

## Overview of STP

STP is a Layer 2 link management protocol that provides path redundancy while preventing undesirable loops in the network. For a Layer 2 Ethernet network to function properly, only one active path can exist between any two stations. A loop-free subset of a network topology is called a spanning tree. The operation of a spanning tree is transparent to end stations, which cannot detect whether they are connected to a single LAN segment or a switched LAN of multiple segments.

A switch use STP (the IEEE 802.1D bridge protocol) on all VLANs. By default, a single spanning tree runs on each configured VLAN (provided you do not manually disable the spanning tree). You can enable and disable a spanning tree on a per-VLAN basis.

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 at regular intervals. The switches do not forward these frames, but use the frames to construct a loop-free path.

Multiple active paths between end stations cause loops in the network. If a loop exists in the network, end stations might receive duplicate messages and switches might learn end station MAC addresses on multiple Layer 2 interfaces. These conditions result in an unstable network.

A 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. A 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 ports on a switch are part of a loop, the spanning tree port priority and port path cost setting determine which port is put in the forwarding state and which port 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 located it is to pass traffic. The spanning tree port path cost value represents media speed.

## Understanding the Bridge ID

Each VLAN on each network device has a unique 64-bit bridge ID consisting of a bridge priority value, an extended system ID, and an STP MAC address allocation.

### Bridge Priority Value

The bridge priority value determines whether a given redundant link will be given priority and considered part of a given span in a spanning tree. Preference is given to lower values, and if you want to manually configure a preference, assign a lower bridge priority value to a link than to its redundant possibility. With older releases, the bridge priority is a 16-bit value. With later releases, the bridge priority is a 4-bit value when the extended system ID is enabled.

Bridge Priority Value																
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

**Table 14-1 Bridge Priority Value with the Extended System ID Disabled**

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

### Bridge Protocol Data Units

The following elements determine the stable active spanning tree topology of a switched network:

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

Bridge protocol data units (BPDUs) contain information about the transmitting bridge and its ports, including the bridge and MAC addresses, bridge priority, port priority, and path cost. The system computes the spanning tree topology by

transmitting BPDUs among connecting switches, and in one direction from the root switch. Each configuration BPDU contains at least the following:

- The unique bridge ID of the switch that the transmitting switch believes to be the root switch
- The spanning tree path cost to the root
- The bridge ID of the transmitting bridge
- The age of the message
- The identifier of the transmitting port
- Values for the hello, forward delay, and max-age protocol timers

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

A BPDU exchange results in the following:

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

## Election of the Root Bridge

For each VLAN, the switch with the highest bridge priority (the lowest numerical priority value) is elected as the root bridge. If all switches are configured with the default priority value (32,768), the switch with the lowest MAC address in the VLAN becomes the root bridge.

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

A spanning tree uses the information provided by BPDUs to elect the root bridge and root port for the switched network, as well as the root port and designated port for each switched segment.

## STP Timers

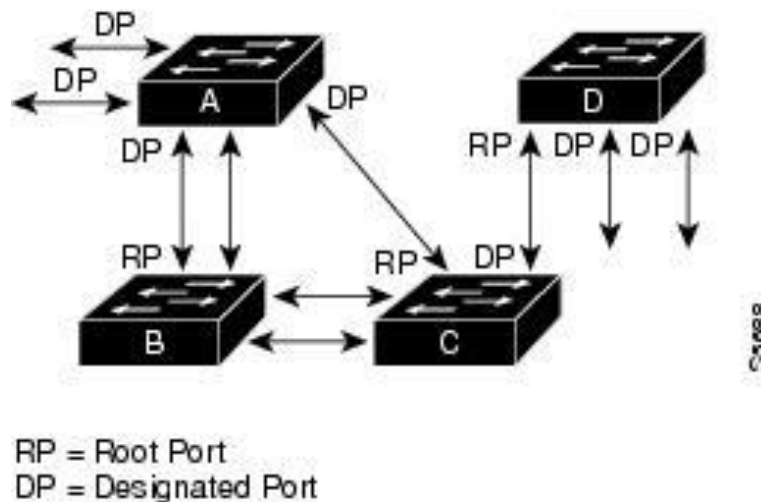
The following table describes the STP timers that affect the performance of the entire spanning tree.

Variable	Description
hello_time	Determines how often the switch broadcasts hello messages to other switches.
forward_time	Determines how long each of the listening and learning states will last before the port begins forwarding.
max_age	Determines the amount of time that protocol information received on a port is stored by the switch.

## Creating the STP Topology

The goal of the spanning tree algorithm is to make the most direct link the root 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 optimal according to link speed. For instance, connecting higher-speed links to a port that has a higher number than the current root port can cause a root-port change.

In the below figure, Switch A is elected as the root bridge. (This could happen if the bridge priority of all the switches is set to the default value [32,768] and Switch A has the lowest MAC address.) However, due to traffic patterns, the number of forwarding ports, or link types, Switch A might not be the ideal root bridge. By increasing the STP port priority (lowering the numerical value) of the ideal switch so that it becomes the root bridge, you force a spanning tree recalculation to form a new spanning tree topology with the ideal switch as the root.



For example, assume that one port on Switch B is a fiber-optic link, and another port on Switch B (an unshielded twisted-pair [UTP] link) is the root port. Network traffic might be more efficient over the high-speed fiber-optic link. By changing the spanning tree port priority on the fiber-optic port to a higher priority (lower numerical value) than the priority set for the root port, the fiber-optic port becomes the new root port.

## STP Port 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 a Layer 2 interface transitions directly from nonparticipation in the spanning tree topology to the forwarding state, it can create temporary data loops. Ports must wait for new topology information to propagate through the switched LAN before starting to forward frames. They must allow the frame lifetime to expire for frames that have been forwarded under the old topology.

Each Layer 2 interface on a switch that uses spanning tree exists in one of the following five states:

- **Blocking**—In this state, the Layer 2 interface does not participate in frame forwarding.
- **Listening**—This state is the first transitional state after the blocking state when spanning tree determines that the Layer 2 interface should participate in frame forwarding.

- Learning—In this state, the Layer 2 interface prepares to participate in frame forwarding.
- Forwarding—In this state, the Layer 2 interface forwards frames.
- Disabled—In this state, the Layer 2 interface does not participate in spanning tree and does not forward frames.

## STP and IEEE 802.1Q Trunks

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

When you connect a Cisco switch to a non-Cisco device (that supports 802.1Q) through an 802.1Q trunk, the Cisco switch combines the spanning tree instance of the 802.1Q native VLAN of the trunk with the spanning tree instance of the non-Cisco 802.1Q switch. However, all per-VLAN spanning tree information is maintained by Cisco switches separated by a network of non-Cisco 802.1Q switches. The non-Cisco 802.1Q network separating the Cisco switches is treated as a single trunk link between the switches.

## Per-VLAN Rapid Spanning Tree

Per-VLAN Rapid Spanning Tree (PVRST+) is the same as PVST+, although PVRST+ utilizes a rapid STP based on IEEE 802.1w rather than 802.1D to provide faster convergence. PVRST+ uses roughly the same configuration as PVST+ and needs only minimal configuration. In PVRST+, dynamic CAM entries are flushed immediately on a per-port basis when any topology change is made. UplinkFast and BackboneFast are enabled but not active in this mode, since the functionality is built into the Rapid STP. PVRST+ provides for rapid recovery of connectivity following the failure of a bridge, bridge port, or LAN. *(More Advanced)*

# Default STP Configuration

The following table shows the default spanning tree configuration.

Feature	Default Value
Enable state	Spanning tree enabled for all VLANs
Bridge priority value	32,768
Spanning tree port priority value (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—used on interfaces configured as Layer 2 access ports)	10-Gigabit Ethernet: 2 Gigabit Ethernet: 4 Fast Ethernet: 19
Spanning tree VLAN port priority value (configurable on a per-VLAN basis—used on interfaces configured as Layer 2 trunk ports)	128
Spanning tree VLAN port cost (configurable on a per-VLAN basis—used on interfaces configured as Layer 2 trunk ports)	10-Gigabit Ethernet: 2 Gigabit Ethernet: 4 Fast Ethernet: 19
Hello time	2 sec
Forward delay time	15 sec
Maximum aging time	20 sec