



# CHAPTER 1

## Configuring Rapid PVST+

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The Spanning Tree Protocol (STP) was implemented to provide a loop-free network. Rapid per VLAN Spanning Tree (Rapid PVST+) is an updated implementation of STP that allows you to create one spanning tree topology for each VLAN. Rapid PVST+ is the default STP mode on the switch.

This chapter includes the following sections:

- [Information About Rapid PVST+, page 1-1](#)
- [Configuring Rapid PVST+, page 1-17](#)
- [Verifying Rapid PVST+ Configurations, page 1-25](#)



### Note

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Spanning tree is used to refer to IEEE 802.1w and IEEE 802.1s. If the text is discussing the IEEE 802.1D Spanning Tree Protocol, 802.1D is stated specifically. See [Chapter 1, “Configuring MST”](#) for complete information on Multiple Spanning Tree (MST) and [Chapter 1, “Configuring STP Extensions”](#) for complete information on STP extensions.

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## Information About Rapid PVST+

This section provides describes the Rapid PVST+ protocol, which is the IEEE 802.1w standard, Rapid Spanning Tree Protocol (RSTP), implemented on a per VLAN basis. Rapid PVST+ interoperates with the IEEE 802.1D standard, which mandates a single STP instance for all VLANs, rather than per VLAN. (See the [“Rapid PVST+ and IEEE 802.1Q Trunks”](#) section on page 1-16).

Rapid PVST+ is enabled by default on the default VLAN (VLAN1) and on all newly created VLANs in software. Rapid PVST+ interoperates with switches that run legacy IEEE 802.1D STP (see the [“Rapid PVST+ Interoperation with Legacy 802.1D STP”](#) section on page 1-16).

RSTP is an improvement on the original STP standard, 802.1D, which allows faster convergence.

This section includes an overview of Rapid PVST+ and consists of these topics:

- [Understanding STP, page 1-2](#)
- [Understanding Rapid PVST+, page 1-6](#)
- [Rapid PVST+ Interoperation with Legacy 802.1D STP, page 1-16](#)
- [Rapid PVST+ Interoperation with 802.1s MST, page 1-17](#)

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## Understanding STP

RSTP, Rapid PVST+, and MST are all extensions of the original IEEE 802.1D STP (see [Chapter 1, “Configuring MST”](#) for complete information on MST). STP is a Layer 2 loop prevention protocol that provides path redundancy while preventing undesirable loops in the network.

This section provides a basic understanding of STP in the following topics:

- [Overview, page 1-2](#)
- [Understanding How a Topology is Created, page 1-2](#)
- [Understanding the Bridge ID, page 1-3](#)
- [Understanding BPDUs, page 1-4](#)
- [Election of the Root Bridge, page 1-5](#)
- [Creating the Spanning Tree Topology, page 1-5](#)

### Overview

For an Ethernet network to function properly, only one active path can exist between any two stations. STP 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.

When you create fault-tolerant internetworks, you must have a loop-free path between all nodes in a network. The STP algorithm calculates the best loop-free path throughout a switched network. LAN ports send and receive STP frames, which are called Bridge Protocol Data Units (BPDUs), at regular intervals. Switches do not forward these frames, but use the frames to construct a loop-free path.

Multiple active paths between end stations cause loops in the network. If a loop exists in the network, end stations might receive duplicate messages and switches might learn end station MAC addresses on multiple LAN ports. These conditions result in a broadcast storm, which creates an unstable network.

STP defines a tree with a root bridge and a loop-free path from the root to all switches in the network. STP forces redundant data paths into a blocked state. If a network segment in the spanning tree fails and a redundant path exists, the STP algorithm recalculates the spanning tree topology and activates the blocked path.

When two LAN ports on a switch are part of a loop, the STP port priority and port path cost setting determine which port on the switch is put in the forwarding state and which port is put in the blocking state.

### Understanding How a Topology is Created

All switches in an extended LAN that participate in a spanning tree gather information about other switches in the network by exchanging of BPDUs. This exchange of BPDUs results in the following actions:

- The system elects a unique root switch for the spanning tree network topology.
- The system elects a designated switch for each LAN segment.
- The system eliminates any loops in the switched network by placing redundant interfaces in a backup state; all paths that are not needed to reach the root switch from anywhere in the switched network are placed in an STP-blocked state.

The topology on an active switched network is determined by the following:

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- The unique switch identifier Media Access Control (MAC) address of the switch that is associated with each switch
- The path cost to the root that is associated with each interface
- The port identifier that is associated with each interface

In a switched network, the root switch is the logical center of the spanning tree topology. STP uses BPDUs to elect the root switch and root port for the switched network, as well as the root port and designated port for each switched segment.

## Understanding the Bridge ID

Each VLAN on each switch has a unique 64-bit bridge ID consisting of a bridge priority value, an extended system ID (IEEE 802.1t), and an STP MAC address allocation.

This section contains the following topics:

- [Bridge Priority Value, page 1-3](#)
- [Extended System ID, page 1-3](#)
- [STP MAC Address Allocation, page 1-4](#)

### Bridge Priority Value

The bridge priority is a 4-bit value when the extended system ID is enabled (see “[Configuring the Rapid PVST+ Bridge Priority of a VLAN](#)” section on page 1-22).



#### Note

In Cisco NX-OS, the extended system ID is always enabled; you cannot be disable the extended system ID.

### Extended System ID

A 12-bit extended system ID field is part of the bridge ID (see [Figure 1-1](#)).

**Figure 1-1 Bridge ID with Extended System ID**



The switches always use the 12-bit extended system ID.

Combined with the bridge ID, the system ID extension functions as the unique identifier for a VLAN (see [Table 1-1](#)).

**Table 1-1 Bridge Priority Value and Extended System ID with the Extended System ID Enabled**

Bridge 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

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## STP MAC Address Allocation

**Note**

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Extended system ID and MAC address reduction is always enabled on the software.

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With MAC address reduction enabled on any switch, you should also enable MAC address reduction on all other connected switches to avoid undesirable root bridge election and spanning tree topology issues.

When MAC address reduction is enabled, the root bridge priority becomes a multiple of 4096 plus the VLAN ID. You can only specify a switch bridge ID (used by the spanning tree algorithm to determine the identity of the root bridge, the lowest being preferred) as a multiple of 4096. Only the following values are possible:

- 0
- 4096
- 8192
- 12288
- 16384
- 20480
- 24576
- 28672
- 32768
- 36864
- 40960
- 45056
- 49152
- 53248
- 57344
- 61440

STP uses the extended system ID plus a MAC address to make the bridge ID unique for each VLAN.

**Note**

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If another bridge in the same spanning tree domain does not run the MAC address reduction feature, it could achieve root bridge ownership because its bridge ID may fall between the values specified by the MAC address reduction feature.

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## Understanding BPDUs

Switches transmit bridge protocol data units (BPDUs) throughout the STP instance. Each switch sends configuration BPDUs to communicate and compute the spanning tree topology. Each configuration BPDU contains the following minimal information:

- The unique bridge ID of the switch that the transmitting switch determines is the root bridge
- The STP path cost to the root
- The bridge ID of the transmitting bridge
- Message age

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- The identifier of the transmitting port
- Values for the hello, forward delay, and max-age protocol timer
- Additional information for STP extension protocols

When a switch transmits a Rapid PVST+ BPDU frame, all switches connected to the VLAN on which the frame is transmitted receive the BPDU. When a switch receives a BPDU, it does not forward the frame but instead uses the information in the frame to calculate a BPDU, and, if the topology changes, initiate a BPDU transmission.

A BPDU exchange results in the following:

- One switch is elected as the root bridge.
- The shortest distance to the root bridge is calculated for each switch based on the path cost.
- A designated bridge for each LAN segment is selected. This is the switch closest to the root bridge through which frames are forwarded to the root.
- A root port is selected. This is the port providing the best path from the bridge to the root bridge.
- Ports included in the spanning tree are selected.

See the [“Rapid PVST+ BPDUs” section on page 1-8](#) for a information about the fields that Rapid PVST+ adds to the BPDU.

## **Election of the Root Bridge**

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

When you change the bridge priority value, you change the probability that the switch will be elected as the root bridge. Configuring a lower value increases the probability; a higher value decreases the probability.

The STP root bridge is the logical center of each spanning tree topology in a network. All paths that are not needed to reach the root bridge from anywhere in the network are placed in STP blocking mode.

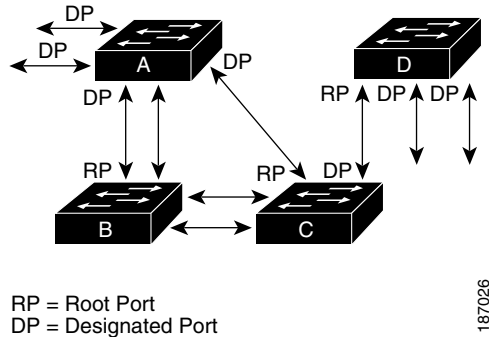
BPDUs contain information about the transmitting bridge and its ports, including bridge and MAC addresses, bridge priority, port priority, and path cost. STP uses this information to elect the root bridge for the STP instance, to elect the root port leading to the root bridge, and to determine the designated port for each segment.

## **Creating the Spanning Tree Topology**

In [Figure 1-2](#), Switch A is elected as the root bridge because the bridge priority of all the switches is set to the default (32768) and Switch A has the lowest MAC address. However, due to traffic patterns, number of forwarding ports, or link types, Switch A might not be the ideal root bridge. By increasing the priority (lowering the numerical value) of the ideal switch so that it becomes the root bridge, you force an STP recalculation to form a new spanning tree topology with the ideal switch as the root.

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**Figure 1-2 Spanning Tree Topology**



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 a port that has a higher number than the current 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 Switch B is a fiber-optic link, and another port on Switch B (an unshielded twisted-pair [UTP] link) is the root port. Network traffic might be more efficient over the high-speed fiber-optic link. By changing the STP port priority on the fiber-optic port to a higher priority (lower numerical value) than the root port, the fiber-optic port becomes the new root port.

## Understanding Rapid PVST+

This section includes the following Rapid PVST+ topics:

- [Overview, page 1-6](#)
- [Rapid PVST+ BPDUs, page 1-8](#)
- [Proposal and Agreement Handshake, page 1-8](#)
- [Protocol Timers, page 1-9](#)
- [Port Roles, page 1-10](#)
- [Port States, page 1-11](#)
- [Synchronization of Port Roles, page 1-13](#)
- [Detecting Unidirectional Link Failure, page 1-14](#)
- [Port Cost, page 1-15](#)
- [Port Priority, page 1-16](#)

### Overview

Rapid PVST+ is the IEEE 802.1w (RSTP) standard implemented per VLAN. A single instance of STP runs on each configured VLAN (if you do not manually disable STP). Each Rapid PVST+ instance on a VLAN has a single root switch. You can enable and disable STP on a per-VLAN basis when you are running Rapid PVST+.



#### Note

Rapid PVST+ is the default STP mode for the switch.

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Rapid PVST+ uses point-to-point wiring to provide rapid convergence of the spanning tree. The spanning tree reconfiguration can occur in less than 1 second with Rapid PVST+ (in contrast to 50 seconds with the default settings in the 802.1D STP).

**Note**

Rapid PVST+ supports one STP instance for each VLAN.

Using Rapid PVST+, STP convergence occurs rapidly. Each designated or root port in the STP sends out a BPDU every 2 seconds by default. On a designated or root port in the topology, if hello messages are missed three consecutive times, or if the maximum age expires, the port immediately flushes all protocol information in the table. A port considers that it loses connectivity to its direct neighbor root or designated port if it misses three BPDUs or if the maximum age expires. This rapid aging of the protocol information allows quick failure detection. The switch automatically checks the PVID.

Rapid PVST+ provides for rapid recovery of connectivity following the failure of a network device, a switch 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—When you configure a port as an edge port on an RSTP switch, the edge port immediately transitions to the forwarding state. (This immediate transition was previously a Cisco-proprietary feature named PortFast.) You should only configure on ports that connect to a single end station as edge ports. Edge ports do not generate topology changes when the link changes.

Enter the **spanning-tree port type** interface configuration command to configure a port as an STP edge port.

**Note**

We recommend that you configure all ports connected to a host as edge ports. See [Chapter 1, “Configuring STP Extensions,”](#) for more information on STP port types.

- Root ports—If Rapid PVST+ 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.

Rapid PVST+ achieves rapid transition to the forwarding state only on edge ports and point-to-point links. Although the link type is configurable, the system automatically derives the link type information from the duplex setting of the port. Full-duplex ports are assumed to be point-to-point ports, while half-duplex ports are assumed to be shared ports.

Edge ports do not generate topology changes, but all other designated and root ports generate a topology change (TC) BPDU when they either fail to receive three consecutive BPDUs from the directly connected neighbor or the maximum age times out. At this point, the designated or root port sends out a BPDU with the TC flag set. The BPDUs continue to set the TC flag as long as the TC While timer runs on that port. The value of the TC While timer is the value set for the hello time plus 1 second. The initial detector of the topology change immediately floods this information throughout the entire topology.

When Rapid PVST+ detects a topology change, the protocol does the following:

- Starts the TC While timer with a value equal to twice the hello time for all the non-edge root and designated ports, if necessary.
- Flushes the MAC addresses associated with all these ports.

The topology change notification floods quickly across the entire topology. The system flushes dynamic entries immediately on a per-port basis when it receives a topology change.

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**Note**

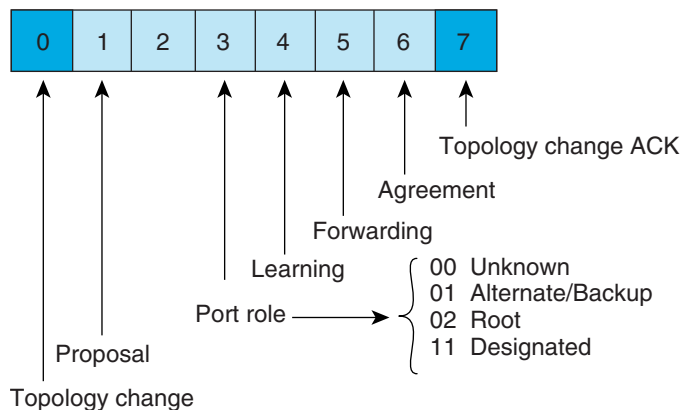
The TCA flag is used only when the switch is interacting with switches that are running legacy 802.1D STP. See the “[Rapid PVST+ Interoperation with Legacy 802.1D STP](#)” section on page 1-16 for information about Rapid PVST+ interaction with 802.1D STP.

The proposal and agreement sequence then quickly propagates toward the edge of the network and quickly restores connectivity after a topology change (see the “[Synchronization of Port Roles](#)” section on page 1-13).

## Rapid PVST+ BPDUs

Rapid PVST+ and 802.1w use all six bits of the flag byte to add the role and state of the port that originates the BPDU, and the proposal and agreement handshake. [Figure 1-3](#) shows the use of the BPDU flags in Rapid PVST+.

**Figure 1-3** Rapid PVST+ Flag Byte in BPDU



Another important change is that the Rapid PVST+ BPDU is type 2, version 2, which makes it possible for the switch to detect connected legacy (802.1D) bridges. The BPDU for 802.1D is version 0.

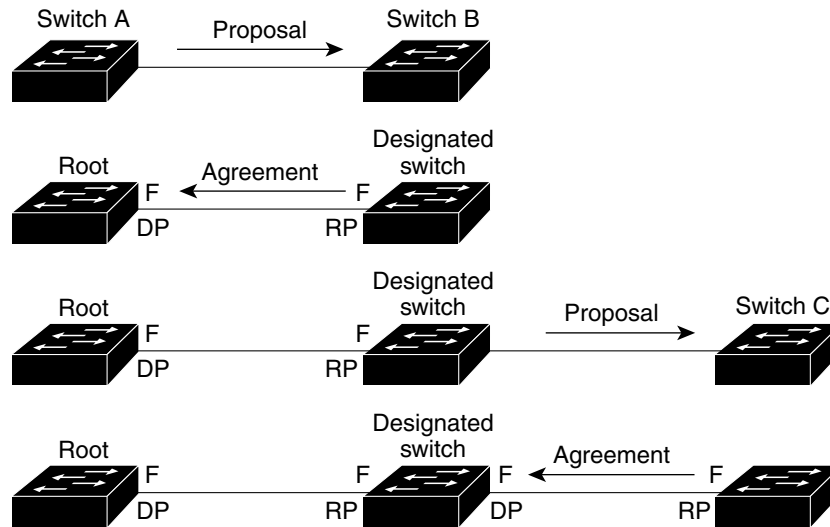
## Proposal and Agreement Handshake

As shown in [Figure 1-4](#), switch A is connected to switch B through a point-to-point link, and all of the ports are in the blocking state. Assume that the priority of switch A is a smaller numerical value than the priority of switch B.



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**Figure 1-4 Proposal and Agreement Handshaking for Rapid Convergence**



DP = designated port  
RP = root port  
F = forwarding

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Switch A sends a proposal message (a configuration BPDU with the proposal flag set) to switch B, proposing itself as the designated switch (see [Figure 1-4](#)).

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

After receiving the agreement message from switch B, switch A also immediately transitions its designated port to the forwarding state. No loops in the network can form because switch B blocked all of its non-edge ports and because there is a point-to-point link between switches A and B. (See the [“Port States”](#) section on page 1-11 for information on port states.)

When switch C connects to switch B, a similar set of handshaking messages are exchanged. Switch C selects the port connected to switch B as its root port, and both ends of the link immediately transition to the forwarding state. With each iteration of this handshaking process, one more network 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 switch learns the link type from the port duplex mode: a full-duplex port is considered to have a point-to-point connection and 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 entering the **spanning-tree link-type** interface configuration command.

This proposal/agreement handshake is initiated only when a non-edge port moves from the blocking to the forwarding state. The handshaking process then proliferates step-by-step throughout the topology.

## Protocol Timers

[Table 1-2](#) describes the protocol timers that affect the Rapid PVST+ performance.

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**Table 1-2 Rapid PVST+ Protocol Timers**

Variable	Description
Hello timer	Determines how often each switch broadcasts BPDUs to other switches. The default is 2 seconds, and the range is from 1 to 10.
Forward delay timer	Determines how long each of the listening and learning states last before the port begins forwarding. This timer is generally not used by the protocol but is used as a backup. The default is 15 seconds, and the range is from 4 to 30 seconds.
Maximum age timer	Determines the amount of time protocol information received on a port is stored by the switch. This timer is generally not used by the protocol, but it is used when interoperating with 802.1D spanning tree. The default is 20 seconds; the range is from 6 to 40 seconds.

## Port Roles

Rapid PVST+ provides rapid convergence of the spanning tree by assigning port roles and learning the active topology. Rapid PVST+ builds upon the 802.1D STP to select the switch with the highest priority (lowest numerical priority value) as the root bridge as described in the [“Election of the Root Bridge” section on page 1-5](#). Rapid PVST+ then assigns one of these port roles to individual ports:

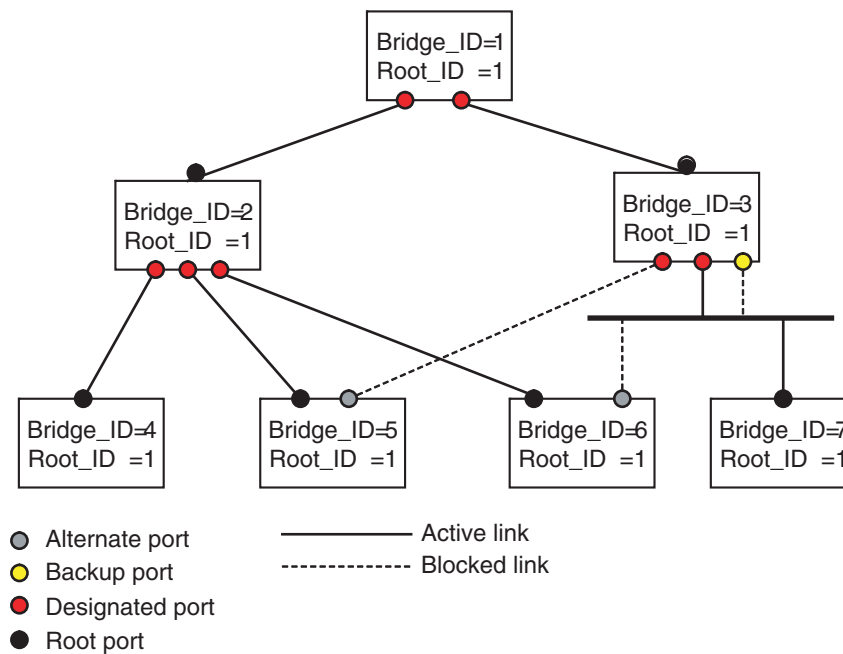
- Root port—Provides the best path (lowest cost) when the switch forwards packets to the root bridge.
- Designated port—Connects to the designated switch, which incurs the lowest path cost when forwarding packets from that LAN to the root bridge. The port through which the designated switch is attached to the LAN is called the designated port.
- Alternate port—Offers an alternate path toward the root bridge to the path provided by the current root port. An alternate port provides a path to another switch in the topology.
- 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 switch has two or more connections to a shared LAN segment. A backup port provides another path in the topology to the switch.
- Disabled port—Has no role within the operation of the spanning tree.

In a stable topology with consistent port roles throughout the network, Rapid PVST+ ensures that every root port and designated port immediately transition to the forwarding state while all alternate and backup ports are always in the blocking state. Designated ports start in the blocking state. The port state controls the operation of the forwarding and learning processes.

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 (see [Figure 1-5](#)).

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**Figure 1-5 Sample Topology Demonstrating Port Roles**



## Port States

This section describes the Rapid PVST+ and MST port states:

- [Rapid PVST+ Port State Overview, page 1-11](#)
- [Blocking State, page 1-12](#)
- [Learning State, page 1-12](#)
- [Forwarding State, page 1-12](#)
- [Disabled State, page 1-13](#)
- [Summary of Port States, page 1-13](#)

## Rapid PVST+ Port State Overview

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 a LAN port transitions directly from nonparticipation in the spanning tree topology to the forwarding state, it can create temporary data loops. Ports must wait for new topology information to propagate through the switched LAN before starting to forward frames.

Each LAN port on a software using Rapid PVST+ or MST exists in one of the following four states:

- Blocking—The LAN port does not participate in frame forwarding.
- Learning—The LAN port prepares to participate in frame forwarding.
- Forwarding—The LAN port forwards frames.
- Disabled—The LAN port does not participate in STP and is not forwarding frames.

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When you enable Rapid PVST+, every port in the software, VLAN, and network goes through the blocking state and the transitory states of learning at power up. If properly configured, each LAN port stabilizes to the forwarding or blocking state.

When the STP algorithm places a LAN port in the forwarding state, the following process occurs:

1. The LAN port is put into the blocking state while it waits for protocol information that suggests it should go to the learning state.
2. The LAN port waits for the forward delay timer to expire, moves the LAN port to the learning state, and restarts the forward delay timer.
3. In the learning state, the LAN port continues to block frame forwarding as it learns the end station location information for the forwarding database.
4. The LAN port waits for the forward delay timer to expire and then moves the LAN port to the forwarding state, where both learning and frame forwarding are enabled.

### **Blocking State**

A LAN port in the blocking state does not participate in frame forwarding.

A LAN port in the blocking state performs as follows:

- Discards frames received from the attached segment.
- Discards frames switched from another port for forwarding.
- Does not incorporate the end station location into its address database. (There is no learning on a blocking LAN port, so there is no address database update.)
- Receives BPDUs and directs them to the system module.
- Receives, processes, and transmits BPDUs received from the system module.
- Receives and responds to network management messages.

### **Learning State**

A LAN port in the learning state prepares to participate in frame forwarding by learning the MAC addresses for the frames. The LAN port enters the learning state from the blocking state.

A LAN port in the learning state performs as follows:

- Discards frames received from the attached segment.
- Discards frames switched from another port for forwarding.
- Incorporates the end station location into its address database.
- Receives BPDUs and directs them to the system module.
- Receives, processes, and transmits BPDUs received from the system module.
- Receives and responds to network management messages.

### **Forwarding State**

A LAN port in the forwarding state forwards frames. The LAN port enters the forwarding state from the learning state.

A LAN port in the forwarding state performs as follows:

- Forwards frames received from the attached segment.
- Forwards frames switched from another port for forwarding.

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- Incorporates the end station location information into its address database.
- Receives BPDUs and directs them to the system module.
- Processes BPDUs received from the system module.
- Receives and responds to network management messages.

### Disabled State

A LAN port in the disabled state does not participate in frame forwarding or STP. A LAN port in the disabled state is virtually nonoperational.

A disabled LAN port performs as follows:

- Discards frames received from the attached segment.
- Discards frames switched from another port for forwarding.
- Does not incorporate the end station location into its address database. (There is no learning, so there is no address database update.)
- Does not receive BPDUs from neighbors.
- Does not receive BPDUs for transmission from the system module.

### Summary of Port States

Table 1-3 lists the possible operational and Rapid PVST+ states for ports and the corresponding inclusion in the active topology.

**Table 1-3 Port State Active Topology**

Operational Status	Port State	Is Port Included in the Active Topology?
Enabled	Blocking	No
Enabled	Learning	Yes
Enabled	Forwarding	Yes
Disabled	Disabled	No

### Synchronization of Port Roles

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

The switch is synchronized with superior root information received on the root port if all other ports are synchronized. An individual port on the switch is synchronized if either of the following applies:

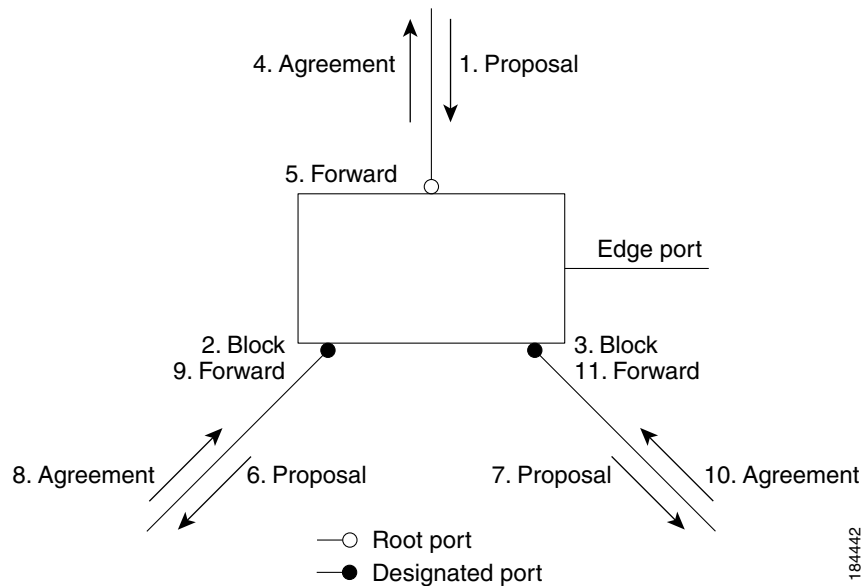
- That port is in the blocking state.
- It is an edge port (a port configured to be at the edge of the network).

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 Rapid PVST+ forces it to synchronize with new root information. In general, when the Rapid PVST+ 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.

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After ensuring that all of the ports are synchronized, the switch sends an agreement message to the designated switch that corresponds to its root port. When the switches connected by a point-to-point link are in agreement about their port roles, Rapid PVST+ immediately transitions the port states to the forwarding state. The sequence of events is shown in Figure 1-6.

**Figure 1-6** Sequence of Events During Rapid Convergence



### Processing Superior BPDU Information

A superior BPDU is a BPDU with root information (such as a lower switch ID or lower path cost) that is superior to what is currently stored for the port.

If a port receives a superior BPDU, Rapid PVST+ triggers a reconfiguration. If the port is proposed and is selected as the new root port, Rapid PVST+ forces all the other ports to synchronize.

If the received BPDU is a Rapid PVST+ BPDU with the proposal flag set, the switch sends an agreement message after all of the other ports are synchronized. The new root port transitions to the forwarding state as soon as the previous port reaches the blocking state.

If the superior information received on the port causes the port to become a backup port or an alternate port, Rapid PVST+ sets the port to the blocking state and sends an agreement message. The designated port continues sending BPDUs with the proposal flag set until the forward-delay timer expires. At that time, the port transitions to the forwarding state.

### Processing Inferior BPDU Information

An inferior BPDU is a BPDU with root information (such as a higher switch ID or higher path cost) that is inferior to what is currently stored for the port.

If a designated port receives an inferior BPDU, it immediately replies with its own information.

### Detecting Unidirectional Link Failure

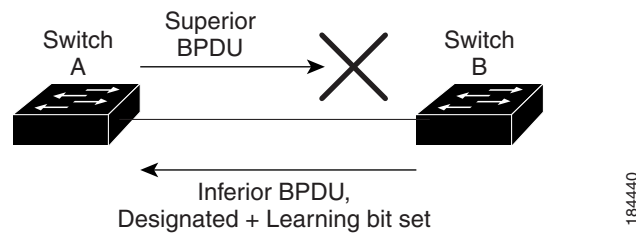
The software checks the consistency of the port role and state in the received BPDUs to detect unidirectional link failures that could cause bridging loops.

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

Figure 1-7 illustrates a unidirectional link failure that typically creates a bridging loop. Switch A is the root bridge, and its BPDUs are lost on the link leading to switch B. The 802.1w-standard BPDUs include the role and state of the sending port. With this information, switch A can detect that switch B does not react to the superior BPDUs it sends and that switch B is the designated, not root port. As a result, switch A blocks (or keeps blocking) its port, thus preventing the bridging loop. The block is shown as an STP dispute.

**Figure 1-7** Detecting Unidirectional Link Failure



## Port Cost



### Note

Rapid PVST+ uses the short (16-bit) pathcost method to calculate the cost by default. With the short pathcost method, you can assign any value in the range of 1 to 65535. However, you can configure the switch to use the long (32-bit) pathcost method, which allows you to assign any value in the range of 1 to 200,000,000. You configure the pathcost calculation method globally.

The STP port path-cost default value is determined from the media speed and path-cost calculation method of a LAN interface (see Table 1-4). If a loop occurs, STP considers the port cost when selecting a LAN interface to put into the forwarding state.

**Table 1-4** Default Port Cost

Bandwidth	Short Path-cost Method of Port Cost	Long Path-cost Method of Port Cost
10 Mbps	100	2,000,000
100 Mbps	19	200,000
1 Gigabit Ethernet	4	20,000
10 Gigabit Ethernet	2	2,000

You can assign lower cost values to LAN interfaces that you want STP to select first and higher cost values to LAN interfaces that you want STP to select last. If all LAN interfaces have the same cost value, STP puts the LAN interface with the lowest LAN interface number in the forwarding state and blocks other LAN interfaces.

On access ports, you assign port cost by the port. On trunk ports, you assign the port cost by the VLAN; you can configure the same port cost to all the VLANs on a trunk port.

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## Port Priority

If a loop occurs and multiple ports have the same path cost, Rapid PVST+ considers the port priority when selecting which LAN port to put into the forwarding state. You can assign lower priority values to LAN ports that you want Rapid PVST+ to select first and higher priority values to LAN ports that you want Rapid PVST+ to select last.

If all LAN ports have the same priority value, Rapid PVST+ puts the LAN port with the lowest LAN port number in the forwarding state and blocks other LAN ports. The possible priority range is from 0 through 224 (the default is 128), configurable in increments of 32. software uses the port priority value when the LAN port is configured as an access port and uses VLAN port priority values when the LAN port is configured as a trunk port.

## Rapid PVST+ and IEEE 802.1Q Trunks

802.1Q trunks impose some limitations on the STP strategy for a network. In a network of Cisco switches connected through 802.1Q trunks, the switches maintain one instance of STP for each VLAN allowed on the trunks. However, non-Cisco 802.1Q switches maintain only one instance of STP for all VLANs allowed on the trunks.

When you connect a Cisco switch to a non-Cisco switch through an 802.1Q trunk, the Cisco switch combines the STP instance of the 802.1Q VLAN of the trunk with the STP instance of the non-Cisco 802.1Q switch. However, all per-VLAN STP information that is maintained by Cisco switches is separated by a cloud of non-Cisco 802.1Q switches. The non-Cisco 802.1Q cloud that separates the Cisco switches is treated as a single trunk link between the switches.

## Rapid PVST+ Interoperation with Legacy 802.1D STP

Rapid PVST+ can interoperate with switches that are running the legacy 802.1D protocol. The switch knows that it is interoperating with equipment running 802.1D when it receives a BPDU version 0. The BPDUs for Rapid PVST+ are version 2. If the BPDU received is an 802.1w BPDU version 2 with the proposal flag set, the switch sends an agreement message after all of the other ports are synchronized. If the BPDU is an 802.1D BPDU version 0, the switch 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.

The switch interoperates with legacy 802.1D switches as follows:

- **Notification**—Unlike 802.1D BPDUs, 802.1w does not use TCN BPDUs. However, for interoperability with 802.1D switches, Cisco NX-OS processes and generates TCN BPDUs.
- **Acknowledgement**—When an 802.1w switch receives a TCN message on a designated port from an 802.1D switch, it replies with an 802.1D configuration BPDU with the TCA bit set. However, if the TC-while timer (the same as the TC timer in 802.1D) is active on a root port connected to an 802.1D switch and a configuration BPDU with the TCA set is received, the TC-while timer is reset.

This method of operation is required only for 802.1D switches. The 802.1w BPDUs do not have the TCA bit set.

- **Protocol migration**—For backward compatibility with 802.1D switches, 802.1w selectively sends 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 802.1w BPDUs are sent), and 802.1w BPDUs are sent. While this timer is active, the switch processes all BPDUs received on that port and ignores the protocol type.



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

**Note**

If you want all switches to renegotiate the protocol, you must restart Rapid PVST+. See the [“Restarting the Protocol”](#) section on page 1-25 for more information.

## Rapid PVST+ Interoperation with 802.1s MST

Rapid PVST+ interoperates seamlessly with the IEEE 802.1s Multiple Spanning Tree (MST) standard. No user configuration is needed.

## Configuring Rapid PVST+

Rapid PVST+, which has the 802.1w standard applied to the Rapid PVST+ protocol, is the default STP setting in the software.

You enable Rapid PVST+ on a per-VLAN basis. The software maintains a separate instance of STP for each VLAN (except on those VLANs on which you disable STP). By default, Rapid PVST+ is enabled on the default VLAN and on each VLAN that you create.

This section includes the following topics:

- [Enabling Rapid PVST+, page 1-17](#)
- [Enabling Rapid PVST+ per VLAN, page 1-18](#)
- [Configuring the Root Bridge ID, page 1-19](#)
- [Configuring a Secondary Root Bridge, page 1-20](#)
- [Configuring the Rapid PVST+ Port Priority, page 1-21](#)
- [Configuring the Rapid PVST+ Pathcost Method and Port Cost, page 1-21](#)
- [Configuring the Rapid PVST+ Bridge Priority of a VLAN, page 1-22](#)
- [Configuring the Rapid PVST+ Hello Time for a VLAN, page 1-23](#)
- [Configuring the Rapid PVST+ Forward Delay Time for a VLAN, page 1-23](#)
- [Configuring the Rapid PVST+ Maximum Age Time for a VLAN, page 1-23](#)
- [Specifying the Link Type, page 1-24](#)
- [Restarting the Protocol, page 1-25](#)

## Enabling Rapid PVST+

Once you enable Rapid PVST+ on the switch, you must enable Rapid PVST+ on the specified VLANs (see [“Enabling Rapid PVST+ per VLAN”](#) section on page 1-18).

Rapid PVST+ is the default STP mode. You cannot simultaneously run MST and Rapid PVST+.

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**Note** Changing the spanning tree mode disrupts traffic because all spanning tree instances are stopped for the previous mode and started for the new mode.

To enable Rapid PVST+ on the switch, perform this task:

	Command	Purpose
Step 1	switch# <b>configure terminal</b>	Enters configuration mode.
Step 2	switch(config)# <b>spanning-tree mode rapid-pvst</b>	Enables Rapid PVST+ on the switch. Rapid PVST+ is the default spanning tree mode.  <b>Note</b> Changing the spanning tree mode disrupts traffic because all spanning tree instances are stopped for the previous mode and started for the new mode.

This example shows how to enable Rapid PVST+ on the switch:

```
switch# configure terminal
switch(config)# spanning-tree mode rapid-pvst
```



**Note** Because STP is enabled by default, entering the **show running** command to view the resulting configuration does not display the command that you entered to enable Rapid PVST+.

## Enabling Rapid PVST+ per VLAN

You can enable or disable Rapid PVST+ on each VLAN.



**Note** Rapid PVST+ is enabled by default on the default VLAN and on all VLANs that you create.

To enable Rapid PVST+ per VLAN, perform this task:

	Command	Purpose
Step 1	switch# <b>configure terminal</b>	Enters configuration mode.
Step 2	switch(config)# <b>spanning-tree vlan-range</b>	Enables Rapid PVST+ (default STP) on a per VLAN basis. The <i>vlan-range</i> value can be 2 through 4094 (except reserved VLAN values. See <a href="#">Chapter 1, "Configuring VLANs."</a> )

This example shows how to enable STP on VLAN 5:

```
switch# configure terminal
switch(config)# spanning-tree vlan 5
```

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To disable Rapid PVST+ per VLAN, perform this task:

Command	Purpose
switch(config)# <b>no spanning-tree</b> <i>vlan-range</i>	Disables Rapid PVST+ on the specified VLAN; see the following Caution for information regarding this command.



### Caution

Do not disable spanning tree on a VLAN unless all switches and bridges in the VLAN have spanning tree disabled. You cannot disable spanning tree on some switches and bridges in a VLAN and leave it enabled on other switches and bridges in the VLAN. This action can have unexpected results because switches and bridges with spanning tree enabled will have incomplete information regarding the physical topology of the network.

Do not disable spanning tree in a VLAN without ensuring that there are no physical loops present in the VLAN. Spanning tree serves as a safeguard against misconfigurations and cabling errors.

## Configuring the Root Bridge ID

The software maintains a separate instance of STP for each active VLAN in Rapid PVST+. For each VLAN, the switch with the lowest bridge ID becomes the root bridge for that VLAN.

To configure a VLAN instance to become the root bridge, modify the bridge priority from the default value (32768) to a significantly lower value.

When you enter the **spanning-tree vlan *vlan\_ID* root** command, the switch checks the bridge priority of the current root bridges for each VLAN. The switch sets the bridge priority for the specified VLANs to 24576 if this value will cause the switch to become the root for the specified VLANs. If any root bridge for the specified VLANs has a bridge priority lower than 24576, the switch sets the bridge priority for the specified VLANs to 4096 less than the lowest bridge priority.



### Note

The **spanning-tree vlan *vlan\_ID* root** command fails if the value required to be the root bridge is less than 1.



### Caution

The root bridge for each instance of STP should be a backbone or distribution switch. Do not configure an access switch as the STP primary root.

Enter the **diameter** keyword to specify the network diameter (that is, the maximum number of bridge hops between any two end stations in the network). When you specify the network diameter, the software automatically selects an optimal hello time, forward delay time, and maximum age time for a network of that diameter, which can significantly reduce the STP convergence time. You can enter the **hello-time** keyword to override the automatically calculated hello time.



### Note

With the switch configured as the root bridge, do not manually configure the hello time, forward-delay time, and maximum-age time using the **spanning-tree mst hello-time**, **spanning-tree mst forward-time**, and **spanning-tree mst max-age** global configuration commands.

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To configure a switch to become the primary root bridge for a VLAN in Rapid PVST+, perform this task:

	Command	Purpose
Step 1	switch# <b>configure terminal</b>	Enters configuration mode.
Step 2	switch(config)# <b>spanning-tree vlan</b> <i>vlan-range</i> <b>root primary</b> [ <b>diameter</b> <i>dia</i> [ <b>hello-time</b> <i>hello-time</i> ]]	Configures a software switch as the primary root bridge. The <i>vlan-range</i> value can be 2 through 4094 (except reserved VLAN values.) The <i>dia</i> default is 7. The <i>hello-time</i> can be from 1 to 10 seconds, and the default value is 2 seconds.

This example shows how to configure the switch as the root bridge for VLAN 5 with a network diameter of 4:

```
switch# configure terminal
switch(config)# spanning-tree vlan 5 root primary diameter 4
```

## Configuring a Secondary Root Bridge

When you configure a software switch as the secondary root, the STP bridge priority is modified from the default value (32768) so that the switch is likely to become the root bridge for the specified VLANs if the primary root bridge fails (assuming the other switches in the network use the default bridge priority of 32768). STP sets the bridge priority to 28672.

Enter the **diameter** keyword to specify the network diameter (that is, the maximum number of bridge hops between any two end stations in the network). When you specify the network diameter, the software automatically selects an optimal hello time, forward delay time, and maximum age time for a network of that diameter, which can significantly reduce the STP convergence time. You can enter the **hello-time** keyword to override the automatically calculated hello time.

You configure more than one switch in this manner to have multiple backup root bridges. Enter the same network diameter and hello time values that you used when configuring the primary root bridge.



### Note

With the switch configured as the root bridge, do not manually configure the hello time, forward-delay time, and maximum-age time using the **spanning-tree mst hello-time**, **spanning-tree mst forward-time**, and **spanning-tree mst max-age** global configuration commands.

To configure a switch to become the secondary root bridge for a VLAN in Rapid PVST+, perform this task:

	Command	Purpose
Step 1	switch# <b>configure terminal</b>	Enters configuration mode.
Step 2	switch(config)# <b>spanning-tree vlan</b> <i>vlan-range</i> <b>root secondary</b> [ <b>diameter</b> <i>dia</i> [ <b>hello-time</b> <i>hello-time</i> ]]	Configures a software switch as the secondary root bridge. The <i>vlan-range</i> value can be 2 through 4094 (except reserved VLAN values.) The <i>dia</i> default is 7. The <i>hello-time</i> can be from 1 to 10 seconds, and the default value is 2 seconds.

This example shows how to configure the switch as the secondary root bridge for VLAN 5 with a network diameter of 4:

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```
switch# configure terminal
switch(config)# spanning-tree vlan 5 root secondary diameter 4
```

## Configuring the Rapid PVST+ Port Priority

You can assign lower priority values to LAN ports that you want Rapid PVST+ to select first and higher priority values to LAN ports that you want Rapid PVST+ to select last. If all LAN ports have the same priority value, Rapid PVST+ puts the LAN port with the lowest LAN port number in the forwarding state and blocks other LAN ports.

The software uses the port priority value when the LAN port is configured as an access port and uses VLAN port priority values when the LAN port is configured as a trunk port.

To assign Rapid PVST+ port priorities to individual ports, perform this task:

	Command	Purpose
Step 1	switch# <b>configure terminal</b>	Enters configuration mode.
Step 2	switch(config)# <b>interface</b> <i>type</i> <i>slot/port</i>	Specifies the interface to configure, and enters the interface configuration mode.
Step 3	switch(config-if)# <b>spanning-tree</b> [ <b>vlan</b> <i>vlan-list</i> ] <b>port-priority</b> <i>priority</i>	Configures the port priority for the LAN interface. The <i>priority</i> value can be from 0 to 224. The lower the value, the higher the priority. The priority values are 0, 32, 64, 96, 128, 160, 192, and 224. All other values are rejected. The default value is 128.

This example shows how to configure the port priority of Ethernet access port 1/4 to 160:

```
switch# configure terminal
switch(config)# interface ethernet 1/4
switch(config-if)# spanning-tree port-priority 160
```

You can only apply this command to a physical Ethernet interface.

## Configuring the Rapid PVST+ Pathcost Method and Port Cost

On access ports, you assign port cost by the port. On trunk ports, you assign the port cost by VLAN; you can configure the same port cost on all the VLANs on a trunk.



### Note

In Rapid PVST+ mode, you can use either the short or long pathcost method, and you can configure the method in either the interface or configuration submenu. The default pathcost method is short.

To set the Rapid PVST+ pathcost method and cost for a port, perform the following task:

	Command	Purpose
Step 1	switch# <b>configure terminal</b>	Enters configuration mode.
Step 2	switch(config)# <b>spanning-tree pathcost</b> <b>method</b> { <b>long</b>   <b>short</b> }	Selects the method used for Rapid PVST+ pathcost calculations. The default method is the short method.

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	Command	Purpose
Step 3	<code>switch(config)# interface type slot/port</code>	Specifies the interface to configure, and enters the interface configuration mode.
Step 4	<code>switch(config-if)# spanning-tree [vlan vlan-id] cost [value   auto]</code>	Configures the port cost for the LAN interface. The cost value, depending on the pathcost calculation method, can be as follows: <ul style="list-style-type: none"> <li>• short—1 to 65535</li> <li>• long—1 to 200000000</li> </ul> <p><b>Note</b> You configure this parameter per port on access ports and per VLAN on trunk ports.</p> <p>The default is <b>auto</b>, which sets the port cost on both the pathcost calculation method and the media speed.</p>

This example shows how to configure the port cost of Ethernet access port 1/4 to 1000:

```
switch# configure terminal
switch (config)# spanning-tree pathcost method long
switch (config)# interface ethernet 1/4
switch(config-if)# spanning-tree cost 1000
```

You can only apply this command to a physical Ethernet interface.

## Configuring the Rapid PVST+ Bridge Priority of a VLAN

You can configure the Rapid PVST+ bridge priority of a VLAN.



### Note

Be careful when using this configuration. For most situations, we recommend that you configure the primary root and secondary root to modify the bridge priority.

To choose the bridge priority for a specific VLAN, perform this task:

	Command	Purpose
Step 1	<code>switch# configure terminal</code>	Enters configuration mode.
Step 2	<code>switch(config)# spanning-tree vlan vlan-range priority value</code>	Configures the bridge priority of a VLAN. Valid values are 0, 4096, 8192, 12288, 16384, 20480, 24576, 28672, 32768, 36864, 40960, 45056, 49152, 53248, 57344, and 61440. All other values are rejected. The default value is 32768.

This example shows how to configure the priority of VLAN 5 on Gigabit Ethernet port 1/4 to 8192:

```
switch# configure terminal
switch(config)# spanning-tree vlan 5 priority 8192
```

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## Configuring the Rapid PVST+ Hello Time for a VLAN

You can configure the Rapid PVST+ hello time for a VLAN.



### Note

Be careful when using this configuration. For most situations, we recommend that you configure the primary root and secondary root to modify the hello time.

To configure the hello time for a VLAN in Rapid PVST+, perform this task:

	Command	Purpose
Step 1	switch# <b>configure terminal</b>	Enters configuration mode.
Step 2	switch(config)# <b>spanning-tree vlan vlan-range hello-time value</b>	Configures the hello time of a VLAN. The hello time value can be from 1 to 10 seconds, and the default is 2 seconds.

This example shows how to configure the hello time for VLAN 5 to 7 seconds:

```
switch# configure terminal
switch(config)# spanning-tree vlan 5 hello-time 7
```

## Configuring the Rapid PVST+ Forward Delay Time for a VLAN

You can configure the forward delay time per VLAN when using Rapid PVST+. To configure the forward delay time per VLAN, perform this task:

	Command	Purpose
Step 1	switch# <b>configure terminal</b>	Enters configuration mode.
Step 2	switch(config)# <b>spanning-tree vlan vlan-range forward-time value</b>	Configures the forward delay time of a VLAN. The forward delay time value can be from 4 to 30 seconds, and the default is 15 seconds.

This example shows how to configure the forward delay time for VLAN 5 to 21 seconds:

```
switch# configure terminal
switch(config)# spanning-tree vlan 5 forward-time 21
```

## Configuring the Rapid PVST+ Maximum Age Time for a VLAN

You can configure the maximum age time per VLAN when using Rapid PVST+. To configure the maximum age time for a VLAN in Rapid PVST+, perform this task:

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	Command	Purpose
Step 1	switch# <b>configure terminal</b>	Enters configuration mode.
Step 2	switch(config)# <b>spanning-tree vlan</b> <i>vlan-range</i> <b>max-age</b> <i>value</i>	Configures the maximum aging time of a VLAN. The maximum aging time value can be from 6 to 40 seconds, and the default is 20 seconds.

This example shows how to configure the maximum aging time for VLAN 5 to 36 seconds:

```
switch# configure terminal
switch(config)# spanning-tree vlan 5 max-age 36
```

## Specifying the Link Type

Rapid connectivity (802.1w standard) is established only on point-to-point links. 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 switch, you can override the default setting on the link type and enable rapid transitions.

If you set the link to shared, STP moves back to 802.1D.

To specify the link type, perform this task:

	Command	Purpose
Step 1	switch# <b>configure terminal</b>	Enters configuration mode.
Step 2	switch(config)# <b>interface</b> <i>type</i> <i>slot/port</i>	Specifies the interface to configure, and enters the interface configuration mode.
Step 3	switch(config-if)# <b>spanning-tree</b> <b>link-type</b> { <b>auto</b>   <b>point-to-point</b>   <b>shared</b> }	Configures the link type to be either a point-to-point link or shared link. The system reads the default value from the switch connection, as follows: half duplex links are shared and full-duplex links are point-to-point. If the link type is shared, the STP reverts to 802.1D. The default is auto, which sets the link type based on the duplex setting of the interface.

This example shows how to configure the link type as a point-to-point link:

```
switch# configure terminal
switch (config)# interface ethernet 1/4
switch(config-if)# spanning-tree link-type point-to-point
```

You can only apply this command to a physical Ethernet interface.



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## Restarting the Protocol

A bridge running Rapid PVST+ can send 802.1D BPDUs on one of its ports when it is connected to a legacy bridge. However, the STP protocol migration cannot determine whether the legacy switch has been removed from the link unless the legacy switch is the designated switch. You can restart the protocol negotiation (force the renegotiation with neighboring switches) on the entire switch or on specified interfaces.

To restart the protocol negotiation, perform this task:

Command	Purpose
switch# <b>clear spanning-tree detected-protocol</b> [ <i>interface interface</i> [ <i>interface-num</i>   <i>port-channel</i> ]]	Restarts Rapid PVST+ on all interfaces on the switch or specified interfaces.

This example shows how to restart Rapid PVST+ on the Ethernet interface on slot 2, port 8:

```
switch# clear spanning-tree detected-protocol interface ethernet 2/8
```

## Verifying Rapid PVST+ Configurations

To display Rapid PVST+ configuration information, perform one of these tasks:

Command	Purpose
switch# <b>show running-config spanning-tree</b> [ <i>all</i> ]	Displays the current spanning tree configuration.
switch# <b>show spanning-tree</b> [ <i>options</i> ]	Displays selected detailed information for the current spanning tree configuration.

This example shows how to display spanning tree status:

```
switch# show spanning-tree brief
```

```
VLAN0001
  Spanning tree enabled protocol rstp
  Root ID    Priority    32768
             Address     001c.b05a.5447
             Cost        2
             Port        131 (Ethernet1/3)
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769 (priority 32768 sys-id-ext 1)
             Address     000d.ec6d.7841
             Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

Interface      Role Sts Cost      Prio.Nbr Type
-----
Eth1/3         Root FWD 2         128.131 P2p Peer (STP)
veth1/1       Desg FWD 2         128.129 Edge P2p
```

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