Spanning Tree Protocol (STP)

Redundancy in Layer 2 Switched Networks

- **Redundancy** ➡️ eliminating **single points of failure**.

- **Path redundancy** ➡️ physical and logical **Layer 2 loops** (frame has not TTL) ➡️ 🔥

- **STP logically blocks physical loops**, preventing frames circling the network forever.

- STP compensates for a failure by recalculating and opening up previously blocked ports.

- **STA: Spanning Tree Algorithm**

  - Creates a loop-free topology by selecting a single root bridge where all the other switches determine a single least-cost path, blocking redundant paths and recalculating in case of Link Failure.

- ⚠️ **STP enabled by default!!!**

STP

- **Problems solved:**
  - 🤓 **MAC database instability**: MAC address table constantly changing from the broadcast frames ➡️ High CPU ➡️ Switch unable to forward frames
  - 🌩️ **Broadcast Storm**: high number of broadcasts overwhelming the network🔥
  - 👯 **Duplicated unicast frames:** devices receive twice the same frame from different paths.

- **Usages:**
  - ♾️ **Solves L2 looping problems**
  - 🛤️ **Provides alternative paths in case of failure**
  - ⚖️ **Provides VLAN Load Balancing between trunks**

STP Step 1️⃣ - Elect the Root Bridge (RB)

- STA designates a single switch as root bridge

- **Root Bridge = Switch with the lowest BID (Bridge ID)**

- **BID = (Bridge Priority + VLAN ID) . Bridge MAC**
  - **Bridge Priority = 32768** (default). Range: 0...61440 (increments of 4096)
    - ⚠️ **Can be changed to elect another root bridge**
  - **VLAN ID = Extended System ID**
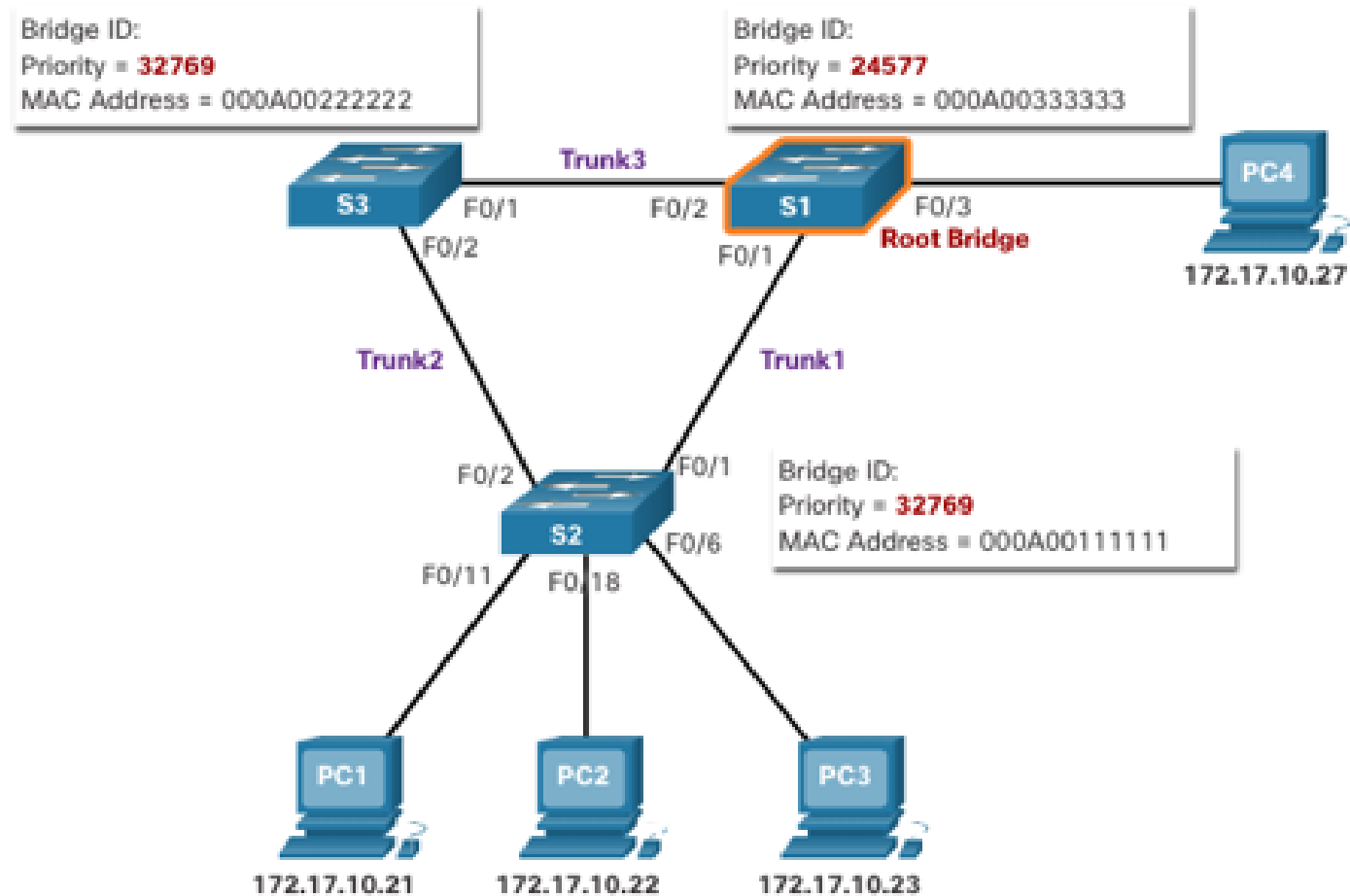 - **Bridge ID = Switch MAC Address**

Example:

S1 BID: `32768.00A0.1101.V001`

S2 BID: `32768.00A0.FF01.6689`

S3 BID: `32767.0010.FF32.991B` ➡️ Lowest BID ➡️ Root Bridge

STP Step 1 - Elect the Root Bridge

Bridge ID:
Priority = 32769
MAC Address = 000A00222222

Bridge ID:
Priority = 24577
MAC Address = 000A00333333

Trunk3

S3   F0/1

F0/2   S1   F0/3
Root Bridge

PC4

172.17.10.27

F0/2

F0/1

Trunk2

Trunk1

F0/2   F0/1

S2

F0/6

Bridge ID:
Priority = 32769
MAC Address = 000A00111111

F0/11   F0/18

PC1   PC2   PC3

172.17.10.21   172.17.10.22   172.17.10.23

STP Step 1️⃣ - Changing and verify Root Bridge

Option 1️⃣: Select root bridge manually

```
S1(config)# spanning-tree VLAN 1 root primary
...
S2(config)# spanning-tree VLAN 1 root secondary
```

Option 2️⃣: Change the priority value

```
S1(config)# spanning-tree VLAN 1 priority 24576
```

Verify Bridge ID and Root Bridge election

```
S1# show spanning-tree
```

STP Step 2 - Elect the Root Ports (RP)

- **EVERY NON-ROOT SWITCH will select one Root Port RP.**
  - **Root port RP** (1 , if equals then 2 , ...):
    - 1 Port with overall lower cost to the Root Bridge
    - 2 Port with lower Sender Bridge ID
    - 3 Port with lower Sender Port Priority
    - 4 Port with lower Sender Port ID

Root Path Cost

Defaults
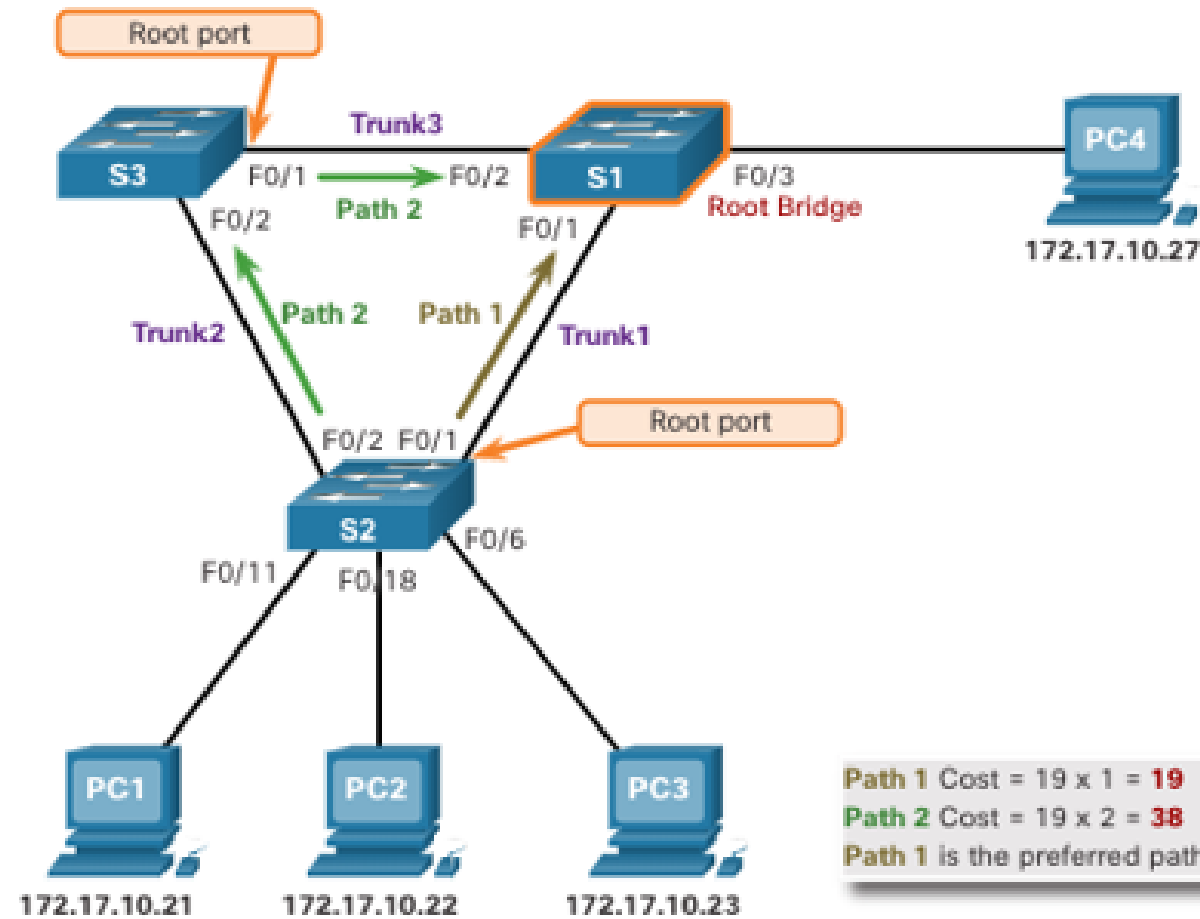
Link Speed	STP Cost: IEEE 802.1D-1998	RSTP Cost: IEEE 802.1w-2004
10 Gbps	2	2,000
1 Gbps	4	20,000
100 Mbps	19	200,000
10 Mbps	100	2,000,000

Modify Path Cost

```
S1(config)# interface f0/1
S1(config-if)# spanning-tree cost 25
```

STP Step 2 - Elect the Root Ports

Root port

Trunk3

S3   F0/1 → F0/2   S1   F0/3
         Path 2   Root Bridge

F0/2   F0/1

Trunk2   Path 2   Path 1   Trunk1

F0/2 F0/1   Root port

S2   F0/6

F0/11   F0/18

PC4
172.17.10.27

PC1   PC2   PC3
172.17.10.21   172.17.10.22   172.17.10.23

Path 1 Cost = 19 x 1 = **19**
Path 2 Cost = 19 x 2 = **38**
Path 1 is the preferred path.

STP Step 3 - Elect Designated Ports (DP)

- **EVERY SEGMENT between 2 switches will have one Designated Port DP.**
  - All ports of Root Bridge ➡ DP
  - One end of a segment is RP ➡ Other end is DP
  - All ports attached to end devices ➡ DP
  - Other segments without DP, one DP (1 , if equals then 2 , ...):
    - 1 Port with overall lower cost to the Root Bridge
    - 2 Port with lower Sender Bridge ID
    - 3 Port with lower Sender Port Priority
    - 4 Port with lower Sender Port ID

STP Step 3 – Elect Designated Ports
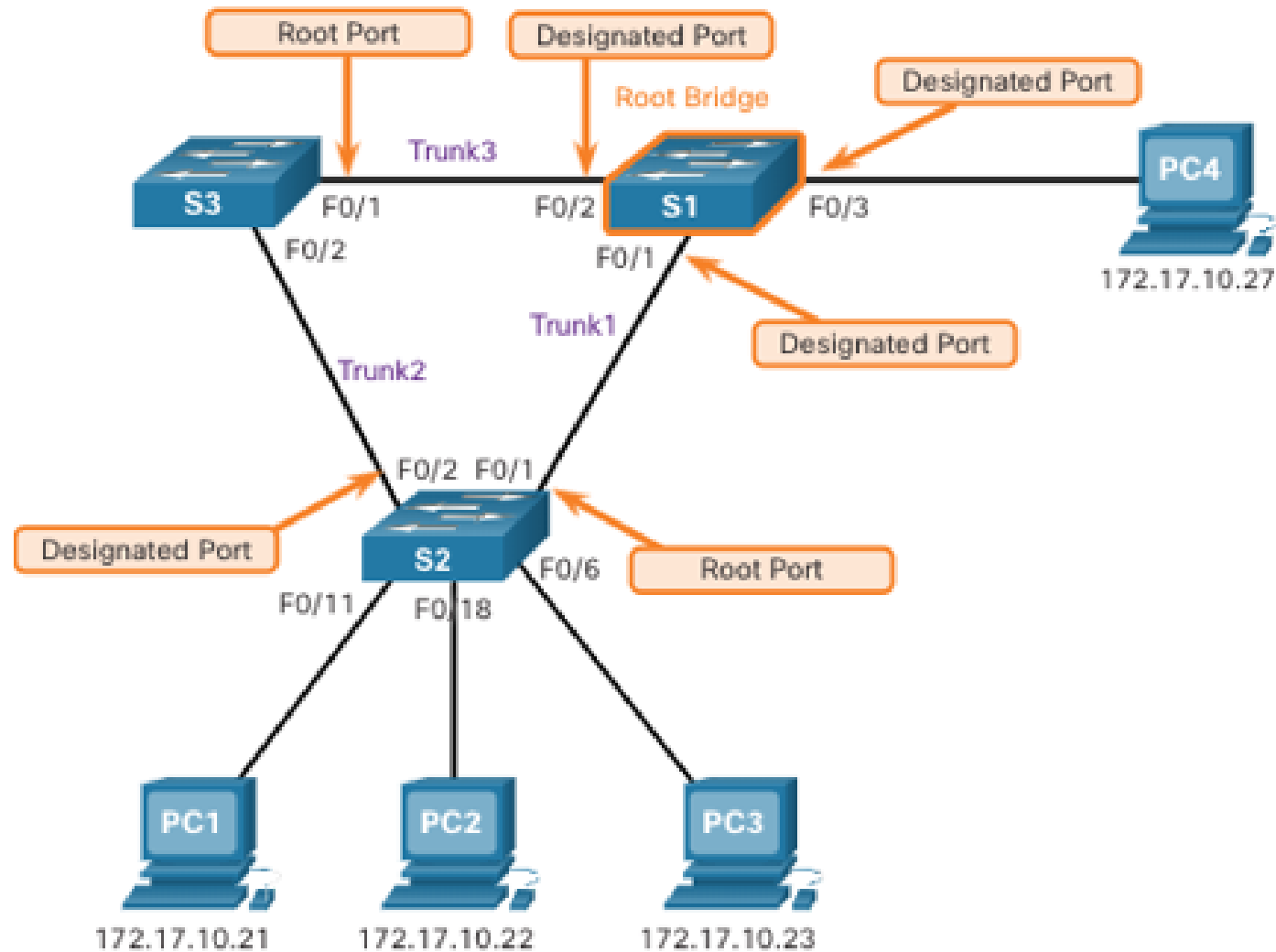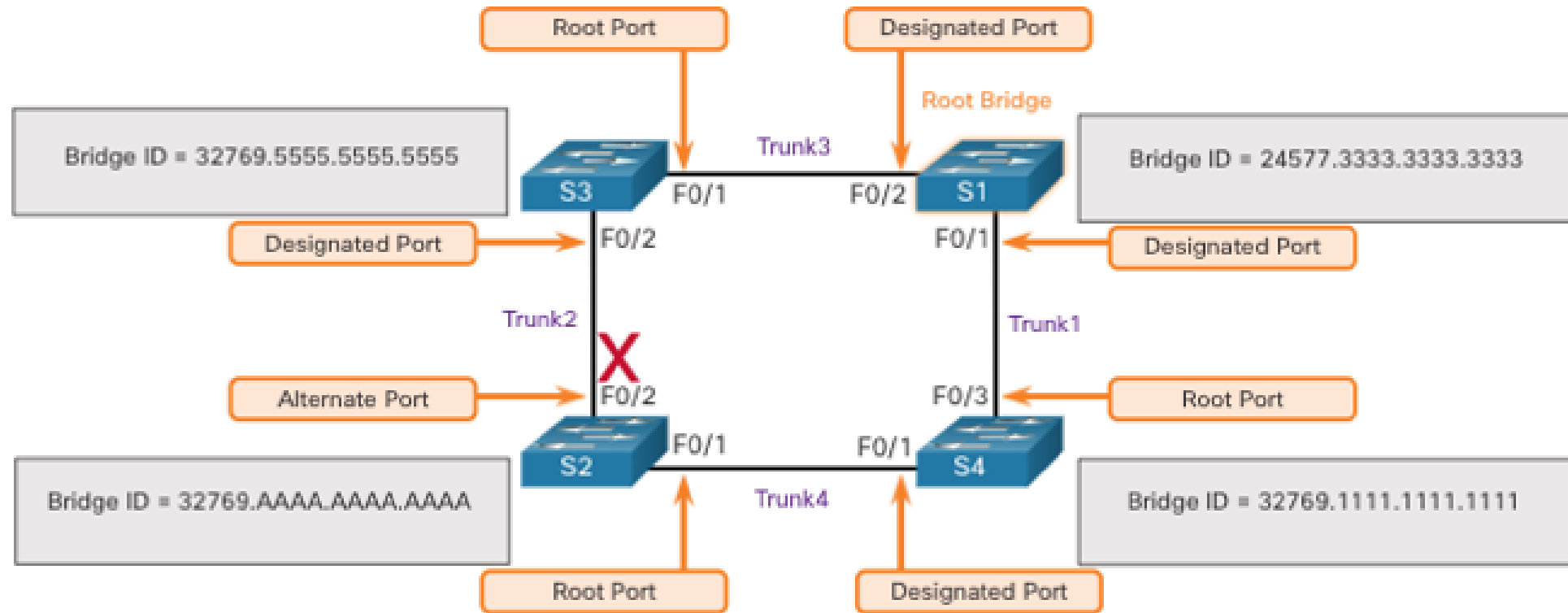
STP Step 4 - Elect Alternate/Blocked Ports (ALT/BLK)

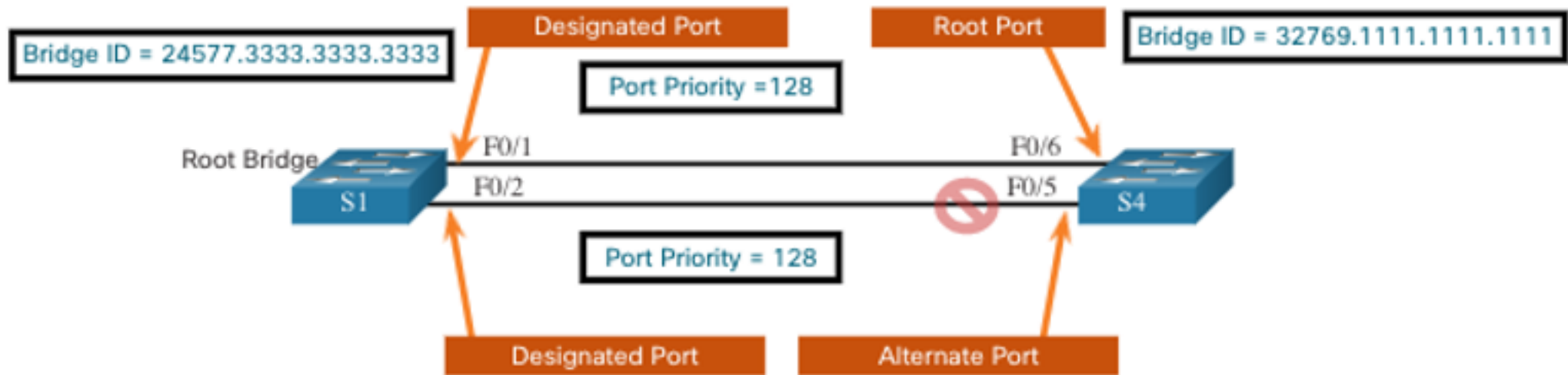- Block ports that are not RP or DP ➡ ALT/BLK
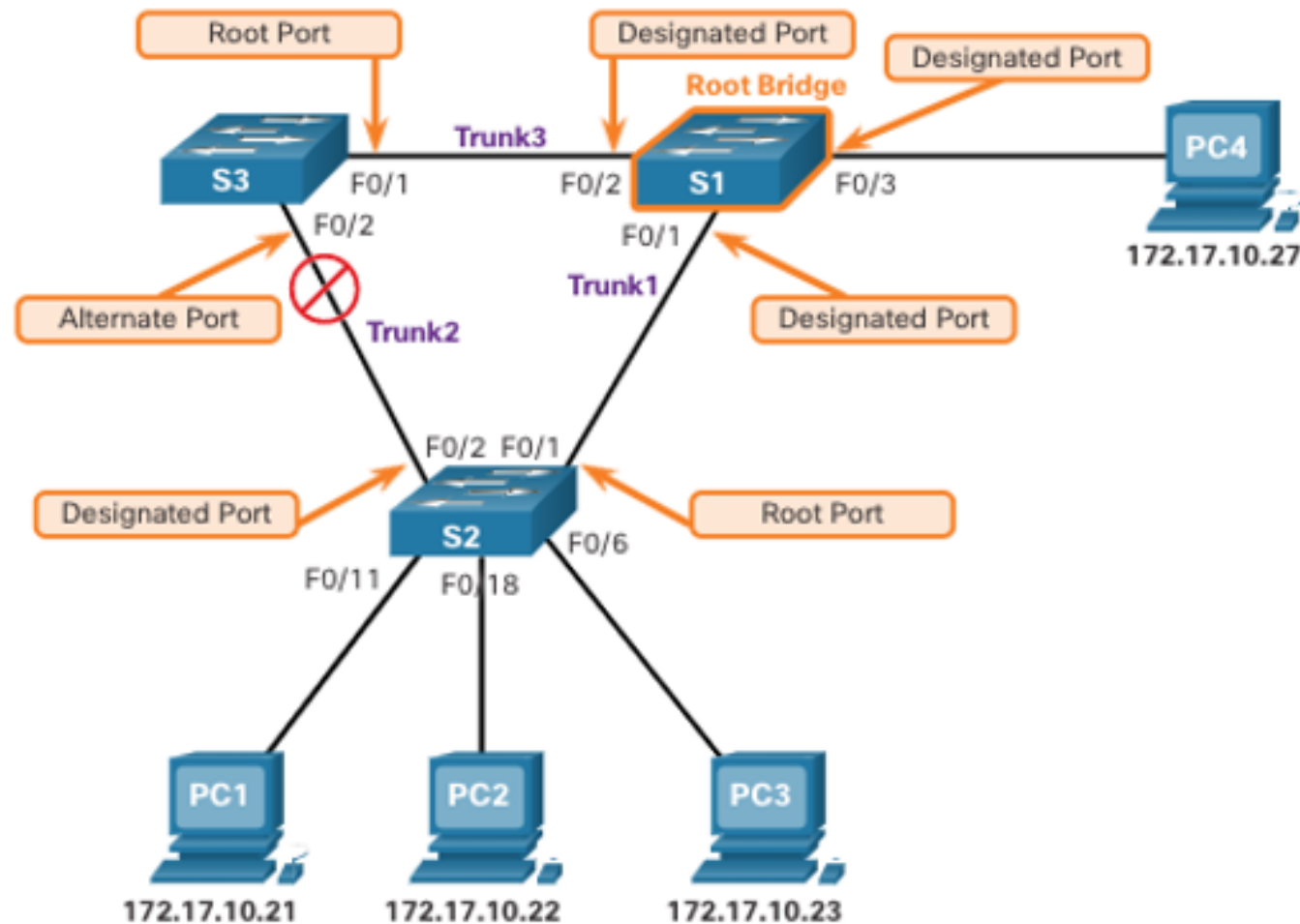
Multiple Equal-Cost Path: Lower Sender BID

S2: RP is F0/1, because S4 has a lower sender BID than S3.

Same cost ➡ Different Sender BID

Multiple Equal-Cost Path: Lower Sender Port ID

> **S4:** RP is F0/6, because S1 F0/1 has a lower sender Port ID than S1 F0/2.
>
> Same cost ➡ Same sender BID ➡ Same Port Priority ➡ Different Sender Port ID

STP Timers and Port States

STP convergence requires 3 timers, defined in Root Bridge (changeable):

- 👋 **Hello Timer**: Interval between PDUS. Default = **2 seconds** (range: 1...10 seconds)

- ↩️ **Forward Delay Timer**: Time that is spent in the listening and learning state. Default = **15 seconds** (range: 4...30 seconds)

- 👵 **Max Age Timer**: Maximum length of time that a switch waits before attempting to change the STP Topology. Default = **20 seconds** (range: 6...40 seconds)
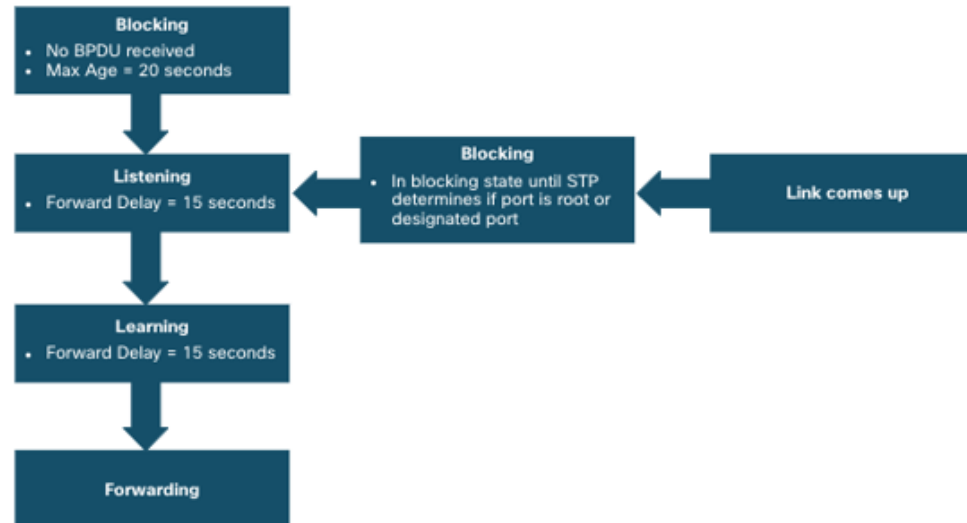
Per-VLAN Spanning Tree (PVST)

A Root Bridge is elected for EACH spanning tree instance/VLAN ➡ Load Balancing

- Cisco switches running IOS 15.0+ run PVST+ by default
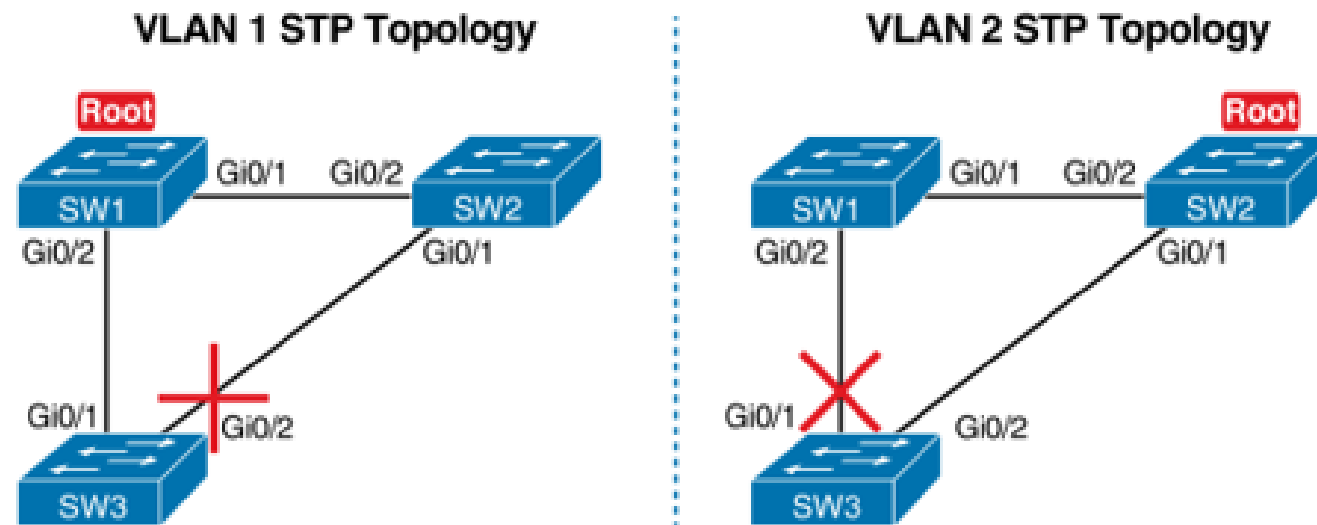
Figure 10-2 *Load Balancing with One Tree for VLAN 1 and Another for VLAN 2*

PVST Config: PortFast and BPDU Guard

- **PortFast**: Ports that have end devices (**Access Ports**). Port in FWD state.

- **BPDU Guard**: Disables a PortFast port if a BPDU is received ➡ Port in `errdisabled`

```
S2(config)# interface range f0/11,f0/18,f0/6
S2(config-if-range)# spanning-tree portfast
S2(config-if-range)# spanning-tree bpduguard enable
```


17
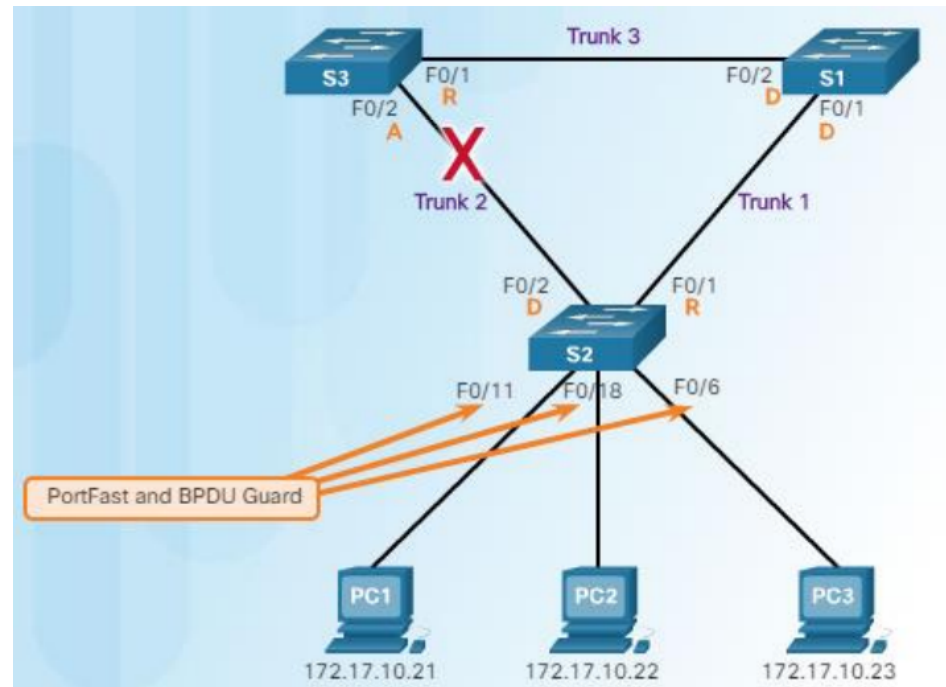
Different Versions of STP

- **Common STP (CST/STP/802.1D)**: 1998. 1 instance regardless number of VLANs.
- **Per-VLAN STP (PVST+)**: Cisco enhanced STP. 1 instance per VLAN. PortFast, BPDU Guard.
- **Rapid STP (RSTP/802.1w)**: Evolution of STP that provides faster convergence
- **Rapid PVST+**: Cisco enhanced RSTP. 1 instance per VLAN.
- **Multiple STP (MSTP/802.1s)**: Maps multiple VLANs into the same spanning tree instance.
- **Multiple Spanning Tree (MST)**: Cisco enhanced MSTP. Provides up to 16 instances of RSTP.

RSTP

- **Alternate Port** (alternate path to the Root Bridge) ➡️ change to FWD state without waiting the network to converge.
- **Backup Port**: backup to a shared medium (Hub). Less common!!

STP	RSTP		STP	RSTP
Disabled			Root Port	Root Port
Blocking	Discarding		Designated Port	Designated Port
Listening				Backup Port
Learning	Learning		Blocked Port (Non-Designated Port)	
Forwarding	Forwarding			Alternate Port