
University of Colorado Boulder

Fundamentals of Data Communications CSCI 5010

Switching

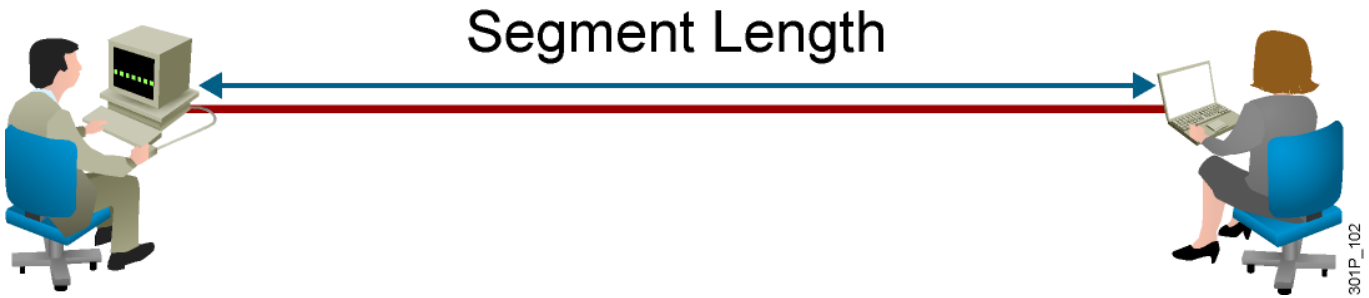
Levi Perigo, Ph.D.
University of Colorado Boulder
Department of Computer Science
Network Engineering

Review

Switching

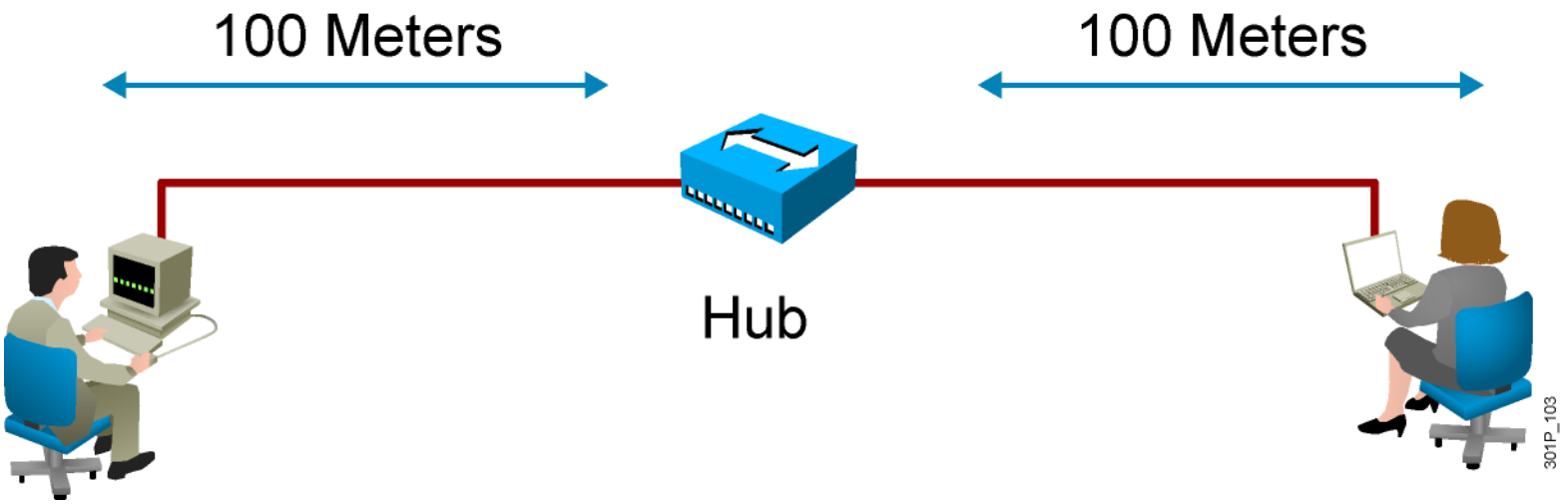
- **What is a switch?**
- **What does a switch do?**
- **Why do we need switches?**
- **VLANs?**
- **Trunking?**

LAN Segment Limitations



- Signals degrade with transmission distance
- Each Ethernet type has a maximum segment length

Extending LAN Segments



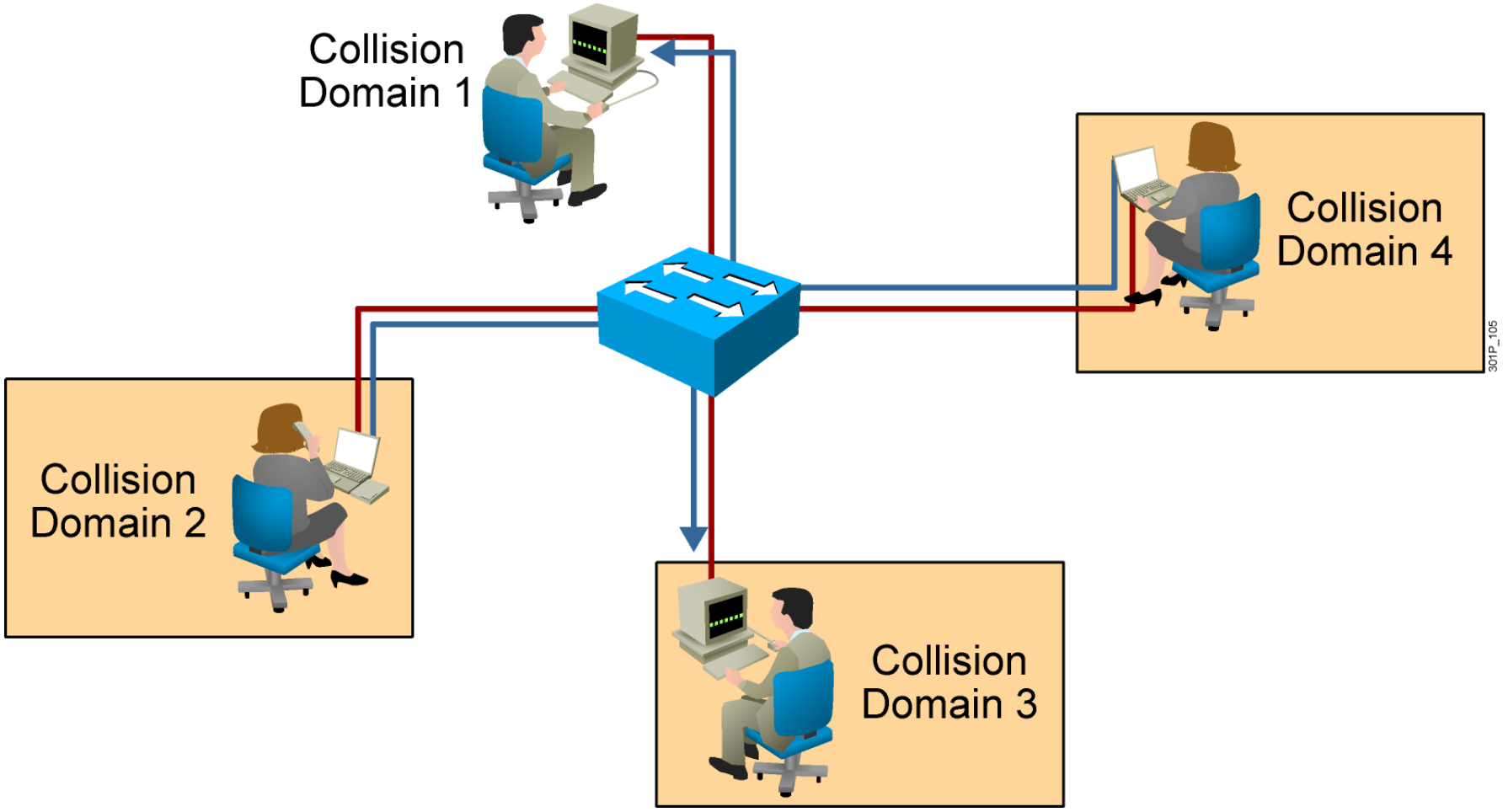
- Shares bandwidth
- Extends cable distances
- Repeats or amplifies signal

LAN Segmentation

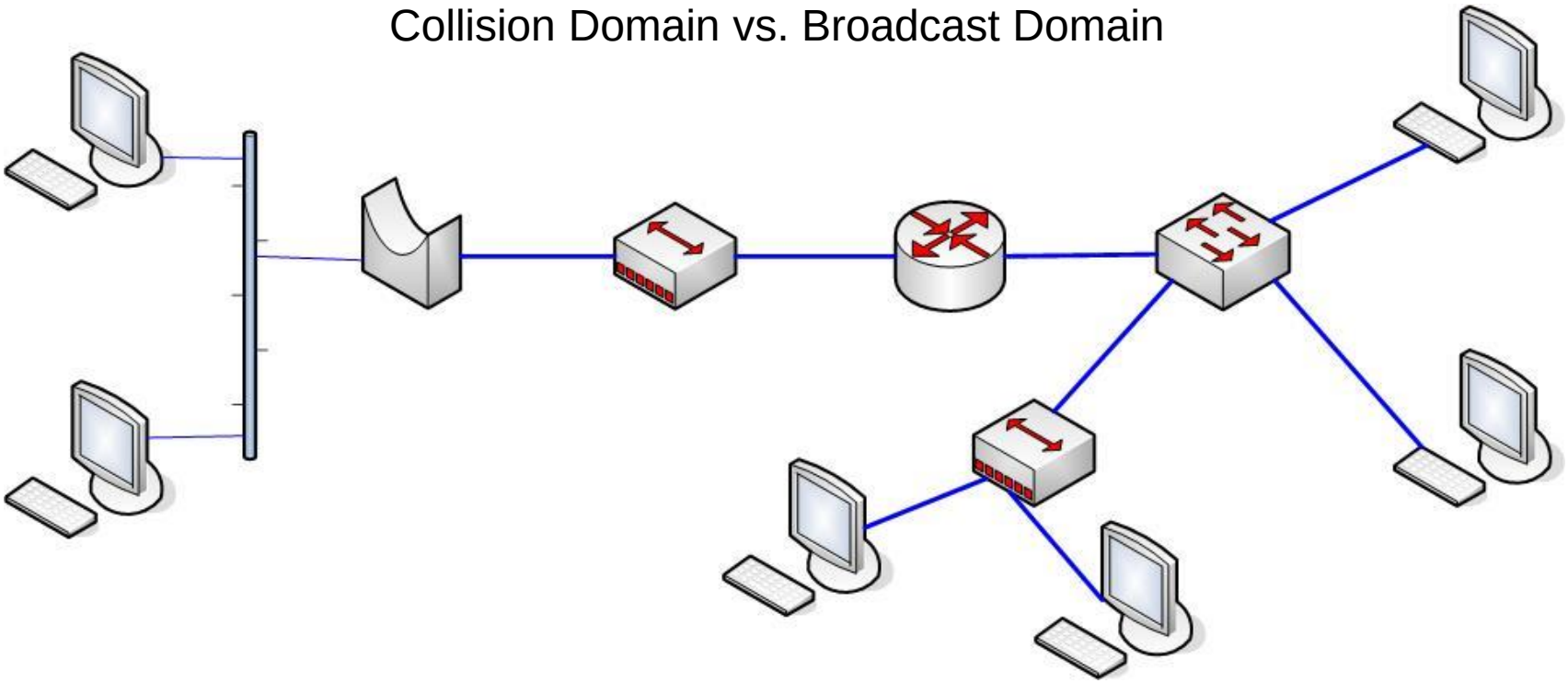
- **Collision Domain (Eth. Segment): set of LAN interfaces that could collide with each other while TX**
  - CMSA/CD (exponential backoff)
  - switch & router splits LANs into collision domains

- **Broadcast Domain: Where L2 broadcasts can be forwarded when one node TX**
  - What is a broadcast?
  - switch & bridge forward broadcasts
  - router splits broadcast domains
  - Relay/helper

Multiple Collision Domains



LAN Segmentation

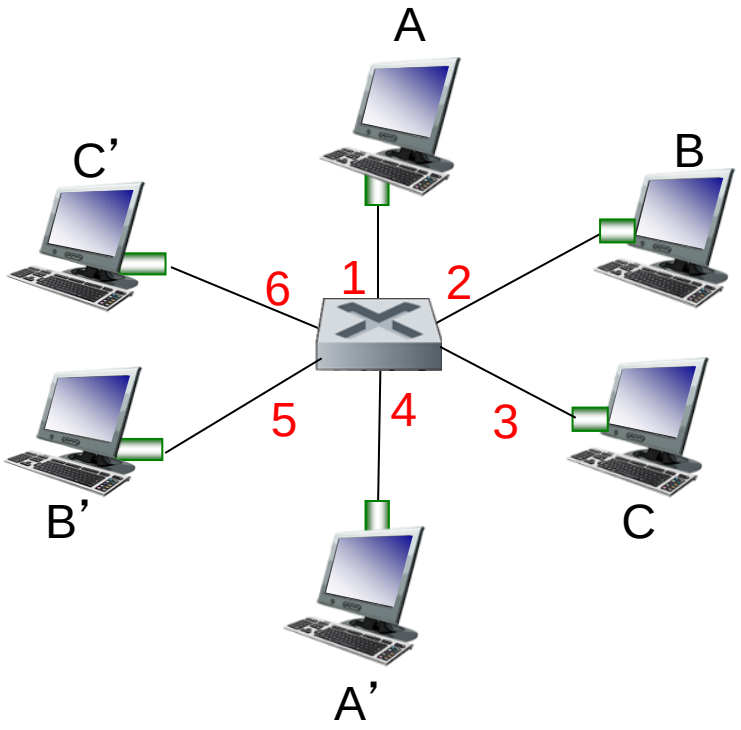


Ethernet Switch

- Link-layer device: takes an *active* role
  - Store/forward Ethernet frames
  - Examine incoming frame's MAC address, selectively forward frame to one-or-more outgoing links when frame is to be forwarded on segment, uses CSMA/CD to access segment
- Transparent
  - Hosts are unaware of presence of switches
- Plug-and-play, self-learning
  - MOST switches do not NEED to be configured for basic networking

Switch: *multiple* simultaneous transmissions

- Hosts have dedicated, direct connection to switch
- Switches buffer packets
- Ethernet protocol used on *each* incoming link, but no collisions; full duplex
  - each link is its own collision domain
- *Switching:* A-to-A' and B-to-B' can transmit simultaneously, without collisions



switch with six interfaces (1,2,3,4,5,6)

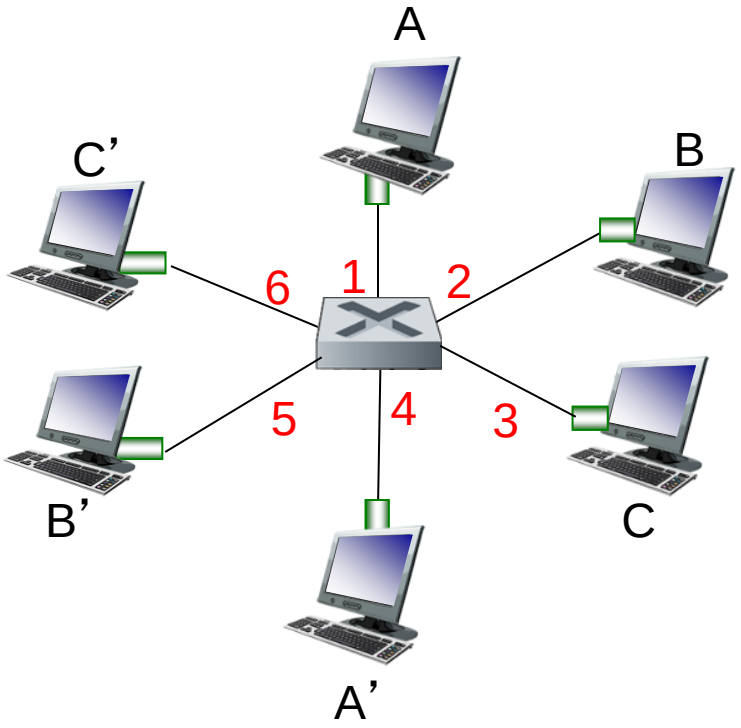
Switch Forwarding Table

Q: How does switch know MAC A' reachable via interface 4, MAC B' reachable via interface 5?

- *A:* Each switch has a switch table, each entry:
  - (MAC address of host, interface to reach host, time stamp)
  - Looks like a routing table!

Q: How are entries created, maintained in switch table?

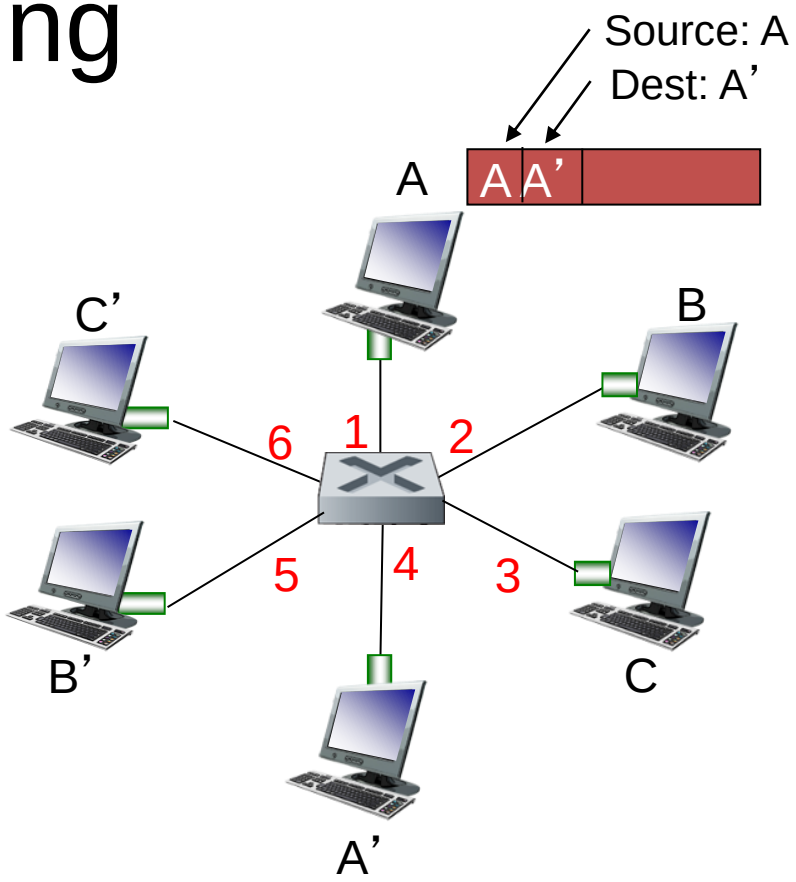
- Something like a routing protocol?



switch with six interfaces (1,2,3,4,5,6)

Switch: Self-learning

- Switch *learns* which hosts can be reached through which interfaces
  - When frame received, switch learns location of sender: incoming LAN segment
  - Records sender/location pair in switch table

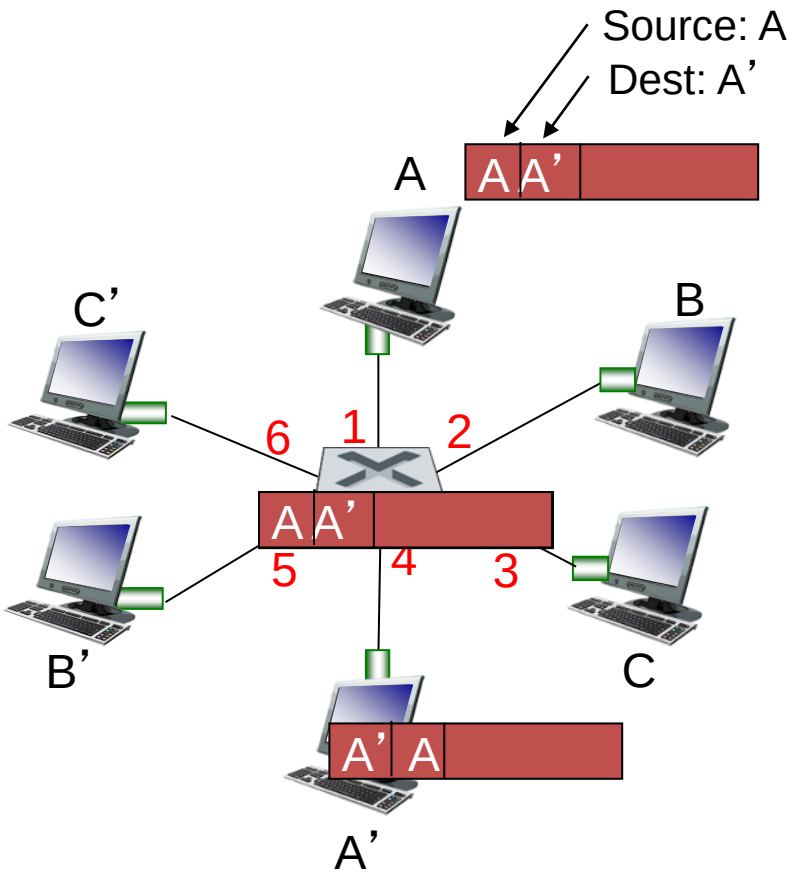


MAC addr	interface	TTL
A	*1*	*60*

Switch table (initially empty)

Switch self-learning, forwarding: example

- Frame destination, A', location unknown: *FLOOD*
- New frame received (reply)
  - Record/Learn new source (A')
  - Look at destination (A)
    - MAC A location known:
      - Selectively send;
      - on just one link

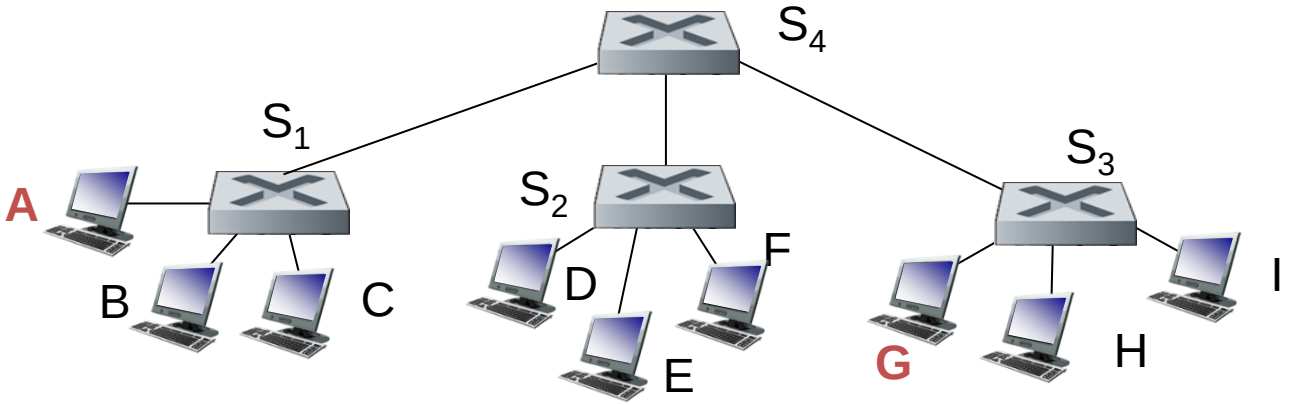


MAC addr	interface	TTL
A	*1*	*60*
A'	*4*	*60*

switch table (initially empty)

Interconnecting Switches

Self-learning switches can be connected together:



Q: Sending from A to G - how does S_1 know to forward frame destined to G via S_4 and S_3?

- *A:* Self learning! (works exactly the same as in single-switch case!)

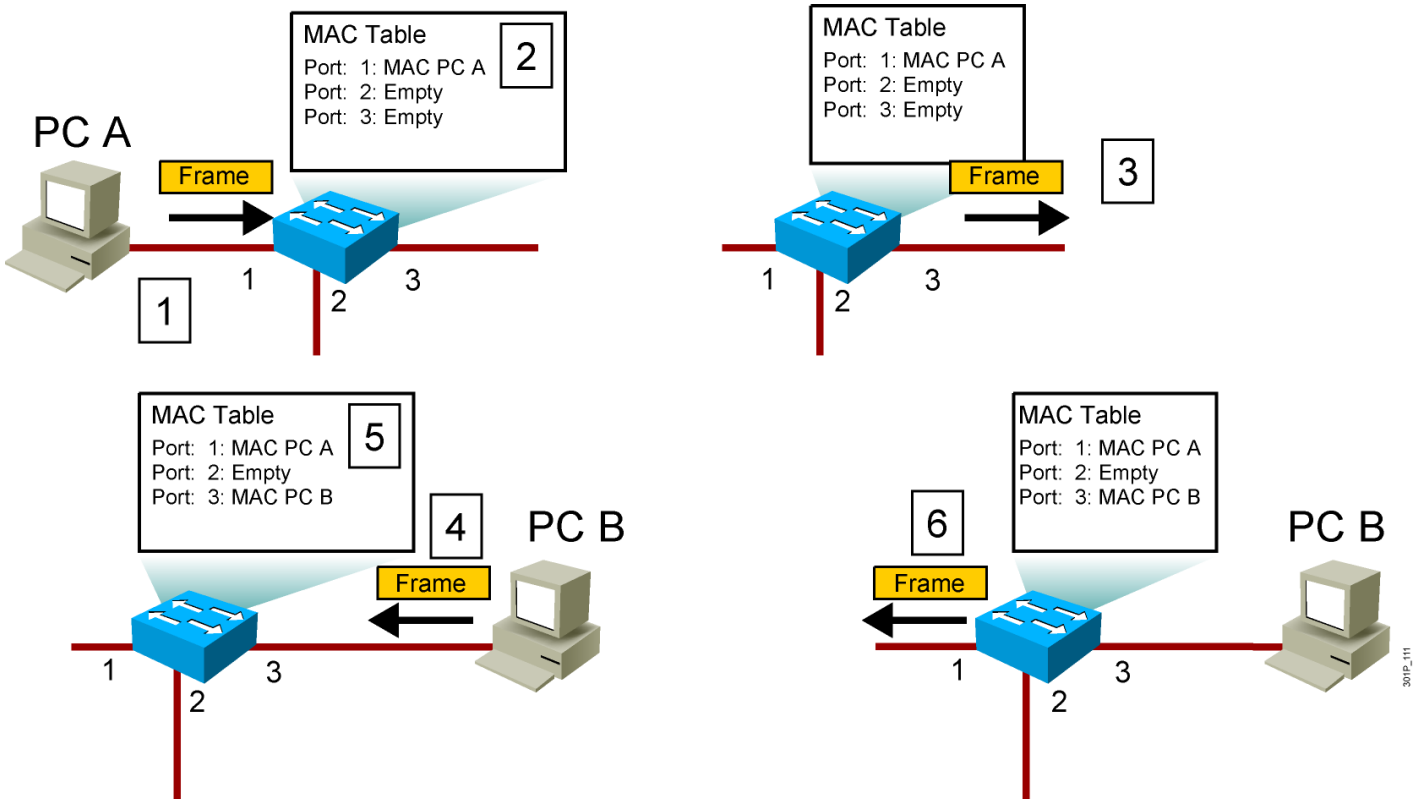
LAN Switch - Review

- Layer 2 device
- Learn and build MAC address table
  - ***MAC address/devices that are located on network segments and map them to associated ports***
- Analyzes incoming frames (destination MAC address)
  - ***Forward***
  - ***Filter***
  - ***Flood***
    - Forward out all ports but the receiving port

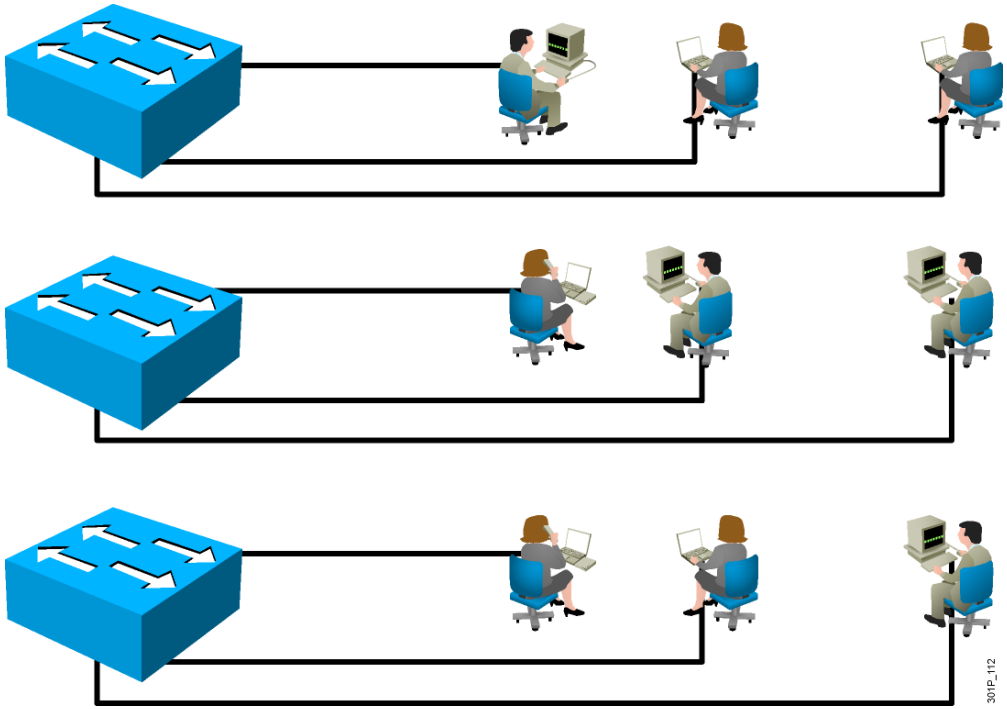
LAN Switch

- High port density
- Large frame buffers
- Mixture of port speeds
- Fast internal switching
- Switching modes:
  - Cut-through
  - Store-and-forward
  - Fragment-free

Switching Frames



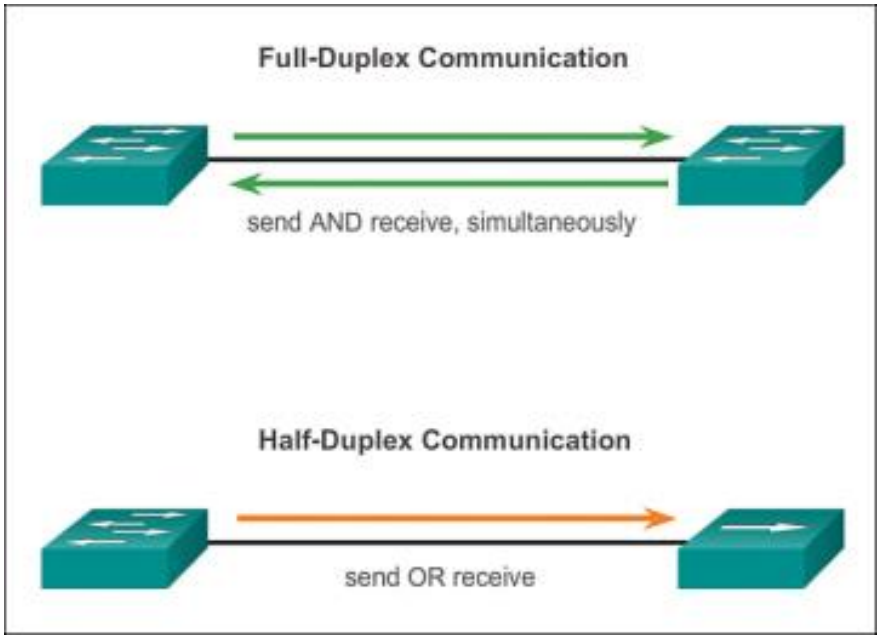
LANs Today



- Users grouped by physical location
- More switches added to networks
- Switches connected by high-speed links

Duplex Overview

- Half Duplex (CSMA/CD)
  - Unidirectional data flow
  - Higher potential for collision
  - Hub connectivity



- Full Duplex
  - Point-to-point only
  - Attached to dedicated switched port
  - Requires full-duplex support on both ends
  - Collision-free
  - Collision detect circuit disabled

Setting Duplex and Speed Options

Cisco Catalyst 2960 Series

```
(config)#interface fa0/1
(config-if)#duplex {auto | full | half}
```

Cisco Catalyst 2960 Series

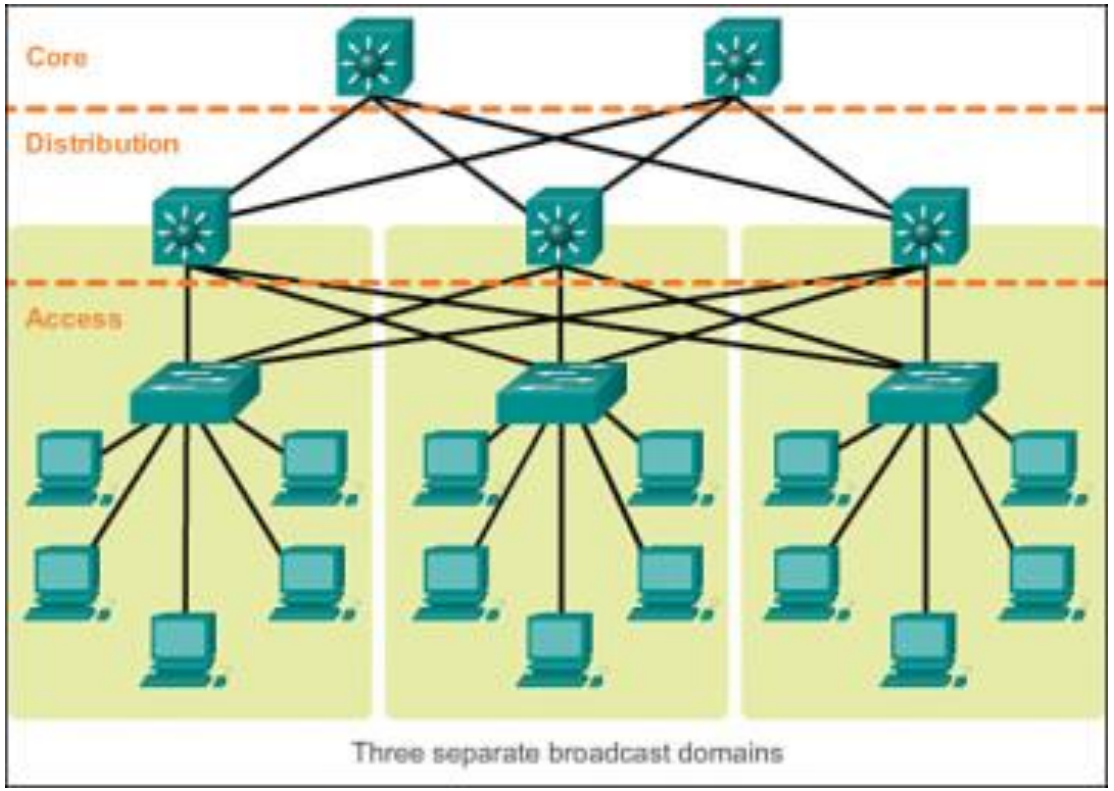
```
(config)#interface fa0/1
(config-if)#speed {10 | 100 | 1000 | auto}
```

The Hierarchy of Connectivity (Traditional)

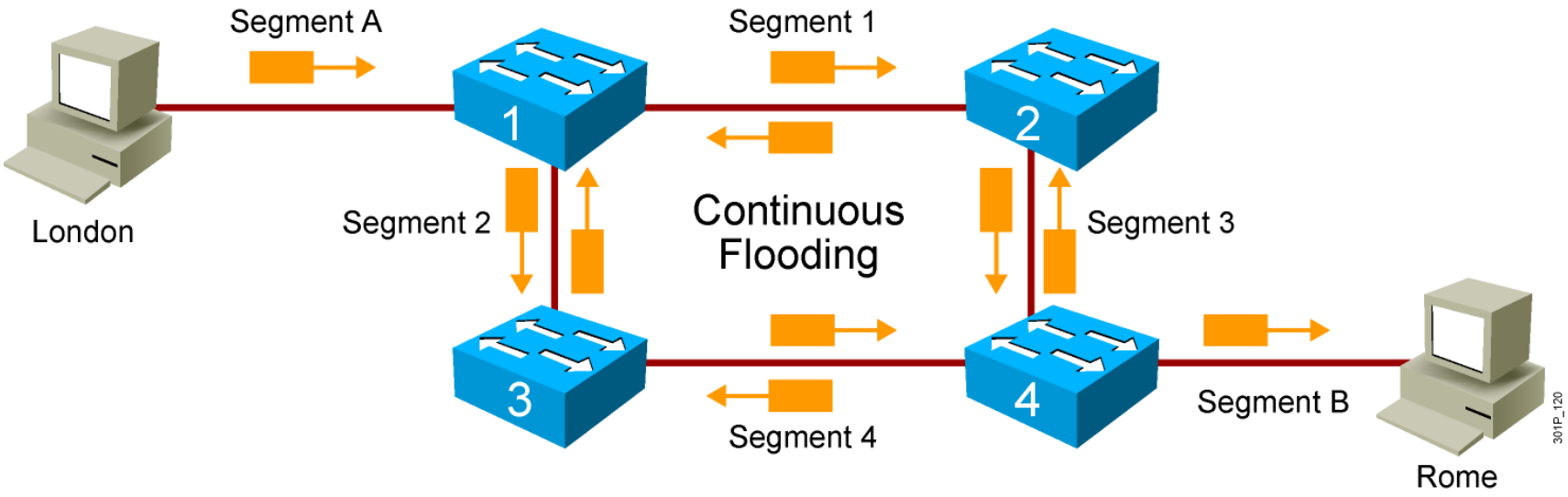
Core Layer – Provides optimal transport between core routers and distribution sites

Distribution Layer – Provided policy-based connectivity, peer reduction, and aggregation

Access Layer – Provides common group access to the internetworking environment



Loops


Segment A
Segment 1
London
1
2
Segment 2
Continuous
Flooding
Segment 3
3
4
Segment 4
Segment B
Rome
301P_120

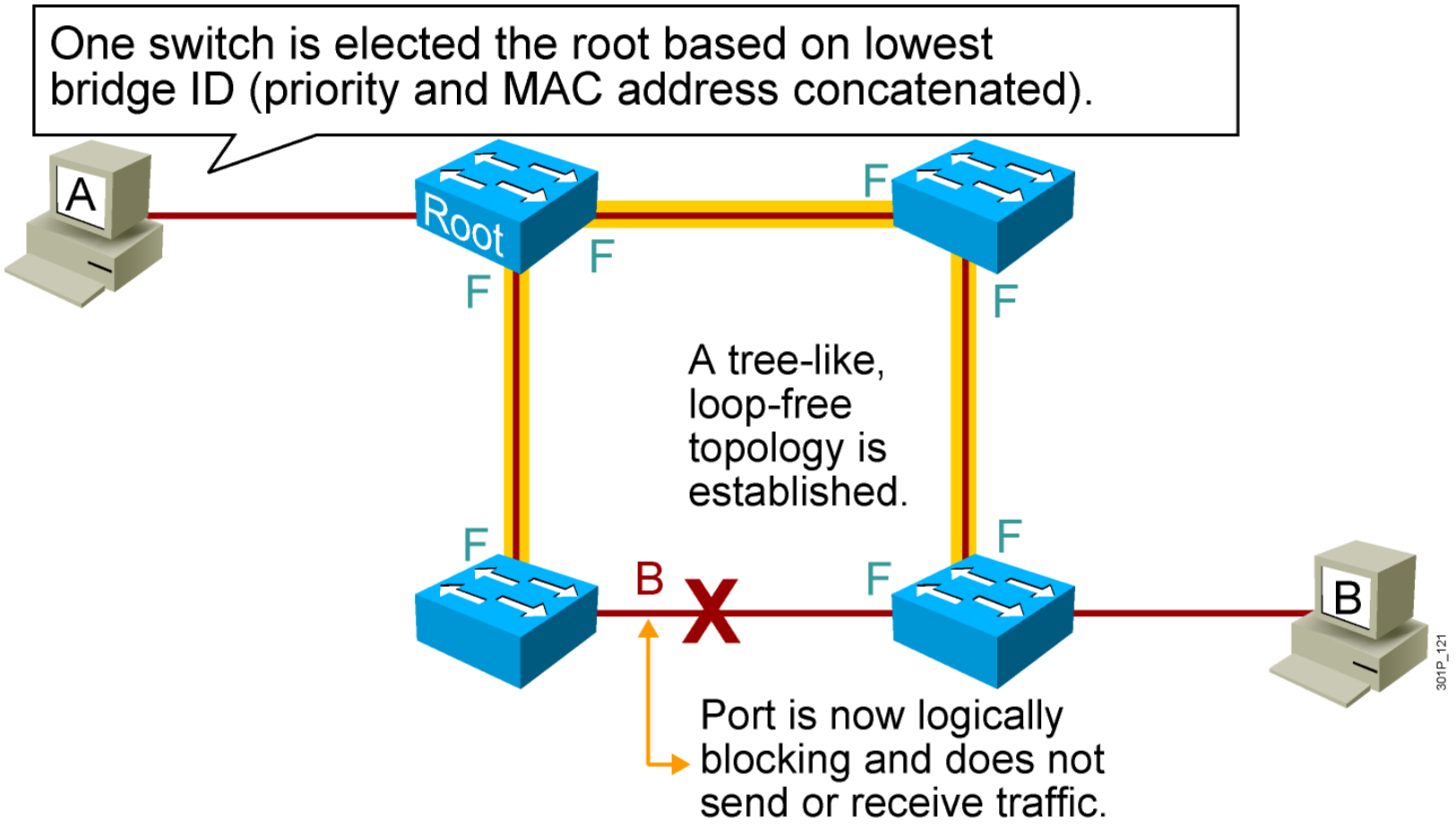
Spanning Tree Protocol (STP)

- **LAN redundancy: fail proof**
- **How loops can happen**
  - Unknown unicast addresses
  - Broadcast frames
- **STP goal:**
  - Create a single currently active logical path between each pair of LAN segments, by blocking some interfaces
  - ***Blocking***: Interface cannot forward or receive frames
    - ***Note: This does not include BPDUs***
  - ***Forwarding***: Interface can send and receive frames

Spanning Tree Protocol

- **L2 Broadcast**
- **Resiliency/Availability**
- **Loop Prevention**
- **Root Bridge**
  - Lowest Bridge ID
  - Cost to Bridge (root port)
  - Designated Port (SW with lowest cost to root for that segment)
- **Ports**
  - Blocking State
    - ***Listening***
    - ***Learning***
  - Forwarding State
  - Disabled (shutdown)

Spanning Tree Protocol

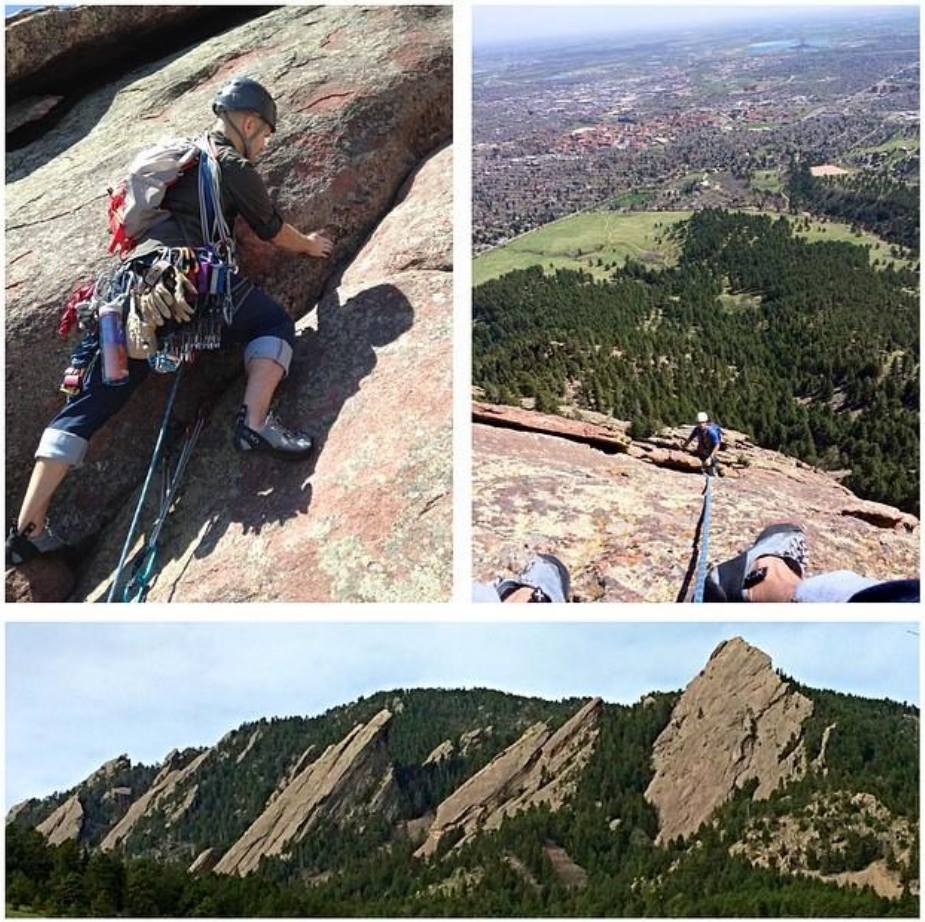


The Layered Approach

- Switches operate at Layer 2 of the OSI model
- Switches provide an interface with the physical media
- Problems generally are seen at Layer 1 and Layer 2
- Layer 3 issues could arise related to access to the management functions of the switch

Switching Example

Questions?



Lab

Appendix

- **Switching Troubleshooting**

Switched Media Issues

- **Media issues have several possible sources:**
  - Wiring gets damaged.
  - New EMI sources are introduced.
  - Traffic patterns change.
  - New equipment is installed.

Excessive Noise

- **Suggested steps:**
  - Use the show interface ethernet EXEC command to determine the status of the device Ethernet interfaces. The presence of many CRC errors but not many collisions is an indication of excessive noise.
  - Inspect the cables for damage.
  - If you are using 100Base-TX, make sure you are using Category 5 cabling.

Excessive Collisions

- **Suggested steps:**
  - Use the show interface ethernet command to check the rate of collisions. The total number of collisions with respect to the total number of output packets should be 0.1 percent or less.
  - Use a time-domain reflectometer (TDR) to find any unterminated Ethernet cables. A TDR is a device that sends signals through a network medium to check cable continuity and other attributes.
  - Look for a jabbering transceiver attached to a host. This might require host-by-host inspection or the use of a protocol analyzer. Jabber occurs when a device that is experiencing circuitry or logic failure continuously sends random (garbage) data.

Late Collisions

- **Suggested steps:**
  - Use a protocol analyzer to check for late collisions. Late collisions should never occur in a properly designed Ethernet network. They usually occur when Ethernet cables are too long or when there are too many repeaters in the network.
  - Verify that the distance between the first and last host on the segment is within specification.

Port Access Issues

- Media-related issues
- Duplex-related issues
- Speed-related issues

Duplex-Related Issues

- **Duplex modes:**
  - One end set to full and the other set to half results in a mismatch.
  - One end set to full and autonegotiation set on the other end:
    - ***Autonegotiation fails, and that end reverts to half.***
    - ***Results in a mismatch.***
  - One end set to half and autonegotiation set on the other:
    - ***Autonegotiation fails, and that end reverts to half.***
    - ***Both ends at half; no mismatch.***
  - Autonegotiation on both ends:
    - ***One end fails to full, and the other end fails to half.***
    - ***Example: A Gigabit Ethernet interface defaults to full, while a 10/100 defaults to half.***
  - Autonegotiation on both ends:
    - ***Autonegotiation fails on both ends, and they revert to half.***
    - ***Both end at half; no mismatch.***

Speed-Related Issues

- **Duplex modes:**
  - One end set to one speed and the other set to another, resulting in a mismatch.
  - One end set to a higher speed and autonegotiation enabled on the other end.
    - ***If autonegotiation fails, the autonegotiation end reverts to its lowest speed.***
    - ***Results in a mismatch.***
  - Autonegotiation on both ends:
    - ***Autonegotiation fails on both ends, and they revert to their lowest speed.***
    - ***Both end at half; no mismatch.***

Configuration Issues

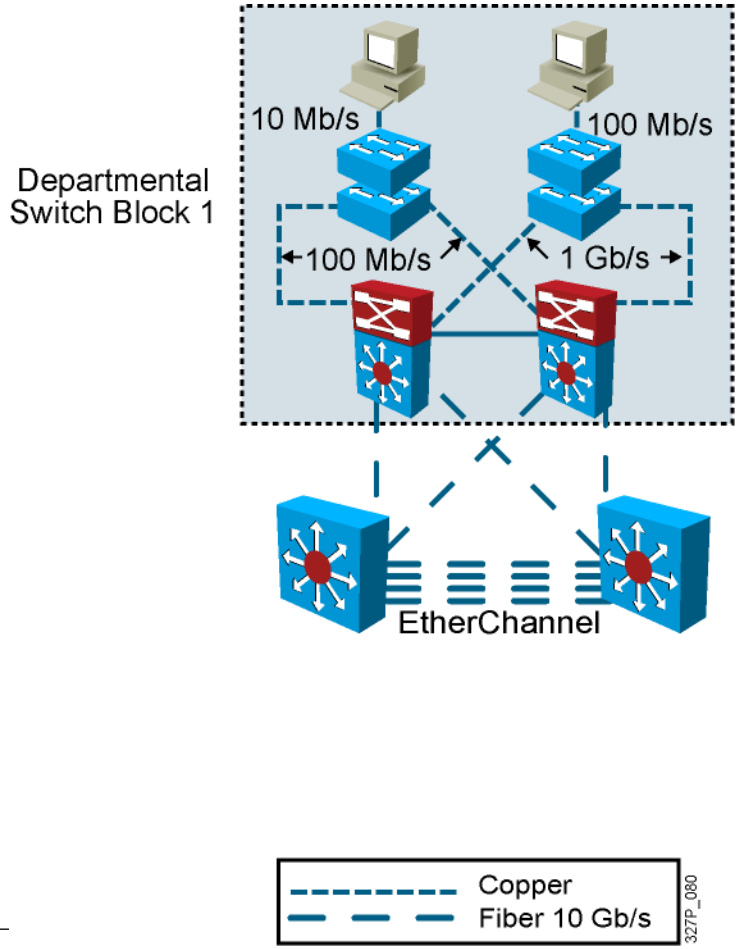
- Know what you have before you start.
  - ***Hard copy***
  - ***Text file***
  - ***TFTP server***
- Verify changes before you save.
  - ***Confirm that the issue was corrected and no new issues were created.***
- Save the current configuration.
  - ***copy running-config start-config***
- Secure the configuration.
  - ***Password-protect the console.***
  - ***Password-protect the vty.***
  - ***Password-protect EXEC mode.***

Appendix B

- **Spanning Tree Protocol (STP)**

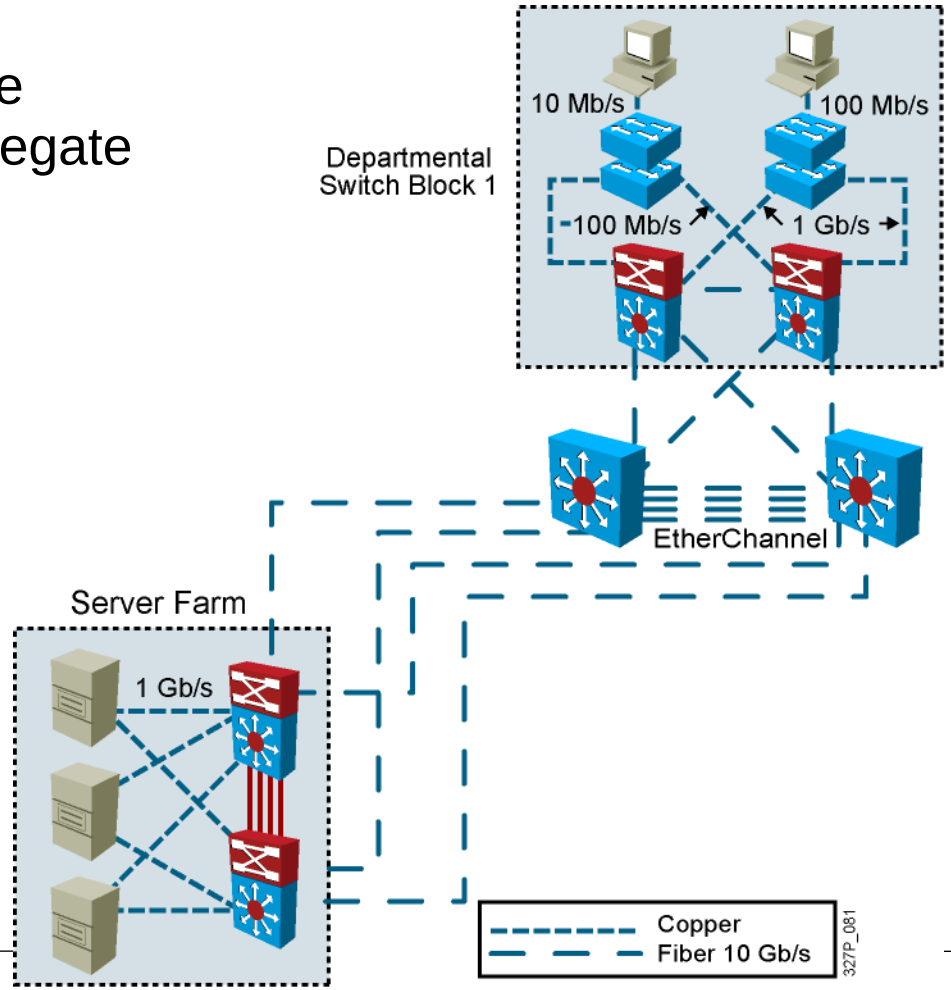
Interconnection Technologies

Technology	Use
Fast Ethernet	Connects end-user devices to the access layer switch
Gigabit Ethernet	Connects access switch to distribution switch and high use servers to switches
10-Gigabit Ethernet	Provides high-speed switch to switch links, backbones
EtherChannel	Provides high-speed switch to switch links, backbones with redundancy



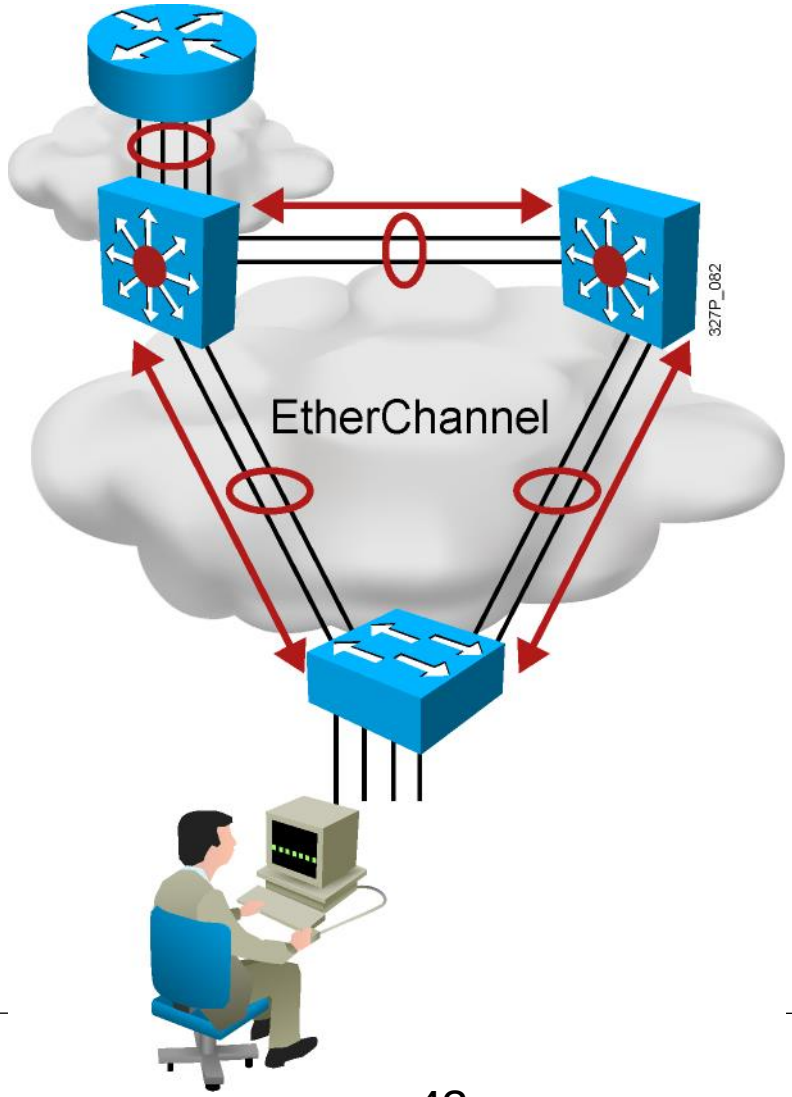
Determining Equipment and Cabling Needs

Each link provides adequate bandwidth for the total aggregate traffic over that link.

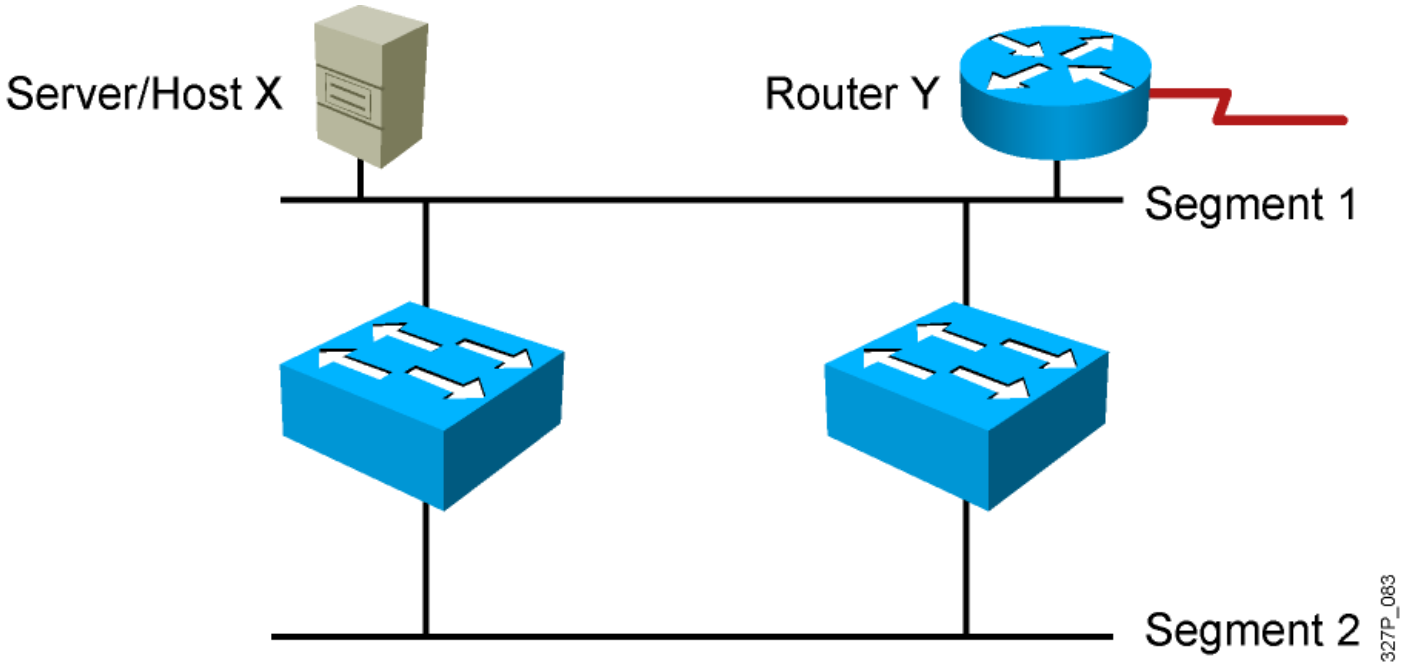


Advantages of EtherChannel

- Logical aggregation of similar links between switches
- Load-shares across links
- Viewed as one logical port to STP
- Redundancy

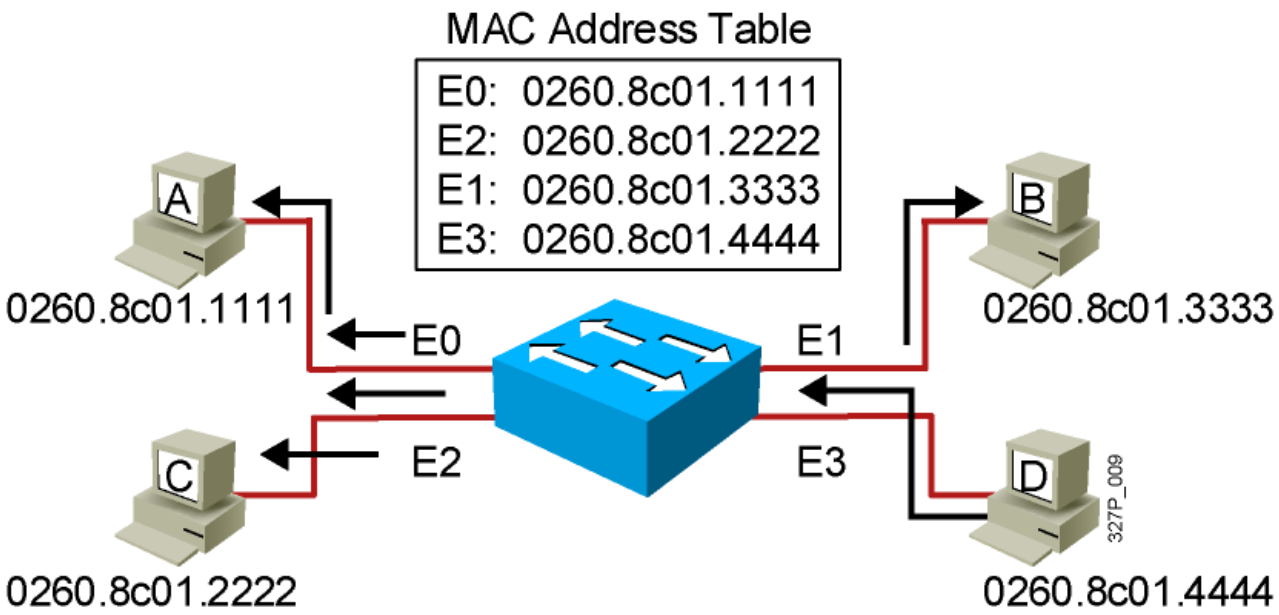


Redundant Topology



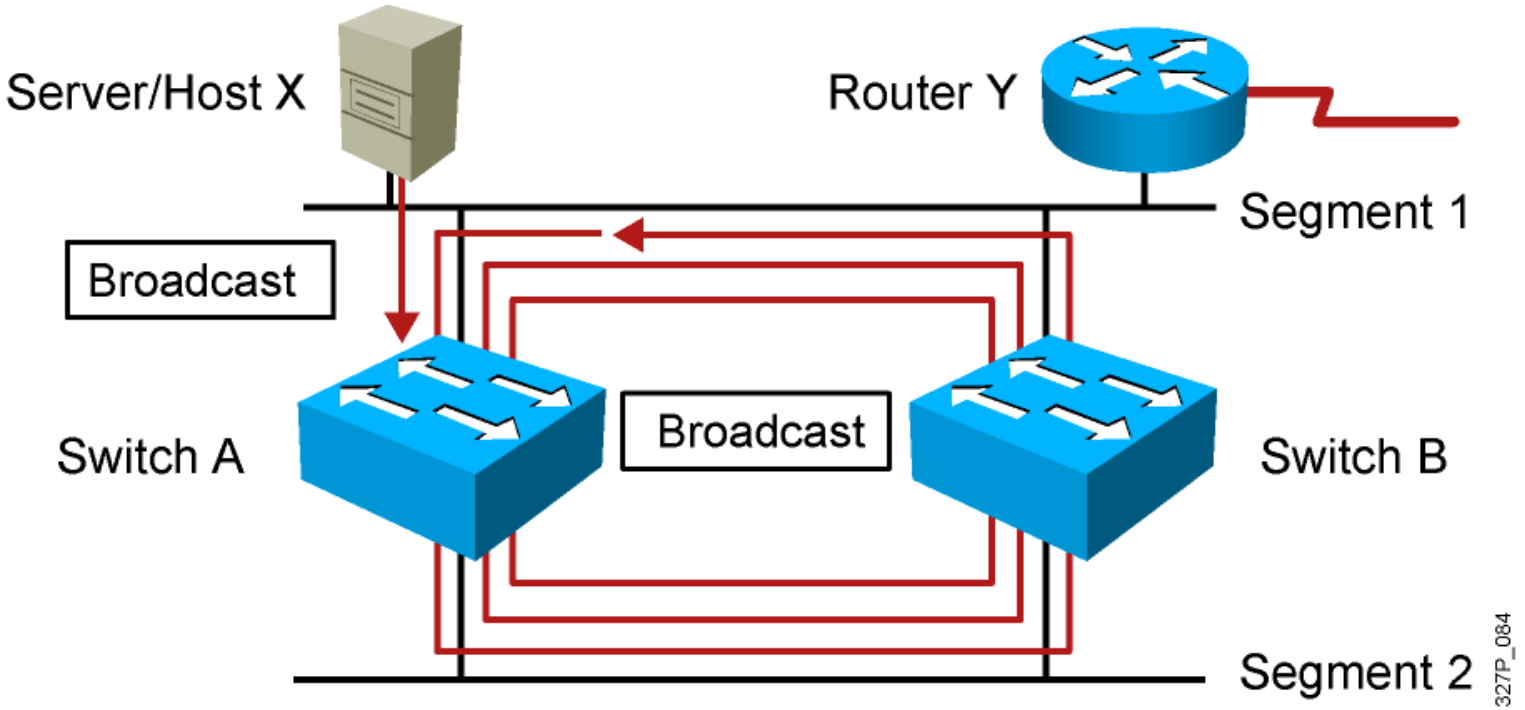
- Redundant topology eliminates single points of failure.
- Redundant topology causes broadcast storms, multiple frame copies, and MAC address table instability problems.

Broadcast Frames



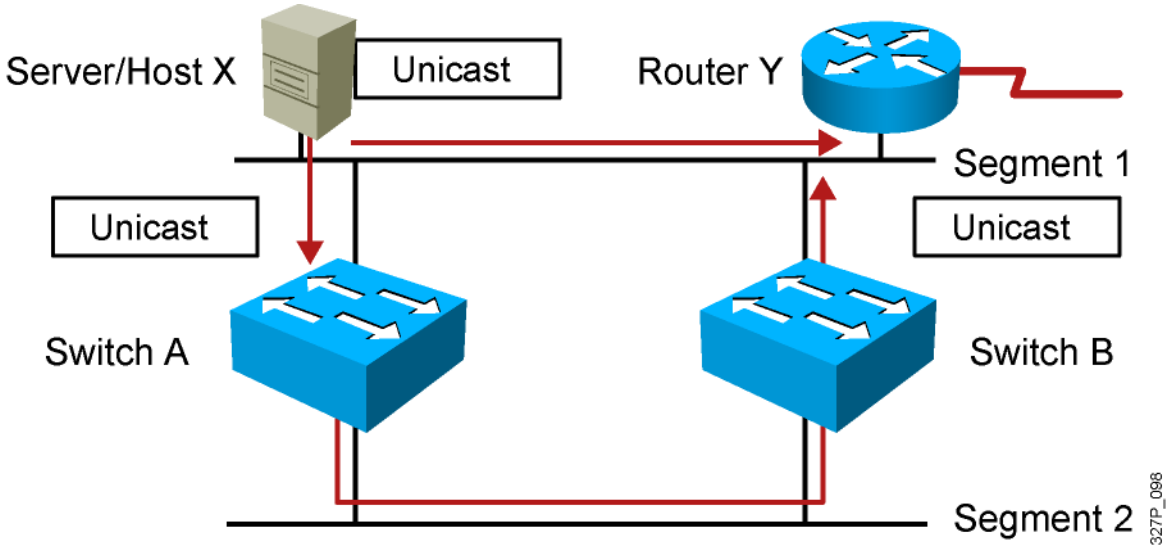
- Station D sends a broadcast frame.
- Broadcast frames are flooded to all ports except the originating port.

Broadcast Storms



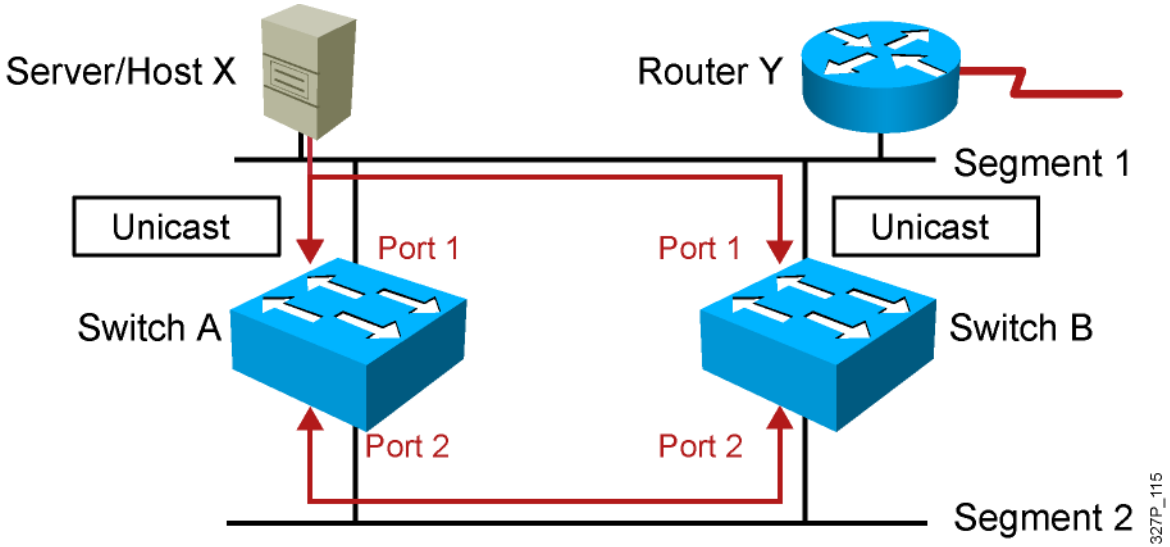
- Host X sends a broadcast.
- Switches continue to propagate broadcast traffic over and over.

Multiple Frame Copies



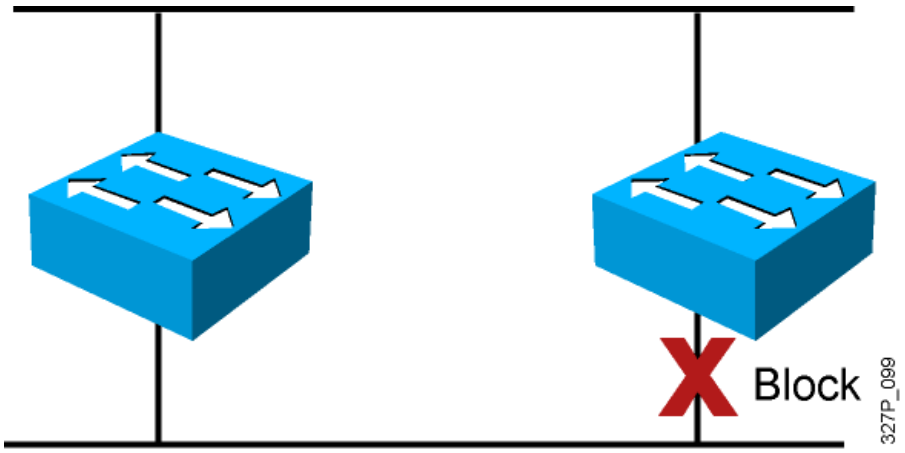
- Host X sends a unicast frame to router Y.
- The MAC address of router Y has not been learned by either switch.
- Router Y will receive two copies of the same frame.

MAC Database Instability



- Host X sends a unicast frame to router Y.
- The MAC address of router Y has not been learned by either switch.
- Switches A and B learn the MAC address of host X on port 1.
- The frame to router Y is flooded.
- Switches A and B incorrectly learn the MAC address of host X on port 2.

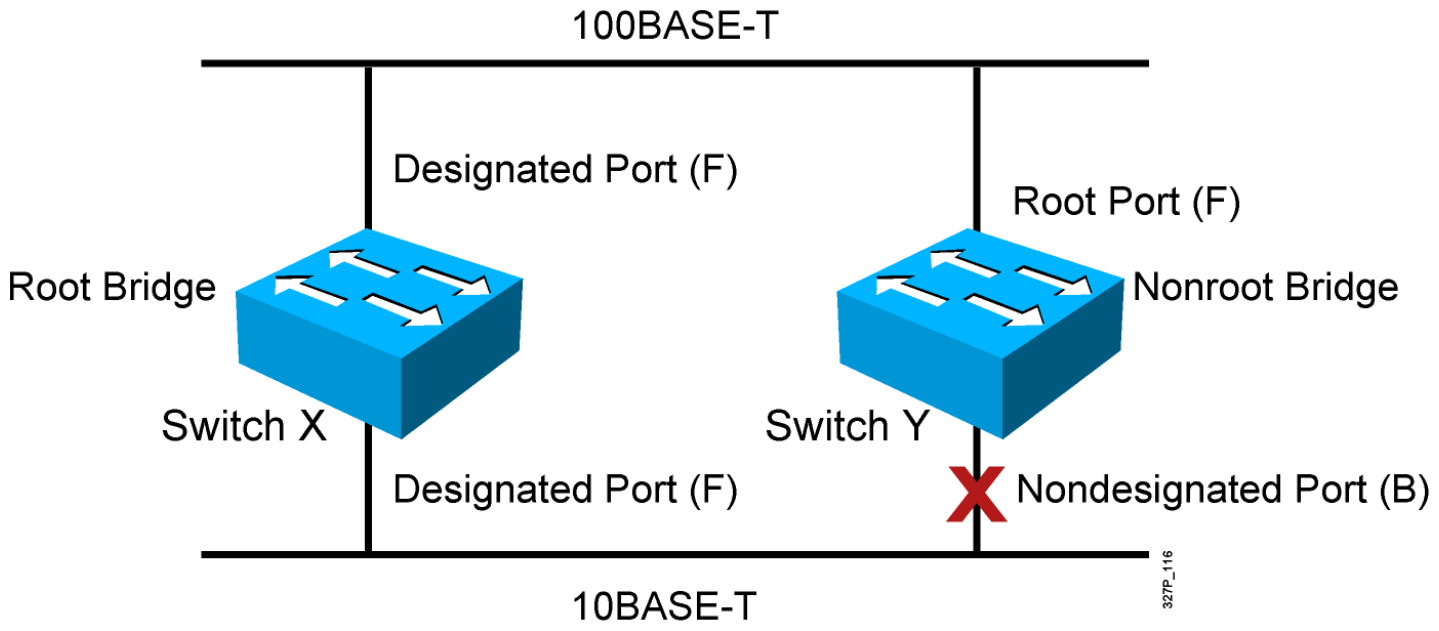
Loop Resolution with STP



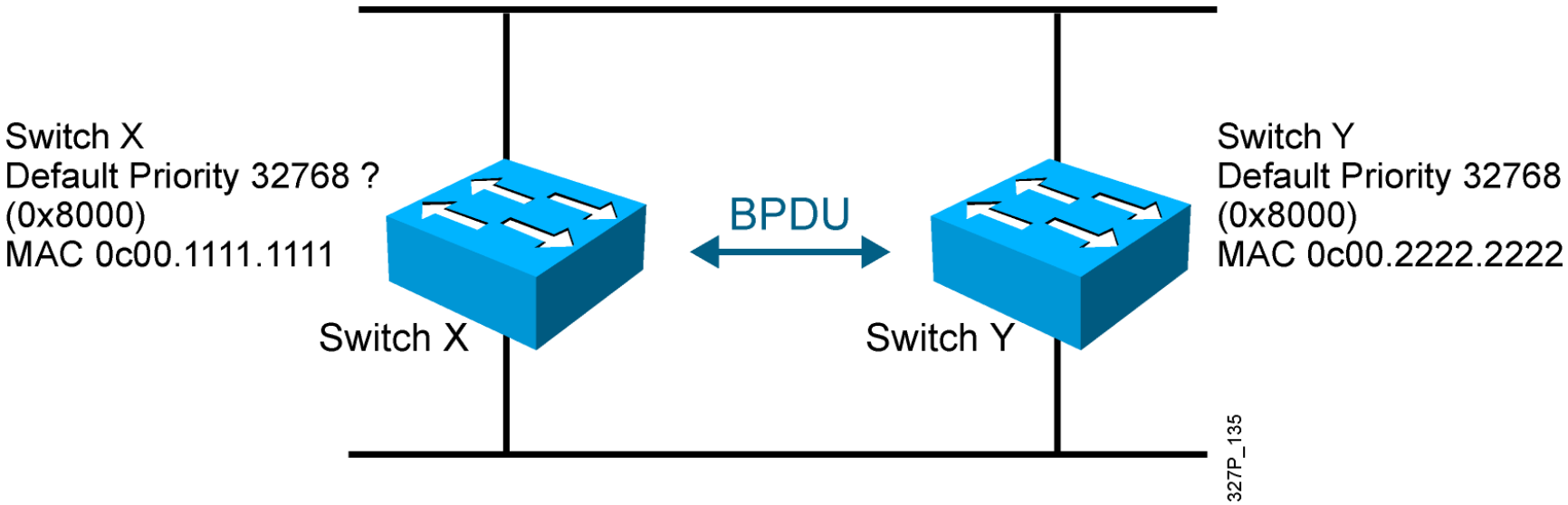
- Provides a loop-free redundant network topology by placing certain ports in the blocking state
- Published in the IEEE 802.1D specification
- Enhanced with the Cisco PVST+ implementation

Spanning-Tree Operation

- One root bridge per broadcast domain.
- One root port per nonroot bridge.
- One designated port per segment.
- Nondesignated ports are unused.



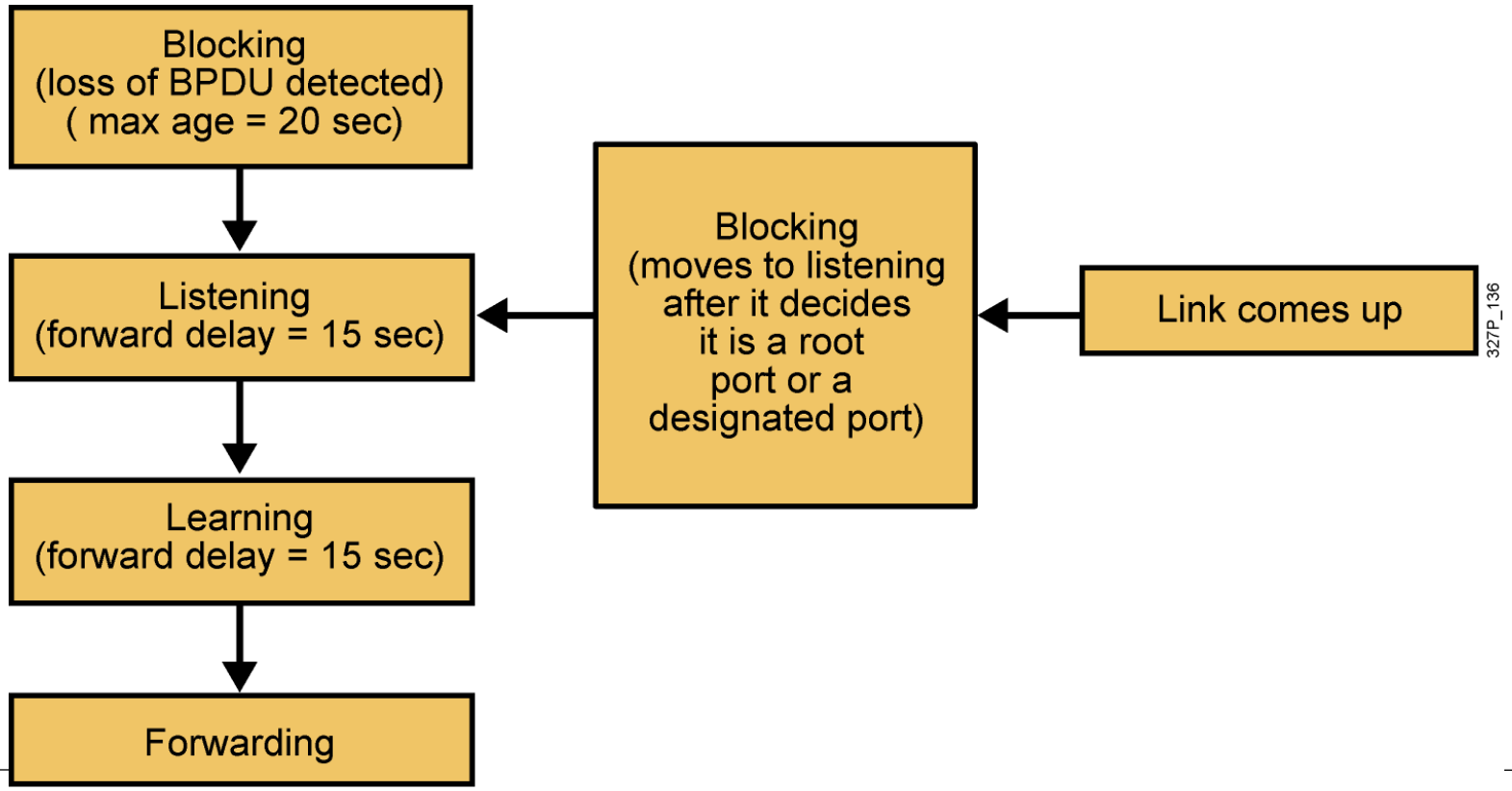
STP Root Bridge Selection



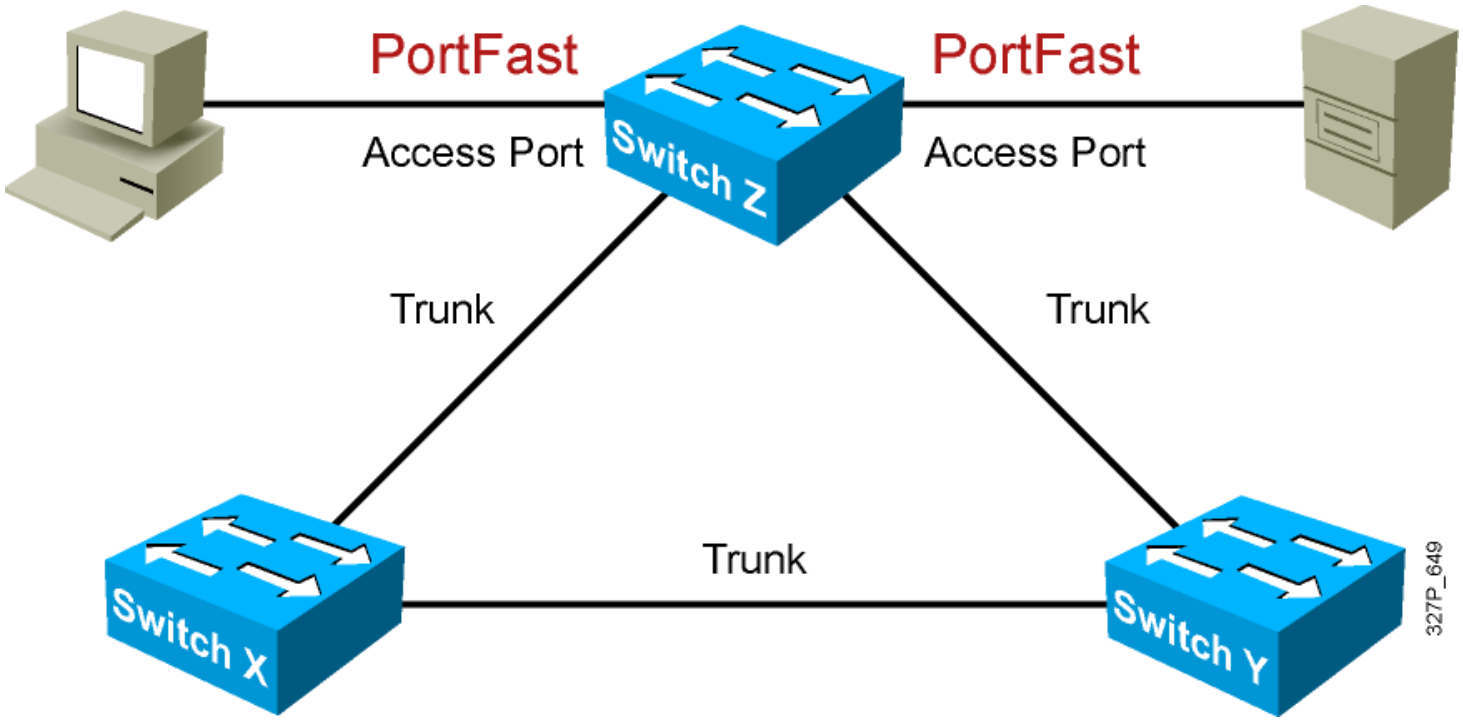
- BPDU (default = sent every 2 seconds)
- Root bridge = bridge with the lowest bridge ID
- Bridge ID = | Bridge Priority | MAC Address |

Spanning-Tree Port States

Spanning tree transits each port through several different states:



Describing PortFast



PortFast is configured on access ports, not trunk ports.

Configuring and Verifying PortFast

```
SwitchX(config-if)#
spanning-tree portfast
```

- Configures PortFast on an interface

OR

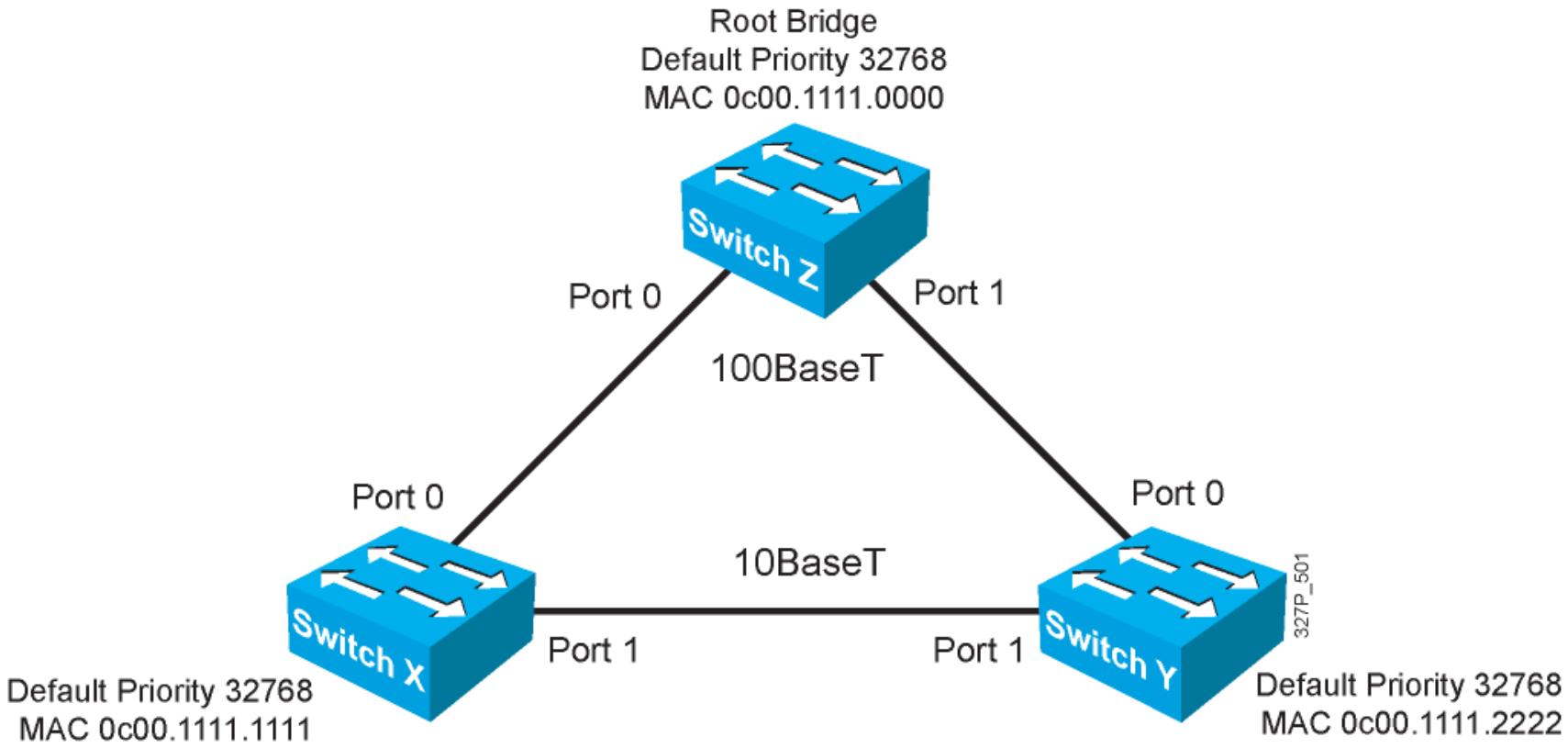
```
SwitchX(config)#
spanning-tree portfast default
```

- Enables PortFast on all non-trunking interfaces

```
SwitchX#
show running-config interface interface
```

- Verifies that PortFast has been configured on an interface

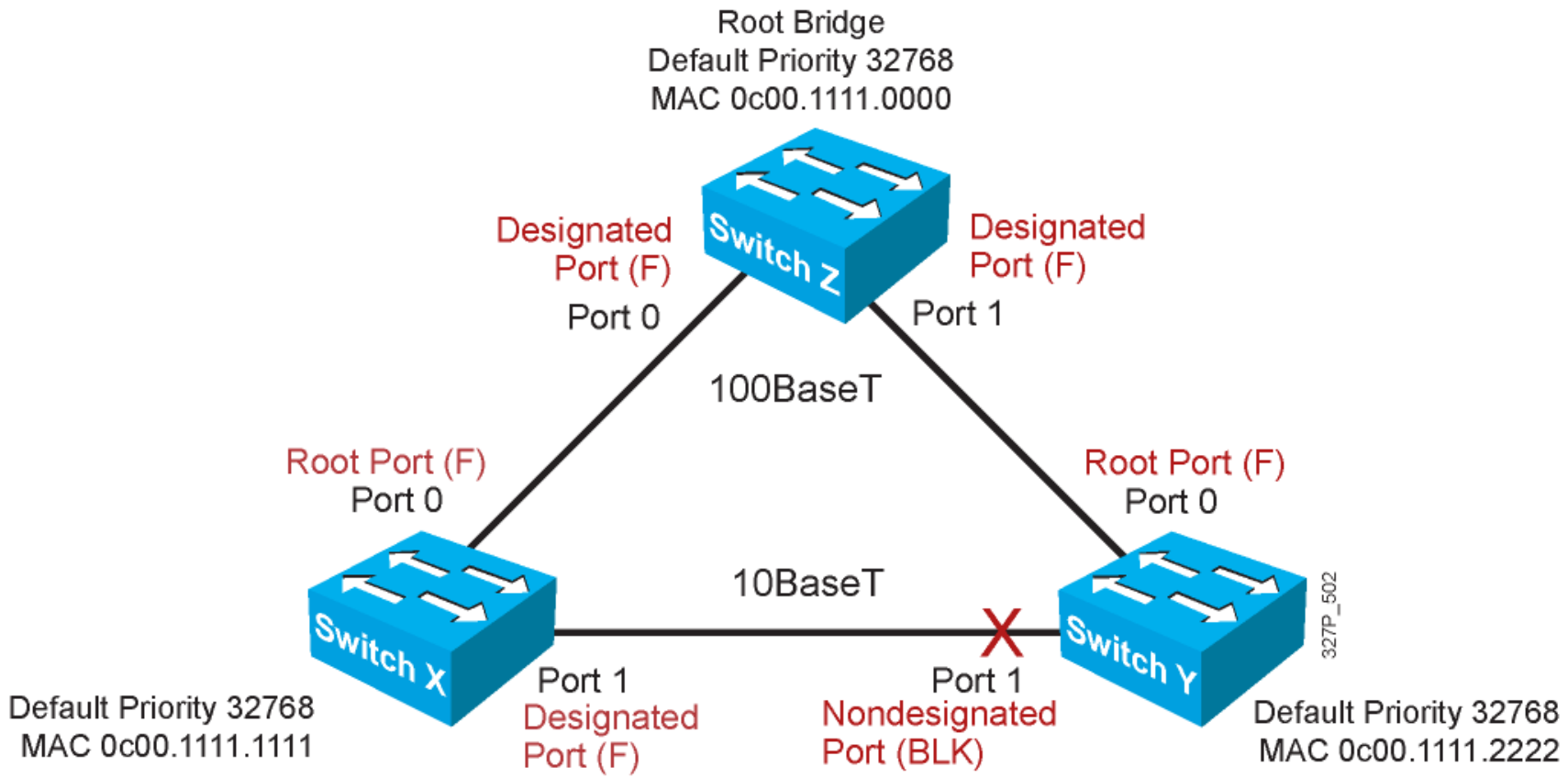
Spanning-Tree Operation Example



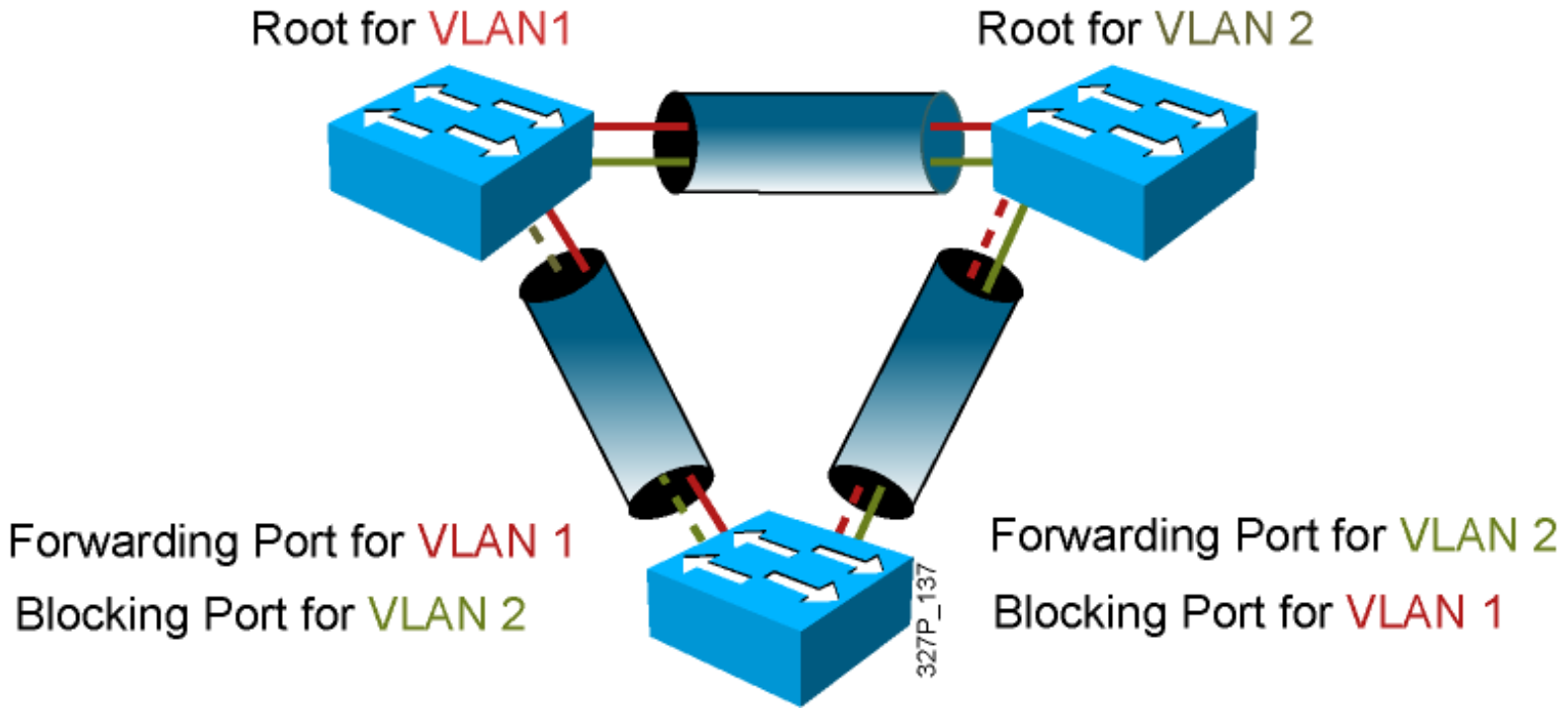
Spanning-Tree Path Cost

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 Recalculation

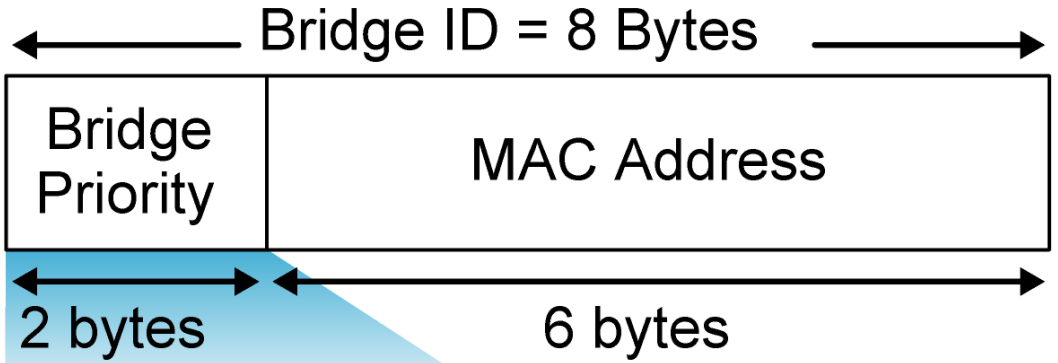


Per VLAN Spanning Tree Plus

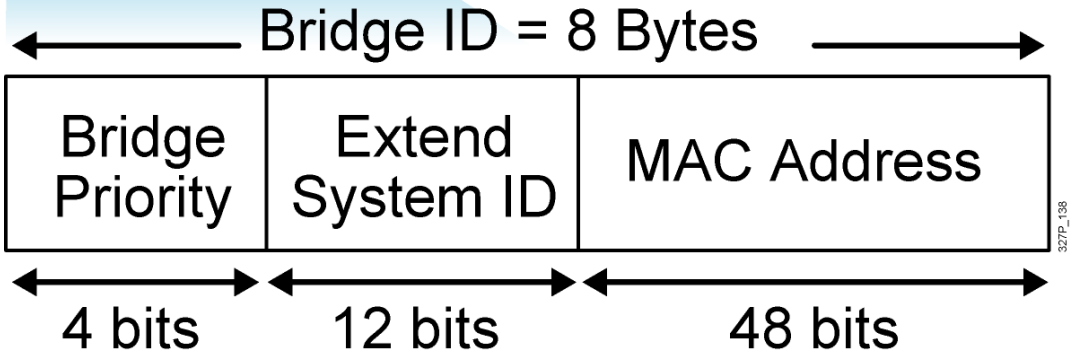


PVST+ Extended Bridge ID

Bridge ID without the extended system ID

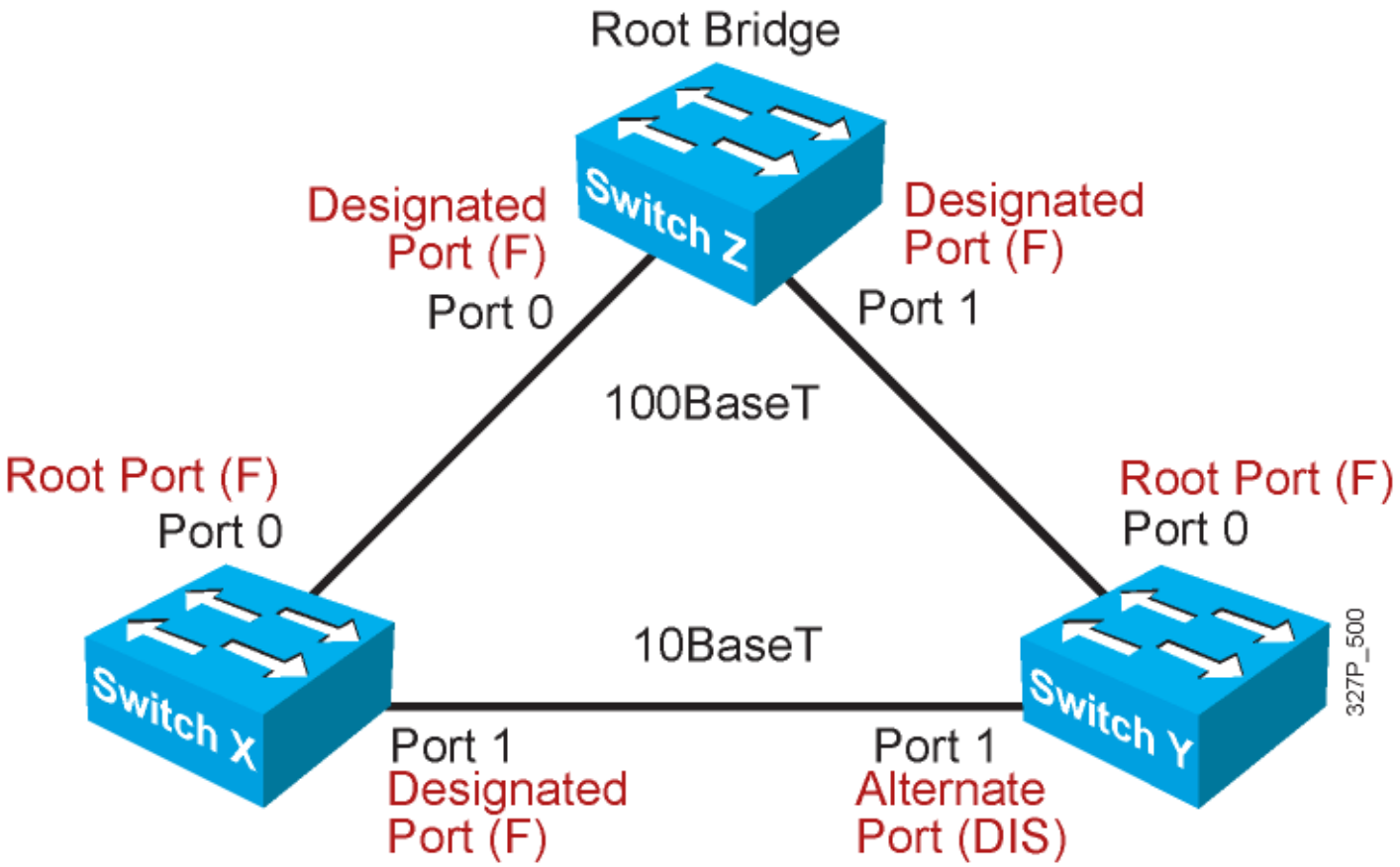


Extended bridge ID with system ID



System ID = VLAN

Rapid Spanning Tree Protocol



Default Spanning-Tree Configuration

- Cisco Catalyst switches support three types of STPs:
  - ***PVST+***
  - ***PVRST+***
  - ***MSTP***
- The default STP for Cisco Catalyst switches is PVST+ :
  - ***A separate STP instance for each VLAN***
  - ***One root bridge for all VLANs***
  - ***No load sharing***

PVRST+ Configuration Guidelines

- **Enable PVRST+.**
- **Designate and configure a switch to be the root bridge.**
- **Designate and configure a switch to be the secondary root bridge.**
- **Verify the configuration.**

PVRST+ Implementation Commands

```
SwitchX(config)#
spanning-tree mode rapid-pvst
```

- Configures PVRST+

```
SwitchX#
show spanning-tree vlan vlan# [detail]
```

- Verifies the spanning-tree configuration

```
SwitchX#
debug spanning-tree pvst+
```

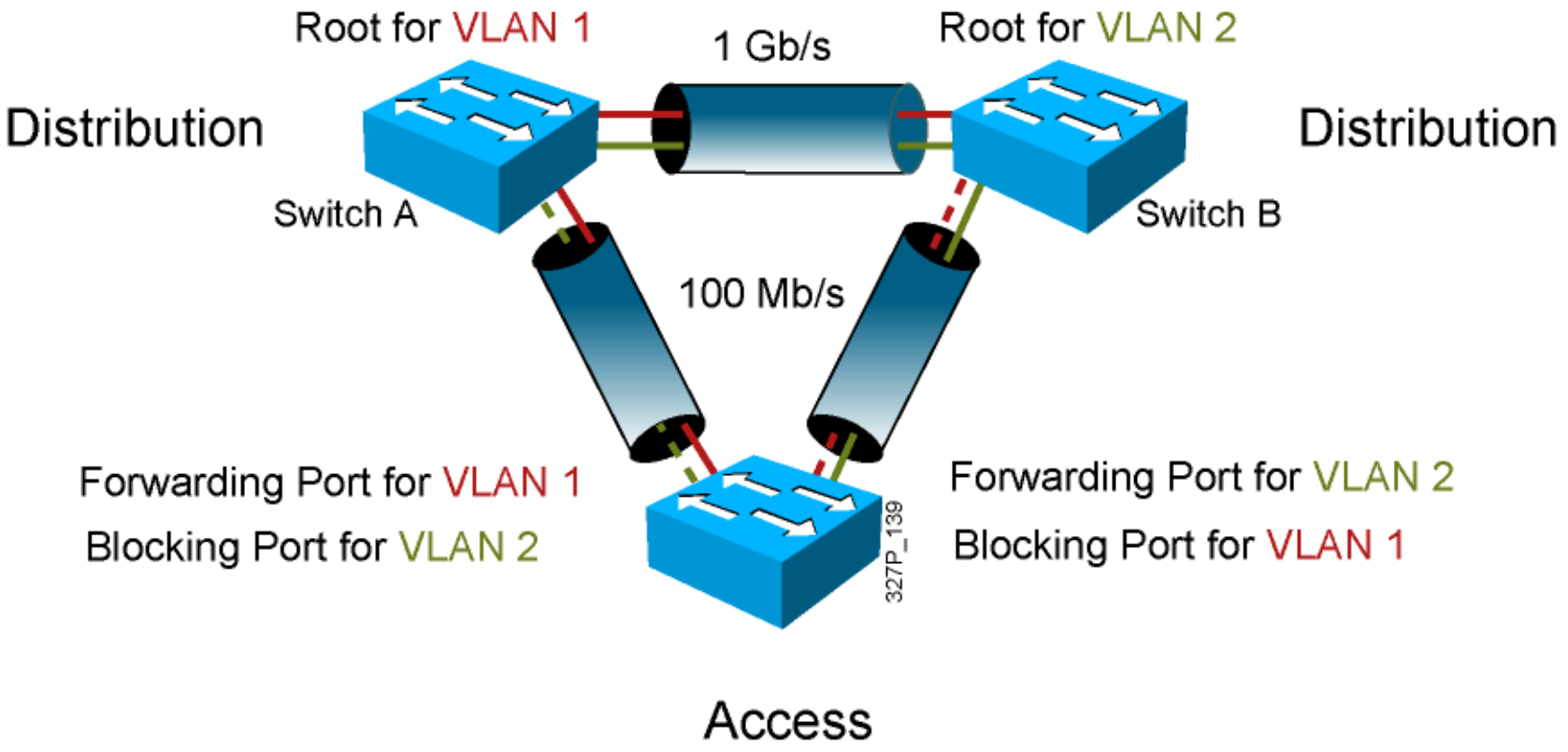
- Displays PVST+ event debug messages

Verifying PVRST+

```
SwitchX# show spanning-tree vlan 30
VLAN0030
Spanning tree enabled protocol rstp
Root ID Priority 24606
Address 00d0.047b.2800
This bridge is the root
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
Bridge ID Priority 24606 (priority 24576 sys-id-ext 30)
Address 00d0.047b.2800
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec
Aging Time 300
Interface Role Sts Cost Prio.Nbr  Type
-------- ----- --- ---  --------  ----
Gi1/1     Desg FWD  4    128.1     P2p
Gi1/2     Desg FWD  4    128.2     P2p
Gi5/1     Desg FWD  4    128.257   P2p
```

The spanning-tree mode is set to PVRST.

Configuring the Root and Secondary Bridges



Configuring the Root and Secondary Bridges: SwitchA

```
SwitchA(config)#
spanning-tree vlan 1 root primary
```

- This command forces this switch to be the root for VLAN 1.

```
SwitchA(config)#
spanning-tree vlan 2 root secondary
```

- This command configures this switch to be the secondary root for VLAN 2.

OR

```
SwitchA(config)#
spanning-tree vlan # priority priority
```

- This command statically configures the priority (increments of 4096).

Configuring the Root and Secondary Bridges: SwitchB

```
SwitchB(config)#
spanning-tree vlan 2 root primary
```

- This command forces the switch to be the root for VLAN 2.

```
SwitchB(config)#
spanning-tree vlan 1 root secondary
```

- This command configures the switch to be the secondary root VLAN 1.

OR

```
SwitchB(config)#
spanning-tree vlan # priority priority
```

- This command statically configures the priority (increments of 4096).