STP – Spanning Tree Protocol (802.1D)

STP states do not change the other information about the interface: connected/not connected **`(#show interfaces status`**), and operational state – access/trunk **`(#show interfaces switchport`**); it only adds an additional STP state.

STP versions and types

IEEE 802.1d (STP, CST – Common Spanning-Tree): really slow but requires very little bridge resources.

PVST+: Cisco proprietary enhancement for STP that provides a separate 802.1d spanning-tree instance for each VLAN. Creates more efficiency of the links in the network, but is just as slow as 802.1d, and it does use more bridge resources than 802.1d.

IEEE 802.1w (RSTP – Rapid Spanning-Tree Protocol): enhanced BPDU exchange, faster network convergence, but still allows only one RB per VLAN. Bridge resources used with RSTP are higher than CST's but less than PVST+.

Rapid PVST+: Cisco's version of RSTP that also uses PVST+ and provides a separate instance of 802.1w per VLAN. Fast convergence times and optimal traffic flow but requires the most CPU and memory of all.

Bridge port roles

FORWARDING PORT – forwards frames and will either be a root port or a DR.

BLOCKING PORT (blocked port) – won't forward frames in order to prevent loops. A blocked port will still listen to BPDU frames from neighbor switches, but it will drop any and all other received frames and will never transmit a frame.

ALTERNATE PORT – corresponds to the BLOCKING state of 802.1d (STP), and is a term used with the newer 802.1w (Rapid STP). An alternate port is located on a switch connected to a LAN segment with two or more switches connected, where one of the other switches holds the DP. Alternate port is backup for RP.

BACKUP PORT – also corresponds to the BLOCKING state of 802.1d, and is a term now used with the newer 802.1w. A backup port is connected to a LAN segment where another port on that switch is acting sa the DP. Backup port is backup for DP.

STP port states

Forwarding state – use the interface as normal

Blocking state – block all user traffic; do not send or receive user traffic on that interface (in that VLAN), except STP messages (and some other overhead messages)

Disabled state – technically not a transition state; a port in the administratively disabled state doesn't participate in frame forwarding or STP. Is virtually nonoperational

Listening state – listens to BPDUs to make sure no loops occur on the network before passing data frames. A port in listening state prepares to forward data frames without without populating the MAC address

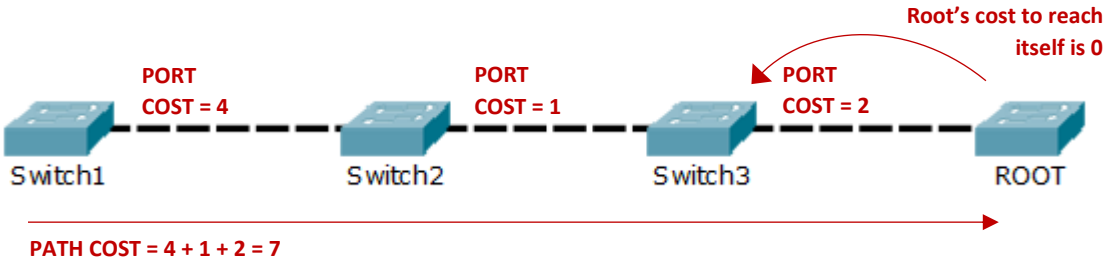
table. Old (unused) MAC addresses are removed from the table during this state. Switches populate the MAC address table in learning and forwarding modes only

Learning state – listens to BPDUs and learns all the paths in the switched network. A port in learning state populates the MAC address table but still does not forward data frames. "Forward delay" refers to the time it takes to transition a port from listening mode to learning mode, which is set to 15s. by default and can be seen in the **`#show spanning-tree`** output

"Working" ports/interfaces (those in a connected state) are all interfaces that COULD forward frames if STP placed them into a forwarding state. Failed interfaces (for example, interfaces with no cable installed) or administratively shutdown interfaces are placed into an STP disabled state.

"Port Cost" determines the best path when multiple links are used between two switches. The cost of a link is determined by its bandwidth.

"Path Cost" = "Root Cost": all unique paths to the RB are analyzed individually, and a PATH COST is calculated by adding up the individual outbound PORT COSTS encountered on the (outbound) way to the Root Bridge.



"STP stable states": Blocking, Forwarding, Disabled

"STP transitory states": Listening, Learning

STP steps

1. STP ELECTS A ROOT SWITCH (Root Bridge – RB). Switch with the lowest BID value (priority) becomes the RB. All "working" interfaces on the root switch become Designated Ports (DPs).

- BID, original format: Priority (2B) + Universal, burned-in MAC of the switch
- BID; system ID extention:
    1) Priority; multiple of 4096, from 0 to 61.440 (4 bits); 32.768 by default
    2) System ID extention; typically holds VLAN ID (12 bits); 1) + 2) = 16 bits
    3) System ID = MAC address of the switch (6 bytes)

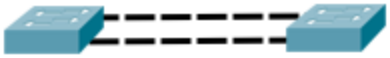
2. EACH "NONROOT BRIDGE" CHOOSES ITS ROOT PORT – the lowest cost interface to reach the RB through. Root switches don't have RPs. Each switch in a given network has EXACTLY 1 root port per VLAN. RB will send "Root Cost = 0" in Hello packets.

STP tiebreakers when choosing the Root Port:

1) cost to the RB -> when that ties ->
2) lowest neighbor BID ->

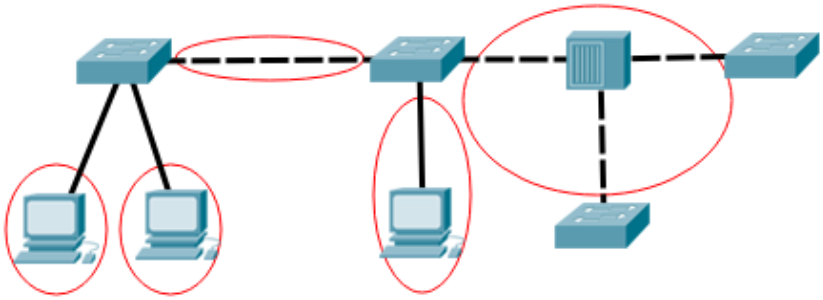
3) lowest neighbor port priority ->
4) lowest neighbor internal port number (Fa0/1, F0/2, etc.)

In these tie-breakers, only those paths that are tied are considered;
3) and 4) only come into play when 2 switches connect to each other with multiple links



3. DESIGNATED PORT ELECTION: on each network segment (link), the port that advertises the lowest price to RB becomes DP. All other ports in that segment will, if they're not RP, become "*non-designated*" ports and they'll be put into either a "*blocking*" or "*discarding*" mode.

Access ports will also automatically become DPs, because the switch is the only device on the segment to send Hellos -> switch is sending least-cost Hellos.



Network segments are marked with red circles.

How STP works in steady-state (nothing changing in the STP topology)

1. The root creates and sends a Hello BPDU, with a root cost of 0, out all its forwarding (working) interfaces;
2. The nonroot switches receive the Hello on their root ports. After changing the Hello to list their own BID as the sender's BID, and listing their own root cost, the switch forwards the Hello out all designated ports.
3. Steps 1 and 2 repeat until something changes.

When a switch ceases to receive Hellos, or receives a changed Hello -> something has failed -> the switch starts the process of changing the spanning-tree topology.

If an interface fails on a switch, the switch can assume that Hellos won't be arriving in that interface anymore.

Hello BPDU fields

1. Root bridge ID -> BID of the switch that the sender of this Hello believes to currently be the root switch (RB).

2. Sender's BID -> BID of the switch sending this Hello BPDU.
3. Sender's ROOT COST -> STP cost between this switch and the current root.
4. Timer values on the RB -> Hello timer, MaxAge, and Forward delay timer.

STP timers (RB dictates timers)

1. Hello (2 seconds): the time period between Hellos created by the root.
2. MaxAge (10 times Hello): how long any switch should wait, after ceasing to hear Hellos, before trying to change the STP topology.
3. Forward delay (15 seconds): when an interface changes from *blocking* to *forwarding* state, a port stays in an interim (међувреме, meanwhile) listening state, and then an interim learning state for >forward delay< # of seconds. This helps prevent temporary loops.

RSTP – Rapid STP (IEEE 802.1w)

- RSTP calls the blocking state "the discarding state"
- STP converges in 50 seconds (by default), RSTP converges within a few seconds, and in slow conditions, in about 10 seconds
- In RSTP, MaxAge is 3 times Hello
- RSTP *Alternate Ports* are the switch's other ports that could be used as a Root Port if the existing RP ever fails. To become an alternate port, an interface must receive Hellos that identify the same root switch (RB) as the root port. The alternate port can take over for the former RP very rapidly, without waiting in other interim STP states (listening, learning). There are no timers, the change (convergence) happens within a second
- RSTP *Backup Port* replaces a designated port when a DP fails. This is only needed in a network where a switch connects two ports to a Hub
- RSTP port types:
    1) point-to-point ports -> ports that connect two switches;
    2) point-to-point edge ports -> ports that connect to a single endpoint device at the edge of a network, like PCs and servers;
    3) shared ports -> ports connected to a hub (half duplex).

    Both 1) and 2) are full duplex.

Portfast: allows a switch to immediately transition from blocking to forwarding, bypassing listening and learning states. Should only be enabled on ports where no other bridges, switches, or other STP-speaking devices will be connected. If enabled, the port will move to an STP forwarding state and forward traffic as soon as the NIC is active on the end device connected to the port.

BPDU guard: disables a port if any BPDUs are received on the port. Should only be enabled on access/Portfast interfaces.