

# LAN Redundancy & Spanning Tree Protocol

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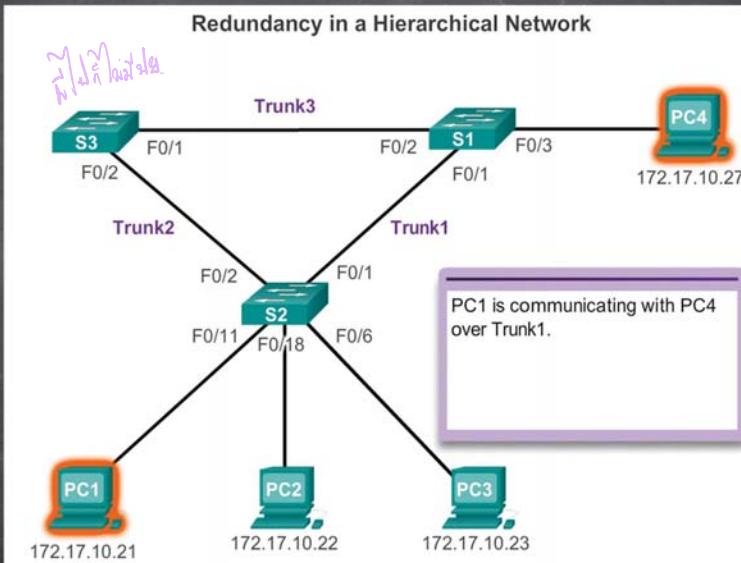
## • LAN Redundancy

- Redundancy at OSI Layer 1 and 2
- Issues with Layer 1 Redundancy
  - MAC Database Instability
  - Broadcast Storm
  - Multiple Frame Transmissions
- Spanning Tree Protocol

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2

## Redundancy at OSI Layer 1 and 2



## Issues with Layer 1 Redundancy

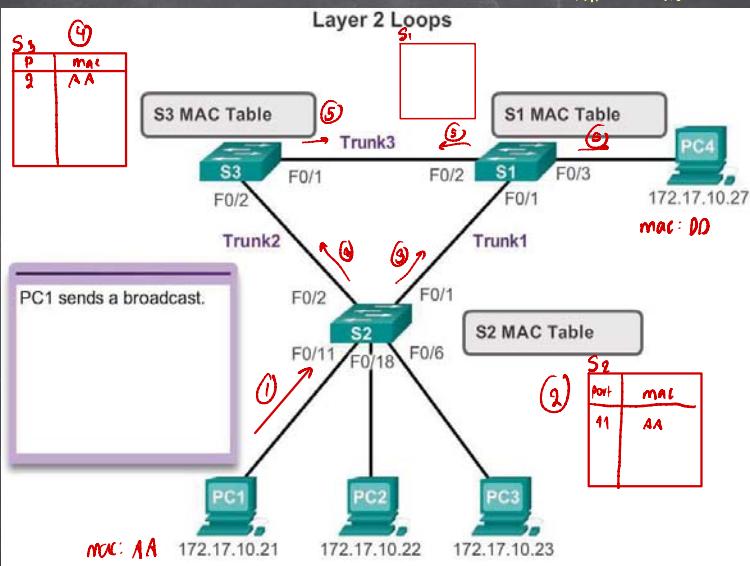
Jirasak

### Considerations When Implementing Redundancy:

- **MAC database instability** - Instability in the content of the MAC address table results from copies of the same frame being received on different ports of the switch. Data forwarding can be impaired when the switch consumes the resources that are coping with instability in the MAC address table.
- **Broadcast storms** - Without some loop-avoidance process, each switch may flood broadcasts endlessly. This situation is commonly called a broadcast storm.
- **Multiple frame transmission** - Multiple copies of unicast frames may be delivered to destination stations. Many protocols expect to receive only a single copy of each transmission. Multiple copies of the same frame can cause unrecoverable errors.

# MAC Database Instability

ໃນ flood ເພື່ອ ສະໜັບປາການ

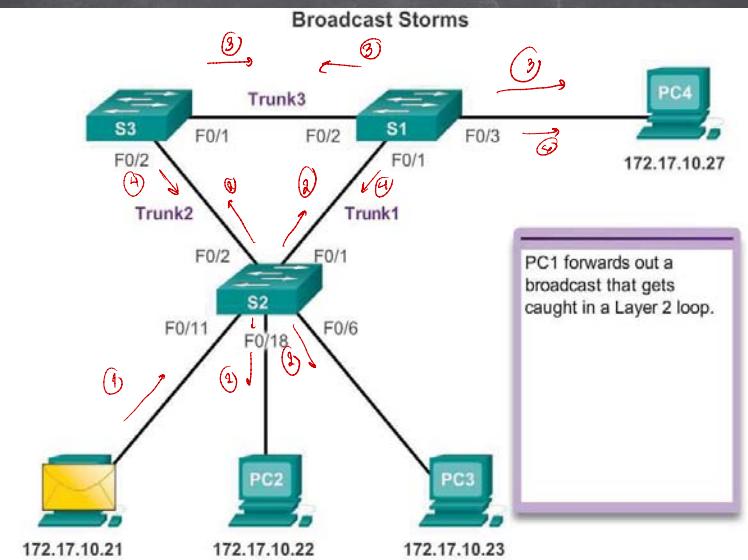


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5

# Broadcast Storm

Broadcast ມີຄວາມເຫັນຫຼາຍ, Broadcast ດັ່ງນັ້ນກ່າວມາດີ



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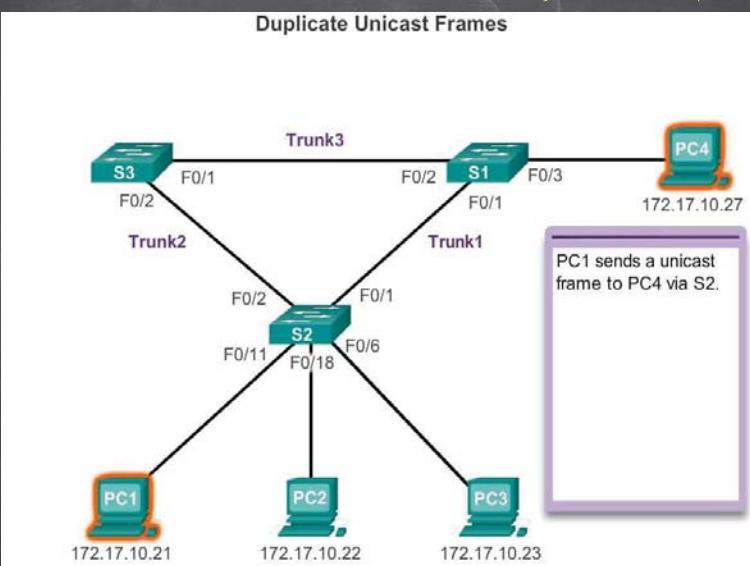
6

# Multiple Frame Transmissions

Dest ດ້ວຍເຫັນ frame ອີງຈາກ



Duplicate Unicast Frames



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7

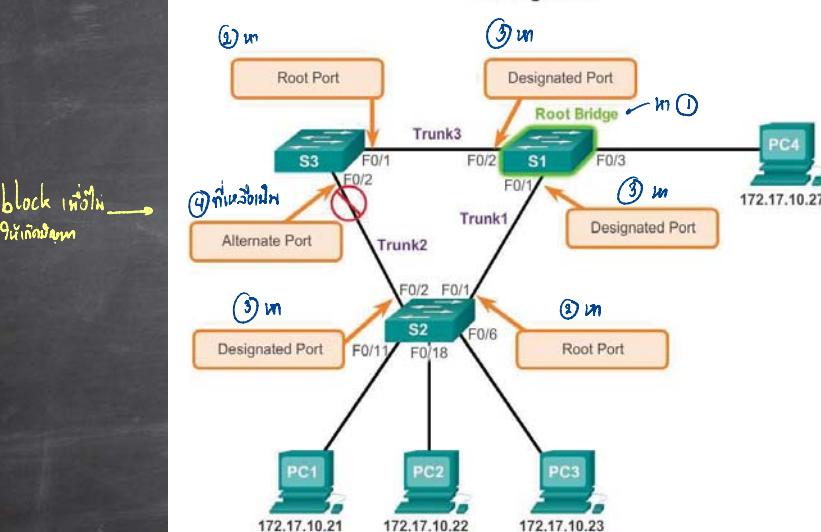
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# Spanning Tree Protocol

① : root Bridge / NW  
② : Root port / non-root Bridge  
③ : Designated port / segment



STP Algorithm



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8

# Spanning Tree Algorithm

- Introduction

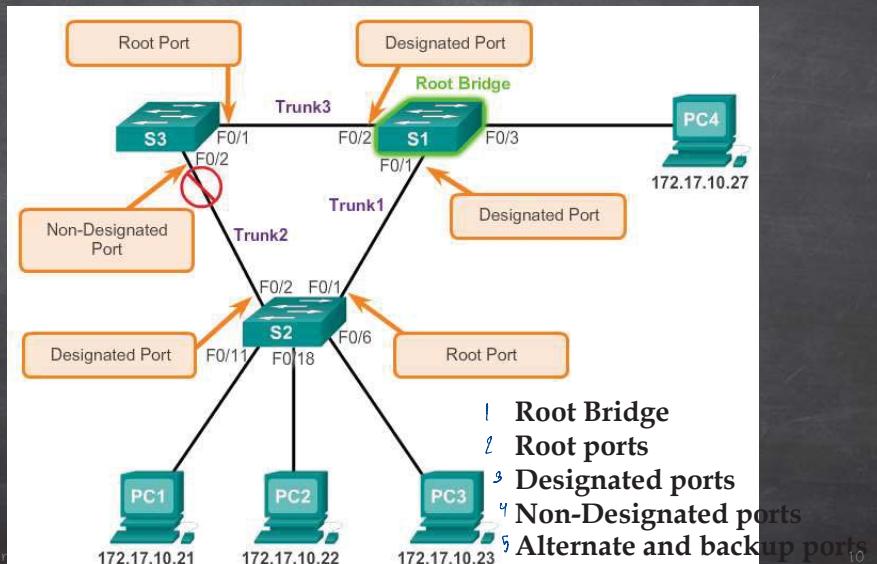
- STP ensures that there is only one logical path between all destinations on the network by intentionally blocking redundant paths that could cause a loop.
- A port is considered blocked when user data is prevented from entering or leaving that port. This does not include bridge protocol data unit (BPDU) frames that are used by STP to prevent loops. switch မျှတော်လုပ်နည်း
- The physical paths still exist to provide redundancy, but these paths are disabled to prevent the loops from occurring.
- If the path is ever needed to compensate for a network cable or switch failure, STP recalculates the paths and unblocks the necessary ports to allow the redundant path to become active.

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# វិនាមិនអ្នក ស្ថាប័នតាមលក្ខណៈ Spanning Tree Algorithm

- Port Roles



Switch មុនmac  
រួម mac នៃមែនុយនៅ S9 - Tree  
ដូចខាងក្រោម

# Spanning Tree Algorithm

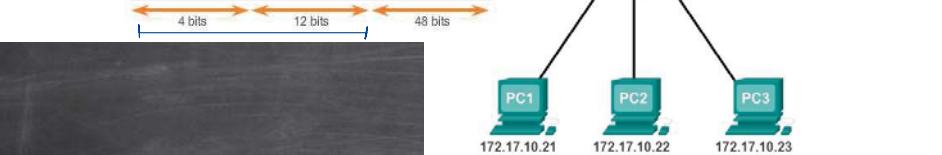
- STP Operation

### — Root Bridge

Bridge ID នឹងតុលេស : សារពីលេស # Bridge priority នៅ  
ទៅ Bridge ID នៅ

ក្នុង Br ID នឹង : ផ្លូវ mac

| Bridge ID with the Extended System ID |                    |             |
|---------------------------------------|--------------------|-------------|
| Bridge Priority                       | Extended System ID | MAC Address |
| 4 bits                                | 12 bits            | 48 bits     |



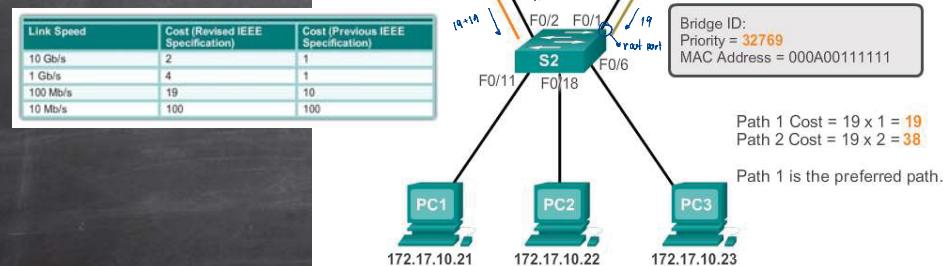
# Spanning Tree Algorithm

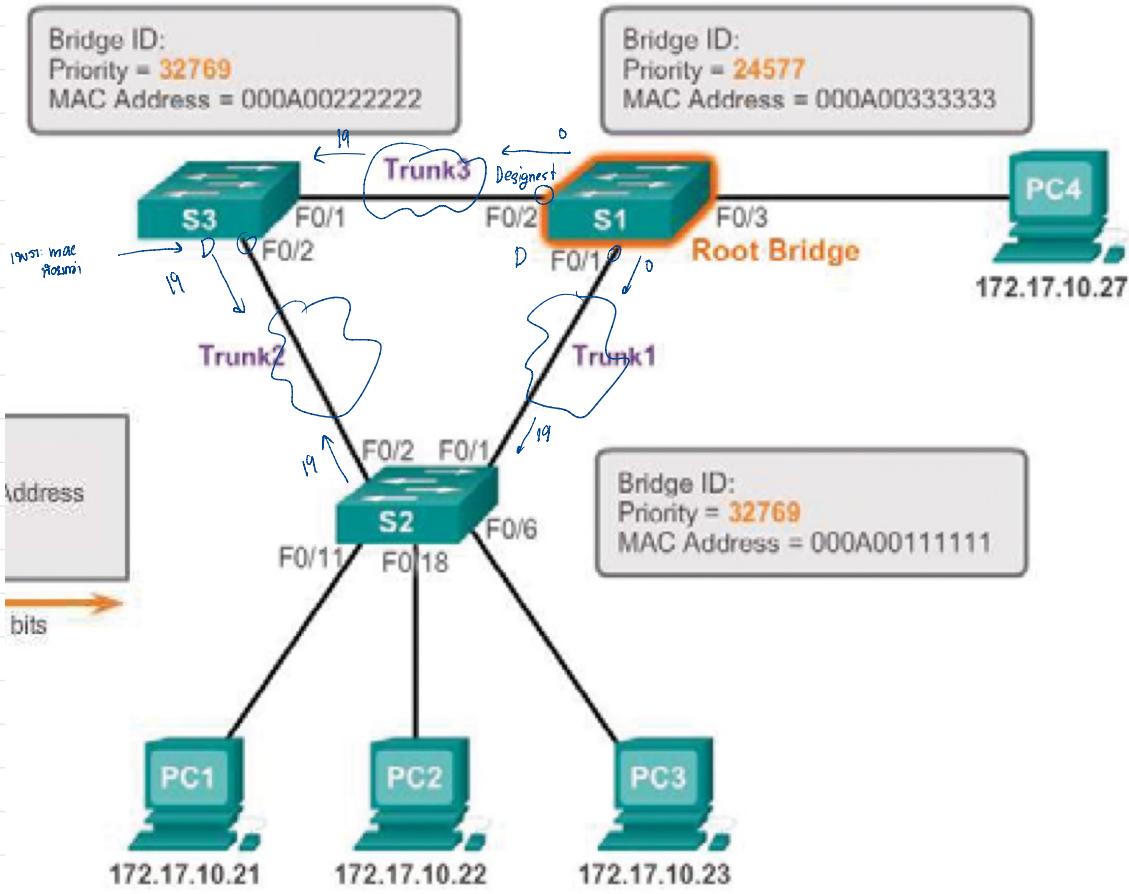
- STP Operation

### — Path Cost

ឯកសារផ្ទាល់លំនៅក្នុងការបង្កើតការពារ  
root port (ក្នុង non-root bridge) និង  
non root bridge នឹងការពារ (non-root bridge)

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

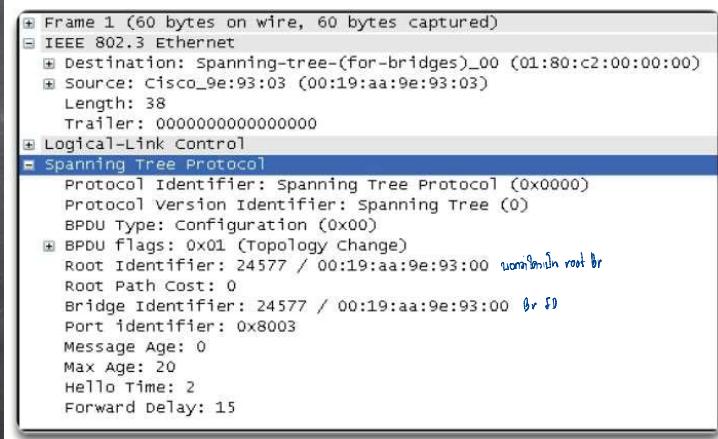




# Spanning Tree Algorithm

- STP Operation

- Path Cost : 802.1D BPDU Frame Format



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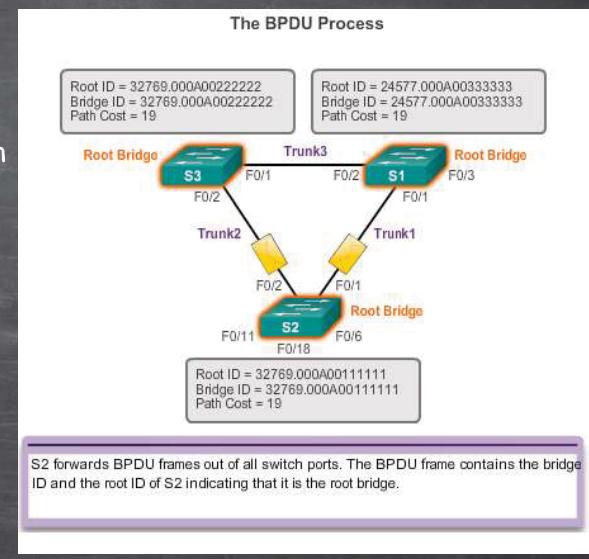
13

# Spanning Tree Algorithm

- STP Operation

- Path Cost

- BPDU Propagation and Process



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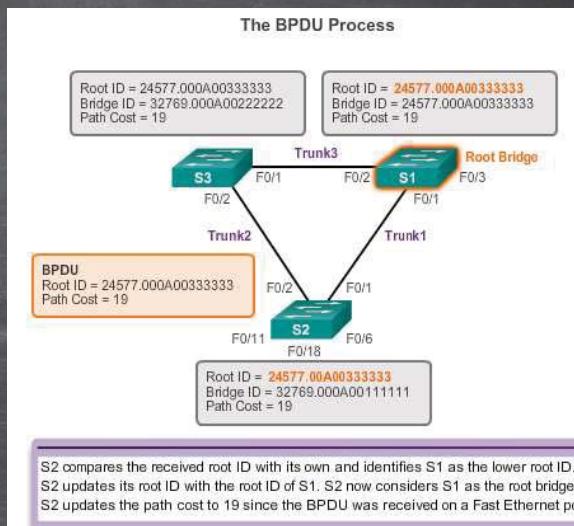
14

# Spanning Tree Algorithm

- STP Operation

- Path Cost

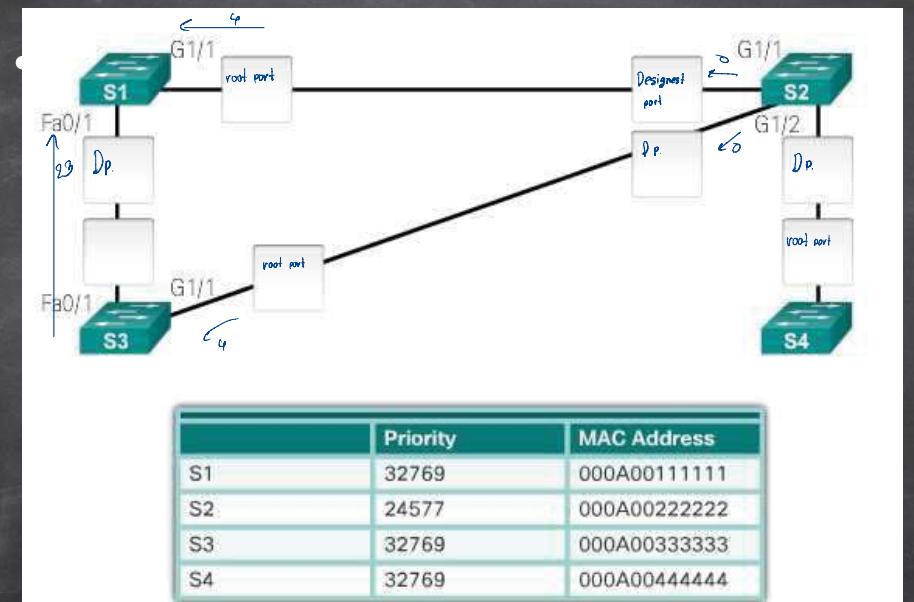
- BPDU Propagation and Process



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15

# Spanning Tree Algorithm

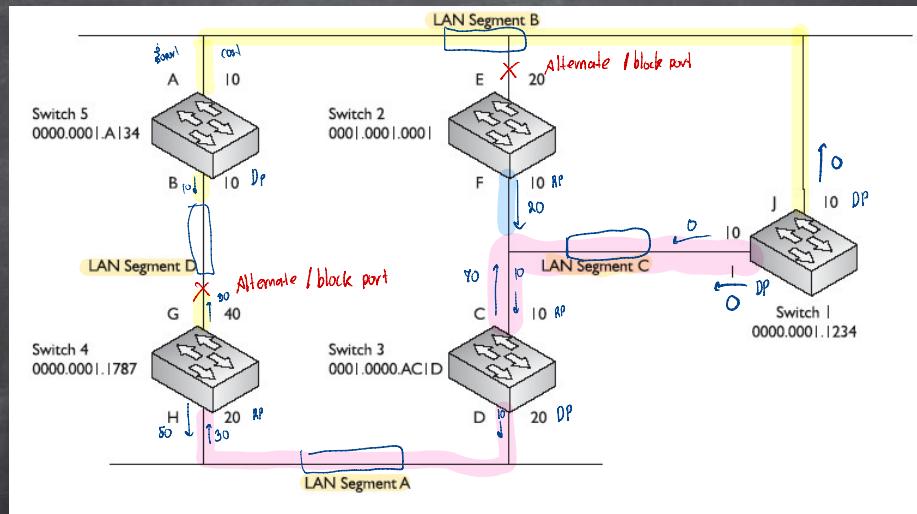


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16

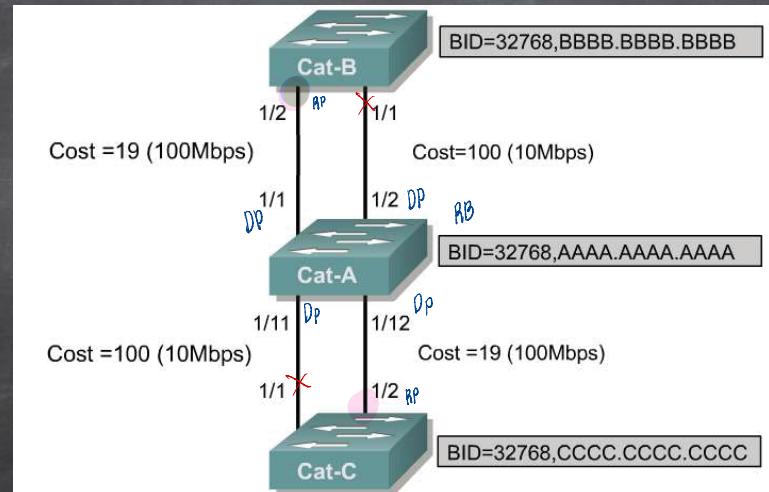
# Spanning Tree Algorithm

- STP Operation



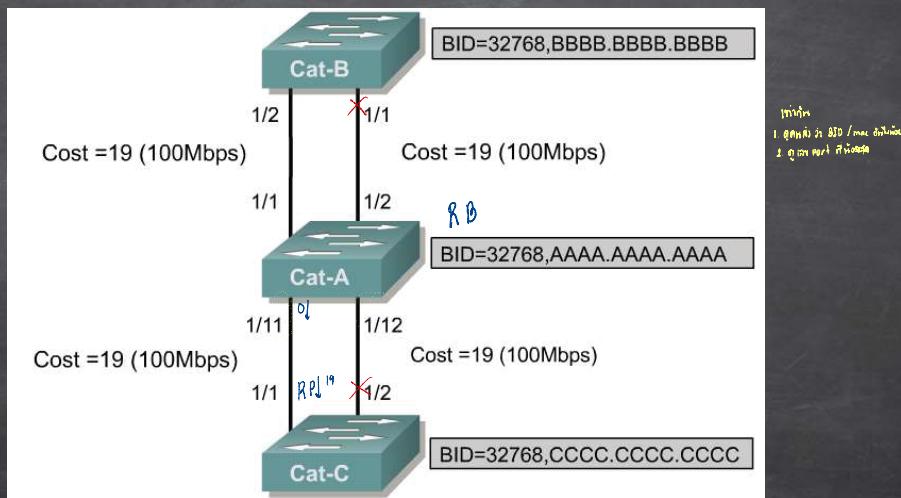
# Spanning Tree Algorithm

- STP Operation



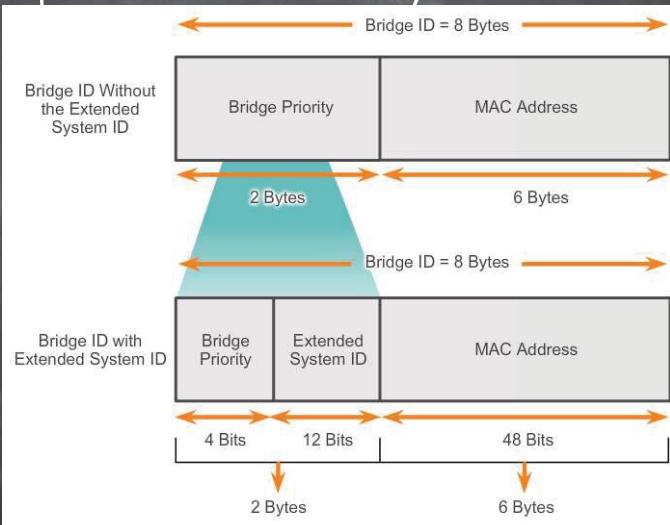
# Spanning Tree Algorithm

- STP Operation



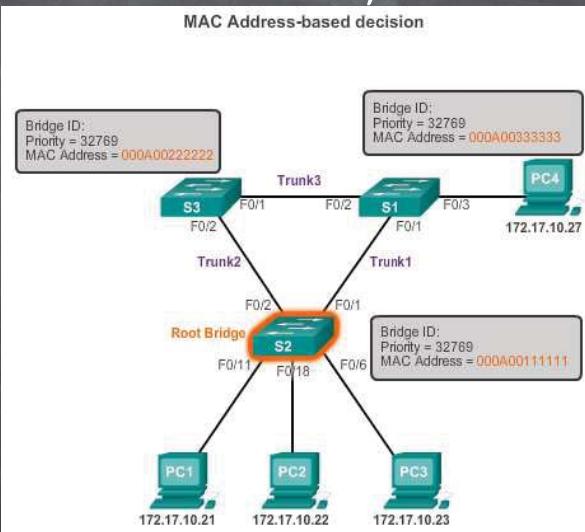
# Spanning Tree Algorithm

- STP Operation : Extended System ID



# Spanning Tree Algorithm

- STP Operation : Extended System ID



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21

# Varieties of Spanning Tree Protocols

- Characteristics of the Spanning Tree Protocols

| Protocol    | Standard     | Resources Needed | Convergence | Tree Calculation |
|-------------|--------------|------------------|-------------|------------------|
| STP         | 802.1D       | Low              | Slow        | All VLANs        |
| PVST+       | Cisco        | High             | Slow        | Per VLAN         |
| RSTP        | 802.1w       | Medium           | Fast        | All VLANs        |
| Rapid PVST+ | Cisco        | Very high        | Fast        | Per VLAN         |
| MSTP        | 802.1s Cisco | Medium or high   | Fast        | Per Instance     |

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22

## PVST+

- Overview of PVST+

— Networks running PVST+ have these characteristics:

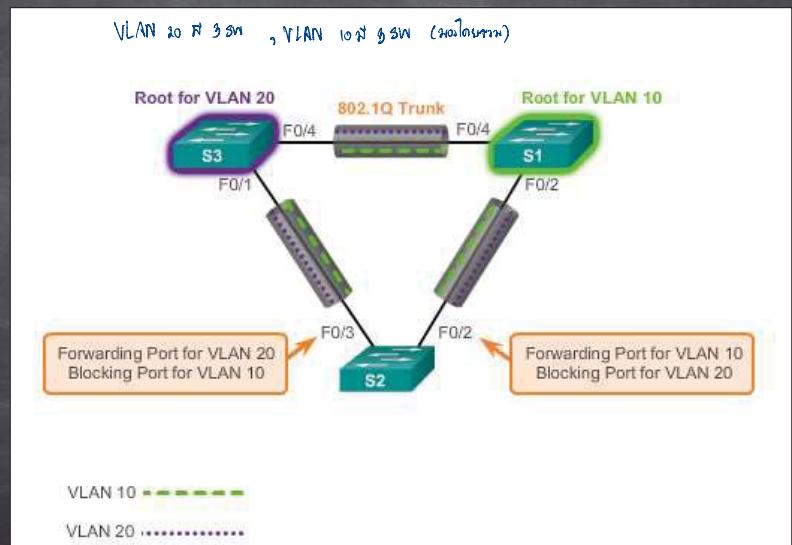
- A network can run an independent IEEE 802.1D STP instance for each VLAN in the network.
- Optimum load balancing can result.
- One spanning-tree instance for each VLAN maintained can mean a considerable waste of CPU cycles for all the switches in the network. In addition to the bandwidth that is used for each instance to send its own BPDU.

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23

## PVST+

- Overview of PVST+



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24

# PVST+

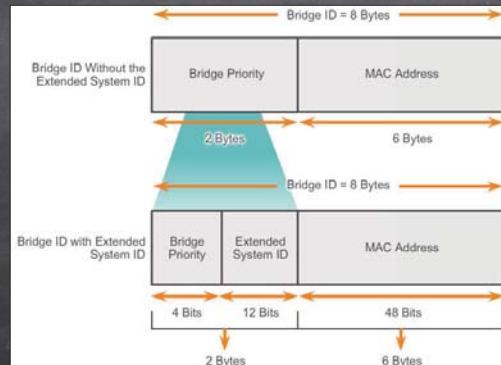
- Port States and PVST+ Operation

| Port States   |          |           |   |            |          |
|---|----------|-----------|---|------------|----------|
|   | LSN      | LAN       | Note: port in status of <i>status</i> of <i>status</i> of <i>status</i> |            |          |
| Processes   | Blocking | Listening | Learning  | Forwarding | Disabled |
| Processes received BPDUs                            | YES      | YES       | YES   | YES        | NO       |
| Forward data frames received on interface           | NO       | NO        | NO  | YES        | NO       |
| Forward data frames switched from another interface | NO       | NO        | NO  | YES        | NO       |
| Learn MAC addresses                                 | NO       | NO        | YES   | YES        | NO       |

# PVST+

- Extended System ID and PVST+ Operation

- In a PVST+ environment, the extended switch ID ensures each switch has a unique BID for each VLAN.
- For example, the VLAN 2 default BID would be 32770; priority 32768, plus the extended system ID of 2.



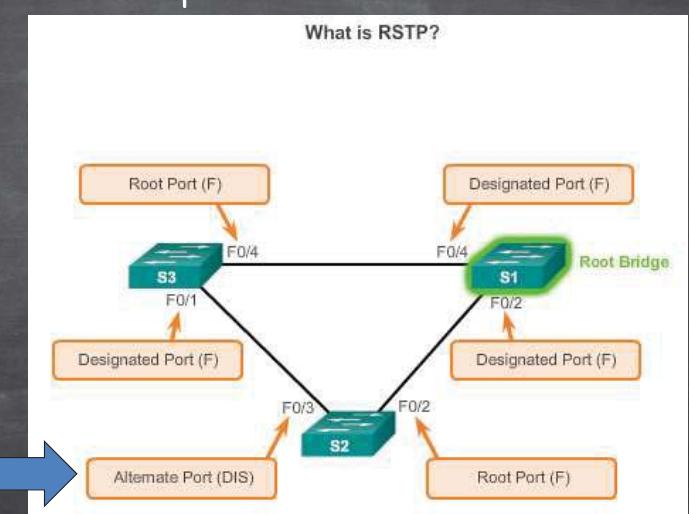
# Rapid PVST+

- Overview of Rapid PVST+

- RSTP is the preferred protocol for preventing Layer 2 loops in a switched network environment.
- With Rapid PVST+, an independent instance of RSTP runs for each VLAN.
- RSTP supports a new port type: an alternate port in discarding state.
- There are no blocking ports. RSTP defines port states as discarding, learning, or forwarding.
- RSTP (802.1w) supersedes STP (802.1D) while retaining backward compatibility
- RSTP keeps the same BPDU format as IEEE 802.1D, except that the version field is set to 2 to indicate RSTP, and the flags field uses all 8 bits.

# Rapid PVST+

- Overview of Rapid PVST+



# Rapid PVST+

- RSTP BPDU

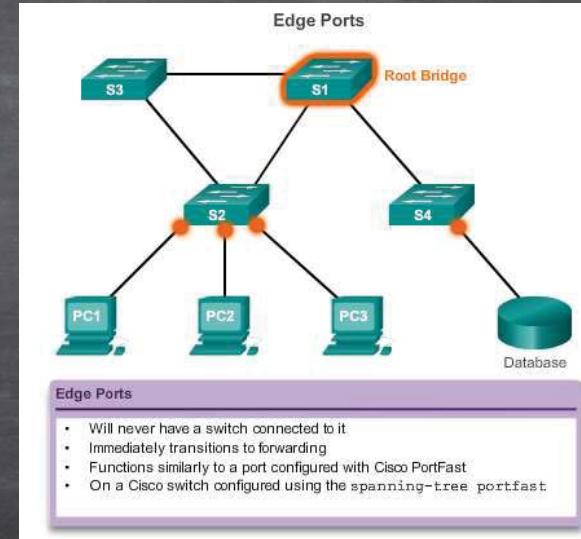
| RSTP Version 2 BPDU      |             |
|--------------------------|-------------|
| Field                    | Byte Length |
| Protocol ID=0x0000       | 2           |
| Protocol Version ID=0x02 | 1           |
| BPDU Type=0X02           | 1           |
| Flags                    | 1           |
| Root ID                  | 8           |
| Root Path Cost           | 4           |
| Bridge ID                | 8           |
| Port ID                  | 2           |
| Message Age              | 2           |
| Max Age                  | 2           |
| Hello Time               | 2           |
| Forward Delay            | 2           |

| Flag Field                     |     |
|--------------------------------|-----|
| Field Bit                      | Bit |
| Topology Change                | 0   |
| Proposal                       | 1   |
| Port Role                      | 2-3 |
| Unknown Port                   | 00  |
| Alternate or Backup Port       | 01  |
| Root Port                      | 10  |
| Designated Port                | 11  |
| Learning                       | 4   |
| Forwarding                     | 5   |
| Agreement                      | 6   |
| Topology Change Acknowledgment | 7   |

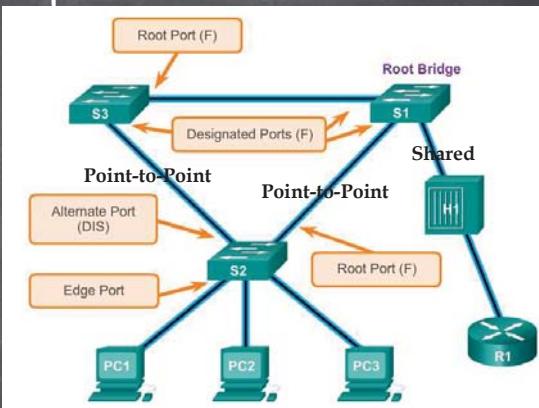
# Rapid PVST+

- Edge Ports port នឹងមិនចាប់ផ្តើមការកំណត់ខ្លួនទៅក្នុង Loop និង convergence របស់វា



# Rapid PVST+

- Link Types



— The link type can determine whether the port can immediately transition to forwarding state. Edge port connections and point-to-point connections are candidates for rapid transition to forwarding state.

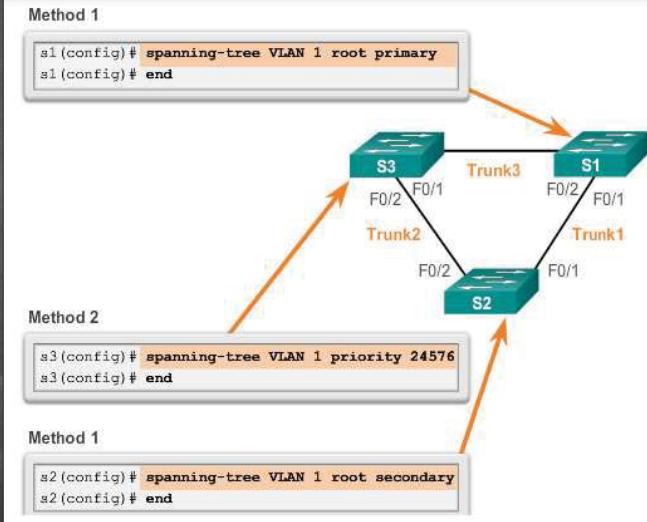
# Spanning Tree Configuration

- 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<br>100 Mb/s: 19<br>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<br>100 Mb/s: 19<br>10 Mb/s: 100  |
| Spanning-tree timers  | Hello time: 2 seconds<br>Forward-delay time: 15 seconds<br>Maximum-aging time: 20 seconds<br>Transmit hold count: 6 BPDUs |

# Spanning Tree Configuration

- Configuring and Verifying the Bridge ID



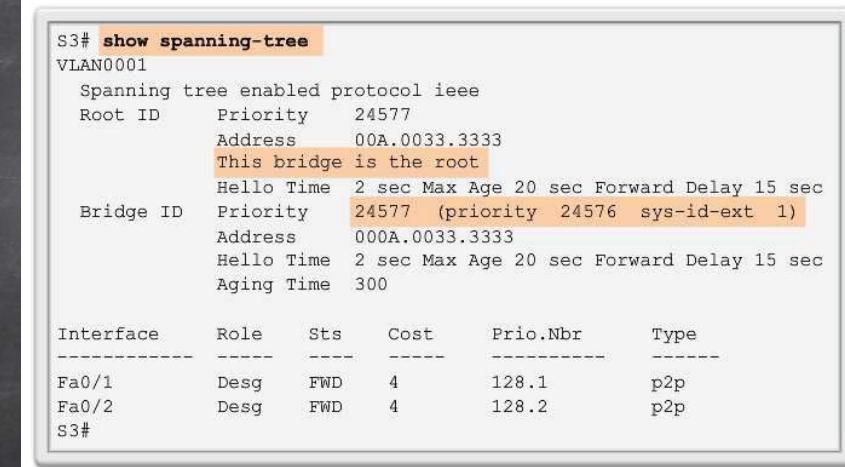
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33

# Spanning Tree Configuration

- Configuring and Verifying the Bridge ID



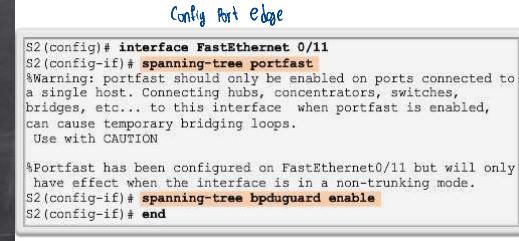
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34

# Spanning Tree Configuration

- PortFast and BPDU Guard

- When a switch port is configured with PortFast that port transitions from blocking to forwarding state immediately.
- BPDU guard puts the port in an error-disabled state on receipt of a BPDU.

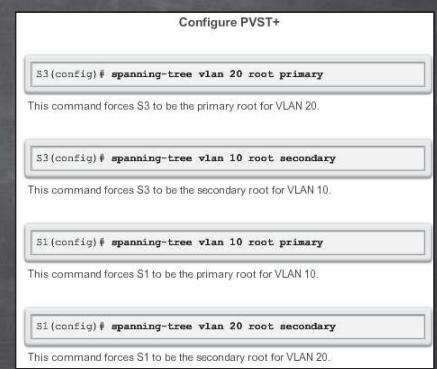
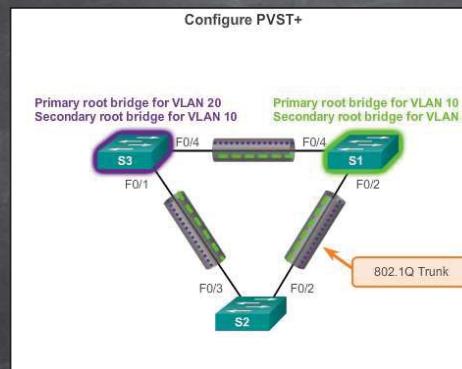


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35

# Spanning Tree Configuration

- PVST+ Load Balancing



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36

# Spanning Tree Configuration

- PVST+ Load Balancing

- Another method to specify the root bridge is to set the spanning tree priority on each switch to the lowest value so that the switch is selected as the primary bridge for its associated VLAN.

Configure PVST+

```
S3(config)# spanning-tree vlan 20 priority 4096
This command sets the priority for S3 to be the lowest possible, making it most likely that S3 will be the primary root for VLAN 20.

S1(config)# spanning-tree vlan 10 priority 4096
This command sets the priority for S1 to be the lowest possible, making it most likely that S1 will be the primary root for VLAN 10.
```

# Spanning Tree Configuration

- PVST+ Load Balancing

Configure PVST+

```
S1# show running-config
Building configuration...
Current configuration : 1595 bytes
!
version 12.2
<output omitted>
!
spanning-tree mode pvst
spanning-tree extend system-id
spanning-tree vlan 1 priority 24576
spanning-tree vlan 10 priority 4096
spanning-tree vlan 20 priority 28672
!
<output omitted>
```

# Spanning Tree Configuration

- PVST+ Load Balancing

- Display and verify spanning tree configuration details

Configure PVST+

```
S3# 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>
```

# Spanning Tree Configuration

- Rapid PVST+ Configuration

Rapid PVST+ is the Cisco implementation of RSTP. It supports RSTP on a per-VLAN basis.

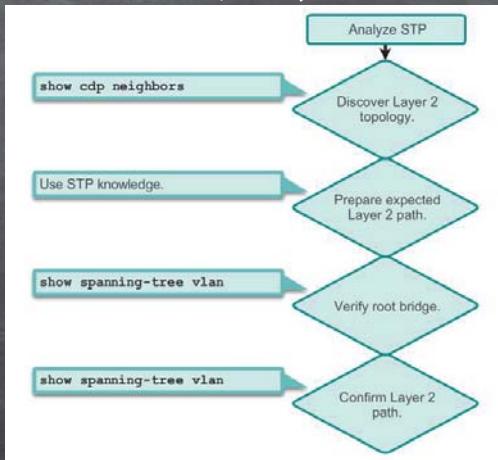
```
S1# configure terminal
S1(config)# spanning-tree mode rapid-pvst
S1(config)# interface f0/2
S1(config-if)# spanning-tree link-type point-to-point
S1(config-if)# end
S1# clear spanning-tree detected-protocols
```

| Cisco IOS Command Syntax   |  |
|--|--|
| Enter global configuration mode.   | configure terminal                     |
| Configure Rapid PVST+ spanning-tree mode.  | spanning-tree mode rapid-pvst          |
| Enter interface configuration mode and specify an interface to configure. Valid interfaces include physical ports, VLANs, and port channels. | interface interface-id                 |
| Specify that the link type for this port is point-to-point.  | spanning-tree link-type point-to-point |
| Return to privileged EXEC mode.  | end                                    |
| Clear all detected STP.  | clear spanning-tree detected-protocols |

# Spanning Tree Configuration

- STP Configuration Issues

- Analyzing the STP Topology



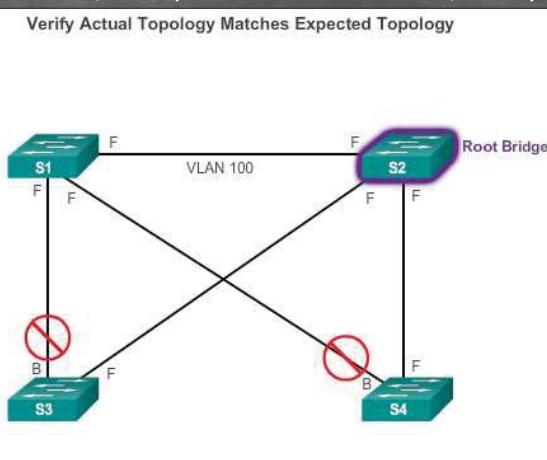
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41

# Spanning Tree Configuration

- STP Configuration Issues

- Expected Topology versus Actual Topology



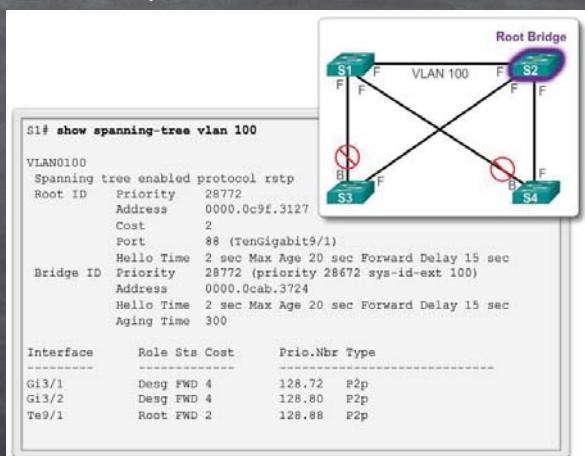
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42

# Spanning Tree Configuration

- STP Configuration Issues

- Overview of Spanning Tree Status



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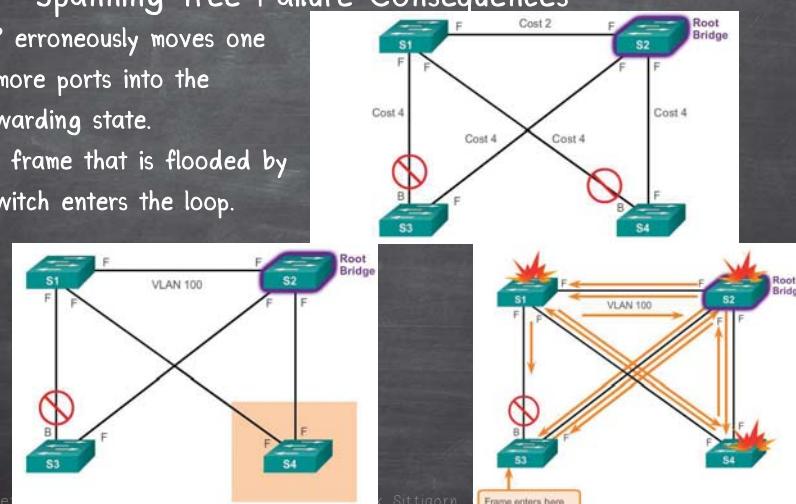
43

# Spanning Tree Configuration

- STP Configuration Issues

- Spanning-Tree Failure Consequences

- STP erroneously moves one or more ports into the forwarding state.
- Any frame that is flooded by a switch enters the loop.



44

# Spanning Tree Configuration

- STP Configuration Issues

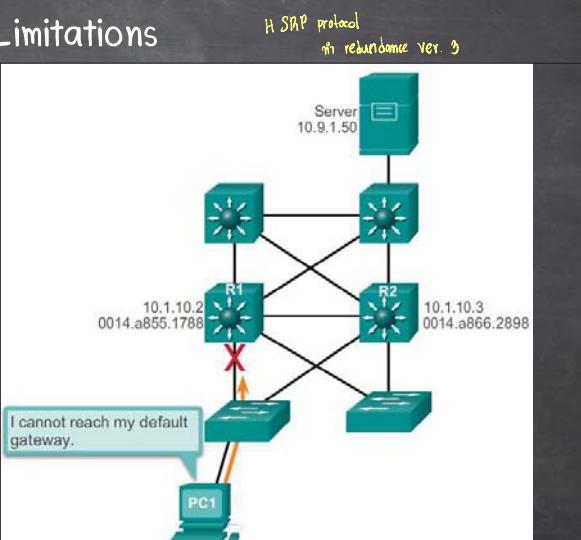
- Repairing a Spanning Tree Problem

- One way to correct spanning-tree failure is to manually remove redundant links in the switched network, either physically or through configuration, until all loops are eliminated from the topology.
    - Before restoring the redundant links, determine and correct the cause of the spanning-tree failure.
    - Carefully monitor the network to ensure that the problem is fixed.

# First-Hop Redundancy Protocols

- Default Gateway Limitations

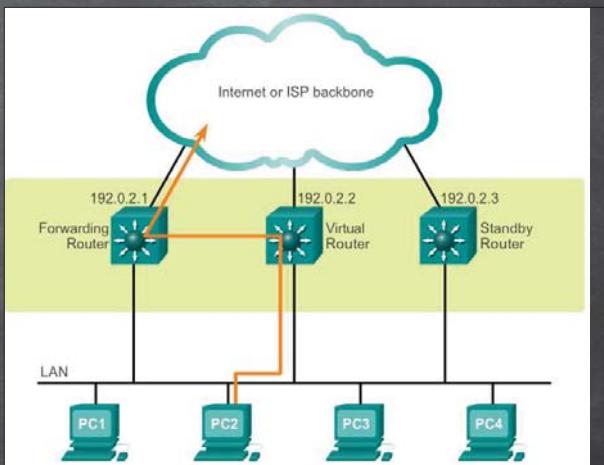
- If the default gateway cannot be reached, the local device is unable to send packets off the local network segment.
  - Even if a redundant router exists that could serve as a default gateway for that segment, there is no dynamic method by which these devices can determine the address of a new default gateway.



# First-Hop Redundancy Protocols

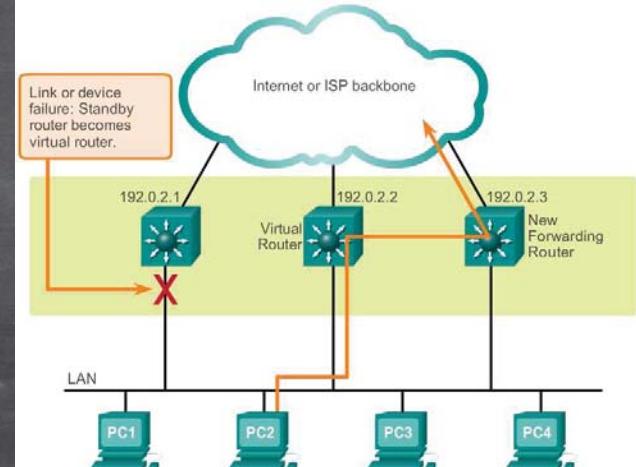
- Router Redundancy

- Multiple routers are configured to work together to present the illusion of a single router to the hosts on the LAN.
  - The ability of a network to dynamically recover from the failure of a device acting as a default gateway is known as first-hop redundancy.



# First-Hop Redundancy Protocols

- Steps for Router Failover

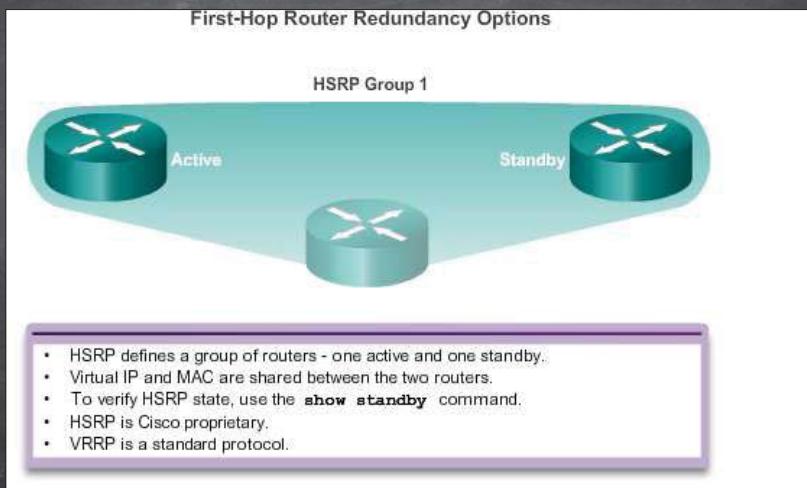


# First-Hop Redundancy Protocols

- Varieties of First-Hop Redundancy Protocols
  - Hot Standby Router Protocol (HSRP)
  - HSRP for IPv6
  - Virtual Router Redundancy Protocol version 2 (VRRPv2)
  - VRRPv3
  - Gateway Load Balancing Protocol (GLBP)
  - GLBP for IPv6
  - ICMP Router Discovery Protocol (IRDP)

# First-Hop Redundancy Protocols

- Varieties of First-Hop Redundancy Protocols



- HSRP defines a group of routers - one active and one standby.
- Virtual IP and MAC are shared between the two routers.
- To verify HSRP state, use the `show standby` command.
- HSRP is Cisco proprietary.
- VRRP is a standard protocol.

# First-Hop Redundancy Protocols

- HSRP Verification

```
Router# show standby
Ethernet0/1 - Group 1
  State is Active
    2 state changes, last state change 00:30:59
  Virtual IP address is 10.1.0.20
    Secondary virtual IP address 10.1.0.21
    Active virtual MAC address is 0004.4d82.7981
    Local virtual MAC address is 0004.4d82.7981 (bia)
    Hello time 4 sec, hold time 12 sec
    Next hello sent in 1.412 secs
    Gratuitous ARP 14 sent, next in 7.412 secs
    Preemption enabled, min delay 50 sec, sync delay 40 sec
    Active router is local
  Standby router is 10.1.0.6, priority 75 (expires in 9.184 sec)
  Priority 95 (configured 120)
  Tracking 2 objects, 0 up
    Down Interface Ethernet0/2, pri 15
    Down Interface Ethernet0/3
  Group name is "HSRP1" (cfgd)
Follow by groups:
E1/0.3 Grp 2 Active 10.0.0.254 0000.0c07.ac02 refresh 30 secs
(next 19.666)
E1/0.4 Grp 2 Active 10.0.0.254 0000.0c07.ac02 refresh 30 secs
(next 19.491)
  Group name is "HSRP1", advertisement interval is 34 sec
```

# First-Hop Redundancy Protocols

- GLBP Verification

— Gateway Load Balancing Protocol (GLBP) is a Cisco proprietary solution to allow automatic selection and simultaneous use of multiple available gateways in addition to automatic failover between those gateways.

```
Router# show glbp
FastEthernet0/1 - Group 1
  State is Active
    1 state change, last state change 00:02:34
  Virtual IP address is 192.168.2.100
    Hello time 3 sec, hold time 10 sec
      Next hello sent in 0.288 secs
    Redirect time 600 sec, forwarder timeout 14400 sec
    Preemption disabled
    Active is local
    Standby is 192.168.2.2, priority 100 (expires in 8.640 sec)
    Priority 100 (default)
    Weighting 100 (default 100), thresholds: lower 1, upper 100
    Load balancing: round-robin
  Group numbers:
    001e.7aa3.5e71 (192.168.2.1) local
    001e.7aa3.5f31 (192.168.2.2)
  There are 2 forwarders (1 active)
  Forwarder 1
    State is Active
      1 state change, last state change 00:02:23
      MAC address is 0007.b400.0101 (default)
      Owner ID is 001e.7aa3.5e71
      Preemption enabled
      Weighting 100
      Active is local, weighting 100
```

## Questions and Answers

