



Layer 2 Configuration Guide, Cisco IOS Release 15.2(7)Ex (Catalyst 1000 Switches)

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CHAPTER 1

Configuring Spanning Tree Protocol

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Restrictions for STP

- An attempt to configure a device as the root device fails if the value necessary to be the root device is less than 1.
- If your network consists of devices that support and do not support the extended system ID, it is unlikely that the device with the extended system ID support will become the root device. The extended system ID increases the device priority value every time the VLAN number is greater than the priority of the connected devices running older software.
- The root device for each spanning-tree instance should be a backbone or distribution device. Do not configure an access device as the spanning-tree primary root.
- The device supports Spanning Tree Protocol for a maximum of 256 VLANs.

Information About STP

Spanning Tree Protocol

Spanning Tree Protocol (STP) is a Layer 2 link management protocol that provides path redundancy while preventing loops in the network. For a Layer 2 Ethernet network to function properly, only one active path can exist between any two stations. Multiple active paths among end stations cause loops in the network. If a loop exists in the network, end stations might receive duplicate messages. Devices might also learn end-station MAC addresses on multiple Layer 2 interfaces. These conditions result in an unstable network. Spanning-tree operation is transparent to end stations, which cannot detect whether they are connected to a single LAN segment or a switched LAN of multiple segments.

The STP uses a spanning-tree algorithm to select one device of a redundantly connected network as the root of the spanning tree. The algorithm calculates the best loop-free path through a switched Layer 2 network by assigning a role to each port based on the role of the port in the active topology:

- Root—A forwarding port elected for the spanning-tree topology
- Designated—A forwarding port elected for every switched LAN segment
- Alternate—A blocked port providing an alternate path to the root bridge in the spanning tree
- Backup—A blocked port in a loopback configuration

The device that has *all* of its ports as the designated role or as the backup role is the root device. The device that has at least *one* of its ports in the designated role is called the designated device.

Spanning tree forces redundant data paths into a standby (blocked) state. If a network segment in the spanning tree fails and a redundant path exists, the spanning-tree algorithm recalculates the spanning-tree topology and activates the standby path. Devices send and receive spanning-tree frames, called bridge protocol data units (BPDUs), at regular intervals. The devices do not forward these frames but use them to construct a loop-free path. BPDUs contain information about the sending device and its ports, including device and MAC addresses, device priority, port priority, and path cost. Spanning tree uses this information to elect the root device and root port for the switched network and the root port and designated port for each switched segment.

When two ports on a device are part of a loop, the spanning-tree and path cost settings control which port is put in the forwarding state and which is put in the blocking state. The spanning-tree port priority value represents the location of a port in the network topology and how well it is located to pass traffic. The path cost value represents the media speed.



Note By default, the sends keepalive messages (to ensure the connection is up) only on interfaces that do not have small form-factor pluggable (SFP) modules. You can change the default for an interface by entering the **[no] keepalive** interface configuration command with no keywords.

Spanning-Tree Topology and BPDUs

The stable, active spanning-tree topology of a switched network is controlled by these elements:

- The unique bridge ID (device priority and MAC address) associated with each VLAN on each device.
- The spanning-tree path cost to the root device.
- The port identifier (port priority and MAC address) associated with each Layer 2 interface.

When the devices in a network are powered up, each functions as the root device. Each device sends a configuration BPDU through all of its ports. The BPDUs communicate and compute the spanning-tree topology. Each configuration BPDU contains this information:

- The unique bridge ID of the device that the sending device identifies as the root device.
- The spanning-tree path cost to the root
- The bridge ID of the sending device.
- Message age
- The identifier of the sending interface

- Values for the hello, forward delay, and max-age protocol timers

When a device receives a configuration BPDU that contains *superior* information (lower bridge ID, lower path cost, and so forth), it stores the information for that port. If this BPDU is received on the root port of the device, the device also forwards it with an updated message to all attached LANs for which it is the designated device.

If a device receives a configuration BPDU that contains *inferior* information to that currently stored for that port, it discards the BPDU. If the device is a designated device for the LAN from which the inferior BPDU was received, it sends that LAN a BPDU containing the up-to-date information stored for that port. In this way, inferior information is discarded, and superior information is propagated on the network.

A BPDU exchange results in these actions:

- One device in the network is elected as the root device (the logical center of the spanning-tree topology in a switched network). See the figure following the bullets.

For each VLAN, the device with the highest device priority (the lowest numerical priority value) is elected as the root device. If all devices are configured with the default priority (32768), the device with the lowest MAC address in the VLAN becomes the root device. The device priority value occupies the most significant bits of the bridge ID, as shown in the following figure.

- A root port is selected for each device (except the root device). This port provides the best path (lowest cost) when the device forwards packets to the root device.
- The shortest distance to the root device is calculated for each device based on the path cost.
- A designated device for each LAN segment is selected. The designated device incurs the lowest path cost when forwarding packets from that LAN to the root device. The port through which the designated device is attached to the LAN is called the designated port.



Note If the **logging event spanning tree** command is configured on multiple interfaces and the topology changes, it may result in several logging messages and high CPU utilization. This may cause the switch to drop or delay the processing of STP BPDUs.

To prevent this behavior, remove the **logging event spanning tree** and **logging event status** commands or disable logging to the console.

All paths that are not needed to reach the root device from anywhere in the switched network are placed in the spanning-tree blocking mode.

Bridge ID, Device Priority, and Extended System ID

The IEEE 802.1D standard requires that each device has a unique bridge identifier (bridge ID), which controls the selection of the root device. Because each VLAN is considered as a different *logical bridge* with PVST+ and Rapid PVST+, the same device must have a different bridge ID for each configured VLAN. Each VLAN on the device has a unique 8-byte bridge ID. The 2 most-significant bytes are used for the device priority, and the remaining 6 bytes are derived from the device MAC address.

The device supports the IEEE 802.1t spanning-tree extensions, and some of the bits previously used for the device priority are now used as the VLAN identifier. The result is that fewer MAC addresses are reserved for the device, and a larger range of VLAN IDs can be supported, all while maintaining the uniqueness of the bridge ID.

The 2 bytes previously used for the device priority are reallocated into a 4-bit priority value and a 12-bit extended system ID value equal to the VLAN ID.

Table 1: Device Priority Value and Extended System ID

Priority Value				Extended System ID (Set Equal to the VLAN ID)											
Bit 16	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1
32768	16384	8192	4096	2048	1024	512	256	128	64	32	16	8	4	2	1

Spanning tree uses the extended system ID, the device priority, and the allocated spanning-tree MAC address to make the bridge ID unique for each VLAN.

Support for the extended system ID affects how you manually configure the root device, the secondary root device, and the device priority of a VLAN. For example, when you change the device priority value, you change the probability that the device will be elected as the root device. Configuring a higher value decreases the probability; a lower value increases the probability.

If any root device for the specified VLAN has a device priority lower than 24576, the device sets its own priority for the specified VLAN to 4096 less than the lowest device priority. 4096 is the value of the least-significant bit of a 4-bit device priority value as shown in the table.

Port Priority Versus Path Cost

If a loop occurs, spanning tree uses port priority when selecting an interface to put into the forwarding state. You can assign higher priority values (lower numerical values) to interfaces that you want selected first and lower priority values (higher numerical values) that you want selected last. If all interfaces have the same priority value, spanning tree puts the interface with the lowest interface number in the forwarding state and blocks the other interfaces.

The spanning-tree path cost default value is derived from the media speed of an interface. If a loop occurs, spanning tree uses cost when selecting an interface to put in the forwarding state. You can assign lower cost values to interfaces that you want selected first and higher cost values that you want selected last. If all interfaces have the same cost value, spanning tree puts the interface with the lowest interface number in the forwarding state and blocks the other interfaces.

Spanning-Tree Interface States

Propagation delays can occur when protocol information passes through a switched LAN. As a result, topology changes can take place at different times and at different places in a switched network. When an interface transitions directly from nonparticipation in the spanning-tree topology to the forwarding state, it can create temporary data loops. Interfaces must wait for new topology information to propagate through the switched LAN before starting to forward frames. They must allow the frame lifetime to expire for forwarded frames that have used the old topology.

Each Layer 2 interface on a device using spanning tree exists in one of these states:

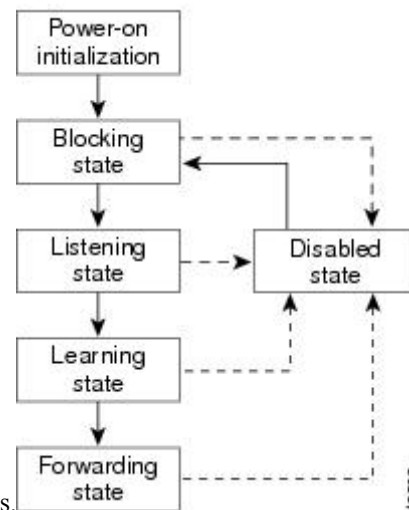
- **Blocking**—The interface does not participate in frame forwarding.
- **Listening**—The first transitional state after the blocking state when the spanning tree decides that the interface should participate in frame forwarding.
- **Learning**—The interface prepares to participate in frame forwarding.

- Forwarding—The interface forwards frames.
- Disabled—The interface is not participating in spanning tree because of a shutdown port, no link on the port, or no spanning-tree instance running on the port.

An interface moves through these states:

- From initialization to blocking
- From blocking to listening or to disabled
- From listening to learning or to disabled
- From learning to forwarding or to disabled
- From forwarding to disabled

Figure 1: Spanning-Tree Interface States



An interface moves through the states.

When you power up the device, spanning tree is enabled by default, and every interface in the device, VLAN, or network goes through the blocking state and the transitory states of listening and learning. Spanning tree stabilizes each interface at the forwarding or blocking state.

When the spanning-tree algorithm places a Layer 2 interface in the forwarding state, this process occurs:

1. The interface is in the listening state while spanning tree waits for protocol information to move the interface to the blocking state.
2. While spanning tree waits for the forward-delay timer to expire, it moves the interface to the learning state and resets the forward-delay timer.
3. In the learning state, the interface continues to block frame forwarding as the device learns end-station location information for the forwarding database.
4. When the forward-delay timer expires, spanning tree moves the interface to the forwarding state, where both learning and frame forwarding are enabled.

Blocking State

A Layer 2 interface in the blocking state does not participate in frame forwarding. After initialization, a BPDU is sent to each device interface. A device initially functions as the root until it exchanges BPDUs with other devices. This exchange establishes which device in the network is the root or root device. If there is only one device in the network, no exchange occurs, the forward-delay timer expires, and the interface moves to the listening state. An interface always enters the blocking state after device initialization.

An interface in the blocking state performs these functions:

- Discards frames received on the interface
- Discards frames switched from another interface for forwarding
- Does not learn addresses
- Receives BPDUs

Listening State

The listening state is the first state a Layer 2 interface enters after the blocking state. The interface enters this state when the spanning tree decides that the interface should participate in frame forwarding.

An interface in the listening state performs these functions:

- Discards frames received on the interface
- Discards frames switched from another interface for forwarding
- Does not learn addresses
- Receives BPDUs

Learning State

A Layer 2 interface in the learning state prepares to participate in frame forwarding. The interface enters the learning state from the listening state.

An interface in the learning state performs these functions:

- Discards frames received on the interface
- Discards frames switched from another interface for forwarding
- Learns addresses
- Receives BPDUs

Forwarding State

A Layer 2 interface in the forwarding state forwards frames. The interface enters the forwarding state from the learning state.

An interface in the forwarding state performs these functions:

- Receives and forwards frames received on the interface
- Forwards frames switched from another interface
- Learns addresses

- Receives BPDUs

Disabled State

A Layer 2 interface in the disabled state does not participate in frame forwarding or in the spanning tree. An interface in the disabled state is nonoperational.

A disabled interface performs these functions:

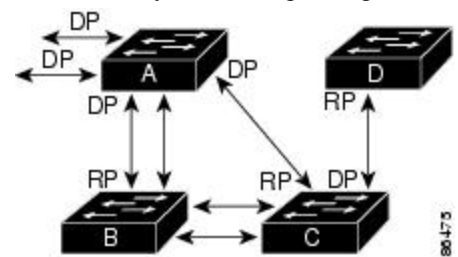
- Discards frames received on the interface
- Discards frames switched from another interface for forwarding
- Does not learn addresses
- Does not receive BPDUs

How a Device or Port Becomes the Root Device or Root Port

If all devices in a network are enabled with default spanning-tree settings, the device with the lowest MAC address becomes the root device.

Figure 2: Spanning-Tree Topology

Device A is elected as the root device because the device priority of all the devices is set to the default (32768) and Device A has the lowest MAC address. However, because of traffic patterns, number of forwarding interfaces, or link types, Device A might not be the ideal root device. By increasing the priority (lowering the numerical value) of the ideal device so that it becomes the root device, you force a spanning-tree recalculation



to form a new topology with the ideal device as the root. RP = Root Port
DP = Designated Port

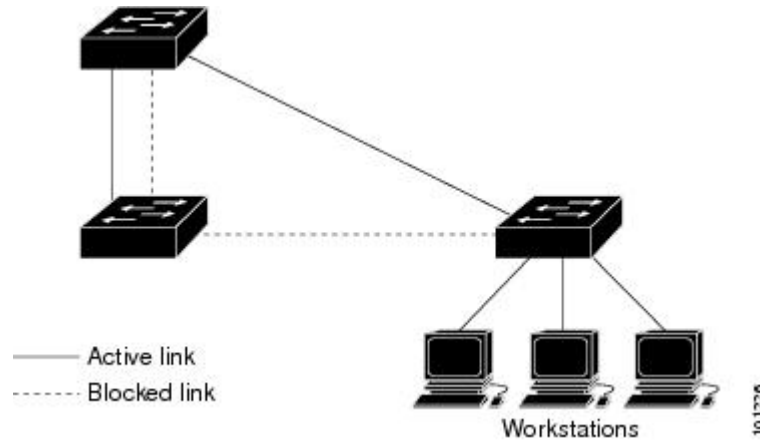
When the spanning-tree topology is calculated based on default parameters, the path between source and destination end stations in a switched network might not be ideal. For instance, connecting higher-speed links to an interface that has a higher number than the root port can cause a root-port change. The goal is to make the fastest link the root port.

For example, assume that one port on Device B is a Gigabit Ethernet link and that another port on Device B (a 10/100 link) is the root port. Network traffic might be more efficient over the Gigabit Ethernet link. By changing the spanning-tree port priority on the Gigabit Ethernet port to a higher priority (lower numerical value) than the root port, the Gigabit Ethernet port becomes the new root port.

Spanning Tree and Redundant Connectivity

Figure 3: Spanning Tree and Redundant Connectivity

You can create a redundant backbone with spanning tree by connecting two device interfaces to another device or to two different devices. Spanning tree automatically disables one interface but enables it if the other one fails. If one link is high-speed and the other is low-speed, the low-speed link is always disabled. If the speeds are the same, the port priority and port ID are added together, and spanning tree disables the link with the



highest value.

You can also create redundant links between devices by using EtherChannel groups.

Spanning-Tree Address Management

IEEE 802.1D specifies 17 multicast addresses, ranging from 0x00180C2000000 to 0x0180C2000010, to be used by different bridge protocols. These addresses are static addresses that cannot be removed.

If spanning tree is enabled, the CPU on the device receives packets destined for 0x0180C2000000 and 0x0180C2000010. If spanning tree is disabled, the device forwards those packets as unknown multicast addresses.

Accelerated Aging to Retain Connectivity

The default for aging dynamic addresses is 5 minutes, the default setting of the **mac address-table aging-time** global configuration command. However, a spanning-tree reconfiguration can cause many station locations to change. Because these stations could be unreachable for 5 minutes or more during a reconfiguration, the address-aging time is accelerated so that station addresses can be dropped from the address table and then relearned. The accelerated aging is the same as the forward-delay parameter value (**spanning-tree vlan vlan-id forward-time seconds** global configuration command) when the spanning tree reconfigures.

Because each VLAN is a separate spanning-tree instance, the device accelerates aging on a per-VLAN basis. A spanning-tree reconfiguration on one VLAN can cause the dynamic addresses learned on that VLAN to be subject to accelerated aging. Dynamic addresses on other VLANs can be unaffected and remain subject to the aging interval entered for the device.

Spanning-Tree Modes and Protocols

The device supports these spanning-tree modes and protocols:

- **PVST+**—This spanning-tree mode is based on the IEEE 802.1D standard and Cisco proprietary extensions. The PVST+ runs on each VLAN on the device up to the maximum supported, ensuring that each has a loop-free path through the network.

The PVST+ provides Layer 2 load-balancing for the VLAN on which it runs. You can create different logical topologies by using the VLANs on your network to ensure that all of your links are used but that no one link is oversubscribed. Each instance of PVST+ on a VLAN has a single root device. This root device propagates the spanning-tree information associated with that VLAN to all other devices in the network. Because each device has the same information about the network, this process ensures that the network topology is maintained.

- **Rapid PVST+**—Rapid PVST+ is the default STP mode on your device. This spanning-tree mode is the same as PVST+ except that it uses a rapid convergence based on the IEEE 802.1w standard. To provide rapid convergence, the Rapid PVST+ immediately deletes dynamically learned MAC address entries on a per-port basis upon receiving a topology change. By contrast, PVST+ uses a short aging time for dynamically learned MAC address entries.

Rapid PVST+ uses the same configuration as PVST+ (except where noted), and the device needs only minimal extra configuration. The benefit of Rapid PVST+ is that you can migrate a large PVST+ install base to Rapid PVST+ without having to learn the complexities of the Multiple Spanning Tree Protocol (MSTP) configuration and without having to reprovise your network. In Rapid PVST+ mode, each VLAN runs its own spanning-tree instance up to the maximum supported.

- **MSTP**—This spanning-tree mode is based on the IEEE 802.1s standard. You can map multiple VLANs to the same spanning-tree instance, which reduces the number of spanning-tree instances required to support a large number of VLANs. The MSTP runs on top of the RSTP (based on IEEE 802.1w), which provides for rapid convergence of the spanning tree by eliminating the forward delay and by quickly transitioning root ports and designated ports to the forwarding state.

Supported Spanning-Tree Instances

In PVST+ or Rapid PVST+ mode, the device supports up to 64 spanning-tree instances.

In MSTP mode, the device supports up to 64 MST instances. The number of VLANs that can be mapped to a particular MST instance is unlimited.

Spanning-Tree Interoperability and Backward Compatibility

In a mixed MSTP and PVST+ network, the common spanning-tree (CST) root must be inside the MST backbone, and a PVST+ device cannot connect to multiple MST regions.

When a network contains devices running Rapid PVST+ and devices running PVST+, we recommend that the Rapid PVST+ device and PVST+ devices be configured for different spanning-tree instances. In the Rapid PVST+ spanning-tree instances, the root device must be a Rapid PVST+ device. In the PVST+ instances, the root device must be a PVST+ device. The PVST+ devices should be at the edge of the network.

Table 2: PVST+, MSTP, and Rapid-PVST+ Interoperability and Compatibility

	PVST+	MSTP	Rapid PVST+
PVST+	Yes	Yes (with restrictions)	Yes (reverts to PVST+)
MSTP	Yes (with restrictions)	Yes	Yes (reverts to PVST+)
Rapid PVST+	Yes (reverts to PVST+)	Yes (reverts to PVST+)	Yes

STP and IEEE 802.1Q Trunks

The IEEE 802.1Q standard for VLAN trunks imposes some limitations on the spanning-tree strategy for a network. The standard requires only one spanning-tree instance for *all* VLANs allowed on the trunks. However, in a network of Cisco devices connected through IEEE 802.1Q trunks, the devices maintain one spanning-tree instance for *each* VLAN allowed on the trunks.

When you connect a Cisco device to a non-Cisco device through an IEEE 802.1Q trunk, the Cisco device uses PVST+ to provide spanning-tree interoperability. If Rapid PVST+ is enabled, the device uses it instead of PVST+. The device combines the spanning-tree instance of the IEEE 802.1Q VLAN of the trunk with the spanning-tree instance of the non-Cisco IEEE 802.1Q device.

However, all PVST+ or Rapid PVST+ information is maintained by Cisco devices separated by a cloud of non-Cisco IEEE 802.1Q devices. The non-Cisco IEEE 802.1Q cloud separating the Cisco devices is treated as a single trunk link between the devices.

Rapid PVST+ is automatically enabled on IEEE 802.1Q trunks, and no user configuration is required. The external spanning-tree behavior on access ports is not affected by PVST+.

VLAN-Bridge Spanning Tree

Cisco VLAN-bridge spanning tree is used with the fallback bridging feature (bridge groups), which forwards non-IP protocols such as DECnet between two or more VLAN bridge domains or routed ports. The VLAN-bridge spanning tree allows the bridge groups to form a spanning tree on top of the individual VLAN spanning trees to prevent loops from forming if there are multiple connections among VLANs. It also prevents the individual spanning trees from the VLANs being bridged from collapsing into a single spanning tree.

To support VLAN-bridge spanning tree, some of the spanning-tree timers are increased. To use the fallback bridging feature, you must have the IP services feature set enabled on your device.

Default Spanning-Tree Configuration

Table 3: Default Spanning-Tree Configuration

Feature	Default Setting
Enable state	Enabled on VLAN 1.
Spanning-tree mode	Rapid PVST+ (PVST+ and MSTP are disabled.)
Device priority	32768
Spanning-tree port priority (configurable on a per-interface basis)	128
Spanning-tree port cost (configurable on a per-interface basis)	1000 Mb/s: 4 100 Mb/s: 19 10 Mb/s: 100
Spanning-tree VLAN port priority (configurable on a per-VLAN basis)	128

Feature	Default Setting
Spanning-tree VLAN port cost (configurable on a per-VLAN basis)	1000 Mb/s: 4 100 Mb/s: 19 10 Mb/s: 100
Spanning-tree timers	Hello time: 2 seconds Forward-delay time: 15 seconds Maximum-aging time: 20 seconds Transmit hold count: 6 BPDUs

How to Configure STP

Changing the Spanning-Tree Mode

The device supports three spanning-tree modes: per-VLAN spanning tree plus (PVST+), Rapid PVST+, or multiple spanning tree protocol (MSTP). By default, the device runs the Rapid PVST+ protocol.

If you want to enable a mode that is different from the default mode, this procedure is required.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree mode {pvst mst rapid-pvst} Example: Device(config)# spanning-tree mode pvst	Configures a spanning-tree mode. • Select pvst to enable PVST+. • Select mst to enable MSTP. • Select rapid-pvst to enable rapid PVST+. Note By default, the device runs Rapid PVST+.

	Command or Action	Purpose
Step 4	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/1 Or Device(config)# interface fastethernet 1/0/1	Specifies an interface to configure, and enters interface configuration mode. Valid interfaces include physical ports, VLANs, and port channels. The VLAN ID range is 1 to 4094. The port-channel range is 1 to 6.
Step 5	spanning-tree link-type point-to-point Example: Device(config-if)# spanning-tree link-type point-to-point	Specifies that the link type for this port is point-to-point. If you connect this port (local port) to a remote port through a point-to-point link and the local port becomes a designated port, the device negotiates with the remote port and rapidly changes the local port to the forwarding state.
Step 6	end Example: Device(config-if)# end	Returns to privileged EXEC mode.
Step 7	clear spanning-tree detected-protocols Example: Device# clear spanning-tree detected-protocols	If any port on the device is connected to a port on a legacy IEEE 802.1D device, this command restarts the protocol migration process on the entire device. This step is optional if the designated device detects that this device is running rapid PVST+.

Disabling Spanning Tree

Spanning tree is enabled by default on VLAN 1 and on all newly created VLANs up to the spanning-tree limit. Disable spanning tree only if you are sure there are no loops in the network topology.



Caution

When spanning tree is disabled and loops are present in the topology, excessive traffic and indefinite packet duplication can drastically reduce network performance.

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example:	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.

	Command or Action	Purpose
	Device> enable	
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	no spanning-tree vlan <i>vlan-id</i> Example: Device(config)# no spanning-tree vlan 300	For <i>vlan-id</i> , the range is 1 to 4094.
Step 4	end Example: Device(config)# end	Returns to privileged EXEC mode.

Configuring the Root Device

The device maintains a separate spanning-tree instance for each active VLAN configured on it. A bridge ID, consisting of the device priority and the device MAC address, is associated with each instance. For each VLAN, the device with the lowest bridge ID becomes the root switch for that VLAN.

To configure a device as the root for the specified VLAN, use the **spanning-tree vlan *vlan-id* root** global configuration command to modify the device priority from the default value (32768) to a significantly lower value. When you enter this command, the software checks the device priority of the root devices for each VLAN. Because of the extended system ID support, the device sets its own priority for the specified VLAN to 24576 if this value will cause this device to become the root for the specified VLAN.



Note If your network consists of devices that support and do not support the extended system ID, it is unlikely that the device with the extended system ID support will become the root device. The extended system ID increases the device priority value every time the VLAN number is greater than the priority of the connected devices running older software.

The root device for each spanning-tree instance should be a backbone or distribution device. Do not configure an access device as the spanning-tree primary root.

Use the **diameter** keyword to specify the Layer 2 network diameter (that is, the maximum number of device hops between any two end stations in the Layer 2 network). When you specify the network diameter, the device automatically sets an optimal hello time, forward-delay time, and maximum-age time for a network of that diameter, which can significantly reduce the convergence time. You can use the **hello** keyword to override the automatically calculated hello time.

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree vlan <i>vlan-id</i> root primary [<i>diameter net-diameter</i> [<i>hello-time seconds</i>]] Example: Device(config)# spanning-tree vlan 20-24 root primary diameter 4 hello-time 5	Configures a device to become the root for the specified VLAN. <ul style="list-style-type: none"> • For <i>vlan-id</i>, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094. • (Optional) For diameter <i>net-diameter</i>, specify the maximum number of devices between any two end stations. The range is 2 to 7. • (Optional) For hello-time<i>seconds</i> seconds, specify the interval in seconds between the generation of configuration messages by the root switch. The range is 1 to 10; the default is 2.
Step 4	end Example: Device(config)# end	Returns to privileged EXEC mode.

What to do next

After configuring the device as the root device, we recommend that you avoid manually configuring the hello time, forward-delay time, and maximum-age time through the **spanning-tree vlan *vlan-id* hello-time**, **spanning-tree vlan *vlan-id* forward-time**, and the **spanning-tree vlan *vlan-id* max-age** global configuration commands.

Configuring a Secondary Root Device

When you configure a device as the secondary root, the device priority is modified from the default value (32768) to 28672. With this priority, the device is likely to become the root device for the specified VLAN

if the primary root device fails. This is assuming that the other network devices use the default device priority of 32768, and therefore, are unlikely to become the root device.

You can execute this command on more than one device to configure multiple backup root devices. Use the same network diameter and hello-time values that you used when you configured the primary root device with the **spanning-tree vlan *vlan-id* root primary** global configuration command.

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree vlan <i>vlan-id</i> root secondary [<i>diameter net-diameter</i> [<i>hello-time seconds</i>]] Example: Device(config)# spanning-tree vlan 20-24 root secondary diameter 4 hello-time 5	Configures a device to become the secondary root for the specified VLAN. <ul style="list-style-type: none"> • For <i>vlan-id</i>, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094. • (Optional) For diameter <i>net-diameter</i>, specify the maximum number of devices between any two end stations. The range is 2 to 7. • (Optional) For hello-time<i>seconds</i> seconds, specify the interval in seconds between the generation of configuration messages by the root switch. The range is 1 to 10; the default is 2. Use the same network diameter value that you used when configuring the primary root device.
Step 4	end Example: Device(config)# end	Returns to privileged EXEC mode.

Configuring Port Priority

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/2 Or Device(config)# interface fastethernet 1/0/2	Specifies an interface to configure, and enters interface configuration mode. Valid interfaces include physical ports and port-channel logical interfaces (port-channel <i>port-channel-number</i>).
Step 4	spanning-tree port-priority <i>priority</i> Example: Device(config-if)# spanning-tree port-priority 0	Configures the port priority for an interface. For <i>priority</i> , the range is 0 to 240, in increments of 16; the default is 128. Valid values are 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, and 240. All other values are rejected. The lower the number, the higher the priority.
Step 5	spanning-tree vlan <i>vlan-id</i> port-priority <i>priority</i> Example: Device(config-if)# spanning-tree vlan 20-25 port-priority 0	Configures the port priority for a VLAN. <ul style="list-style-type: none"> • For <i>vlan-id</i>, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094. • For <i>priority</i>, the range is 0 to 240, in increments of 16; the default is 128. Valid values are 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, and 240. All other values are rejected. The lower the number, the higher the priority.

	Command or Action	Purpose
Step 6	end Example: Device(config-if) # end	Returns to privileged EXEC mode.

Configuring Path Cost

The spanning-tree path cost default value is derived from the media speed of an interface. If a loop occurs, spanning tree uses cost when selecting an interface to put in the forwarding state. You can assign lower cost values to interfaces that you want to select first and higher cost values that you want to select last. If all interfaces have the same cost value, spanning tree puts the interface with the lowest interfacenumber in the forwarding state and blocks the other interfaces.

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/1 Or Device(config)# interface fastethernet 1/0/1	Specifies an interface to configure, and enters interface configuration mode. Valid interfaces include physical ports and port-channel logical interfaces (port-channel <i>port-channel-number</i>).
Step 4	spanning-tree cost <i>cost</i> Example: Device(config-if) # spanning-tree cost 250	Configures the cost for an interface. If a loop occurs, spanning tree uses the path cost when selecting an interface to place into the forwarding state. A lower path cost represents higher-speed transmission. For <i>cost</i> , the range is 1 to 200000000; the default value is derived from the media speed of the interface.

	Command or Action	Purpose
Step 5	spanning-tree vlan <i>vlan-id</i> cost <i>cost</i> Example: <pre>Device(config-if) # spanning-tree vlan 10,12-15,20 cost 300</pre>	Configures the cost for a VLAN. If a loop occurs, spanning tree uses the path cost when selecting an interface to place into the forwarding state. A lower path cost represents higher-speed transmission. <ul style="list-style-type: none"> • For <i>vlan-id</i>, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094. • For <i>cost</i>, the range is 1 to 200000000; the default value is derived from the media speed of the interface.
Step 6	end Example: <pre>Device(config-if) # end</pre>	Returns to privileged EXEC mode.

The **show spanning-tree interface *interface-id*** privileged EXEC command displays information only for ports that are in a link-up operative state. Otherwise, you can use the **show running-config** privileged EXEC command to confirm the configuration.

Configuring the Device Priority of a VLAN

You can configure the device priority and make it more likely that a standalone device will be chosen as the root device.



Note Exercise care when using this command. For most situations, we recommend that you use the **spanning-tree vlan *vlan-id* root primary** and the **spanning-tree vlan *vlan-id* root secondary** global configuration commands to modify the device priority.

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: <pre>Device> enable</pre>	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.

	Command or Action	Purpose
Step 2	configure terminal Example: Device# <code>configure terminal</code>	Enters global configuration mode.
Step 3	spanning-tree vlan <i>vlan-id</i> priority <i>priority</i> Example: Device(config)# <code>spanning-tree vlan 20 priority 8192</code>	Configures the device priority of a VLAN. <ul style="list-style-type: none"> For <i>vlan-id</i>, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094. For <i>priority</i>, the range is 0 to 61440 in increments of 4096; the default is 32768. The lower the number, the more likely the device will be chosen as the root device. Valid priority values are 4096, 8192, 12288, 16384, 20480, 24576, 28672, 32768, 36864, 40960, 45056, 49152, 53248, 57344, and 61440. All other values are rejected.
Step 4	end Example: Device(config-if)# <code>end</code>	Returns to privileged EXEC mode.

Configuring the Hello Time

The hello time is the time interval between configuration messages generated and sent by the root device.



Note Exercise care when using this command. For most situations, we recommend that you use the spanning-tree vlan *vlan-id* root primary and the spanning-tree vlan *vlan-id* root secondary global configuration commands to modify the hello time.

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example:	Enables privileged EXEC mode. <ul style="list-style-type: none"> Enter your password if prompted.

	Command or Action	Purpose
	Device> enable	
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree vlan <i>vlan-id</i> hello-time <i>seconds</i> Example: Device(config)# spanning-tree vlan 20-24 hello-time 3	Configures the hello time of a VLAN. The hello time is the time interval between configuration messages generated and sent by the root device. These messages mean that the device is alive. <ul style="list-style-type: none"> • For <i>vlan-id</i>, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094. • For <i>seconds</i>, the range is 1 to 10; the default is 2.
Step 4	end Example: Device(config-if)# end	Returns to privileged EXEC mode.

Configuring the Forwarding-Delay Time for a VLAN

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree vlan <i>vlan-id</i> forward-time <i>seconds</i>	Configures the forward time of a VLAN. The forwarding delay is the number of seconds an

	Command or Action	Purpose
	Example: Device(config)# spanning-tree vlan 20,25 forward-time 18	interface waits before changing from its spanning-tree learning and listening states to the forwarding state. <ul style="list-style-type: none"> • For <i>vlan-id</i>, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094. • For <i>seconds</i>, the range is 4 to 30; the default is 15.
Step 4	end Example: Device(config)# end	Returns to privileged EXEC mode.

Configuring the Maximum-Aging Time for a VLAN

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree vlan <i>vlan-id</i> max-age <i>seconds</i> Example: Device(config)# spanning-tree vlan 20 max-age 30	Configures the maximum-aging time of a VLAN. The maximum-aging time is the number of seconds a device waits without receiving spanning-tree configuration messages before attempting a reconfiguration. <ul style="list-style-type: none"> • For <i>vlan-id</i>, you can specify a single VLAN identified by VLAN ID number, a range of VLANs separated by a hyphen, or a series of VLANs separated by a comma. The range is 1 to 4094.

	Command or Action	Purpose
		<ul style="list-style-type: none"> For <i>seconds</i>, the range is 6 to 40; the default is 20.
Step 4	end Example: Device(config-if) # end	Returns to privileged EXEC mode.

Configuring the Transmit Hold-Count

You can configure the BPDU burst size by changing the transmit hold count value.



Note Changing this parameter to a higher value can have a significant impact on CPU utilization, especially in Rapid PVST+ mode. Lowering this value can slow down convergence in certain scenarios. We recommend that you maintain the default setting.

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree transmit hold-count <i>value</i> Example: Device(config)# spanning-tree transmit hold-count 6	Configures the number of BPDUs that can be sent before pausing for 1 second. For <i>value</i> , the range is 1 to 20; the default is 6.
Step 4	end Example: Device(config)# end	Returns to privileged EXEC mode.

Monitoring Spanning-Tree Status

Table 4: Commands for Displaying Spanning-Tree Status

show spanning-tree active	Displays spanning-tree information on active interfaces only.
show spanning-tree detail	Displays a detailed summary of interface information.
show spanning-tree vlan <i>vlan-id</i>	Displays spanning-tree information for the specified VLAN.
show spanning-tree interface <i>interface-id</i>	Displays spanning-tree information for the specified interface.
show spanning-tree interface <i>interface-id</i> portfast	Displays spanning-tree portfast information for the specified interface.
show spanning-tree summary [totals]	Displays a summary of interface states or displays the total lines of the STP state section.

To clear spanning-tree counters, use the **clear spanning-tree [interface *interface-id*]** privileged EXEC command.

Feature Information for Optional Spanning-Tree Features

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Use the Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to www.cisco.com/go/cfn. An account on Cisco.com is not required.

Feature Name	Releases	Feature Information
Optional Spanning-Tree Features	Cisco IOS Release 15.2(7)E1	This feature was introduced.



CHAPTER 2

Configuring Multiple Spanning-Tree Protocol

- [Prerequisites for MSTP, on page 25](#)
- [Restrictions for MSTP, on page 25](#)
- [Information About MSTP, on page 26](#)
- [How to Configure MSTP Features, on page 41](#)
- [Configuration Examples for MSTP, on page 57](#)
- [Monitoring MST Configuration and Status, on page 61](#)
- [Feature Information for MSTP, on page 62](#)

Prerequisites for MSTP

- For two or more devices to be in the same multiple spanning tree (MST) region, they must have the same VLAN-to-instance map, the same configuration revision number, and the same name.
- For load-balancing across redundant paths in the network to work, all VLAN-to-instance mapping assignments must match; otherwise, all traffic flows on a single link.
- For load-balancing between a per-VLAN spanning tree plus (PVST+) and an MST cloud or between a rapid-PVST+ and an MST cloud to work, all MST boundary ports must be forwarding. MST boundary ports are forwarding when the root of the internal spanning tree (IST) of the MST cloud is the root of the common spanning tree (CST). If the MST cloud consists of multiple MST regions, one of the MST regions must contain the CST root, and all of the other MST regions must have a better path to the root contained within the MST cloud than a path through the PVST+ or rapid-PVST+ cloud. You might have to manually configure the devices in the clouds.

Restrictions for MSTP

- PVST+, Rapid PVST+, and MSTP are supported, but only one version can be active at any time. (For example, all VLANs run PVST+, all VLANs run Rapid PVST+, or all VLANs run MSTP.)
- VLAN Trunking Protocol (VTP) propagation of the MST configuration is not supported. However, you can manually configure the MST configuration (region name, revision number, and VLAN-to-instance mapping) on each device within the MST region by using the command-line interface (CLI) or through the Simple Network Management Protocol (SNMP) support.

- Partitioning the network into a large number of regions is not recommended. However, if this situation is unavoidable, we recommend that you partition the switched LAN into smaller LANs interconnected by routers or non-Layer 2 devices.
- A region can have one member or multiple members with the same MST configuration; each member must be capable of processing rapid spanning tree protocol (RSTP) Bridge Protocol Data Units (BPDUs). There is no limit to the number of MST regions in a network, but each region can only support up to 65 spanning-tree instances. You can assign a VLAN to only one spanning-tree instance at a time.
- After configuring a device as the root device, we recommend that you avoid manually configuring the hello time, forward-delay time, and maximum-age time through the **spanning-tree mst hello-time**, **spanning-tree mst forward-time**, and the **spanning-tree mst max-age** global configuration commands.

Table 5: PVST+, MSTP, and Rapid PVST+ Interoperability and Compatibility

	PVST+	MSTP	Rapid PVST+
PVST+	Yes	Yes (with restrictions)	Yes (reverts to PVST+)
MSTP	Yes (with restrictions)	Yes	Yes (reverts to PVST+)
Rapid PVST+	Yes (reverts to PVST+)	Yes (reverts to PVST+)	Yes

Information About MSTP

MSTP Configuration

MSTP, which uses RSTP for rapid convergence, enables multiple VLANs to be grouped into and mapped to the same spanning-tree instance, reducing the number of spanning-tree instances needed to support a large number of VLANs. The MSTP provides for multiple forwarding paths for data traffic, enables load balancing, and reduces the number of spanning-tree instances required to support a large number of VLANs. It improves the fault tolerance of the network because a failure in one instance (forwarding path) does not affect other instances (forwarding paths).



Note The multiple spanning-tree (MST) implementation is based on the IEEE 802.1s standard.

The most common initial deployment of MSTP is in the backbone and distribution layers of a Layer 2 switched network. This deployment provides the highly available network required in a service-provider environment.

When the device is in the MST mode, the RSTP, which is based on IEEE 802.1w, is automatically enabled. The RSTP provides rapid convergence of the spanning tree through explicit handshaking that eliminates the IEEE 802.1D forwarding delay and quickly transitions root ports and designated ports to the forwarding state.

Both MSTP and RSTP improve the spanning-tree operation and maintain backward compatibility with equipment that is based on the (original) IEEE 802.1D spanning tree, with existing Cisco-proprietary Multiple Instance STP (MISTP), and with existing Cisco PVST+ and rapid per-VLAN spanning-tree plus (Rapid PVST+).

MSTP Configuration Guidelines

- When you enable MST by using the **spanning-tree mode mst** global configuration command, RSTP is automatically enabled.
- For configuration guidelines about UplinkFast, BackboneFast, and cross-stack UplinkFast, see the relevant sections in the Related Topics section.
- When the device is in MST mode, it uses the long path-cost calculation method (32 bits) to compute the path cost values. With the long path-cost calculation method, the following path cost values are supported:

Speed	Path Cost Value
10 Mb/s	2,000,000
100 Mb/s	200,000
1 Gb/s	20,000
10 Gb/s	2,000
100 Gb/s	200

Root Switch

The device maintains a spanning-tree instance for the group of VLANs mapped to it. A device ID, consisting of the device priority and the device MAC address, is associated with each instance. For a group of VLANs, the device with the lowest device ID becomes the root device.

When you configure a device as the root, you modify the device priority from the default value (32768) to a significantly lower value so that the device becomes the root device for the specified spanning-tree instance. When you enter this command, the device checks the device priorities of the root devices. Because of the extended system ID support, the device sets its own priority for the specified instance to 24576 if this value will cause this device to become the root for the specified spanning-tree instance.

If any root device for the specified instance has a device priority lower than 24576, the device sets its own priority to 4096 less than the lowest device priority. (4096 is the value of the least-significant bit of a 4-bit device priority value. For more information, select "Bridge ID, Device Priority, and Extended System ID" link in Related Topics.

If your network consists of devices that support and do not support the extended system ID, it is unlikely that the device with the extended system ID support will become the root device. The extended system ID increases the device priority value every time the VLAN number is greater than the priority of the connected switches running older software.

The root device for each spanning-tree instance should be a backbone or distribution device. Do not configure an access device as the spanning-tree primary root.

Use the **diameter** keyword, which is available only for MST instance 0, to specify the Layer 2 network diameter (that is, the maximum number of device hops between any two end stations in the Layer 2 network). When you specify the network diameter, the device automatically sets an optimal hello time, forward-delay time, and maximum-age time for a network of that diameter, which can significantly reduce the convergence time. You can use the **hello** keyword to override the automatically calculated hello time.



Note After configuring the switch as the root switch, we recommend that you avoid manually configuring the hello time, forward-delay time, and maximum-age time through the **spanning-tree mst hello-time**, **spanning-tree mst forward-time**, and the **spanning-tree mst max-age** global configuration commands.

Multiple Spanning-Tree Regions

For switches to participate in multiple spanning-tree (MST) instances, you must consistently configure the switches with the same MST configuration information. A collection of interconnected switches that have the same MST configuration comprises an MST region.

The MST configuration controls to which MST region each device belongs. The configuration includes the name of the region, the revision number, and the MST VLAN-to-instance assignment map. You configure the device for a region by specifying the MST region configuration on it. You can map VLANs to an MST instance, specify the region name, and set the revision number. For instructions and an example, select the "Specifying the MST Region Configuration and Enabling MSTP" link in Related Topics.

A region can have one or multiple members with the same MST configuration. Each member must be capable of processing RSTP bridge protocol data units (BPDUs). There is no limit to the number of MST regions in a network, but each region can support up to 65 spanning-tree instances. Instances can be identified by any number in the range from 0 to 4094. You can assign a VLAN to only one spanning-tree instance at a time.

IST, CIST, and CST

Unlike PVST+ and Rapid PVST+ in which all the spanning-tree instances are independent, the MSTP establishes and maintains two types of spanning trees:

- An internal spanning tree (IST), which is the spanning tree that runs in an MST region.

Within each MST region, the MSTP maintains multiple spanning-tree instances. Instance 0 is a special instance for a region, known as the internal spanning tree (IST). All other MST instances are numbered from 1 to 4094.

The IST is the only spanning-tree instance that sends and receives BPDUs. All of the other spanning-tree instance information is contained in M-records, which are encapsulated within MSTP BPDUs. Because the MSTP BPDU carries information for all instances, the number of BPDUs that need to be processed to support multiple spanning-tree instances is significantly reduced.

All MST instances within the same region share the same protocol timers, but each MST instance has its own topology parameters, such as root device ID, root path cost, and so forth. By default, all VLANs are assigned to the IST.

An MST instance is local to the region; for example, MST instance 1 in region A is independent of MST instance 1 in region B, even if regions A and B are interconnected.

- A common and internal spanning tree (CIST), which is a collection of the ISTs in each MST region, and the common spanning tree (CST) that interconnects the MST regions and single spanning trees.

The spanning tree computed in a region appears as a subtree in the CST that encompasses the entire switched domain. The CIST is formed by the spanning-tree algorithm running among switches that support the IEEE 802.1w, IEEE 802.1s, and IEEE 802.1D standards. The CIST inside an MST region is the same as the CST outside a region.

Operations Within an MST Region

The IST connects all the MSTP switches in a region. When the IST converges, the root of the IST becomes the CIST regional root. It is the device within the region with the lowest device ID and path cost to the CIST root. The CIST regional root is also the CIST root if there is only one region in the network. If the CIST root is outside the region, one of the MSTP switches at the boundary of the region is selected as the CIST regional root.

When an MSTP device initializes, it sends BPDUs claiming itself as the root of the CIST and the CIST regional root, with both of the path costs to the CIST root and to the CIST regional root set to zero. The device also initializes all of its MST instances and claims to be the root for all of them. If the device receives superior MST root information (lower device ID, lower path cost, and so forth) than currently stored for the port, it relinquishes its claim as the CIST regional root.

During initialization, a region might have many subregions, each with its own CIST regional root. As switches receive superior IST information, they leave their old subregions and join the new subregion that contains the true CIST regional root. All subregions shrink except for the one that contains the true CIST regional root.

For correct operation, all switches in the MST region must agree on the same CIST regional root. Therefore, any two switches in the region only synchronize their port roles for an MST instance if they converge to a common CIST regional root.

Operations Between MST Regions

If there are multiple regions or legacy IEEE 802.1D devices within the network, MSTP establishes and maintains the CST, which includes all MST regions and all legacy STP devices in the network. The MST instances combine with the IST at the boundary of the region to become the CST.

The IST connects all the MSTP devices in the region and appears as a subtree in the CIST that encompasses the entire switched domain. The root of the subtree is the CIST regional root. The MST region appears as a virtual device to adjacent STP devices and MST regions.

Only the CST instance sends and receives BPDUs, and MST instances add their spanning-tree information into the BPDUs to interact with neighboring devices and compute the final spanning-tree topology. Because of this, the spanning-tree parameters related to BPDU transmission (for example, hello time, forward time, max-age, and max-hops) are configured only on the CST instance but affect all MST instances. Parameters related to the spanning-tree topology (for example, device priority, port VLAN cost, and port VLAN priority) can be configured on both the CST instance and the MST instance.

MSTP devices use Version 3 RSTP BPDUs or IEEE 802.1D STP BPDUs to communicate with legacy IEEE 802.1D devices. MSTP devices use MSTP BPDUs to communicate with MSTP devices.

IEEE 802.1s Terminology

Some MST naming conventions used in Cisco's prestandard implementation have been changed to identify some *internal* or *regional* parameters. These parameters are significant only within an MST region, as opposed to external parameters that are relevant to the whole network. Because the CIST is the only spanning-tree instance that spans the whole network, only the CIST parameters require the external rather than the internal or regional qualifiers.

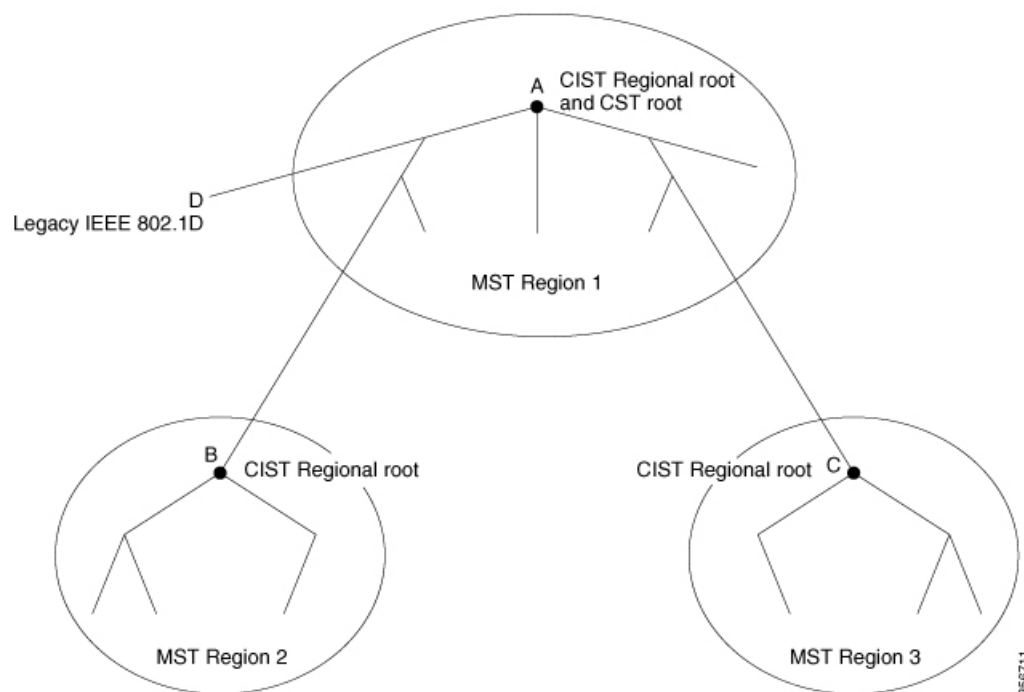
- The CIST root is the root device for the unique instance that spans the whole network, the CIST.
- The CIST external root path cost is the cost to the CIST root. This cost is left unchanged within an MST region. Remember that an MST region looks like a single device for the CIST. The CIST external root path cost is the root path cost calculated between these virtual devices and devices that do not belong to any region.

- If the CIST root is in the region, the CIST regional root is the CIST root. Otherwise, the CIST regional root is the closest device to the CIST root in the region. The CIST regional root acts as a root device for the IST.
- The CIST internal root path cost is the cost to the CIST regional root in a region. This cost is only relevant to the IST, instance 0.

Illustration of MST Regions

This figure displays three MST regions and a legacy IEEE 802.1D device (D). The CIST regional root for region 1 (A) is also the CIST root. The CIST regional root for region 2 (B) and the CIST regional root for region 3 (C) are the roots for their respective subtrees within the CIST. The RSTP runs in all regions.

Figure 4: MST Regions, CIST Regional Root, and CST Root



Hop Count

The IST and MST instances do not use the message-age and maximum-age information in the configuration BPDU to compute the spanning-tree topology. Instead, they use the path cost to the root and a hop-count mechanism similar to the IP time-to-live (TTL) mechanism.

By using the **spanning-tree mst max-hops** global configuration command, you can configure the maximum hops inside the region and apply it to the IST and all MST instances in that region. The hop count achieves the same result as the message-age information (triggers a reconfiguration). The root device of the instance always sends a BPDU (or M-record) with a cost of 0 and the hop count set to the maximum value. When a device receives this BPDU, it decrements the received remaining hop count by one and propagates this value as the remaining hop count in the BPDUs it generates. When the count reaches zero, the device discards the BPDU and ages the information held for the port.

The message-age and maximum-age information in the RSTP portion of the BPDU remain the same throughout the region, and the same values are propagated by the region designated ports at the boundary.

Boundary Ports

In the Cisco prestandard implementation, a boundary port connects an MST region to a single spanning-tree region running RSTP, to a single spanning-tree region running PVST+ or rapid PVST+, or to another MST region with a different MST configuration. A boundary port also connects to a LAN, the designated device of which is either a single spanning-tree device or a device with a different MST configuration.

There is no definition of a boundary port in the IEEE 802.1s standard. The IEEE 802.1Q-2002 standard identifies two kinds of messages that a port can receive:

- internal (coming from the same region)
- external (coming from another region)

When a message is internal, the CIST part is received by the CIST, and each MST instance receives its respective M-record.

When a message is external, it is received only by the CIST. If the CIST role is root or alternate, or if the external BPDU is a topology change, it could have an impact on the MST instances.

An MST region includes both devices and LANs. A segment belongs to the region of its designated port. Therefore, a port in a different region than the designated port for a segment is a boundary port. This definition allows two ports internal to a region to share a segment with a port belonging to a different region, creating the possibility of a port receiving both internal and external messages.

The primary change from the Cisco prestandard implementation is that a designated port is not defined as boundary, unless it is running in an STP-compatible mode.



Note If there is a legacy STP device on the segment, messages are always considered external.

The other change from the Cisco prestandard implementation is that the CIST regional root device ID field is now inserted where an RSTP or legacy IEEE 802.1Q device has the sender device ID. The whole region performs like a single virtual device by sending a consistent sender device ID to neighboring devices. In this example, device C would receive a BPDU with the same consistent sender device ID of root, whether or not A or B is designated for the segment.

IEEE 802.1s Implementation

The Cisco implementation of the IEEE MST standard includes features required to meet the standard, as well as some of the desirable prestandard functionality that is not yet incorporated into the published standard.

Port Role Naming Change

The boundary role is no longer in the final MST standard, but this boundary concept is maintained in Cisco's implementation. However, an MST instance port at a boundary of the region might not follow the state of the corresponding CIST port. Two boundary roles currently exist:

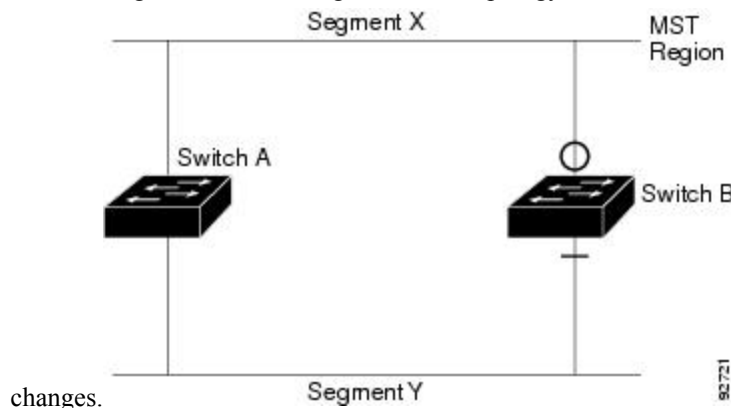
- The boundary port is the root port of the CIST regional root—When the CIST instance port is proposed and is in sync, it can send back an agreement and move to the forwarding state only after all the corresponding MSTI ports are in sync (and thus forwarding).
- The boundary port is not the root port of the CIST regional root—The MSTI ports follow the state and role of the CIST port. The standard provides less information, and it might be difficult to understand why an MSTI port can be alternately blocking when it receives no BPDUs (MRecords). In this case, although the boundary role no longer exists, the **show** commands identify a port as boundary in the *type* column of the output.

Interoperation Between Legacy and Standard Devices

Because automatic detection of prestandard devices can fail, you can use an interface configuration command to identify prestandard ports. A region cannot be formed between a standard and a prestandard device, but they can interoperate by using the CIST. Only the capability of load-balancing over different instances is lost in that particular case. The CLI displays different flags depending on the port configuration when a port receives prestandard BPDUs. A syslog message also appears the first time a device receives a prestandard BPDU on a port that has not been configured for prestandard BPDU transmission.

Figure 5: Standard and Prestandard Device Interoperation

Assume that A is a standard device and B a prestandard device, both configured to be in the same region. A is the root device for the CIST, and B has a root port (BX) on segment X and an alternate port (BY) on segment Y. If segment Y flaps, and the port on BY becomes the alternate before sending out a single prestandard BPDU, AY cannot detect that a prestandard device is connected to Y and continues to send standard BPDUs. The port BY is fixed in a boundary, and no load balancing is possible between A and B. The same problem exists on segment X, but B might transmit topology



Note We recommend that you minimize the interaction between standard and prestandard MST implementations.

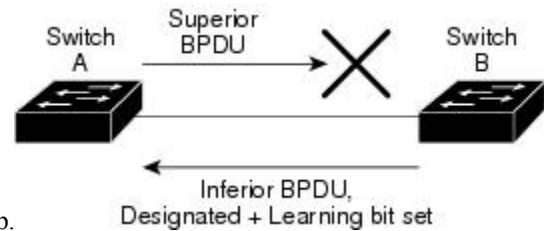
Detecting Unidirectional Link Failure

This feature is not yet present in the IEEE MST standard, but it is included in this Cisco IOS release. The software checks the consistency of the port role and state in the received BPDUs to detect unidirectional link failures that could cause bridging loops.

When a designated port detects a conflict, it keeps its role, but reverts to the discarding state because disrupting connectivity in case of inconsistency is preferable to opening a bridging loop.

Figure 6: Detecting Unidirectional Link Failure

This figure illustrates a unidirectional link failure that typically creates a bridging loop. Device A is the root device, and its BPDUs are lost on the link leading to device B. RSTP and MST BPDUs include the role and state of the sending port. With this information, device A can detect that device B does not react to the superior BPDUs it sends and that device B is the designated, not root device. As a result, device A blocks (or keeps



blocking) its port, which prevents the bridging loop.

Interoperability with IEEE 802.1D STP

A device running MSTP supports a built-in protocol migration mechanism that enables it to interoperate with legacy IEEE 802.1D devices. If this device receives a legacy IEEE 802.1D configuration BPDU (a BPDU with the protocol version set to 0), it sends only IEEE 802.1D BPDUs on that port. An MSTP device also can detect that a port is at the boundary of a region when it receives a legacy BPDU, an MSTP BPDU (Version 3) associated with a different region, or an RSTP BPDU (Version 2).

However, the device does not automatically revert to the MSTP mode if it no longer receives IEEE 802.1D BPDUs because it cannot detect whether the legacy device has been removed from the link unless the legacy device is the designated device. A device might also continue to assign a boundary role to a port when the device to which this device is connected has joined the region. To restart the protocol migration process (force the renegotiation with neighboring devices), use the **clear spanning-tree detected-protocols** privileged EXEC command.

If all the legacy devices on the link are RSTP devices, they can process MSTP BPDUs as if they are RSTP BPDUs. Therefore, MSTP devices send either a Version 0 configuration and TCN BPDUs or Version 3 MSTP BPDUs on a boundary port. A boundary port connects to a LAN, the designated device of which is either a single spanning-tree device or a device with a different MST configuration.

RSTP Overview

The RSTP takes advantage of point-to-point wiring and provides rapid convergence of the spanning tree. Reconfiguration of the spanning tree can occur in less than 1 second (in contrast to 50 seconds with the default settings in the IEEE 802.1D spanning tree).

Port Roles and the Active Topology

The RSTP provides rapid convergence of the spanning tree by assigning port roles and by learning the active topology. The RSTP builds upon the IEEE 802.1D STP to select the device with the highest device priority (lowest numerical priority value) as the root device. The RSTP then assigns one of these port roles to individual ports:

- Root port—Provides the best path (lowest cost) when the device forwards packets to the root device.
- Designated port—Connects to the designated device, which incurs the lowest path cost when forwarding packets from that LAN to the root device. The port through which the designated device is attached to the LAN is called the designated port.

- Alternate port—Offers an alternate path toward the root device to that provided by the current root port.
- Backup port—Acts as a backup for the path provided by a designated port toward the leaves of the spanning tree. A backup port can exist only when two ports are connected in a loopback by a point-to-point link or when a device has two or more connections to a shared LAN segment.
- Disabled port—Has no role within the operation of the spanning tree.

A port with the root or a designated port role is included in the active topology. A port with the alternate or backup port role is excluded from the active topology.

In a stable topology with consistent port roles throughout the network, the RSTP ensures that every root port and designated port immediately transition to the forwarding state while all alternate and backup ports are always in the discarding state (equivalent to blocking in IEEE 802.1D). The port state controls the operation of the forwarding and learning processes.

Table 6: Port State Comparison

Operational Status	STP Port State (IEEE 802.1D)	RSTP Port State	Is Port Included in the Active Topology?
Enabled	Blocking	Discarding	No
Enabled	Listening	Discarding	No
Enabled	Learning	Learning	Yes
Enabled	Forwarding	Forwarding	Yes
Disabled	Disabled	Discarding	No

To be consistent with Cisco STP implementations, this guide defines the port state as *blocking* instead of *discarding*. Designated ports start in the listening state.

Rapid Convergence

The RSTP provides for rapid recovery of connectivity following the failure of a device, a device port, or a LAN. It provides rapid convergence for edge ports, new root ports, and ports connected through point-to-point links as follows:

- Edge ports—If you configure a port as an edge port on an RSTP device by using the **spanning-tree portfast** interface configuration command, the edge port immediately transitions to the forwarding state. An edge port is the same as a Port Fast-enabled port, and you should enable it only on ports that connect to a single end station.
- Root ports—If the RSTP selects a new root port, it blocks the old root port and immediately transitions the new root port to the forwarding state.
- Point-to-point links—If you connect a port to another port through a point-to-point link and the local port becomes a designated port, it negotiates a rapid transition with the other port by using the proposal-agreement handshake to ensure a loop-free topology.

Figure 7: Proposal and Agreement Handshaking for Rapid Convergence

Device A is connected to Device B through a point-to-point link, and all of the ports are in the blocking state. Assume that the priority of Device A is a smaller numerical value than the priority of Device B.

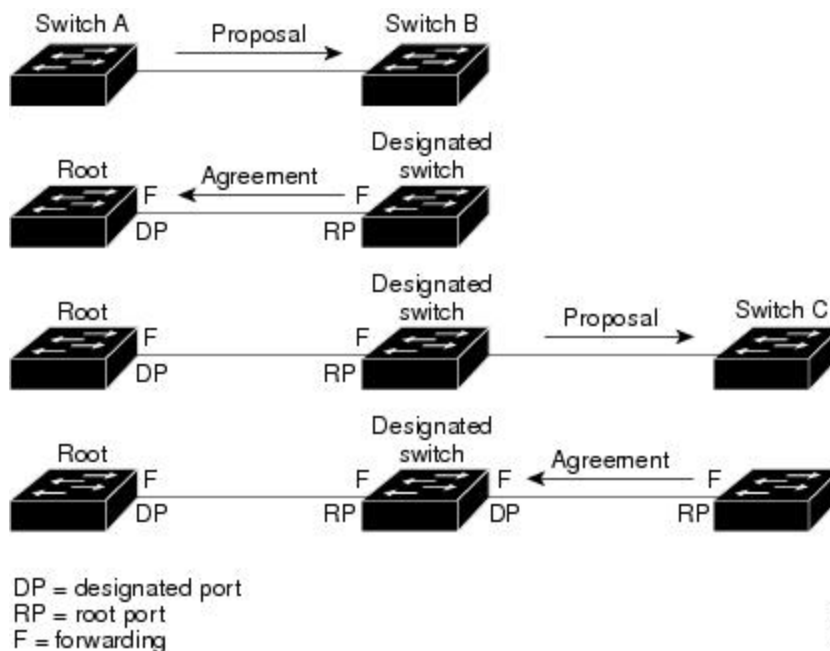
Device A sends a proposal message (a configuration BPDU with the proposal flag set) to Device B, proposing itself as the designated Device.

After receiving the proposal message, Device B selects as its new root port the port from which the proposal message was received, forces all nonedge ports to the blocking state, and sends an agreement message (a BPDU with the agreement flag set) through its new root port.

After receiving Device B's agreement message, Device A also immediately transitions its designated port to the forwarding state. No loops in the network are formed because Device B blocked all of its nonedge ports and because there is a point-to-point link between Devices A and B.

When Device C is connected to Device B, a similar set of handshaking messages are exchanged. Device C selects the port connected to Device B as its root port, and both ends immediately transition to the forwarding state. With each iteration of this handshaking process, one more device joins the active topology. As the network converges, this proposal-agreement handshaking progresses from the root toward the leaves of the spanning tree.

The device learns the link type from the port duplex mode: a full-duplex port is considered to have a point-to-point connection; a half-duplex port is considered to have a shared connection. You can override the default setting that is controlled by the duplex setting by using the **spanning-tree link-type** interface configuration command.



Synchronization of Port Roles

When the device receives a proposal message on one of its ports and that port is selected as the new root port, the RSTP forces all other ports to synchronize with the new root information.

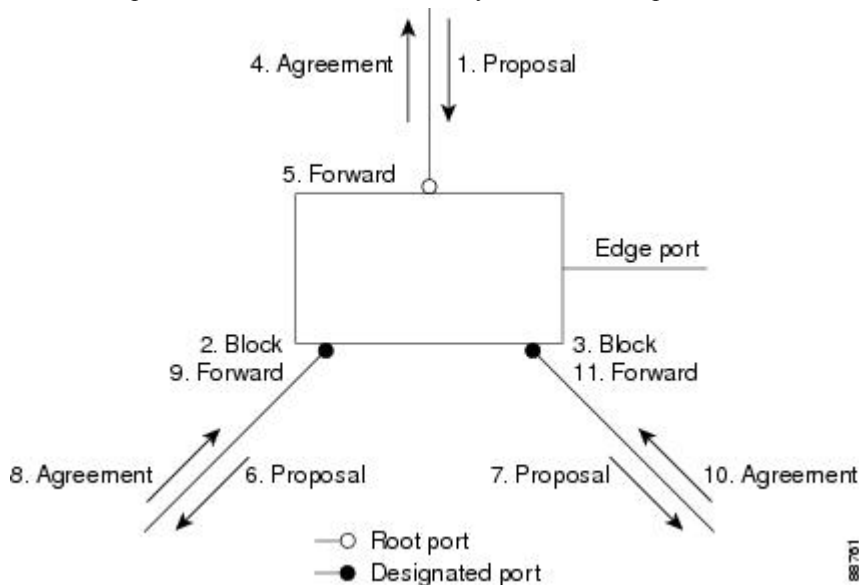
The device is synchronized with superior root information received on the root port if all other ports are synchronized. An individual port on the device is synchronized if

- That port is in the blocking state.
- It is an edge port (a port configured to be at the edge of the network).

If a designated port is in the forwarding state and is not configured as an edge port, it transitions to the blocking state when the RSTP forces it to synchronize with new root information. In general, when the RSTP forces a port to synchronize with root information and the port does not satisfy any of the above conditions, its port state is set to blocking.

Figure 8: Sequence of Events During Rapid Convergence

After ensuring that all of the ports are synchronized, the device sends an agreement message to the designated device corresponding to its root port. When the devices connected by a point-to-point link are in agreement about their port roles, the RSTP immediately transitions the port states to forwarding.



Bridge Protocol Data Unit Format and Processing

The RSTP BPDU format is the same as the IEEE 802.1D BPDU format except that the protocol version is set to 2. A new 1-byte Version 1 Length field is set to zero, which means that no version 1 protocol information is present.

Table 7: RSTP BPDU Flags

Bit	Function
0	Topology change (TC)
1	Proposal
2–3:	Port role:
00	Unknown
01	Alternate port
10	Root port
11	Designated port
4	Learning

Bit	Function
5	Forwarding
6	Agreement
7	Topology change acknowledgement (TCA)

The sending device sets the proposal flag in the RSTP BPDU to propose itself as the designated device on that LAN. The port role in the proposal message is always set to the designated port.

The sending device sets the agreement flag in the RSTP BPDU to accept the previous proposal. The port role in the agreement message is always set to the root port.

The RSTP does not have a separate topology change notification (TCN) BPDU. It uses the topology change (TC) flag to show the topology changes. However, for interoperability with IEEE 802.1D devices, the RSTP device processes and generates TCN BPDUs.

The learning and forwarding flags are set according to the state of the sending port.

Processing Superior BPDU Information

If a port receives superior root information (lower device ID, lower path cost, and so forth) than currently stored for the port, the RSTP triggers a reconfiguration. If the port is proposed and is selected as the new root port, RSTP forces all the other ports to synchronize.

If the BPDU received is an RSTP BPDU with the proposal flag set, the device sends an agreement message after all of the other ports are synchronized. If the BPDU is an IEEE 802.1D BPDU, the device does not set the proposal flag and starts the forward-delay timer for the port. The new root port requires twice the forward-delay time to transition to the forwarding state.

If the superior information received on the port causes the port to become a backup or alternate port, RSTP sets the port to the blocking state but does not send the agreement message. The designated port continues sending BPDUs with the proposal flag set until the forward-delay timer expires, at which time the port transitions to the forwarding state.

Processing Inferior BPDU Information

If a designated port receives an inferior BPDU (such as a higher device ID or a higher path cost than currently stored for the port) with a designated port role, it immediately replies with its own information.

Topology Changes

This section describes the differences between the RSTP and the IEEE 802.1D in handling spanning-tree topology changes.

- **Detection**—Unlike IEEE 802.1D in which *any* transition between the blocking and the forwarding state causes a topology change, *only* transitions from the blocking to the forwarding state cause a topology change with RSTP (only an increase in connectivity is considered a topology change). State changes on an edge port do not cause a topology change. When an RSTP device detects a topology change, it deletes the learned information on all of its nonedge ports except on those from which it received the TC notification.
- **Notification**—Unlike IEEE 802.1D, which uses TCN BPDUs, the RSTP does not use them. However, for IEEE 802.1D interoperability, an RSTP device processes and generates TCN BPDUs.

- **Acknowledgement**—When an RSTP device receives a TCN message on a designated port from an IEEE 802.1D device, it replies with an IEEE 802.1D configuration BPDU with the TCA bit set. However, if the TC-while timer (the same as the topology-change timer in IEEE 802.1D) is active on a root port connected to an IEEE 802.1D device and a configuration BPDU with the TCA bit set is received, the TC-while timer is reset.

This behavior is only required to support IEEE 802.1D devices. The RSTP BPDUs never have the TCA bit set.

- **Propagation**—When an RSTP device receives a TC message from another device through a designated or root port, it propagates the change to all of its nonedge, designated ports and to the root port (excluding the port on which it is received). The device starts the TC-while timer for all such ports and flushes the information learned on them.
- **Protocol migration**—For backward compatibility with IEEE 802.1D devices, RSTP selectively sends IEEE 802.1D configuration BPDUs and TCN BPDUs on a per-port basis.

When a port is initialized, the migrate-delay timer is started (specifies the minimum time during which RSTP BPDUs are sent), and RSTP BPDUs are sent. While this timer is active, the device processes all BPDUs received on that port and ignores the protocol type.

If the device receives an IEEE 802.1D BPDU after the port migration-delay timer has expired, it assumes that it is connected to an IEEE 802.1D device and starts using only IEEE 802.1D BPDUs. However, if the RSTP device is using IEEE 802.1D BPDUs on a port and receives an RSTP BPDU after the timer has expired, it restarts the timer and starts using RSTP BPDUs on that port.

Protocol Migration Process

A device running MSTP supports a built-in protocol migration mechanism that enables it to interoperate with legacy IEEE 802.1D devices. If this device receives a legacy IEEE 802.1D configuration BPDU (a BPDU with the protocol version set to 0), it sends only IEEE 802.1D BPDUs on that port. An MSTP device also can detect that a port is at the boundary of a region when it receives a legacy BPDU, an MST BPDU (Version 3) associated with a different region, or an RST BPDU (Version 2).

However, the device does not automatically revert to the MSTP mode if it no longer receives IEEE 802.1D BPDUs because it cannot detect whether the legacy device has been removed from the link unless the legacy device is the designated device. A device also might continue to assign a boundary role to a port when the device to which it is connected has joined the region.

Default MSTP Configuration

Table 8: Default MSTP Configuration

Feature	Default Setting
Spanning-tree mode	MSTP
Device priority (configurable on a per-CIST port basis)	32768
Spanning-tree port priority (configurable on a per-CIST port basis)	128

Feature	Default Setting
Spanning-tree port cost (configurable on a per-CIST port basis)	1000 Mb/s: 20000
Hello time	3 seconds
Forward-delay time	20 seconds
Maximum-aging time	20 seconds
Maximum hop count	20 hops

About MST-to-PVST+ Interoperability (PVST+ Simulation)

The PVST+ simulation feature enables seamless interoperability between MST and Rapid PVST+. You can enable or disable this per port, or globally. PVST+ simulation is enabled by default.

However, you may want to control the connection between MST and Rapid PVST+ to protect against accidentally connecting an MST-enabled port to a Rapid PVST+-enabled port. Because Rapid PVST+ is the default STP mode, you may encounter many Rapid PVST+-enabled connections.

Disabling this feature causes the switch to stop the MST region from interacting with PVST+ regions. The MST-enabled port moves to a PVST peer inconsistent (blocking) state once it detects it is connected to a Rapid PVST+-enabled port. This port remains in the inconsistent state until the port stops receiving Shared Spanning Tree Protocol (SSTP) BPDUs, and then the port resumes the normal STP transition process.

You can for instance, disable PVST+ simulation, to prevent an incorrectly configured switch from connecting to a network where the STP mode is not MSTP (the default mode is Rapid-PVST+).

Observe these guidelines when you configure MST switches (in the same region) to interact with PVST+ switches:

- Configure the root for all VLANs inside the MST region as shown in this example:

```
Device# show spanning-tree mst interface gigabitEthernet 1/0/1
GigabitEthernet1/0/1 of MST00 is root forwarding
Edge port: no (trunk) port guard : none (default)
Link type: point-to-point (auto) bpdu filter: disable (default)
Boundary : boundary (PVST) bpdu guard : disable (default)
Bpdus sent 10, received 310
```

```
Instance Role Sts Cost Prio.Nbr Vlans mapped
-----
0 Root FWD 20000 128.1 1-2,4-2999,4000-4094
3 Boun FWD 20000 128.1 3,3000-3999
```

The ports that belong to the MST switch at the boundary simulate PVST+ and send PVST+ BPDUs for all the VLANs.

If you enable loop guard on the PVST+ switches, the ports might change to a loop-inconsistent state when the MST switches change their configuration. To correct the loop-inconsistent state, you must disable and re-enable loop guard on that PVST+ switch.

- Do not locate the root for some or all of the VLANs inside the PVST+ side of the MST switch because when the MST switch at the boundary receives PVST+ BPDUs for all or some of the VLANs on its designated ports, root guard sets the port to the blocking state.

- When you connect a PVST+ switch to two different MST regions, the topology change from the PVST+ switch does not pass beyond the first MST region. In such a case, the topology changes are propagated only in the instance to which the VLAN is mapped. The topology change stays local to the first MST region, and the Cisco Access Manager (CAM) entries in the other region are not flushed. To make the topology change visible throughout other MST regions, you can map that VLAN to IST or connect the PVST+ switch to the two regions through access links.
- When you disable the PVST+ simulation, note that the PVST+ peer inconsistency can also occur while the port is already in other states of inconsistency. For example, the root bridge for all STP instances must all be in either the MST region or the Rapid PVST+ side. If the root bridge for all STP instances are not on one side or the other, the software moves the port into a PVST+ simulation-inconsistent state.



Note We recommend that you put the root bridge for all STP instances in the MST region.

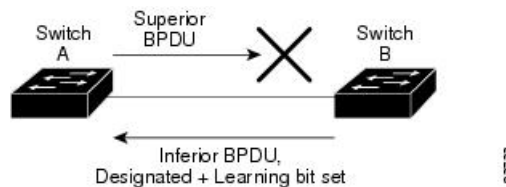
About Detecting Unidirectional Link Failure

The dispute mechanism that detects unidirectional link failures is included in the IEEE 802.1D-2004 RSTP and IEEE 802.1Q-2005 MSTP standard, and requires no user configuration.

The switch checks the consistency of the port role and state in the BPDUs it receives, to detect unidirectional link failures that could cause bridging loops. When a designated port detects a conflict, it keeps its role, but reverts to a discarding (blocking) state because disrupting connectivity in case of inconsistency is preferable to opening a bridging loop.

For example, in the figure below, Switch A is the root bridge and Switch B is the designated port. BPDUs from Switch A are lost on the link leading to switch B.

Figure 9: Detecting Unidirectional Link Failure

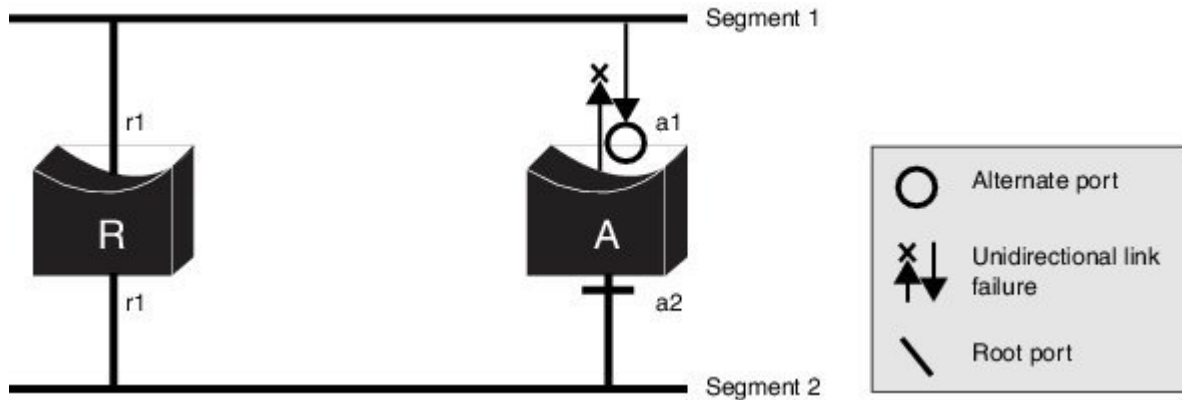


Since Rapid PVST+ (802.1w) and MST BPDUs include the role and state of the sending port, Switch A detects (from the inferior BPDU), that switch B does not react to the superior BPDUs it sends, because switch B has the role of a designated port and not the root bridge. As a result, switch A blocks (or keeps blocking) its port, thus preventing the bridging loop.

Note these guidelines and limitations relating to the dispute mechanism:

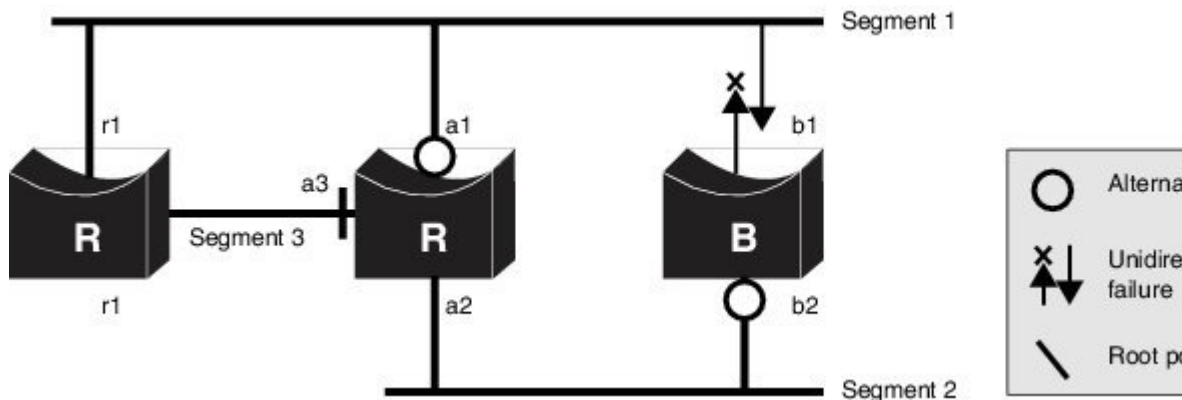
- It works only on switches running RSTP or MST (the dispute mechanism requires reading the role and state of the port initiating BPDUs).
- It may result in loss of connectivity. For example, in the figure below, Bridge A cannot transmit on the port it elected as a root port. As a result of this situation, there is loss of connectivity (r1 and r2 are designated, a1 is root and a2 is alternate. There is only a one way connectivity between A and R).

Figure 10: Loss of Connectivity



- It may cause permanent bridging loops on shared segments. For example, in the figure below, suppose that bridge R has the best priority, and that port b1 cannot receive any traffic from the shared segment 1 and sends inferior designated information on segment 1. Both r1 and a1 can detect this inconsistency. However, with the current dispute mechanism, only r1 will revert to discarding while the root port a1 opens a permanent loop. However, this problem does not occur in Layer 2 switched networks that are connected by point-to-point links.

Figure 11: Bridging Loops on Shared Segments



How to Configure MSTP Features

Specifying the MST Region Configuration and Enabling MSTP

For two or more switches to be in the same MST region, they must have the same VLAN-to-instance mapping, the same configuration revision number, and the same name.

A region can have one member or multiple members with the same MST configuration; each member must be capable of processing RSTP BPDUs. There is no limit to the number of MST regions in a network, but each region can only support up to 65 spanning-tree instances. You can assign a VLAN to only one spanning-tree instance at a time.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree mst configuration Example: Device(config)# spanning-tree mst configuration	Enters MST configuration mode.
Step 4	instance <i>instance-id</i> vlan <i>vlan-range</i> Example: Device(config-mst)# instance 1 vlan 10-20	Maps VLANs to an MST instance. <ul style="list-style-type: none"> • For <i>instance-id</i>, the range is 0 to 4094. • For vlan <i>vlan-range</i>, the range is 1 to 4094. When you map VLANs to an MST instance, the mapping is incremental, and the VLANs specified in the command are added to or removed from the VLANs that were previously mapped. <p>To specify a VLAN range, use a hyphen; for example, instance 1 vlan 1-63 maps VLANs 1 through 63 to MST instance 1.</p> <p>To specify a VLAN series, use a comma; for example, instance 1 vlan 10, 20, 30 maps VLANs 10, 20, and 30 to MST instance 1.</p>
Step 5	name <i>name</i> Example: Device(config-mst)# name region1	Specifies the configuration name. The <i>name</i> string has a maximum length of 32 characters and is case sensitive.
Step 6	revision <i>version</i> Example: Device(config-mst)# revision 1	Specifies the configuration revision number. The range is 0 to 65535.

	Command or Action	Purpose
Step 7	show pending Example: Device(config-mst) # show pending	Verifies your configuration by displaying the pending configuration.
Step 8	exit Example: Device(config-mst) # exit	Applies all changes, and returns to global configuration mode.
Step 9	spanning-tree mode mst Example: Device(config) # spanning-tree mode mst	Enables MSTP. RSTP is also enabled. Changing spanning-tree modes can disrupt traffic because all spanning-tree instances are stopped for the previous mode and restarted in the new mode. You cannot run both MSTP and PVST+ or both MSTP and Rapid PVST+ at the same time.
Step 10	end Example: Device(config) # end	Returns to privileged EXEC mode.

Configuring the Root Device

This procedure is optional.

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device. For instructions, see Related Topics.

You must also know the specified MST instance ID. Step 2 in the example uses 0 as the instance ID because that was the instance ID set up by the instructions listed under Related Topics.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.

	Command or Action	Purpose
Step 2	configure terminal Example: <pre>Device# configure terminal</pre>	Enters global configuration mode.
Step 3	spanning-tree mst <i>instance-id</i> root primary [<i>diameter net-diameter</i> [<i>hello-time seconds</i>]] Example: <pre>Device(config)# spanning-tree mst 0 root primary diameter 4 hello-time 5</pre>	Configures a device as the root device. <ul style="list-style-type: none"> • For <i>instance-id</i>, you can specify a single instance, a range of instances separated by a hyphen, or a series of instances separated by a comma. The range is 0 to 4094. • (Optional) For diameter net-diameter, specify the maximum number of devices between any two end stations. The range is 2 to 7. This keyword is available for MST instance 0. • (Optional) For hello-time seconds, specify the interval in seconds between the generation of configuration messages by the root switch. The range is 1 to 10; the default is 2.
Step 4	end Example: <pre>Device(config)# end</pre>	Returns to privileged EXEC mode.

Configuring a Secondary Root Device

When you configure a device with the extended system ID support as the secondary root, the device priority is modified from the default value (32768) to 28672. The device is then likely to become the root device for the specified instance if the primary root device fails. This is assuming that the other network device use the default device priority of 32768 and therefore are unlikely to become the root device.

You can execute this command on more than one device to configure multiple backup root devices. Use the same network diameter and hello-time values that you used when you configured the primary root device with the **spanning-tree mst *instance-id* root primary** global configuration command.

This procedure is optional.

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device. For instructions, see Related Topics.

You must also know the specified MST instance ID. This example uses 0 as the instance ID.

Procedure

	Command or Action	Purpose
Step 1	enable Example: <pre>Device> enable</pre>	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: <pre>Device# configure terminal</pre>	Enters global configuration mode.
Step 3	spanning-tree mst <i>instance-id</i> root secondary [<i>diameter net-diameter</i> [<i>hello-time seconds</i>]] Example: <pre>Device(config)# spanning-tree mst 0 root secondary diameter 4 hello-time 5</pre>	Configures a device as the secondary root device. <ul style="list-style-type: none"> • For <i>instance-id</i>, you can specify a single instance, a range of instances separated by a hyphen, or a series of instances separated by a comma. The range is 0 to 4094. • (Optional) For diameter <i>net-diameter</i>, specify the maximum number of devices between any two end stations. The range is 2 to 7. This keyword is available for MST instance 0. • (Optional) For hello-time <i>seconds</i> seconds, specify the interval in seconds between the generation of configuration messages by the root switch. The range is 1 to 10; the default is 2. Use the same network diameter and hello-time values that you used when configuring the primary root switch.
Step 4	end Example: <pre>Device(config)# end</pre>	Returns to privileged EXEC mode.

Configuring Port Priority

If a loop occurs, the MSTP uses the port priority when selecting an interface to put into the forwarding state. You can assign higher priority values (lower numerical values) to interfaces that you want selected first and lower priority values (higher numerical values) that you want selected last. If all interfaces have the same priority value, the MSTP puts the interface with the lowest interface number in the forwarding state and blocks the other interfaces.

This procedure is optional.

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device.

You must also know the specified MST instance ID and the interface used. This example uses 0 as the instance ID and GigabitEthernet1/0/1 or FastEthernet1/0/1 as the interface because that was the instance ID and interface set up by the instructions listed under Related Topics.

Procedure

	Command or Action	Purpose
Step 1	enable Example: <pre>Device> enable</pre>	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: <pre>Device# configure terminal</pre>	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: <pre>Device(config)# interface gigabitethernet 1/0/1 Or Device(config)# interface fastethernet 1/0/1</pre>	Specifies an interface to configure, and enters interface configuration mode.
Step 4	spanning-tree mst <i>instance-id</i> port-priority <i>priority</i> Example: <pre>Device(config-if)# spanning-tree mst 0 port-priority 64</pre>	Configures port priority. <ul style="list-style-type: none"> • For <i>instance-id</i>, you can specify a single instance, a range of instances separated by a hyphen, or a series of instances separated by a comma. The range is 0 to 4094. • For <i>priority</i>, the range is 0 to 240 in increments of 16. The default is 128. The lower the number, the higher the priority. The priority values are 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, and 240. All other values are rejected.
Step 5	end Example:	Returns to privileged EXEC mode.

	Command or Action	Purpose
	Device(config-if)# end	

The **show spanning-tree mst interface** *interface-id* privileged EXEC command displays information only if the port is in a link-up operative state. Otherwise, you can use the **show running-config interface** privileged EXEC command to confirm the configuration.

Configuring Path Cost

The MSTP path cost default value is derived from the media speed of an interface. If a loop occurs, the MSTP uses cost when selecting an interface to put in the forwarding state. You can assign lower cost values to interfaces that you want selected first and higher cost values that you want selected last. If all interfaces have the same cost value, the MSTP puts the interface with the lowest interface number in the forwarding state and blocks the other interfaces.

This procedure is optional.

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device. For instructions, see Related Topics.

You must also know the specified MST instance ID and the interface used. This example uses 0 as the instance ID and GigabitEthernet1/0/1 or FastEthernet1/0/1 as the interface because that was the instance ID and interface set up by the instructions listed under Related Topics.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none">• Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/1 Or Device(config)# interface fastethernet 1/0/1	Specifies an interface to configure, and enters interface configuration mode. Valid interfaces include physical ports and port-channel logical interfaces. The port-channel range is 1 to 6.

	Command or Action	Purpose
Step 4	spanning-tree mst <i>instance-id</i> cost <i>cost</i> Example: <pre>Device(config-if) # spanning-tree mst 0 cost 17031970</pre>	Configures the cost. If a loop occurs, the MSTP uses the path cost when selecting an interface to place into the forwarding state. A lower path cost represents higher-speed transmission. <ul style="list-style-type: none"> • For <i>instance-id</i>, you can specify a single instance, a range of instances separated by a hyphen, or a series of instances separated by a comma. The range is 0 to 4094. • For <i>cost</i>, the range is 1 to 200000000; the default value is derived from the media speed of the interface.
Step 5	end Example: <pre>Device(config-if) # end</pre>	Returns to privileged EXEC mode.

The **show spanning-tree mst interface *interface-id*** privileged EXEC command displays information only for ports that are in a link-up operative state. Otherwise, you can use the **show running-config** privileged EXEC command to confirm the configuration.

Configuring the Device Priority

Changing the priority of a device makes it more likely to be chosen as the root device.



Note Exercise care when using this command. For normal network configurations, we recommend that you use the **spanning-tree mst *instance-id* root primary** and the **spanning-tree mst *instance-id* root secondary** global configuration commands to specify a device as the root or secondary root device. You should modify the device priority only in circumstances where these commands do not work.

This procedure is optional.

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device. For instructions, see Related Topics.

You must also know the specified MST instance ID used. This example uses 0 as the instance ID because that was the instance ID set up by the instructions listed under Related Topics.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree mst <i>instance-id</i> priority <i>priority</i> Example: Devic (config) # spanning-tree mst 0 priority 40960	Configures the device priority. <ul style="list-style-type: none"> • For <i>instance-id</i>, you can specify a single instance, a range of instances separated by a hyphen, or a series of instances separated by a comma. The range is 0 to 4094. • For <i>priority</i>, the range is 0 to 61440 in increments of 4096; the default is 32768. The lower the number, the more likely the device will be chosen as the root device. Priority values are 0, 4096, 8192, 12288, 16384, 20480, 24576, 28672, 32768, 36864, 40960, 45056, 49152, 53248, 57344, and 61440. These are the only acceptable values.
Step 4	end Example: Device (config-if) # end	Returns to privileged EXEC mode.

Configuring the Hello Time

The hello time is the time interval between configuration messages generated and sent by the root device.

This procedure is optional.

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree mst hello-time <i>seconds</i> Example: Device(config)# spanning-tree mst hello-time 4	Configures the hello time for all MST instances. The hello time is the time interval between configuration messages generated and sent by the root device. These messages indicate that the device is alive. For <i>seconds</i> , the range is 1 to 10; the default is 3.
Step 4	end Example: Device(config)# end	Returns to privileged EXEC mode.

Configuring the Forwarding-Delay Time

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device. For instructions, see Related Topics.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.

	Command or Action	Purpose
Step 3	spanning-tree mst forward-time <i>seconds</i> Example: <pre>Device(config)# spanning-tree mst forward-time 25</pre>	Configures the forward time for all MST instances. The forwarding delay is the number of seconds a port waits before changing from its spanning-tree learning and listening states to the forwarding state. For <i>seconds</i> , the range is 4 to 30; the default is 20.
Step 4	end Example: <pre>Device(config)# end</pre>	Returns to privileged EXEC mode.

Configuring the Maximum-Aging Time

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device.

Procedure

	Command or Action	Purpose
Step 1	enable Example: <pre>Device> enable</pre>	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: <pre>Device# configure terminal</pre>	Enters global configuration mode.
Step 3	spanning-tree mst max-age <i>seconds</i> Example: <pre>Device(config)# spanning-tree mst max-age 40</pre>	Configures the maximum-aging time for all MST instances. The maximum-aging time is the number of seconds a device waits without receiving spanning-tree configuration messages before attempting a reconfiguration. For <i>seconds</i> , the range is 6 to 40; the default is 20.
Step 4	end Example: <pre>Device(config)# end</pre>	Returns to privileged EXEC mode.

Configuring the Maximum-Hop Count

This procedure is optional.

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree mst max-hops hop-count Example: Device(config)# spanning-tree mst max-hops 25	Specifies the number of hops in a region before the BPDU is discarded, and the information held for a port is aged. For <i>hop-count</i> , the range is 1 to 255; the default is 20.
Step 4	end Example: Device(config)# end	Returns to privileged EXEC mode.

Specifying the Link Type to Ensure Rapid Transitions

If you connect a port to another port through a point-to-point link and the local port becomes a designated port, the RSTP negotiates a rapid transition with the other port by using the proposal-agreement handshake to ensure a loop-free topology.

By default, the link type is controlled from the duplex mode of the interface: a full-duplex port is considered to have a point-to-point connection; a half-duplex port is considered to have a shared connection. If you have a half-duplex link physically connected point-to-point to a single port on a remote device running MSTP, you can override the default setting of the link type and enable rapid transitions to the forwarding state.

This procedure is optional.

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device. For instructions, see Related Topics.

You must also know the specified MST instance ID and the interface used. This example uses 0 as the instance ID and GigabitEthernet1/0/1 or FastEthernet1/0/1 as the interface.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/1 Or Device(config)# interface fastethernet 1/0/1	Specifies an interface to configure, and enters interface configuration mode. Valid interfaces include physical ports, VLANs, and port-channel logical interfaces. The VLAN ID range is 1 to 4094. The port-channel range is 1 to 6.
Step 4	spanning-tree link-type point-to-point Example: Device(config-if)# spanning-tree link-type point-to-point	Specifies that the link type of a port is point-to-point.
Step 5	end Example: Device(config-if)# end	Returns to privileged EXEC mode.

Designating the Neighbor Type

A topology could contain both prestandard and IEEE 802.1s standard compliant devices. By default, ports can automatically detect prestandard devices, but they can still receive both standard and prestandard BPDUs. When there is a mismatch between a device and its neighbor, only the CIST runs on the interface.

You can choose to set a port to send only prestandard BPDUs. The prestandard flag appears in all the **show** commands, even if the port is in STP compatibility mode.

This procedure is optional.

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device. For instructions, see Related Topics.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/1 Or Device(config)# interface fastethernet 0/1	Specifies an interface to configure, and enters interface configuration mode. Valid interfaces include physical ports.
Step 4	spanning-tree mst pre-standard Example: Device(config-if)# spanning-tree mst pre-standard	Specifies that the port can send only prestandard BPDUs.
Step 5	end Example: Device(config-if)# end	Returns to privileged EXEC mode.

Restarting the Protocol Migration Process

This procedure restarts the protocol migration process and forces renegotiation with neighboring devices. It reverts the device to MST mode. It is needed when the device no longer receives IEEE 802.1D BPDUs after it has been receiving them.

Follow these steps to restart the protocol migration process (force the renegotiation with neighboring devices) on the device.

Before you begin

A multiple spanning tree (MST) must be specified and enabled on the device. For instructions, see Related Topics.

If you want to use the interface version of the command, you must also know the MST interface used. This example uses GigabitEthernet1/0/1 or FastEthernet1/0/1 as the interface.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	Enter one of the following commands: <ul style="list-style-type: none"> • clear spanning-tree detected-protocols • clear spanning-tree detected-protocols interface <i>interface-id</i> Example: Device# clear spanning-tree detected-protocols OR Device# clear spanning-tree detected-protocols interface gigabitethernet 1/0/1	The device reverts to the MSTP mode, and the protocol migration process restarts.

What to do next

This procedure may need to be repeated if the device receives more legacy IEEE 802.1D configuration BPDUs (BPDUs with the protocol version set to 0).

Configuring PVST+ Simulation

PVST+ simulation is enabled by default. This means that all ports automatically interoperate with a connected device that is running in Rapid PVST+ mode. If you disabled the feature and want to re-configure it, refer to the following tasks.

To enable PVST+ simulation globally, perform this task:

Procedure

	Command or Action	Purpose
Step 1	enable Example:	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.

	Command or Action	Purpose
	Device> enable	
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree mst simulate pvst global Example: Device(config)# spanning-tree mst simulate pvst global	Enables PVST+ simulation globally. To prevent the switch from automatically interoperating with a connecting switch that is running Rapid PVST+, enter the no version of the command.
Step 4	end Example: Device(config)# end	Returns to privileged EXEC mode.

Enabling PVST+ Simulation on a Port

To enable PVST+ simulation on a port, perform this task:

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	
Step 3	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/1 Or Device(config)# interface fastethernet 1/0/1	Selects a port to configure.

	Command or Action	Purpose
Step 4	spanning-tree mst simulate pvst Example: Device(config-if)# spanning-tree mst simulate pvst	Enables PVST+ simulation on the specified interface. To prevent a specified interface from automatically interoperating with a connecting switch that is not running MST, enter the spanning-tree mst simulate pvst disable command.
Step 5	end Example: Device(config)# end	Returns to privileged EXEC mode.
Step 6	show spanning-tree summary Example: Device# show spanning-tree summary	Verifies the configuration.

Configuration Examples for MSTP

Examples: PVST+ Simulation

This example shows how to prevent the switch from automatically interoperating with a connecting switch that is running Rapid PVST+:

```
Device# configure terminal
Device(config)# no spanning-tree mst simulate pvst global
```

This example shows how to prevent a port from automatically interoperating with a connecting device that is running Rapid PVST+:

```
Device(config)# interface gigabitethernet 1/0/1
Device(config-if)# spanning-tree mst simulate pvst disable
```

The following sample output shows the system message you receive when a SSTP BPDU is received on a port and PVST+ simulation is disabled:

```
Message
SPANTREE_PVST_PEER_BLOCK: PVST BPDU detected on port %s [port number].
```

```
Severity
Critical
```

Explanation

A PVST+ peer was detected on the specified interface on the switch. PVST+ simulation feature is disabled, as a result of which the interface was

moved to the spanning tree
Blocking state.

Action

Identify the PVST+ switch from the network which might be configured incorrectly.

The following sample output shows the system message you receive when peer inconsistency on the interface is cleared:

Message

SPANTREE_PVST_PEER_UNBLOCK: Unblocking port %s [port number].

Severity

Critical

Explanation

The interface specified in the error message has been restored to normal spanning tree state.

Action

None.

This example shows the spanning tree status when port 0/1 has been configured to disable PVST+ simulation and is currently in the peer type inconsistent state:

```
Device# show spanning-tree
VLAN0010
  Spanning tree enabled protocol mstp
  Root ID Priority 32778
        Address 0002.172c.f400
        This bridge is the root
        Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
  Bridge ID Priority 32778 (priority 32768 sys-id-ext 10)
        Address 0002.172c.f400
        Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
        Aging Time 300
Interface      Role Sts Cost          Prio.Nbr Type
-----
Gi0/1          Desg BKN*4      128.270 P2p *PVST_Peer_Inc
```

This example shows the spanning tree summary when PVST+ simulation is enabled in the MSTP mode:

```
Device# show spanning-tree summary
Switch is in mst mode (IEEE Standard)
Root bridge for: MST0
EtherChannel misconfig guard is enabled
Extended system ID is enabled
Portfast Default is disabled
PortFast BPDU Guard Default is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default is disabled
UplinkFast is disabled
BackboneFast is disabled
Pathcost method used is long
```

```
PVST Simulation Default is enabled
```

Name	Blocking	Listening	Learning	Forwarding	STP Active
MST0	2	0	0	0	2
1 mst	2	0	0	0	2

This example shows the spanning tree summary when PVST+ simulation is disabled in any STP mode:

```
Device# show spanning-tree summary
Switch is in mst mode (IEEE Standard)
Root bridge for: MST0
EtherChannel misconfig guard is enabled
Extended system ID is enabled
Portfast Default is disabled
PortFast BPDU Guard Default is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default is disabled
UplinkFast is disabled
BackboneFast is disabled
Pathcost method used is long
PVST Simulation Default is disabled
```

Name	Blocking	Listening	Learning	Forwarding	STP Active
MST0	2	0	0	0	2
1 mst	2	0	0	0	2

This example shows the spanning tree summary when the switch is not in MSTP mode, that is, the switch is in PVST or Rapid-PVST mode. The output string displays the current STP mode:

```
Device# show spanning-tree summary
Switch is in rapid-pvst mode
Root bridge for: VLAN0001, VLAN2001-VLAN2002
EtherChannel misconfig guard is enabled
Extended system ID is enabled
Portfast Default is disabled
PortFast BPDU Guard Default is disabled
Portfast BPDU Filter Default is disabled
Loopguard Default is disabled
UplinkFast is disabled
BackboneFast is disabled
Pathcost method used is short
PVST Simulation Default is enabled but inactive in rapid-pvst mode
```

Name	Blocking	Listening	Learning	Forwarding	STP Active
VLAN0001	2	0	0	0	2
VLAN2001	2	0	0	0	2
VLAN2002	2	0	0	0	2
3 vlans	6	0	0	0	6

This example shows the interface details when PVST+ simulation is globally enabled, or the default configuration:

```
Device# show spanning-tree interface 0/1 detail
Port 269 (GigabitEthernet1/0/1) of VLAN0002 is forwarding
  Port path cost 4, Port priority 128, Port Identifier 128.297.
  Designated root has priority 32769, address 0013.5f20.01c0
  Designated bridge has priority 32769, address 0013.5f20.01c0
  Designated port id is 128.297, designated path cost 0
  Timers: message age 0, forward delay 0, hold 0
  Number of transitions to forwarding state: 1
  Link type is point-to-point by default
  PVST Simulation is enabled by default
  BPDU: sent 132, received 1
```

This example shows the interface details when PVST+ simulation is globally disabled:

```
Device# show spanning-tree interface 0/1 detail
Port 269 (GigabitEthernet1/0/1) of VLAN0002 is forwarding
  Port path cost 4, Port priority 128, Port Identifier 128.297.
  Designated root has priority 32769, address 0013.5f20.01c0
  Designated bridge has priority 32769, address 0013.5f20.01c0
  Designated port id is 128.297, designated path cost 0
  Timers: message age 0, forward delay 0, hold 0
  Number of transitions to forwarding state: 1
  Link type is point-to-point by default
  PVST Simulation is disabled by default
  BPDU: sent 132, received 1
```

This example shows the interface details when PVST+ simulation is explicitly enabled on the port:

```
Device# show spanning-tree interface 0/1 detail
Port 269 (GigabitEthernet1/0/1) of VLAN0002 is forwarding
  Port path cost 4, Port priority 128, Port Identifier 128.297.
  Designated root has priority 32769, address 0013.5f20.01c0
  Designated bridge has priority 32769, address 0013.5f20.01c0
  Designated port id is 128.297, designated path cost 0
  Timers: message age 0, forward delay 0, hold 0
  Number of transitions to forwarding state: 1
  Link type is point-to-point by default
  PVST Simulation is enabled
  BPDU: sent 132, received 1
```

This example shows the interface details when the PVST+ simulation feature is disabled and a PVST Peer inconsistency has been detected on the port:

```
Device# show spanning-tree interface 0/1 detail
Port 269 (GigabitEthernet1/0/1) of VLAN0002 is broken (PVST Peer Inconsistent)
  Port path cost 4, Port priority 128, Port Identifier 128.297.
  Designated root has priority 32769, address 0013.5f20.01c0
  Designated bridge has priority 32769, address 0013.5f20.01c0
  Designated port id is 128.297, designated path cost 0
  Timers: message age 0, forward delay 0, hold 0
  Number of transitions to forwarding state: 1
  Link type is point-to-point by default
  PVST Simulation is disabled
  BPDU: sent 132, received 1
```

Examples: Detecting Unidirectional Link Failure

This example shows the spanning tree status when port **0/1 detail** has been configured to disable PVST+ simulation and the port is currently in the peer type inconsistent state:

```
Device# show spanning-tree
VLAN0010
  Spanning tree enabled protocol rstp
  Root ID      Priority 32778
              Address 0002.172c.f400
              This bridge is the root
              Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
  Bridge ID   Priority 32778 (priority 32768 sys-id-ext 10)
              Address 0002.172c.f400
              Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
              Aging Time 300

Interface      Role Sts Cost      Prio.Nbr Type
-----
Gi0/1          Desg BKN 4          128.270 P2p Dispute
```

This example shows the interface details when a dispute condition is detected:

```
Device# show spanning-tree interface 1/0/1 detail
Port 269 (GigabitEthernet1/0/1) of VLAN0002 is designated blocking (dispute)
  Port path cost 4, Port priority 128, Port Identifier 128.297.
  Designated root has priority 32769, address 0013.5f20.01c0
  Designated bridge has priority 32769, address 0013.5f20.01c0
  Designated port id is 128.297, designated path cost 0
  Timers: message age 0, forward delay 0, hold 0
  Number of transitions to forwarding state: 1
  Link type is point-to-point by default
  BPDU: sent 132, received 1
```

Monitoring MST Configuration and Status

Table 9: Commands for Displaying MST Status

show spanning-tree mst configuration	Displays the MST region configuration.
show spanning-tree mst configuration digest	Displays the MD5 digest included in the current MSTCI.
show spanning-tree mst	Displays MST information for the all instances. Note This command displays information for ports in a link-up operative state.
show spanning-tree mst instance-id	Displays MST information for the specified instance. Note This command displays information only if the port is in a link-up operative state.
show spanning-tree mst interface interface-id	Displays MST information for the specified interface.

Feature Information for MSTP

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Use the Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to www.cisco.com/go/cfn. An account on Cisco.com is not required.

Feature Name	Releases	Feature Information
MSTP	Cisco IOS Release 15.2(7)E1	This feature was introduced.



CHAPTER 3

Configuring Optional Spanning-Tree Features

- [Restriction for Optional Spanning-Tree Features, on page 63](#)
- [Information About Optional Spanning-Tree Features, on page 63](#)
- [How to Configure Optional Spanning-Tree Features, on page 73](#)
- [Configuration Examples for Optional Spanning-Tree Features, on page 87](#)
- [Monitoring the Spanning-Tree Status, on page 89](#)
- [Feature Information for Optional Spanning-Tree Features, on page 90](#)

Restriction for Optional Spanning-Tree Features

- PortFast minimizes the time that interfaces must wait for spanning tree to converge, so it is effective only when used on interfaces connected to end stations. If you enable PortFast on an interface connecting to another switch, you risk creating a spanning-tree loop.

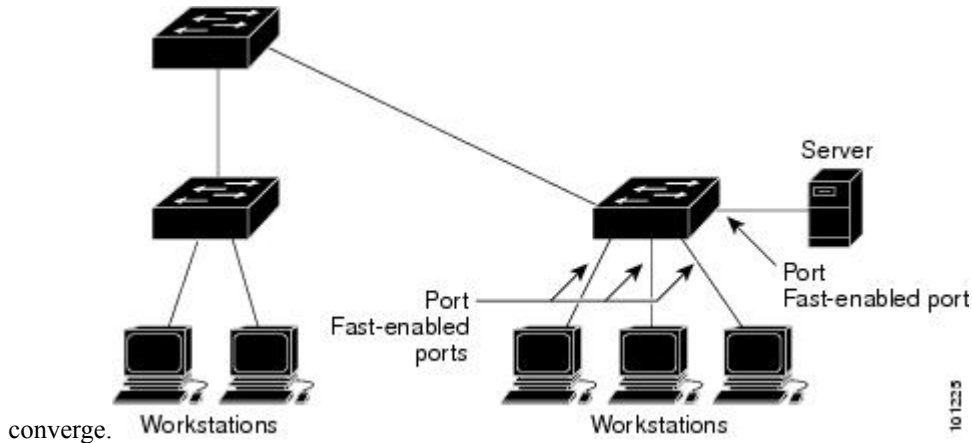
Information About Optional Spanning-Tree Features

PortFast

PortFast immediately brings an interface configured as an access or trunk port to the forwarding state from a blocking state, bypassing the listening and learning states.

Figure 12: PortFast-Enabled Interfaces

You can use PortFast on interfaces connected to a single workstation or server to allow those devices to immediately connect to the network, rather than waiting for the spanning tree to



Interfaces connected to a single workstation or server should not receive bridge protocol data units (BPDUs). An interface with PortFast enabled goes through the normal cycle of spanning-tree status changes when the switch is restarted.

You can enable this feature by enabling it on either the interface or on all nontrunking ports.

BPDU Guard

The Bridge Protocol Data Unit (BPDU) guard feature can be globally enabled on the switch or can be enabled per port, but the feature operates with some differences.

When you enable BPDU guard at the global level on PortFast edge-enabled ports, spanning tree shuts down ports that are in a PortFast edge-operational state if any BPDU is received on them. In a valid configuration, PortFast edge-enabled ports do not receive BPDUs. Receiving a BPDU on a Port Fast edge-enabled port means an invalid configuration, such as the connection of an unauthorized device, and the BPDU guard feature puts the port in the error-disabled state. When this happens, the switch shuts down the entire port on which the violation occurred.

When you enable BPDU guard at the interface level on any port without also enabling the PortFast edge feature, and the port receives a BPDU, it is put in the error-disabled state.

The BPDU guard feature provides a secure response to invalid configurations because you must manually put the interface back in service. Use the BPDU guard feature in a service-provider network to prevent an access port from participating in the spanning tree.

BPDU Filtering

The BPDU filtering feature can be globally enabled on the switch or can be enabled per interface, but the feature operates with some differences.

Enabling BPDU filtering on PortFast edge-enabled interfaces at the global level keeps those interfaces that are in a PortFast edge-operational state from sending or receiving BPDUs. The interfaces still send a few BPDUs at link-up before the switch begins to filter outbound BPDUs. You should globally enable BPDU filtering on a switch so that hosts connected to these interfaces do not receive BPDUs. If a BPDU is received

on a PortFast edge-enabled interface, the interface loses its PortFast edge-operational status, and BPDU filtering is disabled.

Enabling BPDU filtering on an interface without also enabling the PortFast edge feature keeps the interface from sending or receiving BPDUs.



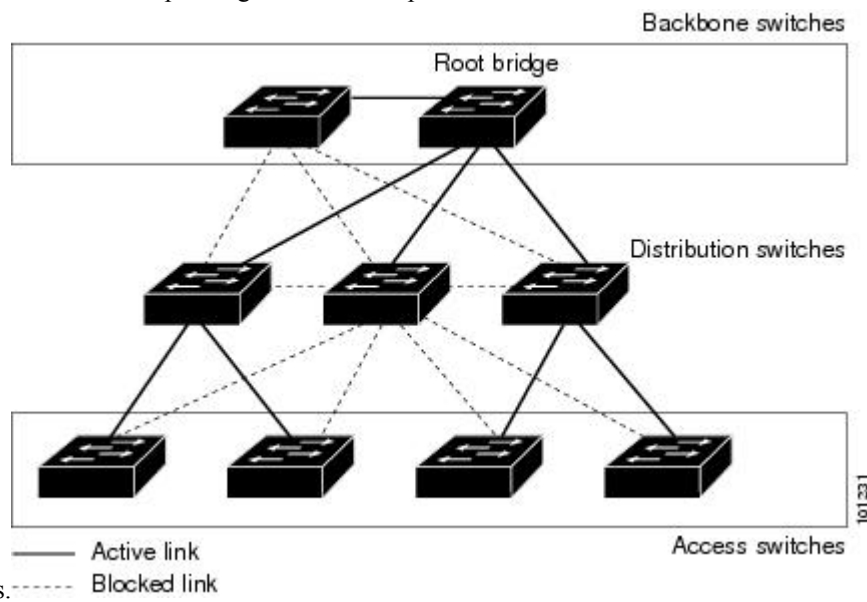
Caution Enabling BPDU filtering on an interface is the same as disabling spanning tree on it and can result in spanning-tree loops.

You can enable the BPDU filtering feature for the entire switch or for an interface.

UplinkFast

Figure 13: Switches in a Hierarchical Network

Switches in hierarchical networks can be grouped into backbone switches, distribution switches, and access switches. This complex network has distribution switches and access switches that each have at least one redundant link that spanning tree blocks to prevent loops.



If a switch loses connectivity, it begins using the alternate paths as soon as the spanning tree selects a new root port. You can accelerate the choice of a new root port when a link or switch fails or when the spanning tree reconfigures itself by enabling UplinkFast. The root port transitions to the forwarding state immediately without going through the listening and learning states, as it would with the normal spanning-tree procedures.

When the spanning tree reconfigures the new root port, other interfaces flood the network with multicast packets, one for each address that was learned on the interface. You can limit these bursts of multicast traffic by reducing the max-update-rate parameter (the default for this parameter is 150 packets per second). However, if you enter zero, station-learning frames are not generated, so the spanning-tree topology converges more slowly after a loss of connectivity.

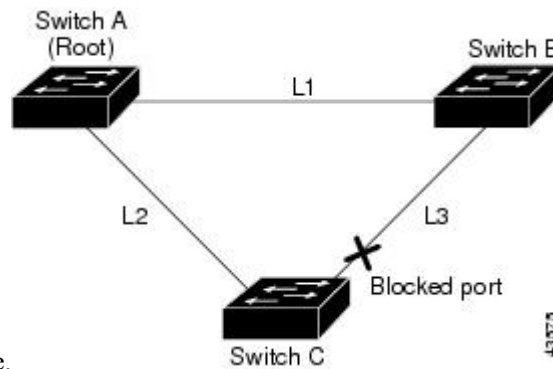


Note UplinkFast is most useful in wiring-closet switches at the access or edge of the network. It is not appropriate for backbone devices. This feature might not be useful for other types of applications.

UplinkFast provides fast convergence after a direct link failure and achieves load-balancing between redundant Layer 2 links using uplink groups. An uplink group is a set of Layer 2 interfaces (per VLAN), only one of which is forwarding at any given time. Specifically, an uplink group consists of the root port (which is forwarding) and a set of blocked ports, except for self-looping ports. The uplink group provides an alternate path in case the currently forwarding link fails.

Figure 14: UplinkFast Example Before Direct Link Failure

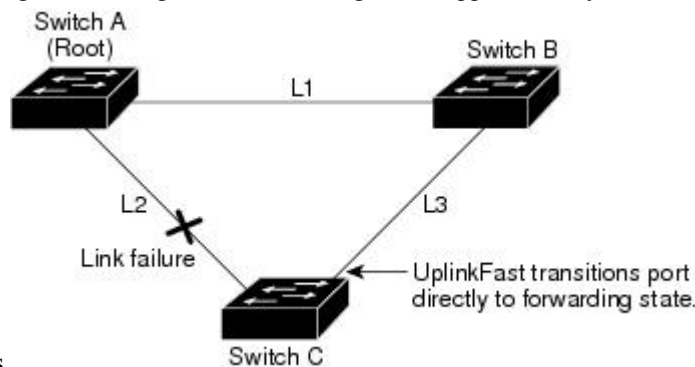
This topology has no link failures. Switch A, the root switch, is connected directly to Switch B over link L1 and to Switch C over link L2. The Layer 2 interface on Switch C that is connected directly to Switch B is in



a blocking state.

Figure 15: UplinkFast Example After Direct Link Failure

If Switch C detects a link failure on the currently active link L2 on the root port (a direct link failure), UplinkFast unblocks the blocked interface on Switch C and transitions it to the forwarding state without going through the listening and learning states. This change takes approximately 1 to



5 seconds.

BackboneFast

BackboneFast detects indirect failures in the core of the backbone. BackboneFast is a complementary technology to the UplinkFast feature, which responds to failures on links directly connected to access switches.

BackboneFast optimizes the maximum-age timer, which controls the amount of time the switch stores protocol information received on an interface. When a switch receives an inferior BPDU from the designated port of

another switch, the BPDU is a signal that the other switch might have lost its path to the root, and BackboneFast tries to find an alternate path to the root.

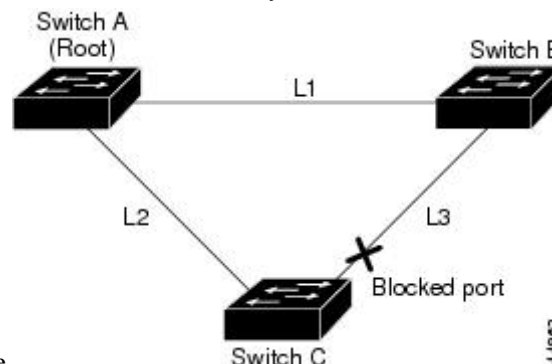
BackboneFast starts when a root port or blocked interface on a switch receives inferior BPDUs from its designated switch. An inferior BPDU identifies a switch that declares itself as both the root bridge and the designated switch. When a switch receives an inferior BPDU, it means that a link to which the switch is not directly connected (an indirect link) has failed (that is, the designated switch has lost its connection to the root switch). Under spanning-tree rules, the switch ignores inferior BPDUs for the maximum aging time (default is 20 seconds).

The switch tries to find if it has an alternate path to the root switch. If the inferior BPDU arrives on a blocked interface, the root port and other blocked interfaces on the switch become alternate paths to the root switch. (Self-looped ports are not considered alternate paths to the root switch.) If the inferior BPDU arrives on the root port, all blocked interfaces become alternate paths to the root switch. If the inferior BPDU arrives on the root port and there are no blocked interfaces, the switch assumes that it has lost connectivity to the root switch, causes the maximum aging time on the root port to expire, and becomes the root switch according to normal spanning-tree rules.

If the switch discovers that it still has an alternate path to the root, it expires the maximum aging time on the interface that received the inferior BPDU. If all the alternate paths to the root switch indicate that the switch has lost connectivity to the root switch, the switch expires the maximum aging time on the interface that received the RLQ reply. If one or more alternate paths can still connect to the root switch, the switch makes all interfaces on which it received an inferior BPDU its designated ports and moves them from the blocking state (if they were in the blocking state), through the listening and learning states, and into the forwarding state.

Figure 16: BackboneFast Example Before Indirect Link Failure

This is an example topology with no link failures. Switch A, the root switch, connects directly to Switch B over link L1 and to Switch C over link L2. The Layer 2 interface on Switch C that connects directly to Switch B



B is in the blocking state.

Figure 17: BackboneFast Example After Indirect Link Failure

If link L1 fails, Switch C cannot detect this failure because it is not connected directly to link L1. However, because Switch B is directly connected to the root switch over L1, it detects the failure, elects itself the root, and begins sending BPDUs to Switch C, identifying itself as the root. When Switch C receives the inferior BPDUs from Switch B, Switch C assumes that an indirect failure has occurred. At that point, BackboneFast allows the blocked interface on Switch C to move immediately to the listening state without waiting for the maximum aging time for the interface to expire. BackboneFast then transitions the Layer 2 interface on Switch C to the forwarding state, providing a path from Switch B to Switch A. The root-switch election takes approximately 30 seconds, twice the Forward Delay time if the default Forward Delay time of 15 seconds is

set. BackboneFast reconfigures the topology to account for the failure of link

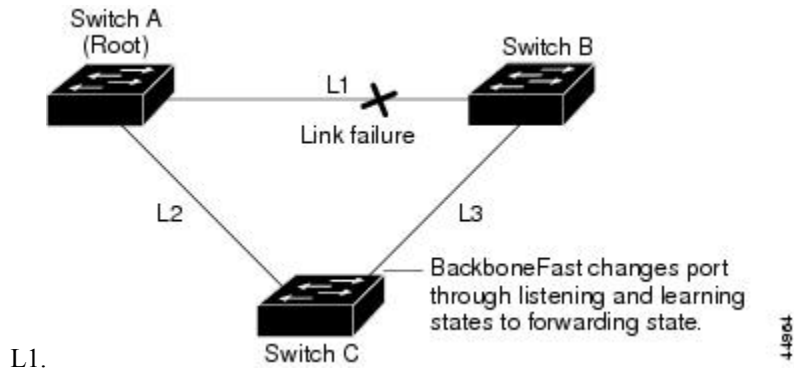
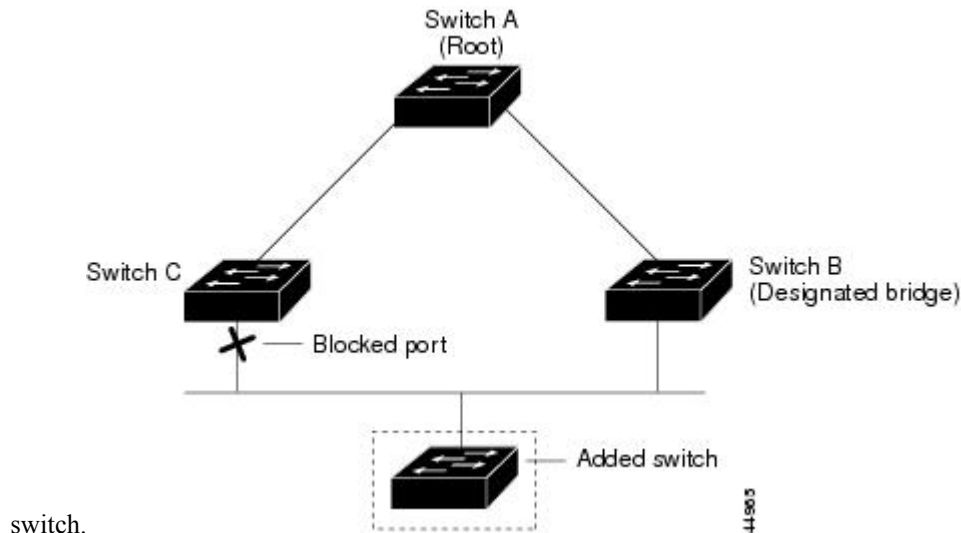


Figure 18: Adding a Switch in a Shared-Medium Topology

If a new switch is introduced into a shared-medium topology, BackboneFast is not activated because the inferior BPDUs did not come from the recognized designated switch (Switch B). The new switch begins sending inferior BPDUs that indicate it is the root switch. However, the other switches ignore these inferior BPDUs, and the new switch learns that Switch B is the designated switch to Switch A, the root



EtherChannel Guard

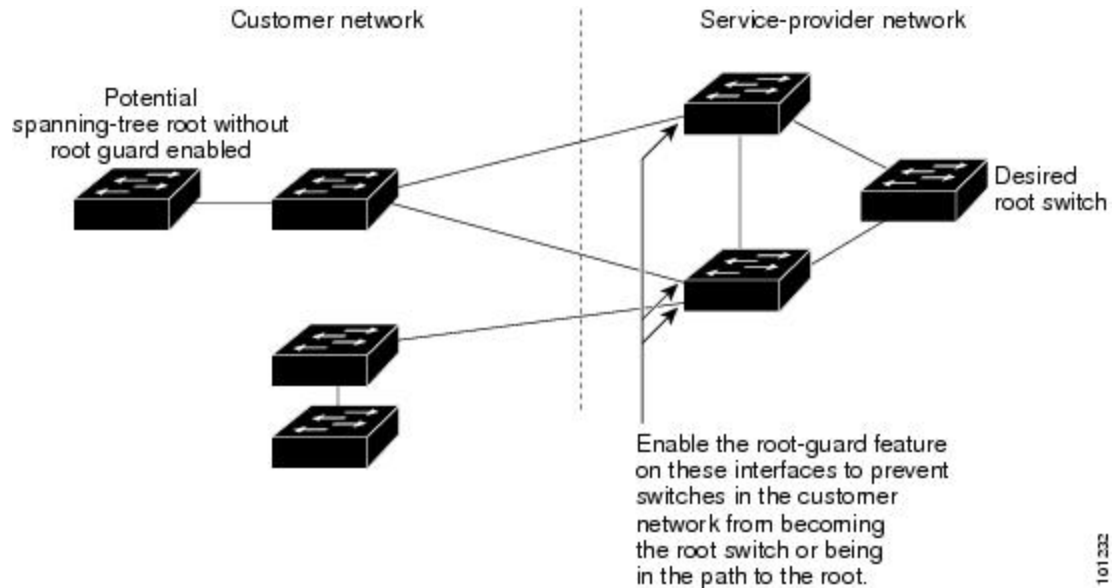
You can use EtherChannel guard to detect an EtherChannel misconfiguration between the switch and a connected device. A misconfiguration can occur if the switch interfaces are configured in an EtherChannel, but the interfaces on the other device are not. A misconfiguration can also occur if the channel parameters are not the same at both ends of the EtherChannel.

If the switch detects a misconfiguration on the other device, EtherChannel guard places the switch interfaces in the error-disabled state, and displays an error message.

Root Guard

Figure 19: Root Guard in a Service-Provider Network

The Layer 2 network of a service provider (SP) can include many connections to switches that are not owned by the SP. In such a topology, the spanning tree can reconfigure itself and select a customer switch as the root switch. You can avoid this situation by enabling root guard on SP switch interfaces that connect to switches in your customer's network. If spanning-tree calculations cause an interface in the customer network to be selected as the root port, root guard then places the interface in the root-inconsistent (blocked) state to prevent the customer's switch from becoming the root switch or being in the path to the root.



If a switch outside the SP network becomes the root switch, the interface is blocked (root-inconsistent state), and spanning tree selects a new root switch. The customer's switch does not become the root switch and is not in the path to the root.

If the switch is operating in multiple spanning-tree (MST) mode, root guard forces the interface to be a designated port. If a boundary port is blocked in an internal spanning-tree (IST) instance because of root guard, the interface also is blocked in all MST instances. A boundary port is an interface that connects to a LAN, the designated switch of which is either an IEEE 802.1D switch or a switch with a different MST region configuration.

Root guard enabled on an interface applies to all the VLANs to which the interface belongs. VLANs can be grouped and mapped to an MST instance.



Caution

Misuse of the root guard feature can cause a loss of connectivity.

Loop Guard

You can use loop guard to prevent alternate or root ports from becoming designated ports because of a failure that leads to a unidirectional link. This feature is most effective when it is enabled on the entire switched

network. Loop guard prevents alternate and root ports from becoming designated ports, and spanning tree does not send BPDUs on root or alternate ports.

When the switch is operating in PVST+ or rapid-PVST+ mode, loop guard prevents alternate and root ports from becoming designated ports, and spanning tree does not send BPDUs on root or alternate ports.

When the switch is operating in MST mode, BPDUs are not sent on nonboundary ports only if the interface is blocked by loop guard in all MST instances. On a boundary port, loop guard blocks the interface in all MST instances.

STP PortFast Port Types

You can configure a spanning tree port as an edge port, a network port, or a normal port. A port can be in only one of these states at a given time. The default spanning tree port type is normal. You can configure the port type either globally or per interface.

Depending on the type of device to which the interface is connected, you can configure a spanning tree port as one of these port types:

- A PortFast edge port—is connected to a Layer 2 host. This can be either an access port or an edge trunk port (**portfast edge trunk**). This type of port interface immediately transitions to the forwarding state, bypassing the listening and learning states. Use PortFast edge on Layer 2 access ports connected to a single workstation or server to allow those devices to connect to the network immediately, rather than waiting for spanning tree to converge.

Even if the interface receives a bridge protocol data unit (BPDU), spanning tree does not place the port into the blocking state. Spanning tree sets the port's operating state to *non-port fast* even if the configured state remains *port fast edge* and starts participating in the topology change.



Note If you configure a port connected to a Layer 2 switch or bridge as an edge port, you might create a bridging loop.

- A PortFast network port—is connected only to a Layer 2 switch or bridge. Bridge Assurance is enabled only on PortFast network ports. For more information, refer to *Bridge Assurance*.



Note If you configure a port that is connected to a Layer 2 host as a spanning tree network port, the port will automatically move into the blocking state.

- A PortFast normal port—is the default type of spanning tree port.



Note Beginning with Cisco IOS Release 15.2(4)E, or IOS XE 3.8.0E, if you enter the **spanning-tree portfast** [trunk] command in the global or interface configuration mode, the system automatically saves it as **spanning-tree portfast edge** [trunk].

Bridge Assurance

You can use Bridge Assurance to help prevent looping conditions that are caused by unidirectional links (one-way traffic on a link or port), or a malfunction in a neighboring switch. Here a malfunction refers to a switch that is not able to run STP any more, while still forwarding traffic (a brain dead switch).

BPDUs are sent out on all operational network ports, including alternate and backup ports, for each hello time period. Bridge Assurance monitors the receipt of BPDUs on point-to-point links on all network ports. When a port does not receive BPDUs within the allotted hello time period, the port is put into a blocked state (the same as a port inconsistent state, which stops forwarding of frames). When the port resumes receipt of BPDUs, the port resumes normal spanning tree operations.

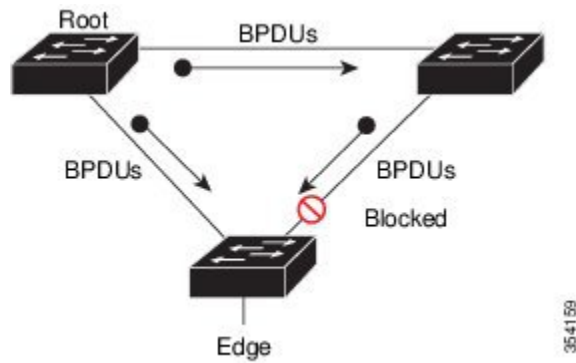


Note Only Rapid PVST+ and MST spanning tree protocols support Bridge Assurance. PVST+ does not support Bridge Assurance.

The following example shows how Bridge Assurance protects your network from bridging loops.

The following figure shows a network with normal STP topology.

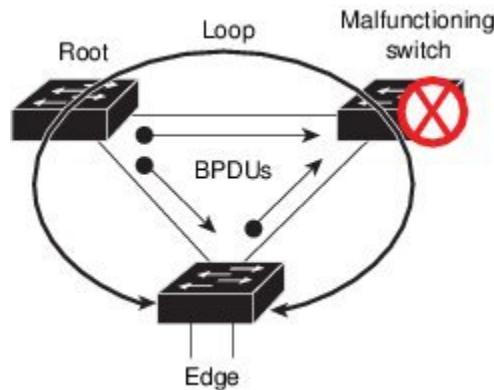
Figure 20: Network with Normal STP Topology



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The following figure demonstrates a potential network problem when the device fails (brain dead) and Bridge Assurance is not enabled on the network.

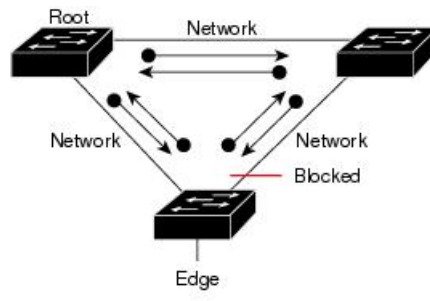
Figure 21: Network Loop Due to a Malfunctioning Switch



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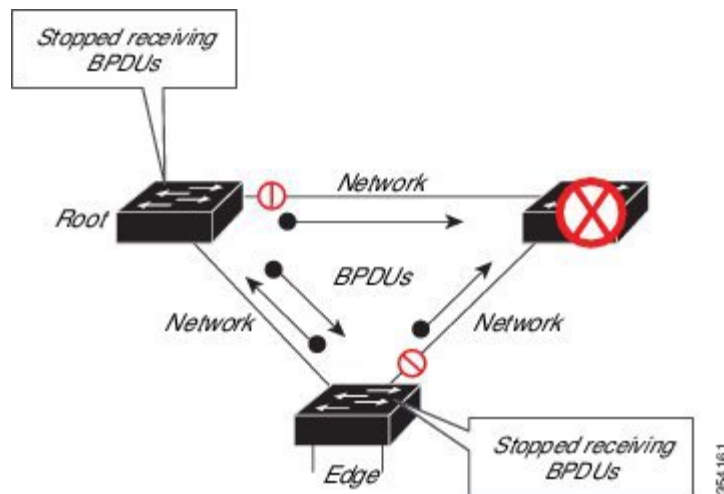
The following figure shows the network with Bridge Assurance enabled, and the STP topology progressing normally with bidirectional BDPUs issuing from every STP network port.

Figure 22: Network with STP Topology Running Bridge Assurance



The following figure shows how the potential network problem shown in figure *Network Loop Due to a Malfunctioning Switch* does not occur when you have Bridge Assurance enabled on your network.

Figure 23: Network Problem Averted with Bridge Assurance Enabled



The system generates syslog messages when a port is block and unblocked. The following sample output shows the log that is generated for each of these states:

BRIDGE_ASSURANCE_BLOCK

```
Sep 17 09:48:16.249 PDT: %SPANTREE-2-BRIDGE_ASSURANCE_BLOCK: Bridge Assurance blocking port
GigabitEthernet1/0/1 on VLAN0001.
```

BRIDGE_ASSURANCE_UNBLOCK

```
Sep 17 09:48:58.426 PDT: %SPANTREE-2-BRIDGE_ASSURANCE_UNBLOCK: Bridge Assurance unblocking
port GigabitEthernet1/0/1 on VLAN0001.
```

Follow these guidelines when enabling Bridge Assurance:

- It can only be enabled or disabled globally.
- It applies to all operational network ports, including alternate and backup ports.

- Only Rapid PVST+ and MST spanning tree protocols support Bridge Assurance. PVST+ does not support Bridge Assurance.
- For Bridge Assurance to work properly, it must be supported and configured on both ends of a point-to-point link. If the device on one side of the link has Bridge Assurance enabled and the device on the other side does not, the connecting port is blocked and in a Bridge Assurance inconsistent state. We recommend that you enable Bridge Assurance throughout your network.
- To enable Bridge Assurance on a port, BPDU filtering and BPDU Guard must be disabled.
- You can enable Bridge Assurance in conjunction with Loop Guard.
- You can enable Bridge Assurance in conjunction with Root Guard. The latter is designed to provide a way to enforce the root bridge placement in the network.

How to Configure Optional Spanning-Tree Features

Enabling PortFast

An interface with the PortFast feature enabled is moved directly to the spanning-tree forwarding state without waiting for the standard forward-time delay.

If you enable the voice VLAN feature, the PortFast feature is automatically enabled. When you disable voice VLAN, the PortFast feature is not automatically disabled.

You can enable this feature if your switch is running PVST+, Rapid PVST+, or MSTP.



Caution

Use PortFast only when connecting a single end station to an access or trunk port. Enabling this feature on an interface connected to a switch or hub could prevent spanning tree from detecting and disabling loops in your network, which could cause broadcast storms and address-learning problems.

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.

	Command or Action	Purpose
Step 3	interface <i>interface-id</i> Example: <pre>Device(config)# interface gigabitethernet 1/0/2</pre> Or <pre>Device(config)# interface fastethernet 1/0/2</pre>	Specifies an interface to configure, and enters interface configuration mode.
Step 4	spanning-tree portfast { disable edge network } Example: <pre>Device(config-if)# spanning-tree portfast edge</pre>	<p>Enables PortFast on an access port connected to a single workstation or server.</p> <p>Enter the following keywords for additional options:</p> <ul style="list-style-type: none"> • Enter disable to disable portfast for the interface. • Enter edge to enable portfast edge for the interface. • Enter network to enable portfast network for the interface. <p>By default, PortFast is disabled on all interfaces.</p>
Step 5	end Example: <pre>Device(config-if)# end</pre>	Returns to privileged EXEC mode.

What to do next

You can use the **spanning-tree portfast default** global configuration command to globally enable the PortFast feature on all nontrunking ports.

Enabling BPDU Guard

You can enable the BPDU guard feature if your switch is running PVST+, Rapid PVST+, or MSTP.

**Caution**

Configure PortFast edge only on ports that connect to end stations; otherwise, an accidental topology loop could cause a data packet loop and disrupt switch and network operation.

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: Device (config)# interface gigabitethernet 1/0/2 Or Device (config)# interface fastethernet 1/0/2	Specifies the interface connected to an end station, and enters interface configuration mode.
Step 4	spanning-tree portfast edge Example: Device (config-if)# spanning-tree portfast edge	Enables the PortFast edge feature.
Step 5	end Example: Device (config-if)# end	Returns to privileged EXEC mode.

What to do next

To prevent the port from shutting down, you can use the **errdisable detect cause bpduguard shutdown vlan** global configuration command to shut down just the offending VLAN on the port where the violation occurred.

You also can use the **spanning-tree bpduguard enable** interface configuration command to enable BPDU guard on any port without also enabling the PortFast edge feature. When the port receives a BPDU, it is put in the error-disabled state.

Enabling BPDU Filtering

You can also use the **spanning-tree bpdudfilter enable** interface configuration command to enable BPDU filtering on any interface without also enabling the PortFast edge feature. This command prevents the interface from sending or receiving BPDUs.



Caution Enabling BPDU filtering on an interface is the same as disabling spanning tree on it and can result in spanning-tree loops.

You can enable the BPDU filtering feature if your switch is running PVST+, Rapid PVST+, or MSTP.



Caution Configure PortFast edge only on interfaces that connect to end stations; otherwise, an accidental topology loop could cause a data packet loop and disrupt switch and network operation.

This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree portfast edge bpdufilter default Example: Device(config)# spanning-tree portfast edge bpdufilter default	Globally enables BPDU filtering. By default, BPDU filtering is disabled.
Step 4	interface interface-id Example: Device(config)# interface gigabitethernet 1/0/2 Or Device(config)# interface fastethernet 1/0/2 Example:	Specifies the interface connected to an end station, and enters interface configuration mode.
Step 5	spanning-tree portfast edge Example: Device(config-if)# spanning-tree portfast edge	Enables the PortFast edge feature on the specified interface.

	Command or Action	Purpose
Step 6	end Example: Device(config-if)# end	Returns to privileged EXEC mode.

Enabling UplinkFast for Use with Redundant Links



Note When you enable UplinkFast, it affects all VLANs on the switch. You cannot configure UplinkFast on an individual VLAN.

You can configure the UplinkFast feature for Rapid PVST+ or for the MSTP, but the feature remains disabled (inactive) until you change the spanning-tree mode to PVST+.

This procedure is optional. Follow these steps to enable UplinkFast and CSUF.

Before you begin

UplinkFast cannot be enabled on VLANs that have been configured with a switch priority. To enable UplinkFast on a VLAN with switch priority configured, first restore the switch priority on the VLAN to the default value using the **no spanning-tree vlan *vlan-id* priority** global configuration command.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree uplinkfast [max-update-rate pkts-per-second] Example: Device(config)# spanning-tree uplinkfast max-update-rate 200	Enables UplinkFast. (Optional) For <i>pkts-per-second</i> , the range is 0 to 32000 packets per second; the default is 150. If you set the rate to 0, station-learning frames are not generated, and the spanning-tree topology converges more slowly after a loss of connectivity.

	Command or Action	Purpose
		When you enter this command, CSUF also is enabled on all nonstack port interfaces.
Step 4	end Example: Device(config)# end	Returns to privileged EXEC mode.

When UplinkFast is enabled, the switch priority of all VLANs is set to 49152. If you change the path cost to a value less than 3000 and you enable UplinkFast or UplinkFast is already enabled, the path cost of all interfaces and VLAN trunks is increased by 3000 (if you change the path cost to 3000 or above, the path cost is not altered). The changes to the switch priority and the path cost reduce the chance that a switch will become the root switch.

When UplinkFast is disabled, the switch priorities of all VLANs and path costs of all interfaces are set to default values if you did not modify them from their defaults.

When you enable the UplinkFast feature using these instructions, CSUF is automatically globally enabled on nonstack port interfaces.

Disabling UplinkFast

This procedure is optional.

Follow these steps to disable UplinkFast and Cross-Stack UplinkFast (CSUF).

Before you begin

UplinkFast must be enabled.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	no spanning-tree uplinkfast Example: Device(config)# no spanning-tree uplinkfast	Disables UplinkFast and CSUF on the switch and all of its VLANs.

	Command or Action	Purpose
Step 4	<pre>end</pre> <p>Example:</p> <pre>Device(config-if) # end</pre>	Returns to privileged EXEC mode.

When UplinkFast is disabled, the switch priorities of all VLANs and path costs of all interfaces are set to default values if you did not modify them from their defaults.

When you disable the UplinkFast feature using these instructions, CSUF is automatically globally disabled on nonstack port interfaces.

Enabling BackboneFast

You can enable BackboneFast to detect indirect link failures and to start the spanning-tree reconfiguration sooner.

You can configure the BackboneFast feature for Rapid PVST+ or for the MSTP, but the feature remains disabled (inactive) until you change the spanning-tree mode to PVST+.

This procedure is optional. Follow these steps to enable BackboneFast on the switch.

Before you begin

If you use BackboneFast, you must enable it on all switches in the network. BackboneFast is not supported on Token Ring VLANs. This feature is supported for use with third-party switches.

Procedure

	Command or Action	Purpose
Step 1	<pre>enable</pre> <p>Example:</p> <pre>Device> enable</pre>	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	<pre>configure terminal</pre> <p>Example:</p> <pre>Device# configure terminal</pre>	Enters global configuration mode.
Step 3	<pre>spanning-tree backbonefast</pre> <p>Example:</p> <pre>Device(config) # spanning-tree backbonefast</pre>	Enables BackboneFast.
Step 4	<pre>end</pre> <p>Example:</p>	Returns to privileged EXEC mode.

	Command or Action	Purpose
	Device (config-if) # end	

Enabling EtherChannel Guard

You can enable EtherChannel guard to detect an EtherChannel misconfiguration if your device is running PVST+, Rapid PVST+, or MSTP.

This procedure is optional.

Follow these steps to enable EtherChannel Guard on the device.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree etherchannel guard misconfig Example: Device (config) # spanning-tree etherchannel guard misconfig	Enables EtherChannel guard.
Step 4	end Example: Device (config-if) # end	Returns to privileged EXEC mode.

What to do next

You can use the **show interfaces status err-disabled** privileged EXEC command to show which device ports are disabled because of an EtherChannel misconfiguration. On the remote device, you can enter the **show etherchannel summary** privileged EXEC command to verify the EtherChannel configuration.

After the configuration is corrected, enter the **shutdown** and **no shutdown** interface configuration commands on the port-channel interfaces that were misconfigured.

Enabling Root Guard

Root guard enabled on an interface applies to all the VLANs to which the interface belongs. Do not enable the root guard on interfaces to be used by the UplinkFast feature. With UplinkFast, the backup interfaces (in the blocked state) replace the root port in the case of a failure. However, if root guard is also enabled, all the backup interfaces used by the UplinkFast feature are placed in the root-inconsistent state (blocked) and are prevented from reaching the forwarding state.



Note You cannot enable both root guard and loop guard at the same time.

You can enable this feature if your switch is running PVST+, Rapid PVST+, or MSTP.

This procedure is optional.

Follow these steps to enable root guard on the switch.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/2 Or Device(config)# interface fastethernet 1/0/2	Specifies an interface to configure, and enters interface configuration mode.
Step 4	spanning-tree guard root Example: Device(config-if)# spanning-tree guard root	Enables root guard on the interface. By default, root guard is disabled on all interfaces.
Step 5	end Example: Device(config-if)# end	Returns to privileged EXEC mode.

Enabling Loop Guard

You can use loop guard to prevent alternate or root ports from becoming designated ports because of a failure that leads to a unidirectional link. This feature is most effective when it is configured on the entire switched network. Loop guard operates only on interfaces that are considered point-to-point by the spanning tree.



Note You cannot enable both loop guard and root guard at the same time.

You can enable this feature if your device is running PVST+, Rapid PVST+, or MSTP.

This procedure is optional. Follow these steps to enable loop guard on the device.

Procedure

	Command or Action	Purpose
Step 1	Enter one of the following commands: <ul style="list-style-type: none"> • <code>show spanning-tree active</code> • <code>show spanning-tree mst</code> Example: Device# <code>show spanning-tree active</code> or Device# <code>show spanning-tree mst</code>	Verifies which interfaces are alternate or root ports.
Step 2	configure terminal Example: Device# <code>configure terminal</code>	Enters global configuration mode.
Step 3	spanning-tree loopguard default Example: Device(config)# <code>spanning-tree loopguard default</code>	Enables loop guard. By default, loop guard is disabled.
Step 4	end Example: Device(config-if)# <code>end</code>	Returns to privileged EXEC mode.

Enabling PortFast Port Types

This section describes the different steps to enable Portfast Port types.

Configuring the Default Port State Globally

To configure the default PortFast state, perform this task:

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	spanning-tree portfast [edge network normal] default Example: Device(config)# spanning-tree portfast default	Configures the default state for all interfaces on the switch. You have these options: <ul style="list-style-type: none"> • (Optional) edge—Configures all interfaces as edge ports. This assumes all ports are connected to hosts/servers. • (Optional) network—Configures all interfaces as spanning tree network ports. This assumes all ports are connected to switches and bridges. Bridge Assurance is enabled on all network ports by default. • (Optional) normal—Configures all interfaces normal spanning tree ports. These ports can be connected to any type of device. • default—The default port type is normal.
Step 4	end Example: Device(config-if)# end	Returns to privileged EXEC mode.

Configuring PortFast Edge on a Specified Interface

Interfaces configured as edge ports immediately transition to the forwarding state, without passing through the blocking or learning states, on linkup.



Note Because the purpose of this type of port is to minimize the time that access ports must wait for spanning tree to converge, it is most effective when used on access ports. If you enable PortFast edge on a port connecting to another switch, you risk creating a spanning tree loop.

To configure an edge port on a specified interface, perform this task:

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> port-channel <i>port_channel_number</i> Example: Device (config)# interface gigabitethernet 1/0/2 Or Device (config)# interface fastethernet 1/0/2	Specifies an interface to configure.
Step 4	spanning-tree portfast edge [trunk] Example: Device (config-if)# spanning-tree portfast trunk	Enables edge behavior on a Layer 2 access port connected to an end workstation or server. <ul style="list-style-type: none"> • (Optional) trunk—Enables edge behavior on a trunk port. Use this keyword if the link is a trunk. Use this command only on ports that are connected to end host devices that terminate VLANs and from which the port should never receive STP BPDUs. Such end host devices include workstations, servers, and ports on routers that are not configured to support bridging. • Use the no version of the command to disable PortFast edge.
Step 5	end Example:	Exits configuration mode.

	Command or Action	Purpose
	Device(config-if)# end	
Step 6	show running interface <i>interface-id</i> port-channel <i>port_channel_number</i> Example: Device# show running interface gigabitethernet 1/0/2 Or Device# show running interface fastethernet 1/0/2	Verifies the configuration.

Configuring a PortFast Network Port on a Specified Interface

Ports that are connected to Layer 2 switches and bridges can be configured as network ports.



Note Bridge Assurance is enabled only on PortFast network ports. For more information, refer to *Bridge Assurance*.

To configure a port as a network port, perform this task.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> port-channel <i>port_channel_number</i> Example: Device(config)# interface gigabitethernet 1/0/1 Or Device(config)# interface fastethernet 1/0/1	Specifies an interface to configure.

	Command or Action	Purpose
Step 4	spanning-tree portfast network Example: <pre>Device(config-if)# spanning-tree portfast network</pre>	Enables edge behavior on a Layer 2 access port connected to an end workstation or server. <ul style="list-style-type: none"> • Configures the port as a network port. If you have enabled Bridge Assurance globally, it automatically runs on a spanning tree network port. • Use the no version of the command to disable PortFast.
Step 5	end Example: <pre>Device(config-if)# end</pre>	Exits configuration mode.
Step 6	show running interface <i>interface-id</i> port-channel <i>port_channel_number</i> Example: <pre>Device# show running interface gigabitethernet 1/0/1</pre> Or <pre>Device# show running interface fastethernet 1/0/1</pre>	Verifies the configuration.

Enabling Bridge Assurance

To configure the Bridge Assurance, perform the steps given below:

Procedure

	Command or Action	Purpose
Step 1	enable Example: <pre>Device> enable</pre>	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: <pre>Device# configure terminal</pre>	Enters global configuration mode.
Step 3	spanning-tree bridge assurance Example:	Enables Bridge Assurance on all network ports on the switch. Bridge Assurance is enabled by default.

	Command or Action	Purpose
	Device(config)# spanning-tree bridge assurance	Use the no version of the command to disable the feature. Disabling Bridge Assurance causes all configured network ports to behave as normal spanning tree ports.
Step 4	end Example: Device(config-if)# end	Returns to privileged EXEC mode.
Step 5	show spanning-tree summary Example: Device# show spanning-tree summary	Displays spanning tree information and shows if Bridge Assurance is enabled.

Configuration Examples for Optional Spanning-Tree Features

Examples: Configuring PortFast Edge on a Specified Interface

This example shows how to enable edge behavior on GigabitEthernet interface 1/0/1:

```
Switch# configure terminal
Switch(config)# interface gigabitethernet 1/0/1
Switch(config-if)# spanning-tree portfast edge
Switch(config-if)# end
Switch#
```

This example shows how to verify the configuration:

```
Switch# show running-config interface gigabitethernet 1/0/1
Building configuration...
Current configuration:
!
interface GigabitEthernet1/0/1
no ip address
switchport
switchport access vlan 200
switchport mode access
spanning-tree portfast edge
end
```

This example shows how you can display that port GigabitEthernet1/0/1 is currently in the edge state:

```
Switch# show spanning-tree vlan 200
VLAN0200
Spanning tree enabled protocol rstp
Root ID Priority 2
Address 001b.2a68.5fc0
Cost 3
Port 125 (GigabitEthernet1/5/9)
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
Bridge ID Priority 2 (priority 0 sys-id-ext 2)
Address 7010.5c9c.5200
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
```

```

Aging Time 0 sec
Interface Role Sts Cost Prio.Nbr Type
-----
Gi0/1 Desg FWD 4 128.1 P2p Edge

```

Examples: Configuring a PortFast Network Port on a Specified Interface

This example shows how to configure GigabitEthernet interface 1/0/1 as a network port:

```

Switch# configure terminal
Switch(config)# interface gigabitethernet 1/0/1
Switch(config-if)# spanning-tree portfast network
Switch(config-if)# end
Switch#

```

This example shows how to verify the configuration:

```

Switch# show running-config interface gigabitethernet 1/0/1
Building configuration...
Current configuration:
!
interface GigabitEthernet1/0/1
no ip address
switchport
switchport access vlan 200
switchport mode access
spanning-tree portfast network
end

```

This example shows the output for show spanning-tree vlan

```

Switch# show spanning-tree vlan
Sep 17 09:51:36.370 PDT: %SYS-5-CONFIG_I: Configured from console by console2

VLAN0002
  Spanning tree enabled protocol rstp
  Root ID    Priority    2
             Address     7010.5c9c.5200
             This bridge is the root
             Hello Time 2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    2          (priority 0 sys-id-ext 2)
             Address     7010.5c9c.5200
             Hello Time 2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 0    sec

Interface          Role Sts Cost      Prio.Nbr Type
-----
Gi1/0/1            Desg FWD 4         128.1   P2p Edge
Po4                Desg FWD 3         128.480 P2p Network
Gi4/0/1            Desg FWD 4         128.169 P2p Edge
Gi4/0/47           Desg FWD 4         128.215 P2p Network

Switch#

```

Example: Configuring Bridge Assurance

This output shows port GigabitEthernet 1/0/1 has been configured as a network port and it is currently in the Bridge Assurance inconsistent state.

Command	Purpose
show spanning-tree interface <i>interface-id</i>	Displays spanning-tree information for the specified interface.
show spanning-tree mst interface <i>interface-id</i>	Displays MST information for the specified interface.
show spanning-tree summary [totals]	Displays a summary of interface states or displays the total lines of the spanning-tree state section.
show spanning-tree mst interface <i>interface-id</i> portfast edge	Displays spanning-tree portfast information for the specified interface.

Feature Information for Optional Spanning-Tree Features

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Use the Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to www.cisco.com/go/cfn. An account on Cisco.com is not required.

Feature Name	Releases	Feature Information
Optional Spanning-Tree Features	Cisco IOS Release 15.2(7)E1	This feature was introduced.



CHAPTER 4

Configuring Resilient Ethernet Protocol

- [Overview of Resilient Ethernet Protocol, on page 91](#)
- [How to Configure Resilient Ethernet Protocol, on page 96](#)
- [Monitoring Resilient Ethernet Protocol Configuration, on page 104](#)
- [Configuration Examples for Resilient Ethernet Protocol, on page 106](#)
- [Feature Information for Resilient Ethernet Protocol, on page 107](#)

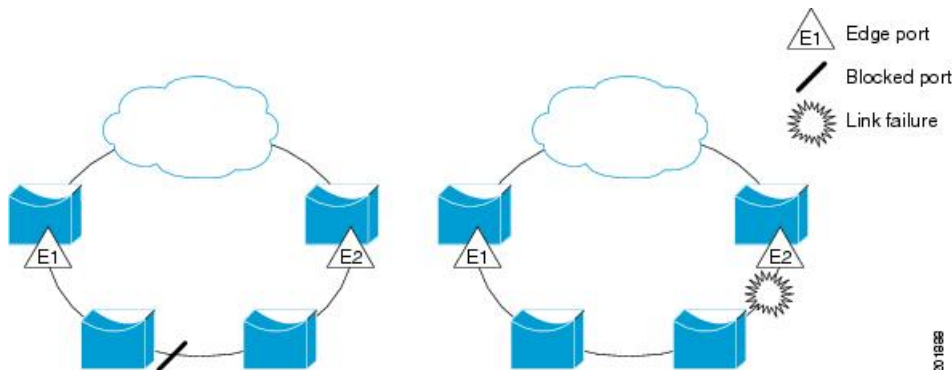
Overview of Resilient Ethernet Protocol

Resilient Ethernet Protocol (REP) is a Cisco-proprietary protocol that provides an alternative to Spanning Tree Protocol (STP) to control network loops, handle link failures, and improve convergence time. REP controls a group of ports connected in a segment, ensures that the segment does not create any bridging loops, and responds to link failures within the segment. REP provides a basis for constructing more complex networks and supports VLAN load balancing.

A REP segment is a chain of ports connected to each other and configured with a segment ID. Each segment consists of standard (nonedge) segment ports and two user-configured edge ports. A device can have no more than two ports that belong to the same segment, and each segment port can have only one external neighbor. A segment can go through a shared medium, but on any link, only two ports can belong to the same segment. REP is supported only on Trunk Ethernet Flow Point (EFP) interfaces.

The following figure shows an example of a segment consisting of six ports spread across four switches. Ports E1 and E2 are configured as edge ports. When all the ports are operational (as in the segment on the left), a single port is blocked, as shown by the diagonal line. When there is a failure in the network, the blocked port returns to the forwarding state to minimize network disruption.

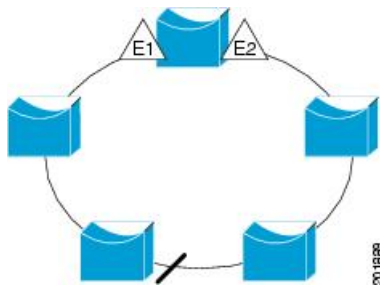
Figure 24: REP Open Segment



The segment shown in the figure above is an open segment; there is no connectivity between the two edge ports. The REP segment cannot cause a bridging loop, and you can safely connect the segment edges to any network. All the hosts connected to devices inside the segment have two possible connections to the rest of the network through the edge ports, but only one connection is accessible at any time. If a failure occurs on any segment or on any port on a REP segment, REP unblocks all the ports to ensure that connectivity is available through the other gateway.

The segment shown in the following figure is a ring segment, with both the edge ports located on the same device. With this configuration, you can create a redundant connection between any two devices in the segment.

Figure 25: REP Ring Segment



REP segments have the following characteristics:

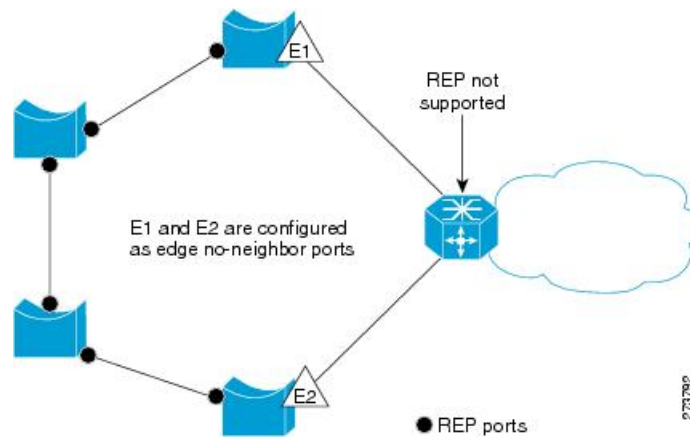
- If all the ports in a segment are operational, one port (referred to as the *alternate* port) is in the blocked state for each VLAN. If VLAN load balancing is configured, two ports in the segment control the blocked state of VLANs.
- If one or more ports in a segment is not operational, and cause a link failure, all the ports forward traffic on all the VLANs to ensure connectivity.
- In case of a link failure, alternate ports are unblocked as quickly as possible. When the failed link is up, a logically blocked port per VLAN is selected with minimal disruption to the network.

You can construct almost any type of network based on REP segments. REP also supports VLAN load balancing, which is controlled by the primary edge port (any port in the segment).

In access ring-topologies, the neighboring switch might not support REP as shown in the following figure. In this scenario, you can configure the non-REP-facing ports (E1 and E2) as edge no-neighbor ports. These ports inherit all the properties of edge ports, and you can configure them the same as any edge port, including

configuring them to send STP or REP topology change notices to the aggregation switch. In this scenario, the STP topology change notice (TCN) that is sent is a multiple spanning-tree (MST) STP message.

Figure 26: Edge No-Neighbor Ports



REP has these limitations:

- You must configure each segment port; an incorrect configuration might cause forwarding loops in the networks.
- REP can manage only a single failed port within the segment; multiple port failures within the REP segment cause loss of network connectivity.
- You should configure REP only in networks with redundancy. Configuring REP in a network without redundancy causes loss of connectivity.

Link Integrity

REP does not use an end-to-end polling function between edge ports to verify link integrity. It implements local link failure detection. The REP Link Status Layer (LSL) detects its REP-aware neighbor and establishes connectivity within the segment. All the VLANs are blocked on an interface until the neighbor is detected. After the neighbor is identified, REP determines which neighbor port should become the alternate port and which ports should forward traffic.

Each port in a segment has a unique port ID. The port ID format is similar to that used by the spanning tree algorithm: a port number (unique on the bridge) associated to a MAC address (unique in the network). When a segment port is coming up, its LSL starts sending packets that include the segment ID and the port ID. The port is declared as operational after it performs a three-way handshake with a neighbor in the same segment.

A segment port does not become operational if:

- No neighbor has the same segment ID.
- More than one neighbor has the same segment ID.
- A neighbor does not acknowledge a local port as a peer.

Each port creates an adjacency with its immediate neighbor. After the neighbor adjacencies are created, the ports negotiate with each other to determine the blocked port for the segment, which will function as the alternate port. All the other ports become unblocked. By default, REP packets are sent to a bridge protocol

data unit-class MAC address. The packets can also be sent to a Cisco multicast address, which is used only to send blocked port advertisement (BPA) messages when there is a failure in the segment. The packets are dropped by the devices not running REP.

Fast Convergence

REP runs on a physical link basis and not on a per-VLAN basis. Only one hello message is required for all the VLANs, and this reduces the load on the protocol. We recommend that you create VLANs consistently on all the switches in a given segment and configure the same allowed VLANs on the REP trunk ports. To avoid the delay introduced by relaying messages in software, REP also allows some packets to be flooded to a regular multicast address. These messages operate at the hardware flood layer (HFL) and are flooded to the entire network, not just the REP segment. Switches that do not belong to the segment treat them as data traffic. You can control flooding of these messages by configuring an administrative VLAN for the entire domain or for a particular segment.

VLAN Load Balancing

One edge port in the REP segment acts as the primary edge port; and another as the secondary edge port. It is the primary edge port that always participates in VLAN load balancing in the segment. REP VLAN balancing is achieved by blocking some VLANs at a configured alternate port and all the other VLANs at the primary edge port. When you configure VLAN load balancing, you can specify the alternate port in one of three ways:

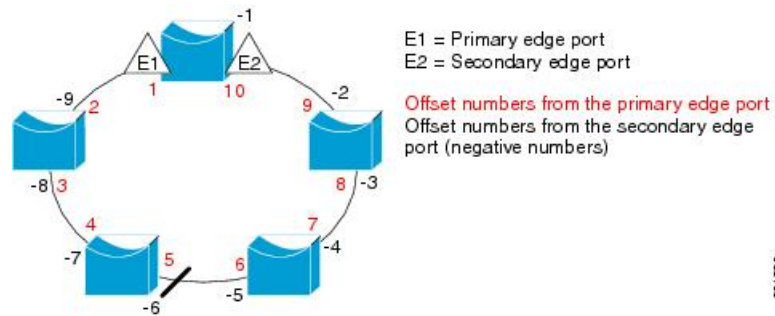
- By entering the port ID of the interface. To identify the port ID of a port in the segment, enter the **show interface rep detail** interface configuration command for the port.
- By entering the **preferred** keyword to select the port that you previously configured as the preferred alternate port with the **rep segment segment-id preferred** interface configuration command.
- By entering the neighbor offset number of a port in the segment, which identifies the downstream neighbor port of an edge port. The neighbor offset number range is -256 to $+256$; a value of 0 is invalid. The primary edge port has an offset number of 1; positive numbers above 1 identify downstream neighbors of the primary edge port. Negative numbers indicate the secondary edge port (offset number -1) and its downstream neighbors.



Note Configure offset numbers on the primary edge port by identifying a port's downstream position from the primary (or secondary) edge port. Never enter an offset value of 1 because that is the offset number of the primary edge port.

The following figure shows neighbor offset numbers for a segment, where E1 is the primary edge port and E2 is the secondary edge port. The red numbers inside the ring are numbers offset from the primary edge port; the black numbers outside of the ring show the offset numbers from the secondary edge port. Note that you can identify all the ports (except the primary edge port) by either a positive offset number (downstream position from the primary edge port) or a negative offset number (downstream position from the secondary edge port). If E2 became the primary edge port, its offset number would then be 1 and E1 would be -1.

Figure 27: Neighbor Offset Numbers in a Segment



When the REP segment is complete, all the VLANs are blocked. When you configure VLAN load balancing, you must also configure triggers in one of two ways:

- Manually trigger VLAN load balancing at any time by entering the **rep preempt segment** *segment-id* privileged EXEC command on the switch that has the primary edge port.
- Configure a preempt delay time by entering the **rep preempt delay** *seconds* interface configuration command. After a link failure and recovery, VLAN load balancing begins after the configured preemption time period elapses. Note that the delay timer restarts if another port fails before the time has elapsed.



Note When VLAN load balancing is configured, it does not start working until triggered by either manual intervention or a link failure and recovery.

When VLAN load balancing is triggered, the primary edge port sends out a message to alert all the interfaces in the segment about the preemption. When the secondary port receives the message, the message is sent to the network to notify the alternate port to block the set of VLANs specified in the message and to notify the primary edge port to block the remaining VLANs.

You can also configure a particular port in the segment to block all the VLANs. Only the primary edge port initiates VLAN load balancing, which is not possible if the segment is not terminated by an edge port on each end. The primary edge port determines the local VLAN load-balancing configuration.

Reconfigure the primary edge port to reconfigure load balancing. When you change the load-balancing configuration, the primary edge port waits for the **rep preempt segment** command or for the configured preempt delay period after a port failure and recovery, before executing the new configuration. If you change an edge port to a regular segment port, the existing VLAN load-balancing status does not change. Configuring a new edge port might cause a new topology configuration.

Spanning Tree Interaction

REP does not interact with the STP feature but can coexist with it. REP does not interact with the Flex Link feature, but can coexist with it also. A port that belongs to a segment is removed from spanning tree control, and STP BPDUs are not accepted or sent from segment ports. Therefore, STP cannot run on a segment.

To migrate from an STP ring configuration to an REP segment configuration, begin by configuring a single port in the ring as part of the segment and continue by configuring contiguous ports to minimize the number of segments. Since each segment always contains a blocked port, multiple segments means multiple blocked

ports and a potential loss of connectivity. After the segment is configured in both directions up to the location of the edge ports, configure the edge ports.

REP Ports

REP segments consist of Failed, Open, or Alternate ports:

- A port configured as a regular segment port starts as a failed port.
- After the neighbor adjacencies are determined, the port transitions to alternate port state, blocking all the VLANs on the interface. Blocked-port negotiations occur, and when the segment settles, one blocked port remains in the alternate role and all the other ports become open ports.
- When a failure occurs in a link, all the ports move to the Failed state. When the Alternate port receives the failure notification, it changes to the Open state, forwarding all the VLANs.

A regular segment port converted to an edge port, or an edge port converted to a regular segment port, does not always result in a topology change. If you convert an edge port into a regular segment port, VLAN load balancing is not implemented unless it has been configured. For VLAN load balancing, you must configure two edge ports in the segment.

A segment port that is reconfigured as a spanning tree port restarts according to the spanning tree configuration. By default, this is a designated blocking port. If PortFast is configured or if STP is disabled, the port goes into the forwarding state.

How to Configure Resilient Ethernet Protocol

A segment is a collection of ports connected to one another in a chain and configured with a segment ID. To configure REP segments, configure the REP administrative VLAN (or use the default VLAN 1) and then add the ports to the segment, using interface configuration mode. You should configure two edge ports in a segment, with one of them being the primary edge port and the other the secondary edge port by default. A segment should have only one primary edge port. If you configure two ports in a segment as primary edge ports, for example, ports on different switches, the REP selects one of them to serve as the segment's primary edge port. If required, you can configure the location to which segment topology change notices (STCNs) and VLAN load balancing are to be sent.

Default REP Configuration

REP is disabled on all the interfaces. When enabled, the interface is a regular segment port unless it is configured as an edge port.

When REP is enabled, the task of sending segment topology change notices (STCNs) is disabled, all the VLANs are blocked, and the administrative VLAN is VLAN 1.

When VLAN load balancing is enabled, the default is manual preemption with the delay timer disabled. If VLAN load balancing is not configured, the default after manual preemption is to block all the VLANs in the primary edge port.

REP Configuration Guidelines

Follow these guidelines when configuring REP:

- We recommend that you begin by configuring one port and then configure contiguous ports to minimize the number of segments and the number of blocked ports.
- If more than two ports in a segment fail when no external neighbors are configured, one port goes into a forwarding state for the data path to help maintain connectivity during configuration. In the **show rep interface** command output, the Port Role for this port is displayed as **Fail Logical Open**; the Port Role for the other failed port is displayed as **Fail No Ext Neighbor**. When the external neighbors for the failed ports are configured, the ports go through the alternate port transitions and eventually go to an open state, or remain as the alternate port, based on the alternate port selection mechanism.
- REP ports must be Layer 2 IEEE 802.1Q or Trunk ports.
- We recommend that you configure all the trunk ports in a segment with the same set of allowed VLANs.
- Be careful when configuring REP through a Telnet connection because REP blocks all the VLANs until another REP interface sends a message to unblock it. You might lose connectivity to the router if you enable REP in a Telnet session that accesses the router through the same interface.
- You cannot run REP and STP on the same segment or interface.
- You cannot run REP and Flex Links on the same segment or interface.
- If you connect an STP network to an REP segment, be sure that the connection is at the segment edge. An STP connection that is not at the edge might cause a bridging loop because STP does not run on REP segments. All the STP BPDUs are dropped at REP interfaces.
- You must configure all the trunk ports in a segment with the same set of allowed VLANs. If this is not done, misconfiguration occurs.
- If REP is enabled on two ports on a switch, both the ports must be either regular segment ports or edge ports. REP ports follow these rules:
 - There is no limit to the number of REP ports on a switch. However, only two ports on a switch can belong to the same REP segment.
 - If only one port on a switch is configured in a segment, the port should be an edge port.
 - If two ports on a switch belong to the same segment, they must both be edge ports, regular segment ports, or one regular port and one edge no-neighbor port. An edge port and regular segment port on a switch cannot belong to the same segment.
 - If two ports on a switch belong to the same segment, and one is configured as an edge port and one as a regular segment port (a misconfiguration), the edge port is treated as a regular segment port.
- REP interfaces come up in a blocked state and remain in a blocked state until they are safe to be unblocked. You must, therefore, be aware of the status of REP interfaces to avoid sudden connection losses.
- REP sends all the LSL PDUs in the untagged frames to the native VLAN. The BPA message sent to a Cisco multicast address is sent to the administration VLAN, which is VLAN 1 by default.
- You can configure the duration for which a REP interface remains up without receiving a hello from a neighbor. Use the **rep lsl-age-timer** value interface configuration command to set the time from 120 ms to 10000 ms. The LSL hello timer is then set to the age-timer value divided by 3. In normal operation, three LSL hellos are sent before the age timer on the peer switch expires and checks for hello messages.

- EtherChannel port channel interfaces do not support LSL age-timer values less than 1000 ms. If you try to configure a value less than 1000 ms on a port channel, you receive an error message and the command is rejected.
- REP ports cannot be configured as one of the following port types:
 - Switched Port Analyzer (SPAN) destination port
 - Tunnel port
 - Access port
- REP is supported on EtherChannels, but not on an individual port that belongs to an EtherChannel.
- There can be a maximum of 64 REP segments per switch.

Configuring REP Administrative VLAN

To avoid the delay created by link-failure messages, and VLAN-blocking notifications during load balancing, REP floods packets to a regular multicast address at the hardware flood layer (HFL). These messages are flooded to the whole network, and not just the REP segment. You can control the flooding of these messages by configuring an administrative VLAN.

Follow these guidelines when configuring the REP administrative VLAN:

- If you do not configure an administrative VLAN, the default is VLAN 1.
- You can configure one admin VLAN on the switch for all segments.
- The administrative VLAN cannot be the RSPAN VLAN.

To configure the REP administrative VLAN, follow these steps, beginning in privileged EXEC mode:

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 2	rep admin vlan <i>vlan-id</i> Example: Device(config)# rep admin vlan 2	Specifies the administrative VLAN. The range is from 2 to 4094. To set the admin VLAN to 1, which is the default, enter the no rep admin vlan global configuration command.
Step 3	end Example: Device(config)# end	Exits global configuration mode and returns to privileged EXEC mode.

	Command or Action	Purpose
Step 4	show interface [<i>interface-id</i>] rep detail Example: Device(config)# show interface gigabitethernet 1/0/1 rep detail Or Device(config)# interface fastethernet 1/0/1 rep detail	(Optional) Verifies the configuration on a REP interface.
Step 5	copy running-config startup config Example: Device# copy running-config startup config	(Optional) Saves your entries in the switch startup configuration file.

Configuring a REP Interface

To configure REP, enable REP on each segment interface and identify the segment ID. This task is mandatory, and must be done before other REP configurations. You must also configure a primary and secondary edge port on each segment. All the other steps are optional.

Follow these steps to enable and configure REP on an interface:

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/1 Or Device(config)# interface fastethernet 1/0/1	Specifies the interface, and enters interface configuration mode. The interface can be a physical Layer 2 interface or a port channel (logical interface).
Step 4	switchport mode trunk Example: Device# switchport mode trunk	Configures the interface as a Layer 2 trunk port.

	Command or Action	Purpose
Step 5	<p>rep segment <i>segment-id</i> [edge [no-neighbor] [primary]] [preferred]</p> <p>Example:</p> <pre>Device# rep segment 1 edge no-neighbor primary</pre>	<p>Enables REP on the interface and identifies a segment number. The segment ID range is from 1 to 1024.</p> <p>Note You must configure two edge ports, including one primary edge port, for each segment.</p> <p>These optional keywords are available:</p> <ul style="list-style-type: none"> • (Optional) edge: Configures the port as an edge port. Each segment has only two edge ports. Entering the keyword edge without the keyword primary configures the port as the secondary edge port. • (Optional) primary: Configures the port as the primary edge port, the port on which you can configure VLAN load balancing. • (Optional) no-neighbor: Configures a port with no external REP neighbors as an edge port. The port inherits all the properties of an edge port, and you can configure the properties the same way you would for an edge port. <p>Note Although each segment can have only one primary edge port, if you configure edge ports on two different switches and enter the keyword primary on both the switches, the configuration is valid. However, REP selects only one of these ports as the segment primary edge port. You can identify the primary edge port for a segment by entering the show rep topology privileged EXEC command.</p> <ul style="list-style-type: none"> • (Optional) preferred: Indicates that the port is the preferred alternate port or the preferred port for VLAN load balancing. <p>Note Configuring a port as preferred does not guarantee that it becomes the alternate port; it merely gives the port a slight edge over equal contenders. The alternate port is usually a previously failed port.</p>

	Command or Action	Purpose
Step 6	<p>rep stcn {interface <i>interface id</i> segment <i>id-list</i> stp}</p> <p>Example:</p> <pre>Device# rep stcn segment 25-50</pre>	<p>(Optional) Configures the edge port to send segment topology change notices (STCNs).</p> <ul style="list-style-type: none"> • interface <i>interface-id</i>: Designates a physical interface or port channel to receive STCNs. • segment <i>id-list</i>: Identifies one or more segments to receive STCNs. The range is from 1 to 1024. • stp: Sends STCNs to STP networks. <p>Note Spanning Tree (MST) mode is required on edge no-neighbor nodes when rep stcn stp command is configured for sending STCNs to STP networks.</p>
Step 7	<p>rep block port {id <i>port-id</i> <i>neighbor-offset</i> preferred} vlan {<i>vlan-list</i> all}</p> <p>Example:</p> <pre>Device# rep block port id 0009001818D68700 vlan 1-100</pre>	<p>(Optional) Configures VLAN load balancing on the primary edge port, identifies the REP alternate port in one of three ways (id <i>port-id</i>, <i>neighbor_offset</i>, preferred), and configures the VLANs to be blocked on the alternate port.</p> <ul style="list-style-type: none"> • id <i>port-id</i>: Identifies the alternate port by port ID. The port ID is automatically generated for each port in the segment. You can view interface port IDs by entering the show interface type number rep [detail] privileged EXEC command. • <i>neighbor_offset</i>: Number to identify the alternate port as a downstream neighbor from an edge port. The range is from -256 to 256, with negative numbers indicating the downstream neighbor from the secondary edge port. A value of 0 is invalid. Enter -1 to identify the secondary edge port as the alternate port. <p>Note Because you enter the rep block port command at the primary edge port (offset number 1), you cannot enter an offset value of 1 to identify an alternate port.</p> <ul style="list-style-type: none"> • preferred: Selects the regular segment port previously identified as the preferred alternate port for VLAN load balancing.

	Command or Action	Purpose
		<ul style="list-style-type: none"> • vlan <i>vlan-list</i>: Blocks one VLAN or a range of VLANs. • vlan all: Blocks all the VLANs. <p>Note Enter this command only on the REP primary edge port.</p>
Step 8	rep preempt delay <i>seconds</i> Example: Device# <code>rep preempt delay 100</code>	(Optional) Configures a preempt time delay. <ul style="list-style-type: none"> • Use this command if you want VLAN load balancing to be automatically triggered after a link failure and recovery. • The time delay range is between 15 to 300 seconds. The default is manual preemption with no time delay. <p>Note Enter this command only on the REP primary edge port.</p>
Step 9	rep lsl-age-timer <i>value</i> Example: Device# <code>rep lsl-age-timer 2000</code>	(Optional) Configures a time (in milliseconds) for which the REP interface remains up without receiving a hello from a neighbor. The range is from 120 to 10000 ms in 40-ms increments. The default is 5000 ms (5 seconds). <p>Note</p> <ul style="list-style-type: none"> • EtherChannel port channel interfaces do not support LSL age-timer values that are less than 1000 ms. • Both the ports on the link should have the same LSL age configured in order to avoid link flaps.
Step 10	end Example: Device(config)# <code>end</code>	Exits global configuration mode and returns to privileged EXEC mode.
Step 11	show interface [<i>interface-id</i>] rep [detail] Example: Device# <code>show interface gigabitethernet 1/0/1 rep detail</code>	(Optional) Displays the REP interface configuration.

	Command or Action	Purpose
	Or Device# <code>show interface fastethernet 1/0/1 rep detail</code>	
Step 12	copy running-config startup-config Example: Device(config)# <code>copy running-config startup-config</code>	(Optional) Saves your entries in the router startup configuration file.

Setting Manual Preemption for VLAN Load Balancing

If you do not enter the `rep preempt delay seconds` interface configuration command on the primary edge port to configure a preemption time delay, the default is to manually trigger VLAN load balancing on the segment. Be sure that all the other segment configurations have been completed before manually preempting VLAN load balancing. When you enter the `rep preempt delay segment segment-id` command, a confirmation message is displayed before the command is executed because preemption might cause network disruption.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> <code>enable</code>	Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted.
Step 2		
Step 3	configure terminal Example: Device# <code>configure terminal</code>	Enters global configuration mode.
Step 4	rep preempt segment segment-id Example: Device# <code>rep preempt segment 100</code> The command will cause a momentary traffic disruption. Do you still want to continue? [confirm]	Manually triggers VLAN load balancing on the segment. You need to confirm the command before it is executed.
Step 5	show rep topology segment segment-id Example: Device# <code>show rep topology segment 100</code>	(Optional) Displays REP topology information.
Step 6	end Example: Device# <code>end</code>	Exits privileged EXEC mode.

Configuring SNMP Traps for REP

You can configure a router to send REP-specific traps to notify the Simple Network Management Protocol (SNMP) server of link-operational status changes and port role changes.

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: Device# <code>configure terminal</code>	Enters global configuration mode.
Step 2	snmp mib rep trap-rate <i>value</i> Example: Device(config)# <code>snmp mib rep trap-rate 500</code>	Enables the switch to send REP traps, and sets the number of traps sent per second. <ul style="list-style-type: none"> • Enter the number of traps sent per second. The range is from 0 to 1000. The default is 0 (no limit is imposed; a trap is sent at every occurrence).
Step 3	end Example: Device(config)# <code>end</code>	Returns to privileged EXEC mode.
Step 4	show running-config Example: Device# <code>show running-config</code>	(Optional) Displays the running configuration, which can be used to verify the REP trap configuration.
Step 5	copy running-config startup-config Example: Device# <code>copy running-config startup-config</code>	(Optional) Saves your entries in the switch startup configuration file.

Monitoring Resilient Ethernet Protocol Configuration

You can display the rep interface and rep topology details using the commands in this topic.

- **show interface** [*interface-id*] **rep** [**detail**]

Displays REP configuration and status for an interface or for all the interfaces.

- (Optional) **detail**: Displays interface-specific REP information.

Example:

```
Device# show interfaces TenGigabitEthernet4/1/1 rep detail

TenGigabitEthernet4/1/1 REP enabled
Segment-id: 3 (Primary Edge)
PortID: 03010015FA66FF80
```

```

Preferred flag: No
Operational Link Status: TWO_WAY
Current Key: 02040015FA66FF804050
Port Role: Open
Blocked VLAN: <empty>
Admin-vlan: 1
Preempt Delay Timer: disabled
Configured Load-balancing Block Port: none
Configured Load-balancing Block VLAN: none
STCN Propagate to: none
LSL PDU rx: 999, tx: 652
HFL PDU rx: 0, tx: 0
BPA TLV rx: 500, tx: 4
BPA (STCN, LSL) TLV rx: 0, tx: 0
BPA (STCN, HFL) TLV rx: 0, tx: 0
EPA-ELECTION TLV rx: 6, tx: 5
EPA-COMMAND TLV rx: 0, tx: 0
EPA-INFO TLV rx: 135, tx: 136

```

- **show rep topology** [*segment segment-id*] [*archive*] [*detail*]

Displays REP topology information for a segment or for all the segments, including the primary and secondary edge ports in the segment.

- (Optional) **archive**: Displays the last stable topology.



Note An archive topology is not retained when the switch reloads.

- (Optional) **detail**: Displays detailed archived information.

Example:

```
Device# show rep topology
```

```

REP Segment 1
BridgeName      PortName      Edge Role
-----
10.64.106.63    Te5/4         Pri  Open
10.64.106.228   Te3/4         Open
10.64.106.228   Te3/3         Open
10.64.106.67    Te4/3         Open
10.64.106.67    Te4/4         Alt
10.64.106.63    Te4/4         Sec  Open

REP Segment 3
BridgeName      PortName      Edge Role
-----
10.64.106.63    Gi50/1        Pri  Open
SVT_3400_2      Gi0/3         Open
SVT_3400_2      Gi0/4         Open
10.64.106.68    Gi40/2        Open
10.64.106.68    Gi40/1        Open
10.64.106.63    Gi50/2        Sec  Alt

```

Configuration Examples for Resilient Ethernet Protocol

This section provides the following configuration examples:

Example: Configuring the REP Administrative VLAN

This example shows how to configure the administrative VLAN as VLAN 100, and verify the configuration by entering the **show interface rep detail** command on one of the REP interfaces:

```
Device# configure terminal
Device(config)# rep admin vlan 100
Device(config)# end
Device# show interface gigabitethernet1/0/1 rep detail

GigabitEthernet1/0/1 REP enabled
Segment-id: 2 (Edge)
PortID: 00010019E7144680
Preferred flag: No
Operational Link Status: TWO_WAY
Current Key: 0002001121A2D5800E4D
Port Role: Open
Blocked Vlan: <empty>
Admin-vlan: 100
Preempt Delay Timer: disabled
LSL Ageout Timer: 5000 ms
Configured Load-balancing Block Port: none
Configured Load-balancing Block VLAN: none
STCN Propagate to: none
LSL PDU rx: 3322, tx: 1722
HFL PDU rx: 32, tx: 5
BPA TLV rx: 16849, tx: 508
BPA (STCN, LSL) TLV rx: 0, tx: 0
BPA (STCN, HFL) TLV rx: 0, tx: 0
EPA-ELECTION TLV rx: 118, tx: 118
EPA-COMMAND TLV rx: 0, tx: 0
EPA-INFO TLV rx: 4214, tx: 4190
```

The following example shows how to create an administrative VLAN per segment. Here, VLAN 2 is configured as the administrative VLAN only for REP segment 2. All the remaining segments that are not configured have VLAN 1 as the administrative VLAN by default.

```
Device# configure terminal
Device(config)# rep admin vlan 2 segment 2
Device(config)# end
```

Example: Configuring a REP Interface

This example shows how to configure an interface as the primary edge port for segment 1, to send STCNs to segments 2 through 5, and to configure the alternate port as the port with port ID 0009001818D68700 to block all the VLANs after a preemption delay of 60 seconds after a segment port failure and recovery. The interface is configured to remain up for 6000 ms without receiving a hello from a neighbor.

```
Device# configure terminal
Device(config)# interface gigabitethernet 1/0/1
Device(config-if)# rep segment 1 edge primary
Device(config-if)# rep stcn segment 2-5
Device(config-if)# rep block port 0009001818D68700 vlan all`
```

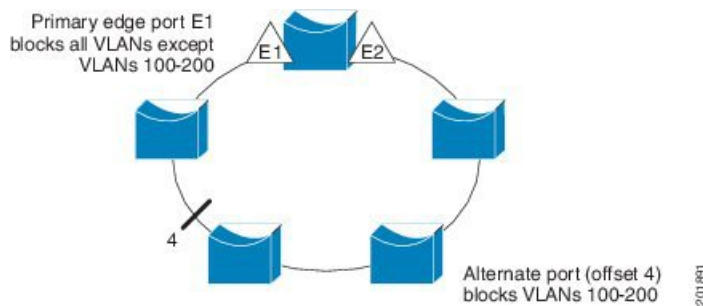
```
Device(config-if)# rep preempt delay 60
Device(config-if)# rep lsl-age-timer 6000
Device(config-if)# end
```

This example shows how to configure the same configuration when the interface has no external REP neighbor:

```
Device# configure terminal
Device(config)# interface gigabitethernet 1/0/1
Device(config-if)# rep segment 1 edge no-neighbor primary
Device(config-if)# rep stcn segment 2-5
Device(config-if)# rep block port 0009001818D68700 vlan all
Device(config-if)# rep preempt delay 60
Device(config-if)# rep lsl-age-timer 6000
Device(config-if)# end
```

This example shows how to configure the VLAN blocking configuration shown in the Figure 5. The alternate port is the neighbor with neighbor offset number 4. After manual preemption, VLANs 100 to 200 are blocked at this port, and all the other VLANs are blocked at the primary edge port E1 (Gigabit Ethernet port 1/1).

Figure 28: Example of VLAN Blocking



```
Device# configure terminal
Device(config)# interface gigabitethernet 1/0/1
Device(config-if)# rep segment 1 edge primary
Device(config-if)# rep block port 4 vlan 100-200
Device(config-if)# end
```

Feature Information for Resilient Ethernet Protocol

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to www.cisco.com/go/cfn. An account on Cisco.com is not required.

Feature Name	Release	Feature Information
Resilient Ethernet Protocol	Cisco IOS Release 15.2(7)E1	This feature was introduced.



CHAPTER 5

Configuring EtherChannels

- [Restrictions for EtherChannels, on page 109](#)
- [Information about EtherChannels, on page 109](#)
- [How to Configure EtherChannels, on page 117](#)
- [Monitoring EtherChannel, PAgP, and LACP Status, on page 127](#)
- [Configuration Examples for Configuring EtherChannels, on page 127](#)
- [Feature Information for EtherChannels, on page 130](#)

Restrictions for EtherChannels

- All ports in an EtherChannel must be assigned to the same VLAN or they must be configured as trunk ports.
- When the ports in an EtherChannel are configured as trunk ports, all the ports must be configured with the same mode (either Inter-Switch Link [ISL] or IEEE 802.1Q).

Information about EtherChannels

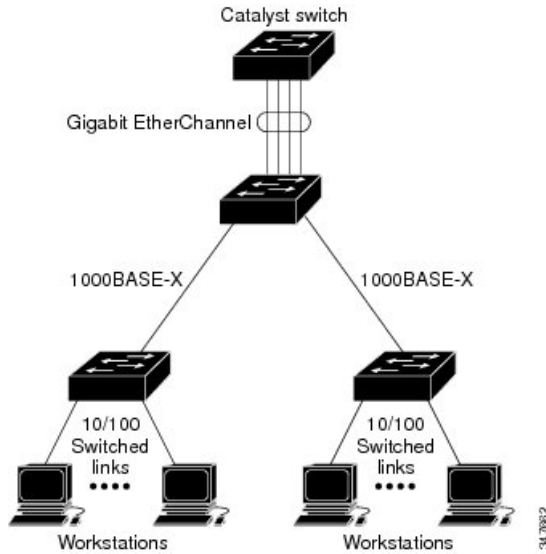
This section provides information about EtherChannels

EtherChannel Overview

EtherChannel provides fault-tolerant high-speed links between switches, routers, and servers. You can use the EtherChannel to increase the bandwidth between the wiring closets and the data center, and you can deploy it anywhere in the network where bottlenecks are likely to occur. EtherChannel provides automatic recovery for the loss of a link by redistributing the load across the remaining links. If a link fails, EtherChannel redirects traffic from the failed link to the remaining links in the channel without intervention.

An EtherChannel consists of individual Ethernet links bundled into a single logical link.

Figure 29: Typical EtherChannel Configuration



The number of EtherChannels is limited to 6.

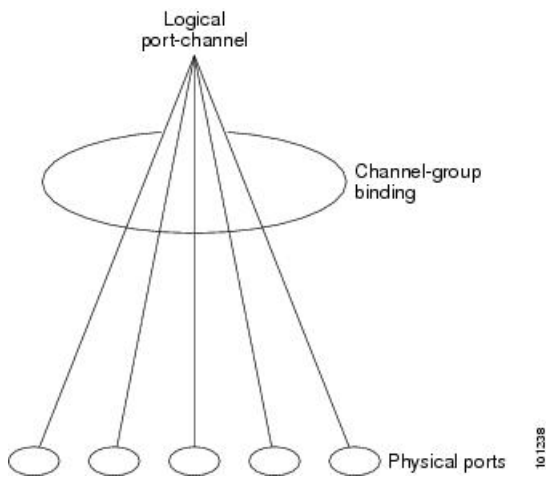
Each EtherChannel can consist of up to eight compatibly configured Ethernet ports.

Channel Groups and Port-Channel Interfaces

An EtherChannel comprises a channel group and a port-channel interface. The channel group binds physical ports to the port-channel interface. Configuration changes applied to the port-channel interface apply to all the physical ports bound together in the channel group.

Figure 30: Relationship of Physical Ports, Channel Group and Port-Channel Interface

The **channel-group** command binds the physical port and the port-channel interface together. Each EtherChannel has a port-channel logical interface numbered from 1 to 6. This port-channel interface number corresponds to the one specified with the **channel-group** interface configuration command.



- With Layer 2 ports, use the **channel-group** interface configuration command to dynamically create the port-channel interface.

You also can use the **interface port-channel** *port-channel-number* global configuration command to manually create the port-channel interface, but then you must use the **channel-group** *channel-group-number* command to bind the logical interface to a physical port. The *channel-group-number* can be the same as the *port-channel-number*, or you can use a new number. If you use a new number, the **channel-group** command dynamically creates a new port channel.

Port Aggregation Protocol

The Port Aggregation Protocol (PAgP) is a Cisco-proprietary protocol that can be run only on Cisco devices and on those devices licensed by vendors to support PAgP. PAgP facilitates the automatic creation of EtherChannels by exchanging PAgP packets between Ethernet ports.

By using PAgP, the switch learns the identity of partners capable of supporting PAgP and the capabilities of each port. It then dynamically groups similarly configured ports (on a single switch) into a single logical link (channel or aggregate port). Similarly configured ports are grouped based on hardware, administrative, and port parameter constraints. For example, PAgP groups the ports with the same speed, duplex mode, native VLAN, VLAN range, and trunking status and type. After grouping the links into an EtherChannel, PAgP adds the group to the spanning tree as a single switch port.

PAgP Modes

PAgP modes specify whether a port can send PAgP packets, which start PAgP negotiations, or only respond to PAgP packets received.

Table 11: EtherChannel PAgP Modes

Mode	Description
auto	Places a port into a passive negotiating state, in which the port responds to PAgP packets it receives but does not start PAgP packet negotiation. This setting minimizes the transmission of PAgP packets.
desirable	Places a port into an active negotiating state, in which the port starts negotiations with other ports by sending PAgP packets.

Switch ports exchange PAgP packets only with partner ports configured in the **auto** or **desirable** modes. Ports configured in the **on** mode do not exchange PAgP packets.

Both the **auto** and **desirable** modes enable ports to negotiate with partner ports to form an EtherChannel based on criteria such as port speed, and for Layer 2 EtherChannels, based on trunk state and VLAN numbers.

Ports can form an EtherChannel when they are in different PAgP modes as long as the modes are compatible. For example:

- A port in the **desirable** mode can form an EtherChannel with another port that is in the **desirable** or **auto** mode.
- A port in the **auto** mode can form an EtherChannel with another port in the **desirable** mode.

A port in the **auto** mode cannot form an EtherChannel with another port that is also in the **auto** mode because neither port starts PAgP negotiation.

Silent Mode

If your switch is connected to a partner that is PAgP-capable, you can configure the switch port for nonsilent operation by using the **non-silent** keyword. If you do not specify **non-silent** with the **auto** or **desirable** mode, silent mode is assumed.

Use the silent mode when the switch is connected to a device that is not PAgP-capable and seldom, if ever, sends packets. An example of a silent partner is a file server or a packet analyzer that is not generating traffic. In this case, running PAgP on a physical port connected to a silent partner prevents that switch port from ever becoming operational. However, the silent setting allows PAgP to operate, to attach the port to a channel group, and to use the port for transmission.

PAgP Learn Method and Priority

Network devices are classified as PAgP physical learners or aggregate-port learners. A device is a physical learner if it learns addresses by physical ports and directs transmissions based on that knowledge. A device is an aggregate-port learner if it learns addresses by aggregate (logical) ports. The learn method must be configured the same at both ends of the link.

When a device and its partner are both aggregate-port learners, they learn the address on the logical port-channel. The device sends packets to the source by using any of the ports in the EtherChannel. With aggregate-port learning, it is not important on which physical port the packet arrives.

PAgP cannot automatically detect when the partner device is a physical learner and when the local device is an aggregate-port learner. Therefore, you must manually set the learning method on the local device to learn addresses by physical ports. You also must set the load-distribution method to source-based distribution, so that any given source MAC address is always sent on the same physical port.

You also can configure a single port within the group for all transmissions and use other ports for hot-standby. The unused ports in the group can be swapped into operation in just a few seconds if the selected single port loses hardware-signal detection. You can configure which port is always selected for packet transmission by changing its priority with the **pagp port-priority** interface configuration command. The higher the priority, the more likely that the port will be selected.



Note The switch supports address learning only on aggregate ports even though the **physical-port** keyword is provided in the CLI. The **pagp learn-method** command and the **pagp port-priority** command have no effect on the switch hardware, but they are required for PAgP interoperability with devices that only support address learning by physical ports, such as the Catalyst 1900 switch.

PAgP Interaction with Other Features

The Dynamic Trunking Protocol (DTP) and the Cisco Discovery Protocol (CDP) send and receive packets over the physical ports in the EtherChannel. Trunk ports send and receive PAgP protocol data units (PDUs) on the lowest numbered VLAN.

In Layer 2 EtherChannels, the first port in the channel that comes up provides its MAC address to the EtherChannel. If this port is removed from the bundle, one of the remaining ports in the bundle provides its MAC address to the EtherChannel.

PAgP sends and receives PAgP PDUs only from ports that are up and have PAgP enabled for the auto or desirable mode.

Link Aggregation Control Protocol

The LACP is defined in IEEE 802.3ad and enables Cisco devices to manage Ethernet channels between devices that conform to the IEEE 802.3ad protocol. LACP facilitates the automatic creation of EtherChannels by exchanging LACP packets between Ethernet ports.

By using LACP, the switch learns the identity of partners capable of supporting LACP and the capabilities of each port. It then dynamically groups similarly configured ports into a single logical link (channel or aggregate port). Similarly configured ports are grouped based on hardware, administrative, and port parameter constraints. For example, LACP groups the ports with the same speed, duplex mode, native VLAN, VLAN range, and trunking status and type. After grouping the links into an EtherChannel, LACP adds the group to the spanning tree as a single switch port.

The independent mode behavior of ports in a port channel is changed. With CSCtn96950, by default, standalone mode is enabled. When no response is received from an LACP peer, ports in the port channel are moved to suspended state.

LACP Modes

LACP modes specify whether a port can send LACP packets or only receive LACP packets.

Table 12: EtherChannel LACP Modes

Mode	Description
active	Places a port into an active negotiating state in which the port starts negotiations with other ports by sending LACP packets.
passive	Places a port into a passive negotiating state in which the port responds to LACP packets that it receives, but does not start LACP packet negotiation. This setting minimizes the transmission of LACP packets.

Both the **active** and **passive LACP** modes enable ports to negotiate with partner ports to an EtherChannel based on criteria such as port speed, and for Layer 2 EtherChannels, based on trunk state and VLAN numbers.

Ports can form an EtherChannel when they are in different LACP modes as long as the modes are compatible. For example:

- A port in the **active** mode can form an EtherChannel with another port that is in the **active** or **passive** mode.
- A port in the **passive** mode cannot form an EtherChannel with another port that is also in the **passive** mode because neither port starts LACP negotiation.

LACP Interaction with Other Features

The DTP and the CDP send and receive packets over the physical ports in the EtherChannel. Trunk ports send and receive LACP PDUs on the lowest numbered VLAN.

In Layer 2 EtherChannels, the first port in the channel that comes up provides its MAC address to the EtherChannel. If this port is removed from the bundle, one of the remaining ports in the bundle provides its MAC address to the EtherChannel.

LACP sends and receives LACP PDUs only from ports that are up and have LACP enabled for the active or passive mode.

EtherChannel On Mode

EtherChannel **on** mode can be used to manually configure an EtherChannel. The **on** mode forces a port to join an EtherChannel without negotiations. The **on** mode can be useful if the remote device does not support PAgP or LACP. In the **on** mode, a usable EtherChannel exists only when the device at both ends of the link are configured in the **on** mode.

Ports that are configured in the **on** mode in the same channel group must have compatible port characteristics, such as speed and duplex. Ports that are not compatible are suspended, even though they are configured in the **on** mode.



Caution

You should use care when using the **on** mode. This is a manual configuration, and ports on both ends of the EtherChannel must have the same configuration. If the group is misconfigured, packet loss or spanning-tree loops can occur.

Default EtherChannel Configuration

The default EtherChannel configuration is described in this table.

Table 13: Default EtherChannel Configuration

Feature	Default Setting
Channel groups	None assigned.
Port-channel logical interface	None defined.
PAgP mode	No default.
PAgP learn method	Aggregate-port learning on all ports.
PAgP priority	128 on all ports.
LACP mode	No default.
LACP learn method	Aggregate-port learning on all ports.
LACP port priority	32768 on all ports.
LACP system priority	32768.
LACP system ID	LACP system priority and the device MAC address.

EtherChannel Configuration Guidelines

If improperly configured, some EtherChannel ports are automatically disabled to avoid network loops and other problems. Follow these guidelines to avoid configuration problems:

- Configure a PAgP EtherChannel with up to eight Ethernet ports of the same type.

- Configure a LACP EtherChannel with up to 16 Ethernet ports of the same type. Up to eight ports can be active, and up to eight ports can be in standby mode.
- Configure all ports in an EtherChannel to operate at the same speeds and duplex modes.
- Enable all ports in an EtherChannel. A port in an EtherChannel that is disabled by using the **shutdown** interface configuration command is treated as a link failure, and its traffic is transferred to one of the remaining ports in the EtherChannel.
- When a group is first created, all ports follow the parameters set for the first port to be added to the group. If you change the configuration of one of these parameters, you must also make the changes to all ports in the group:
 - Allowed-VLAN list
 - Spanning-tree path cost for each VLAN
 - Spanning-tree port priority for each VLAN
 - Spanning-tree Port Fast setting
- Do not configure a port to be a member of more than one EtherChannel group.
- Do not configure an EtherChannel in both the PAgP and LACP modes. EtherChannel groups running PAgP and LACP can coexist on the same device. Individual EtherChannel groups can run either PAgP or LACP, but they cannot interoperate.
- Do not configure a secure port as part of an EtherChannel or the reverse.
- Do not configure a port that is an active or a not-yet-active member of an EtherChannel as an IEEE 802.1x port. If you try to enable IEEE 802.1x on an EtherChannel port, an error message appears, and IEEE 802.1x is not enabled.
- If EtherChannels are configured on device interfaces, remove the EtherChannel configuration from the interfaces before globally enabling IEEE 802.1x on a device by using the **dot1x system-auth-control** global configuration command.
- Do not enable link-state tracking on individual interfaces that will be part of a downstream Etherchannel interface.

Layer 2 EtherChannel Configuration Guidelines

When configuring Layer 2 EtherChannels, follow these guidelines:

- Assign all ports in the EtherChannel to the same VLAN, or configure them as trunks. Ports with different native VLANs cannot form an EtherChannel.
- An EtherChannel supports the same allowed range of VLANs on all the ports in a trunking Layer 2 EtherChannel. If the allowed range of VLANs is not the same, the ports do not form an EtherChannel even when PAgP is set to the **auto** or **desirable** mode.
- Ports with different spanning-tree path costs can form an EtherChannel if they are otherwise compatibly configured. Setting different spanning-tree path costs does not, by itself, make ports incompatible for the formation of an EtherChannel.

Auto-LAG

The auto-LAG feature provides the ability to auto create EtherChannels on ports connected to a switch. By default, auto-LAG is disabled globally and is enabled on all port interfaces. The auto-LAG applies to a switch only when it is enabled globally.

On enabling auto-LAG globally, the following scenarios are possible:

- All port interfaces participate in creation of auto EtherChannels provided the partner port interfaces have EtherChannel configured on them. For more information, see the *"The supported auto-LAG configurations between the actor and partner devices"* table below.
- Ports that are already part of manual EtherChannels cannot participate in creation of auto EtherChannels.
- When auto-LAG is disabled on a port interface that is already a part of an auto created EtherChannel, the port interface will unbundle from the auto EtherChannel.

The following table shows the supported auto-LAG configurations between the actor and partner devices:

Table 14: The supported auto-LAG configurations between the actor and partner devices

Actor/Partner	Active	Passive	Auto
Active	Yes	Yes	Yes
Passive	Yes	No	Yes
Auto	Yes	Yes	Yes

On disabling auto-LAG globally, all auto created Etherchannels become manual EtherChannels.

You cannot add any configurations in an existing auto created EtherChannel. To add, you should first convert it into a manual EtherChannel by executing the **port-channel<channel-number>persistent**.



Note Auto-LAG uses the LACP protocol to create auto EtherChannel. Only one EtherChannel can be automatically created with the unique partner devices.

Auto-LAG Configuration Guidelines

Follow these guidelines when configuring the auto-LAG feature.

- When auto-LAG is enabled globally and on the port interface, and if you do not want the port interface to become a member of the auto EtherChannel, disable the auto-LAG on the port interface.
- A port interface will not bundle to an auto EtherChannel when it is already a member of a manual EtherChannel. To allow it to bundle with the auto EtherChannel, first unbundle the manual EtherChannel on the port interface.
- When auto-LAG is enabled and auto EtherChannel is created, you can create multiple EtherChannels manually with the same partner device. But by default, the port tries to create auto EtherChannel with the partner device.
- The auto-LAG is supported only on Layer 2 EtherChannel. It is not supported on Layer 3 interface and Layer 3 EtherChannel.

How to Configure EtherChannels

After you configure an EtherChannel, configuration changes applied to the port-channel interface apply to all the physical ports assigned to the port-channel interface, and configuration changes applied to the physical port affect only the port where you apply the configuration.

Configuring Layer 2 EtherChannels

You configure Layer 2 EtherChannels by assigning ports to a channel group with the **channel-group** interface configuration command. This command automatically creates the port-channel logical interface.

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 2	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/1 Or Device(config)# interface fastethernet 1/0/1	Specifies a physical port, and enters interface configuration mode. Valid interfaces are physical ports. For a PAgP EtherChannel, you can configure up to eight ports of the same type and speed for the same group. For a LACP EtherChannel, you can configure up to 16 Ethernet ports of the same type. Up to eight ports can be active, and up to eight ports can be in standby mode.
Step 3	switchport mode {access trunk} Example: Device(config-if)# switchport mode access	Assigns all ports as static-access ports in the same VLAN, or configure them as trunks. If you configure the port as a static-access port, assign it to only one VLAN. The range is 1 to 4094.
Step 4	switchport access vlan <i>vlan-id</i> Example: Device(config-if)# switchport access vlan 22	(Optional) If you configure the port as a static-access port, assign it to only one VLAN. The range is 1 to 4094.

	Command or Action	Purpose
Step 5	<p>channel-group <i>channel-group-number</i> mode {auto [non-silent] desirable [non-silent] on } { active passive }</p> <p>Example:</p> <pre>Device(config-if) # channel-group 5 mode auto</pre>	<p>Assigns the port to a channel group, and specifies the PAgP or the LACP mode.</p> <p>For <i>channel-group-number</i>, the range is 1 to 6.</p> <p>For mode, select one of these keywords:</p> <ul style="list-style-type: none"> • auto—Enables PAgP only if a PAgP device is detected. It places the port into a passive negotiating state, in which the port responds to PAgP packets it receives but does not start PAgP packet negotiation. • desirable—Unconditionally enables PAgP. It places the port into an active negotiating state, in which the port starts negotiations with other ports by sending PAgP packets. • on—Forces the port to channel without PAgP or LACP. In the on mode, an EtherChannel exists only when a port group in the on mode is connected to another port group in the on mode. • non-silent—(Optional) If your device is connected to a partner that is PAgP-capable, configures the switch port for nonsilent operation when the port is in the auto or desirable mode. If you do not specify non-silent, silent is assumed. The silent setting is for connections to file servers or packet analyzers. This setting allows PAgP to operate, to attach the port to a channel group, and to use the port for transmission. • active—Enables LACP only if a LACP device is detected. It places the port into an active negotiating state in which the port starts negotiations with other ports by sending LACP packets. • passive—Enables LACP on the port and places it into a passive negotiating state in which the port responds to LACP packets that it receives, but does not start LACP packet negotiation.
Step 6	<p>end</p> <p>Example:</p>	<p>Returns to privileged EXEC mode.</p>

	Command or Action	Purpose
	Device(config-if) # <code>end</code>	

Configuring the PAgP Learn Method and Priority

This task is optional.

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: Device# <code>configure terminal</code>	Enters global configuration mode.
Step 2	interface <i>interface-id</i> Example: Device(config)# <code>interface gigabitethernet 1/0/2</code> Or Device(config)# <code>interface fastethernet 1/0/2</code>	Specifies the port for transmission, and enters interface configuration mode.
Step 3	pagp learn-method physical-port Example: Device(config-if) # <code>pagp learn-method physical port</code>	Selects the PAgP learning method. By default, aggregation-port learning is selected, which means the device sends packets to the source by using any of the ports in the EtherChannel. With aggregate-port learning, it is not important on which physical port the packet arrives. Selects physical-port to connect with another device that is a physical learner. The learning method must be configured the same at both ends of the link.
Step 4	pagp port-priority <i>priority</i> Example: Device(config-if) # <code>pagp port-priority 200</code>	Assigns a priority so that the selected port is chosen for packet transmission. For <i>priority</i> , the range is 0 to 255. The default is 128. The higher the priority, the more likely that the port will be used for PAgP transmission.

	Command or Action	Purpose
Step 5	end Example: Device (config-if) # end	Returns to privileged EXEC mode.

Configuring LACP Hot-Standby Ports

When enabled, LACP tries to configure the maximum number of LACP-compatible ports in a channel, up to a maximum of 16 ports. Only eight LACP links can be active at one time. The software places any additional links in a hot-standby mode. If one of the active links becomes inactive, a link that is in the hot-standby mode becomes active in its place.

If you configure more than eight links for an EtherChannel group, the software automatically decides which of the hot-standby ports to make active based on the LACP priority. To every link between systems that operate LACP, the software assigns a unique priority made up of these elements (in priority order):

- LACP system priority
- System ID (the device MAC address)
- LACP port priority
- Port number

In priority comparisons, numerically lower values have higher priority. The priority decides which ports should be put in standby mode when there is a hardware limitation that prevents all compatible ports from aggregating.

Determining which ports are active and which are hot standby is a two-step procedure. First the system with a numerically lower system priority and system ID is placed in charge of the decision. Next, that system decides which ports are active and which are hot standby, based on its values for port priority and port number. The port priority and port number values for the other system are not used.

You can change the default values of the LACP system priority and the LACP port priority to affect how the software selects active and standby links.

Configuring the LACP System Priority

You can configure the system priority for all the EtherChannels that are enabled for LACP by using the **lACP system-priority** global configuration command. You cannot configure a system priority for each LACP-configured channel. By changing this value from the default, you can affect how the software selects active and standby links.

You can use the **show etherchannel summary** privileged EXEC command to see which ports are in the hot-standby mode (denoted with an H port-state flag).

Follow these steps to configure the LACP system priority. This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	lacp system-priority <i>priority</i> Example: Device(config)# lacp system-priority 32000	Configures the LACP system priority. The range is 1 to 65535. The default is 32768. The lower the value, the higher the system priority.
Step 4	end Example: Device(config)# end	Returns to privileged EXEC mode.

Configuring the LACP Port Priority

By default, all ports use the same port priority. If the local system has a lower value for the system priority and the system ID than the remote system, you can affect which of the hot-standby links become active first by changing the port priority of LACP EtherChannel ports to a lower value than the default. The hot-standby ports that have lower port numbers become active in the channel first. You can use the **show etherchannel summary** privileged EXEC command to see which ports are in the hot-standby mode (denoted with an H port-state flag).



Note If LACP is not able to aggregate all the ports that are compatible (for example, the remote system might have more restrictive hardware limitations), all the ports that cannot be actively included in the EtherChannel are put in the hot-standby state and are used only if one of the channeled ports fails.

Follow these steps to configure the LACP port priority. This procedure is optional.

Procedure

	Command or Action	Purpose
Step 1	enable	Enables privileged EXEC mode.

	Command or Action	Purpose
	Example: Device> enable	Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: Device(config)# interface gigabitethernet 1/0/2 Or Device(config)# interface fastethernet 1/0/2	Specifies the port to be configured, and enters interface configuration mode.
Step 4	lacp port-priority <i>priority</i> Example: Device(config-if)# lacp port-priority 32000	Configures the LACP port priority. The range is 1 to 65535. The default is 32768. The lower the value, the more likely that the port will be used for LACP transmission.
Step 5	end Example: Device(config-if)# end	Returns to privileged EXEC mode.

Configuring the LACP Port Channel Min-Links Feature

You can specify the minimum number of active ports that must be in the link-up state and bundled in an EtherChannel for the port channel interface to transition to the link-up state. Using EtherChannel min-links, you can prevent low-bandwidth LACP EtherChannels from becoming active. Port channel min-links also cause LACP EtherChannels to become inactive if they have too few active member ports to supply the required minimum bandwidth.

To configure the minimum number of links that are required for a port channel. Perform the following tasks.

Procedure

	Command or Action	Purpose
Step 1	enable	Enables privileged EXEC mode.

	Command or Action	Purpose
	Example: Device> enable	Enter your password if prompted.
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface port-channel <i>channel-number</i> Example: Device(config)# interface port-channel 2	Enters interface configuration mode for a port-channel. For <i>channel-number</i> , the range is 1 to 6.
Step 4	port-channel min-links <i>min-links-number</i> Example: Device(config-if)# port-channel min-links 3	Specifies the minimum number of member ports that must be in the link-up state and bundled in the EtherChannel for the port channel interface to transition to the link-up state. For <i>min-links-number</i> , the range is 2 to 8.
Step 5	end Example: Device(config)# end	Returns to privileged EXEC mode.

Configuring LACP Fast Rate Timer

You can change the LACP timer rate to modify the duration of the LACP timeout. Use the **lacp rate** command to set the rate at which LACP control packets are received by an LACP-supported interface. You can change the timeout rate from the default rate (30 seconds) to the fast rate (1 second). This command is supported only on LACP-enabled interfaces.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. Enter your password if prompted.

	Command or Action	Purpose
Step 2	configure terminal Example: Device# configure terminal	Enters global configuration mode.
Step 3	interface {fastethernet gigabitethernet tengigabitethernet} slot/port Example: Device(config)# interface gigabitethernet 2/0/1 Or Device(config)# interface fastethernet 1/0/1	Configures an interface and enters interface configuration mode.
Step 4	lacp rate {normal fast} Example: Device(config-if)# lacp rate fast	Configures the rate at which LACP control packets are received by an LACP-supported interface. To reset the timeout rate to its default, use the no lacp rate command.
Step 5	end Example: Device(config)# end	Returns to privileged EXEC mode.
Step 6	show lacp internal Example: Device# show lacp internal Device# show lacp counters	Verifies your configuration.

Configuring Auto-LAG Globally

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. Enter your password if prompted.

	Command or Action	Purpose
Step 2	configure terminal Example: Device# <code>configure terminal</code>	Enters global configuration mode.
Step 3	[no] port-channel auto Example: Device(config)# <code>port-channel auto</code>	Enables the auto-LAG feature on a switch globally. Use the no form of this command to disable the auto-LAG feature on the switch globally. Note By default, the auto-LAG feature is enabled on the port.
Step 4	end Example: Device(config)# <code>end</code>	Returns to privileged EXEC mode.
Step 5	show etherchannel auto Example: Device# <code>show etherchannel auto</code>	Displays that EtherChannel is created automatically.

Configuring Auto-LAG on a Port Interface

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> <code>enable</code>	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	configure terminal Example: Device# <code>configure terminal</code>	Enters global configuration mode.
Step 3	interface <i>interface-id</i> Example: Device(config)# <code>interface gigabitethernet 1/0/1</code>	Specifies the port interface to be enabled for auto-LAG, and enters interface configuration mode.

	Command or Action	Purpose
	Or Device(config)# interface fastethernet 1/0/1	
Step 4	[no] channel-group auto Example: Device(config-if) # channel-group auto	(Optional) Enables auto-LAG feature on individual port interface. Use the no form of this command to disable the auto-LAG feature on individual port interface. Note By default, the auto-LAG feature is enabled on the port.
Step 5	end Example: Device(config-if) # end	Returns to privileged EXEC mode.
Step 6	show etherchannel auto Example: Device# show etherchannel auto	Displays that EtherChannel is created automatically.

Configuring Persistence with Auto-LAG

You use the persistence command to convert the auto created EtherChannel into a manual one and allow you to add configuration on the existing EtherChannel.

Procedure

	Command or Action	Purpose
Step 1	enable Example: Device> enable	Enables privileged EXEC mode. Enter your password if prompted.
Step 2	port-channel <i>channel-number</i> persistent Example: Device# port-channel 1 persistent	Converts the auto created EtherChannel into a manual one and allows you to add configuration on the EtherChannel.
Step 3	show etherchannel summary Example: Device# show etherchannel summary	Displays the EtherChannel information.

Monitoring EtherChannel, PAgP, and LACP Status

You can display EtherChannel, PAgP, and LACP status using the commands listed in this table.

Table 15: Commands for Monitoring EtherChannel, PAgP, and LACP Status

Command	Description
clear lacp { <i>channel-group-number</i> counters counters }	Clears LACP channel-group information and traffic counters.
clear pagp { <i>channel-group-number</i> counters counters }	Clears PAgP channel-group information and traffic counters.
show etherchannel [<i>channel-group-number</i> { detail load-balance port port-channel protocol summary }] [detail load-balance port port-channel protocol auto summary]	Displays EtherChannel information in a brief, detailed, and one-line summary form. Also displays the load-balance or frame-distribution scheme, port, port-channel, protocol, and Auto-LAG information.
show pagp [<i>channel-group-number</i>] { counters internal neighbor }	Displays PAgP information such as traffic information, the internal PAgP configuration, and neighbor information.
show pagp [<i>channel-group-number</i>] dual-active	Displays the dual-active detection status.
show lacp [<i>channel-group-number</i>] { counters internal neighbor sys-id }	Displays LACP information such as traffic information, the internal LACP configuration, and neighbor information.
show running-config	Verifies your configuration entries.
show etherchannel load-balance	Displays the load balance or frame distribution scheme among ports in the port channel.

Configuration Examples for Configuring EtherChannels

This section provides configuration examples for configuring EtherChannels:

Configuring Layer 2 EtherChannels: Examples

This example shows how to configure an EtherChannel on a single device. It assigns two ports as static-access ports in VLAN 10 to channel 5 with the PAgP mode **desirable**:

```
Device# configure terminal
Device(config)# interface range gigabitethernet 1/0/1 - 2
Device(config-if-range)# switchport mode access
Device(config-if-range)# switchport access vlan 10
Device(config-if-range)# channel-group 5 mode desirable non-silent
Device(config-if-range)# end
```

This example shows how to configure an EtherChannel on a single device. It assigns two ports as static-access ports in VLAN 10 to channel 5 with the LACP mode **active** :

```
Device# configure terminal
Device(config)# interface range gigabitethernet 1/0/1 - 2
Device(config-if-range)# switchport mode access
Device(config-if-range)# switchport access vlan 10
Device(config-if-range)# channel-group 5 mode active
Device(config-if-range)# end
```

PoE or LACP negotiation errors may occur if you configure two ports from switch to the access point (AP). This scenario can be avoided if the port channel configuration is on the switch side. For more details, see the following example:

```
interface Port-channel1
  switchport access vlan 20
  switchport mode access
  switchport nonegotiate
  no port-channel standalone-disable  <--this one
  spanning-tree portfast
```



Note If the port reports LACP errors on port flap, you should include the following command as well: **no errdisable detect cause pagp-flap**

Configuring Auto LAG: Examples

This example shows how to configure Auto-LAG on a switch

```
Device> enable
Device# configure terminal
Device(config)# port-channel auto
Device(config-if)# end
Device# show etherchannel auto
```

The following example shows the summary of EtherChannel that was created automatically.

```
Device# show etherchannel auto
Flags: D - down          P - bundled in port-channel
       I - stand-alone  s - suspended
       H - Hot-standby (LACP only)
       R - Layer3       S - Layer2
       U - in use       f - failed to allocate aggregator
       M - not in use, minimum links not met
       u - unsuitable for bundling
       w - waiting to be aggregated
       d - default port
       A - formed by Auto LAG
```

```
Number of channel-groups in use: 1
Number of aggregators:          1
```

Group	Port-channel	Protocol	Ports
1	Pol(SUA)	LACP	Gi1/0/45(P) Gi2/0/21(P) Gi3/0/21(P)

The following example shows the summary of auto EtherChannel after executing the **port-channel 1 persistent** command.

```

Device# port-channel 1 persistent

Device# show etherchannel summary
Switch# show etherchannel summary
Flags: D - down          P - bundled in port-channel
       I - stand-alone  s - suspended
       H - Hot-standby (LACP only)
       R - Layer3       S - Layer2
       U - in use       f - failed to allocate aggregator
       M - not in use, minimum links not met
       u - unsuitable for bundling
       w - waiting to be aggregated
       d - default port
       A - formed by Auto LAG

Number of channel-groups in use: 1
Number of aggregators:          1

Group  Port-channel  Protocol    Ports
-----+-----+-----+-----
1      Po1(SU)        LACP        Gi1/0/45(P) Gi2/0/21(P) Gi3/0/21(P)

```

Configuring LACP Port Channel Min-Links: Examples

This example shows how to configure LACP port-channel min-links:

```

Device > enable
Device# configure terminal
Device(config)# interface port-channel 5
Device(config-if)# port-channel min-links 3
Device# show etherchannel 25 summary
Device# end

```

When the minimum links requirement is not met in standalone switches, the port-channel is flagged and assigned SM/SN or RM/RN state.

```

Device# show etherchannel 5 summary

Flags: D - down P - bundled in port-channel
       I - stand-alone s - suspended
       H - Hot-standby (LACP only)
       R - Layer3 S - Layer2
       U - in use N- not in use, no aggregation
       f - failed to allocate aggregator
       M - not in use, no aggregation due to minimum links not met
       m- not in use, port not aggregated due to minimum links not met
       u - unsuitable for bundling
       w - waiting to be aggregated
       d - default port
Number of channel-groups in use: 6
Number of aggregators: 6

Group  Port-channel  Protocol    Ports
-----+-----+-----+-----
6      Po25(RM)      LACP        Gi1/3/1(D) Gi1/3/2(D) Gi2/2/25(D) Gi2/2/26(W)

```

Example: Configuring LACP Fast Rate Timer

This example shows you how to configure the LACP rate:

```

Device> enable
Device# configure terminal
Device(config)# interface gigabitethernet 2/0/1
Device(config-if)# lacp rate fast
Device(config-if)# exit
Device(config)# end
Device# show lacp internal
Device# show lacp counters

```

The following is sample output from the **show lacp internal** command:

```

Device# show lacp internal
Flags: S - Device is requesting Slow LACPDUs
F - Device is requesting Fast LACPDUs
A - Device is in Active mode P - Device is in Passive mode
Channel group 6
LACP port Admin Oper Port Port
Port Flags State Priority Key Key Number State
Te1/49 FA bndl 32768 0x19 0x19 0x32 0x3F
Te1/50 FA bndl 32768 0x19 0x19 0x33 0x3F
Te1/51 FA bndl 32768 0x19 0x19 0x34 0x3F
Te1/52 FA bndl 32768 0x19 0x19 0x35 0x3F

```

The following is sample output from the **show lacp counters** command:

```

Device# show lacp counters

LACPDUs Marker Marker Response LACPDUs
Port Sent Recv Sent Recv Sent Recv Pkts Err
-----
Channel group: 6
Te1/1/27 2 2 0 0 0 0 0
Te2/1/25 2 2 0 0 0 0 0

```

Feature Information for EtherChannels

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Use the Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to www.cisco.com/go/cfn. An account on Cisco.com is not required.

Table 16: Feature Information for EtherChannels

Feature Name	Releases	Feature Information
Configuring EtherChannels	Cisco IOS Release 15.2(7)E1	The feature was introduced.



CHAPTER 6

Configuring Link-State Tracking

- [Restrictions for Configuring Link-State Tracking, on page 131](#)
- [Understanding Link-State Tracking, on page 131](#)
- [How to Configure Link-State Tracking, on page 133](#)
- [Configuring Link-State Tracking: Example, on page 134](#)
- [Monitoring Link-State Tracking, on page 135](#)
- [Feature Information for Link-State Tracking, on page 135](#)

Restrictions for Configuring Link-State Tracking

- You can configure only two link-state groups per switch.
- An interface cannot be a member of more than one link-state group.
- An interface that is defined as an upstream interface in a link-state group cannot also be defined as a downstream interface in the link-state group.
- Do not enable link-state tracking on individual interfaces that will part of a downstream EtherChannel interface.
- Add the upstream interfaces to the link state group before adding the downstream interfaces. Otherwise, the downstream interface is put in error-disabled state.
- When a downstream interface is configured as a SPAN destination port, it is placed in error-disabled state when all upstream interfaces in its group are down. When an upstream interface is configured as a SPAN destination port, it is considered as a link-down event on the interface.

Understanding Link-State Tracking

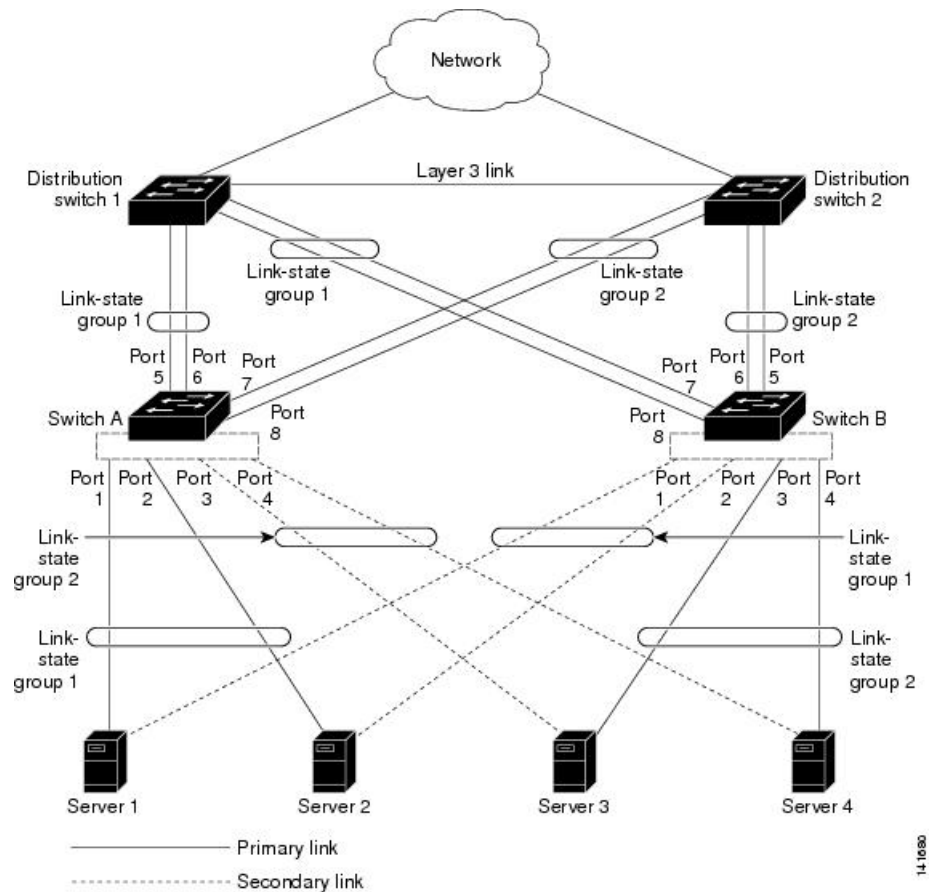
Link-state tracking, also known as trunk failover, binds the link state of multiple interfaces. Link-state tracking can be with server NIC adapter teaming to provide redundancy in the network. When the server NIC adapters are configured in a primary or secondary relationship, and the link is lost on the primary interface, network connectivity is transparently changed to the secondary interface.



Note An interface can be an aggregation of ports (an EtherChannel) or a single physical port in either access or trunk mode .

The configuration in this figure ensures that the network traffic flow is balanced.

Figure 31: Typical Link-State Tracking Configuration



- For links to switches and other network devices
 - Server 1 and server 2 use switch A for primary links and switch B for secondary links.
 - Server 3 and server 4 use switch B for primary links and switch A for secondary links.
- Link-state group 1 on switch A
 - Switch A provides primary links to server 1 and server 2 through link-state group 1. Port 1 is connected to server 1, and port 2 is connected to server 2. Port 1 and port 2 are the downstream interfaces in link-state group 1.
 - Port 5 and port 6 are connected to distribution switch 1 through link-state group 1. Port 5 and port 6 are the upstream interfaces in link-state group 1.
- Link-state group 2 on switch A

- Switch A provides secondary links to server 3 and server 4 through link-state group 2. Port 3 is connected to server 3, and port 4 is connected to server 4. Port 3 and port 4 are the downstream interfaces in link-state group 2.
- Port 7 and port 8 are connected to distribution switch 2 through link-state group 2. Port 7 and port 8 are the upstream interfaces in link-state group 2.
- Link-state group 2 on switch B
 - Switch B provides primary links to server 3 and server 4 through link-state group 2. Port 3 is connected to server 3, and port 4 is connected to server 4. Port 3 and port 4 are the downstream interfaces in link-state group 2.
 - Port 5 and port 6 are connected to distribution switch 2 through link-state group 2. Port 5 and port 6 are the upstream interfaces in link-state group 2.
- Link-state group 1 on switch B
 - Switch B provides secondary links to server 1 and server 2 through link-state group 1. Port 1 is connected to server 1, and port 2 is connected to server 2. Port 1 and port 2 are the downstream interfaces in link-state group 1.
 - Port 7 and port 8 are connected to distribution switch 1 through link-state group 1. Port 7 and port 8 are the upstream interfaces in link-state group 1.

In a link-state group, the upstream ports can become unavailable or lose connectivity because the distribution switch or router fails, the cables are disconnected, or the link is lost. These are the interactions between the downstream and upstream interfaces when link-state tracking is enabled:

- If any of the upstream interfaces are in the link-up state, the downstream interfaces can change to or remain in the link-up state.
- If all of the upstream interfaces become unavailable, link-state tracking automatically puts the downstream interfaces in the error-disabled state. Connectivity to and from the servers is automatically changed from the primary server interface to the secondary server interface. For example, in the previous figure, if the upstream link for port 6 is lost, the link states of downstream ports 1 and 2 do not change. However, if the link for upstream port 5 is also lost, the link state of the downstream ports changes to the link-down state. Connectivity to server 1 and server 2 is then changed from link-state group 1 to link-state group 2. The downstream ports 3 and 4 do not change state because they are in link-group 2.
- If the link-state group is configured, link-state tracking is disabled, and the upstream interfaces lose connectivity, the link states of the downstream interfaces remain unchanged. The server does not recognize that upstream connectivity has been lost and does not failover to the secondary interface.

You can recover a downstream interface link-down condition by removing the failed downstream port from the link-state group. To recover multiple downstream interfaces, disable the link-state group.

How to Configure Link-State Tracking

To enable link-state tracking, create a link-state group and specify the interfaces that are assigned to the group. This task is optional.

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: Device# <code>configure terminal</code>	Enters global configuration mode.
Step 2	link state track <i>number</i> Example: Device(config)# <code>link state track 2</code>	Creates a link-state group and enables link-state tracking. The group number can be 1 or 2; the default is 1.
Step 3	interface <i>interface-id</i> Example: Device(config)# <code>interface gigabitethernet 1/0/1</code> Or Device(config)# <code>interface fastethernet 1/0/1</code>	Specifies a physical interface or range of interfaces to configure, and enters interface configuration mode. Valid interfaces include switch ports in access or trunk mode (IEEE 802.1q) or routed ports. Note Do not enable link-state tracking on individual interfaces that will be part of an Etherchannel interface.
Step 4	link state group [<i>number</i>]{<u>upstream</u> <u>downstream</u>} Example: Device(config-if)# <code>link state group 2 upstream</code>	Specifies a link-state group and configures the interface as either an upstream or downstream interface in the group.
Step 5	end Example: Device(config-if)# <code>end</code>	Returns to privileged EXEC mode.

Configuring Link-State Tracking: Example

This example shows how to create the link-state group 1 and configure the interfaces in the link-state group.

```

Device# configure terminal
Device(config)# link state track 1
Device(config-if)# interface range gigabitethernet 1/0/21-22
Device(config-if)# link state group 1 upstream
Device(config-if)# interface gigabitethernet 1/0/1
Device(config-if)# link state group 1 downstream

```



```

Device(config-if)# interface gigabitethernet 1/0/3
Device(config-if)# link state group 1 downstream
Device(config-if)# interface gigabitethernet 1/0/5
Device(config-if)# link state group 1 downstream
Device(config-if)# end

```

Monitoring Link-State Tracking

Table 17: Commands for Monitoring Link-State Tracking Status

Command	Description
<code>show link state group [number] [detail]</code>	Displays the link-state group information.

Feature Information for Link-State Tracking

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Use the Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to www.cisco.com/go/cfn. An account on Cisco.com is not required.

Table 18: Feature Information for Link-State Tracking

Feature Name	Releases	Feature Information
Link-State Tracking	Cisco IOS Release 15.2(7)E1	The feature was introduced.



CHAPTER 7

Configuring UniDirectional Link Detection

- [Restrictions for Configuring UDLD, on page 137](#)
- [Information About UDLD, on page 137](#)
- [How to Configure UDLD, on page 140](#)
- [Monitoring and Maintaining UDLD, on page 142](#)
- [Feature Information for Configuring UDLD, on page 142](#)

Restrictions for Configuring UDLD

The following are restrictions for configuring UniDirectional Link Detection (UDLD):

- A UDLD-capable port cannot detect a unidirectional link if it is connected to a UDLD-incapable port of another device.
- When configuring the mode (normal or aggressive), make sure that the same mode is configured on both sides of the link.



Caution

Loop guard works only on point-to-point links. We recommend that each end of the link has a directly connected device that is running STP.

Information About UDLD

UniDirectional Link Detection (UDLD) is a Layer 2 protocol that enables devices connected through fiber-optic or twisted-pair Ethernet cables to monitor the physical configuration of the cables and detect when a unidirectional link exists. All connected devices must support UDLD for the protocol to successfully identify and disable unidirectional links. When UDLD detects a unidirectional link, it disables the affected port and alerts you. Unidirectional links can cause a variety of problems, including spanning-tree topology loops.

Modes of Operation

UDLD supports two modes of operation: normal (the default) and aggressive. In normal mode, UDLD can detect unidirectional links due to misconnected ports on fiber-optic connections. In aggressive mode, UDLD

can also detect unidirectional links due to one-way traffic on fiber-optic and twisted-pair links and to misconnected ports on fiber-optic links.

In normal and aggressive modes, UDLD works with the Layer 1 mechanisms to learn the physical status of a link. At Layer 1, autonegotiation takes care of physical signaling and fault detection. UDLD performs tasks that autonegotiation cannot perform, such as detecting the identities of neighbors and shutting down misconnected ports. When you enable both autonegotiation and UDLD, the Layer 1 and Layer 2 detections work together to prevent physical and logical unidirectional connections and the malfunctioning of other protocols.

A unidirectional link occurs whenever traffic sent by a local device is received by its neighbor but traffic from the neighbor is not received by the local device.

Normal Mode

In normal mode, UDLD detects a unidirectional link when fiber strands in a fiber-optic port are misconnected and the Layer 1 mechanisms do not detect this misconnection. If the ports are connected correctly but the traffic is one way, UDLD does not detect the unidirectional link because the Layer 1 mechanism, which is supposed to detect this condition, does not do so. In this case, the logical link is considered undetermined, and UDLD does not disable the port.

When UDLD is in normal mode, if one of the fiber strands in a pair is disconnected, as long as autonegotiation is active, the link does not stay up because the Layer 1 mechanisms detects a physical problem with the link. In this case, UDLD does not take any action and the logical link is considered undetermined.

Aggressive Mode

In aggressive mode, UDLD detects a unidirectional link by using the previous detection methods. UDLD in aggressive mode can also detect a unidirectional link on a point-to-point link on which no failure between the two devices is allowed. It can also detect a unidirectional link when one of these problems exists:

- On fiber-optic or twisted-pair links, one of the ports cannot send or receive traffic.
- On fiber-optic or twisted-pair links, one of the ports is down while the other is up.
- One of the fiber strands in the cable is disconnected.

In these cases, UDLD disables the affected port.

In a point-to-point link, UDLD hello packets can be considered as a heart beat whose presence guarantees the health of the link. Conversely, the loss of the heart beat means that the link must be shut down if it is not possible to reestablish a bidirectional link.

If both fiber strands in a cable are working normally from a Layer 1 perspective, UDLD in aggressive mode detects whether those fiber strands are connected correctly and whether traffic is flowing bidirectionally between the correct neighbors. This check cannot be performed by autonegotiation because autonegotiation operates at Layer 1.

Methods to Detect Unidirectional Links

UDLD operates by using two methods:

- Neighbor database maintenance
- Event-driven detection and echoing

Neighbor Database Maintenance

UDLD learns about other UDLD-capable neighbors by periodically sending a hello packet (also called an advertisement or probe) on every active port to keep each device informed about its neighbors.

When the device receives a hello message, it caches the information until the age time (hold time or time-to-live) expires. If the device receives a new hello message before an older cache entry ages, the device replaces the older entry with the new one.

Whenever a port is disabled and UDLD is running, whenever UDLD is disabled on a port, or whenever the device is reset, UDLD clears all existing cache entries for the ports affected by the configuration change. UDLD sends at least one message to inform the neighbors to flush the part of their caches affected by the status change. The message is intended to keep the caches synchronized.

Event-Driven Detection and Echoing

UDLD relies on echoing as its detection operation. Whenever a UDLD device learns about a new neighbor or receives a resynchronization request from an out-of-sync neighbor, it restarts the detection window on its side of the connection and sends echo messages in reply. Because this behavior is the same on all UDLD neighbors, the sender of the echoes expects to receive an echo in reply.

If the detection window ends and no valid reply message is received, the link might shut down, depending on the UDLD mode. When UDLD is in normal mode, the link might be considered undetermined and might not be shut down. When UDLD is in aggressive mode, the link is considered unidirectional, and the port is disabled.

UDLD Reset Options

If an interface becomes disabled by UDLD, you can use one of the following options to reset UDLD:

- The **udld reset** interface configuration command.
- The **shutdown** interface configuration command followed by the **no shutdown** interface configuration command restarts the disabled port.
- The **no udld {aggressive | enable}** global configuration command followed by the **udld {aggressive | enable}** global configuration command reenables the disabled ports.
- The **no udld port** interface configuration command followed by the **udld port [aggressive]** interface configuration command reenables the disabled fiber-optic port.
- The **errdisable recovery cause udld** global configuration command enables the timer to automatically recover from the UDLD error-disabled state, and the **errdisable recovery interval interval** global configuration command specifies the time to recover from the UDLD error-disabled state.

Default UDLD Configuration

Table 19: Default UDLD Configuration

Feature	Default Setting
UDLD global enable state	Globally disabled
UDLD per-port enable state for fiber-optic media	Disabled on all Ethernet fiber-optic ports

Feature	Default Setting
UDLD per-port enable state for twisted-pair (copper) media	Disabled on all Ethernet 10/100 and 1000BASE-TX ports
UDLD aggressive mode	Disabled

How to Configure UDLD

This section provides information on how to configure UDLD.

Enabling UDLD Globally

Follow these steps to enable UDLD in the aggressive or normal mode and to set the configurable message timer on all fiber-optic ports on the device.

Procedure

	Command or Action	Purpose
Step 1	configure terminal Example: Device# <code>configure terminal</code>	Enters global configuration mode.
Step 2	udld {aggressive enable message time message-timer-interval} Example: Device(config)# <code>udld enable</code> <code>message time 10</code>	Specifies the UDLD mode of operation: <ul style="list-style-type: none"> • aggressive—Enables UDLD in aggressive mode on all fiber-optic ports. • enable—Enables UDLD in normal mode on all fiber-optic ports on the device. UDLD is disabled by default. An individual interface configuration overrides the setting of the udld enable global configuration command. • message time message-timer-interval—Configures the period of time between UDLD probe messages on ports that are in the advertisement phase and are detected to be bidirectional. The range is from 1 to 90 seconds; the default value is 15.

	Command or Action	Purpose
		<p>Note This command affects fiber-optic ports only. Use the udld interface configuration command to enable UDLD on other port types.</p> <p>Use the no form of this command, to disable UDLD.</p>
Step 3	<p>end</p> <p>Example:</p> <pre>Device(config)# end</pre>	Returns to privileged EXEC mode.

Enabling UDLD on an Interface

Follow these steps either to enable UDLD in the aggressive or normal mode or to disable UDLD on a port.

Procedure

	Command or Action	Purpose
Step 1	<p>configure terminal</p> <p>Example:</p> <pre>Device# configure terminal</pre>	Enters global configuration mode.
Step 2	<p>interface <i>interface-id</i></p> <p>Example:</p> <pre>Device(config)# interface gigabitethernet 1/0/1</pre> <p>Or</p> <pre>Device(config)# interface fastethernet 1/0/1</pre>	Specifies the port to be enabled for UDLD, and enters interface configuration mode.
Step 3	<p>udld port [aggressive]</p> <p>Example:</p> <pre>Device(config-if)# udld port aggressive</pre>	<p>UDLD is disabled by default.</p> <ul style="list-style-type: none"> • udld port: Enables UDLD in normal mode on the specified port. • udld port aggressive: (Optional) Enables UDLD in aggressive mode on the specified port.

	Command or Action	Purpose
		Note Use the no udld port interface configuration command to disable UDLD on a specified fiber-optic port.
Step 4	end Example: Device(config-if) # end	Returns to privileged EXEC mode.

Monitoring and Maintaining UDLD

Command	Purpose
show udld [<i>interface-id</i> neighbors]	Displays the UDLD status for the specified port or for all ports.

Feature Information for Configuring UDLD

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Use the Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to www.cisco.com/go/cfn. An account on Cisco.com is not required.

Table 20: Feature Information for Configuring UDLD

Feature Name	Releases	Feature Information
Configuring UDLD	Cisco IOS Release 15.2(7)E1	The feature was introduced.