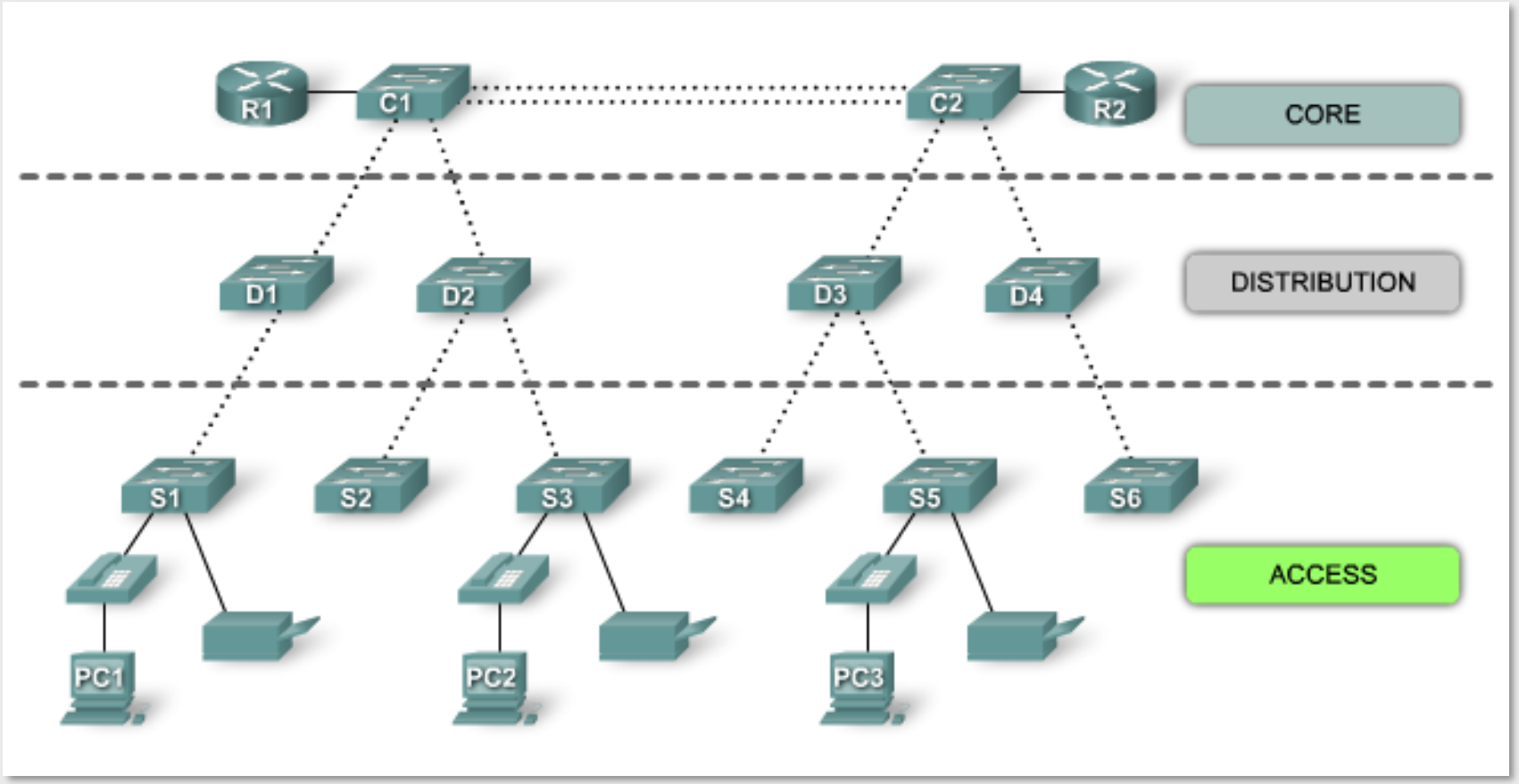
Lab 10

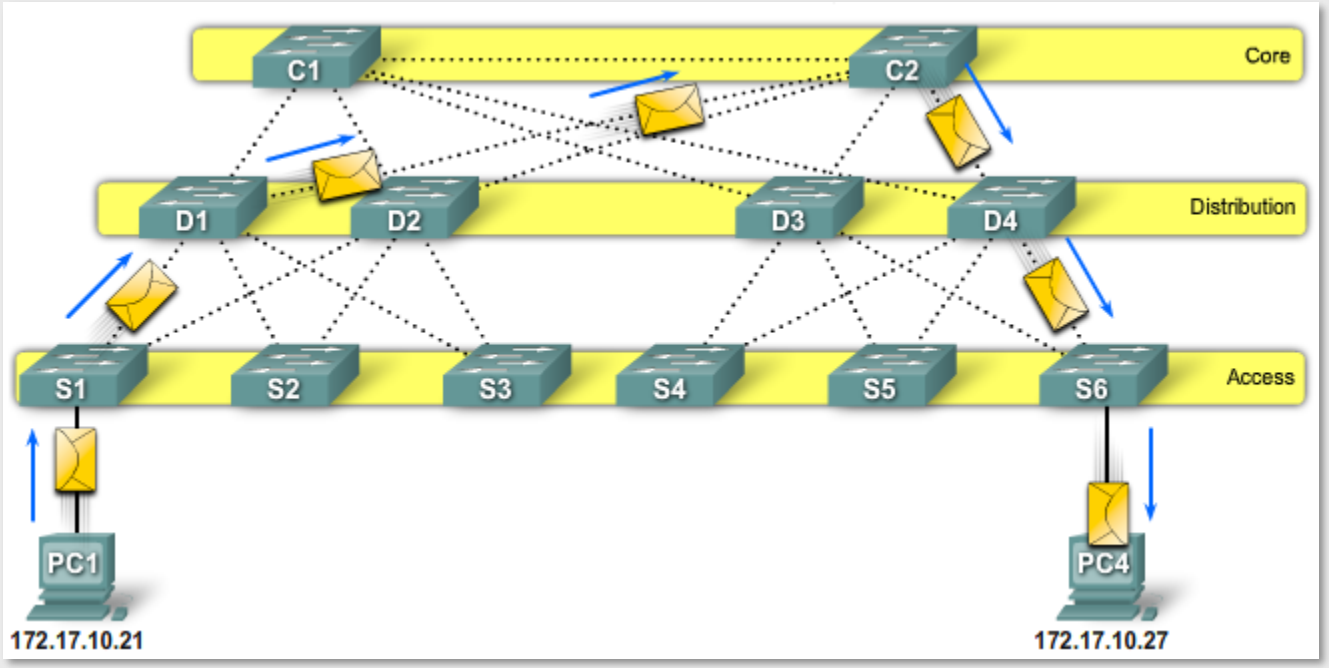
Spanning Tree Protocol

LAN hierarchical design



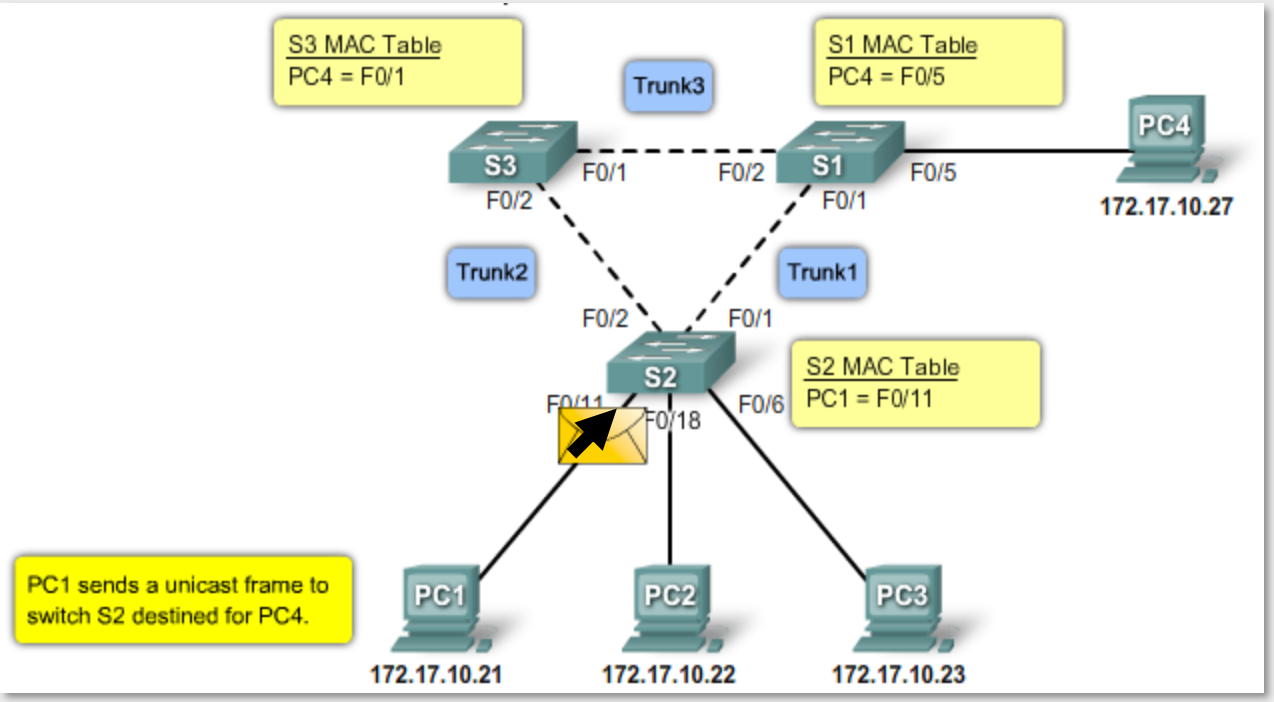
Redundant design

- Additional hardware plus multiple paths
- Accommodate a single point of failure
  - Path failure (access to distribution or distribution to core)
  - Switch failure (distribution or core)



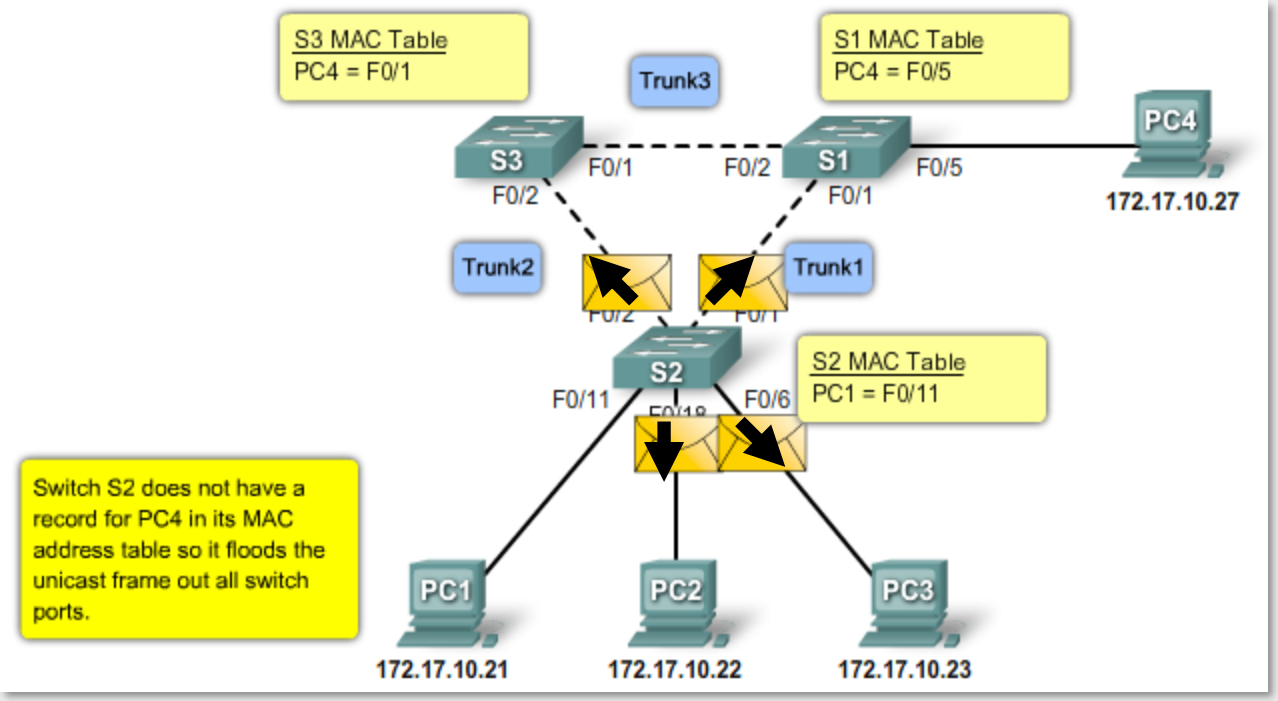
Issues with redundancy

- Duplicate unicast frames



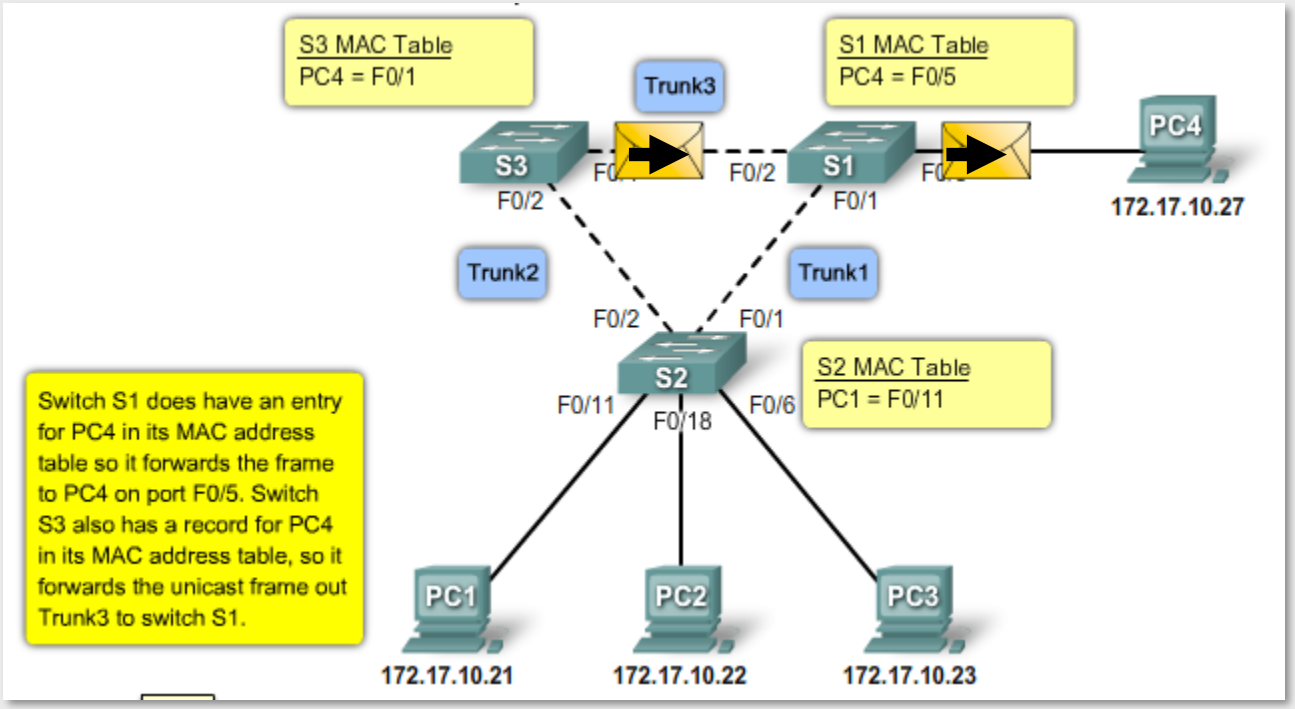
Issues with redundancy

- Duplicate unicast frames



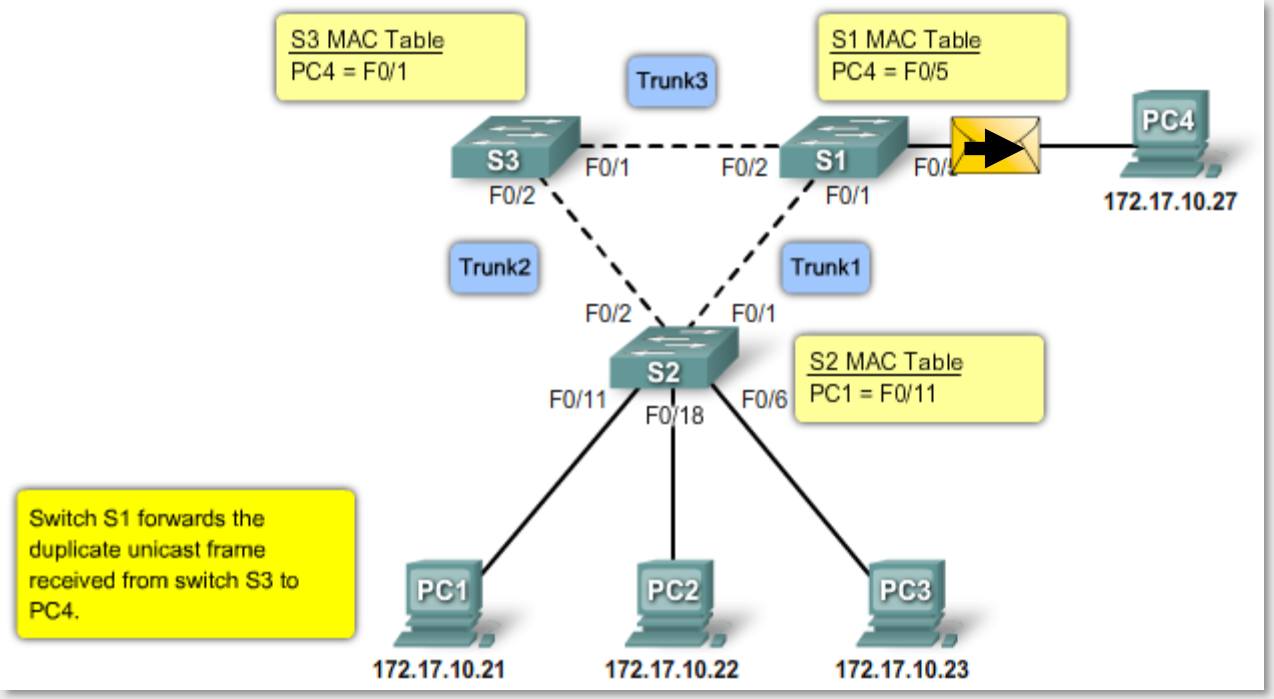
Issues with redundancy

- Duplicate unicast frames



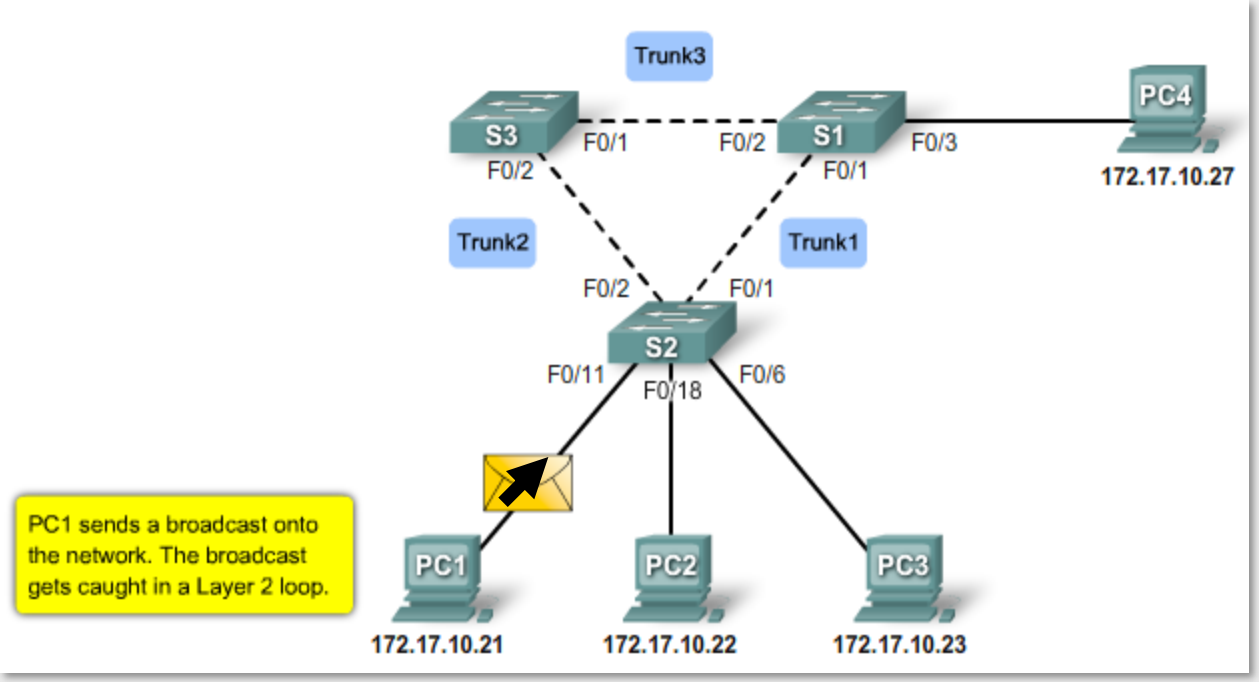
Issues with redundancy

- Duplicate unicast frames



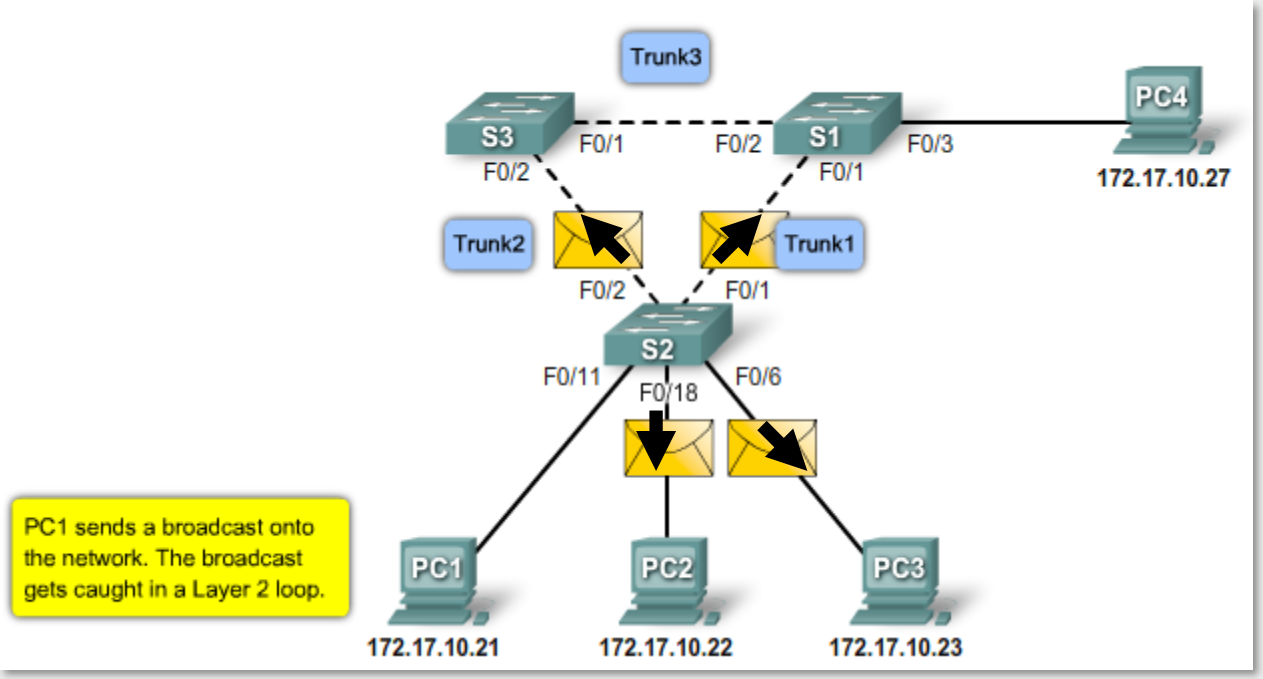
Issues with redundancy

- Broadcast storms



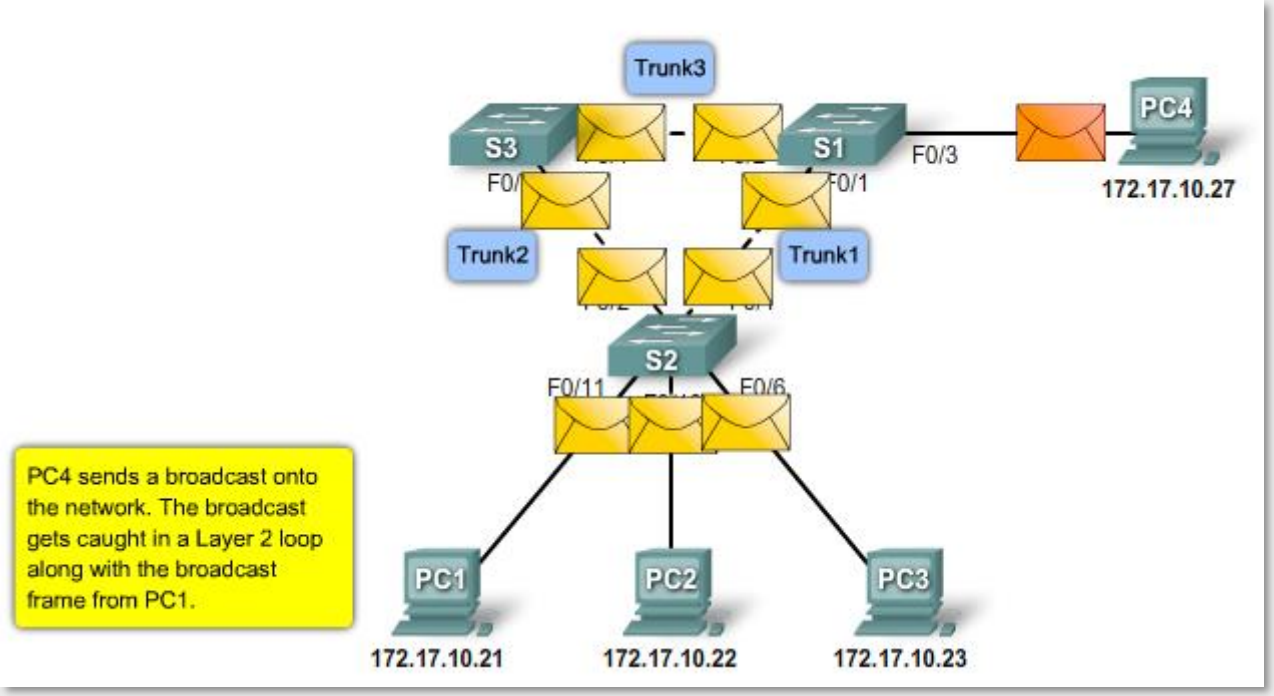
Issues with redundancy

- Broadcast storms



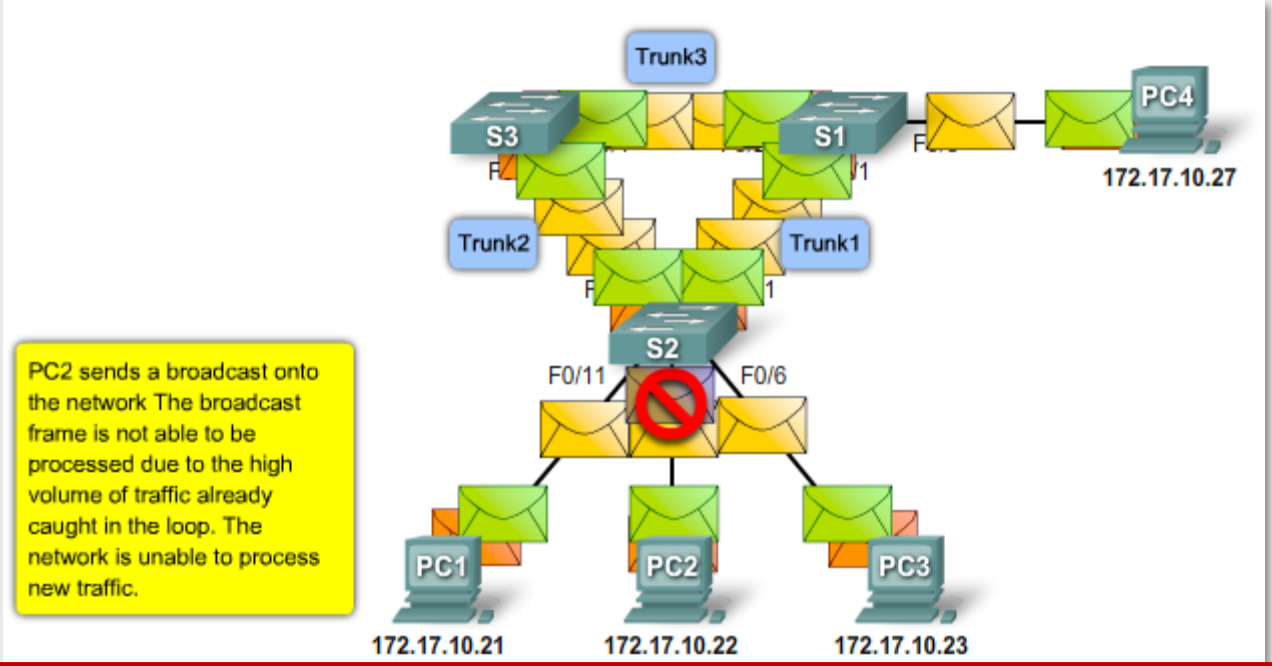
Issues with redundancy

- Broadcast storms



Issues with redundancy

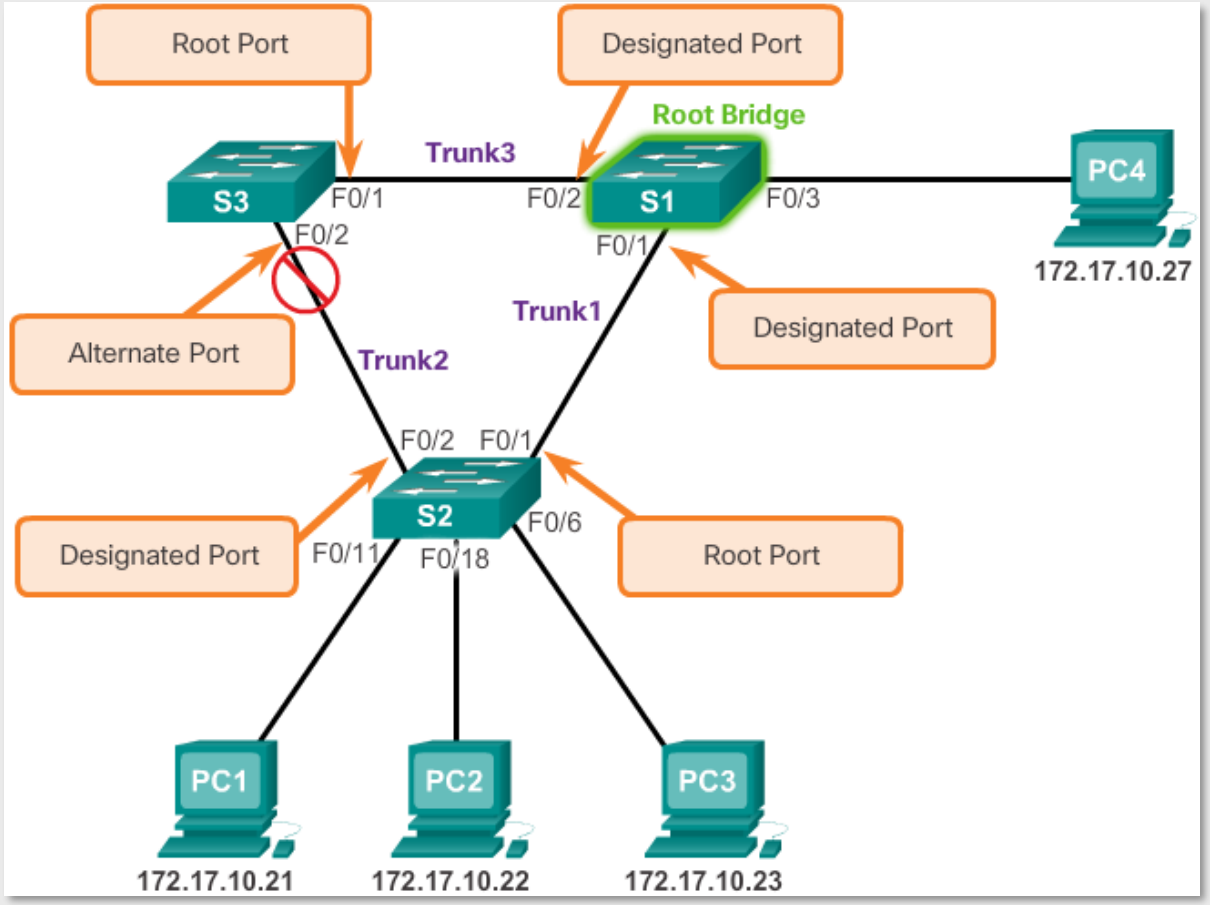
- Broadcast storms



The Spanning Tree Protocol (STP) addresses loop issues, ensuring that **there is only one logical path between all destinations on the network** by intentionally blocking redundant paths that could cause a loop

Spanning Tree Protocol

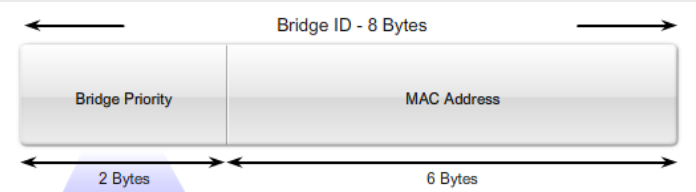
- Basic concept: block frame forwarding over selected ports to avoid loops
- Fully distributed protocol, goes through three phases
  - Root bridge election
  - Root port selection
  - Designated port selection



Bridge Protocol Data Unit (BPDU)

Configuration BPDU

Field #	Bytes	Field
1-4	2	Protocol ID
	1	Version
	1	Message type
	1	Flags
5-8	8	Root ID
	4	Cost of path
	8	Bridge ID
	2	Port ID
9-12	2	Message age
	2	Max age
	2	Hello time
	2	Forward delay



- **Flags**
  - TC: Topology Change
  - TCA: Topology Change Acknowledgement
- **Root ID**: the identifier of the (candidate) root bridge
- **Bridge ID**: the identifier of the bridge transmitting the BPDU
- **Root path cost**: cost of the path to the root bridge from the bridge sending the BPDU
- **Port ID**: the identifier of the port through which the BPDU is sent by the bridge
- **Message age**: time elapsed since the root sent the first configuration BPDU
- **Max age**: max time of validity, after which the STP process must be restarted
- **Hello time**: time period between two root bridge configuration BPDUs
- **Forward delay**: controls port state transitions (more later on)

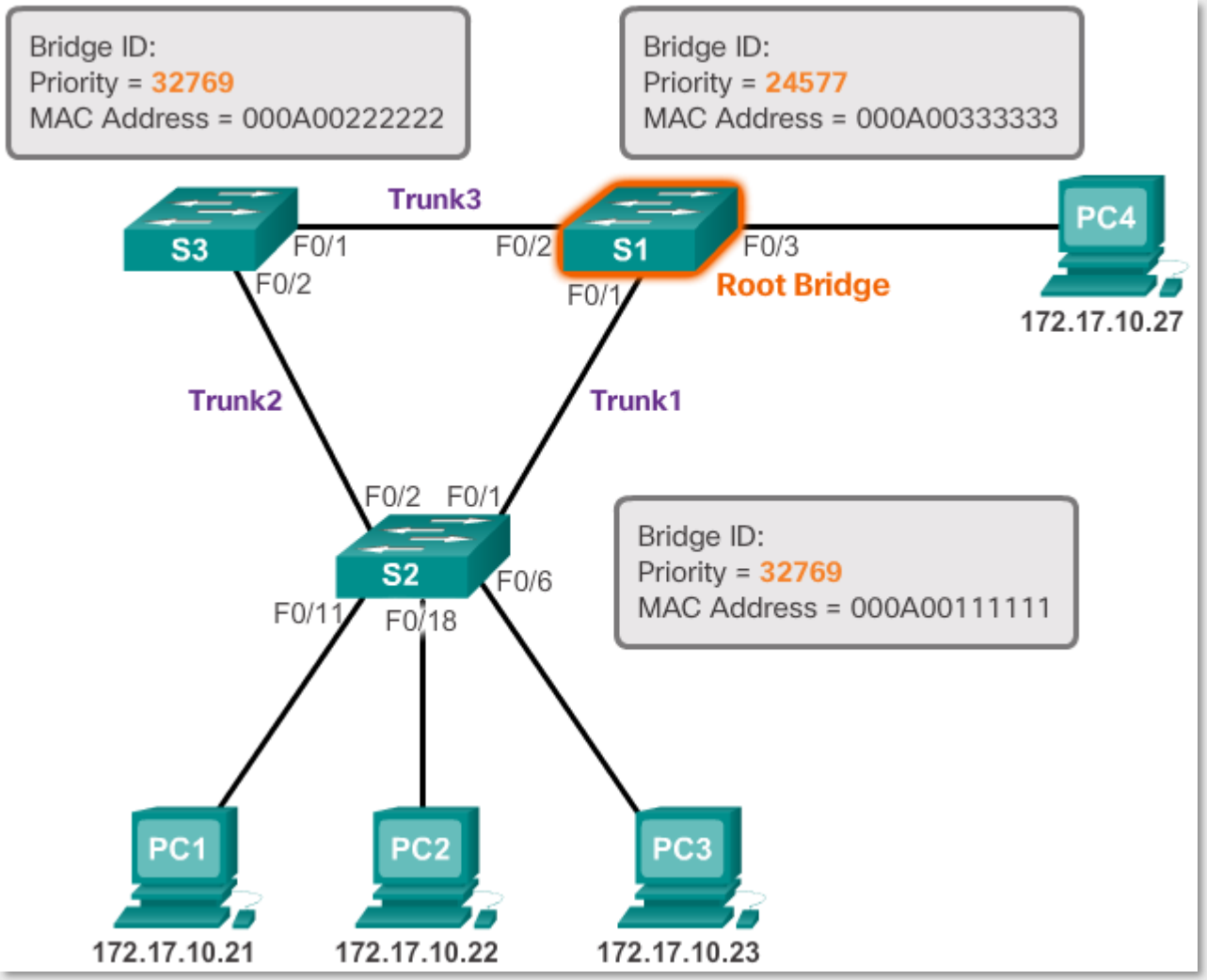
Root bridge election

- Each switch assumes to be the root bridge, and advertises its Bridge ID as the Root ID in BPDUs sent periodically (2s default) over all ports

- If the switch receives a BPDU with a **lower** Root ID
  - the root ID field is updated on the switch
  - the Root path cost is updated by adding the Path cost associated to the ingress port (more on this later on)
  - the new root ID and path cost are advertised in all future BPDU frame transmissions

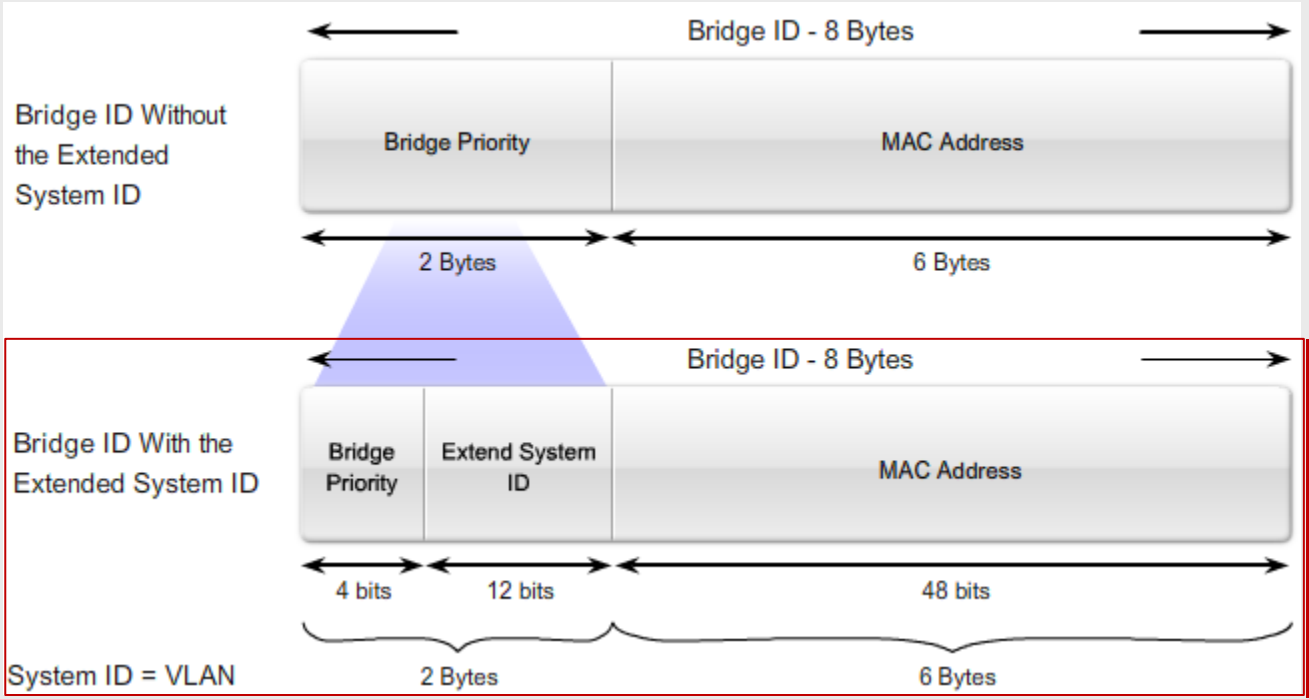
- After some time, there will be only one switch generating configuration BPDUs with Root ID equal to the switch Bridge ID
  - the root is elected

Root bridge election – example



Bridge ID

- Bridge ID definition



Multiple STP instances (one per VLAN)

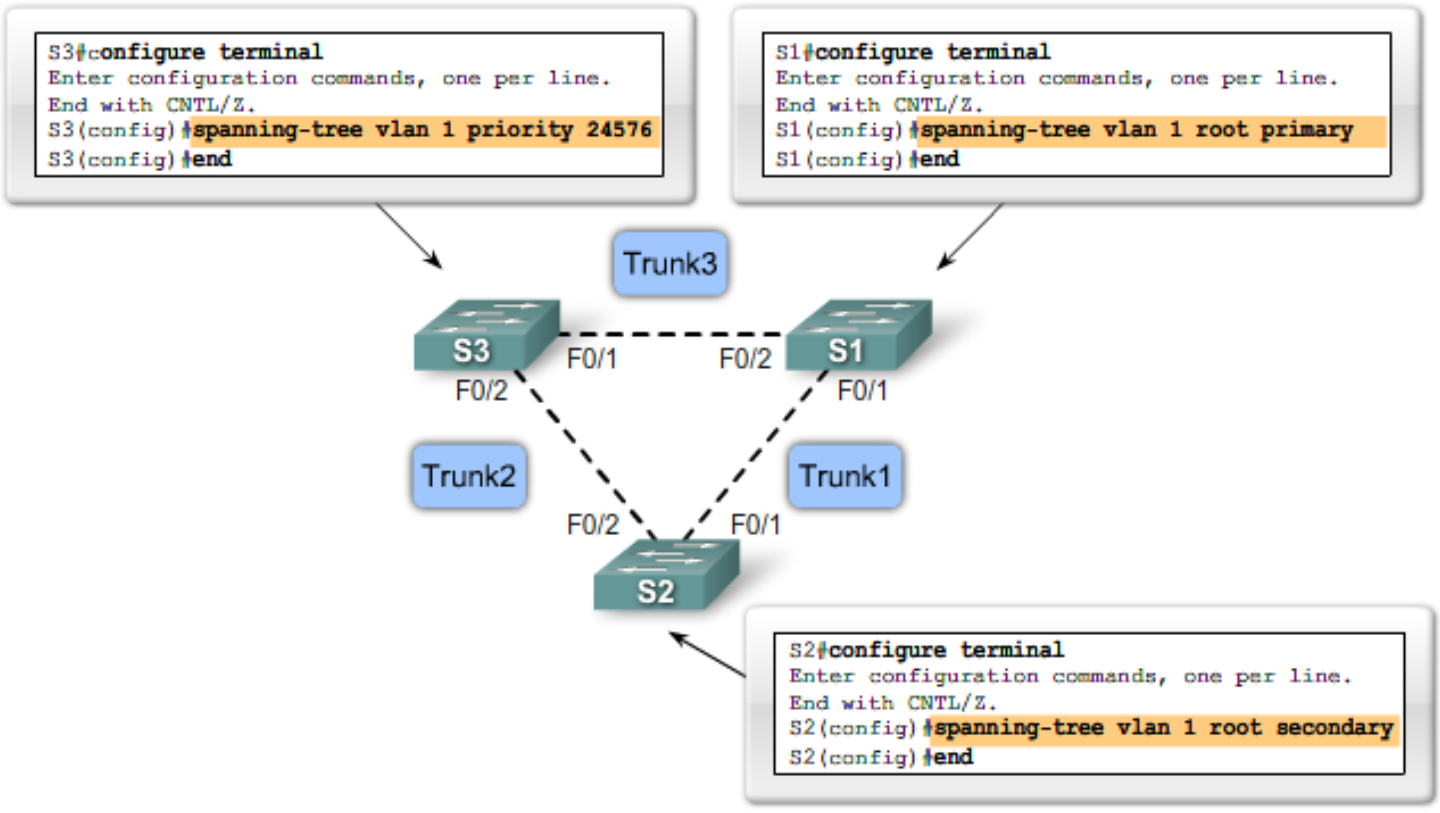
This format is Cisco specific

- Bridge priority default value: 32768
  - Increment or decrement by multiple values of 4096 (recommended practice)

Bridge ID

- Configure the priority

```
Sw1(config)#spanning-tree vlan vlan-id priority value
Sw1(config)#spanning-tree vlan vlan-id root primary
Sw1(config)#spanning-tree vlan vlan-id root secondary
```



Bridge ID

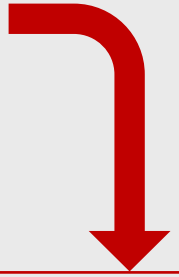
- Verify configuration

```
S1#show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     000A.0033.3333
              This bridge is the root
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    24577  (priority 24576 sys-id-ext 1)
              Address     000A.0033.3333
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/1            Desg FWD 4         128.1    P2p
Fa0/2            Desg FWD 4         128.2    P2p
S1#
```

Root port selection

- The root port is the switch port with the **lowest path cost** to the root bridge
  - Every switch has a single root port defined, except for the root bridge

- Root path cost associated to a port **=** Root path cost included in the received BPDU **+** path cost associated to the port
- Tie break rules
  - Received BPDU includes the lowest Bridge ID
  - Received BPDU includes the lowest Port ID
  - Port ID associated to the port



- This step is executed concurrently with root bridge election!
  - Path costs are updated during BPDU exchange
  - Root port is determined accordingly
  - Root port may change multiple times before STP converges

Path cost

- Default port costs are defined by the port speed

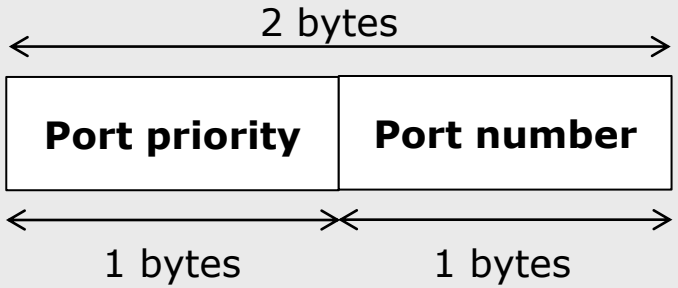
Link Speed	Cost (Revised IEEE Specification)
10 Gb/s	2
1 Gb/s	4
100 Mb/s	19
10 Mb/s	100

- Port cost may be reconfigured to control the spanning tree formation

```
S2#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
S2(config)#interface f0/1
S2(config-if)#spanning-tree cost 25
S2(config-if)#end
S2#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
S2(config)#interface f0/1
S2(config-if)#no spanning-tree cost
S2(config-if)#end
S2#
```

Port ID

- Port ID definition

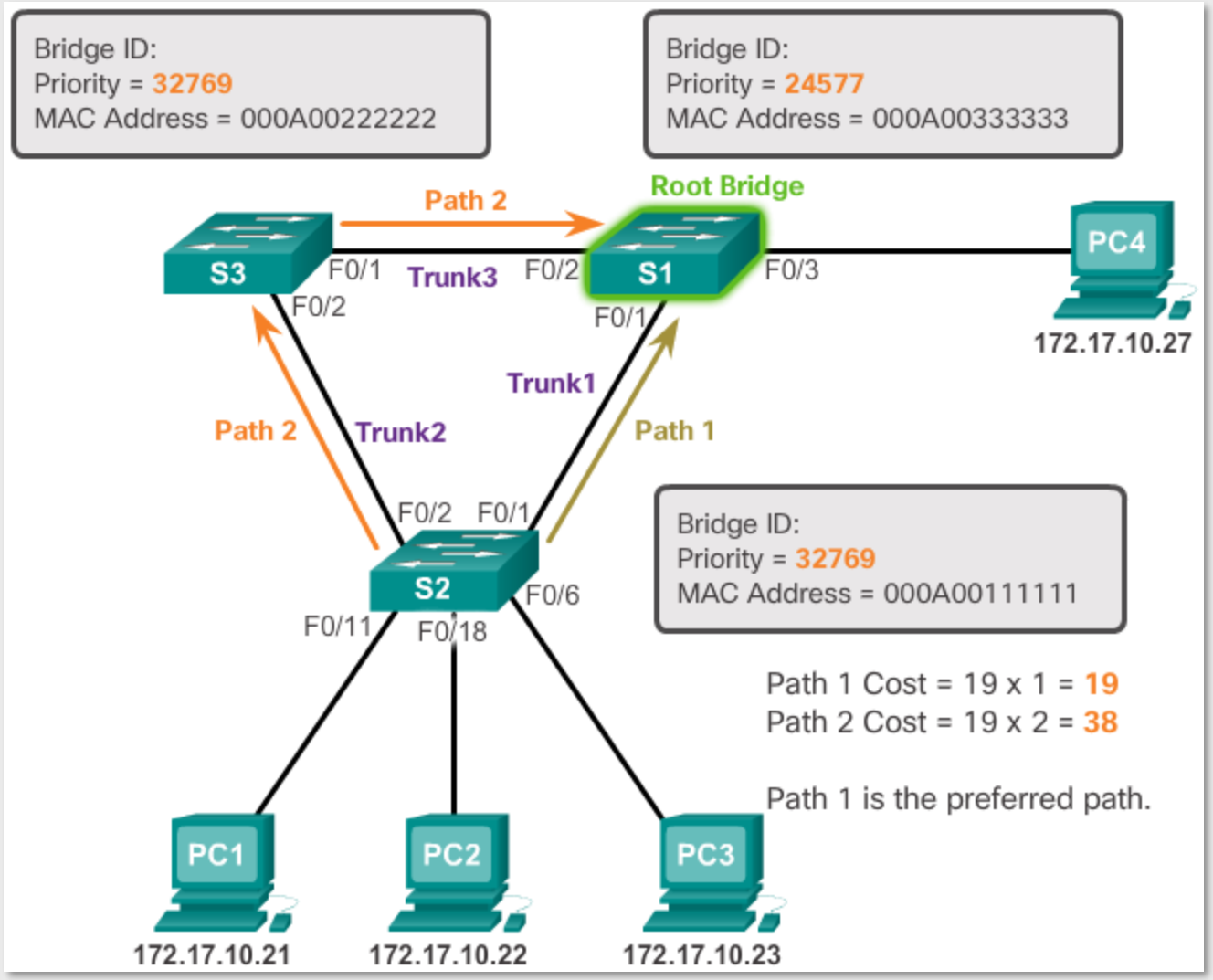


- Port priority default value: 128
  - Increment or decrement by multiple values of 16 (recommended)

- Configure priority

```
S2#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
S2(config)#interface f0/1
S2(config-if)#spanning-tree port-priority 112
S2(config-if)#end
S2#
```

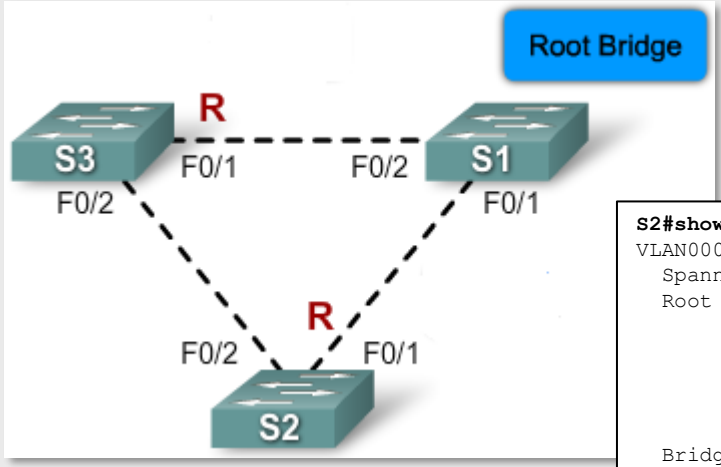
Root port selection



Root port selection

```
S3#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     000A.0033.3333
              Cost        19
              Port        1(FastEthernet0/1)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     000A.0022.2222
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------
Fa0/1            Root FWD 19        128.1    P2p
Fa0/2            Altn BLK 19        128.2    P2p
```

```
S1#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     000A.0033.3333
              This bridge is the root
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    24577  (priority 24576 sys-id-ext 1)
              Address     000A.0033.3333
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time 20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/2            Desg FWD 19        128.2    P2p
Fa0/1            Desg FWD 19        128.1    P2p
```




```
S2#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     000A.0033.3333
              Cost        19
              Port        1(FastEthernet0/1)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     000A.0011.1111
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/1            Root FWD 19        128.1    P2p
Fa0/2            Desg FWD 19        128.2    P2p
```

Designated port selection

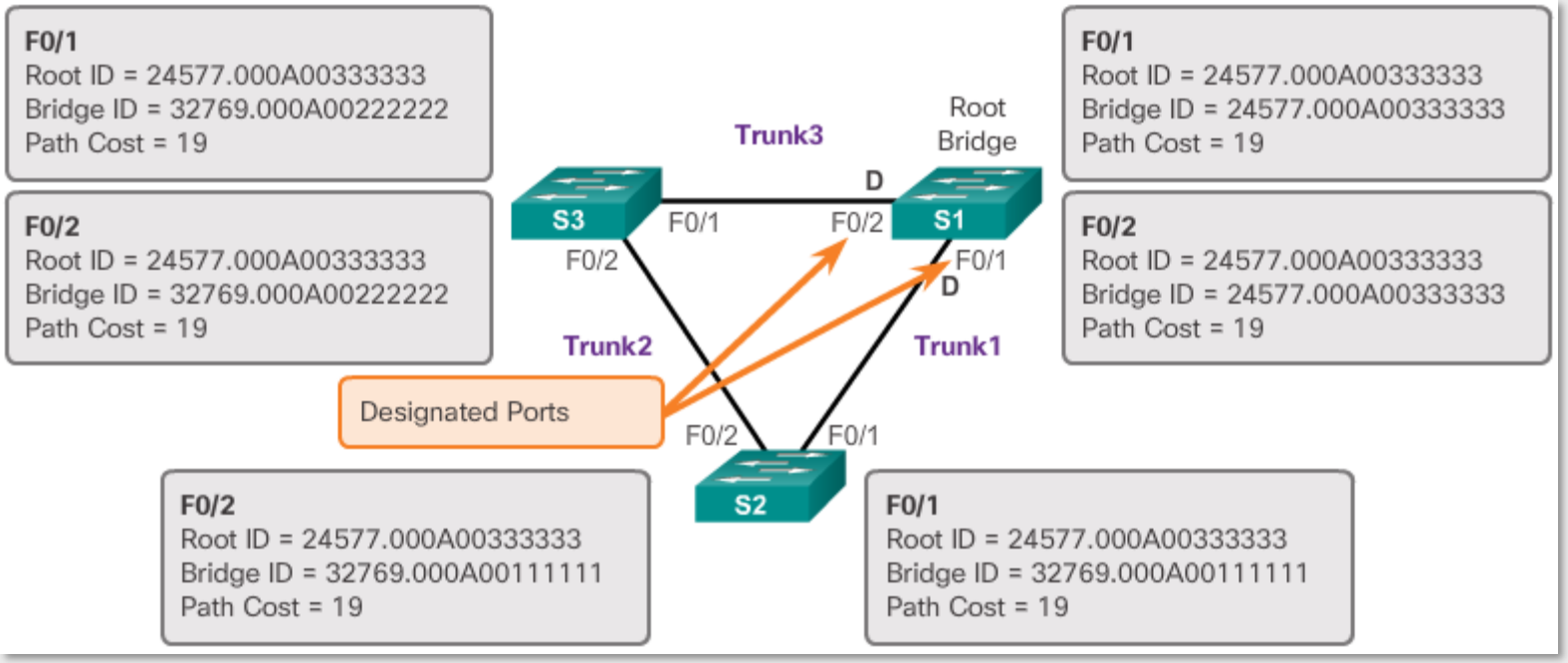
- The root bridge configures all of its ports as designated

- If a switch does not receive BPDUs on a given non-root port, the port is configured as designated (i.e., forwarding)
- If a switch receives BPDUs on a given non-root port, a competition for port designation must occur
  - Only one non-root port shall be designated, i.e., forwarding, on a given LAN segment, otherwise a loop occurs

- Competition is won by the switch port through which the BPDU with the highest priority is transmitted
  - **Lowest** tuple <root path cost, bridge ID, Port ID>
- The winning switch port is configured as designated
- All other ports are configured as alternate ports, i.e., in a blocking state

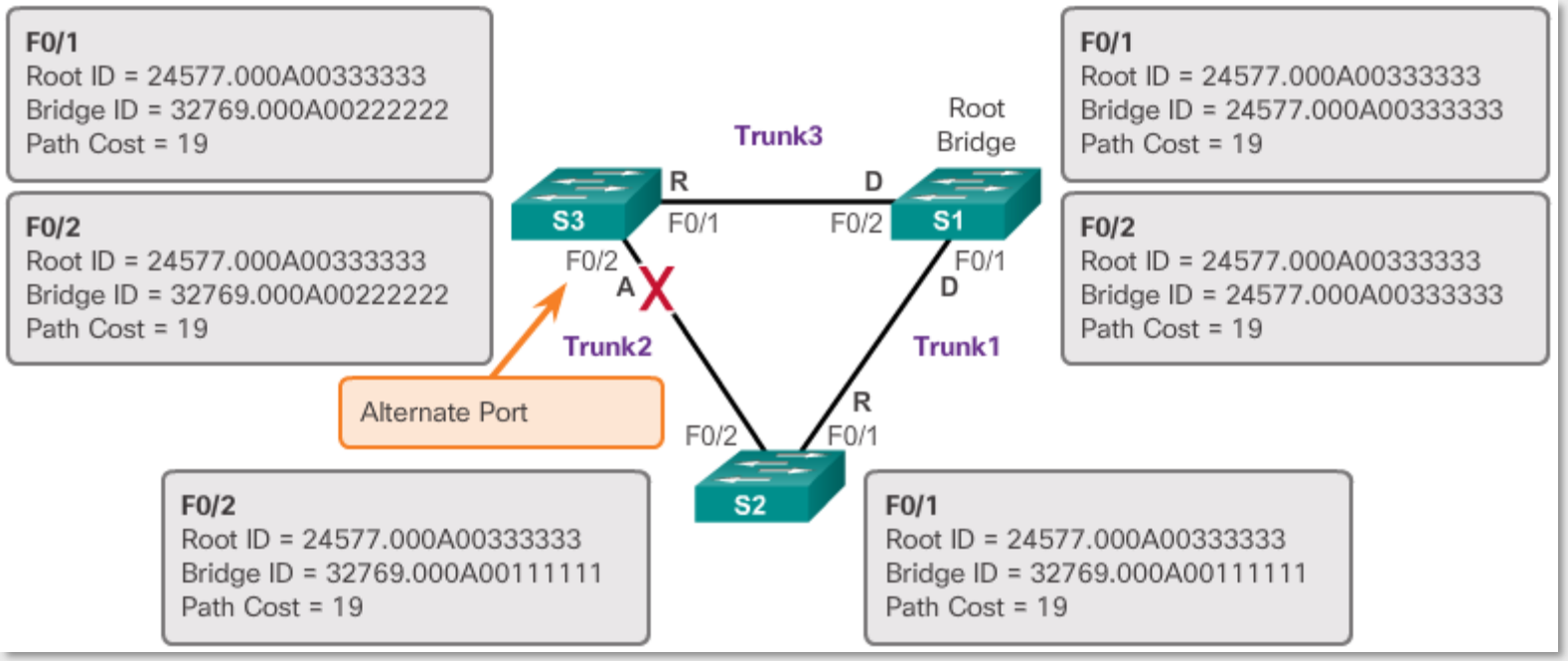
Designated port selection

- S1 (root bridge) configures both of its trunk ports as designated ports



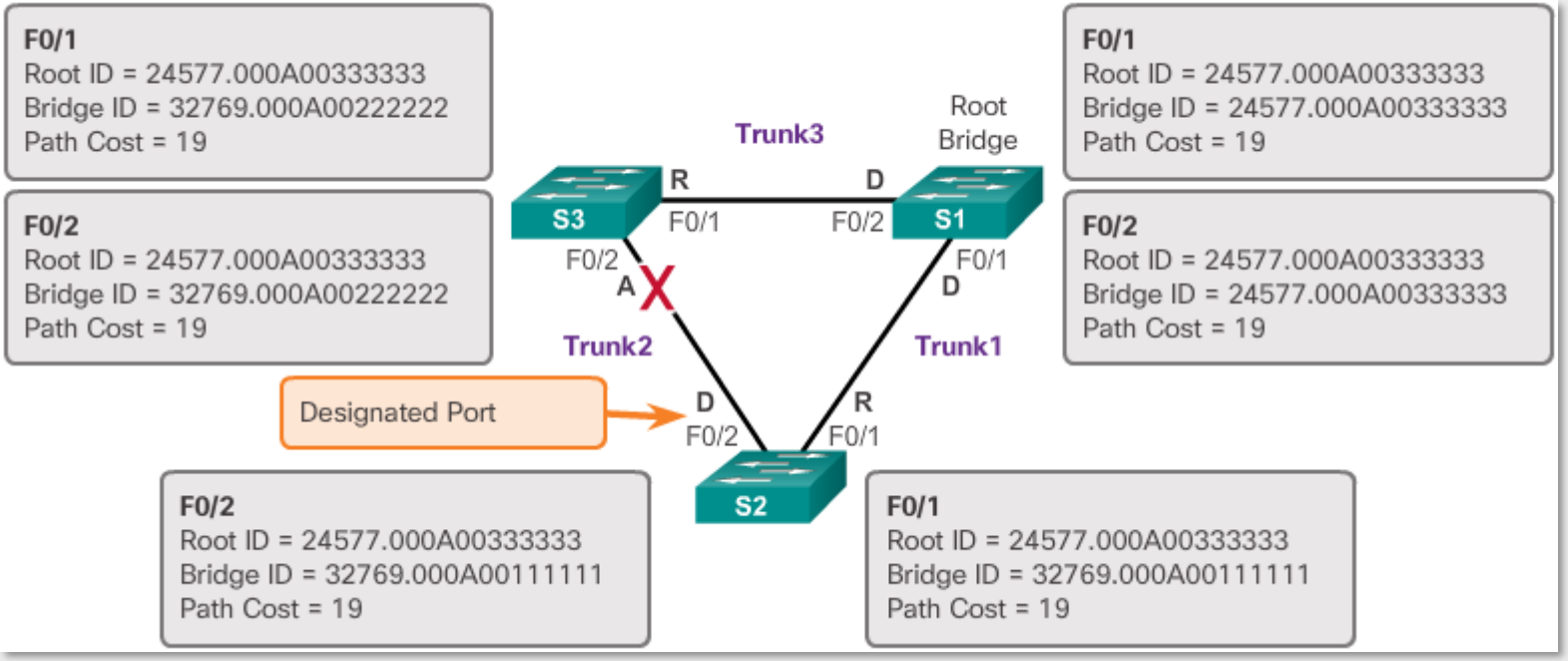
Designated port selection

- S2 and S3 exchange BPDU frames. S3 identifies S2 as having the same root path cost but a lower Bridge ID. S3 configures port F0/2 as an alternate port.



Designated port selection

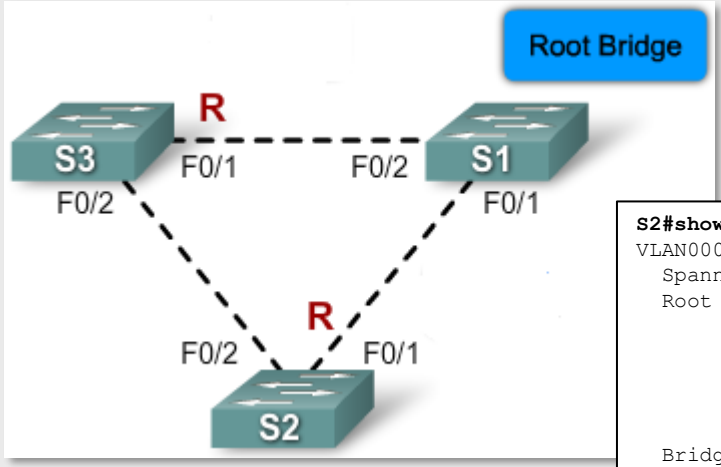
- S2 configures port F0/2 as a designated port.



Designated port selection

```
S3#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     000A.0033.3333
              Cost        19
              Port        1(FastEthernet0/1)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     000A.0022.2222
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------
Fa0/1            Root FWD 19        128.1    P2p
Fa0/2            Altn BLK 19        128.2    P2p
```

```
S1#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     000A.0033.3333
              This bridge is the root
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    24577  (priority 24576 sys-id-ext 1)
              Address     000A.0033.3333
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time 20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/2            Desg FWD 19        128.2    P2p
Fa0/1            Desg FWD 19        128.1    P2p
```




```
S2#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     000A.0033.3333
              Cost        19
              Port        1(FastEthernet0/1)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     000A.0011.1111
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/1            Root FWD 19        128.1    P2p
Fa0/2            Desg FWD 19        128.2    P2p
```

RSTP and other STP variants

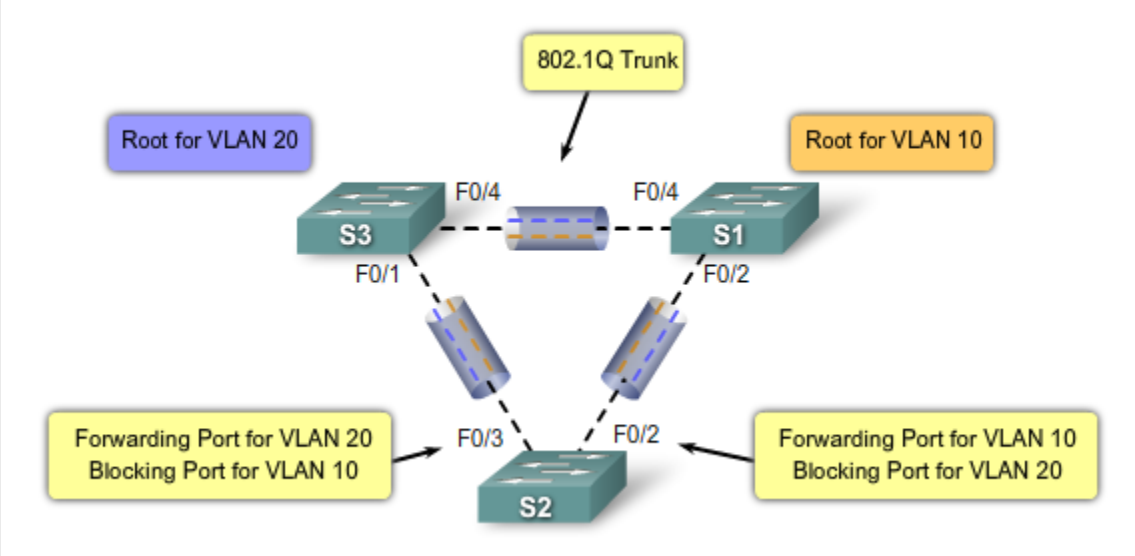
- Rapid Spanning Tree Protocol
  - Faster convergence: respond to changes within 3 × Hello times (default: 3 times 2 seconds) or within a few hundred milliseconds of a physical link failure
  - Requires additional assumptions
    - All switches run RSTP
    - Only p2p connections between switches
  - Originally std IEEE 802.1w, is now incorporated into std IEEE 802.1D-2004 and obsoletes the original STP!

- Multiple STP
  - "Per-VLAN" Multiple Spanning Tree Protocol
    - configures a separate Spanning Tree for each VLAN group
  - Originally std IEEE 802.1s, now incorporated into std IEEE 802.1Q-2005

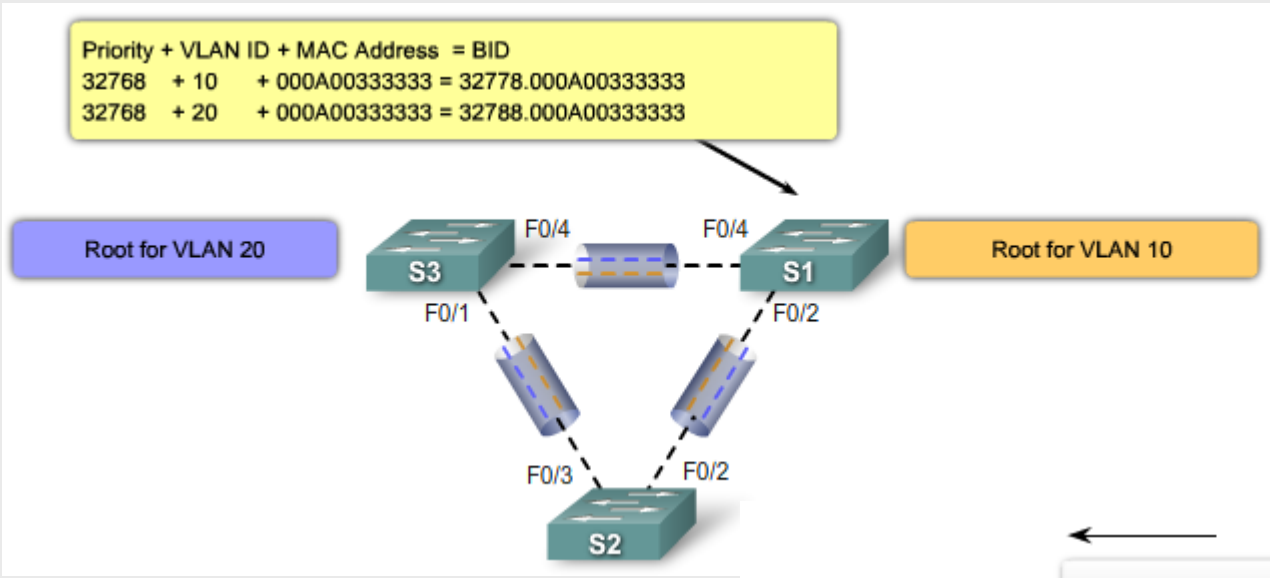
RSTP and other STP variants

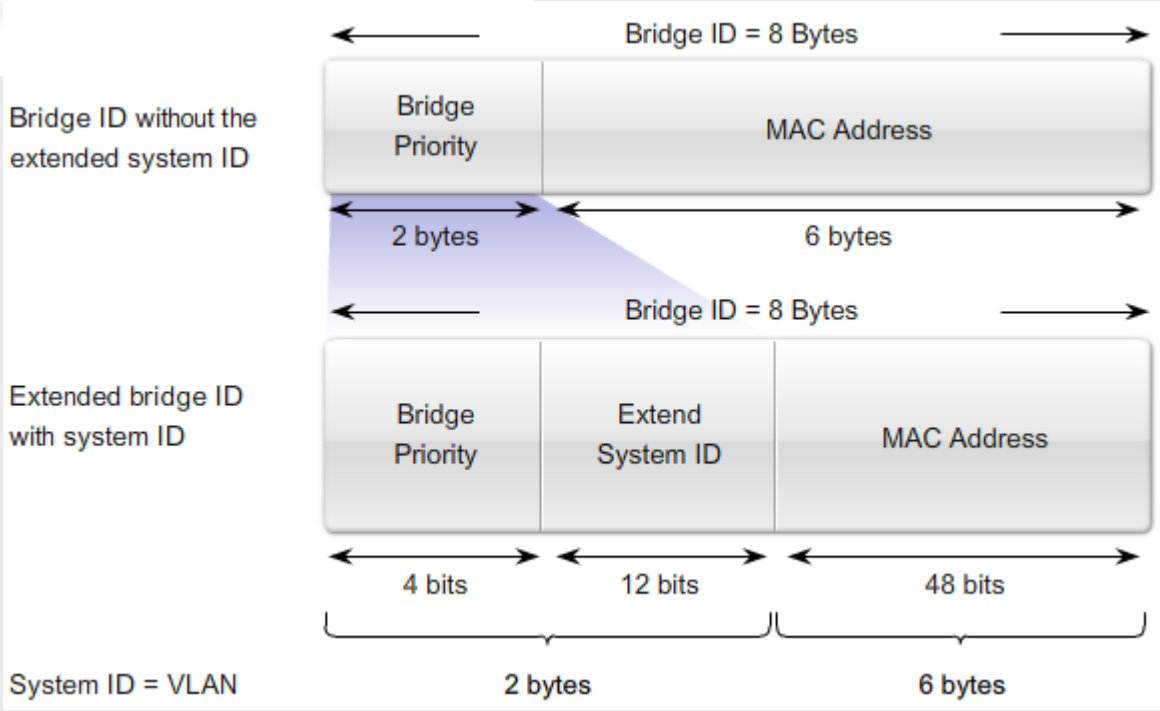
- Cisco proprietary STP variants
  - Per-VLAN STP (PVST), PVST+, Rapid-PVSTP+

- Per-VLAN spanning tree protocol plus (PVST+)
  - Provides support for IEEE 802.1Q trunking
  - Dedicated STP instance per VLAN
    - Allows for fine tuning of bandwidth resources



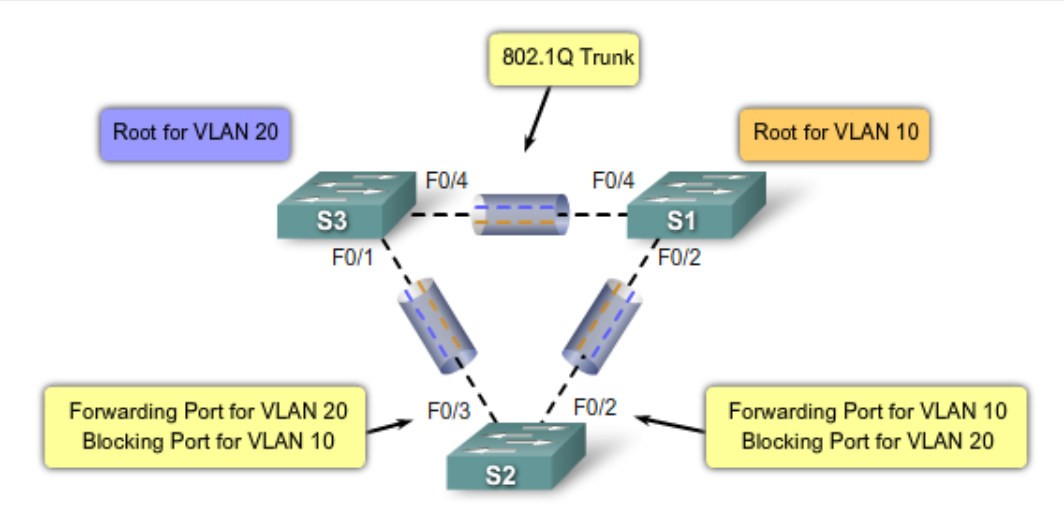
PVST+ Bridge ID





PVST+ configuration

```
S3(config)#spanning-tree vlan 20 root primary
S3(config)#spanning-tree vlan 10 root secondary

S1(config)#spanning-tree vlan 10 root primary
S1(config)#spanning-tree vlan 20 root secondary
```



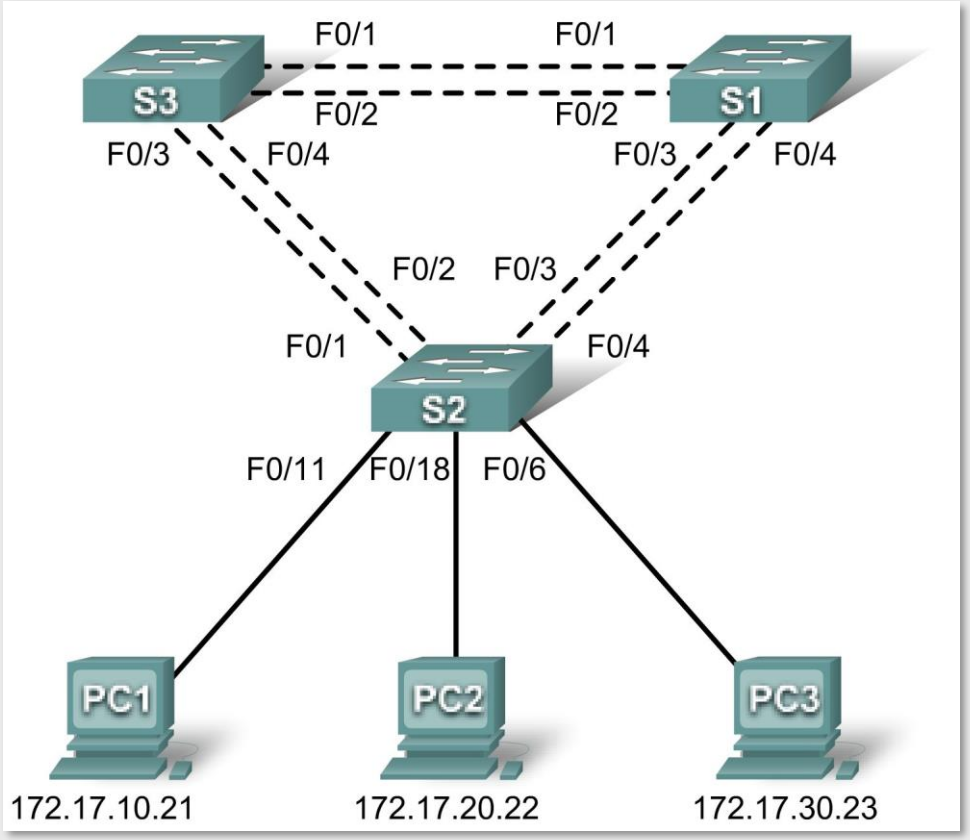

```
S1#show spanning-tree active
<output omitted>
VLAN0010
  Spanning tree enabled protocol ieee
  Root ID     Priority    4106
              Address     0019.aa9e.b000
              This bridge is the root
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID   Priority    4106   (priority 4096 sys-id-ext 10)
              Address     0019.aa9e.b000
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time 300
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/2            Desg FWD 19        128.2    P2p
Fa0/4            Desg FWD 19        128.4    P2p
<output omitted>
```

Catalyst 2960 default configuration

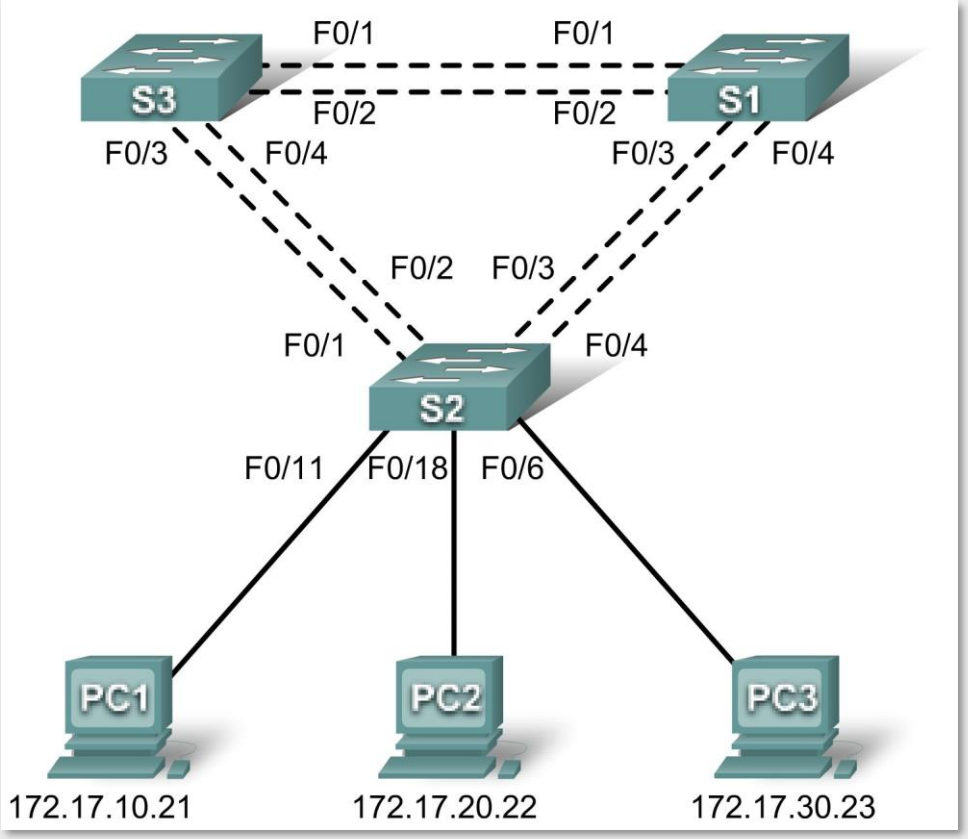
Feature	Default Setting
Enable state	Enabled on VLAN 1
Spanning-tree mode	PVST+ (Rapid PVST+ and MSTP are disabled.)
Switch priority	32768
Spanning-tree port priority (configurable on a per-interface basis)	128
Spanning-tree port cost (configurable on a per-interface basis)	1000 Mb/s: 4, 100 Mb/s: 19, 10 Mb/s: 100
Spanning-tree VLAN port priority (configurable on a per-VLAN basis)	128
Spanning-tree VLAN port cost (configurable on a per-VLAN basis)	1000 Mb/s: 4, 100 Mb/s: 19, 10 Mb/s: 100
Spanning-tree timers	Hello time: 2 seconds Forward-delay time: 15 seconds Maximum-aging time: 20 seconds Transmit hold count: 6 BPDUs

Lab activity

- Note: configure VLANs manually (instead of using VTP)



Lab activity



Lab activity

- Note: configure VLANs manually (instead of using VTP)