VLAN. This ensures better utilization of the statistics resources in the hardware.
- Statistics for VLANs with VE interfaces consider only the switched frames. Packets which are routed into or out of the VE interface are not counted.
- Enabling statistics on a VLAN has a heavy impact on the data traffic.

Enabling statistics on a VLAN

Follow this procedure to enable statistics on a VLAN.

1. Enter the global configuration mode.

```
device# configure terminal
```

2. Enter the **vlan** command to create a topology group at the global configuration level.

```
device(config)# vlan 5
device(config-vlan-5)#
```

3. Enter the **statistics** command to enable statistics for all ports and port channels on configured VLANs.

```
device(config-vlan-5)# statistics
```

> NOTE
> Use the **no statistics** command to disable statistics on VLANs.

```
device(config-vlan-5)# no statistics
```

Displaying statistics for VLANs

Do the following to display statistics information for VLANs.

Enter the **show statistics vlan** command to view the statistics for all ports and port channels on all configured VLANs.

```
device# show statistics vlan

Vlan 10 Statistics
Interface     RxPkts          RxBytes         TxPkts          TxBytes
eth 0/1       821729          821729          95940360        95940360
eth 0/2       884484          885855          95969584        95484555
po  1        8884            8855             9684            9955

Vlan 20 Statistics
```

```
Interface     RxPkts          RxBytes          TxPkts          TxBytes
eth 0/6       821729          821729           95940360        95940360
eth 0/21      8884            8855              9684            9955
po  2       884484          885855           95969584        95484555
```

TABLE 2 Output descriptions of the show statistics vlan command

Field	Description
Interface	The interface whose counter statistics are displayed.
RxPkts	The number of packets received at the specified port.
RxBytes	The number of bytes received at the specified port.
TxPkts	The number of packets transmitted from the specified port.
TxBytes	The number of bytes transmitted from the specified port.

Displaying VLAN statistics for a specific VLAN

Enter the **show statistics vlan** *vlan ID* command to view the statistics for a specific VLAN. Here *vlan ID* is the specific VLAN ID.

```
device# show statistics vlan 10

Vlan 10 Statistics
Interface     RxPkts          RxBytes          TxPkts          TxBytes
eth 0/1       821729          821729           95940360        95940360
eth 0/2       884484          885855           95969584        95484555
po  1       8884            8855             9684            9955
```

Clearing statistics on VLANs

Follow the procedure to clear statistics' information for VLANs.

Enter the **clear statistics vlan** command to clear the statistics for all ports and port channels on all configured VLANs.

```
device# clear statistics vlan
```

Clearing statistics for a specific VLAN

Enter the **clear statistics vlan** *vlan ID* command to clear the statistics for a specific VLAN. Here *vlan ID* is the specific VLAN ID.

```
device# clear statistics vlan 10
```

Configuring the MAC address table and conversational MAC learning

Each DCB port has a MAC address table that stores the source MAC address of all frames. In addition, there is a configurable aging timer. If a source MAC address remains inactive for a specified number of seconds, it is removed from the address table.

Conversational MAC learning

Layer 2 switches use forwarding tables to direct traffic to specific ports, based on the VLAN number and destination MAC address of the frame.

When there is no entry corresponding to the destination MAC address in the incoming VLAN, the frame is sent to all forwarding ports within the respective VLAN, which causes flooding. MAC address learning is an essential Layer 2 feature whereby the source MAC addresses of each received packet is stored so that future packets destined for that address can be forwarded only to the bridge interface on which the address is located.

Using the global **mac-address-table** command with the **conversational** keyword enables conversational MAC (address) learning, or CML, globally on a switch.

Specifying or disabling the aging time for MAC addresses

You can set the length of time that a dynamic entry remains in the MAC address table after the entry is used or updated. Static address entries are never aged or removed from the table. You can also disable the aging time. The default is 300 seconds.

> NOTE
> To disable the aging time for MAC addresses, enter an aging time value of 0.

Do the following to specify an aging time or disable the aging time for MAC addresses.

1. Enter the **configure terminal** command to access global configuration mode.

   ```
   device# configure terminal
   ```

2. The following example specifies an aging-time of 600 seconds.

   ```
   device(config)# mac-address-table aging-time 600
   ```

3. Enter the **no mac-address-table aging-time** command to restore the default aging time (300 seconds).

   ```
   device(config)# no mac-address-table aging-time
   ```

   The maximum value supported is 100000 seconds. The default value is 300 seconds.

   NOTE: There may be a short delay in the configured MAC aging time. The hardware scans the MAC entries every 1/7th of the aging time. For example, if the configured aging time is 300 seconds, there can be a delay of 43 seconds. In a scaled environment, the hardware sends only 16 K aging events for every aging cycle.

Adding static addresses to the MAC address table

Do the following to add a static address to the MAC address table.

1. Enter the **configure terminal** command to access global configuration mode.

   ```
   device# configure terminal
   ```

2. Enter the **mac-address-table** command with **static** keyword to configure the static address 0011.2222.3333 to the MAC address table, for a packet received on VLAN 100 on a Ethernet interface, as in the following example.

   ```
   device(config)# mac-address-table static 0011.2222.3333 forward ethernet 0/1 vlan 100
   ```

Enabling conversational MAC learning (CML)

You can enable conversation-based MAC address learning by means of the **mac-address-table learning-mode conversational** command.

> ATTENTION
> The ability to disable source MAC address learning on a per-port, per-VLAN basis constrains traffic flooding to only the ports that are part of a VLAN. Disabling traditional dynamic MAC learning prevents the MAC address table from being saturated. For example, when a device is being attacked by many packets with different source MAC address, the updating of the MAC address table is significantly impaired.

> NOTE
> For the CML scale supported, refer to the Release Notes.

Do the following in global configuration mode to enable CML globally.

```
device(config)# mac-address-table learning-mode conversational
```

Do the following to revert to legacy dynamic MAC learning mode.

```
device(config)# no mac-address-table learning-mode conversational
```

Do the following to configure the destination MAC address aging interval to 60 seconds.

```
device(config)# mac-address-table aging-time conversational 60
```

Do the following to revert to the default aging interval of 300 seconds.

```
device(config)# no mac-address-table aging-time conversational
```

Configuring virtual routing interfaces

The Brocade device sends Layer 3 traffic at Layer 2 within a protocol-based VLAN. However, Layer 3 traffic from one protocol-based VLAN to another must be routed. If you want the device to be able to send Layer 3 traffic from one protocol-based VLAN to another on the same device, you must configure a virtual routing interface on each protocol-based VLAN, then configure routing parameters on the virtual routing interfaces.

A *virtual routing interface* is a logical routing interface that the Brocade device uses to route Layer 3 protocol traffic between protocol-based VLANs. It is a logical port on which you can configure Layer 3 routing parameters.

For example, to enable a Brocade device to route IP traffic from one IP protocol VLAN to another, you must configure a virtual routing interface on each IP protocol VLAN, then configure the appropriate IP routing parameters on each of the virtual routing interfaces.

To attach a router interface to a VLAN, using the **router-interface** command:

```
device# configure terminal
device(config)# vlan 2
device(config-vlan-2)# router-interface ve 2
```

> NOTE
> Only one router VE interface can be mapped to a VLAN. The VLAN ID and the VE ID need not be the same.

Use the **no router interface ve** command to remove the router VE interface.

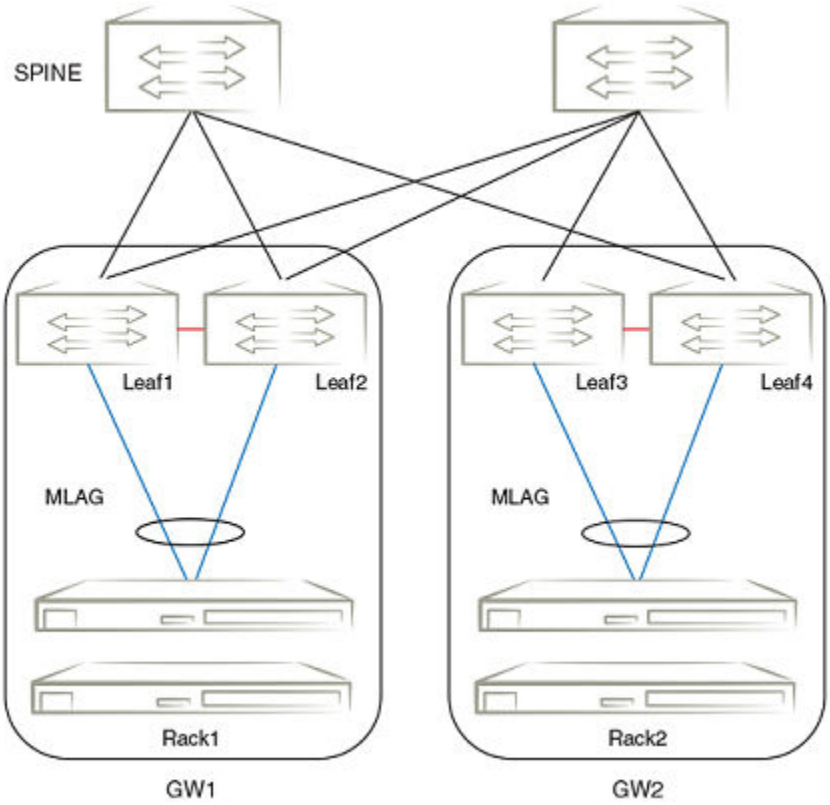
Multi-Chassis Trunking (MCT)

MCT Overview

Multi-Chassis Trunking (MCT) is trunking that initiates at a single MCT-unaware server or switch and terminates at two MCT-aware switches. MCT allows the links to the two MCT-aware switches to appear to a downstream device as if they are coming from a single device on a single Link Aggregation (LAG) trunk interface or physical port.

In a datacenter network environment, LAG trunks provide link level redundancy and increased capacity. However, they do not provide switch-level redundancy. If the switch connected to the LAG trunk fails, the entire trunk loses network connectivity.

For SLX-OS MCT, the connected switches are MCT peer switches and communicate through an interface called a peer link. While the peer link's primary purpose is exchanging MCT control information between peer switches, it also carries data traffic from devices that are attached to only one MCT peer and have no alternative path. An MCT domain consists of the peer switches and the peer links that connect the switches.



SLX-OS Layer 2 MCT is based on RFC 7432 (BGP MPLS-Based Ethernet VPN). The MP-BGP EVPN extension is the control plane on the SLX-OS device to perform both MAC synchronization and cluster management. MAC synchronization between the MCT peers synchronizes the MAC tables between the MCT nodes for node resiliency and faster convergence.

For the data plane, all data packets transmitted over a port connecting two MCT nodes are encapsulated with a Network Service Header (NSH).

Layer 3 protocols can be configured on a VE interface with an LAG as a switch port. Transmitted packet will use the local LAG port as an egress interface. If the local LAG port is down, packets are transmitted over the peer interface and will reach remote node using the remote LAG interface.

SLX-OS MCT uses the spanning tree protocol for loop prevention. For more information, see Loop prevention in MCT through STP on page 48.

MCT terminology

Before implementing MCT in your network, you must understand some key terms and definitions.

MCT peer devices	A pair of SLX-OS device configured as peers. The LAG interface is spread across two MCT peer devices and acts as the single logical endpoint to the MCT client.
MCT client	The MCT client is the device that connects with the MCT peer devices. It can be a switch or an endpoint server host in the single-level MCT topology or another pair of MCT switches in a multi-tier MCT topology.
MP-BGP EVPN extension	The control plane for Layer 2 MCT on the SLX-OS device.
MCT Cluster Client Edge Port (CCEP)	A port on one of the MCT peer devices that is a member of the LAG interface to the MCT client. To have a running MCT instance, at least one Link Aggregation Interface is needed with a member port on each peer device. While there is a LAG on the client device, CCEP on the MCT device can be a LAG or a physical port.

MCT Cluster Edge Port (CEP)	A port on MCT peer device that a member of a MCT VLAN and is not a Cluster Client Edge Port.
MCT VLANs	VLANs on which MCT clients are operating. These VLANs are explicitly configured in the MCT configuration.
MCT bridge domain	Bridge domain (BD) that is extended to the two MCT cluster nodes for multitenancy. Active-active forwarding occurs on traffic belonging to the BD.
Peer link	Interface through which MCT peer switches exchange MCT control information. It also carries data traffic from devices that are attached to only one MCT peer and have no alternative path.
MCT domain	Peer switches and the peer links that connect them.

MCT peer link

An MCT peer link is a physical interface or a channel group that connects two MCT peer switches.

> NOTE
> A peer link cannot be a Layer 3 interface.
> When the peer interface is configured, it is an internal switch port. An external switch port configuration on peer interface is not allowed.

As a tagged Layer 2 link, it carries packets for multiple VLANs. Only MCT member VLANs are carried over a peer link. For MCT member VLANs, MAC learning is disabled on the link. Each node learns the MAC addresses through Layer 2 forwarding which uses source MAC learning methodology and locally learned MACs are synced between the peers.

All data packets transmitted over the peer link are encapsulated with the Network service header (NSH) as the way to share metadata between devices. For forwarding traffic from the edge port over the peer link, the edge port VLANs must be configured as MCT member VLANs.

Cluster control VLAN

The cluster control VLAN is required to learn MAC addresses, resolve ARP for the BGP peer, and derive the outer MAC for the NSH tunnel. By default, the MCT cluster control vlan is 4090 and can be configured. If MCT is configured, other switch ports must not be part of the cluster control VLAN.

SLX-OS MCT control plane

Multiprotocol-BGP (MP-BGP) EVPN extension, as specified in RFC 7432, is used as the SLX-OS MCT control plane.

The control plane consist of the following components:

- EVPN instance—Mapped to a Layer 2 VLAN that the RFC refers to the VLAN-Based service interface.
- Ethernet segment ID (ESI)—10-byte integer that uniquely identifies the set of links connecting MCT leaf nodes to the client CE. SLX-OS MCT supports both dynamic and static LAG between MCT leaf node and MCT client and uses ESI type 0 that is encoded as follows:
  - 1-byte ESI type = 0
  - 9 byte ESI value = user-input through the SLX-OS **esi** command

  By default, the ESI is auto generated.
- MP-BGP route distinguisher (RD)—Encoded using RD type 1 as defined in RFC 4364 that consists of the following subfields:
  - 4-byte administrator subfield that is set with the 4-byte router ID
  - 2-byte assigned number subfield that is encoded with the all zeros for the Ethernet segment (ES) route, client ID for the Ethernet auto-discovery route, and EVPN ID (VLAN ID) for MAC and multicast routes.

- MP-BGP EVPN capability—When a BGP session is brought up to a MCT peer, BGP indicates to the peer that it is EVPN capable using BGP capability advertisement with the following information:
  - Capability code = 1 (MP-BGP)
  - AFI = 25 (L2VPN)
  - SAFI = 70 (EVPN)

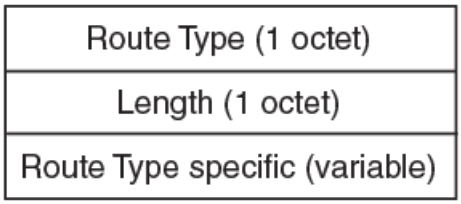
  If a BGP session already existed to the same peer, the existing BGP session is flapped to allow the advertisement of the EVPN capability.
- MP-BGP EVPN route types—Includes Ethernet Auto-Discovery (A-D), MAC/IP Advertisement, Inclusive Multicast Ethernet Tag, and Ethernet Segment routes.
- Network service header (NSH)—Inserted onto encapsulated packets or frames to provide a mechanism to carry shared metadata between network devices. The semantics of the shared metadata is communicated through the control plane to the participating nodes.
- Virtual Rbridge ID (VRB ID) assignment—In the NSH, the VRB ID is used for source suppression. Its 16-bit field is used to propagate the ESI label.
- Designated forwarder (DF)—A leaf node in a set of multi-homing leaf nodes connected to the same Ethernet segment that is elected for sending BUM traffic to a client for a VLAN ID on an Ethernet segment. By default, DF load balancing is disabled.

SLX-OS MCT operates in dual-homing mode.

MP-BGP EVPN Routes

RFC 7432 defines EVPN Network Layer Reachability Information (NLRI) with the format as shown in the following figure:

FIGURE 1 EVPN NLRI format



SLX-OS MCT supports the following route types.

TABLE 3 SLX-OS MCT route types

Route type	Route name	SLX-OS usage
1	Ethernet Auto-Discovery (per Ethernet Segment only)	Mass MAC withdraw and Designated forwarder election. The leaf node advertises one Ethernet A-D route for each client interface. When the client interface goes down, the leaf node withdraws the Ethernet A-D route which is served as a trigger for the remote leaf node to remove all MAC addresses learned over the affected client interface instead of withdrawing an individual MAC.
2	MAC/IP Advertisement	MAC synchronization of the MAC addresses between two MCT peers.
3	Inclusive Multicast Ethernet Tag	Advertisement of ingress replication usage and multicast label expected for each EVPN instance when receiving BUM traffic.
4	Ethernet Segment (ES)	Designated forwarder election. The ES route is used to update the remote peer when the MCT client is deployed and undeployed.

Network Service Header (NSH)

All data traffic passing through the MCT peer link is Network Service Header (NSH) encoded. The NSH is inserted onto encapsulated packets or frames to carry shared metadata between network devices.

The semantics of the shared metadata is communicated through the control plane to participating nodes, including classification information used for policy enforcement and a network context for forwarding post service delivery.

The NSH is transport independent and is carried in an overlay over existing underlays. After the NSH is added to a packet, an outer encapsulation is used to forward the original packet and the associated metadata. Transit network nodes forward the encapsulated packets as is.

NSH encapsulation examples

The following examples are for the Ethernet IPv4 packet and Layer 2 frame.

IPv4 Packet:

Outer Ethernet, ET=0x894F	NSH, NP= 0x1	original IP packet

L2 Frame:

Outer Ethernet, ET=0x894F	NSH, NP= 0x3	original frame

The following example is for the NHS in the SLX switch including the VRB ID used for source suppression.

NSH Format

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Ver		O	C	R	R	R	R	R	R	Length						MD-type=0x1								Next Protocol							
Egress BD (16 Bit)																Service Index															
M	VRB Id (15 Bit)																														
Network Shared Context																															
Service Platform Context																															
Service Shared Context																															

The 16-bit VRB ID field is used to propagate the ESI label. Each cluster client represent one multi-chassis trunk link aggregation (MLAG) or ESI between the MCT peers. There is one-to-one mapping between the cluster client ID and the ESI. The cluster client ID is used to derive the VRB ID in NSH header for source suppression of BUM traffic. A maximum of 512 ESI or cluster clients are supported.

Designated forwarder election and load balancing

By default, DF load balancing is disabled. With load balancing disabled, one leaf node is the DF for all VLANs. The DF changes or a new DF is elected when the current DF leaf node goes down or its client interface is down. A non-DF leaf node that goes down does not impact the appointed DF. Also, any new node joining the Ethernet segment (ES) does not impact the appointed DF.

When DF load balancing is enabled, designated forwarder election can occur. To elect a designated forwarder (DF) for a VLAN ID on an ES, each leaf node exchanges its router IP address with its multi-homing leaf nodes through the ES route. The following algorithm uses the IP address to select the DF.

1. Upon the discovery of a new ES, a leaf node advertises the ES route and waits a default of three seconds for its peer to advertise the ES route.
2. When the timer expires, the leaf node builds a sorted list of leaf node IP addresses including its own address connected to the same ES.

3. The leaf node with the ordinal number that equals (V mod N) is elected the DF. V is the VLAN ID and N is the number of leaf nodes.
4. When the ES link fails, the leaf node withdraws its ES route which triggers the selection process to select a new DF. When a leaf node failure occurs, DF election is also triggered when the leaf node is up and down.

Designated forwarder election is triggered in the following scenarios:

- A client is deployed locally or remotely, or the BGP session comes up.

  The DF timer is started and the DF election is not performed until the timer expires.
- CCEP goes up or down.

  DF election is triggered as soon as ES/Enet-AD route from the remote peer is received or withdrawn to minimize the traffic loss.

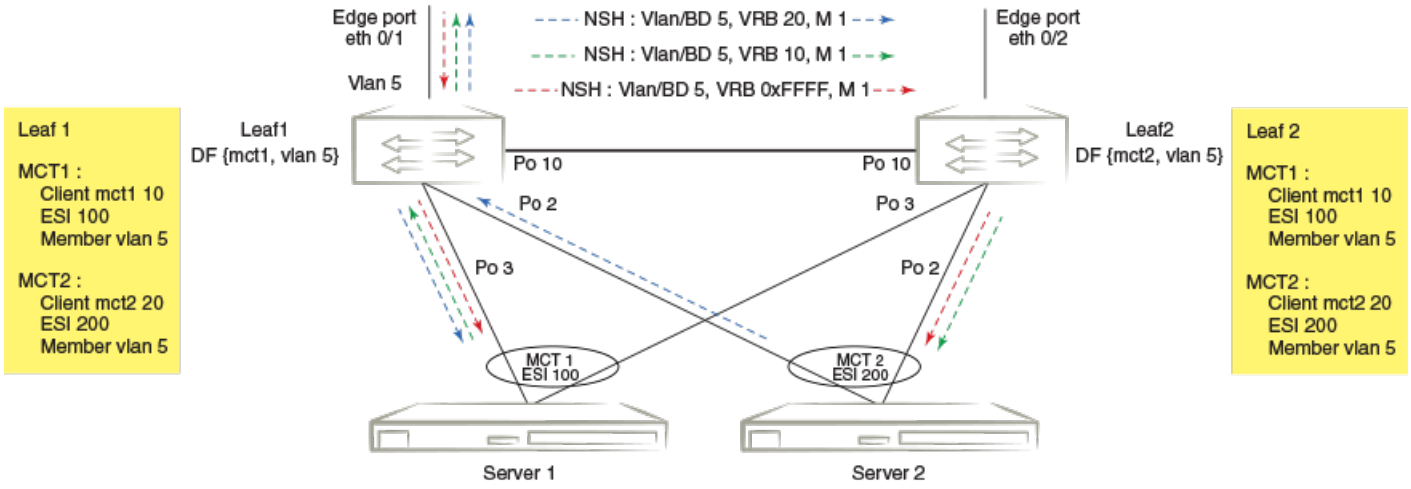
MCT data plane traffic forwarding

The MCT data plane provide the following traffic forwarding:

- BUM forwarding using NSH
- Unicast traffic forwarding

BUM forwarding using NSH

The following topology describes BUM forwarding using NSH.



Leaf1 and Leaf2 are MCT peers. MCT1 and MCT2 are two LAGs. On both leaf nodes, MCT1 is configured with client ID 10, ESI 100 and member VLAN 5. Similarly, MCT2 is configured with client ID 20, ESI 200, and member VLAN 5. In this example, Leaf1 is DF for {ESI 100, vlan 5} and Leaf2 is DF for {ESI 200, vlan 5}.

For the BUM traffic on the edge port, as indicated by the red arrows:

- In Leaf1, the BUM traffic received on edge port eth 0/1 is flooded based on the VLAN MGID. The packet transmitted over the peer link (Po10) is encapsulated with the NSH including the VLAN encoded with the same value as the incoming VLAN, the VRB ID set to the reserved value for the edge port (0xFFFE), and the M bit set to indicate the BUM packet.
- In the Leaf2, packet is flooded based on VLAN MGID.

For the BUM traffic on the client interface of the DF, as indicated by the green arrows:

- The BUM traffic received on client interface Po3 of MCT1, for which Leaf1 is DF, is flooded based on the VLAN MGID. The packet transmitted over peer link (Po10) is encapsulated with the NSH including the VLAN encoded with the same value as the incoming VLAN, the VRB ID set to 10 (the client ID of MCT1), and the M bit set to indicate the BUM packet.
- In Leaf2, the received VRB ID is used for source suppression and the packet is flooded based on VLAN MGID.

For the BUM traffic on the client interface of the non-DF node, as indicated by the blue arrows:

- The BUM traffic received on client interface Po2 of MCT2, for which Leaf1 is not the DF, is flooded based on the VLAN MGID. The packet transmitted over peer link (Po10) is encapsulated with the NSH including the VLAN encoded with same value as the incoming VLAN, the VRB ID set to 20 (the client ID of MCT2), and the M bit set to indicate the BUM packet.
- In Leaf2, the received VRB ID is used for source suppression and the packet is flooded based on the VLAN MGID.

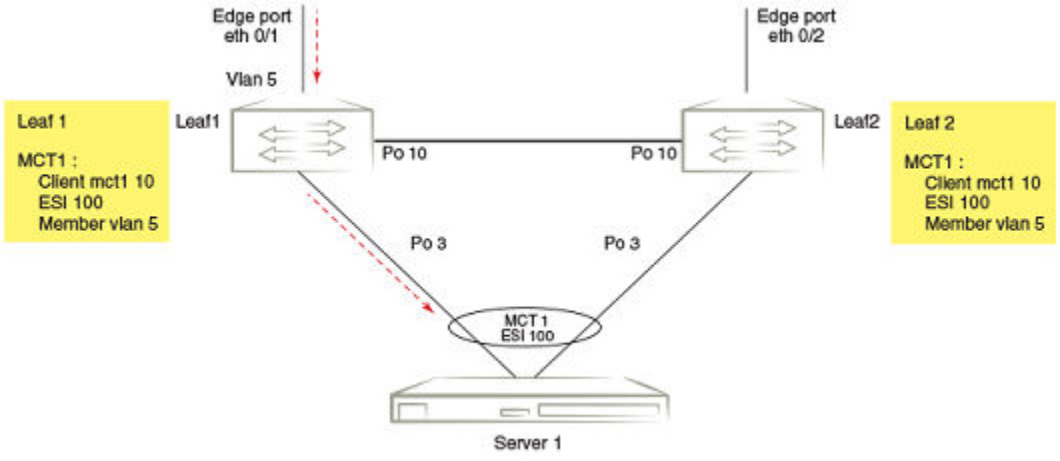
Unicast traffic forwarding

The following examples describe the following unicast forwarding traffic:

- Unicast local forwarding
- Unicast forwarding over the peer link from the edge port
- Unicast forwarding over peer link from client interface

Unicast local forwarding example

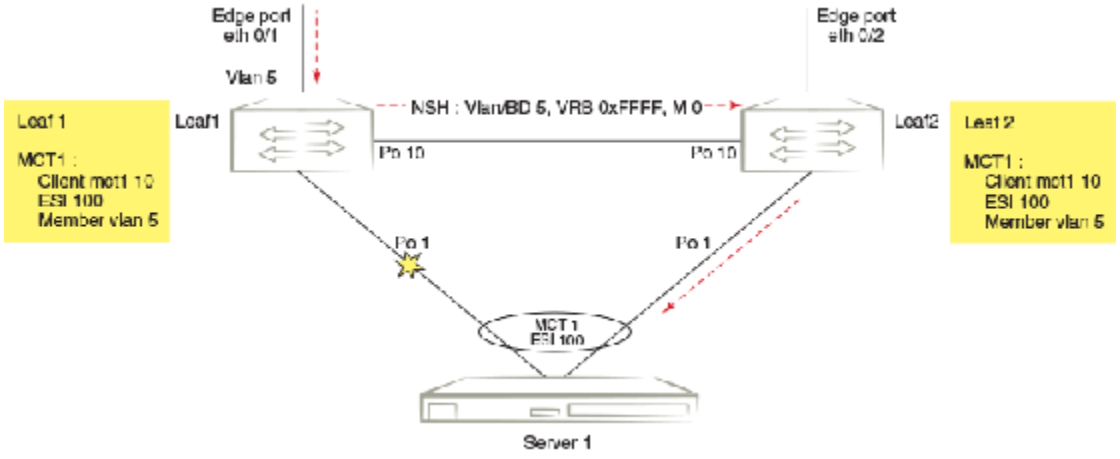
Unicast traffic sent between edge port eth 0/1 and Server 1 follows normal Layer 2 forwarding.



Unicast forwarding over the peer link from the edge port example

The unicast packet transmitted over the peer link (Po10) is encapsulated with the NSH including the VLAN encoded with the same value as the incoming VLAN, the VRB ID set to the reserved value for the edge port (0xFFFE), and the M bit set to zero to indicate the unicast packet.

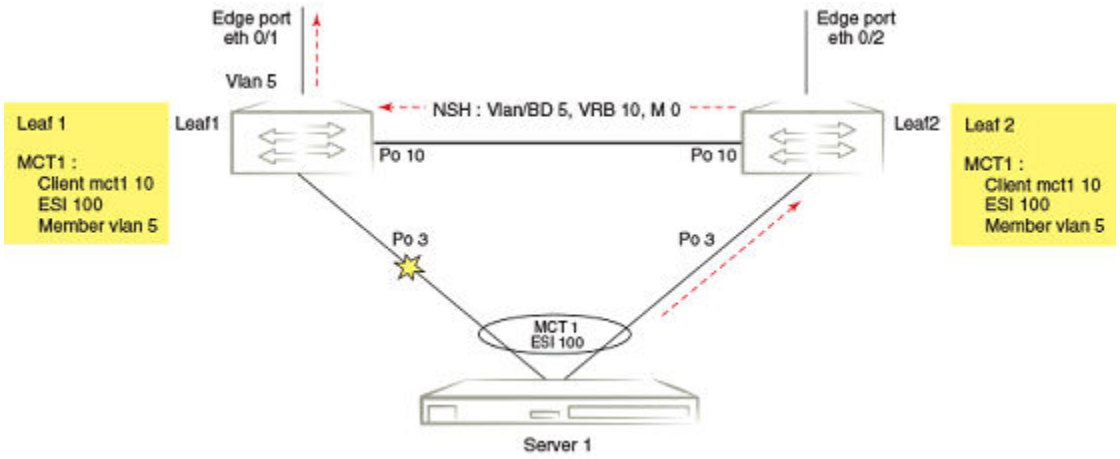
In Leaf2, the packet follows normal Layer 2 forwarding.



Unicast forwarding over peer link from client interface example

The unicast packet transmitted over the peer link (Po10) is encapsulated with the NSH including the VLAN encoded with same value as the incoming VLAN, the VRB ID set to 10 (the client ID of MCT1), and the M bit set to zero to indicate the unicast packet.

In Leaf1 packet follows normal Layer 2 forwarding.



Configuration considerations

- The SLX-OS device does not assume that the MCT peers are directly connected.
- A switch supports only one cluster.
- The cluster peer IP address is the IP address of the remote MCT node.

- The cluster peer interface is a directly connected port.
- Since the The SLX-OS device supports both dynamic and static LAG between the MCT node and CE, it uses Ethernet segment identifier (ESI) type 0 regardless of the LAG type.
  - The ESI is auto generated and its configuration is optional. If you configure the ESI value, the auto-generated value is overwritten.
  - You can configure the 9-byte ESI value that is used to form a 10-byte integer globally unique ESI.
  - You must configure the same 9-byte ESI value for each client on both MCT devices.
- You must configure and activate a BGP EVPN neighbor as the peer interface.
- The peer link must be configured and must be a switch port. When the peer interface is configured, it is an internal switch port. An external switch port configuration on peer interface is not allowed.
- The peer link will be part of all configured member VLANs.
- The cluster client ID for a specific ESI must be the same in both peers. The cluster client ID is used to derive VRB ID which is used in NSH header for source suppression.
- BGP Bidirectional Forwarding Detection (BFD) is used for the MCT peer keep alive.
- To form an MLAG, both MCT peers must use a unique LACP actor system ID and actor port key. The actor system ID is derived by appending a cluster ID to the MCT base system ID which is a device-defined value.

  System ID = mct_base_system_id (0180.c200) + cluster_id

  The actor port key is derived by appending a client ID to the MCT port key base which is a device-defined value.

  Key = MCT_LACP_KEY_BASE (3000) + client_ID

Configuring the BGP EVPN peer

Create a BGP EVPN address family to configure and activate the cluster EVPN peer. This configuration is associated with the MCT cluster peer configuration.

1. In privileged EXEC mode, enter global configuration mode.

   ```
   device# configure terminal
   ```

2. Enable BGP routing.

   ```
   device(config-terminal)# router bgp
   ```

3. Configure the EVPN peer with the autonomous system number (ASN).

   ```
   device(config-bgp-router)# neighbor 10.1.1.1 remote-as 100
   ```

4. Enter EVPN address family configuration mode

   ```
   device(config-bgp-router)# address-family evpn
   ```

5. Activate the EVPN peer.

   ```
   device(config-bgp-evpn)# neighbor 10.1.1.1 activate
   ```

The following example are the steps in the previous configuration.

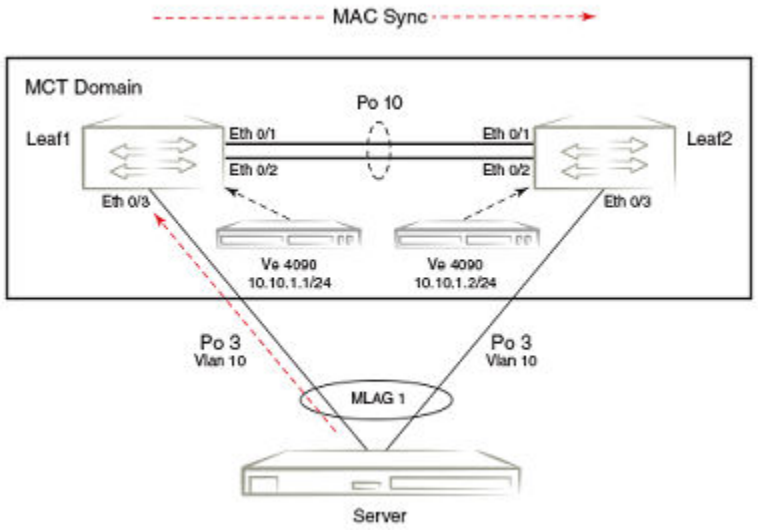
```
device(config-terminal)# router bgp
device(config-bgp-router)# neighbor 10.1.1.1 remote-as 100
device(config-bgp-router)# address-family evpn
device(config-bgp-evpn)# neighbor 10.1.1.1 activate
```

Configuring the MCT domain between a leaf switch pair

Before configuring MCT domain between a leaf switch pair, ensure that the following configurations exist:

- Layer 2 interface for the cluster peer interface
- VLANs for the cluster members
- Port channel for Link Aggregation or an Ethernet interface as a client interface

Refer to the following figure for configuring the Leaf1 and Leaf2 clusters and clients.



Configuring the Leaf1 cluster and client

Perform the following steps to configure the Leaf1 cluster and client of the MCT switch pair.

1. In privileged EXEC mode, enter global configuration mode.

   ```
   device# configure terminal
   ```

2. Create a cluster on the device.

   ```
   device (config)# cluster MCT1 1
   ```

3. Add the VLANs as members to the cluster.

   ```
   device(config-cluster-1)# member vlan add 10
   ```

4. Add the bridge-domains as members to the cluster, if required.

   ```
   device(config-cluster-1)# member bridge-domain add 1-5
   ```

   For more information on the bridge domain configuration, see Bridge domain for Layer 2 multitenancy on page 51.

5. Configure the peer address.

```
device(config-cluster-1)# peer 10.1.1.2
```

   The peer address is the remote MCT node IP address. In this example, it is the address for leaf2.

   This address corresponds with the neighbor in BGP EVPN address family configuration for the peer.

6. Configure the peer interface.

```
device(config-cluster-1)# peer-interface port-channel 10
```

   The peer interface must be a valid Layer 2 interface. You should configure the peer interface before deploying the configuration.

   NOTE
   A peer link cannot be a Layer 3 interface.
   When the peer interface is configured, it is an internal switch port. An external switch port configuration on peer interface is not allowed.

7. Deploy the cluster.

```
device(config-cluster-1)# deploy
```

8. Create the client for the cluster and access cluster client configuration mode.

```
device(config-cluster-1)# client mlag1 1
```

   On both MCT nodes, you must configure the same client ID.

9. Configure the interface to the cluster client instance.

```
device(config-cluster-client-1)# client-interface port-channel 3
```

   The port channel specifies the LAG ID.

   The client interface can also be a physical interface, for example:

```
device(config-cluster-client-1)# client-interface Ethernet 0/5
```

   The client interface cannot be added under multiple client entries.

10. Optionally, set the 9-octet Ethernet Segment ID (ESI) value which is used to uniquely identify the cluster client.

```
device(config-cluster-client-1)# esi 00.a1.b2.c3.d4.e5.f6.89.00
```

    You must configure the same value on both MCT nodes to create the MCT client LAG.

    The ESI cannot be added under multiple client entries.

11. Deploy the cluster client.

```
device(config-cluster-client-1)# deploy
```

The following example is the steps in the previous configuration.

```
device# configure terminal
device (config)# cluster MCT1 1
device(config-cluster-1)# member vlan add 10
device(config-cluster-1)# member bridge-domain add 1-5
device(config-cluster-1)# peer 10.1.1.2
device(config-cluster-1)# peer-interface port-channel 10
device(config-cluster-1)# deploy
device(config-cluster-1)# client mlag1 1
device(config-cluster-client-1)# client-interface port-channel 3
device(config-cluster-client-1)# esi 00.a1.b2.c3.d4.e5.f6.89.00
device(config-cluster-client-1)# deploy
```

After configuring the Leaf1 cluster and client, configure the Leaf2 cluster and client.

Configuring the Leaf2 cluster and client

Perform the following steps to configure the Leaf2 cluster and client of the MCT switch pair.

1. In privileged EXEC mode, enter global configuration mode.

```
device# configure terminal
```

2. Create a cluster on the device.

```
device (config)# cluster MCT1 1
```

3. Add the VLANs as members to the cluster.

```
device(config-cluster-1)# member vlan add 10
```

4. Add the bridge-domains as members to the cluster, if required.

```
device(config-cluster-1)# member bridge-domain add 1-5
```

   For more information on the bridge domain configuration, see Bridge domain for Layer 2 multitenancy on page 51.

5. Configure the peer address.

```
device(config-cluster-1)# peer 10.1.1.1
```

   The peer address is the peer MCT node IP address. In this example, it is the address for Leaf1.

   This address corresponds with the neighbor in BGP EVPN address family configuration for the peer.

6. Configure the peer interface.

```
device(config-cluster-1)# peer-interface port-channel 10
```

   The peer interface must be a valid Layer 2 interface and is the same as the MCT peer. You should configure the peer interface before deploying the configuration.

   NOTE
   A peer link cannot be a Layer 3 interface.
   When the peer interface is configured, it is an internal switch port. An external switch port configuration on peer interface is not allowed.

7. Deploy the cluster.

```
device(config-cluster-1)# deploy
```

8. Create the client for the cluster and access cluster client configuration mode.

```
device(config-cluster-1)# client mlag1 1
```

   On both MCT nodes, you must configure the same client ID.

9. Configure the interface to the cluster client instance.

```
device(config-cluster-client-1)# client-interface port-channel 3
```

   The port channel specifies the LAG ID.

   The client interface can also be a physical interface, for example:

```
device(config-cluster-client-1)# client-interface Ethernet 0/5
```

   The client interface cannot be added under multiple client entries.

10. Optionally, set the 9-octet Ethernet Segment ID (ESI) value which is used to uniquely identify the cluster client.

```
device(config-cluster-client-1)# esi 00.a1.b2.c3.d4.e5.f6.89.00
```

    You must configure the same value on both MCT nodes to create the MCT client LAG.

    The ESI cannot be added under multiple client entries.

11. Deploy the cluster client.

```
device(config-cluster-client-1)# deploy
```

The following example is the steps in the previous configuration.

```
device# configure terminal
device (config)# cluster MCT1 1
device(config-cluster-1)# member vlan add 10
device(config-cluster-1)# member bridge-domain add 1-5
device(config-cluster-1)# peer 10.1.1.1
device(config-cluster-1)# peer-interface port-channel 10
device(config-cluster-1)# deploy
device(config-cluster-1)# client mlag1 1
device(config-cluster-client-1)# client-interface port-channel 3
device(config-cluster-client-1)# esi 00.a1.b2.c3.d4.e5.f6.89.00
device(config-cluster-client-1)# deploy
```

Configuring additional MCT cluster parameters

The SLX-OS device has additional cluster commands with default values. You can change the parameters for these commands in cluster configuration mode.

Changing the client-isolation mode

Isolation mode defines the action to be taken when the BGP control session goes down between the MCT nodes while the cluster is in deployed state. When the client-isolation mode is strict, the client interface will be shutdown.

By default, client-isolation mode is loose. In loose mode, both peers act as DF masters. When the EVPN control session goes down, the peer device performs the master/slave negotiation. After negotiation, the slave shuts down its peer ports, and the master peer ports continue to forward the traffic (keep-alive VLAN configured).

You can configure strict mode. In this mode, when the EVPN control session goes down, the interfaces on both the cluster devices are administratively shut down. In strict mode, the client is completely isolated from the network if the control session is not operational.

Use the **client-isolation-strict** command to configure the strict mode on both nodes, as shown in the following example.

```
device(config-cluster-1)# client-isolation-strict
```

Changing the designated-forwarder hold timer value

Upon expiration of the designated-forwarder hold timer, the reelection of the designated forwarder is considered.

By default, the hold time is three seconds. Use the **designated-forwarder-hold-time** command to change the time in seconds from 1 to 60 seconds, as shown in the following example.

```
device(config-cluster-1)# designated-forwarder-hold-time 35
```

Enabling DF load balancing

By default, DF load balancing is disabled. When DF load balancing is disabled, DF election is triggered only when the current DF leaf node goes down or its client interface is down. When a non-DF leaf node goes down or a new node joins the ES, DF election is not triggered.

When DF load balancing is enabled, the DF election is triggered in the following scenarios:

- A client is deployed locally or remotely.
- The BGP cluster control protocol (CCP) session comes up.
- Remote CCEP goes up or down.

Use the **df-load-balance** command to enable DF load balancing, as shown in the following example.

```
device(config-cluster-1)# df-load-balance
```

Changing the cluster control VLAN

The cluster control VLAN is required for MAC learning, resolving ARP for the BGP peer, and to derive the outer MAC address for the NSH tunnel.

By default, the control VLAN is 4090. You can configure a value from 1 to 4090. Use the **cluster-control-vlan** command, as shown in the following example.

```
device(config-cluster-1)# cluster-control-vlan 20
```

NOTE
If MCT is configured, other switch ports must not be part of the cluster control VLAN.

Moving the traffic from an MCT node to the remote node

Use the **client-interfaces-shutdown** command to move all the traffic on the node to the remote MCT node by disabling the local client interfaces administratively, as shown in the following example.

```
device(config-cluster-1)# client-interfaces-shutdown
```

Displaying MCT information

You can display detailed MCT information and related MCT MAC addresses.

To display the EVPN neighbor information, use **show ip bgp neighbors** command. This information includes the peer configured for the EVPN address family, the undeplyed MCT cluster, and the negotiation of the EVPN address family.

Displaying the cluster information

The following example shows the information of the cluster on the SLX-OS device.

```
device# show cluster 1

Cluster MCT1 1
==============
Cluster State: Deploy
Client Isolation Mode: Loose
DF Hold Time: 3
Configured Member Vlan Range: 2, 4-7
Active Member Vlan Range: 2, 4-7
Cluster Control Vlan: 4090
Configured Member BD Range:
Active Member BD Range:
No. of Peers: 0
No. of Clients: 0

 Peer Info:
 ----------
 Peer IP: 10.10.10.20, State: Up
 Peer Interface: Ethernet 0/1

 Client Info:
 ------------
 Name     Id   ESI                           Interface    Local/Remote State
 access1  100  00.a1.b2.c3.d4.e5.f6.89.00     Eth 0/3         Up/UP
 access2  200  00.11.22.33.44.55.66.77.88     po-chan-2       Dep/UnDep
 access3  300  00.24.46.0e.cd.ab.66.16.00     Eth 0/8         Up/Down
```

Displaying the cluster client information

The following example displays client 100 information for cluster 10.

```
device# show cluster 10 client 100

Client Info:
============
Client                : access1
Client-id             : 100
Client state          : Undeployed
Interface state       : Up
Interface             : Ethernet 0/8
Vlans                 : 1-10, 100
Bridge Domains        :
Number of DF Vlans    : 0
Elected DF for vlans  :
Number of DF Bridge Domains   : 0
Elected DF for Bridge Domains :
```

Displaying and clearing the MAC address table cluster information

The following example displays the MCT cluster information in the MAC address table.

```
device# show mac-address-table cluster 1
Type Code - CL:Cluster Local MAC   CCL:Cluster Client Local MAC
            CR:Cluster Remote MAC  CCR:Cluster Client Remote MAC
VlanId/BDId   Mac-address       Type        State      Ports/LIF/PW
10 (V)        0000.1111.1111    CCR         Active     Eth 0/43
10 (V)        0000.1111.1112    Dynamic-CCL Active     Eth 0/43
20 (V)        0000.1111.1113    Dynamic-CL  Active     Eth 0/44
20 (V)        0000.1111.1114    CR          Active     Eth 0/10
4090 (V)      609c.9f5b.1301    Dynamic     Active     Eth 0/10
Total MAC addresses    :  5
```

You can also view the MAC entries for a specific client.

Clearing the MCT cluster MAC table entries

You can clear all cluster entries from the MAC address table or the entries for a specified client. The following example clears the MAC entries for client 3 of cluster 1.

```
device# clear mac-address-table cluster 1 client 3
```

Only the local MAC entries are deleted from the current node. Individual MAC withdrawal flush messages are sent through the EVPN. However, BGP still batches multiple routes to the remote node.

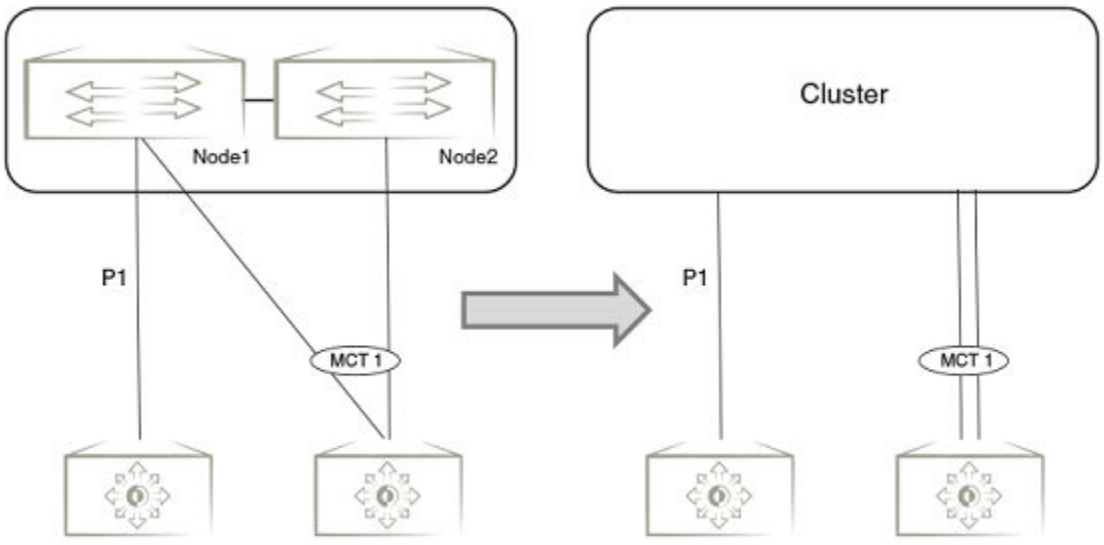
When the remote MCT peer receives the MAC withdrawal message, it only deletes the remote MAC entry. To clear MAC addresses on both nodes, you must issue **clear mac-address-table** commands on both MCT nodes.

Loop prevention in MCT through STP

In a cluster deployment, a loop situation may occur due to misconfigurations or any faulty connection in the network. When you enable spanning tree protocol (STP) on the SLX-OS device, the device uses STP as the mechanism for preventing loops in MCT interfaces.

> NOTE
> For more information on STP, refer to the "802.1d Spanning Tree Protocol" chapter.

The SLX-OS device treats the cluster as one virtual xSTP bridge with xSTP running between the cluster or standalone nodes.



- Each cluster has a unique bridge ID and priority.
- STP is enabled on the cluster edge ports connecting to other cluster or standalone nodes.

> NOTE
> STP is supported on the cluster edge ports only. STP cannot be enabled on peer link ports connecting the nodes in the cluster. STP does not update the port state of peer link ports.

Each node runs the spanning tree instance in a distributed manner. This instance considers all edge ports and the best information from the remote node to arrive at the spanning tree topology.

Each node updates the other member about its best information for each spanning tree instance and maintains a table of this information. This table is identical across all nodes in the cluster. The table information is used to determine the roles and states for the local edge ports. Thus, each node considers the port roles and states of the other node to arrive at a final spanning tree topology.

Bridge ID

In SLX-OS, when the cluster mode is disabled, the physical MAC address is used as the bridge identifier (ID). When cluster mode is enabled, the virtual MAC address is used as the bridge ID .

The bridge ID or switch MAC used in all nodes participating in the STP domain must have a unique MAC address. A cluster should act as a single node for all peer bridges in the STP topology. Since any of the switches in the cluster can be swapped out and moved to another cluster, the bridge ID does not belong to any piece of hardware.

Virtual bridge ID format

The bridge ID is derived from the reserved Brocade MAC address (Brocade OUI). The Brocade OUI is 00:E0:52.

The bridge ID has the following form:

<Brocade OUI (3bytes)>: <Cluster ID (2bytes)>:00

For example, the bridge identifier for a cluster with an ID as 2 will have the following ID:

00:E0:52:00:02:00

By default, the last byte is 0. However, it is configurable.

Bridge ID collision

The possibility of a virtual bridge ID collision can occur if bridges in the spanning-tree topology have the same cluster ID. If this exists, you can avoid collisions by using the **cluster-system-id** command to change the last byte of the virtual bridge ID. For more information, refer to the "Avoiding bridge ID collisions".

Port ID

In spanning tree, each port participating in the tree is assigned an ID which is the direct port number. In a cluster environment, this port number must be unique across both nodes. Also, for MCT interfaces, the port ID must be the same in both cluster nodes.

The port ID used in BPDUs is 16 bits long with two parts:

- 4 bits for port priority
- 12 bits for the port number. Port number allocation for MCT interfaces, regular LAG interfaces and Ethernet interfaces is done in these 12 bits.
  - Bit 11—MCT Type bit. For MCT interfaces, this bit is set. The MCT client ID will be encoded in rest of the 11 bits (Bit 10:0).
  - Bit 10—Node ID. When the cluster is enabled, this bit is set. The node ID is either 0 or 1. The cluster node with highest peer IP address is 1 and the other node is 0.
  - Bit 9—LAG Type bit. For LAG interfaces with non MCT interfaces, this bit is set. The LAG ID is encoded in the rest of the 9 bits (Bit 8:0).
  - Bit 8:0—Port number. The port number is encoded in these 9 bits.

This static encoding of the port IDs ensures that the ID is unique across the cluster and no two ports will have the same port ID.

Loop prevention configuration considerations.

- By default global spanning tree is disabled in the SLX-OS device. When the global spanning tree configuration is enabled, all switchports are enabled with spanning tree. By default, the physical MAC is used as the bridge ID and the port ID computation is local mode. However, when the cluster is deployed, the virtual MAC address is used as the bridge ID.
- Mismatched global configuration of xSTP across different nodes in cluster is not supported. For example, if one of the nodes in a cluster is configured for RSTP and the another one is configured for STP or MSTP, this is not supported.
- Spanning tree protocol can be enabled on the switch by the **protocol spanning-tree** command. An interface starts to participate in the spanning tree once it is configured by the **no spanning-tree shutdown** command.
- STP in MCT is supported on the cluster edge ports only. You cannot enable STP on a peer link.
- If STP is already enabled when changing the cluster, there will be a change in the bridge ID and port ID that can cause a possible re-convergence. Configure the cluster before enabling STP to avoid any re-convergence.

Configuring the last byte of the bridge ID

The bridge ID (Switch MAC) used by all nodes participating in the STP domain should have a unique MAC address. You can configure the last byte of the bridge ID to ensure that two or more clusters do not have the same bridge IDs in a Layer 2 topology.

Before changing the last byte of the bridge ID, the cluster must be configured.

Ensure that the global STP configuration is consistent on both cluster nodes. Configuration mismatch handling is not supported.

1. In privileged EXEC mode, enter global configuration mode.

   ```
   device# configure terminal
   ```

2. Enable a version of STP globally and access its configuration mode.

   ```
   device(config)# protocol spanning-tree rstp
   ```

   In this step, RSTP is enabled.

3. Change the last byte on the bridge ID to a unique value.

   ```
   device(config-rstp)# cluster-system-id 2
   ```

   By default, the value of the last byte is 0. Enter an integer from 1 to 255.

4. Verify the change to the bridge ID.

   ```
   device(config-rstp)# do show spanning-tree brief
   ...
   Bridge ID Priority 32768
             Address 00e0.5200.0102
             Hello Time 2, Max Age 20,Forward Delay 15, Tx-HoldCount6
             Migrate Time 3 sec
   ...
   ```

5. Repeat the previous steps on the other node in the cluster. You must configure the cluster nodes with the same value.

The following example show the previously configured steps.

```
device# configure terminal
device(config)# protocol spanning-tree rstp
device(config-rstp)# cluster-system-id 2
device(config-rstp)# do show spanning-tree brief
```

Displaying the root port on the cluster

In the following example, the **show spanning-tree brief** command displays the root port (RTPT), Ethernet 0/22, is on the current node in the cluster.

```
device# show spanning-tree brief
     Spanning-tree Mode: Rapid Spanning Tree Protocol
     Root ID    Priority 32768
                Address 0005.1ecd.0b8a
                Hello Time 2, Max Age 20, Forward Delay 15
                Root Port ID: Eth 0/22
     Bridge ID  Priority 32768
                Address 0105.3352.6f28
                Hello Time 2, Max Age 20, Forward Delay 15, Tx-HoldCount 6
                Migrate Time 3 sec
Interface  Role   Sts   Cost   Prio   Link-type   Edge
-------------------------------------------------------------------
Eth 0/1    DES    FWD   2000   128    P2P         No
Eth 0/2    DES    FWD   2000   128    P2P         No
Eth 0/22   RTPT   FWD   2000   128    P2P         No
```

If the root port is on another node in the cluster, the **show spanning-tree brief** command displays the following output for Ethernet 0/23 as the alternate (ALT) port.

```
# show spanning-tree brief
     Spanning-tree Mode: Rapid Spanning Tree Protocol
     Root ID    Priority 32768
                Address 0005.1ecd.0b8a
                Hello Time 2, Max Age 20, Forward Delay 15
                Root Port ID : Eth 0/22 (Remote)
     Bridge ID  Priority 32768
                Address 0105.3352.6f28
                Hello Time 2, Max Age 20, Forward Delay 15, Tx-HoldCount 6
                Migrate Time 3 sec
Interface  Role   Sts   Cost   Prio   Link-type   Edge
-------------------------------------------------------------------
Eth 0/1    DES    FWD   2000   128    P2P         No
Eth 0/2    DES    FWD   2000   128    P2P         No
Eth 0/23   ALT    DSC   2000   128    P2P         No
```

Bridge domain for Layer 2 multitenancy

A bridge domain (BD) is a generic broadcast domain that contains logical interfaces of Layer 2 interfaces and MCT interfaces with different VLAN classifications.

> NOTE
> A BD broadcast domain is different from a VLAN broadcast domain.

You must create a logical interface with specific VLANs on an Ethernet or port channel interface. Then, the logical interface is added to the bridge domain to bind them.

When the BD is created, a unique internal VLAN ID (IVID) is allocated for the BD by the device. The IVID allows only the logical interfaces belonging to the BD to forward traffic with each other. The flooding and forwarding of the Layer 2 traffic is restricted to the broadcast domain of the BD.

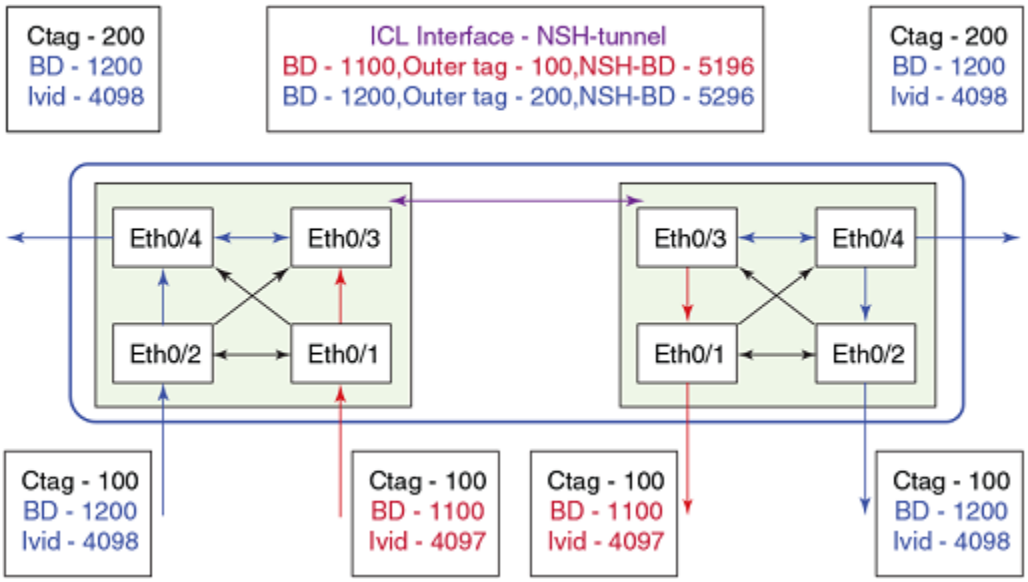
The SLX-OS device supports multitenancy for a bridge domain in an MCT cluster deployment. The BD traffic is extended to a node through the ICL using NSH tunnel encapsulation. The BD is mapped to an NSH BD sent across the ICL.

On the other node, traffic on this NSH BD, is classified to the BD IVID. Based on the configuration for this BD on this node, the traffic may be forwarded or flooded in this IVID.

MCT bridge domain example

In the following example, a dot1q VLAN tag (ctag) 100 is required by two customers. Two BDs are required.

- BD 1100—The device gives a unique IVID 4097 and maps ctag 100 and 200 traffic to this BD.
- BD 1200—The device gives a unique IVID 4098 and maps ctag 100 and 200 traffic to this BD.



For customer 1, nodes, 1 and 2 are configured with ctag 100 on the respective eth0/1 interface. A logical interface on eth0/1 is configured for VLAN 100 and is added to BD 1100.

For customer 2, nodes 1 and 2 are configured with the same ctag 100 on eth0/2 and ctag 200 on eth0/4, and added to BD 1200. A logical interface on eth0/2 is configured for VLAN 100 and is added to BD 1200. A logical interface on eth0/4 is configured for VLAN 200 and is added to BD 1200.

When the BD is added as a member to an MCT cluster, the traffic for each BD is carried to the other node using NSH BD in the NSH encapsulation. On the receiving node, the NSH BD is mapped to the configured BD.

Configuration considerations for bridge domain for MCT

- The BD must contain the CCEP interfaces and the peer interface.
- The peer interface can be a physical port or a port-channel.
- The peer interface carries only the MCT BD traffic.
- The logical interface is not created for the peer interface.
- Only the unknown flood traffic hits the flood multicast group ID(MGID) of MCT BD and is flooded. The learnt traffic hits the forwarding database (FDB). The FDB points to the CCEP logical interface (LIF) and the traffic goes to the egress port of the CCEP LIF.
- The egress port of the CCEP LIF is either the CCEP interface or the peer interface based on the availability of the link.

Configuring a bridge domain

A bridge domain is a broadcast domain for the forwarding and flooding of Layer 2 traffic restricted to the domain of the BD. After you configure the BD for Layer 2 multitenancy, you can add it as a member to an MCT cluster.

Prior to completing the following task, the Ethernet logical interface and VLANs must be created. There is an example at the end of this task that shows all the steps in order.

You can configure a bridge domain by completing the following task.

1. From privileged EXEC mode, enter global configuration mode.

```
device# configure terminal
```

2. Create a bridge domain.

```
device(config)# bridge-domain 50
```

   In this example, bridge domain 50 is created as a multipoint service. By default, the bridge-domain service type is multipoint.

3. Bind the logical interfaces for attachment circuit endpoints to the bridge domain.

```
device(config-bridge-domain-50)# logical-interface port-channel 52.5
```

   In this example, the port-channel logical interface 52.5 is bound to bridge domain 50. You can also bind an Ethernet interface.

4. Repeat the previous step to bind additional logical interface to the bridge domain.

```
device(config-bridge-domain-50)# logical-interface port-channel 110.55
```

5. Enter Privileged EXEC mode.

```
device(config-bridge-domain-50)# end
```

6. (Optional) Display the running configuration of the bridge domain.

```
device# show running-config bridge-domain
bridge-domain 50 p2mp
logical-interface port-channel 110.55
logical-interface port-channel 52.5
!
```

7. (Optional) Display the information about the configured bridge domain.

```
device# show bridge-domain
Bridge-domain 50
------------------------------
Bridge-domain Type: MP
Number of configured end-points: 2 , Number of Active end-points: 2
VE if-indx: 0, bpdu-drop-enable: TRUE
mac-limit: 0
VLAN: 5, Tagged ports: 1(1 up), Un-tagged ports: 0 (0 up)
Tagged Ports: po52.5
Un-tagged Ports:
VLAN: 4093, Tagged ports: 0(0 up), Un-tagged ports: 1 (1 up)
Tagged Ports:
Un-tagged Ports: po110.55
```

The following example shows the creation of a logical interface and VLAN in addition to the bridge domain configuration.

```
device# configure terminal
device(config)# interface port-channel 52
device(config-Port-channel-52)# switchport
device(config-Port-channel-52)# switchport mode trunk
device(config-Port-channel-52)# logical-interface port-channel 52.5
device(conf-if-po-lif-52.5)# vlan 5
device(conf-if-po-lif-52.5)# exit
device(config-Port-channel-52)# exit
device(config)# interface port-channel 110
device(config-Port-channel-110)# switchport
device(config-Port-channel-110)# switchport mode trunk-no-default-native
device(config-Port-channel-110)# logical-interface port-channel 110.55
device(conf-if-po-lif-110.55)# untagged
device(conf-if-po-lif-110.55)# exit
device(config-Port-channel-110)# exit
device(config)# bridge-domain 50
device(config-bridge-domain-50)# logical-interface port-channel 52.5
device(config-bridge-domain-50)# logical-interface port-channel 110.55
```

Enabling and displaying bridge domain statistics

By default, bridge domain statistics are disabled on the device. Follow this procedure to enable statistics on a bridge domain and display its statistics.

1. Enter the global configuration mode.

```
device# configure terminal
```

2. Access the configuration mode for the bridge domain.

```
device(config)# bridge-domain 50
```

3. Enable statistics for the bridge domains.

```
device(config-bridge-domain-50)# statistics
```

4. Display the statistics for the bridge domain.

```
device(config-bridge-domain-50)# do show statistics bridge-domain
Bridge-Domain Statistics
BD Index      Rx Pkts              Rx Bytes             Tx Pkts              Tx Bytes
50            0                    0                    0                    0
```

Clearing the bridge domain statistics

Use the **clear statistics bridge-domain** command to clear the statistics for the bridge domains.

```
device# clear statistics bridge-domain
```

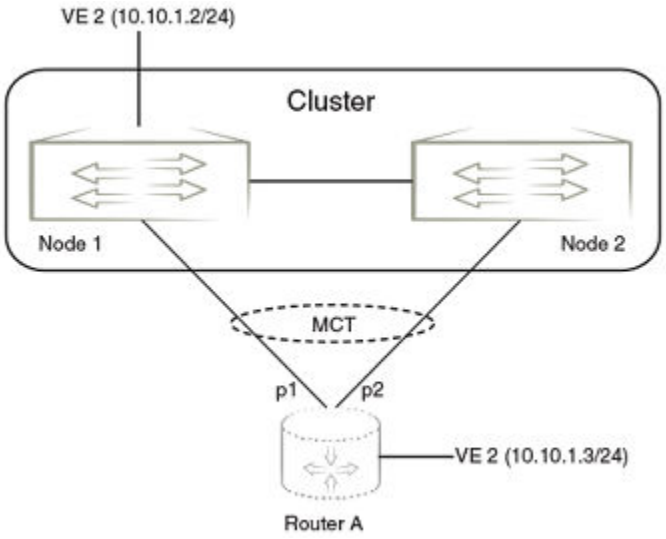
To clear the statistics for a specific bridge domain, specify the bridge domain with the **clear statistics bridge-domain** command.

```
device# clear statistics bridge-domain 1
```

BFD support for Layer 3 protocols on MCT

Layer 3 BFD sessions are supported on MCT interfaces used by SVI sessions.

For more information on BFD, refer to the *SLX-OS Layer 3 Configuration Guide*. The following figure shows BFD on MCT.



BFD packet transmission

Cluster Node 1 hosting the BFD session starts the BFD packet transmission over the local member port p1. If the local member port goes down, the parent VE interface of MCT is in the operationally UP state and is reachable using the MCTclient interface of cluster Node 2. In case all local MCT client ports go down, the BFD packets is the transmitter through the peer interface to the remote cluster node. Also, the remote node forwards the BFD packet through its local MCT client interface.

BFD packet reception

The BFD packet received in the MCT member ports of the remote Node 1 is redirected to the destination Node 1 through the peer interface.

Enabling Layer3 routing for an MCT VLAN

Layer 3 routing is supported for IPv4 and IPv6 BGP, and OSPF routing protocols on an MCT VLAN.

The enabling of the Layer 3 protocols on the MCT VLAN are the same as enabling them on a VE interface. You must first create the VE interface for an MCT VLAN.

The following configuration example enables OSPFv2 and OSPFv3 protocols on VE 200 for the MCT member VLAN 2.

```
router ospf
  area 0

ipv6 router ospf
  area 0

vlan 2
 router-interface Ve 200

interface Ve 200
 ipv6 address 2001::1/64
 ip address 10.2.2.1/24

 ip ospf area 0
 ipv6 ospf area 0
```

```
 !
 no shutdown
!
```

802.1d Spanning Tree Protocol

Spanning Tree Protocol overview

The Spanning Tree Protocol (STP) prevents Layer 2 loops in a network by providing redundant links. If a primary link fails, the backup link is activated and network traffic is not affected. STP also ensures that the least cost path is taken when multiple paths exist between ports or VLANs.

The IEEE 802.1d Spanning Tree Protocol (STP) runs on bridges and switches that are 802.1d-compliant.

These variants are Rapid STP (RSTP), Multiple STP (MSTP), Per-VLAN Spanning Tree Plus (PVST+), and Rapid-PVST+ (R-PVST+)

When the spanning tree algorithm is run, the network switches transform the real network topology into a spanning tree topology. In an STP topology any LAN in the network can be reached from any other LAN through a unique path. The network switches recalculate a new spanning tree topology whenever there is a change to the network topology.

For each LAN, the switches that attach to the LAN select a designated switch that is the closest to the root switch. The designated switch forwards all traffic to and from the LAN. The port on the designated switch that connects to the LAN is called the designated port. The switches decide which of their ports is part of the spanning tree. A port is included in the spanning tree if it is a root port or a designated port.

STP runs one spanning tree instance (unaware of VLANs) and relies on long duration forward-delay timers for port state transition between disabled, blocking, listening, learning and forwarding states.

Spanning Tree Protocol configuration notes

Enabling the Spanning Tree Protocol (STP) creates a loop-free topology of Ethernet LANs connected by bridge devices.

The Brocade device supports STP as described in the IEEE 802.1d-1998 specification.

The STP is disabled by default on the Brocade device. Thus, any new VLANs you configure on the Brocade device have STP disabled by default.

Optional features

The following STP configuration features are optional:

- Root guard
- BPDU guard
- PortFast

STP states

Each Layer 2 interface participating in a spanning tree is in one of five states.

A network topology of bridges typically contains redundant connections to provide alternate paths in case of link failures. The redundant connections create a potential for loops in the system. As there is no concept of time to live (TTL) in Ethernet frames, a situation may arise where there is a permanent circulation of frames when the network contains loops. To prevent this, a spanning tree connecting all the bridges is formed in real time.

Every Layer 2 interface running the STP is in one of these states:

State	Action or inaction
Blocking	The interface does not forward frames. Redundant ports are put in a blocking state and enabled when required. This is a transitional state after initialization.
Listening	The interface is identified by the spanning tree as one that should participate in frame forwarding. This is a transitional state after the blocking state for a legacy STP.
Learning	The interface prepares to participate in frame forwarding. This is a transitional state after the blocking state for a legacy STP.
Forwarding	The interface forwards frames. This is a transitional state after the learning state.
Disabled	The interface is not participating in a spanning tree because of shutdown of a port or the port is not operationally up. Any of the other states may transition into this state.

BPDUs

To build a spanning tree for the bridge topology, the bridges must exchange control frames called Bridge Protocol data units (BPDUs).

To construct a spanning tree requires knowledge of the all the participants. The bridges must determine the root bridge and compute the port roles (root, designated, or blocked) with only the information that they have. To ensure that each bridge has enough information, the bridges use BPDUs to exchange information about bridge IDs and root path costs.

A bridge sends a BPDU frame using the unique MAC address of the port itself as a source address, and a destination address of the STP multicast address 01:80:C2:00:00:00.

BPDUs are exchanged regularly (every 2 seconds by default) and enable switches to keep track of network changes and to start and stop forwarding through ports as required.

When a device is first attached to a switch port, it does not immediately forward data. It instead goes through a number of states while it processes inbound BPDUs and determines the topology of the network. When a host is attached, after a listening and learning delay of about 30 seconds, the port always goes into the forwarding state. The time spent in the listening and learning states is determined by the forward delay. However, if instead another switch is connected, the port may remain in blocking mode if it would cause a loop in the network.

There are four types of BPDUs in the original STP specification:

- Configuration BPDU (CBPDU) is used for spanning tree computation.
- Topology Change Notification (TCN) BPDU is used to announce changes in the network topology.
- RSTP BPDU is used for RSTP
- MSTP BPDU is used for MSTP

TCN BPDUs

TCN BPDUs are used to inform other switches of port changes.

TCNs are injected into the network by a non-root switch and propagated to the root. Upon receipt of the TCN, the root switch will set a Topology Change flag in its normal BPDUs. This flag is propagated to all other switches to instruct them to rapidly age out their forwarding table entries.

Consider these configuration rules:

- TCN BPDUs are sent per VLAN.
- TCN BPDUs are sent only in those VLANs in which a topology change is detected.
- TCN BPDUs are sent only in those VLANs for which the bridge is not the root bridge.
- If a topology change is detected on a VLAN for which the bridge is the root bridge, the topology change flag is set in the configuration BPDU that is sent out.

For a given link, in conjunction with the configuration rules, a TCN BPDU is sent out as follows:

- On an access port, only a standard IEEE TCN BPDU is sent out. This TCN BPDU corresponds to a topology change in the access VLAN.
- On a trunk port, if VLAN 1 is allowed (either untagged or untagged), a standard IEEE TCN BPDU is sent for VLAN 1.
- On a trunk port, if the native VLAN is not 1, an untagged TCN BPDU is sent to Cisco or Brocade proprietary MAC address for that VLAN.
- On a trunk port, a tagged TCN BPDU is sent to Cisco or Brocade proprietary MAC address for a tagged VLAN.

As part of the response to TCN BPDUs, the Topology Change and Topology Change Acknowledgment flags are set in all configuration BPDUs corresponding to the VLAN for which the TCN was received.

When a topology change is detected on a trunk port, it is similar to detecting topology changes in each VLAN that is allowed on that trunk port. TCN BPDUs are sent for each VLAN as per the rules.

STP configuration guidelines and restrictions

Follow these configuration guidelines and restrictions when configuring STP and STP variants:

- Only one form of a standing tree protocol, such as STP or RSTP, can be enabled at a time. You must disable one form of xSTP before enabling another.
- When any form of STP is enabled globally, that form of STP is enabled by default on all switch ports.
- LAGs are treated as normal links for any form of STP.
- The STP is disabled by default on the SLX device. Thus, any new VLANs you configure on the SLX device have STP disabled by default.
- PVST/RPVST BPDUs are flooded only if PVST/RPVST is not enabled. STP/RSTP (IEEE) BPDUs are never flooded if STP/RSTP is not enabled.

Understanding the default STP configuration

You should be familiar with STP defaults before you make configuration changes.

TABLE 4 Default STP configuration

Parameter	Default setting
Spanning-tree mode	By default, STP, RSTP, and MSTP are disabled

TABLE 4 Default STP configuration (continued)

Parameter	Default setting
Bridge priority	32768
Bridge forward delay	15 seconds
Bridge maximum aging time	20 seconds
Error disable timeout timer	Disabled
Error disable timeout interval	300 seconds
Port-channel path cost	Standard
Bridge hello time	2 seconds

The following table lists the switch defaults for the interface-specific configuration.

TABLE 5 Default interface specific configuration

Parameter	Default setting
Spanning tree	Enabled on the interface
Automatic edge detection	Disabled
Path cost	2000
Edge port	Disabled
Guard root	Disabled
Hello time	2 seconds
Link type	Point-to-point
Portfast	Disabled
Port priority	128
BPDU restriction	Restriction is disabled.

STP features

The following sections discuss root guard, BPDU guard, and PortFast.

Root guard

Root guard can be used to predetermine a root bridge location and prevent rogue or unwanted switches from becoming the root bridge.

At times it is necessary to protect the root bridge from malicious attack or even unintentional misconfigurations where a bridge device that is not intended to be the root bridge becomes the root bridge, causing severe bottlenecks in the data path. These types of mistakes or attacks can be avoided by configuring root guard on ports of the root bridge.

The root guard feature provides a way to enforce the root bridge placement in the network and allows STP and its variants to interoperate with user network bridges while still maintaining the bridged network topology that the administrator requires. Errors are triggered if any change from the root bridge placement is detected.

When root guard is enabled on a port, it keeps the port in designated FORWARDING state. If the port receives a superior BPDU, which is a root guard violation, it sets the port into a DISCARDING state and triggers a Syslog message and an SNMP trap. No further traffic will be forwarded on this port. This allows the bridge to prevent traffic from being forwarded on ports connected to rogue or wrongly configured STP or RSTP bridges.

Root guard should be configured on all ports where the root bridge should not appear. In this way, the core bridged network can be cut off from the user network by establishing a protective perimeter around it.

Once the port stops receiving superior BPDUs, root guard automatically sets the port back to a FORWARDING state after the timeout period has expired.

BPDU guard

In an STP environment, switches, end stations, and other Layer 2 devices use BPDUs to exchange information that STP will use to determine the best path for data flow.

In a valid configuration, edge port-configured interfaces do not receive BPDUs. If an edge port-configured interface receives a BPDU, an invalid configuration exists, such as the connection of an unauthorized device. The BPDU Guard provides a secure response to invalid configurations because the administrator must manually put the interface back in service.

BPDU guard removes a node that reflects BPDUs back in the network. It enforces the STP domain borders and keeps the active topology predictable by not allowing any network devices behind a BPDU guard-enabled port to participate in STP.

In some instances, it is unnecessary for a connected device, such as an end station, to initiate or participate in an STP topology change. In this case, you can enable the STP BPDU guard feature on the Brocade device port to which the end station is connected. The STP BPDU guard shuts down the port and puts it into an "error disabled" state. This disables the connected device's ability to initiate or participate in an STP topology. A log message is then generated for a BPDU guard violation, and a message is displayed to warn the network administrator of an invalid configuration.

The BPDU Guard provides a secure response to invalid configurations because the administrator must manually put the interface back in service with the **no shutdown** command if error disable recovery is not enabled by enabling the **errdisable-timeout** command. The interface can also be automatically configured to be enabled after a timeout. However, if the offending BPDUs are still being received, the port is disabled again.

Expected behavior in an interface context

When BPDU Guard is enabled on an interface, the device is expected to put the interface in Error Disabled state when BPDU is received on the port when edge-port and BPDU guard is enabled on the switch interface. When the port ceases to receive the BPDUs, it does not automatically switch to edge port mode, you must configure **error disable timeout** or **no shutdown** on the port to move the port back into edge port mode.

Error disable recovery

A port is placed into an error-disabled state when:

- A BPDU guard violation or loop detection violation occurs
- The number of inError packets exceeds the configured threshold
- An EFM-OAM enabled interface receives a critical event from the remote device (functionally equivalent to a disable state)

Once in an error disable state, the port remains in that state until it is re-enabled automatically or manually.

In STP, RSTP, MSTP, PVST+, or R-PVST+ mode, you can specify the time in seconds it takes for an interface to time out. The range is from 10 through 1000000 seconds. The default is 300 seconds. By default, the timeout feature is disabled.

PortFast

PortFast allows an interface to transition quickly to the forwarding state.

Consider the following when configuring PortFast:

- Do not enable PortFast on ports that connect to other devices.
- PortFast only needs to be enabled on ports that connect to workstations or PCs. Repeat this configuration for every port connected to workstations or PCs.
- Enabling PortFast on ports can cause temporary bridging loops, in both trunking and nontrunking mode.
- If BPDUs are received on a PortFast- enabled interface, the interface loses the edge port status unless it receives a **shutdown**/**no shutdown** command.
- PortFast immediately puts the interface into the forwarding state without having to wait for the standard forward time.

STP parameters

The following section discusses bridge parameters.

Bridge parameters

These parameters are set in STP, RSTP, MSTP, PVST+, and R-PVST+.

Bridge priority

Use this parameter to specify the priority of a device and to determine the root bridge.

Each device has a unique bridge identifier called the bridge ID. The bridge ID is an 8 byte value that is composed of two fields: a 2 B bridge priority field and the 6 B MAC address field. The value for the bridge priority ranges from 0 to 61440 in increments of 4096. The default value for the bridge priority is 32768. You use the **bridge-priority** command to set the appropriate values to designate a device as the root bridge or root device. A default bridge ID may appear as 32768.768e.f805.5800. If the bridge priorities are equal, the device with the lowest MAC address is elected the root.

After you decide what device to designate as the root, you set the appropriate device bridge priorities. The device with the lowest bridge priority becomes the root device. When a device has a bridge priority that is lower than that of all the other devices, it is automatically selected as the root.

The root device should be centrally located and not in a "disruptive" location. Backbone devices typically serve as the root because they usually do not connect to end stations. All other decisions in the network, such as which port to block and which port to put in forwarding mode, are made from the perspective of the root device.

You may also specify the bridge priority for a specific VLAN. If the VLAN parameter is not provided, the priority value is applied globally for all per-VLAN instances. However, for the VLANs that have been configured explicitly, the per-VLAN configuration takes precedence over the global configuration.

Bridge Protocol data units (BPDUs) carry information between devices. All the devices in the Layer 2 network, participating in any variety of STP, gather information on other devices in the network through an exchange of BPDUs. As the result of exchange of the BPDUs, the device with the lowest bridge ID is elected as the root bridge

When setting the bridge forward delay, bridge maximum aging time, and the hello time parameters keep in mind that the following relationship should be kept:

```
(2 × (forward-delay − 1)) ≥ max-age ≥ (2 ×(hello-time + 1))
```

Bridge forward delay

The bridge forward delay parameter specifies how long an interface remains in the listening and learning states before the interface begins forwarding all spanning tree instances. The valid range is from 4 through 30 seconds. The default is 15 seconds.

Additionally, you may specify the forward delay for a specific VLAN. If the VLAN parameter is not provided, the bridge forward delay value is applied globally for all per-VLAN instances. However, for the VLANs that have been configured explicitly, the per-VLAN configuration takes precedence over the global configuration.

Bridge maximum aging time

You can use this setting to configure the maximum length of time that passes before an interface saves its BPDU configuration information.

Keeping with the inequality shown above, when configuring the maximum aging time, you must set the value greater than the hello time. The range of values is 6 through 40 seconds while he default is 20 seconds.

You may specify the maximum aging for a specific VLAN. If the VLAN parameter is not provided, the priority value is applied globally for all per-VLAN instances. However, for the VLANs that have been configured explicitly, the per-VLAN configuration takes precedence over the global configuration.

Bridge hello time

You can use this parameter to set how often the device interface broadcasts hello BPDUs to other devices.

Use the **hello-time** command to configure the bridge hello time. The range is from 1 through 10 seconds. The default is 2 seconds.

You may also specify the hello time for a specific VLAN. If the VLAN parameter is not provided, the priority value is applied globally for all per-VLAN instances. However, for the VLANs that have been configured explicitly, the per-VLAN configuration takes precedence over the global configuration.

Error disable timeout parameter

Configure this parameter to enable a timer that brings a port out of the disabled state.

These parameters are be set in STP, RSTP, MSTP, PVST+, and R-PVST+.

When the STP BPDU guard disables a port, the port remains in the disabled state unless the port is enabled manually. The parameter specifies the time in seconds it takes for an interface to time out. The range is from 10 through 1000000 seconds. The default is 300 seconds.

By default, the timeout feature is disabled.

Port-channel path cost parameter

You configure this parameter to specify the port channel path cost.

This parameter can be set in STP, RSTP, MSTP, PVST+, and R-PVST+ mode.

There are two path cost options:

- Custom - Specifies that the path cost changes according to the port channel bandwidth.
- Standard - Specifies that the path cost does not change according to the port channel bandwidth.

The default port cost is standard.

Configuring STP

The following section discusses configuring STP.

Enabling and configuring STP globally

Follow these steps to enable or disable STP and configure STP parameters.

You can enable STP or STP with one or more parameters enabled.

The parameters can be configured individually by:

1. Entering the commands in steps 1 and 2
2. Running the relevant parameter command
3. Verifying the result
4. Saving the configuration

For detailed descriptions of the parameters and features, see the sections STP parameters and STP features.

1. Enter global configuration mode.

   ```
   device# configure terminal
   ```

2. Enable STP globally.

   ```
   device(config)# protocol spanning-tree stp
   ```

   A spanning tree can be disabled by entering the **no protocol spanning-tree stp** command.

3. Describe or name the STP.

   ```
   device(config-stp)# description stp1
   ```

   A description is not required.

4. Specify the bridge priority.

   ```
   device(config-stp)# bridge-priority 4096
   ```

   The bridge with the lowest priority number (highest priority) is designated the root bridge . The range of values is 0 through 61440; values can be set only in increments of 4096. The default priority is 32678.

5. Specify the bridge forward delay.

   ```
   device(config-stp)# forward-delay 20
   ```

   The forward delay specifies how long an interface remains in the listening and learning states before it begins forwarding all spanning tree instances. The valid range is from 4 through 30 seconds. The default is 15 seconds.

6. Configure the maximum aging time.

   ```
   device(config-stp)# max-age 25
   ```

   This parameter controls the maximum length of time that passes before an interface saves its BPDU configuration information. You must set the maximum age to be greater than the hello time. The range is 6 through 40 seconds. The default is 20 seconds.

7. Configure the maximum hello time.

```
device(config-stp)# hello-time 8
```

   The hello time determines how often the switch interface broadcasts hello BPDUs to other devices. The default is 2 seconds while the range is from 1 through 10 seconds.

8. Enable the error disable timeout timer.

```
device(config-stp)# error-disable-timeout enable
```

   This parameter enables a timer that brings a port out of the disabled state. By default, the timeout feature is disabled.

9. Set the error disable timeout timer.

```
device(config-stp)# error-disable-timeout interval 60
```

   When enabled the default is 300 seconds and the range is from 10 through 1000000 seconds.

10. Configure the port channel path cost.

```
device(config-stp)# port-channel path-cost custom
```

   Specifying **custom** means the path cost changes according to the port channel's bandwidth.

11. Return to privileged EXEC mode.

```
device(config-stp)# end
```

12. Verify the configuration.

```
device# show spanning-tree brief

 Spanning-tree Mode: Spanning Tree Protocol

      Root ID      Priority 4096
                   Address 768e.f805.5800
                   Hello Time 8, Max Age 25, Forward Delay 20

      Bridge ID    Priority 4096
                   Address 768e.f805.5800
                   Hello Time 8, Max Age 25, Forward Delay 20

 Interface    Role  Sts  Cost       Prio  Link-type     Edge
 -------------------------------------------------------------
 Eth 0/2      DES   FWD  2000       128   P2P            No
 Eth 0/20     DIS   DIS  20000000   128   P2P            No
 Eth 0/25     DIS   DIS  20000000   128   P2P            No
 Eth 0/30     DIS   DIS  20000000   128   P2P            No
 Eth 0/31     DIS   DIS  2000000    128   P2P            No
```

   Observe that the settings comply with the formula set out in the STP parameter configuration section, as:

   `(2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))`

   Or in this case `38 ≥ 25 ≥ 18`.

13. Save the configuration.

```
device# copy running-config startup-config
```

STP configuration example

```
device# configure terminal
device(config)# protocol spanning-tree stp
device(config-stp)# description stpForInterface
device(config-stp)# bridge-priority 4096
device(config-stp)# forward-delay 20
device(config-stp)# max-age 25
device(config-stp)# hello-time 8
device(config-stp)# error-disable-timeout enable
device(config-stp)# error-disable-timeout interval 60
device(config-stp)# port-channel path-cost custom
device(config-stp)# end
device# show spanning-tree brief
device# copy running-config startup-config
```

Enabling and configuring STP on an interface

Follow these steps to enable STP and STP features on an interface.

Globally enable STP and STP parameters.

The parameters can be configured individually by:

1. Entering the commands in steps 1-3
2. Running the relevant parameter command
3. Verifying the result
4. Saving the configuration

For detailed descriptions of the parameters and features, see the sections STP parameters and STP features.

1. Enter global configuration mode.

   ```
   device# configure terminal
   ```

2. Enter interface configuration mode.

   ```
   device(config)# interface ethernet 0/20
   ```

3. Enable the interface.

   ```
   device(conf-if-eth-0/20)# no shutdown
   ```

4. Configure the path cost for spanning tree calculations on the interface.

   ```
   device(conf-if-eth-0/20)# spanning-tree cost 10000
   ```

   The lower the path cost means a greater chance that the interface becomes the root port. The range is 1 through 200000000. The default path cost is assigned as per the port speed.

5. Enable BPDU guard on the interface.

   ```
   device(conf-if-eth-0/20)# spanning-tree port-fast bpdu-guard
   ```

   BPDU guard removes a node that reflects BPDUs back in the network. It enforces the STP domain borders and keeps the active topology predictable by not allowing any network devices behind a BPDU guard-enabled port to participate in STP.

6. Configure Root Guard on the interface.

```
device(conf-if-eth-0/20)# spanning-tree guard root
```

   Root Guard protects the root bridge from malicious attacks and unintentional misconfigurations where a bridge device that is not intended to be the root bridge becomes the root bridge.

7. Specify an interface link-type.

```
device(conf-if-eth-0/20)# spanning-tree link-type point-to-point
```

   Specifying a point-to-point link enables rapid spanning tree transitions to the forwarding state. Specifying a shared link disables spanning tree rapid transitions. The default setting is point-to-point.

8. Specify port priority to influence the selection of root or designated ports.

```
device(conf-if-eth-0/20)# spanning-tree priority 64
```

   The range is from 0 through 240 in increments of 16. The default value is 128.

9. Verify the configuration.

```
device# show spanning-tree brief

 Spanning-tree Mode: Spanning Tree Protocol

      Root ID      Priority 4096
                   Address 768e.f805.5800
                   Hello Time 8, Max Age 25, Forward Delay 20

      Bridge ID    Priority 4096
                   Address 768e.f805.5800
                   Hello Time 8, Max Age 25, Forward Delay 20

 Interface    Role  Sts  Cost       Prio  Link-type     Edge
 ------------------------------------------------------------
 Eth 0/2      DES   FWD  2000       128   P2P            No
 Eth 0/20     DES   FWD  1000        64   P2P            No
 Eth 0/25     DIS   DIS  20000000   128   P2P            No
 Eth 0/30     DIS   DIS  20000000   128   P2P            No
 Eth 0/31     DIS   DIS  2000000    128   P2P            No
```

   NOTE

   Observe that the settings comply with the formula set out in the STP parameters section, as:
   `(2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))`
   or in this case: `38 ≥ 25 ≥ 18`

```
device# show running-config interface ethernet 0/20
interface ethernet 0/20
switchport
switchport mode access
switchport access val 1
spanning-tree cost 1000
spanning-tree guard root
spanning-tree link-type point-to-point
spanning-tree portfast bpdu-guard
spanning-tree priority 64
```

10. Save the settings by copying the running configuration to the startup configuration.

```
device# copy running-config startup-config
```

STP on an interface configuration example

```
device# configure terminal
device(config)# interface ethernet 0/20
device(conf-if-eth-0/20)# no shutdown
device(conf-if-eth-0/20)# spanning-tree cost 10000
device(conf-if-eth-0/20)# spanning-tree port-fast bpdu-guard
device(conf-if-eth-0/20)# spanning-tree guard root
device(conf-if-eth-0/20)# spanning-tree link-type point-to-point
device(conf-if-eth-0/20)# spanning-tree priority 64
device(conf-if-eth-0/20)# end
device# show spanning-tree brief
device# copy running-config startup-config
```

Configuring basic STP parameters

Follow this example to configure basic STP behavior.

1. Enter global configuration mode.

   ```
   device# configure terminal
   ```

2. Enable STP globally

   ```
   device(config)# protocol spanning-tree stp
   ```

3. Name the STP.

   ```
   device(config-stp)# description stp1
   ```

4. Designate the root switch.

   ```
   device(conf-stp)# bridge-priority 28672
   ```

   The priority values can be set only in increments of 4096. The range is 0 through 61440.

5. Specify the bridge forward delay.

   ```
   device(config-stp)# forward-delay 20
   ```

6. Configure the maximum aging time.

   ```
   device(config-stp)# max-age 25
   ```

7. Configure the maximum hello time.

   ```
   device(config-stp)# hello-time 8
   ```

8. Enable the error disable timeout timer.

   ```
   device(config-stp)# error-disable-timeout enable
   ```

9. Set the error disable timeout timer interval.

   ```
   device(config-stp)# error-disable-timeout interval 60
   ```

10. Enable port fast on switch ports.
    a) Configure port fast on Ethernet port 0/1.

```
device(config)# interface ethernet 0/1
device(conf-if-eth-0/1)# spanning-tree portfast
device(conf-if-eth-0/1)# exit
```

    Spanning trees are automatically enabled on switch ports.

    b) Configure port fast on Ethernet port 0/2.

```
device(config)# interface ethernet 0/2
device(conf-if-eth-0/2)# spanning-tree portfast
device(conf-if-eth-0/2)# exit
```

    c) Repeat these commands for every port connected to workstations or PCs.

```
device(config)# interface ethernet ...
```

11. Specify port priorities to influence the selection of the root and designated ports.

```
device(config)# interface ethernet 0/1
device(conf-if-eth-0/1)# spanning-tree priority 1
device(conf-if-eth-0/1)# exit
```

12. Enable the guard root feature.

```
device(config)# interface ethernet 0/12
device(conf-if-eth-0/12)# no shutdown
device(conf-if-eth-0/12)# spanning-tree guard root
```

    Root guard lets the device top participate in the STP but only when the device does not attempt to become the root.

13. Return to privileged exec mode.

```
device(conf-if-eth-0/12)# end
```

14. Verify the configuration.

```
device# show spanning-tree brief
Spanning-tree Mode: Spanning Tree Protocol
Root ID Priority 4096
Address 768e.f805.5800
Hello Time 8, Max Age 25, Forward Delay 20
Bridge ID Priority 4096
Address 768e.f805.5800
Hello Time 8, Max Age 25, Forward Delay 20
Interface     Role     Sts     Cost     Prio     Link-type     Edge
-------------------------------------------------------------------
Eth 0/1       DES      FWD     2000     128      P2P           No
Eth 0/2       DES      FWD     2000     128      P2P           No
Eth 0/12      DES      FWD     2000     128      P2P           No
```

    Observe that the settings comply with the formula set out in the STP parameter configuration section, as:

    `(2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))`

    or in this case `38 ≥ 25 ≥ 18`.

15. Save the configuration.

```
device# copy running-config startup-config
```

Basic STP configuration example

```
device# configure terminal
device(config)# protocol spanning-tree stp
device(config-stp)# description stp1
device(conf-stp)# bridge-priority 28672
device(config-stp)# forward-delay 20
device(config-stp)# max-age 25
device(config-stp)# hello-time 8
device(config-stp)# error-disable-timeout enable
device(config-stp)# error-disable-timeout interval 60
device(config)# interface ethernet 0/1
device(conf-if-eth-0/1)# spanning-tree portfast
device(conf-if-eth-0/1)# exit
device(config)# interface ethernet 0/2
device(conf-if-eth-0/2)# spanning-tree portfast
device(conf-if-eth-0/2)# exit
device(config)# interface ethernet 0/1
device(conf-if-eth-0/1)# spanning-tree priority 1
device(conf-if-eth-0/1)# exit
device(config)# interface ethernet 0/12
device(conf-if-eth-0/12)# no shutdown
device(conf-if-eth-0/12)# spanning-tree guard root
device(conf-if-eth-0/12)# end
device# show spanning-tree brief
device# copy running-config startup-config
```

Re-enabling an error-disabled port automatically

Enable a port to automatically recover from the error-disabled state after the expiration of an error recovery timer.

1. Enter global configuration mode.

   ```
   device# configure terminal
   ```

2. Enter STP configuration mode.

   ```
   device(config)# protocol spanning-tree stp
   ```

3. Enable the error-disable-timeout timer.

   ```
   device(config-stp)# error-disable-timeout enable
   ```

4. Set an interval after which port shall be enabled.

   ```
   device(config-stp)# error-disable-timeout interval 60
   ```

   The interval range is from 0 to 1000000 seconds, the default is 300 seconds.

5. Return to privileged EXEC mode.

   ```
   device(config-stp)# end
   ```

6. Verify the configuration.

```
device# show spanning-tree
 Spanning-tree Mode: Spanning Tree Protocol

 Root Id: 8000.768e.f805.5800 (self)
 Bridge Id: 8000.768e.f805.5800

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: enabled
 Bpdu-guard errdisable timeout interval: 60 sec
```

Automatically re-enable an error-disabled port configuration example

```
device# configure terminal
device(config)# protocol spanning-tree stp
device(config-stp)# error-disable-timeout enable
device(config-stp)# error-disable-timeout interval 60
device(config-stp)# end
device# show spanning-tree
```

Clearing spanning tree counters

Follow these steps to clear spanning tree counters on all interfaces or on the specified interface.

1. Clear spanning tree counters on all interfaces.

```
device# clear spanning-tree counter
```

2. Clear spanning tree counters on a specified Ethernet interface.

```
device# clear spanning-tree counter interface ethernet 0/3
```

3. Clear spanning tree counters on a specified port channel interface.

```
device# clear spanning-tree counter interface port-channel 12
```

   Port channel interface numbers range from 1 through 64.

Clearing spanning tree-detected protocols

Follow these steps to restart the protocol migration process.

These commands force a spanning tree renegotiation with neighboring devices on either all interfaces or on a specified interface.

1. Restart the spanning tree migration process on all interfaces.

```
device# clear spanning-tree detected-protocols
```

2. Restart the spanning tree migration process on a specific Ethernet interface.

```
device# clear spanning-tree detected-protocols interface ethernet 0/3
```

3. Restart the spanning tree migration process on a specific port channel interface.

```
device# clear spanning-tree detected-protocols port-channel 12
```

   Port channel interface numbers range from 1 through 64.

Shutting down STP

Follow these steps to o shut down STP either globally, on a specific interface, or a specific VLAN.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Shut down STP.
   - Shut down STP globally and return to privileged EXEC mode.

```
device(config)# protocol spanning-tree stp
device(config-stp)# shutdown
device(config-stp)# end
```

   - Shut down STP on a specific interface and return to privileged EXEC mode.

```
device(config)# interface ethernet 0/2
device(conf-if-eth-0/2)# spanning-tree shutdown
device(conf-if-eth-0/2)# end
```

   - Shut down STP on a specific VLAN and return to privileged EXEC mode.

```
device(config)# vlan 10
device(config-vlan-10)# spanning-tree shutdown
device(config-vlan-10)# end
```

3. Verify the configuration.

```
device# show spanning-tree
device#
```

4. Save the running configuration to the startup configuration.

```
device# copy running-config startup-config
```

Shut down STP configuration example

```
device# configure terminal
device(config)# vlan 10
device(config-vlan-10)# spanning-tree shutdown
device(config-stp)# end
device# show spanning-tree
device# copy running-config startup-config
```

NOTE

Shutting down STP on a VLAN is used in this example.

802.1w Rapid Spanning Tree Protocol

Rapid Spanning Tree Protocol overview

The RSTP is a way to provide rapid traffic reconvergence for point-to-point links within a few milliseconds (< 500 milliseconds), following the failure of a bridge or bridge port.

The STP (802.1d) standard was designed at a time when recovering connectivity after an outage within a minute or so was considered adequate performance. With the advent of Layer 3 switching in LAN environments, bridging competes with routed solutions where protocols such as OSPF are able to provide an alternate path in less time.

The RSTP can be seen as evolution of STP standard. It provides rapid convergence of connectivity following the failure of bridge, a bridge port or a LAN. It provides rapid convergence of edge ports, new root ports and port connected through point-to-point links. The port, which qualifies for fast convergence, is derived from the duplex mode of a port. A port operating in full-duplex will be assumed to be point-to-point, while a half-duplex port will be considered as a shared port by default. This automatic setting can be overridden by explicit configuration.

RSTP is designed to be compatible and interoperate with the STP. However, the benefit of the RSTP fast convergence is lost when interacting with legacy STP (802.1d) bridges since the RSTP downgrades itself to the STP when it detects a connection to a legacy bridge.

The states for every Layer 2 interface running the RSTP are as follows:

State	Action
Learning	The interface prepares to participate in frame forwarding.
Forwarding	The interface forwards frames.
Discarding	The interface discards frames. Ports in the discarding state do not take part in the active topology and do not learn MAC addresses.

NOTE
The STP disabled, blocking, and listening states are merged into the RSTP discarding state.

The RSTP port roles for the interface are also different. The RSTP differentiates explicitly between the state of the port and the role it plays in the topology. The RSTP uses the root port and designated port roles defined im the STP, but splits the blocked port role into backup port and alternate port roles:

Backup port	Provides a backup for the designated port and can only exist where two or more ports of the switch are connected to the same LAN; the LAN where the bridge serves as a designated switch.
Alternate port	Serves as an alternate port for the root port providing a redundant path towards the root bridge.

Only the root port and the designated ports are part of the active topology; the alternate and backup ports do not participate in it. When the network is stable, the root and the designated ports are in the forwarding state, while the alternate and backup ports are in the discarding state. When there is a topology change, the new RSTP port roles allow a faster transition of an alternate port into the forwarding state.

For more information about spanning trees, see the introductory sections in the 802.1d Spanning Tree Protocol chapter.

RSTP parameters on a Brocade device

The parameters you would normally set when you configure STP are applicable to RSTP. Before you configure RSTP see the STP parameters sections for descriptions of the bridge parameters. the error disable timeout parameter and the port channel path cost parameter.

There is one parameter that can be configured in RSTP that is not available in STP; the transmit hold count. This parameter configures the BPDU burst size by specifying the maximum number of BPDUs transmitted per second for before pausing for 1 second. The range is 1 through 10 while the default is 6. See the section Enabling RSTP and configuring RSTP parameters for the procedure to configure this parameter.

The edge port and auto edge features can be enabled in RSTP as well. See the section Edge port and automatic edge detection and the section Configuring RSTP on an interface for descriptions of these features and how they are configured.

Edge port and automatic edge detection

Configuring the edge port feature makes a port transition directly from initialization to the forwarding state, skipping the listening and learning states.

From an interface, you can configure a device to automatically identify the edge port. The port can become an edge port if no BPDU is received. By default, automatic edge detection is disabled.

Follow these guidelines to configure a port as an edge port:

- When edge port is enabled, the port still participates in a spanning tree.
- A port can become an edge port if no BPDU is received.
- When an edge port receives a BPDU, it becomes a normal spanning tree port and is no longer an edge port.
- Because ports that are directly connected to end stations cannot create bridging loops in the network, edge ports transition directly to the forwarding state and skip the listening and learning states.

  NOTE
  If BPDUs are received on a port fast enabled interface, the interface loses the edge port status unless it receives a **shutdown** or **no shutdown** command.

Configuring RSTP

Enabling and configuring RSTP globally

Follow these steps to enable and configure RSTP.

See the section STP parameters for parameters applicable to all STP variants.

You can enable RSTP or RSTP with one or more parameters enabled. The parameters can be enabled or changed individually by entering the commands in steps 1 and 2, running the parameter command, verifying the result, and then saving the configuration.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Enable RSTP.

```
device(config)# protocol spanning-tree rstp
```

   You can shut down RSTP by entering the **shutdown** command.

3. Designate the root device.

```
device(conf-rstp)# bridge-priority 28582
```

   The range is 0 through 61440 and the priority values can be set only in increments of 4096.

   You can shut down RSTP by entering the **shutdown** command when in RSTP configuration mode.

4. Configure the bridge forward delay value.

```
device(conf-rstp)# forward-delay 15
```

5. Configure the bridge maximum aging time value.

```
device(conf-rstp)# max-age 20
```

6. Enable the error disable timeout timer.
   a) Enable the timer.

```
device(conf-rstp)# error-disable-timeout enable
```

   b) Configure the error disable timeout interval value.

```
device(conf-rstp)# error-disable-timeout interval 60
```

7. Configure the port-channel path cost.

```
device(conf-rstp)# port-channel path-cost custom
```

8. Configure the bridge hello-time value.

```
device(conf-rstp)# hello-time 2
```

9. Specify the transmit hold count.

```
device(config-rstp)# transmit-holdcount 5
```

   This command configures the maximum number of BPDUs transmitted per second.

10. Return to privileged exec mode.

```
device(conf-rstp)# end
```

11. Verify the configuration

```
device# show spanning-tree

 Spanning-tree Mode: Rapid Spanning Tree Protocol

 Root Id: 8000.01e0.5200.0180 (self)
 Bridge Id: 8000.01e0.5200.0180

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: enabled
 Bpdu-guard errdisable timeout interval: 60 sec
```

    Observe that the settings comply with the formula set out in the STP parameters section, as:

    (2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

    or in this case: 28 ≥ 20 ≥ 6.

12. Save the configuration.

```
device# copy running-config startup-config
```

Enabling RSTP and configuring RSTP parameters example

```
device# configure terminal
device(config)# protocol spanning-tree rstp
device(conf-rstp)# bridge-priority 28582
device(conf-rstp)# forward-delay 20
device(conf-rstp)# max-age 25
device(conf-rstp)# error-disable-timeout enable
device(conf-rstp)# error-disable-timeout interval 60
device(conf-rstp)# port-channel path-cost custom
device(conf-rstp)# hello-time 5 forward-delay 16 max-age 21
device(conf-rstp)# transmit-holdcount 5
device(conf-rstp# end
device# show spanning-tree
device# copy running-config startup-config
```

Enabling and configuring RSTP on an interface

Follow these steps to configure RSTP on an Ethernet interface.

You can configure the parameters individually on an interface by doing the following:

1. Entering the commands in Steps 1 through 3.
2. Specifying additional parameters, as appropriate.
3. Verifying the result.
4. Saving the configuration.

For detailed descriptions of the parameters and features, see the sections STP parameters and STP features.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Enter interface subtype configuration mode.

```
device(config)# interface ethernet 0/10
```

3. Enable the interface.

```
device(conf-if-eth-0/10)# no shutdown
```

To disable the spanning tree on the interface you use the **spanning-tree shutdown** command.

4. Specify the port priority on the interface.

```
device(conf-if-eth-0/10)# spanning-tree priority 128
```

The range is from 0 through 240 in increments of 16. The default value is 128.

5. Specify the path cost on the interface.

```
device(conf-if-eth-0/10)# spanning-tree cost 20000000
```

The lower the path cost means a greater chance that the interface becomes the root port. The range is 1 through 200000000. The default path cost is assigned as per the port speed.

6. Enable edge port.

```
device(conf-if-eth-0/10)# spanning-tree edgeport
```

If BPDUs are received on a port fast enabled interface, the interface loses the edge port status unless it receives a **shutdown** or **no shutdown** command.

7. Enable BPDU guard on the interface.

```
device(conf-if-eth-0/10)# spanning-tree edgeport bpdu-guard
```

BPDU guard removes a node that reflects BPDUs back in the network. It enforces the STP domain borders and keeps the active topology predictable by not allowing any network devices behind a BPDU guard-enabled port to participate in STP.

8. Enable automatic edge detection on the interface.

```
device(conf-if-eth-0/10)# spanning-tree autoedge
```

You use this command to automatically identify the edge port. A port becomes an edge port if it receives no BPDUs. By default, automatic edge detection is disabled.

9. Enable root guard on the interface.

```
device(conf-if-eth-0/10)# spanning-tree guard root
```

Root guard protects the root bridge from malicious attacks and unintentional misconfigurations where a bridge device that is not intended to be the root bridge becomes the root bridge.

10. Specify a link type on the interface.

```
device(conf-if-eth-0/10)# spanning-tree link-type point-to-point
```

> NOTE
> The link type is explicitly configured as **point-to-point** rather than **shared**.

11. Return to privileged EXEC mode.

```
device(conf-if-eth-0/10)# end
```

12. Verify the configuration.

```
device# show spanning-tree

 Spanning-tree Mode: Rapid Spanning Tree Protocol

 Root Id: 8000.01e0.5200.0180 (self)
 Bridge Id: 8000.01e0.5200.0180

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: enabled
 Bpdu-guard errdisable timeout interval: 60 sec


 Port Eth 0/10 enabled
    Ifindex: 201359360; Id: 8002; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Spanning Tree Protocol - Received None - Sent STP
    Edgeport: on; AutoEdge: yes; AdminEdge: no; EdgeDelay: 3 sec
    Configured Root guard: on; Operational Root guard: on
    Bpdu-guard: on
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

Interface   Role     Sts     Cost       Prio     Link-type     Edge
-------------------------------------------------------------------
Eth 0/10    DES      FWD     20000000   128      P2P           No
```

The **forward-delay**, **hello-time**, and **max-age** parameters are set globally, not on the interface.

Observe that the settings comply with the formula set out in the STP parameters section, as:

(2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

or in this case: 28 ≥ 20 ≥ 6.

13. Save the configuration.

```
device# copy running-config startup-config
```

RSTP on an interface configuration example

```
device# configure terminal
device(config)# interface ethernet 0/10
device(conf-if-eth-0/10)# no spanning-tree shutdown
device(conf-if-eth-0/10)# spanning-tree priority 128
device(conf-if-eth-0/10)# spanning-tree cost 20000000
device(conf-if-eth-0/10)# spanning-tree edgeport
device(conf-if-eth-0/10)# spanning-tree edgeport bpdu-guard
device(conf-if-eth-0/10)# spanning-tree autoedge
device(conf-if-eth-0/10)# spanning-tree guard root
device(conf-if-eth-0/10)# spanning-tree link-type point-to-point
device(conf-if-eth-0/10)# end
device# show spanning-tree
device# copy running-config startup-config
```

Configuring basic RSTP parameters

Follow these steps to configure basic RSTP parameters.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Enable RSTP.

```
device(config)# protocol spanning-tree rstp
```

3. Designate the root device.

```
device(conf-rstp)# bridge-priority 28582
```

4. Enable the error disable timeout timer value.

```
device(conf-rstp)# error-disable-timeout enable
```

5. Configure the error-disable-timeout interval value.

```
device(conf-rstp)# error-disable-timeout interval 60
```

6. Enable edge port on switch ports.
   a) Enter interface subtype configuration mode for the switchport.

```
device(conf-rstp)# interface ethernet 0/10
```

   b) Enable edge port.

```
device(conf-if-eth-0/10)# spanning-tree edge-port
```

   c) Return to global configuration mode.

```
device(conf-if-eth-0/10)# exit
```

   d) Repeat the above steps for all ports that connect to a workstation or PC.
7. Specify port priorities.
   a) Enter interface subtype configuration mode.

```
device(config)# interface ethernet 0/11
```

   b) Configure the port priority.

```
device(conf-if-eth-0/11)# spanning-tree priority 1
```

   c) Return to global configuration mode.

```
device(conf-if-eth-0/11)# exit
```

8. Enable the guard root feature.
   a) Enter interface configuration mode.

```
device(config)# interface ethernet 0/1
```

   b) Configure the port priority.

```
device(conf-if-eth-0/1)# spanning-tree guard root
```

   c) Return to privileged EXEC mode.

```
device(conf-if-eth-0/1)# exit
```

9. Verify the configuration.

```
device# show spanning-tree

Spanning-tree Mode: Rapid Spanning Tree Protocol

Root Id: 4096.01e0.5200.0180 (self)
Bridge Id: 4096.01e0.5200.0180
Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
Number of topology change(s): 0
Bpdu-guard errdisable timeout: disabled
Bpdu-guard errdisable timeout interval: 300 sec
switch# show spanning-tree brief
Spanning-tree Mode: Rapid Spanning Tree Protocol
Root ID Priority 4096
Address 768e.f805.5800
Hello Time 2, Max Age 20, Forward Delay 15
Bridge ID Priority 4096
Address 768e.f805.5800

Interface   Role     Sts     Cost     Prio     Link-type     Edge
-------------------------------------------------------------------
Eth 0/1     DES      FWD     2000     128      P2P           No
Eth 0/10    DES      FWD     2000     128      P2P           No
Eth 0/11    DES      FWD     2000     128      P2P           No
```

   Observe that the settings comply with the formula set out in the STP parameters section, as follows:

   (2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

   or in this case: 28 ≥ 20 ≥ 6.

10. Save the configuration.

```
device# copy running-config startup-config
```

Basic RSTP configuration example

```
device# configure terminal
device(config)# protocol spanning-tree rstp
device(conf-rstp)# bridge-priority 28582
device(conf-rstp)# error-disable-timeout enable
device(conf-rstp)# error-disable-timeout interval 60
device(conf-rstp)# interface etherne 0/10
device(conf-if-eth-0/10)# spanning-tree edge-port
device(conf-if-eth-0/10)# exit
device(config)# interface ethernet 0/11
device(conf-if-eth-0/11)# spanning-tree priority 1
device(conf-if-eth-0/11)# exit
device(config)# interface ethernet 0/1
device(conf-if-eth-0/1)# spanning-tree guard root
device(conf-if-eth-0/1)# exit
device# show spanning-tree
device# copy running-config startup-config
```

Clearing spanning tree counters

Follow these steps to clear spanning tree counters on all interfaces or on the specified interface.

1. Clear spanning tree counters on all interfaces.

   ```
   device# clear spanning-tree counter
   ```

2. Clear spanning tree counters on a specified Ethernet interface.

   ```
   device# clear spanning-tree counter interface ethernet 0/3
   ```

3. Clear spanning tree counters on a specified port channel interface.

   ```
   device# clear spanning-tree counter interface port-channel 12
   ```

   Port channel interface numbers range from 1 through 64.

Clearing spanning tree-detected protocols

Follow these steps to restart the protocol migration process.

These commands force a spanning tree renegotiation with neighboring devices on either all interfaces or on a specified interface.

1. Restart the spanning tree migration process on all interfaces.

   ```
   device# clear spanning-tree detected-protocols
   ```

2. Restart the spanning tree migration process on a specific Ethernet interface.

   ```
   device# clear spanning-tree detected-protocols interface ethernet 0/3
   ```

3. Restart the spanning tree migration process on a specific port channel interface.

   ```
   device# clear spanning-tree detected-protocols port-channel 12
   ```

   Port channel interface numbers range from 1 through 64.

Shutting down RSTP

Follow these steps to shut down RSTP either globally or on a specific interface.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Shut down RSTP.
   - Shut down STP globally and return to privileged EXEC mode.

```
device(config)# protocol spanning-tree rstp
device(conf-rstp)# shutdown
device(conf-rstp)# end
```

   - Shut down RSTP on a specific interface and return to privileged EXEC mode.

```
device(config)# interface ethernet 0/2
device(conf-if-eth-0/2)# spanning-tree shutdown
device(conf-if-eth-0/2)# end
```

   - Shut down RSTP on a specific VLAN and return to privileged EXEC mode.

```
device(config)# vlan 10
device(config-vlan-10)# spanning-tree shutdown
device(config-vlan-10)# end
```

3. Verify the configuration.

```
device# show spanning-tree
device#
```

4. Save the configuration.

```
device# copy running-config startup-config
```

Per-VLAN Spanning Tree+ and Rapid Per-VLAN Spanning Tree+

PVST+ and R-PVST+ overview

The Per-VLAN Spanning Tree Plus (PVST+) protocol runs a spanning tree instance for each VLAN in the network. The version of PVST+ that uses the RSTP state machine is called Rapid-PVST Plus (R-PVST+). R-PVST+ has one instance of spanning tree for each VLAN on the device.

Both the STP and the RSTP build a single logical topology. A typical network has multiple VLANs. A single logical topology does not efficiently utilize the availability of redundant paths for multiple VLANs. A single logical topology does not efficiently utilize the availability of redundant paths for multiple VLANs. If a port is set to the blocked state or the discarding state for one VLAN (under the STP or the RSTP), it is the same for all other VLANs. PVST+ builds on the STP on each VLAN, and R-PVST+ builds on the RSTP on each VLAN.

PVST+ R-PVST+ provide interoperability with Cisco PVST and R-PVST and other vendor switches which implement Cisco PVST or R-PVST. the PVST+ and R-PVST+ implementations are extensions to PVST and R-PVST, which can interoperate with an STP topology, including MSTP (CIST), on Brocade and other vendor devices sending untagged IEEE BPDUs.

PVST+ and R-PVST+ guidelines and restrictions

Consider the following when configuring PVST+ and R-PVST+:

- Brocade supports PVST+ and R-PVST+ only. The PVST and R-PVST protocols are proprietary to Cisco and are not supported.
- A port native VLAN is the native VLAN ID associated with a trunk port on a Brocade switch. This VLAN ID is associated with all untagged packets on the port. The default native VLAN ID for a trunk port is 1.
- IEEE compliant switches run just one instance of STP protocol shared by all VLANs, creating a Mono Spanning Tree (MST). A group of such switches running a single spanning tree forms an MST region.
- You can configure up to 128 PVST+ or R-PVST+ instances. If you have more than 128 VLANs configured on the switch and enable PVST then the first 128 VLANs are PVST/+ or R-PVST+ enabled.
- In PVST/+ or R-PVST+ mode, when you are connected to a Cisco or MLX switch, the Cisco proprietary MAC address to which the BPDUs are sent/processed must be explicitly configured on a per-port basis.
- In PVST/+ or R-PVST+ mode, when you connect to a Cisco switch using a trunk port, the Brocade switch must have a native VLAN configured on the trunk port (same configuration as on the other side).
- A Common Spanning Tree (CST) is the single spanning tree instance used by Brocade switches to interoperate with 802.1q bridges. This spanning tree instance stretches across the entire network domain (including PVST, PVST+ and 802.1q regions). It is associated with VLAN 1 on the Brocade switch.
- In order to interact with STP and IEEE 802.1q trunk, PVST evolved to PVST+ to interoperate with STP topology by STP BPDU on the native or default VLAN.
- A group of switches running PVST+ is called a PVST+ region.

For more information about spanning trees, see the introductory sections in the Spanning Tree Protocol chapter.

PVST+ and R-PVST+ parameters

The parameters you would normally set when you configure STP are applicable to PVST+ and R-PVST+. Before you configure PVST+ or R-PVST+ parameters see the sections in the Standing Tree Protocol chapter explaining bridge parameters, the error disable timeout parameter and the port channel path cost parameter.

There is one parameter that can be configured in R-PVST+ that is not available in STP or PVST+; the transmit hold count. This parameter configures the BPDU burst size by specifying the maximum number of BPDUs transmitted per second for before pausing for 1 second. The range is 1 through 10 while the default is 6. See the section Configuring R-PVST+ for the procedure to configure this parameter.

Bridge protocol data units in different VLANs

PVST+ uses the spanning tree instance for VLAN 1 to join the CST in the network to build the CST, PVST+ processes and sends standard IEEE Bridge protocol data units (BPDUs) on all the ports in VLAN 1 (access/trunk).

Across IEEE 802.1q trunks, Brocade switches run PVST+. The goal is to interoperate with standard IEEE STP (or RSTP or MSTP), while transparently tunneling PVST+ instance BPDUs across the MST region to potentially connect to other Brocade switches across the MST region.

On trunk ports that allow VLAN 1, PVST+ also sends PVST+ BPDUs to a Cisco-proprietary multicast MAC address (0100.0ccc.cccd) or Brocade-proprietary multicast MAC address (0304.0800.0700) depending on the configuration. By default, the PVST+ BPDUs are sent to Brocade-proprietary multicast MAC address on brocade switches. These BPDUs are tunneled across an MST region. The PVST+ BPDUs for VLAN 1 are only used for the purpose of consistency checks and that it is only the IEEE BPDUs that are used for building the VLAN 1 spanning tree. So in order to connect to the CST, it is necessary to allow VLAN 1 on all trunk ports.

For all other VLANs, PVST+ BPDUs are sent on a per-VLAN basis on the trunk ports. These BPDUs are tunneled across an MST region. Consequently, for all other VLANs, MST region appears as a logical hub. The spanning tree instances for each VLAN in one PVST+ region map directly to the corresponding instances in another PVST+ region and the spanning trees are calculated using the per-VLAN PVST+ BPDUs.

Similarly, when a PVST+ region connects to a MSTP region, from the point of view of MSTP region, the boundary bridge thinks it is connected to a standard IEEE compliant bridge sending STP BPDUs. So it joins the CIST of the MSTP region to the CST of the PVST+ region (corresponding to VLAN 1). The PVST+ BPDUs are tunneled transparently through the MSTP region. So from the Brocade bridge point of view, the MSTP region looks like a virtual hub for all VLANs except VLAN 1.

The PVST+ BPDUs are sent untagged for the native VLAN and tagged for all other VLANs on the trunk port.

On access ports, Brocade switches run classic version of IEEE STP/RSTP protocol, where the BPDUs are sent to the standard IEEE multicast address "0180.C200.0000". So if we connect a standard IEEE switch to an access port on the Brocade switch, the spanning tree instance (corresponding to the access VLAN on that port) of the Brocade switch is joined with the IEEE STP instance on the adjacent switch.

For introductory information about STP BPDUs, see the section BPDUs on page 58.

BPDU configuration notes

In order to build a spanning tree for the bridge topology, the bridges must exchange control frames. These frames are called Bridge Protocol data units (BPDU).

Topology Change Notification (TCN) BPDUs are used to inform other switches of port changes. TCNs are injected into the network by a non-root switch and propagated to the root. Upon receipt of the TCN, the root switch will set a Topology Change flag in its normal BPDUs. This flag is propagated to all other switches to instruct them to rapidly age out their forwarding table entries.

In PVST+, three types of TCN BPDUs are sent out depending on the type of the link. See Brocade PVST+ TCN BPDU headers/fields on page 87 and Cisco PVST TCN BPDU headers/fields on page 87.

- Standard IEEE TCN BPDU.
- Untagged TCN BPDU sent to the Cisco/Brocade proprietary MAC address.
- Tagged TCN BPDU sent to the Cisco/Brocade proprietary MAC address.

BPDU R-PVST+ header and field comparisons

These tables outline the differences between Brocade R-PVST+ BPDU and Cisco R-PVST+ BPDU header fields.

Brocade R-PVST+ BPDU headers/fields

Header/field	Standard IEEE STP/RSTP BPDU (64B padded)	R-PVST+ untagged BPDU (64B padded)	R-PVST+ tagged BPDU (72B padded)
Source Address (MAC SA)	6B	6B	6B
Destination Address (MAC DA)	0180C2.000000 (6B)	030408.000700 (6B)	030408.000700 (6B)
Length	2B	2B	-
Type	-	-	81 00 (2B)
802.1q tag	-	-	4B
Source Service Access Point (SSAP)	42	AA 03	AA 03
Destination Service Access Point (DSAP)	42	AA	AA
Brocade Organizationally Unique Identifier (OUI)	-	02 04 08	02 04 08
PVST PID	-	01 0B	01 0B
Logical Link Control (LLC)	3B	+	+
SubNetwork Access Protocol (SNAP)	-	Yes (2B)	Yes (2B)
IEEE BPDU INFO	35B	35B	35B
Type, Length, Value (TLV) Pad Type Length VLAN ID	-	6B 00 (1B) 00 00 00 02 2B	6B 00 (1B) 00 00 00 02 2B

Cisco R-PVST+ BPDU headers/fields

Header/field	Standard IEEE STP/RSTP BPDU (64B padded)	R-PVST+ untagged BPDU (64B padded)	R-PVST+ tagged BPDU (72B padded)
MAC SA	6B	6B	6B
MAC DA	0180C2.000000 (6B)	01000C.CCCCCD (6B)	010002.CCCCCD (6B)
Length	2B	2B	-
Type	-	-	81 00 (2B)
802.1q tag	-	-	4B
SSAP	42 03	AA 03	AA 03

Header/field	Standard IEEE STP/RSTP BPDU (64B padded)	R-PVST+ untagged BPDU (64B padded)	R-PVST+ tagged BPDU (72B padded)
DSAP	42	AA	AA
Cisco OUI	-	00 00 0C	00 00 0C
PVST PID	-	01 0B	01 0B
LLC	3B	+	+
SNAP	-	Yes	Yes
IEEE BPDU INFO	35B	35B	35B
TLV Pad Type Length VLAN ID	-	6B 00 (1B) 00 00 00 02 2B	6B 00 (1B) 00 00 00 02 2B

Sent BPDUs

On an 802.1q trunk, the PVST+ enabled switch sends the following BPDUs:

1.
2. If PVST+ is enabled on the untagged (native) VLAN of the port, an untagged SSTP BPDU is sent to the Brocade or Cisco MAC address on the native VLAN of the trunk. It is possible that the native VLAN on the Brocade or Cisco port is not VLAN 1. This BPDU is also forwarded on the native VLAN of the IEEE 802.1q switch just like any other frame sent to an unknown multicast address.
3.
4. A standard IEEE BPDU (802.1d) is also sent, corresponding to the information of VLAN 1 on the Brocade or Cisco switch. This BPDU is not sent if VLAN 1 is explicitly disabled on the trunk port.

The following table lists the types of BPDUs sent in case of different port types. The numbers in the third column are the VLAN instance for which these BPDUs are sent/processed.

TABLE 6 Types of BPDUs sent for different port types

Port Configuration	Brocade or Cisco - PVST(+)	VLAN instance
Access - VLAN 1	Standard IEEE BPDU (64B)	1
Access - VLAN 100	Standard IEEE BPDU (64B)	100
Trunk - Native VLAN 1 Allowed VLANs - 1, 100, 200	Standard IEEE BPDU (64B) Brocade or Cisco untagged BPDU (68B) Brocade or Cisco tagged BPDU (72B) Brocade or Cisco tagged BPDU (72B)	1 1 100 200
Trunk - Native VLAN 100 Allowed VLANs - 1, 100, 200	Standard IEEE BPDU (64B) Brocade or Cisco untagged BPDU (68B) Brocade or Cisco tagged BPDU (72B Brocade or Cisco tagged BPDU (72B)	1 100 1 200
Trunk - Native VLAN 100 Allowed VLANs - 100	Brocade or Cisco untagged BPDU (68B)	100

TABLE 6 Types of BPDUs sent for different port types (continued)

Port Configuration	Brocade or Cisco - PVST(+)	VLAN instance
Trunk - Native VLAN 100 Allowed VLANs - 100, 200	Brocade or Cisco untagged BPDU (68B) Brocade or Cisco tagged BPDU (72B)	100 200

TCN headers and fields

Since PVST+ is based on STP, and Rapid-PVST+ is based on RSTP, TCN BPDUs are sent only in PVST+ and not in Rapid-PVST+ mode.

For introductory information about STP BPDUs, see the section TCN BPDUs on page 59.

Brocade PVST+ TCN BPDU headers/fields

Header/field	Standard IEEE STP TCN BPDU (64B with padding)	PVST+ untagged TCN BPDU (64B with padding)	PVST+ tagged TCN BPDU (68B with padding)
MAC SA	6B	6B	6B
MAC DA	0180C2.000000 (6B)	030408.000700 (6B)	030408.000700 ((6B)
Length	2B	2B	-
Type	-	-	81 00 (2B)
802.1q tag	-	-	4B
SSAP	42 03	AA 03	AA 03
DSAP	42	AA	AA
Cisco OUI	-	02 04 08	02 04 08
PVST PID	-	01 0B	01 0B
LLC	3B	8B	8B
SNAP	4B	Entire BPDU with type = TCN 35B	Entire BPDU with type = TCN 35B

Cisco PVST TCN BPDU headers/fields

Header/field	Standard IEEE STP TCN BPDU (64B padded)	PVST untagged TCN BPDU (64B padded)	PVST tagged TCN BPDU (68B padded)
MAC SA	6B	6B	6B
MAC DA	0180C2.000000 (6B)	01000C.CCCCCD (6B)	01000C.CCCCCD (6B)
Length	2B	2B	-
Type	-	-	81 00 (2B)
802.1q tag	-	-	4B
SSAP	42 03	AA 03	AA 03
DSAP	42	AA	AA
Cisco OUI	-	00 00 0C	00 00 0C
PVST PID	-	01 0B	01 0B
LLC	3B	8B	8B
SNAP	-	Yes	Yes
IEEE TCN BPDU INFO	4B	Entire BPDU with type = TCN 35B	Entire BPDU with type = TCN 35B

PortFast

PortFast allows an interface to transition quickly to the forwarding state.

Consider the following when configuring PortFast:

- Do not enable PortFast on ports that connect to other devices.
- PortFast only needs to be enabled on ports that connect to workstations or PCs. Repeat this configuration for every port connected to workstations or PCs.
- Enabling PortFast on ports can cause temporary bridging loops, in both trunking and nontrunking mode.
- If BPDUs are received on a PortFast- enabled interface, the interface loses the edge port status unless it receives a **shutdown**/**no shutdown** command.
- PortFast immediately puts the interface into the forwarding state without having to wait for the standard forward time.

Edge port and automatic edge detection

Configuring the edge port feature makes a port transition directly from initialization to the forwarding state, skipping the listening and learning states.

From an interface, you can configure a device to automatically identify the edge port. The port can become an edge port if no BPDU is received. By default, automatic edge detection is disabled.

Follow these guidelines to configure a port as an edge port:

- When edge port is enabled, the port still participates in a spanning tree.
- A port can become an edge port if no BPDU is received.
- When an edge port receives a BPDU, it becomes a normal spanning tree port and is no longer an edge port.
- Because ports that are directly connected to end stations cannot create bridging loops in the network, edge ports transition directly to the forwarding state and skip the listening and learning states.

  NOTE
  If BPDUs are received on a port fast enabled interface, the interface loses the edge port status unless it receives a **shutdown** or **no shutdown** command.

Configuring PVST+ and R-PVST+

Enabling and configuring PVST+ globally

Use this procedure to enable and set parameters for PVST+.

You can enable PVST+ with one or more parameters configured. The parameters can be configured or changed individually by entering the commands in steps 1 and 2, running the parameter command, verifying the result, and then saving the configuration.

For more information about spanning trees and spanning tree parameters, see the introductory sections in the Spanning Tree Protocol chapter.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Enable PVST+.

```
device(config)# protocol spanning-tree pvst
```

3. Configure the bridge priority for the common instance.

```
device(config-pvst)# bridge-priority 4096
```

Valid values range from 0 through 61440 in increments of 4096. Assigning a lower priority value indicates that the bridge might become root.

You can shut down PVST+ by entering the **shutdown** command when in PVST configuration mode.

4. Configure the forward delay parameter.

```
device(config-pvst)# forward-delay  11
```

5. Configure the hello time parameter.

```
device(config-pvst)# hello-time 2
```

6. Configure the maximum age parameter.

```
device(config-pvst)# max-age 7
```

7. Return to privileged exec mode.

```
device(config-pvst)# end
```

8. Verify the configuration.

```
device#  show spanning-tree brief
VLAN 1

 Spanning-tree Mode: PVST Protocol

      Root ID      Priority 4097
                   Address 01e0.5200.0180
                   Hello Time 2, Max Age 7, Forward Delay 11

      Bridge ID    Priority 4097
                   Address 01e0.5200.0180
                   Hello Time 2, Max Age 7, Forward Delay 11

 Interface     Role  Sts  Cost       Prio  Link-type        Edge
 ---------------------------------------------------------------------

VLAN 100

 Spanning-tree Mode: PVST Protocol

      Root ID      Priority 4196
                   Address 01e0.5200.0180
                   Hello Time 2, Max Age 7, Forward Delay 11

      Bridge ID    Priority 4196
                   Address 01e0.5200.0180
                   Hello Time 2, Max Age 7, Forward Delay 11

 Interface     Role  Sts  Cost       Prio  Link-type        Edge
 ---------------------------------------------------------------------
```

Observe that the settings comply with the formula set out in the STP parameters section, as:

(2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

or in this case: 20 ≥7 ≥ 6.

9. Save the configuration.

```
device# copy running-config startup-config
```

PVST+ configuration example

```
device# configure terminal
device(config)# protocol spanning-tree pvst
device(config-pvst)# bridge-priority 4096
device(config-pvst)# forward-delay 11
device(config-pvst)# hello-time 2
device(config-pvst)# max-age 7
device(config-pvst)# end
device# show spanning-tree brief
device# copy running-config startup-config
```

For more information about configuring PVST+ parameters, see STP parameters on page 62. PVST+, R-PVST+, and other types of spanning trees share many tasks with STP.

Enabling and configuring PVST+ on an interface

Follow these steps to enable and configure PVST+ on an interface.

The ports and parameters can be configured individually on a system by:

1. Entering the commands in steps 1, and 2
2. Running the relevant addition steps and parameter commands
3. Verifying the result
4. Saving the configuration

For detailed descriptions of the parameters and features, see the sections STP parameters and STP features.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Enable PVST+.

```
device(config)# protocol spanning-tree pvst
```

3. Enter interface configuration mode.

```
device(config-pvst)# interface ethernet 0/3
```

4. Enable spanning tree on the interface.

```
device(conf-if-eth-0/3)# no spanning-tree shutdown
```

5. Configure the interface link type.

```
device(conf-if-eth-0/3)# spanning-tree link-type point-to-point
```

6. Specify the port priority to influence the selection of root or designated ports.

```
device(conf-if-eth-0/3)# spanning-tree priority 64
```

   The range is from 0 through 240 in increments of 16. The default value is 128.

7. Configure the path cost for spanning tree calculations on the interface.

```
device(conf-if-eth-0/3)# spanning-tree cost 10000
```

   The lower the path cost means a greater chance that the interface becomes the root port. The range is 1 through 200000000. The default path cost is assigned as per the port speed.

8. Configure the path cost for spanning tree calculations a specific VLAN.

```
device(conf-if-eth-0/3)# spanning-tree vlan 10 cost 10000
```

   The lower the path cost means a greater chance that the interface becomes the root port. The range is 1 through 200000000. The default path cost is assigned as per the port speed.

9. Enable root guard on the interface.

```
device(conf-if-eth-0/3)# spanning-tree guard root
```

   Root guard protects the root bridge from malicious attacks and unintentional misconfigurations where a bridge device that is not intended to be the root bridge becomes the root bridge.

10. Enable BPDU guard on the interface.

```
device(conf-if-eth-0/3)# spanning-tree port-fast bpdu-guard
```

   BPDU guard removes a node that reflects BPDUs back in the network. It enforces the STP domain borders and keeps the active topology predictable by not allowing any network devices behind a BPDU guard-enabled port to participate in STP.

11. Return to privileged EXEC mode.

```
device(conf-if-eth-0/3)# exit
```

12. Verify the configuration.

```
device# show spanning-tree brief

 Spanning-tree Mode: PVST Protocol

      Root ID      Priority 4096
                   Address 768e.f805.5800
                   Hello Time 8, Max Age 25, Forward Delay 20

      Bridge ID    Priority 4096
                   Address 768e.f805.5800
                   Hello Time 8, Max Age 25, Forward Delay 20

 Interface    Role  Sts  Cost       Prio  Link-type     Edge
 -------------------------------------------------------------
 Eth 0/3      DES   FWD  200000     64    P2P            No
```

   Observe that the settings comply with the formula set out in the STP parameters section, as:

   (2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

   or in this case :38 ≥ 25 ≥ 18.

13. Save the configuration.

```
device# copy running-config startup-config
```

PVST+ on an interface configuration example

```
device# configure terminal
device(config)# protocol spanning-tree pvst
device(conf-pvst)# interface ethernet 0/3
device(conf-if-eth-0/3)# no spanning-tree shutdown
device(conf-if-eth-0/3)# spanning-tree link-type point-to-point
device(conf-if-eth-0/3)# spanning-tree priority 64
device(conf-if-eth-0/3)# spanning-tree cost 10000
device(conf-if-eth-0/3)# spanning-tree vlan 10 cost 10000
device(conf-if-eth-0/3)# spanning-tree guard root
device(conf-if-eth-0/3)# spanning-tree port-fast bpdu-guard
device(conf-if-eth-0/3)# exit
device# show spanning-tree
device# copy running-config startup-config
```

Enabling and configuring PVST+ on a system

Follow the steps to configure PVST+ on a system.

The ports and parameters can be configured individually on a system by:

1. Entering the commands in steps 1, and 2
2. Running the relevant addition steps and parameter commands
3. Verifying the result
4. Saving the configuration

For detailed descriptions of the parameters and features, see the sections STP parameters and STP features.

1. Enter global configuration mode.

   ```
   device# configure terminal
   ```

2. Enable PVST+.

   ```
   device(config)# protocol spanning-tree pvst
   ```

3. Configure the bridge priority for the common instance.

   ```
   device(config-pvst)# bridge-priority 4096
   ```

   Valid values range from 0 through 61440 in multiples of 4096. Assigning a lower priority value indicates that the bridge might become root.

4. Configure the forward delay parameter.

   ```
   device(config-pvst)# forward-delay  15
   ```

5. Configure the hello time parameter.

   ```
   device(config-pvst)# hello-time 2
   ```

6. Configure the maximum age parameter.

   ```
   device(config-pvst)# max-age 20
   ```

7. Add VLANs.
   a) Configure VLAN 100 with a priority of 0.

      ```
      device(config-pvst)# vlan 100 priority 0
      ```

      The bridge priority in configured in multiples of 4096.
   b) Configure VLAN 201 with a priority of 12288.

      ```
      device(config-pvst)# vlan 201 priority 12288
      ```

   c) Configure VLAN 301 with a priority of 20480.

      ```
      device(config-pvst)# vlan 301 priority 20480
      ```

8. Set the switching characteristics for interface 0/3.
   a) Enter interface configuration mode.

      ```
      device(config)# interface ethernet 0/3
      ```

   b) Set the switching characteristics of the interface.

      ```
      device(conf-if-eth-0/3)# switchport
      ```

   c) Set the interface mode to trunk.

      ```
      device(conf-if-eth-0/3)# switchport mode trunk
      ```

   d) Add VLAN 100 as a member VLAN.

      ```
      device(conf-if-eth-0/3)# switchport trunk allowed vlan add 100
      ```

   e) Add VLAN 201 as a member VLAN.

      ```
      device(conf-if-eth-0/3)# switchport trunk allowed vlan add 201
      ```

   f) Add VLAN 301 as a member VLAN.

      ```
      device(conf-if-eth-0/3)# switchport trunk allowed vlan add 301
      ```

   g) Enable spanning tree on the interface.

      ```
      device(conf-if-eth-0/3)# no spanning-tree shutdown
      ```

   h) Return to privileged EXEC mode.

      ```
      device(conf-if-eth-0/3)# exit
      ```

9. Set the switching characteristics for interface 0/4.
   a) Enter interface configuration mode.

```
device(config)# interface ethernet 0/4
```

   b) Set the switching characteristics of the interface.

```
device(conf-if-eth-0/4)# switchport
```

   c) Set the interface mode to trunk.

```
device(conf-if-eth-0/4)# switchport mode trunk
```

   d) Add VLAN 100 as a member VLAN.

```
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 100
```

   e) Add VLAN 201 as a member VLAN.

```
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 201
```

   f) Add VLAN 301 as a member VLAN.

```
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 301
```

   g) Enable spanning tree on the interface.

```
device(conf-if-eth-0/4)# no spanning-tree shutdown
```

   h) Return to privileged EXEC mode.

```
device(conf-if-eth-0/4)# exit
```

10. To interoperate with switches other than Brocade VDX switches in PVST+ mode, you must configure the interface that is connected to that switch.
   a) Enter interface configuration mode for the port that interoperates with a VDX device.

```
device(config)# interface ethernet 0/12
```

   b) Specify the MAC address for the device.

```
device(conf-if-eth-0/12)# spanning-tree bpdu-mac 0100.0ccc.cccd
```

   c) Enable spanning tree on the interface.

```
device(conf-if-eth-0/12)# no spanning-tree shutdown
```

   d) Return to privileged EXEC mode.

```
device(conf-if-eth-0/12)# end
```

11. Verify the configuration.

```
device# show spanning-tree

VLAN 1

 Spanning-tree Mode: PVST Protocol

 Root Id: 0001.01e0.5200.0180 (self)
 Bridge Id: 0001.01e0.5200.0180

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: disabled
 Bpdu-guard errdisable timeout interval: 300 sec

 Port Et 0/3 enabled
    Ifindex: 201351168; Id: 8001; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

 Port Et 0/4 enabled
    Ifindex: 201359360; Id: 8002; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

VLAN 100

 Spanning-tree Mode: PVST Protocol

 Root Id: 0064.01e0.5200.0180 (self)
 Bridge Id: 0064.01e0.5200.0180

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: disabled
 Bpdu-guard errdisable timeout interval: 300 sec

 Port Et 0/3 enabled
    Ifindex: 201351168; Id: 8001; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
```

```
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

 Port Et 0/4 enabled
    Ifindex: 201359360; Id: 8002; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

VLAN 201

 Spanning-tree Mode: PVST Protocol

 Root Id: 30c9.01e0.5200.0180 (self)
 Bridge Id: 30c9.01e0.5200.0180

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: disabled
 Bpdu-guard errdisable timeout interval: 300 sec

 Port Et 0/3 enabled
    Ifindex: 201351168; Id: 8001; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

 Port Et 0/4 enabled
    Ifindex: 201359360; Id: 8002; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

VLAN 301

 Spanning-tree Mode: PVST Protocol

 Root Id: 512d.01e0.5200.0180 (self)
 Bridge Id: 512d.01e0.5200.0180

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: disabled
 Bpdu-guard errdisable timeout interval: 300 sec
```

```
Port Et 0/3 enabled
   Ifindex: 201351168; Id: 8001; Role: Disabled; State: Disabled
   Designated Path Cost: 0
   Configured Path Cost: 20000000
   Designated Port Id: 0; Port Priority: 128
   Designated Bridge: 0000.0000.0000.0000
   Number of forward-transitions: 0
   Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
   Portfast: off
   Configured Root guard: off; Operational Root guard: off
   Bpdu-guard: off
   Link-type: point-to-point
   Received BPDUs: 0; Sent BPDUs: 0

Port Et 0/4 enabled
   Ifindex: 201359360; Id: 8002; Role: Disabled; State: Disabled
   Designated Path Cost: 0
   Configured Path Cost: 20000000
   Designated Port Id: 0; Port Priority: 128
   Designated Bridge: 0000.0000.0000.0000
   Number of forward-transitions: 0
   Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
   Portfast: off
   Configured Root guard: off; Operational Root guard: off
   Bpdu-guard: off
   Link-type: point-to-point
   Received BPDUs: 0; Sent BPDUs: 0
```

Observe that the settings comply with the formula set out in the STP parameters section, as:

(2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

or in this case: 28 ≥ 20 ≥ 6.

12. Save the configuration.

```
device# copy running-config startup-config
```

Enable PVST+ on a system configuration example

```
device# configure terminal
device(config)# protocol spanning-tree pvst
device(config-pvst)# bridge-priority 4096
device(config-pvst)# forward-delay  15
device(config-pvst)# hello-time 2
device(config-pvst)# max-age 20
device(config-pvst)# vlan 100 priority 0
device(config-pvst)# vlan 201 priority 12288
device(config-pvst)# vlan 301 priority 20480
device(config-pvst)# interface ethernet 0/3
device(conf-if-eth-0/3)# switchport
device(conf-if-eth-0/3)# switchport mode trunk
device(conf-if-eth-0/3)# switchport trunk allowed vlan add 100
device(conf-if-eth-0/3)# switchport trunk allowed vlan add 201
device(conf-if-eth-0/3)# switchport trunk allowed vlan add 301
device(conf-if-eth-0/3)# no spanning-tree shutdown
device(conf-if-eth-0/3)# exit
device(config)# interface ethernet 0/4
device(conf-if-eth-0/4)# switchport
device(conf-if-eth-0/4)# switchport mode trunk
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 100
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 201
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 301
device(conf-if-eth-0/4)# no spanning-tree shutdown
device(conf-if-eth-0/4)# end
device# show spanning-tree
device# copy running-config startup-config
```

Enabling and configuring R-PVST+ globally

Use this procedure to enable the Rapid Per-VLAN Spanning Tree Protocol Plus (R-PVST+).

1. Enter global configuration mode.

```
device# configure terminal
```

2. Enable R-PVST+.

```
device(config)# protocol spanning-tree rpvst
```

3. Configure the bridge priority for the common instance.

```
device(config-rpvst)# bridge-priority 4096
```

   Valid priority values range from 0 through 61440 in multiples of 4096. Assigning a lower priority value indicates that the bridge might become root.

4. Configure the forward delay parameter.

```
device(config-rpvst)# forward-delay  20
```

5. Configure the hello time parameter.

```
device(config-rpvst)# hello-time 22
```

6. Configure the maximum age parameter.

```
device(config-rpvst)# max-age 8
```

7. Set the transmit hold count for the bridge.

```
device(config-rpvst)# transmit-holdcount 9
```

   This command configures the maximum number of BPDUs transmitted per second before pausing for 1 second. The range is 1 through 10. The default is 6.

8. Return to privileged exec mode.

```
device(config-rpvst)# end
```

9. Verify the configuration.

```
device# show spanning-tree brief
VLAN 1

 Spanning-tree Mode: Rapid PVST Protocol

      Root ID      Priority 4096
                   Address 01e0.5200.0180
                   Hello Time 2, Max Age 7, Forward Delay 11

      Bridge ID    Priority 32769
                   Address 01e0.5200.0180
                   Hello Time 8, Max Age 22, Forward Delay 20, Tx-HoldCount 9
                   Migrate Time 3 sec

 Interface     Role  Sts  Cost       Prio  Link-type        Edge
 -------------------------------------------------------------------
```

   Observe that the settings comply with the formula set out in the STP parameters section, as:

   (2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

   or in this case: 20 ≥ 7 ≥ 6.

10. Save the configuration.

```
device# copy running-config startup-config
```

R-PVST+ configuration example

```
device# configure terminal
device(config)# protocol spanning-tree rpvst
device(config-rpvst)# bridge-priority 4096
device(config-rpvst)# forward-delay 20
device(config-rpvst)# hello-time 22
device(config-rpvst)# max-age 8
device(config-rpvst)# transmit-holdcount 9
device(config-rpvst)# end
device# show spanning-tree brief
device# copy running-config startup-config
```

For more information about configuring parameters, see the section STP parameter configuration.

Enabling and configuring R-PVST+ on an interface

Follow these steps to enable and configure R-PVST+ on an interface.

The ports and parameters can be configured individually on a system by:

1. Entering the commands in steps 1-3
2. Running the relevant addition steps and parameter commands
3. Verifying the result
4. Saving the configuration

For detailed descriptions of the parameters and features, see the sections STP parameters and STP features.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Enable R-PVST+.

```
device(config)# protocol spanning-tree rpvst
```

3. Enter interface configuration mode.

```
device(config-rpvst)# interface ethernet 0/3
```

4. Enable the spanning tree on the interface.

```
device(conf-if-eth-0/3)# no spanning-tree shutdown
```

5. Configure the interface link type.

```
device(conf-if-eth-0/3)# spanning-tree link-type point-to-point
```

6. Specify the port priority to influence the selection of root or designated ports.

```
device(conf-if-eth-0/3)# spanning-tree priority 64
```

   The range of priority values is from 0 through 240 in multiples of 16. The default value is 128.

7. Configure the path cost for spanning tree calculations on the interface.

```
device(conf-if-eth-0/3)# spanning-tree cost 200000
```

   The lower the path cost means a greater chance that the interface becomes the root port. The range is 1 through 200000000. The default path cost is assigned as per the port speed.

8. Configure the path cost for spanning tree calculations a specific VLAN.

```
device(conf-if-eth-0/3)# spanning-tree vlan 10 cost 10000
```

   The lower the path cost means a greater chance that the interface becomes the root port. The range is 1 through 200000000. The default path cost is assigned as per the port speed.

9. Enable automatic edge detection on the interface.

```
device(conf-if-eth-0/3)# spanning-tree autoedge
```

   You use this command to automatically identify the edge port. A port becomes an edge port if it receives no BPDUs. By default, automatic edge detection is disabled.

10. Enable root guard on the interface.

```
device(conf-if-eth-0/3)# spanning-tree guard root
```

    Root guard protects the root bridge from malicious attacks and unintentional misconfigurations where a bridge device that is not intended to be the root bridge becomes the root bridge.

11. Enable the spanning tree on the edge port.

```
device(conf-if-eth-0/3)# spanning-tree edgeport
```

    If BPDUs are received on a port fast enabled interface, the interface loses the edge port status unless it receives a **shutdown** or **no shutdown** command.

12. Enable BPDU guard on the interface.

```
device(conf-if-eth-0/3)# spanning-tree edgeport bpdu-guard
```

    BPDU guard removes a node that reflects BPDUs back in the network. It enforces the STP domain borders and keeps the active topology predictable by not allowing any network devices behind a BPDU guard-enabled port to participate in STP.

13. Return to privileged EXEC mode.

```
device(conf-if-eth-0/3)# exit
```

14. Verify the configuration.

```
device# show spanning-tree brief

 Spanning-tree Mode: Rapid PVST Protocol

      Root ID      Priority 4096
                   Address 768e.f805.5800
                   Hello Time 8, Max Age 25, Forward Delay 20

      Bridge ID    Priority 4096
                   Address 768e.f805.5800
                   Hello Time 8, Max Age 25, Forward Delay 20

 Interface    Role  Sts  Cost       Prio  Link-type     Edge
 ------------------------------------------------------------
 Eth 0/3      DES   FWD  200000     128   P2P            No
```

    Observe that the settings comply with the formula set out in the STP parameters section, as:

    (2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

    or in this case: 38 ≥ 25 ≥ 18.

15. Save the configuration.

```
device# copy running-config startup-config
```

R-PVST+ on an interface configuration example

```
device# configure terminal
device(config)# protocol spanning-tree rpvst
device(config-rpvst)# interface ethernet 0/3
device(conf-if-eth-0/3)# no spanning-tree shutdown
device(conf-if-eth-0/3)# spanning-tree link-type point-to-point
device(conf-if-eth-0/3)# spanning-tree priority 64
device(conf-if-eth-0/3)# spanning-tree cost 200000
device(conf-if-eth-0/3)# spanning-tree vlan 10 cost 10000
device(conf-if-eth-0/3)# spanning-tree autoedge
device(conf-if-eth-0/3)# spanning-tree guard root
device(conf-if-eth-0/3)# spanning-tree edgeport
device(conf-if-eth-0/3)# spanning-tree edgeport bpdu-guard
device(conf-if-eth-0/3)# exit
device# show spanning-tree
device# copy running-config startup-config
```

Enabling and configuring R-PVST+ on a system

Follow the steps to configure R-PVST+ on a system.

The ports and parameters can be configured individually by:

1. Entering the commands in steps 1 and 2
2. Running the relevant addition steps and parameter commands
3. Verifying the result
4. Saving the configuration

For detailed descriptions of the parameters and features, see the sections STP parameters and STP features.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Enable R-PVST+.

```
device(config)# protocol spanning-tree rpvst
```

   You can shut down R-PVST+ by entering the **shutdown** command when in `rpvst` configuration mode.

3. Configure the bridge priority for the common instance.

```
device(config-rpvst)# bridge-priority 4096
```

   Valid values range from 0 through 61440 in increments of 4096. Assigning a lower priority value indicates that the bridge might become root.

4. Configure the forward delay parameter.

```
device(config-rpvst)# forward-delay  20
```

5. Configure the hello time parameter.

```
device(config-rpvst)# hello-time 8
```

6. Configure the maximum age parameter.

```
device(config-rpvst)# max-age 22
```

7. Specify the transmit hold count.

```
device(config-rpvst)# transmit-holdcount 5
```

   This command configures the maximum number of BPDUs transmitted per second. The range of values is 1 through 10.

8. Configure VLANs.
   a) Configure VLAN 100 with a priority of 0.

```
device(config-rpvst)# vlan 100 priority 0
```

      Valid priority values range from 0 through 61440 in multiples of 4096.

   b) Configure VLAN 201 with a priority of 12288.

```
device(config-rpvst)# vlan 201 priority 12288
```

   c) Configure VLAN 301 with a priority of 20480.

```
device(config-rpvst)# vlan 301 priority 20480
```

9. Set the switching characteristics for interface 0/3.
   a) Enter interface configuration mode.

```
device(config-rpvst)# interface ethernet 0/3
```

   b) Set the switching characteristics of the interface.

```
device(conf-if-eth-0/3)# switchport
```

   c) Set the interface mode to trunk.

```
device(conf-if-eth-0/3)# switchport mode trunk
```

   d) Add VLAN 100 as a member VLAN.

```
device(conf-if-eth-0/3)# switchport trunk allowed vlan add 100
```

   e) Add VLAN 201 as a member VLAN.

```
device(conf-if-eth-0/3)# switchport trunk allowed vlan add 201
```

   f) Add VLAN 301 as a member VLAN.

```
device(conf-if-eth-0/3)# switchport trunk allowed vlan add 301
```

   g) Enable spanning tree on the interface.

```
device(conf-if-eth-0/3)# no spanning-tree shutdown
```

   h) Return to privileged EXEC mode.

```
device(conf-if-eth-0/3)# exit
```

10. Set the switching characteristics for interface 0/4.
    a) Enter interface configuration mode.

```
device(config-rpvst)# interface ethernet 0/4
```

    b) Set the switching characteristics of the interface.

```
device(conf-if-eth-0/4)# switchport
```

    c) Set the interface mode to trunk.

```
device(conf-if-eth-0/4)# switchport mode trunk
```

    d) Add VLAN 100 as a member VLAN.

```
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 100
```

    e) Add VLAN 201 as a member VLAN.

```
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 201
```

    f) Add VLAN 301 as a member VLAN.

```
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 301
```

    g) Enable spanning tree on the interface.

```
device(conf-if-eth-0/4)# no spanning-tree shutdown
```

    h) Return to privileged EXEC mode.

```
device(conf-if-eth-0/4)# exit
```

11. To interoperate with switches other than Brocade VDX switches in R-PVST+ mode, you must configure the interface that is connected to that switch.
    a) Enter interface configuration mode for the port that interoperates with a VDX switch.

```
device(config)# interface ethernet 0/12
```

    b) Specify the MAC address for the device.

```
device(conf-if-eth-0/12)# spanning-tree bpdu-mac 0100.0ccc.cccd
```

    c) Enable spanning tree on the interface.

```
device(conf-if-eth-0/12)# no spanning-tree shutdown
```

    d) Return to privileged EXEC mode.

```
device(conf-if-eth-0/12)# end
```

12. Verify the configuration.

```
device# show spanning-tree

VLAN 1

 Spanning-tree Mode: Rapid PVST Protocol

 Root Id: 0001.01e0.5200.0180 (self)
 Bridge Id: 0001.01e0.5200.0180

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 20; Hello Time: 8; Max Age: 22; Max-hops: 20
 Tx-HoldCount 5
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: disabled
 Bpdu-guard errdisable timeout interval: 300 sec

 Port Et 0/3 enabled
    Ifindex: 201351168; Id: 8001; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

 Port Et 0/4 enabled
    Ifindex: 201359360; Id: 8002; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

VLAN 100

 Spanning-tree Mode: Rapid PVST Protocol

 Root Id: 0064.01e0.5200.0180 (self)
 Bridge Id: 0064.01e0.5200.0180

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 20; Hello Time: 8; Max Age: 22; Max-hops: 20
 Tx-HoldCount 5
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: disabled
 Bpdu-guard errdisable timeout interval: 300 sec

 Port Et 0/3 enabled
    Ifindex: 201351168; Id: 8001; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
```

```
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

 Port Et 0/4 enabled
    Ifindex: 201359360; Id: 8002; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

VLAN 201

 Spanning-tree Mode: Rapid PVST Protocol

 Root Id: 30c9.01e0.5200.0180 (self)
 Bridge Id: 30c9.01e0.5200.0180

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 20; Hello Time: 8; Max Age: 22; Max-hops: 20
 Tx-HoldCount 5
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: disabled
 Bpdu-guard errdisable timeout interval: 300 sec

 Port Et 0/3 enabled
    Ifindex: 201351168; Id: 8001; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

 Port Et 0/4 enabled
    Ifindex: 201359360; Id: 8002; Role: Disabled; State: Disabled
    Designated Path Cost: 0
    Configured Path Cost: 20000000
    Designated Port Id: 0; Port Priority: 128
    Designated Bridge: 0000.0000.0000.0000
    Number of forward-transitions: 0
    Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
    Portfast: off
    Configured Root guard: off; Operational Root guard: off
    Bpdu-guard: off
    Link-type: point-to-point
    Received BPDUs: 0; Sent BPDUs: 0

VLAN 301

 Spanning-tree Mode: Rapid PVST Protocol

 Root Id: 512d.01e0.5200.0180 (self)
 Bridge Id: 512d.01e0.5200.0180

 Root Bridge Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 20; Hello Time: 8; Max Age: 22; Max-hops: 20
 Tx-HoldCount 5
```

```
Number of topology change(s): 0

Bpdu-guard errdisable timeout: disabled
Bpdu-guard errdisable timeout interval: 300 sec

Port Et 0/3 enabled
   Ifindex: 201351168; Id: 8001; Role: Disabled; State: Disabled
   Designated Path Cost: 0
   Configured Path Cost: 20000000
   Designated Port Id: 0; Port Priority: 128
   Designated Bridge: 0000.0000.0000.0000
   Number of forward-transitions: 0
   Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
   Portfast: off
   Configured Root guard: off; Operational Root guard: off
   Bpdu-guard: off
   Link-type: point-to-point
   Received BPDUs: 0; Sent BPDUs: 0

Port Et 0/4 enabled
   Ifindex: 201359360; Id: 8002; Role: Disabled; State: Disabled
   Designated Path Cost: 0
   Configured Path Cost: 20000000
   Designated Port Id: 0; Port Priority: 128
   Designated Bridge: 0000.0000.0000.0000
   Number of forward-transitions: 0
   Version: Per-VLAN Spanning Tree Protocol - Received None - Sent STP
   Portfast: off
   Configured Root guard: off; Operational Root guard: off
   Bpdu-guard: off
   Link-type: point-to-point
   Received BPDUs: 0; Sent BPDUs: 0
```

Observe that the settings comply with the formula set out in the STP parameters section, as:

(2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

or in this case: 28 ≥ 20 ≥ 6.

13. Save the configuration.

```
device# copy running-config startup-config
```

Enable R-PVST+ on a system configuration example

```
device# configure terminal
device(config)# protocol spanning-tree rpvst
device(config-rpvst)# bridge-priority 4096
device(config-rpvst)# forward-delay  20
device(config-rpvst)# hello-time 8
device(config-rpvst)# max-age 22
device(config-rpvst)# transmit-holdcount 5
device(config-rpvst)# vlan 100 priority 0
device(config-rpvst)# vlan 201 priority 12288
device(config-rpvst)# vlan 301 priority 20480
device(config-rpvst)# interface ethernet 0/3
device(conf-if-eth-0/3)# switchport
device(conf-if-eth-0/3)# switchport mode trunk
device(conf-if-eth-0/3)# switchport trunk allowed vlan add 100
device(conf-if-eth-0/3)# switchport trunk allowed vlan add 201
device(conf-if-eth-0/3)# switchport trunk allowed vlan add 301
device(conf-if-eth-0/3)# no spanning-tree shutdown
device(conf-if-eth-0/3)# exit
device(config)# interface ethernet 0/4
device(conf-if-eth-0/4)# switchport
device(conf-if-eth-0/4)# switchport mode trunk
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 100
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 201
device(conf-if-eth-0/4)# switchport trunk allowed vlan add 301
device(conf-if-eth-0/4)# no spanning-tree shutdown
device(conf-if-eth-0/4)# end
device# show spanning-tree
device# copy running-config startup-config
```

Clearing spanning tree counters

Follow these steps to clear spanning tree counters on all interfaces or on the specified interface.

1. Clear spanning tree counters on all interfaces.

   ```
   device# clear spanning-tree counter
   ```

2. Clear spanning tree counters on a specified Ethernet interface.

   ```
   device# clear spanning-tree counter interface ethernet 0/3
   ```

3. Clear spanning tree counters on a specified port channel interface.

   ```
   device# clear spanning-tree counter interface port-channel 12
   ```

   Port channel interface numbers range from 1 through 64.

Clearing spanning tree-detected protocols

Follow these steps to restart the protocol migration process.

These commands force a spanning tree renegotiation with neighboring devices on either all interfaces or on a specified interface.

1. Restart the spanning tree migration process on all interfaces.

   ```
   device# clear spanning-tree detected-protocols
   ```

2. Restart the spanning tree migration process on a specific Ethernet interface.

   ```
   device# clear spanning-tree detected-protocols interface ethernet 0/3
   ```

3. Restart the spanning tree migration process on a specific port channel interface.

```
device# clear spanning-tree detected-protocols port-channel 12
```

   Port channel interface numbers range from 1 through 64.

Shutting down PVST+ or R-PVST+

Follow these steps to o shut down PVST+, or R-PVST+ either globally, on a specific interface, or a specific VLAN.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Shut down PVST+ or R-PVST+.
   - Shut down PVST+ or R-PVST+ globally and return to privileged EXEC mode.

```
device(config)# protocol spanning-tree pvst
device(config-pvst)# shutdown
device(config-pvst)# end
```

   - Shut down PVST+ or R-PVST+ on a specific interface and return to privileged EXEC mode.

```
device(config)# interface ethernet 0/2
device(conf-if-eth-0/2)# spanning-tree shutdown
device(conf-if-eth-0/2)# end
```

   - Shut down PVST+ or R-PVST+ on a specific VLAN. and return to privileged EXEC mode.

```
device(config)# vlan 10
device(config-vlan-10)# spanning-tree shutdown
device(config-vlan-10)# end
```

3. Verify the configuration.

```
device# show spanning-tree
device#
```

4. Save the running configuration to the startup configuration.

```
device# copy running-config startup-config
```

Shut down PVST+ or R-PVST+ configuration example

```
device# configure terminal
device(config)# vlan 10
device(config-vlan-10)# spanning-tree shutdown
device(config-vlan-10)# end
device# show spanning-tree
device# copy running-config startup-config
```

NOTE

Shutting down PVST+ on a VLAN is used in this example.

802.1s Multiple Spanning Tree Protocol

MSTP overview

IEEE 802.1s Multiple STP (MSTP) helps create multiple loop-free active topologies on a single physical topology.

MSTP uses RSTP to group VLANs into separate spanning-tree instance. Each instance has its own spanning-tree topology independent of other spanning tree instances, which allows multiple forwarding paths, permits load balancing, and facilitates the movement of data traffic. A failure in one instance does not affect other instances. By enabling the MSTP, you are able to more effectively utilize the physical resources present in the network and achieve better load balancing of VLAN traffic.

The MSTP evolved as a compromise between the two extremes of the RSTP and R-PVST+, it was standardized as IEEE 802.1s and later incorporated into the IEEE 802.1Q-2003 standard. The MSTP configures a meshed topology into a loop-free, tree-like topology. When the link on a bridge port goes up, an MSTP calculation occurs on that port. The result of the calculation is the transition of the port into either a forwarding or blocking state. The result depends on the position of the port in the network and the MSTP parameters. All the data frames are forwarded over the spanning tree topology calculated by the protocol.

> NOTE
> Multiple switches must be configured consistently with the same MSTP configuration to participate in multiple spanning tree instances. A group of interconnected switches that have the same MSTP configuration is called an MSTP region.
> MSTP is backward compatible with the STP and the RSTP.

Common Spanning Tree (CST)

The single Spanning Tree instance used by the Brocade device, and other vendor devices to interoperate with MSTP bridges. This spanning tree instance stretches across the entire network domain (including PVST, PVST+ and MSTP regions). It is associated with VLAN 1 on the Brocade device.

Internal Spanning Tree (IST)

An MSTP bridge must handle at least these two instances: one IST and one or more MSTIs (Multiple Spanning Tree Instances). Within each MST region, the MSTP maintains multiple spanning-tree instances. Instance 0 is a special instance known as IST, which extends CST inside the MST region. IST always exists if the device runs MSTP. Besides IST, this implementation supports up to 31 MSTIs.

Common Internal Spanning Tree (CIST)

The single spanning tree calculated by STP (including PVST+) and RSTP (including R-PVST+) and the logical continuation of that connectivity through MSTP bridges and regions, calculated by MSTP to ensure that all LANs in the bridged LAN are simply and fully connected

Multiple Spanning Tree Instance (MSTI)

One of a number of spanning trees calculated by the MSTP within an MST Region, to provide a simply and fully connected active topology for frames classified as belonging to a VLAN that is mapped to the MSTI by the MST configuration table used by the MST bridges of that MST region.

The Brocade implementation supports up to 32 spanning tree instances in an MSTP enabled bridge that can support up to 32 different Layer 2 topologies. The spanning tree algorithm used by the MSTP is the RSTP, which provides quick convergence.

By default all configured VLANs including the default VLAN are assigned to and derive port states from CIST until explicitly assigned to MSTIs.

MST regions

MST regions are clusters of bridges that run multiple instances of the MSTP protocol. Multiple bridges detect that they are in the same region by exchanging their configuration (instance to VLAN mapping), name, and revision-level. Therefore, if you need to have two bridges in the same region, the two bridges must have identical configurations, names, and revision-levels. Also, one or more VLANs can be mapped to one MST instance (IST or MSTI) but a VLAN cannot be mapped to multiple MSTP instances

MSTP regions

MSTP introduces a hierarchical way of managing device domains using regions. Devices that share common MSTP configuration attributes belong to a region. The MSTP configuration determines the MSTP region where each device resides. The common MSTP configuration attributes are as follows:

- Alphanumeric configuration name (32 bytes)
- Configuration revision number (2 bytes)
- 4096-element table that maps each of the VLANs to an MSTP instance

Region boundaries are determined by the above attributes. An MSTI is an RSTP instance that operates inside an MSTP region and determines the active topology for the set of VLANs mapping to that instance. Every region has a CIST that forms a single spanning tree instance which includes all the devices in the region. The difference between the CIST instance and the MSTP instance is that the CIST instance operates across the MSTP region and forms a loop-free topology across regions, while the MSTP instance operates only within a region. The CIST instance can operate using the RSTP only if all the devices across the regions support the RSTP. However, if any of the devices operate using the STP, the CIST instance reverts to the STP.

Each region is viewed logically as a single STP or a single RSTP bridge to other regions.

> **NOTE**
> Brocade supports 32 MSTP instances and one MSTP region.

For more information about spanning trees, see the introductory sections in the Spanning Tree Protocol chapter.

MSTP guidelines and restrictions

Follow these restrictions and guidelines when configuring the MSTP:

- Create VLANs before mapping them to the MSTP instances.
- The Brocade implementation of the MSTP supports up to 32 MSTP instances and one MSTP region.
- The MSTP **force-version** option is not supported.
- You must create VLANs before mapping them to the MSTP instances.

- For two or more switches to be in the same the MSTP region, they must have the same VLAN-to-instance map, the same configuration revision number, and the same region name.
- MSTP is backward compatible with the STP and the RSTP.
- Only one MSTP region can be configured on a bridge.
- A maximum of 4090 VLANs can be configured across the 32 MSTP instances.
- MSTP and topology groups cannot be configured together.

Default MSTP configuration

As well as the defaults listed in the section Understanding the default STP configuration on page 59 there are defaults that apply only to MSTP configurations.

Parameter	Default setting
Cisco interoperability	Disabled
Device priority (when mapping a VLAN to an MSTP instance)	32768
Maximum hops	20 hops
Revision number	0

Interoperability with PVST+ and R-PVST+

Since Brocade or other vendor devices enabled with PVST+ and R-PVST+ send IEEE STP BPDUs in addition to the PVST and R-PVST BPDUs, the VLAN 1 spanning tree joins the Common Spanning Tree (CST) of the network and thus interoperates with MSTP. The IEEE compliant devices treat the BPDUs addressed to the Brocade proprietary multicast MAC address as an unknown multicast address and flood them over the active topology for the particular VLAN.

MSTP global level parameters

To configure a switch for MSTP, first you set the region name and the revision on each switch that is being configured for MSTP. You must then create an MSTP Instance and assign an ID. VLANs are then assigned to MSTP instances. These instances must be configured on all switches that interoperate with the same VLAN assignments.

Each of the steps used to configure and operate MSTP are described in the following:

NOTE
The MSTP Region and Revision global parameters are enabled for interface level parameters as described below.

- Set the MSTP region name — Each switch that is running MSTP is configured with a name. It applies to the switch which can have many different VLANs that can belong to many different MSTP regions. The default MSTP name is "NULL".
- Set the MSTP revision number — Each switch that is running MSTP is configured with a revision number. It applies to the switch, which can have many different VLANs that can belong to many different MSTP regions.
- Enabling and disabling Cisco interoperability — While in MSTP mode, use the **cisco-interoperability** command to enable or disable the ability to interoperate with certain legacy Cisco switches. If Cisco interoperability is required on any switch in the network, then all switches in the network must be compatible, and therefore enabled by means of this command. By default the Cisco interoperability is disabled.

- The parameters you would normally set when you configure STP are applicable to MSTP. Before you configure MSTP parameters see the sections explaining bridge parameters, the error disable timeout parameter and the port-channel path cost parameter in the STP section of this guide.

MSTP interface level parameters

Edge port and automatic edge detection

Configuring the edge port feature makes a port transition directly from initialization to the forwarding state, skipping the listening and learning states.

From an interface, you can configure a device to automatically identify the edge port. The port can become an edge port if no BPDU is received. By default, automatic edge detection is disabled.

Follow these guidelines to configure a port as an edge port:

- When edge port is enabled, the port still participates in a spanning tree.
- A port can become an edge port if no BPDU is received.
- When an edge port receives a BPDU, it becomes a normal spanning tree port and is no longer an edge port.
- Because ports that are directly connected to end stations cannot create bridging loops in the network, edge ports transition directly to the forwarding state and skip the listening and learning states.

  NOTE
  If BPDUs are received on a port fast enabled interface, the interface loses the edge port status unless it receives a **shutdown** or **no shutdown** command.

BPDU guard

In an STP environment, switches, end stations, and other Layer 2 devices use BPDUs to exchange information that STP will use to determine the best path for data flow.

In a valid configuration, edge port-configured interfaces do not receive BPDUs. If an edge port-configured interface receives a BPDU, an invalid configuration exists, such as the connection of an unauthorized device. The BPDU Guard provides a secure response to invalid configurations because the administrator must manually put the interface back in service.

BPDU guard removes a node that reflects BPDUs back in the network. It enforces the STP domain borders and keeps the active topology predictable by not allowing any network devices behind a BPDU guard-enabled port to participate in STP.

In some instances, it is unnecessary for a connected device, such as an end station, to initiate or participate in an STP topology change. In this case, you can enable the STP BPDU guard feature on the Brocade device port to which the end station is connected. The STP BPDU guard shuts down the port and puts it into an "error disabled" state. This disables the connected device's ability to initiate or participate in an STP topology. A log message is then generated for a BPDU guard violation, and a message is displayed to warn the network administrator of an invalid configuration.

The BPDU Guard provides a secure response to invalid configurations because the administrator must manually put the interface back in service with the **no shutdown** command if error disable recovery is not enabled by enabling the **errdisable-timeout** command. The interface can also be automatically configured to be enabled after a timeout. However, if the offending BPDUs are still being received, the port is disabled again.

Expected behavior in an interface context

When BPDU Guard is enabled on an interface, the device is expected to put the interface in Error Disabled state when BPDU is received on the port when edge-port and BPDU guard is enabled on the switch interface. When the port ceases to receive the BPDUs, it does not automatically switch to edge port mode, you must configure **error disable timeout** or **no shutdown** on the port to move the port back into edge port mode.

Restricted role

Configuring restricted role on a port causes the port not to be selected as root port for the CIST or any MSTI, even if it has the best spanning tree priority vector.

Restricted role ports are selected as an alternate port after the root port has been selected. It is configured by a network administrator to prevent bridges external to a core region of the network influencing the spanning tree active topology, possibly because those bridges are not under the full control of the administrator. It will protect the root bridge from malicious attack or even unintentional misconfigurations where a bridge device which is not intended to be root bridge, becomes root bridge causing severe bottlenecks in data path. These types of mistakes or attacks can be avoided by configuring 'restricted-role' feature on ports of the root bridge . This feature is similar to the "root-guard" feature which is proprietary implementation of Cisco for STP and RSTP but had been adapted in the 802.1Q standard as "restricted-role". The "restricted-role" feature if configured on an incorrect port can cause lack of spanning tree connectivity.

Expected behavior in an interface context

When this feature is enabled on an interface the device is expected to prevent a port configured with restricted-role feature from assuming the role of a Root port. Such a port is expected to assume the role of an Alternate port instead, once Root port is selected.

Restricted TCN

TCN BPDUs are used to inform other switches of port changes.

Configuring "restricted TCN" on a port causes the port not to propagate received topology change notifications and topology changes originated from a bridge external to the core network to other ports. It is configured by a network administrator to prevent bridges external to a core region of the network from causing MAC address flushing in that region, possibly because those bridges are not under the full control of the administrator for the attached LANs. If configured on an incorrect port it can cause temporary loss of connectivity after changes in a spanning trees active topology as a result of persistent incorrectly learned station location information.

Expected behavior in an interface context

When this feature is enabled on an interface, the device is expected to prevent propagation of topology change notifications from a port configured with the Restricted TCN feature to other ports. In this manner, the device prevents TCN propagation from causing MAC flushes in the entire core network.

Configuring MSTP

Enabling and configuring MSTP globally

Follow this procedure to configure the Multiple Spanning Tree Protocol.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Enable MSTP.

```
device(config)# protocol spanning-tree mstp
```

This command creates a context for MSTP. MSTP is automatically enabled. All MSTP specific CLI commands can be issued only from this context. Entering **no protocol spanning-tree mstp** deletes the context and all the configurations defined within the context.

3. Specify the region name.

```
device(config-mstp)# region kerry
```

4. Specify the revision number.

```
device(config-mstp)# revision 1
```

5. Configure an optional description of the MSTP instance.

```
device(config-mstp)# description kerry switches
```

6. Specify the maximum hops for a BPDU to prevent the messages from looping indefinitely on the interface.

```
device(config-mstp)# max-hops 25
```

Setting this parameter prevents messages from looping indefinitely on the interface. The range is 1 through 40 hops while the default is 20 .

7. Map VLANs to MSTP instances and set the instance priority.
   a) Map VLANs 7 and 8 to instance 1.

```
device(config-mstp)# instance 1 vlan 7,8
```

   b) Map VLANs 21, 22, and 23 to instance 2.

```
device(config-mstp)# instance 2 vlan 21-23
```

   c) Set the priority of instance 1.

```
device(config-mstp)# instance 1 priority 4096
```

This command can be used only after the VLAN is created. VLAN instance mapping is removed from the configuration if the underlying VLANs are deleted.

8. Configure a bridge priority for the CIST bridge.

```
device(config-mstp)# bridge-priority 4096
```

The range is 0 through 61440 in increments of 4096. The default is 32768.

9. Set the error disable parameters.
   a) Enable the timer to bring the port out of error disable state.

```
device(config-mstp)# error-disable-timeout enable
```

   b) Specify the time in seconds it takes for an interface to time out..

```
device(config-mstp)# error-disable-timeout interval 60
```

   The range is fro 10 to 1000000 seconds with a default of 300 seconds.
10. Configure forward delay.
   a) Specify the bridge forward delay.

```
device(config-mstp)# forward-delay 15
```

   This command allows you to specify how long an interface remains in the listening and learning states before it begins forwarding. This command affects all MSTP instances. The range of values is from 4 to 30 seconds with a default of 15 seconds.
11. Configure hello time.

```
device(config-mstp)# hello-time 2
```

   The hello time determines how often the switch interface broadcasts hello BPDUs to other devices. The range is from 1 through 10 seconds with a default of 2 seconds.
12. Configure the maximum age.

```
device(config-mstp)# max-age 20
```

   You must set the **max-age** so that it is greater than the **hello-time**. The range is 6 through 40 seconds with a default of 20 seconds.
13. Specify the port-channel path cost.

```
device(config-mstp)# port-channel path-cost custom
```

   This command allows you to control the path cost of a port channel according to bandwidth.
14. Specify the transmit hold count.

```
device(config-mstp)# transmit-holdcount 5
```

   The transmit hold count is used to limit the maximum number of MSTP BPDUs that the bridge can transmit on a port before pausing for 1 second. The range is from 1 to 10 seconds with a default of 6 seconds.
15. Configure Cisco interoperability.

```
device(config-mstp)# cisco-interoperability enable
```

   This command enables the ability to interoperate with certain legacy Cisco switches. The default is Cisco interoperability is disabled.
16. Return to privileged exec mode.

```
device(config-mstp)# end
```

17. Verify the configuration. The following is an example configuration.

```
device# show spanning-tree mst-config

Spanning-tree Mode: Multiple Spanning Tree Protocol

 CIST Root Id: 8000.001b.ed9f.1700
 CIST Bridge Id: 8000.768e.f80a.6800
 CIST Reg Root Id: 8000.001b.ed9f.1700

 CIST Root Path Cost: 0; CIST Root Port: Eth 0/2
 CIST Root Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 19
 Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20;
 Tx-HoldCount: 6
 Number of topology change(s): 139; Last change occurred 00:03:36 ago on Eth 0/2

 Bpdu-guard errdisable timeout: disabled
 Bpdu-guard errdisable timeout interval: 300 sec
 Migrate Time: 3 sec

  Name           : kerry
  Revision Level : 1
  Digest         : 0x9357EBB7A8D74DD5FEF4F2BAB50531AA

  Instance        VLAN
  --------        ----
   0:             1
   1:             7,8
   2:             21-23
```

Observe that the settings comply with the formula set out in the STP parameters section, as:

(2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

or in this case: 28 ≥ 20 ≥ 6.

18. Save the configuration.

```
device# copy running-config startup-config
```

MSTP configuration example

```
device# configure terminal
device(config)# protocol spanning-tree mstp
device(config-mstp)# region kerry
device(config-mstp)# revision 1
device(config-mstp)# description kerry switches
device(config-mstp)# max-hops 20
device(config-mstp)# instance 1 vlan 7,8
device(config-mstp)# instance 2 vlan 21-23
device(config-mstp)# instance 1 priority 4096
device(config-mstp)# bridge-priority 4096
device(config-mstp)# error-disable-timeout enable
device(config-mstp)# error-disable-timeout interval 60
device(config-mstp)# forward-delay 16
device(config-mstp)# hello-time 5
device(config-mstp)# max-age 16
device(config-mstp)# port-channel path-cost custon
device(config-mstp)# transmit-holdcount 5
device(config-mstp)# cisco-interoperability enable
device(config-mstp)# end
device# show spanning-tree mst
device# copy running-config startup-config
```

Enabling and configuring MSTP on an interface

Follow these steps to configure and enable MSTP on an Ethernet interface.

The parameters can be configured individually on an interface by:

1. Entering the commands in Steps 1 through Step 3 for the target interface
2. Running the relevant parameter command
3. Verifying the result
4. Saving the configuration

For detailed descriptions of the parameters and features, see the sections STP parameters and STP features.

1. Enter configuration mode.

```
device# configure terminal
```

2. Enable MSTP.

```
device(config)# protocol spanning-tree mstp
```

3. Enter interface configuration mode.

```
device(config-mstp)# interface ethernet 0/5
```

4. Enable the interface.

```
device(conf-if-eth-0/5)# no shutdown
```

5. Configure the restricted role feature for the port.

```
device(conf-if-eth-0/5)# spanning-tree restricted-role
```

   This command keeps a port from becoming a root.

6. Restrict topology change notifications (TCN) BPDUs for an MSTP instance.

```
device(conf-if-eth-0/5)# spanning-tree instance 5 restricted-tcn
```

   This prevents the port from propagating received TCNs and topology changes originating from a bridge, external to the core network, to other ports.

7. Enable auto detection of an MSTP edge port.

```
device(conf-if-eth-0/5)# spanning-tree autoedge
```

   Enabling this feature allows the system to automatically identify the edge port. The port can become an edge port if no BPDU is received. By default, automatic edge detection is disabled.

8.

```
device(conf-if-eth-0/5)# spanning-tree edgeport
```

   Enabling edge port allows the port to quickly transition to the forwarding state. By default, automatic edge detection is disabled.

9. Enable BPDU guard on the port

```
device(conf-if-eth-0/5)# spanning-tree edgeport bpdu-guard
```

   BPDU guard removes a node that reflects BPDUs back in the network. It enforces the STP domain borders and keeps the active topology predictable by not allowing any network devices behind a BPDU guard-enabled port to participate in STP.

10. Set the path cost of a port.

```
device(conf-if-eth-0/5)# spanning-tree cost 200000
```

    The path cost range is from 1 to 200000000. Leaving the default adjusts path cost relative to changes in the bandwidth. A lower path cost indicates greater likelihood of becoming root port.

11. Configure the link type.

```
device(conf-if-eth-0/5)# spanning-tree link-type point-to-point
```

    The options are point-to-point or shared.

12. Enable port priority.

```
device(conf-if-eth-0/5)# spanning-tree priority 128
```

    The range is from 0 to 240 in increments of 16 with a default of 32. A lower priority indicates greater likelihood of becoming root port.

13. Return to privileged exec mode.

```
device(conf-if-eth-0/5)# end
```

14. Verify the configuration.

```
device# show spanning-tree interface ethernet 0/5

Spanning-tree Mode: Multiple Spanning Tree Protocol

 Root Id: 8000.001b.ed9f.1700
 Bridge Id: 8000.01e0.5200.011d

 Port Eth 0/5 enabled
    Ifindex: 411271175; Id: 8002; Role: Designated; State: Forwarding
    Designated External Path Cost: 0; Internal Path Cost: 20000000
    Configured Path Cost: 200000
    Designated Port Id: 8002; Port Priority: 128
    Designated Bridge: 8000.01e0.5200.011d
    Number of forward-transitions: 1
    Version: Multiple Spanning Tree Protocol - Received MSTP - Sent MSTP
    Edgeport: yes; AutoEdge: yes; AdminEdge: no; EdgeDelay: 3 sec
    Restricted-role is enabled
    Restricted-tcn is enabled
    Boundary: no
    Bpdu-guard: on
    Link-type: point-to-point
    Received BPDUs: 86; Sent BPDUs: 1654
```

15. Save the configuration.

```
device# copy running-config startup-config
```

Enable MSTP on an interface configuration example

```
device# configure terminal
device(config)# protocol spanning-tree mstp
device(config-mstp)# interface ethernet 0/5
device(conf-if-eth-0/5)# no shutdown
device(conf-if-eth-0/5)# spanning-tree restricted-role
device(conf-if-eth-0/5)# spanning-tree instance 5 restricted-tcn
device(conf-if-eth-0/5)# spanning-tree autoedge
device(conf-if-eth-0/5)# spanning-tree edgeport
device(conf-if-eth-0/5)# spanning-tree edgeport bpdu-guard
device(conf-if-eth-0/5)# spanning-tree cost 200000
device(conf-if-eth-0/5)# spanning-tree link-type point-to-point
device(conf-if-eth-0/5)# spanning-tree priority 128
device(conf-if-eth-0/5)# end
device# show spanning-tree interface ethernet 0/5
device# copy running-config startup-config
```

Enabling MSTP on a VLAN

1. Enter configuration mode.

   ```
   device# configure terminal
   ```

2. Enter the protocol command to enable MSTP configuration.

   ```
   device(config)# protocol spanning-tree mstp
   ```

3. Map a VLAN to an MSTP instance.

   ```
   device(config-mstp)# instance 5 vlan 300
   ```

4. Return to privileged EXEC mode.

   ```
   device(config-mstp)# end
   ```

5. Verify the configuration.

```
device# show spanning-tree mst

 Spanning-tree Mode: Multiple Spanning Tree Protocol

 CIST Root Id: 8000.609c.9f5d.4800 (self)
 CIST Bridge Id: 8000.609c.9f5d.4800
 CIST Reg Root Id: 8000.609c.9f5d.4800 (self)

 CIST Root Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20;
 Tx-HoldCount: 6
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: disabled
 Bpdu-guard errdisable timeout interval: 300 sec
 Migrate Time: 3 sec

  Name           : NULL
  Revision Level : 0
  Digest         : 0xD5FF4C3F6C18E2F27AF3A8300297ABAA

  Instance        VLAN
  --------        ----
   0:             1
   5:             100
```

   Observe that the settings comply with the formula set out in the STP parameters section, as:

   (2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))

   or in this case: 28 ≥ 20 ≥ 6.

6. Save the configuration.

```
device# copy running-config startup-config
```

Enable spanning tree on a VLAN configuration example

```
device# configure terminal
device(config)# protocol spanning-tree mstp
device(config-mstp)# instance 5 vlan 300
device(config-mstp)# end
device# show spanning-tree mst
device# copy running-config startup-config
```

Configuring basic MSTP parameters

Follow these steps to configure basic MSTP parameters.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Enable MSTP.

```
device(config)# protocol spanning-tree mstp
```

3. Specify the region name.

```
device(config-mstp)# region connemara
```

4. Specify the revision number.

```
device(config-mstp)# revision 1
```

5. Map MSTP instances to VLANs.
   a) Map instance 1 to VLANs 2 and 3.

```
device(config-mstp)# instance 1 vlan 2,3
```

   b) Map instance 2 to VLANs 4, 5, and 6.

```
device(config-mstp)# instance 2 vlan 4-6
```

6. Set a priority for an instance.

```
device(conf-Mstp)# instance 1 priority 28672
```

   The priority ranges from 0 through 61440 and the value must be in multiples of 4096.

7. Specify the maximum hops for a BPDU.

```
device(conf-Mstp)# max-hops 25
```

   This prevents the messages from looping indefinitely on an interface

8. Return to privileged EXEC mode.

```
device(conf-Mstp)# end
```

9. Verify the configuration.

```
device# show spanning-tree mst

 Spanning-tree Mode: Multiple Spanning Tree Protocol

 CIST Root Id: 8000.609c.9f5d.4800 (self)
 CIST Bridge Id: 8000.609c.9f5d.4800
 CIST Reg Root Id: 8000.609c.9f5d.4800 (self)

 CIST Root Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 20
 Configured Forward Delay: 15; Hello Time: 2; Max Age: 20; Max-hops: 25;
 Tx-HoldCount: 6
 Number of topology change(s): 0

 Bpdu-guard errdisable timeout: disabled
 Bpdu-guard errdisable timeout interval: 300 sec
 Migrate Time: 3 sec

  Name           : connemara
  Revision Level : 1
  Digest         : 0xD5FF4C3F6C18E2F27AF3A8300297ABAA

  Instance        VLAN
  --------        ----
   0:             1,7,8,9
   1:             2,3
   2:             4-6
```

NOTE

Observe that the settings comply with the formula set out in the STP parameters section, as:
(2 × (forward delay - 1)) ≥ maximum age ≥ (2 × (hello time + 1))
or in this case: 28 ≥ 20 ≥ 6.

```
device# show running-config | begin spanning-tree
protocol spanning-tree mstp
 instance 1 vlan 2,3
 instance 1 priority 28672
 instance 2 vlan 4-6
 region connemars
 revision 1
 max-hops 25
 !
...
```

10. Save the configuration

```
device# copy running-config startup-config
```

Basic MSTP configuration example

```
device# configure terminal
device(config)# protocol spanning-tree mstp
device(config-mstp)# region connemara
device(config-mstp)# revision 1
device(config-mstp)# instance 1 vlan 2,3
device(config-mstp)# instance 2 vlan 4-6
device(conf-Mstp)# instance 1 priority 28582
device(conf-Mstp)# max-hops 25
device(conf-Mstp)# end
device# show spanning-tree mst
device# copy running-config startup-config
```

Clearing spanning tree counters

Follow these steps to clear spanning tree counters on all interfaces or on the specified interface.

1. Clear spanning tree counters on all interfaces.

```
device# clear spanning-tree counter
```

2. Clear spanning tree counters on a specified Ethernet interface.

```
device# clear spanning-tree counter interface ethernet 0/3
```

3. Clear spanning tree counters on a specified port channel interface.

```
device# clear spanning-tree counter interface port-channel 12
```

   Port channel interface numbers range from 1 through 64.

Clearing spanning tree-detected protocols

Follow these steps to restart the protocol migration process.

These commands force a spanning tree renegotiation with neighboring devices on either all interfaces or on a specified interface.

1. Restart the spanning tree migration process on all interfaces.

```
device# clear spanning-tree detected-protocols
```

2. Restart the spanning tree migration process on a specific Ethernet interface.

```
device# clear spanning-tree detected-protocols interface ethernet 0/3
```

3. Restart the spanning tree migration process on a specific port channel interface.

```
device# clear spanning-tree detected-protocols port-channel 12
```

   Port channel interface numbers range from 1 through 64.

Shutting down MSTP

Follow these steps to o shut down MSTP either globally, on a specific interface, or a specific VLAN.

1. Enter global configuration mode.

```
device# configure terminal
```

2. Shut down MSTP.
   - Shut down MSTP globally and return to privileged EXEC mode.

     ```
     device(config)# protocol spanning-tree mstp
     device(config-mstp)# shutdown
     device(config-mstp)# end
     ```

   - Shut down MSTP on a specific interface and return to privileged EXEC mode.

     ```
     device(config)# interface ethernet 0/2
     device(conf-if-eth-0/2)# spanning-tree shutdown
     device(conf-if-eth-0/2)# end
     ```

   - Shut down MSTP on a specific VLAN and return to privileged EXEC mode.

     ```
     device(config)# vlan 10
     device(config-vlan-10)# spanning-tree shutdown
     device(config-vlan-10)# end
     ```

3. Verify the configuration.

   ```
   device# show spanning-tree
   device#
   ```

4. Save the running configuration to the startup configuration.

   ```
   device# copy running-config startup-config
   ```

Shut down MSTP configuration example

```
device# configure terminal
device(config)# vlan 10
device(config-vlan-10)# spanning-tree shutdown
device(config-stp)# end
device# show spanning-tree
device# copy running-config startup-config
```

NOTE

Shutting down MSTP on a VLAN is used in this example.