

This chapter describes the IEEE 802.1D Spanning Tree Protocol (STP) and the ML-Series implementation of the IEEE 802.1W Rapid Spanning Tree Protocol (RSTP). It also explains how to configure STP and RSTP on the ML-Series card.

This chapter consists of these sections:

- [STP Features](#)
- [RSTP](#)
- [Interoperability with IEEE 802.1D STP](#)
- [Configuring STP and RSTP Features](#)
- [Verifying and Monitoring STP and RSTP Status](#)

## Contents

- [1 STP Features](#)
  - ◆ [1.1 STP Overview](#)
  - ◆ [1.2 Supported STP Instances](#)
  - ◆ [1.3 Bridge Protocol Data Units](#)
  - ◆ [1.4 Election of the Root Switch](#)
  - ◆ [1.5 Bridge ID, Switch Priority, and Extended System ID](#)
    - ◇ [1.5.1 Table 7-1: Switch Priority Value and Extended System ID](#)
  - ◆ [1.6 Spanning-Tree Timers](#)
    - ◇ [1.6.1 Table 7-2: Spanning-Tree Timers](#)
  - ◆ [1.7 Creating the Spanning-Tree Topology](#)
    - ◇ [1.7.1 Figure 7-1: Spanning-Tree Topology](#)
  - ◆ [1.8 Spanning-Tree Interface States](#)
    - ◇ [1.8.1 Figure 7-2: Spanning-Tree Interface States](#)
    - ◇ [1.8.2 Blocking State](#)
    - ◇ [1.8.3 Listening State](#)
    - ◇ [1.8.4 Learning State](#)
    - ◇ [1.8.5 Forwarding State](#)
    - ◇ [1.8.6 Disabled State](#)
  - ◆ [1.9 Spanning-Tree Address Management](#)
  - ◆ [1.10 STP and IEEE 802.1Q Trunks](#)
  - ◆ [1.11 Spanning Tree and Redundant Connectivity](#)
    - ◇ [1.11.1 Figure 7-3: Spanning Tree and Redundant Connectivity](#)
  - ◆ [1.12 Accelerated Aging to Retain Connectivity](#)
- [2 RSTP](#)
  - ◆ [2.1 Supported RSTP Instances](#)
  - ◆ [2.2 Port Roles and the Active Topology](#)
    - ◇ [2.2.1 Table 7-3: Port State Comparison](#)
  - ◆ [2.3 Rapid Convergence](#)
    - ◇ [2.3.1 Figure 7-4: Proposal and Agreement Handshaking for Rapid Convergence](#)
  - ◆ [2.4 Synchronization of Port Roles](#)
    - ◇ [2.4.1 Figure 7-5: Sequence of Events During Rapid Convergence](#)
  - ◆ [2.5 Bridge Protocol Data Unit Format and Processing](#)
    - ◇ [2.5.1 Table 7-4: RSTP BPDU Flags](#)
    - ◇ [2.5.2 Processing Superior BPDU Information](#)

- ◇ [2.5.3 Processing Inferior BPDU Information](#)

- ◆ [2.6 Topology Changes](#)

- [3 Interoperability with IEEE 802.1D STP](#)

- [4 Configuring STP and RSTP Features](#)

- ◆ [4.1 Default STP and RSTP Configuration](#)

- ◇ [4.1.1 Table 7-5: Default STP and RSTP Configuration](#)

- ◆ [4.2 Disabling STP and RSTP](#)

- ◆ [4.3 Configuring the Root Switch](#)

- ◆ [4.4 Configuring the Port Priority](#)

- ◆ [4.5 Configuring the Path Cost](#)

- ◆ [4.6 Configuring the Switch Priority of a Bridge Group](#)

- ◆ [4.7 Configuring the Hello Time](#)

- ◆ [4.8 Configuring the Forwarding-Delay Time for a Bridge Group](#)

- ◆ [4.9 Configuring the Maximum-Aging Time for a Bridge Group](#)

- [5 Verifying and Monitoring STP and RSTP Status](#)

- ◆ [5.1 Table 7-6: Commands for Displaying Spanning-Tree Status](#)

- ◆ [5.2 Example 7-1: show spanning-tree Commands](#)

## STP Features

These sections describe how the spanning-tree features work:

- [STP Overview](#)
- [Supported STP Instances](#)
- [Bridge Protocol Data Units](#)
- [Election of the Root Switch](#)
- [Bridge ID, Switch Priority, and Extended System ID](#)
- [Spanning-Tree Timers](#)
- [Creating the Spanning-Tree Topology](#)
- [Spanning-Tree Interface States](#)
- [Spanning-Tree Address Management](#)
- [STP and IEEE 802.1Q Trunks](#)
- [Spanning Tree and Redundant Connectivity](#)
- [Accelerated Aging to Retain Connectivity](#)

## 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. 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.

When you create fault-tolerant internetworks, you must have a loop-free path between all nodes in a network. The spanning-tree algorithm calculates the best loop-free path throughout a switched Layer 2 network. 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 the frames to construct a loop-free path.

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 defines a tree with a root switch and a loop-free path from the root to all switches in the Layer 2 network. 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.

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 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 media speed.

## Supported STP Instances

The ML-Series card supports the per-VLAN spanning tree (PVST+) and a maximum of 255 spanning-tree instances.

## Bridge Protocol Data Units

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

- Unique bridge ID (switch priority and MAC address) associated with each VLAN on each switch
- Spanning-tree path cost to the root switch
- 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:

- Unique bridge ID of the switch that the sending switch identifies as the root switch
- Spanning-tree path cost to the root
- Bridge ID of the sending switch
- Message age
- 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, etc.), 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.
- 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 interfaces not included in the spanning tree are blocked.

## Election of the Root Switch

All switches in the Layer 2 network participating in the spanning tree gather information about other switches in the network through an exchange of BPDU data messages. This exchange of messages results in these actions:

- Election of a unique root switch for each spanning-tree instance
- Election of a designated switch for every switched LAN segment
- Removal of loops in the switched network by blocking Layer 2 interfaces connected to redundant links

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.

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.

The root switch is the logical center of the spanning-tree topology in a switched network. 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.

BPDU contains 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.

## Bridge ID, Switch Priority, and Extended System ID

The IEEE 802.1D standard requires that each switch has a 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+, 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.

The ML-Series card supports the IEEE 802.1T spanning-tree extensions, and some of the bits previously used for the switch priority are now used as the bridge ID. 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 7-1](#), 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 bridge ID. In earlier releases, the switch priority is a 16-bit value.

**Table 7-1: Switch Priority Value and Extended System ID**

| Switch Priority Value |        |        |        | Extended System ID (Set Equal to the Bridge 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.

## Spanning-Tree Timers

Table 7-2 describes the timers that affect the entire spanning-tree performance.

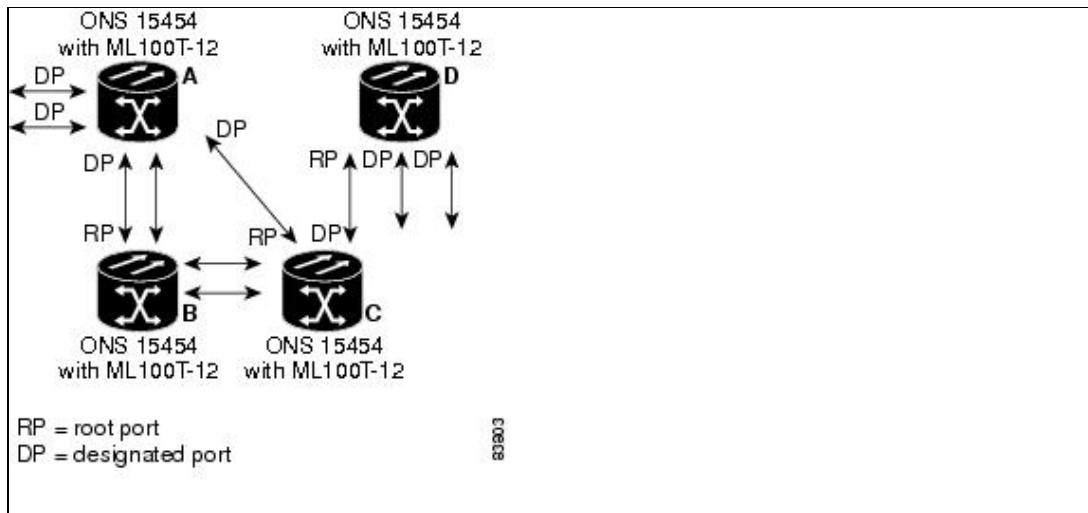
Table 7-2: Spanning-Tree Timers

| Variable            | Description  |
|---------------------|--|
| Hello timer         | When this timer expires, the interface sends out a Hello message to the neighboring nodes.                 |
| Forward-delay timer | Determines how long each of the listening and learning states last before the interface begins forwarding. |
| Maximum-age timer   | Determines the amount of time the switch stores protocol information received on an interface.             |

## Creating the Spanning-Tree Topology

In Figure 7-1, 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 7-1: 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 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.

## 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:

1. From initialization to blocking
2. From blocking to listening or to disabled
3. From listening to learning or to disabled
4. From learning to forwarding or to disabled
5. From forwarding to disabled

Figure 7-2 illustrates how an interface moves through the states.

**Figure 7-2: Spanning-Tree Interface States**

Output/43569.jpg

When you power up the switch, STP 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 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:

- Forwards frames switched from another interface for forwarding
- Learns addresses
- Does not receive BPDUs

## 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.

The ML-Series card switches supported BPDUs (0x0180C2000000 and 01000CCCCCD) when they are being tunneled via the protocol tunneling feature.

## STP and IEEE 802.1Q Trunks

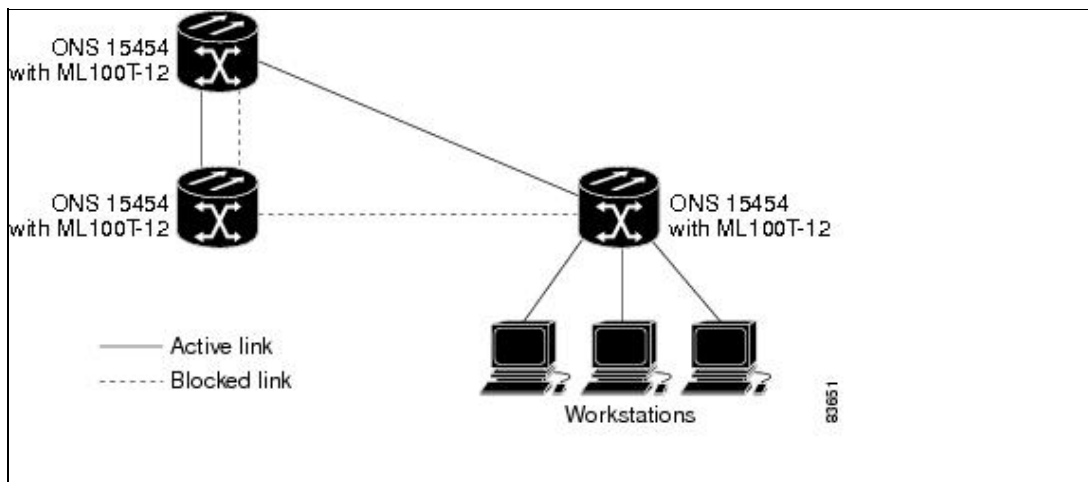
When you connect a Cisco switch to a non-Cisco device through an IEEE 802.1Q trunk, the Cisco switch uses PVST+ to provide spanning-tree interoperability. PVST+ is automatically enabled on IEEE 802.1Q trunks after users assign a protocol to a bridge group. The external spanning-tree behavior on access ports and Inter-Switch Link (ISL) trunk ports is not affected by PVST+.

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

## 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 7-3](#). 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 7-3: Spanning Tree and Redundant Connectivity**



You can also create redundant links between switches by using EtherChannel groups. For more information, see [Configuring Link Aggregation](#).

## Accelerated Aging to Retain Connectivity

The default for aging dynamic addresses is 5 minutes, which is the default setting of the *'bridge bridge-group-number 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.



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.

## RSTP

RSTP provides rapid convergence of the spanning tree. It improves the fault tolerance of the network because a failure in one instance (forwarding path) does not affect other instances (forwarding paths). The most common initial deployment of RSTP is in the backbone and distribution layers of a Layer 2 switched network; this deployment provides the highly available network required in a service-provider environment.

RSTP improves the operation of the spanning tree while maintaining backward compatibility with equipment that is based on the (original) IEEE 802.1D spanning tree.

RSTP takes advantage of point-to-point wiring and provides rapid convergence of the spanning tree. Reconfiguration of the spanning tree can occur in less than 2 second (in contrast to 50 seconds with the default settings in the IEEE 802.1D spanning tree), which is critical for networks carrying delay-sensitive traffic such as voice and video.

These sections describe how RSTP works:

- [Supported RSTP Instances](#)
- [Port Roles and the Active Topology](#)
- [Rapid Convergence](#)
- [Synchronization of Port Roles](#)
- [Bridge Protocol Data Unit Format and Processing](#)
- [Topology Changes](#)

### Supported RSTP Instances

The ML Series supports per-VLAN rapid spanning tree (PVRST) and a maximum of 255 rapid spanning-tree instances.

### Port Roles and the Active Topology

The RSTP provides rapid convergence of the spanning tree by assigning port roles and by determining the active topology. The RSTP builds upon the IEEE 802.1D STP to select the switch with the highest switch priority (lowest numerical priority value) as the root switch as described in the [Election of the Root Switch](#). Then the RSTP 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 switch.
- Designated port-Connects to the designated switch, which 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.
- Alternate port-Offers an alternate path toward the root switch to that provided by the current root port.
- Backup port-Acts as a backup for the path provided by a designated port toward the leaves of the spanning tree. A backup port can exist only when two ports are connected together in a loopback by a point-to-point link or when a switch has two or more connections to a shared LAN segment.
- Disabled port-Has no role within the operation of the spanning tree.

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

In a stable topology with consistent port roles throughout the network, the RSTP ensures that every root port and designated port immediately transition to the forwarding state while all alternate and backup ports are always in the discarding state (equivalent to blocking in IEEE 802.1D). The port state controls the operation of the forwarding and learning processes. [Table 7-3](#) provides a comparison of IEEE 802.1D and RSTP port states.

**Table 7-3: Port State Comparison**

| Operational Status | STP Port State | RSTP Port State | Is Port Included in the Active Topology? |
|--------------------|----------------|-----------------|--|
| Enabled            | Blocking       | Discarding      | No                                       |
| Enabled            | Listening      | Discarding      | No                                       |
| Enabled            | Learning       | Learning        | Yes                                      |
| Enabled            | Forwarding     | Forwarding      | Yes                                      |
| Disabled           | Disabled       | Discarding      | No                                       |

**Caution!** STP edge ports are bridge ports that do not need STP enabled, where loop protection is not needed out of that port or an STP neighbor does not exist out of that port. For RSTP, it is important to disable STP on edge ports, which are typically front-side Ethernet ports, using the command `bridge bridge-group-number spanning-disabled` on the appropriate interface. If RSTP is not disabled on edge ports, convergence times will be excessive for packets traversing those ports.

**Note:** To be consistent with Cisco STP implementations, [Table 7-3](#) describes the port state as blocking instead of discarding. Designated ports start in the listening state.

## Rapid Convergence

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

- Root ports-If the RSTP selects a new root port, it blocks the old root port and immediately transitions the new root port to the forwarding state.
- Point-to-point links-If you connect a port to another port through a point-to-point link and the local port becomes a designated port, it negotiates a rapid transition with the other port by using the proposal-agreement handshake to ensure a loop-free topology.

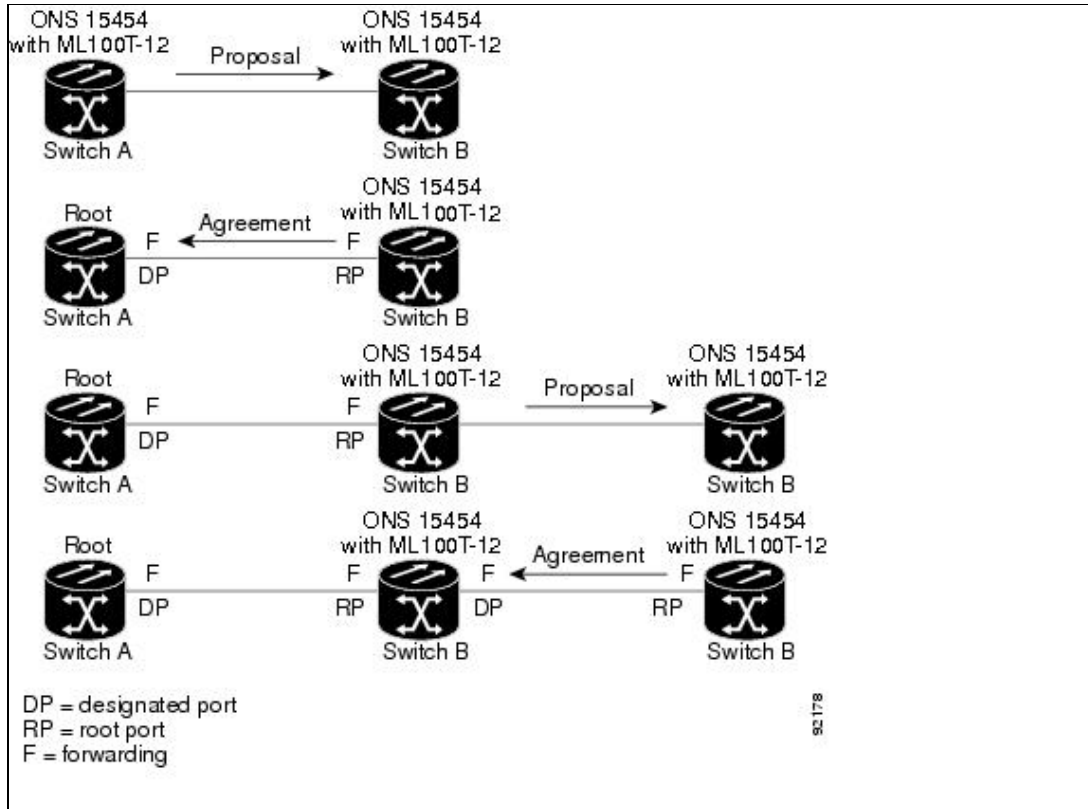
As shown in [Figure 7-4](#), Switch A is connected to Switch B through a point-to-point link, and all of the ports are in the blocking state. Assume that the priority of Switch A is a smaller numerical value than the priority of Switch B. Switch A sends a proposal message (a configuration BPDU with the proposal flag set) to Switch B, proposing itself as the designated switch.

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 an agreement message from Switch B, Switch A also immediately transitions its designated port to the forwarding state. No loops in the network are formed because Switch B blocked all of its non edge ports and because there is a point-to-point link between Switches A and B.

When Switch C is connected 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 immediately transition to the forwarding

state. With each iteration of this handshaking process, one more switch 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 determines the link type from the port duplex mode: a full-duplex port is considered to have a point-to-point connection; a half-duplex port is considered to have a shared connection.

**Figure 7-4: Proposal and Agreement Handshaking for Rapid Convergence**



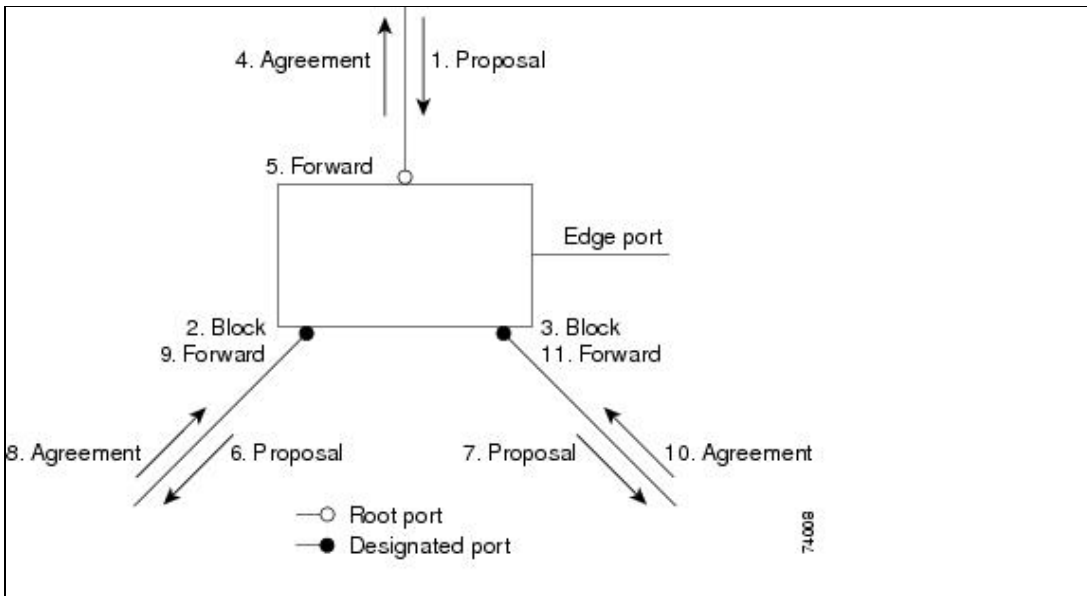
### Synchronization of Port Roles

When the switch receives a proposal message on one of its ports and that port is selected as the new root port, the RSTP 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.

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

After ensuring all of the ports are synchronized, the switch sends an agreement message to the designated switch corresponding to its root port. When the switches connected by a point-to-point link are in agreement about their port roles, the RSTP immediately transitions the port states to forwarding. The sequence of events is shown in [Figure 7-5](#).

**Figure 7-5: Sequence of Events During Rapid Convergence**



## Bridge Protocol Data Unit Format and Processing

The RSTP BPDU format is the same as the IEEE 802.1D BPDU format except that the protocol version is set to 2. A new Length field is set to zero, which means that no version 1 protocol information is present. [Table 7-4](#) shows the RSTP flag fields.

**Table 7-4: RSTP BPDU Flags**

| Bit  | Function                        |
|------|---------------------------------|
| 0    | Topology change (TC)            |
| 1    | Proposal                        |
| 2-3: | Port role:                      |
|      | 00 Unknown                      |
|      | 01 Alternate port               |
|      | 10 Root port                    |
|      | 11 Designated port              |
| 4    | Learning                        |
| 5    | Forwarding                      |
| 6    | Agreement                       |
| 7    | Topology change acknowledgement |

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

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

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

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

### Processing Superior BPDU Information

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

If the BPDU received is an RSTP BPDU with the proposal flag set, the switch sends an agreement message after all of the other ports are synchronized. If the BPDU is an IEEE 802.1D BPDU, 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.

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

### Processing Inferior BPDU Information

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

### Topology Changes

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

- **Detection**-Unlike IEEE 802.1D in which any transition between the blocking and the forwarding state causes a topology change, only transitions from the blocking to the forwarding state cause a topology change with RSTP. (Only an increase in connectivity is considered a topology change.) State changes on an edge port do not cause a topology change. When an RSTP switch detects a topology change, it flushes the learned information on all of its non edge ports.
- **Notification**-Unlike IEEE 802.1D, which uses TCN BPDUs, the RSTP does not use them. However, for IEEE 802.1D interoperability, an RSTP switch processes and generates TCN BPDUs.
- **Acknowledgement**-When an RSTP switch receives a TCN message on a designated port from an IEEE 802.1D switch, it replies with an IEEE 802.1D configuration BPDU with the topology change acknowledgement bit set. However, if the TC-while timer (the same as the topology-change timer in IEEE 802.1D) is active on a root port connected to an IEEE 802.1D switch and a configuration BPDU with the topology change acknowledgement bit set is received, the TC-while timer is reset.

This behavior is only required to support IEEE 802.1D switches. The RSTP BPDUs never have the topology change acknowledgement bit set.

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

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

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

## Interoperability with IEEE 802.1D STP

A switch running RSTP supports a built-in protocol migration mechanism that enables it to interoperate with legacy IEEE 802.1D switches. If this switch receives a legacy IEEE 802.1D configuration BPDU (a BPDU with the protocol version set to 0), it sends only IEEE 802.1D BPDUs on that port.

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

## Configuring STP and RSTP Features

These sections describe how to configure spanning-tree features:

- [Default STP and RSTP Configuration](#)
- [Disabling STP and RSTP](#)
- [Configuring the Root Switch](#)
- [Configuring the Port Priority](#)
- [Configuring the Path Cost](#)
- [Configuring the Switch Priority of a Bridge Group](#)
- [Configuring the Hello Time](#)
- [Configuring the Forwarding-Delay Time for a Bridge Group](#)
- [Configuring the Maximum-Aging Time for a Bridge Group](#)

## Default STP and RSTP Configuration

[Table 7-5](#) shows the default STP and RSTP configuration.

**Table 7-5: Default STP and RSTP Configuration**

| Feature   | Default Setting   |
|---|---|
| Enable state  | Up to 255 spanning-tree instances can be enabled.                       |
| Switch priority   | 32768 + Bridge ID   |
| Spanning-tree port priority (configurable on a per-interface basis-used on interfaces configured as Layer 2 access ports) | 128   |
| Spanning-tree port cost (configurable on a per-interface basis)   | 1000 Mbps: 4<br>100 Mbps: 19<br>10 Mbps: 100<br>STS-1: 37<br>STS-3c: 14 |

|                    |            |
|--------------------|------------|
|                    | STS-6c: 9  |
|                    | STS-9c: 7  |
|                    | STS-12c: 6 |
|                    | STS-24c: 3 |
| Hello time         | 2 seconds  |
| Forward-delay time | 15 seconds |
| Maximum-aging time | 20 seconds |

## Disabling STP and RSTP

STP is enabled by default on native VLAN 1 and on all newly created VLANs up to the specified spanning-tree limit of 255. Disable STP only if you are sure there are no loops in the network topology.

**Caution!** STP edge ports are bridge ports that do not need STP enabled, where loop protection is not needed out of that port or an STP neighbor does not exist out of that port. For RSTP, it is important to disable STP on edge ports, which are typically front-side Ethernet ports, using the command `bridge bridge-group-number spanning-disabled` on the appropriate interface. If RSTP is not disabled on edge ports, convergence times will be excessive for packets traversing those ports.

**Caution!** When STP 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 STP or RSTP on a per-VLAN basis:

| Step | Command  | Purpose  |
|------|--|--|
| 1    | Router# <b>configure terminal</b>  | Enters the global configuration mode.          |
| 2    | Router(config)# <code>interface interface-id</code>                              | Enters the interface configuration mode.       |
| 3    | Router(config-if)# <b>bridge-group<br/>bridge-group-number spanning disabled</b> | Disables STP or RSTP on a per-interface basis. |
| 4    | Router(config-if)# <b>end</b>  | Returns to privileged EXEC mode.               |

To reenable STP, use the **no bridge-group bridge-group-number spanning disabled** interface-level 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.

**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 bridge ID is greater than the priority of the connected switches that are running older software.

## 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:

| Step | Command   | Purpose   |
|------|---|---|
| 1    | Router# <b>configure terminal</b>   | Enters the global configuration mode.   |
| 2    | Router(config)# <b>interface</b><br><i>interface-id</i>                                       | Enters the interface configuration mode, and specifies an interface to configure.<br><br>Valid interfaces include physical interfaces and port-channel logical interfaces ( <b>port-channel</b> <i>port-channel-number</i> ). |
| 3    | Router(config-if)# <b>bridge-group</b><br><i>bridge-group-number</i><br><i>priority-value</i> | Configures the port priority for an interface that is an access port.<br><br>For the <i>priority-value</i> , the range is 0 to 255; the default is 128 in increments of 16. The lower the number, the higher the priority.    |
| 4    | Router(config-if)# <b>end</b>   | Return to privileged EXEC mode.   |

To return the interface to its default setting, use the **no bridge-group id** *bridge-group-number* *priority-value* command.

## 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 to interfaces 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:

| Step | Command   | Purpose  |
|------|---|--|
| 1    | Router# <b>configure terminal</b>   | Enters the global configuration mode.  |
| 2    | Router(config)# <b>interface</b><br><i>interface-id</i>   | Enters the interface configuration mode and specifies an interface to configure.<br><br>Valid interfaces include physical interfaces and port-channel logical interfaces ( <b>port-channel</b> <i>port-channel-number</i> ). |
| 3    | Router(config-if)#<br><b>bridge-group</b><br><i>bridge-group-number</i> <b>path-cost</b><br><i>cost</i> | Configures the cost for an interface that is an access port.<br><br>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.<br><br>For <i>cost</i> , the range is 0 to 65535; the default value is derived from the media speed of the interface. |
| 4 | Router(config-if) # <b>end</b> | Returns to the privileged EXEC mode.  |

**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 bridge-group bridge-group-number path-cost cost** command.

## Configuring the Switch Priority of a Bridge Group

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

Beginning in privileged EXEC mode, follow these steps to configure the switch priority of a bridge group:

| Step | Command  | Purpose  |
|------|--|--|
| 1    | Router# <b>configure terminal</b>  | Enters the global configuration mode.  |
| 2    | Router(config)# <b>bridge</b><br><i>bridge-group-number</i> <b>priority</b><br><i>priority</i> | Configures the switch priority of a bridge group.<br><br>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.<br><br>The value entered is rounded to the lower multiple of 4096. The actual number is computed by adding this number to the bridge group number. |
| 3    | Router(config)# <b>end</b>   | Return to the privileged EXEC mode.  |

To return the switch to its default setting, use the **no bridge bridge-group-number priority priority** command.

## Configuring the Hello Time

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

Beginning in privileged EXEC mode, follow these steps to configure the hello time of a bridge group:

| Step | Command   | Purpose  |
|------|---|--|
| 1    | Router# <b>configure terminal</b>   | Enters global configuration mode.  |
| 2    | Router(config)# <b>bridge</b><br><i>bridge-group-number</i> <b>hello-time</b><br><i>seconds</i> | Configures the hello time of a bridge group. The hello time is the interval between the generation of configuration messages by the root switch. These messages mean that the switch is alive.<br><br>For <i>seconds</i> , the range is 1 to 10; the default is 2. |
| 3    | Router(config)# <b>end</b>  | Returns to privileged EXEC mode.   |

To return the switch to its default setting, use the **no bridge *bridge-group-number* hello-time *seconds*** command.

## Configuring the Forwarding-Delay Time for a Bridge Group

Beginning in privileged EXEC mode, follow these steps to configure the forwarding-delay time for a bridge group:

| Step | Command  | Purpose  |
|------|--|--|
| 1    | Router# <b>configure terminal</b>  | Enters global configuration mode.  |
| 2    | Router(config)# <b>bridge<br/><i>bridge-group-number</i><br/>forward-time <i>seconds</i></b> | Configures 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.<br><br>For <i>seconds</i> , the range is 4 to 200; the default is 15. |
| 3    | Router(config)# <b>end</b>   | Returns to privileged EXEC mode.   |

To return the switch to its default setting, use the **no bridge *bridge-group-number* forward-time *seconds*** command.

## Configuring the Maximum-Aging Time for a Bridge Group

Beginning in privileged EXEC mode, follow these steps to configure the maximum-aging time for a bridge group:

| Step | Command   | Purpose   |
|------|---|---|
| 1    | Router# <b>configure terminal</b>   | Enters global configuration mode.   |
| 2    | Router(config)# <b>bridge<br/><i>bridge-group-number</i> max-age<br/><i>seconds</i></b> | Configures the maximum-aging time of a bridge group. The maximum-aging time is the number of seconds a switch waits without receiving spanning-tree configuration messages before attempting a reconfiguration.<br><br>For <i>seconds</i> , the range is 6 to 200; the default is 20. |
| 3    | Router(config)# <b>end</b>  | Returns to privileged EXEC mode.  |

To return the switch to its default setting, use the **no bridge *bridge-group-number* max-age *seconds*** command.

## Verifying and Monitoring STP and RSTP Status

To display the STP or RSTP status, use one or more of the privileged EXEC commands in [Table 7-6](#):

**Table 7-6: Commands for Displaying Spanning-Tree Status**

| Command  | Purpose   |
|--|---|
| ML_Series# <b>show spanning-tree</b>                                   | Displays detailed STP or RSTP information.                    |
| ML_Series# <b>show spanning-tree<br/>brief</b>                         | Displays summary of STP or RSTP information.                  |
| ML_Series# <b>show spanning-tree<br/>interface <i>interface-id</i></b> | Displays STP or RSTP information for the specified interface. |
|  |   |

|   |   |
|---|---|
| ML_Series# <b>show spanning-tree summary [totals]</b> | Displays a summary of port states or displays the total lines of the STP or RSTP state section. |
|---|---|

**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.

Examples of the **show spanning-tree** privileged EXEC command commands are shown here:

**Example 7-1: show spanning-tree Commands**

```
Router# show spanning-tree brief
```

```
Bridge group 1
Spanning tree enabled protocol ieee
Root ID    Priority    32769
Address    0005.9a39.6634
This bridge is the root
Hello Time  2 sec    Max Age 20 sec    Forward Delay 15 sec

Bridge ID  Priority    32769 (priority 32768 sys-id-ext 1)
Address    0005.9a39.6634
Hello Time  2 sec    Max Age 20 sec    Forward Delay 15 sec
Aging Time 300
```

| Interface | Role | Sts | Cost | Prio.Nbr | Type |
|-----------|------|-----|------|----------|------|
| Fa0       | Desg | FWD | 19   | 128.3    | P2p  |
| PO0       | Desg | FWD | 3    | 128.20   | P2p  |

```
Router# show spanning-tree detail
```

```
Bridge group 1 is executing the ieee compatible Spanning Tree protocol
Bridge Identifier has priority 32768, sysid 1, address 0005.9a39.6634
Configured hello time 2, max age 20, forward delay 15
We are the root of the spanning tree
Topology change flag not set, detected flag not set
Number of topology changes 2 last change occurred 00:16:45 ago
from POS0
Times: hold 1, topology change 35, notification 2
hello 2, max age 20, forward delay 15
Timers: hello 0, topology change 0, notification 0, aging 300
```

```
Port 3 (FastEthernet0) of Bridge group 1 is forwarding
Port path cost 19, Port priority 128, Port Identifier 128.3.
Designated root has priority 32769, address 0005.9a39.6634
Designated bridge has priority 32769, address 0005.9a39.6634
Designated port id is 128.3, designated path cost 0
Timers: message age 0, forward delay 0, hold 0
Number of transitions to forwarding state: 1
Link type is point-to-point by default
BPDU: sent 641, received 0
```

```
Port 20 (POS0) of Bridge group 1 is forwarding
Port path cost 3, Port priority 128, Port Identifier 128.20.
Designated root has priority 32769, address 0005.9a39.6634
Designated bridge has priority 32769, address 0005.9a39.6634
Designated port id is 128.20, designated path cost 0
Timers: message age 0, forward delay 0, hold 0
Number of transitions to forwarding state: 6
Link type is point-to-point by default
BPDU: sent 582, received 15
```

## ONS\_15454\_and\_ONS\_15454\_SDH\_Ethernet\_Configuration\_Guide\_R8.5.1\_--\_Configuring\_STP\_and\_RSTP

```
Router# show spanning-tree interface fast 0
```

| Bridge Group   | Role | Sts | Cost | Prio.Nbr | Type |
|----------------|------|-----|------|----------|------|
| Bridge group 1 | Desg | FWD | 19   | 128.3    | P2p  |

```
Router# show spanning-tree interface pos 0
```

| Bridge Group   | Role | Sts | Cost | Prio.Nbr | Type |
|----------------|------|-----|------|----------|------|
| Bridge group 1 | Desg | FWD | 3    | 128.20   | P2p  |

```
Router# show spanning-tree summary totals
```

```
Switch is in pvst mode
```

```
Root bridge for: Bridge group 1
```

| Name     | Blocking | Listening | Learning | Forwarding | STP | Active |
|----------|----------|-----------|----------|------------|-----|--------|
| 1 bridge | 0        | 0         | 0        | 2          |     | 2      |