



Configuring STP

This chapter describes how to configure the Spanning Tree Protocol (STP) on port-based VLANs on your Catalyst 3550 switch. The switch can use either the per-VLAN spanning-tree plus (PVST+) protocol based on the IEEE 802.1D standard and Cisco proprietary extensions, or the rapid per-VLAN spanning-tree plus (rapid-PVST+) protocol based on the IEEE 802.1w standard.

For information about the Multiple Spanning Tree Protocol (MSTP) and how to map multiple VLANs to the same spanning-tree instance, see [Chapter 16, “Configuring MSTP.”](#)

For information about other spanning-tree features such as Port Fast, UplinkFast, root guard, and so forth, see [Chapter 17, “Configuring Optional Spanning-Tree Features.”](#)



Note

For complete syntax and usage information for the commands used in this chapter, see the command reference for this release.

This chapter consists of these sections:

- [Understanding Spanning-Tree Features, page 15-1](#)
- [Configuring Spanning-Tree Features, page 15-11](#)
- [Displaying the Spanning-Tree Status, page 15-24](#)

Understanding Spanning-Tree Features

These sections describe how basic spanning-tree features work:

- [STP Overview, page 15-2](#)
- [Spanning-Tree Topology and BPDUs, page 15-2](#)
- [Bridge ID, Switch Priority, and Extended System ID, page 15-3](#)
- [Spanning-Tree Interface States, page 15-4](#)
- [How a Switch or Port Becomes the Root Switch or Root Port, page 15-7](#)
- [Spanning Tree and Redundant Connectivity, page 15-7](#)
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- [Spanning-Tree Modes and Protocols, page 15-9](#)
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- [Spanning-Tree Interoperability and Backward Compatibility, page 15-10](#)
- [STP and IEEE 802.1Q Trunks, page 15-10](#)
- [VLAN-Bridge Spanning Tree, page 15-11](#)

For configuration information, see the “[Configuring Spanning-Tree Features](#)” section on page 15-11.

For information about optional spanning-tree features, see [Chapter 17, “Configuring Optional Spanning-Tree Features.”](#)

STP Overview

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

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. Switches send and receive spanning-tree frames, called bridge protocol data units (BPDUs), at regular intervals. The switches do not forward these frames but use them to construct a loop-free path. BPDUs contain information about the sending switch and its ports, including switch and MAC addresses, switch priority, port priority, and path cost. Spanning tree uses this information to elect the root switch and root port for the switched network and the root port and designated port for each switched segment.

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

Spanning-Tree Topology and BPDUs

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

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

When the switches in a network are powered up, each functions as the root switch. Each switch 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 switch that the sending switch identifies as the root switch
- The spanning-tree path cost to the root
- The bridge ID of the sending switch
- Message age
- The identifier of the sending interface
- Values for the hello, forward-delay, and max-age protocol timers

When a switch 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 switch, the switch also forwards it with an updated message to all attached LANs for which it is the designated switch.

If a switch receives a configuration BPDU that contains *inferior* information to that currently stored for that port, it discards the BPDU. If the switch is a designated switch 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 switch in the network is elected as the root switch (the logical center of the spanning-tree topology in a switched network).

For each VLAN, the switch with the highest switch priority (the lowest numerical priority value) is elected as the root switch. If all switches are configured with the default priority (32768), the switch with the lowest MAC address in the VLAN becomes the root switch. The switch priority value occupies the most significant bits of the bridge ID, as shown in [Table 15-1 on page 15-4](#).

- A root port is selected for each switch (except the root switch). This port provides the best path (lowest cost) when the switch forwards packets to the root switch.
- The shortest distance to the root switch is calculated for each switch based on the path cost.
- A designated switch for each LAN segment is selected. The designated switch incurs the lowest path cost when forwarding packets from that LAN to the root switch. The port through which the designated switch is attached to the LAN is called the designated port.
- Interfaces included in the spanning-tree instance are selected. Root ports and designated ports are put in the forwarding state.
- All paths that are not needed to reach the root switch from anywhere in the switched network are placed in the spanning-tree blocking mode.

Bridge ID, Switch Priority, and Extended System ID

The IEEE 802.1D standard requires that each switch has an unique bridge identifier (bridge ID), which determines the selection of the root switch. Because each VLAN is considered as a different *logical bridge* with PVST+ and rapid PVST+, the same switch must have as many different bridge IDs as VLANs configured on it. Each VLAN on the switch has a unique 8-byte bridge ID; the two most-significant bytes are used for the switch priority, and the remaining six bytes are derived from the switch MAC address.

In Cisco IOS Release 12.1(8)EA1 and later, the switch supports the 802.1t spanning-tree extensions. Some of the bits previously used for the switch priority are now used as the VLAN identifier. The result is that fewer MAC addresses are reserved for the switch, and a larger range of VLAN IDs can be supported, all while maintaining the uniqueness of the bridge ID. As shown in [Table 15-1](#), the two bytes previously used for the switch priority are reallocated into a 4-bit priority value and a 12-bit extended system ID value equal to the VLAN ID. In earlier releases, the switch priority is a 16-bit value.

Table 15-1 Switch Priority Value and Extended System ID

Switch 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 switch priority, and the allocated spanning-tree MAC address to make the bridge ID unique for each VLAN. With earlier releases, spanning tree used one MAC address per VLAN to make the bridge ID unique for each VLAN.

Support for the extended system ID affects how you manually configure the root switch, the secondary root switch, and the switch priority of a VLAN. For example, when you change the switch priority value, you change the probability that the switch will be elected as the root switch. Configuring a higher value decreases the probability; a lower value increases the probability. For more information, see the [“Configuring the Root Switch”](#) section on page 15-14, the [“Configuring a Secondary Root Switch”](#) section on page 15-16, and the [“Configuring the Switch Priority of a VLAN”](#) section on page 15-20.

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 switch using spanning tree exists in one of these states:

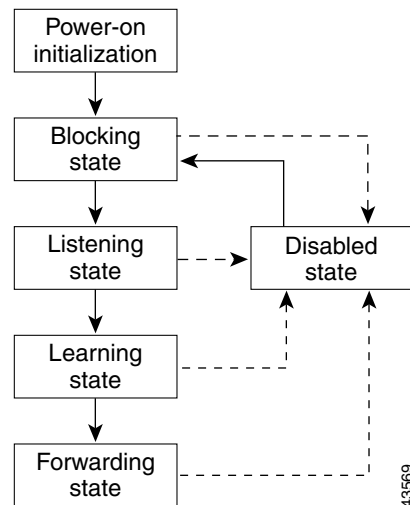
- **Blocking**—The interface does not participate in frame forwarding.
- **Listening**—The first transitional state after the blocking state when the spanning tree determines that the interface should participate in frame forwarding.
- **Learning**—The interface prepares to participate in frame forwarding.
- **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 15-1 illustrates how an interface moves through the states.

Figure 15-1 Spanning-Tree Interface States



When you power up the switch, spanning tree is enabled by default, and every interface in the switch, 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 transition the interface to the blocking state.
2. While the 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 switch 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 interface in the switch. A switch initially functions as the root until it exchanges BPDUs with other switches. This exchange establishes which switch in the network is the root or root switch. If there is only one switch in the network, no exchange occurs, the forward-delay timer expires, and the interfaces move to the listening state. An interface always enters the blocking state after switch initialization.

An interface in the blocking state performs as follows:

- Discards frames received on the port
- 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 determines that the interface should participate in frame forwarding.

An interface in the listening state performs as follows:

- Discards frames received on the port
- 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 as follows:

- Discards frames received on the port
- 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 as follows:

- Receives and forwards frames received on the port
- Forwards frames switched from another port
- 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.

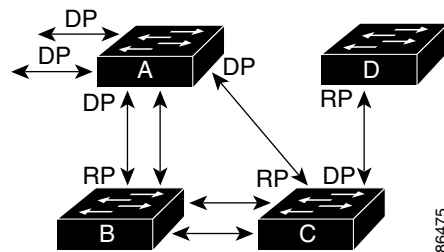
A disabled interface performs as follows:

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

How a Switch or Port Becomes the Root Switch or Root Port

If all switches in a network are enabled with default spanning-tree settings, the switch with the lowest MAC address becomes the root switch. In [Figure 15-2](#), Switch A is elected as the root switch because the switch priority of all the switches is set to the default (32768) and Switch A has the lowest MAC address. However, because of traffic patterns, number of forwarding interfaces, or link types, Switch A might not be the ideal root switch. By increasing the priority (lowering the numerical value) of the ideal switch so that it becomes the root switch, you force a spanning-tree recalculation to form a new topology with the ideal switch as the root.

Figure 15-2 Spanning-Tree Topology



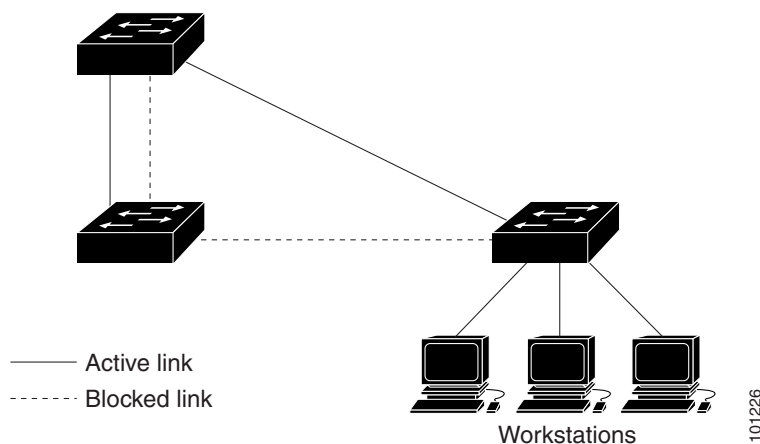
RP = Root Port
DP = Designated Port

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 Switch B is a Gigabit Ethernet link and that another port on Switch B (a 10/100 Mbps 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 interface to a higher priority (lower numerical value) than the root port, the Gigabit Ethernet interface becomes the new root port.

Spanning Tree and Redundant Connectivity

You can create a redundant backbone with spanning tree by connecting two switch interfaces to another device or to two different devices. Spanning tree automatically disables one interface but enables it if the other one fails, as shown in [Figure 15-3](#). 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 lowest value.

Figure 15-3 Spanning Tree and Redundant Connectivity

You can also create redundant links between switches by using EtherChannel groups. For more information, see [Chapter 31, “Configuring EtherChannels.”](#)

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.

Regardless of the spanning-tree state, the switch receives but does not forward packets destined for addresses between 0x0180C2000000 and 0x0180C200000F.

If spanning tree is enabled, the switch CPU receives packets destined for 0x0180C2000000 and 0x0180C2000010. If spanning-tree is disabled, the switch 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 switch 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 switch.

Spanning-Tree Modes and Protocols

The switch supports these spanning-tree modes and protocols:

PVST+—This spanning-tree mode is based on the IEEE 802.1D standard and Cisco proprietary extensions. It is the default spanning-tree mode used on all Ethernet, Fast Ethernet, and Gigabit Ethernet port-based VLANs. The PVST+ runs on each VLAN on the switch 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 switch. This root switch propagates the spanning-tree information associated with that VLAN to all other switches in the network. Because each switch has the same information about the network, this process ensures that the network topology is maintained.

- **Rapid PVST+—**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.

The rapid PVST+ uses the same configuration as PVST+ (except where noted), and the switch 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 MSTP configuration and without having to reprovision 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. You cannot run MSTP without RSTP.

The most common initial deployment of MSTP is in the backbone and distribution layers of a Layer 2 switched network. For more information, see [Chapter 16, “Configuring MSTP.”](#) For information about the number of supported spanning-tree instances, see the next section.

Supported Spanning-Tree Instances

In PVST+ or rapid-PVST+ mode, the switch supports up to 128 spanning-tree instances.

In MSTP mode, the switch supports up to 65 MST instances. The number of VLANs that can be mapped to a particular MST instance is unlimited.

For information about how spanning tree interoperates with the VLAN Trunking Protocol (VTP), see the [“Spanning-Tree Configuration Guidelines”](#) section on page 15-12.

Spanning-Tree Interoperability and Backward Compatibility

Table 15-2 lists the interoperability and compatibility among the supported spanning-tree modes in a network.

Table 15-2 *PVST+, MSTP, and Rapid-PVST+ Interoperability*

	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

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

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

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 switches connected through IEEE 802.1Q trunks, the switches maintain one spanning-tree instance for *each* VLAN allowed on the trunks.

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

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

PVST+ is automatically enabled on 802.1Q trunks, and no user configuration is required. The external spanning-tree behavior on access ports and Inter-Switch Link (ISL) trunk ports is not affected by PVST+.

For more information on IEEE 802.1Q trunks, see [Chapter 11, “Configuring VLANs.”](#)

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 enhanced multilayer software image installed on your switch. For more information, see [Chapter 37, “Configuring Fallback Bridging.”](#)

Configuring Spanning-Tree Features

These sections describe how to configure spanning-tree features:

- [Default Spanning-Tree Configuration, page 15-11](#)
- [Spanning-Tree Configuration Guidelines, page 15-12](#)
- [Changing the Spanning-Tree Mode, page 15-13](#) (required)
- [Disabling Spanning Tree, page 15-14](#) (optional)
- [Configuring the Root Switch, page 15-14](#) (optional)
- [Configuring a Secondary Root Switch, page 15-16](#) (optional)
- [Configuring the Port Priority, page 15-17](#) (optional)
- [Configuring the Path Cost, page 15-18](#) (optional)
- [Configuring the Switch Priority of a VLAN, page 15-20](#) (optional)
- [Configuring Spanning-Tree Timers, page 15-20](#) (optional)

Default Spanning-Tree Configuration

[Table 15-3](#) shows the default spanning-tree configuration.

Table 15-3 **Default Spanning-Tree Configuration**

Feature	Default Setting
Enable state	Enabled on VLAN 1. For more information, see the “Supported Spanning-Tree Instances” section on page 15-9 .
Spanning-tree mode	PVST+. (Rapid PVST+ and MSTP are disabled.)
Switch priority	32768.
Spanning-tree port priority (configurable on a per-interface basis)	128.

Table 15-3 **Default Spanning-Tree Configuration (continued)**

Feature	Default Setting
Spanning-tree port cost (configurable on a per-interface basis)	1000 Mbps: 4. 100 Mbps: 19. 10 Mbps: 100.
Spanning-tree VLAN port priority (configurable on a per-VLAN basis)	128.
Spanning-tree VLAN port cost (configurable on a per-VLAN basis)	1000 Mbps: 4. 100 Mbps: 19. 10 Mbps: 100.
Spanning-tree timers	Hello time: 2 seconds. Forward-delay time: 15 seconds. Maximum-aging time: 20 seconds. Transmit hold count: 6 BPDUs

Spanning-Tree Configuration Guidelines

If more VLANs are defined in the VTP than there are spanning-tree instances, you can enable PVST+ or rapid PVST+ on only 128 VLANs. The remaining VLANs operate with spanning tree disabled. If the number of VLANs exceeds 128, we recommend that you enable the MSTP to map multiple VLANs to a single spanning-tree instance. For more information, see [Chapter 16, “Configuring MSTP.”](#)

For information on the recommended trunk port configuration, see the [“Interaction with Other Features” section on page 11-19.](#)

If 128 instances of spanning tree are already in use, you can disable spanning tree on one of the VLANs and then enable it on the VLAN where you want it to run. Use the **no spanning-tree vlan** *vlan-id* global configuration command to disable spanning tree on a specific VLAN, and use the **spanning-tree vlan** *vlan-id* global configuration command to enable spanning tree on the desired VLAN.



Caution

Switches that are not running spanning tree still forward received BPDUs so that the other switches on the VLAN with a running spanning-tree instance can break loops. Therefore, spanning tree must be running on enough switches to break all the loops in the network. For example, at least one switch on each loop in the VLAN must be running spanning tree. It is not absolutely necessary to run spanning tree on all switches in the VLAN; however, if you are running spanning tree only on a minimal set of switches, an incautious change to the network that introduces another loop into the VLAN can result in a broadcast storm.



Note

If you have already used all available spanning-tree instances on your switch, adding another VLAN anywhere in the VTP domain creates a VLAN that is not running spanning tree on that switch. If you have the default allowed list on the trunk ports of that switch, the new VLAN is carried on all trunk ports. Depending on the topology of the network, this could create a loop in the new VLAN that will not be broken, particularly if there are several adjacent switches that have all run out of spanning-tree instances. You can prevent this possibility by setting up allowed lists on the trunk ports of switches that have used up their allocation of spanning-tree instances. Setting up allowed lists is not necessary in many cases and can make it more labor-intensive to add another VLAN to the network.

Spanning-tree commands determine the configuration of VLAN spanning-tree instances. You create a spanning-tree instance when you assign an interface to a VLAN. The spanning-tree instance is removed when the last interface is moved to another VLAN. You can configure switch and port parameters before a spanning-tree instance is created; these parameters are applied when the spanning-tree instance is created.

The switch supports PVST+, rapid PVST+, and MSTP, 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.) For information about the different spanning-tree modes and how they interoperate, see the [“Spanning-Tree Interoperability and Backward Compatibility”](#) section on page 15-10.

For configuration guidelines about UplinkFast, BackboneFast, and cross-stack UplinkFast, see the [“Optional Spanning-Tree Configuration Guidelines”](#) section on page 17-14.

Changing the Spanning-Tree Mode

The switch supports three spanning-tree modes: PVST+, rapid PVST+, or MSTP. By default, the switch runs the PVST+ protocol.

Beginning in privileged EXEC mode, follow these steps to change the spanning-tree mode. If you want to enable a mode that is different from the default mode, this procedure is required.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	spanning-tree mode {pvst mst rapid-pvst}	Configure a spanning-tree mode. <ul style="list-style-type: none"> • Select pvst to enable PVST+ (the default setting). • Select mst to enable MSTP (and RSTP). For more configuration steps, see Chapter 16, “Configuring MSTP.” • Select rapid-pvst to enable rapid PVST+.
Step 3	interface interface-id	(Recommended for rapid-PVST+ mode only) Specify an interface to configure, and enter interface configuration mode. Valid interfaces include physical ports, VLANs, and port channels. Valid VLAN IDs are 1 to 4094. The port-channel range is 1 to 64.
Step 4	spanning-tree link-type point-to-point	(Recommended for rapid-PVST+ mode only) Specify 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 switch negotiates with the remote port and rapidly transitions the local port to the forwarding state.
Step 5	end	Return to privileged EXEC mode.
Step 6	clear spanning-tree detected-protocols	(Recommended for rapid-PVST+ mode only) If any port on the switch is connected to a port on a legacy IEEE 802.1D switch, restart the protocol migration process on the entire switch. This step is optional if the designated switch determines that this switch is running rapid PVST+.

	Command	Purpose
Step 7	show spanning-tree summary and show spanning-tree interface <i>interface-id</i>	Verify your entries.
Step 8	copy running-config startup-config	(Optional) Save your entries in the configuration file.

To return to the default setting, use the **no spanning-tree mode** global configuration command. To return the port to its default setting, use the **no spanning-tree link-type** interface configuration command.

Disabling Spanning Tree

Spanning tree is enabled by default on VLAN 1 and on all newly created VLANs up to the spanning-tree limit specified in the “[Supported Spanning-Tree Instances](#)” section on page 15-9. 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.

Beginning in privileged EXEC mode, follow these steps to disable spanning tree on a per-VLAN basis. This procedure is optional.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	no spanning-tree vlan <i>vlan-id</i>	Disable spanning tree on a per-VLAN basis. 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.
Step 3	end	Return to privileged EXEC mode.
Step 4	show spanning-tree vlan <i>vlan-id</i>	Verify your entries.
Step 5	copy running-config startup-config	(Optional) Save your entries in the configuration file.

To re-enable spanning tree, use the **spanning-tree vlan** *vlan-id* global configuration command.

Configuring the Root Switch

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

To configure a switch to become the root for the specified VLAN, use the **spanning-tree vlan** *vlan-id* **root** global configuration command to modify the switch priority from the default value (32768) to a significantly lower value. When you enter this command, the switch checks the switch priority of the

root switches for each VLAN. Because of the extended system ID support, the switch sets its own priority for the specified VLAN to 24576 if this value will cause this switch to become the root for the specified VLAN.

If any root switch for the specified VLAN has a switch priority lower than 24576, the switch sets its own priority for the specified VLAN to 4096 less than the lowest switch priority. (4096 is the value of the least-significant bit of a 4-bit switch priority value as shown in [Table 15-1 on page 15-4](#).)

**Note**

The **spanning-tree vlan *vlan-id* root** global configuration command fails if the value necessary to be the root switch is less than 1.

Before Cisco IOS Release 12.1(8)EA1, entering the **spanning-tree vlan *vlan-id* root** global configuration command on a Catalyst 3550 switch (no extended system ID) caused it to set its own switch priority for the specified VLAN to 8192 if this value caused this switch to become the root for the specified VLAN. If any root switch for the specified VLAN has a switch priority lower than 8192, the switch sets its own priority for the specified VLAN to 1 less than the lowest switch priority.

These examples show the effect of the **spanning-tree vlan *vlan-id* root** command with and without the extended system ID support:

- For Catalyst 3550 switches with the extended system ID (Cisco IOS Release 12.1(8)EA1 and later), if all network devices in VLAN 20 have the default priority of 32768, entering the **spanning-tree vlan 20 root primary** command on the switch sets the switch priority to 24576, which causes this switch to become the root switch for VLAN 20.
- For Catalyst 3550 switches without the extended system ID (software earlier than Cisco IOS Release 12.1(8)EA1), if all network devices in VLAN 100 have the default priority of 32768, entering the **spanning-tree vlan 100 root primary** command on the switch sets the switch priority for VLAN 100 to 8192, which causes this switch to become the root switch for VLAN 100.

**Note**

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

**Note**

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

Use the **diameter** keyword to specify the Layer 2 network diameter (that is, the maximum number of switch hops between any two end stations in the Layer 2 network). When you specify the network diameter, the switch 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 by using 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.

Beginning in privileged EXEC mode, follow these steps to configure a switch to become the root for the specified VLAN. This procedure is optional.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	spanning-tree vlan <i>vlan-id</i> root primary [<i>diameter net-diameter</i> [<i>hello-time seconds</i>]]	<p>Configure a switch to become the root for the specified VLAN.</p> <p>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.</p> <ul style="list-style-type: none"> • (Optional) For <i>diameter net-diameter</i>, specify the maximum number of switches between any two end stations. The range is 2 to 7. • (Optional) For <i>hello-time seconds</i>, specify the interval in seconds between the generation of configuration messages by the root switch. The range is 1 to 10 seconds; the default is 2 seconds. <p>Note When you enter this command without the optional keywords, the switch recalculates the forward-time, hello-time, max-age, and priority settings. If you had previously configured these parameters, the switch recalculates them.</p>
Step 3	end	Return to privileged EXEC mode.
Step 4	show spanning-tree detail	Verify your entries.
Step 5	copy running-config startup-config	(Optional) Save your entries in the configuration file.

To return the switch to its default setting, use the **no spanning-tree vlan *vlan-id* root** global configuration command.

Configuring a Secondary Root Switch

When you configure a Catalyst 3550 switch that supports the extended system ID as the secondary root, the switch priority is modified from the default value (32768) to 28672. The switch is then likely to become the root switch for the specified VLAN if the primary root switch fails. This is assuming that the other network switches use the default switch priority of 32768 and therefore are unlikely to become the root switch. For Catalyst 3550 switches without the extended system ID support (software earlier than Cisco IOS Release 12.1(8)EA1), the switch priority is changed to 16384.

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

Beginning in privileged EXEC mode, follow these steps to configure a switch to become the secondary root for the specified VLAN. This procedure is optional.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	spanning-tree vlan <i>vlan-id</i> root secondary [<i>diameter net-diameter</i> [<i>hello-time</i> <i>seconds</i>]]	<p>Configure a switch to become the secondary root for the specified VLAN.</p> <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 <i>diameter net-diameter</i>, specify the maximum number of switches between any two end stations. The range is 2 to 7. (Optional) For <i>hello-time seconds</i>, specify the interval in seconds between the generation of configuration messages by the root switch. The range is 1 to 10 seconds; the default is 2 seconds. <p>Use the same network diameter and hello-time values that you used when configuring the primary root switch. See the “Configuring the Root Switch” section on page 15-14.</p>
Step 3	end	Return to privileged EXEC mode.
Step 4	show spanning-tree detail	Verify your entries.
Step 5	copy running-config startup-config	(Optional) Save your entries in the configuration file.

To return the switch to its default setting, use the **no spanning-tree vlan *vlan-id* root** global configuration command.

Configuring the Port Priority

If a loop occurs, spanning tree 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, spanning tree puts the interface with the lowest interface number in the forwarding state and blocks the other interfaces.

Beginning in privileged EXEC mode, follow these steps to configure the port priority of an interface. This procedure is optional.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	interface <i>interface-id</i>	<p>Specify an interface to configure, and enter interface configuration mode.</p> <p>Valid interfaces include physical interfaces and port-channel logical interfaces (port-channel <i>port-channel-number</i>).</p>

	Command	Purpose
Step 3	spanning-tree port-priority <i>priority</i>	Configure the port priority for an interface. 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. Valid 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 4	spanning-tree vlan <i>vlan-id</i> port-priority <i>priority</i>	Configure the VLAN port priority for an interface. <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. The lower the number, the higher the priority. Valid 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	Return to privileged EXEC mode.
Step 6	show spanning-tree interface <i>interface-id</i> or show spanning-tree vlan <i>vlan-id</i>	Verify your entries.
Step 7	copy running-config startup-config	(Optional) Save your entries in the configuration file.

**Note**

The **show spanning-tree 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.

To return the interface to its default setting, use the **no spanning-tree [vlan *vlan-id*] port-priority** interface configuration command. For information on how to configure load sharing on trunk ports by using spanning-tree port priorities, see the [“Load Sharing Using STP” section on page 11-23](#).

Configuring the 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 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.

Beginning in privileged EXEC mode, follow these steps to configure the cost of an interface. This procedure is optional.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	interface <i>interface-id</i>	Specify an interface to configure, and enter interface configuration mode. Valid interfaces include physical interfaces and port-channel logical interfaces (port-channel <i>port-channel-number</i>).
Step 3	spanning-tree cost <i>cost</i>	Configure 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.
Step 4	spanning-tree vlan <i>vlan-id</i> cost <i>cost</i>	Configure 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 5	end	Return to privileged EXEC mode.
Step 6	show spanning-tree interface <i>interface-id</i> or show spanning-tree vlan <i>vlan-id</i>	Verify your entries.
Step 7	copy running-config startup-config	(Optional) Save your entries in the configuration file.

**Note**

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.

To return the interface to its default setting, use the **no spanning-tree [vlan *vlan-id*] cost** interface configuration command. For information on how to configure load sharing on trunk ports by using spanning-tree path costs, see the [“Load Sharing Using STP”](#) section on page 11-23.

Configuring the Switch Priority of a VLAN

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



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 switch priority.

Beginning in privileged EXEC mode, follow these steps to configure the switch priority of a VLAN. This procedure is optional.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	spanning-tree vlan <i>vlan-id</i> priority <i>priority</i>	Configure the switch 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 switch will be chosen as the root switch. 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 3	end	Return to privileged EXEC mode.
Step 4	show spanning-tree vlan <i>vlan-id</i>	Verify your entries.
Step 5	copy running-config startup-config	(Optional) Save your entries in the configuration file.

To return the switch to its default setting, use the **no spanning-tree vlan *vlan-id* priority** global configuration command.

Configuring Spanning-Tree Timers

Table 15-4 describes the timers that affect the entire spanning-tree performance.

Table 15-4 Spanning-Tree Timers

Variable	Description
Hello timer	Determines how often the switch broadcasts hello messages to other switches.
Forward-delay timer	Determines how long each of the listening and learning states last before the interface begins forwarding.

Table 15-4 *Spanning-Tree Timers (continued)*

Variable	Description
Maximum-age timer	Determines the amount of time the switch stores protocol information received on an interface.
Transmit hold count	Controls the number of BPDUs sent every second.

The sections that follow provide the configuration steps.

Configuring the Hello Time

You can configure the interval between the generation of configuration messages by the root switch by changing the hello time.



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.

Beginning in privileged EXEC mode, follow these steps to configure the hello time of a VLAN. This procedure is optional.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	spanning-tree vlan <i>vlan-id</i> hello-time <i>seconds</i>	Configure the hello time of a VLAN. The hello time is the interval between the generation of configuration messages by the root switch. These messages mean that the switch 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 3	end	Return to privileged EXEC mode.
Step 4	show spanning-tree vlan <i>vlan-id</i>	Verify your entries.
Step 5	copy running-config startup-config	(Optional) Save your entries in the configuration file.

To return the switch to its default setting, use the **no spanning-tree vlan *vlan-id* hello-time** global configuration command.

Configuring the Forwarding-Delay Time for a VLAN

Beginning in privileged EXEC mode, follow these steps to configure the forwarding-delay time for a VLAN. This procedure is optional.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	spanning-tree vlan <i>vlan-id</i> forward-time <i>seconds</i>	Configure the forward time of a VLAN. The forward delay is the number of seconds a port 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 3	end	Return to privileged EXEC mode.
Step 4	show spanning-tree vlan <i>vlan-id</i>	Verify your entries.
Step 5	copy running-config startup-config	(Optional) Save your entries in the configuration file.

To return the switch to its default setting, use the **no spanning-tree vlan *vlan-id* forward-time** global configuration command.

Configuring the Maximum-Aging Time for a VLAN

Beginning in privileged EXEC mode, follow these steps to configure the maximum-aging time for a VLAN. This procedure is optional.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	spanning-tree vlan <i>vlan-id</i> max-age <i>seconds</i>	Configure the maximum-aging time of a VLAN. The maximum-aging time is the number of seconds a switch 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. For <i>seconds</i>, the range is 6 to 40; the default is 20.
Step 3	end	Return to privileged EXEC mode.
Step 4	show spanning-tree vlan <i>vlan-id</i>	Verify your entries.
Step 5	copy running-config startup-config	(Optional) Save your entries in the configuration file.

To return the switch to its default setting, use the **no spanning-tree vlan *vlan-id* max-age** global configuration command.

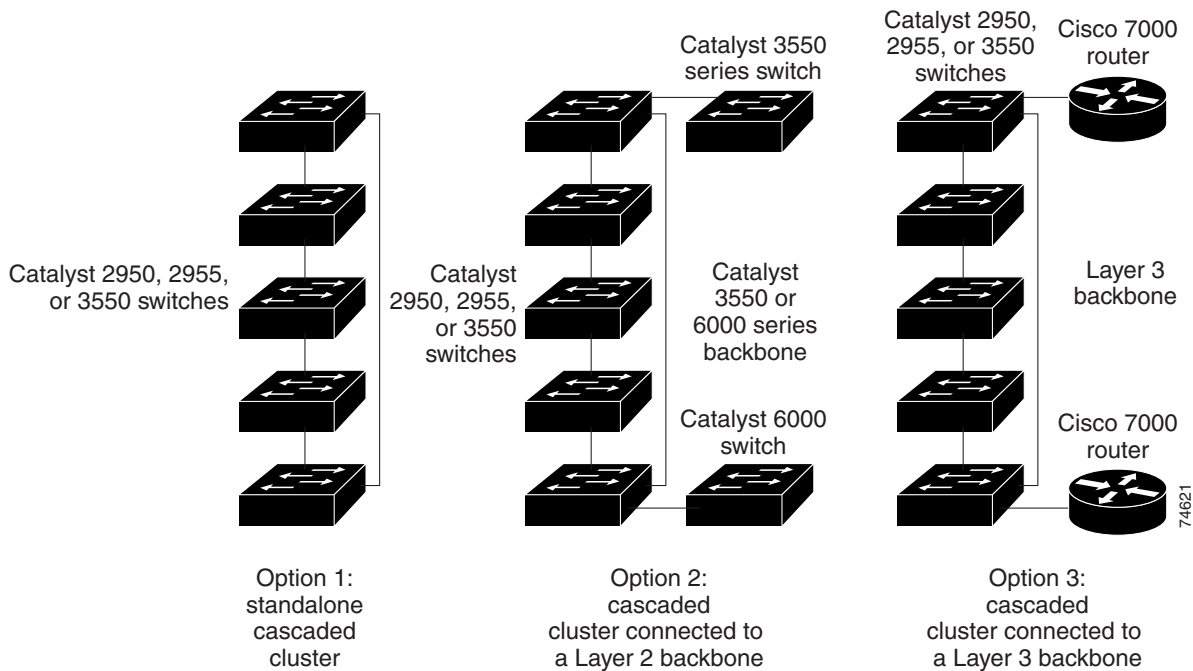
Configuring Spanning Tree for Use in a Cascaded Stack

Spanning tree uses default values that can be reduced when configuring your switch in cascaded configurations. If a root switch is part of a cluster that is one switch from a cascaded stack, you can customize spanning tree to reconverge more quickly after a switch failure. Figure 15-4 shows switches in three cascaded stacks that use the GigaStack GBIC. Table 15-5 shows the default spanning-tree settings and those that are acceptable for these configurations.

Table 15-5 Default and Acceptable Spanning-Tree Parameter Settings (in seconds)

STP Parameter	STP Default	Acceptable for Option 1	Acceptable for Option 2	Acceptable for Option 3
Hello Time	2	1	1	1
Max Age	20	6	10	6
Forwarding Delay	15	4	7	4

Figure 15-4 Gigabit Ethernet Stack



Configuring the Transmit Hold Count

You can configure the maximum number of BPDUs that can be sent in one second by changing the transmit hold-count value.



Note

Increasing the transmit hold-count value can have a significant impact on CPU utilization in rapid-PVST+ mode. Decreasing this value might slow down convergence. We recommend that you maintain the default setting.

Beginning in privileged EXEC mode, follow these steps to configure the transmit hold count. This procedure is optional.

	Command	Purpose
Step 1	configure terminal	Enter global configuration mode.
Step 2	spanning-tree transmit hold-count <i>value</i>	Configure the number of BPDUs sent every second. For <i>value</i> , the range is 1 to 20; the default is 6.
Step 3	end	Return to privileged EXEC mode.
Step 4	show spanning-tree detail	Verify your entries.
Step 5	copy running-config startup-config	(Optional) Save your entries in the configuration file.

To return to the default setting, use the **no spanning-tree transmit hold-count** *value* global configuration command.

Displaying the Spanning-Tree Status

To display the spanning-tree status, use one or more of the privileged EXEC commands in [Table 15-6](#):

Table 15-6 *Commands for Displaying Spanning-Tree Status*

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

You can clear spanning-tree counters by using the **clear spanning-tree** [**interface** *interface-id*] privileged EXEC command.

For information about other keywords for the **show spanning-tree** privileged EXEC command, see the command reference for this release.