APPENDIX C

Understanding Spanning-Tree Protocol

Spanning-Tree Protocol is a link management protocol that provides path redundancy while preventing undesirable loops in the network. For an Ethernet network to function properly, only one active path can exist between two stations.

Multiple active paths between stations cause loops in the network. If a loop exists in the network topology, the potential exists for duplication of messages. When loops occur, some switches see stations appear on both sides of the switch. This condition confuses the forwarding algorithm and allows duplicate frames to be forwarded.

To provide path redundancy, Spanning-Tree Protocol defines a tree that spans all switches in an extended network. Spanning-Tree Protocol forces certain redundant data paths into a standby (blocked) state. If one network segment in the Spanning-Tree Protocol becomes unreachable, or if Spanning-Tree Protocol costs change, the spanning-tree algorithm reconfigures the spanning-tree topology and reestablishes the link by activating the standby path.

Spanning-Tree Protocol operation is transparent to end stations, which are unaware whether they are connected to a single LAN segment or a switched LAN of multiple segments.

Election of the Root Switch

All switches in an extended LAN participating in Spanning-Tree Protocol gather information on other switches in the network through an exchange of data messages. These messages are bridge protocol data units (BPDUs). This exchange of messages results in the following:

- The election of a unique root switch for the stable spanning-tree network topology.
- The election of a designated switch for every switched LAN segment.
- The removal of loops in the switched network by placing redundant switch ports in a backup state.

The Spanning-Tree Protocol 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 Spanning-Tree Protocol backup mode. Table C-1 describes the root switch variables, that affect the entire spanning-tree performance.

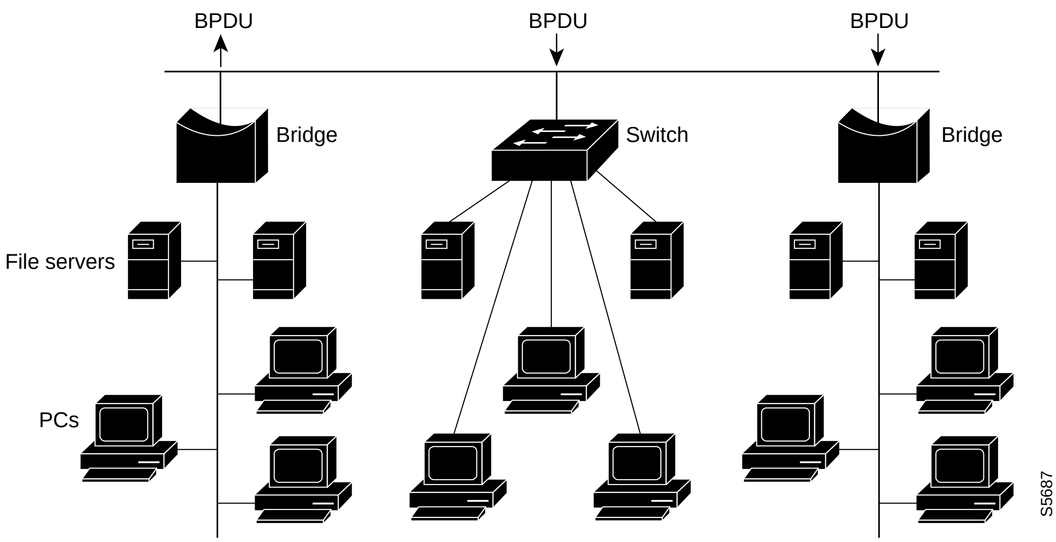
Table C-1 Root Switch Variables Affecting STP

Variable	Description
Hello Time	Determines how often the switch broadcasts its hello message to other switches.
Maximum Age Timer	Measures the age of the received protocol information recorded for a port and ensures that this information is discarded when its age limit exceeds the value to the maximum age parameter recorded by the switch. The timeout value for this timer is the maximum age parameter of the switches.
Forward Delay Timer	Monitors the time spent by a port in the learning and listening states. The timeout value is the forward delay parameter of the switches.

BPDUs contain information about the transmitting switch and its ports, including switch and port Media Access Control (MAC) addresses, switch priority, port priority, and port cost. The Spanning-Tree Protocol uses this information to elect the root switch and root port for the switched network, as well as the root port and designated port for each switched segment.

Figure C-1 shows how BPDUs enable a Spanning-Tree Protocol topology.

Figure C-1 BPDUs Enabling a Stable Spanning-Tree Protocol Topology



Bridge Protocol Data Units

The stable active topology of a switched network is determined by the following:

- The unique switch identifier (MAC address) associated with each switch.
- The path cost to the root associated with each switch port.
- The port identifier (MAC address) associated with each switch port.

Each configuration BPDU contains the following minimal information:

- The unique identifier of the switch that the transmitting switch believes to be the root switch.
- The cost of the path to the root from the transmitting port.

- The identifier of the transmitting port.

The switch sends configuration BPDUs to communicate and compute the spanning-tree topology. A MAC frame conveying a BPDU sends the switch group address to the destination address field. All switches connected to the LAN on which the frame is transmitted receive the BPDU. BPDUs are not directly forwarded by the switch, but the information contained in the frame can be used to calculate a BPDU by the receiving switch, and, if the topology changes, instigate a BPDU transmission.

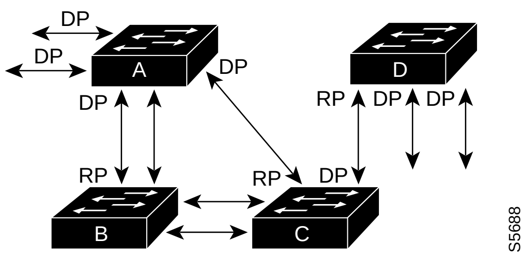
A BPDU exchange results in the following:

- One switch is elected as the root switch.
- The shortest distance to the root switch is calculated for each switch.
- A designated switch is selected. This is the switch closest to the root switch through which frames will be forwarded to the root.
- A port for each switch is selected. This is the port providing the best path from the switch to the root switch.
- Ports included in the Spanning-Tree Protocol are selected.

Spanning-Tree Protocol Configuration

If all switches are enabled with default settings, the switch with the lowest MAC address in the network becomes the root switch. The network in Figure C-2 assumes that Switch A has the lowest MAC address and is therefore the root switch. However, due to traffic patterns, number of forwarding ports, or line types, Switch A might not be the ideal root switch. By increasing the priority (lowering the numerical priority number) of the ideal switch so that it then becomes the root switch, you force a Spanning-Tree Protocol recalculation to form a new, stable topology.

Figure C-2 Configuring a Stable Topology

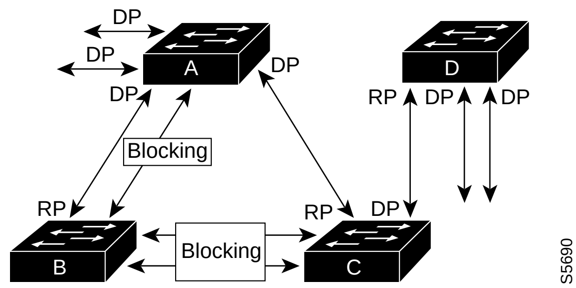


RP = Root Port
DP = Designated Port

When the stable Spanning-Tree Protocol topology is based on default parameters, the path between source and destination stations in a switched network might not be the most ideal. For instance, connecting higher speed links to a port that has a higher number than the current root port can cause a root-port change. The point is to make the fastest link the root port.

For example, assume that Port 2 on Switch B in Figure C-3 is a fiber-optic link, and that Port 1 on Switch B (a UTP link) is the root port. Network traffic might be more efficiently handled over the high-speed fiber-optic link. By changing the Port Priority parameter for Port 2 to a higher priority (lower numerical value) than Port 1, Port 2 becomes the root port. The same change can occur by changing the Port Cost parameter for Port 2 to a lower value than that of Port 1.

Figure C-3 Default Parameters Resulting in Lower Network Efficiency



Spanning-Tree Protocol Port States

Propagation delays can occur when protocol information is passed 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 switch port transitions directly from non-participation in the stable 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 also allow the frame lifetime to expire for frames that have been forwarded using the old topology.

Each port on a switch using Spanning-Tree Protocol exists in one of the following five states:

- Blocking
- Listening
- Learning
- Forwarding
- Disabled

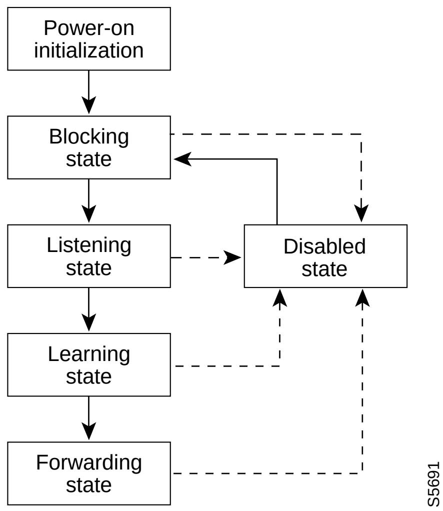
A port moves through these five states as follows:

- 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 C-4 illustrates how a port moves through the five states.

Figure C-4 Spanning-Tree Protocol Port States



You can modify each port state by using management software. When Spanning-Tree Protocol is enabled, every switch in the network goes through the blocking state and the transitory states of listening and learning at power up. If properly configured, the ports then stabilize to the forwarding or blocking state.

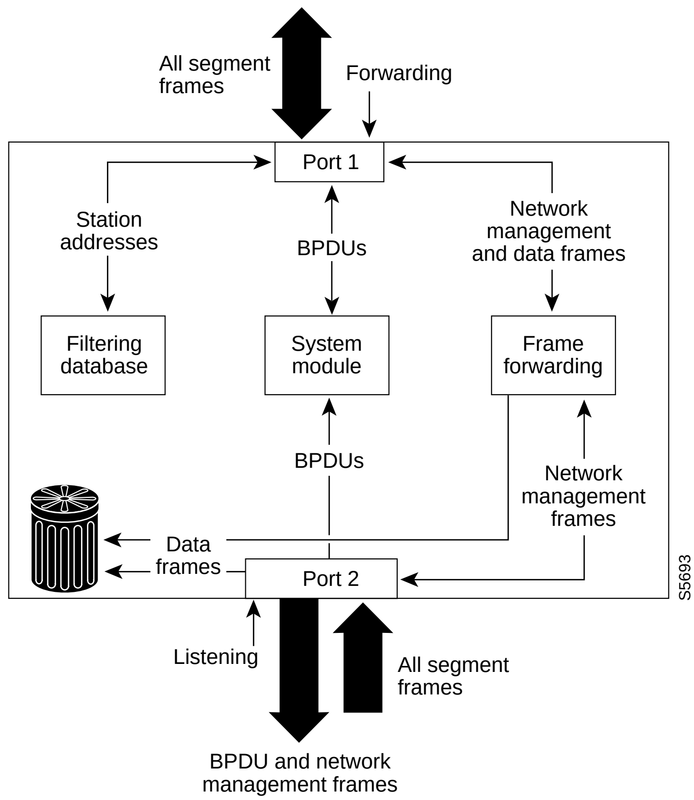
When the spanning-tree algorithm determines that a port should be placed in the forwarding state, the following occurs:

- The port is put into the listening state while it waits for protocol information that suggests it should go to the blocking state.
- The port waits for the expiration of a protocol timer that moves the port to the learning state.
- In the learning state, the port continues to block frame forwarding as it learns station location information for the forwarding database.
- The expiration of a protocol timer moves the port to the forwarding state, where both learning and forwarding are enabled.

Blocking State

A port in the blocking state does not participate in frame forwarding, as shown in Figure C-5. After initialization, a BPDU is sent to each port in the switch. A switch initially assumes it is the root until it exchanges BPDUs with other switches. This exchange establishes which switch in the network is really the root. If only one switch resides in the network, no exchange occurs, the forward delay timer expires, and the ports move to the listening state. A switch always enters the blocking state following switch initialization.

Figure C-5 Port States



A port in the blocking state performs as follows:

- Discards frames received from the attached segment.
- Discards frames switched from another port for forwarding.
- Does not incorporate station location into its address database. (There is no learning at this point, so there is no address database update.)
- Receives BPDUs and directs them to the system module.

- Does not transmit BPDUs received from the system module.
- Receives and responds to network management messages.

Listening State

The listening state is the first transitional state a port enters after the blocking state, when Spanning-Tree Protocol determines that the port should participate in frame forwarding. Learning is disabled in the listening state. Figure C-5 shows a port in the listening state.

A port in the listening state performs as follows:

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

Learning State

A port in the learning state is preparing to participate in frame forwarding. This is the second transitional state through which a port moves in anticipation of frame forwarding. The port enters the learning state from the listening state through the operation of Spanning-Tree Protocol.

A port in the learning state performs as follows:

- Discards frames received from the attached segment.
- Discards frames switched from another port for forwarding.
- Incorporates station location into its address database.
- Receives BPDUs and directs them to the system module.

- Receives, processes, and transmits BPDUs received from the system module.
- Receives and responds to network management messages.

Forwarding State

A port in the forwarding state forwards frames, as shown in Figure C-5. The port enters the forwarding state from the learning state through the operation of Spanning-Tree Protocol.

A port in the forwarding state performs as follows:

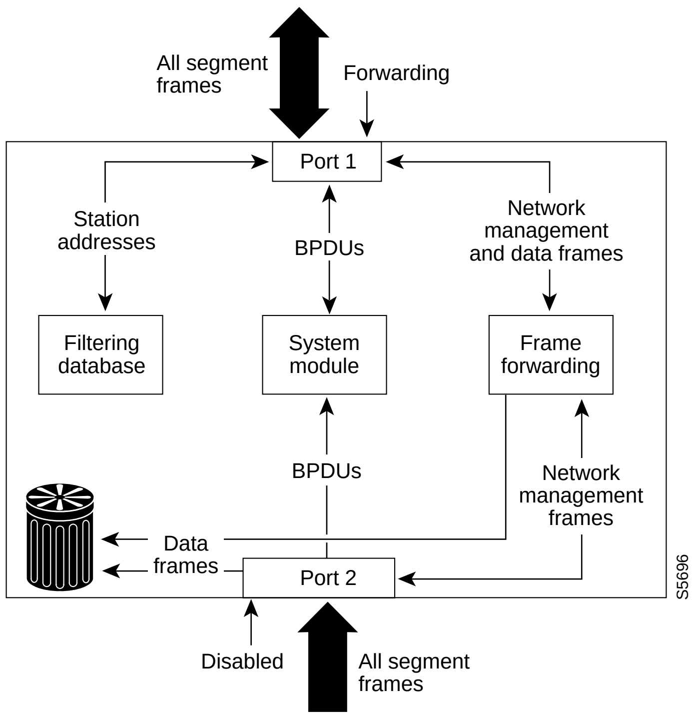
- Forwards frames received from the attached segment.
- Forwards frames switched from another port for forwarding.
- Incorporates station location information into its address database.
- Receives BPDUs and directs them to the system module.
- Processes BPDUs received from the system module.
- Receives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

Caution Use the immediate-forwarding (**portfast**) mode only on ports connected to individual workstations to allow these ports to come up and go directly to the forwarding state, rather than having to go through the entire spanning-tree initialization process. To prevent illegal topologies, enable Spanning-Tree Protocol on ports connected to switches or other devices that forward messages.

Disabled State

A port in the disabled state does not participate in frame forwarding or the operation of Spanning-Tree Protocol, as shown in Figure C-6. A port in the disabled state is virtually nonoperational.

Figure C-6 Port 2 in Disabled State



A disabled port performs as follows:

- Discards frames received from the attached segment.
- Discards frames switched from another port for forwarding.
- Does not incorporate station location into its address database. (There is no learning, so there is no address database update.)
- Receives BPDUs, but does not direct them to the system module.
- Does not receive BPDUs for transmission from the system module.
- Receives and responds to network management messages.