**Spanning Tree • Part 1**

### Spanning Tree Protocols

<table>
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<th>PVST</th>
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<th>MST</th>
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<td>Legacy ST</td>
<td>Legacy ST</td>
<td>Rapid ST</td>
<td>Rapid ST</td>
<td>Rapid ST</td>
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<tr>
<td><strong>Definition</strong></td>
<td>802.1D-1998</td>
<td>Cisco</td>
<td>Cisco</td>
<td>802.1w, 802.1D-2004</td>
<td>Cisco</td>
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<tr>
<td><strong>Instances</strong></td>
<td>One</td>
<td>Per VLAN</td>
<td>Per VLAN</td>
<td>One</td>
<td>Per VLAN</td>
<td>Configurable</td>
</tr>
<tr>
<td><strong>Trunking</strong></td>
<td>N/A</td>
<td>ISL</td>
<td>802.1Q, ISL</td>
<td>N/A</td>
<td>802.1Q, ISL</td>
<td>802.1Q, ISL</td>
</tr>
</tbody>
</table>

### Spanning Tree Instance Comparison

- **STP**: One per VLAN, N/A
- **PVST**: Per VLAN, ISL, 802.1Q, ISL
- **PVST+**: Per VLAN, 802.1Q, ISL
- **RSTP**: One, N/A
- **RPVST+**: One, Configurable
- **MST**: Per VLAN, 802.1Q, ISL

### BPDU Format

- **Protocol ID**: 16
- **Version**: 8
- **BPDU Type**: 8
- **Flags**: 8
- **Root ID**: 64
- **Root Path Cost**: 32
- **Bridge ID**: 64
- **Port ID**: 16
- **Message Age**: 16
- **Max Age**: 16
- **Hello Time**: 16
- **Forward Delay**: 16

### Default Timers

- **Hello**: 2s
- **Forward Delay**: 15s
- **Max Age**: 20s

### Spanning Tree Specification

- **Open Standards**
  - **IEEE 802.1D-1998**: Deprecated legacy STP standard
  - **IEEE 802.1w**: Introduced Rapid STP (RSTP)
  - **IEEE 802.1D-2004**: Replaced legacy STP with RSTP
  - **IEEE 802.1s**: Introduced Multiple Spanning Tree (MST)
  - **IEEE 802.1Q-2003**: Added MST to 802.1Q

### Cisco Proprietary Implementations

- **PVST**: Per-VLAN implementation of legacy STP
- **PVST+**: Added 802.1Q trunking to PVST
- **RPVST+**: Per-VLAN implementation of RSTP

### Spanning Tree Operation

1. **Determine root bridge**: The bridge advertising the lowest bridge ID becomes the root bridge.
2. **Select root port**: Each bridge selects its primary port facing the root.
3. **Select designated ports**: One designated port is selected per segment.
4. **Block ports with loops**: All non-root and non-designated ports are blocked.

### Link Costs

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Mbps</td>
<td>250</td>
</tr>
<tr>
<td>10 Mbps</td>
<td>100</td>
</tr>
<tr>
<td>16 Mbps</td>
<td>62</td>
</tr>
<tr>
<td>45 Mbps</td>
<td>39</td>
</tr>
<tr>
<td>100 Mbps</td>
<td>19</td>
</tr>
<tr>
<td>155 Mbps</td>
<td>14</td>
</tr>
<tr>
<td>622 Mbps</td>
<td>6</td>
</tr>
<tr>
<td>1 Gbps</td>
<td>4</td>
</tr>
<tr>
<td>10 Gbps</td>
<td>2</td>
</tr>
</tbody>
</table>

### Port States

<table>
<thead>
<tr>
<th>Legacy ST</th>
<th>Rapid ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disabled</td>
<td>Discarding</td>
</tr>
<tr>
<td>Blocking</td>
<td>Discarding</td>
</tr>
<tr>
<td>Listening</td>
<td>Discarding</td>
</tr>
<tr>
<td>Learning</td>
<td>Learning</td>
</tr>
<tr>
<td>Forwarding</td>
<td>Forwarding</td>
</tr>
</tbody>
</table>

### Port Roles

<table>
<thead>
<tr>
<th>Legacy ST</th>
<th>Rapid ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root</td>
<td>Root</td>
</tr>
<tr>
<td>Designated</td>
<td>Designated</td>
</tr>
<tr>
<td>Blocking</td>
<td>Alternate</td>
</tr>
<tr>
<td>Blocking</td>
<td>Backup</td>
</tr>
</tbody>
</table>
## PVST+ and RPVST+ Configuration

- **Set STP type**
  ```
  spanning-tree mode {pvst | rapid-pvst}
  ```

- **Bridge priority**
  ```
  spanning-tree vlan 1-4094 priority 32768
  ```

- **Timers, in seconds**
  ```
  spanning-tree vlan 1-4094 hello-time 2
  spanning-tree vlan 1-4094 forward-time 15
  spanning-tree vlan 1-4094 max-age 20
  ```

- **Enabling PortFast by default**
  ```
  spanning-tree portfast default
  ```

- **PVST+ Enhancements**
  ```
  spanning-tree backbonefast
  spanning-tree uplinkfast
  ```

- **Interface attributes**
  ```
  interface FastEthernet0/1
  spanning-tree [vlan 1-4094] port-priority 128
  spanning-tree [vlan 1-4094] cost 19
  ```

- **Manual link type specification**
  ```
  spanning-tree link-type {point-to-point | shared}
  ```

- **Enables spanning tree if running PVST+, or designates an edge port under RPVST+**
  ```
  spanning-tree portfast
  ```

- **Spanning tree protection**
  ```
  spanning-tree guard {loop | root | none}
  ```

- **Per-interface toggling**
  ```
  spanning-tree bpduguard enable
  spanning-tree bpdufilter enable
  ```

## MST Configuration

- **Set STP type**
  ```
  spanning-tree mode mst
  ```

- **MST Configuration**
  ```
  spanning-tree mst configuration
  name MyTree
  revision 1
  ```

- **Map VLANS to instances**
  ```
  instance 1 vlan 20, 30
  instance 2 vlan 40, 50
  ```

- **Bridge priority (per instance)**
  ```
  spanning-tree mst 1 priority 32768
  ```

- **Timers, in seconds**
  ```
  spanning-tree mst hello-time 2
  spanning-tree mst forward-time 15
  spanning-tree mst max-age 20
  ```

- **Maximum hops for BPDUs**
  ```
  spanning-tree mst max-hops 20
  ```

- **Interface attributes**
  ```
  interface FastEthernet0/1
  spanning-tree mst 1 port-priority 128
  spanning-tree mst 1 cost 19
  ```

## Bridge ID Format

<table>
<thead>
<tr>
<th>Priority</th>
<th>Sys ID Ext</th>
<th>MAC Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>12</td>
<td>48</td>
</tr>
</tbody>
</table>

- **Priority** · 4-bit configurable priority (configurable from 0 to 61440 in increments of 4096)
- **System ID Extension** · 12-bit value taken from VLAN number
- **MAC Address** · 48-bit value to ensure uniqueness

## Path Selection

1. Prefer the neighbor advertising the lowest root ID
2. Prefer the neighbor advertising the lowest cost to root
3. Prefer the neighbor with the lowest bridge ID
4. Prefer the lowest sender port ID

## Optional PVST+ Enhancements

- **PortFast** Enables immediate transition into the forwarding state on edge ports
- **UplinkFast** Enables access switches to maintain backup paths to root
- **BackboneFast** Enables immediate expiration of the Max Age timer on an indirect link failure

## Spanning Tree Protection

- **Root Guard** Prevents a port from becoming the root port
- **BPDU Guard** Error disables a port if a BPDU is received
- **Loop Guard** Prevents a blocked port from transitioning to listening after the Max Age timer has expired
- **BPDU Filter** Blocks BPDUs on an interface

## RSTP Link Types

- **Point-to-Point** Connects to exactly one other bridge (a full duplex interface)
- **Shared** Potentially connects to multiple bridges (a half duplex interface)
- **Edge** Connects to a single host; designated by applying PortFast

## Troubleshooting

- `show spanning-tree [summary | detail]`
- `show spanning-tree root`
- `show spanning-tree vlan <VLAN>`
- `show spanning-tree interface <interface>`
- `show spanning-tree mst [{<instance>} | detail]`
- `show spanning-tree mst configuration`
- `show spanning-tree mst interface <interface>`