# LAN Switching and VLAN

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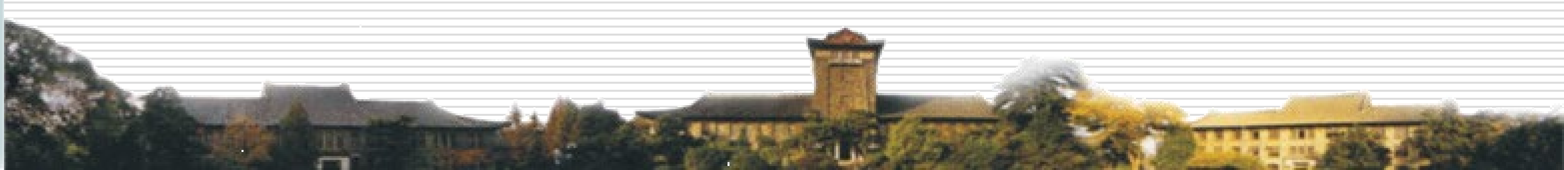

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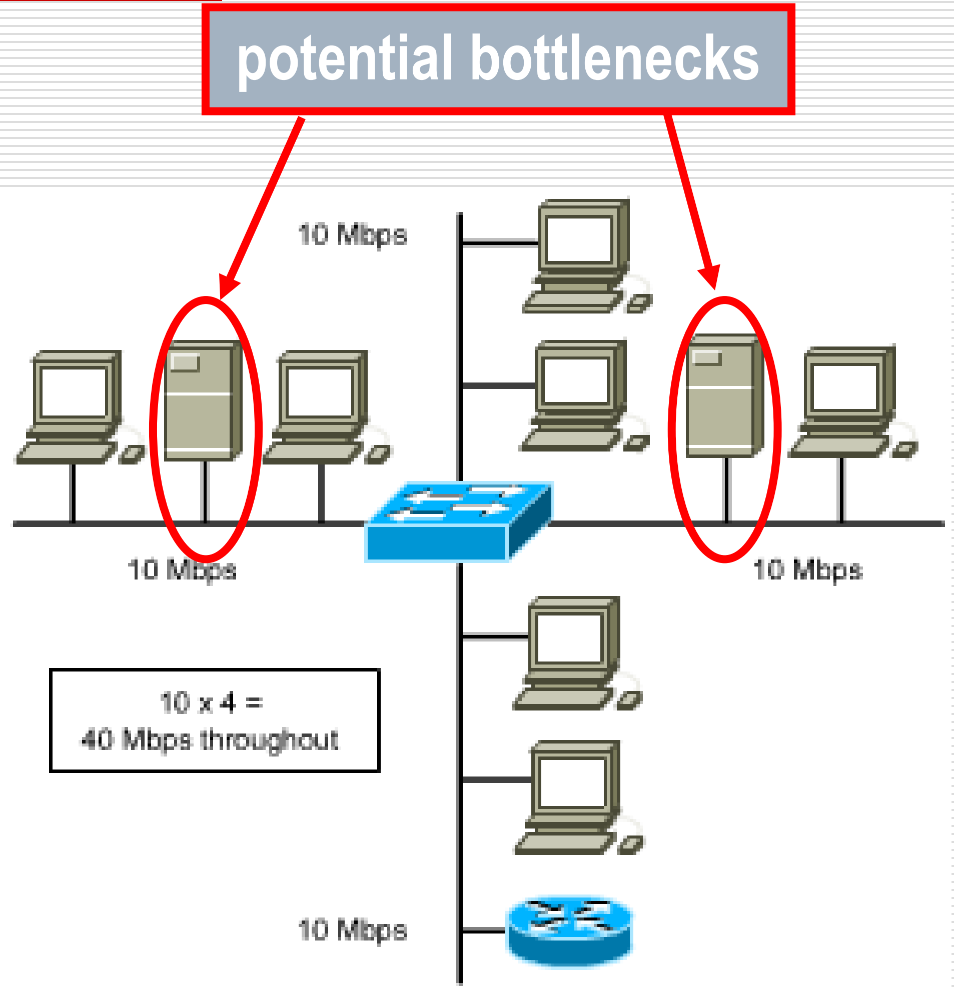
# Switch Operation

- Switches perform two basic functions:
  - Building and maintaining switching tables (similar to a bridge table) based on MAC addresses
  - Switching frames out the interface to the destination

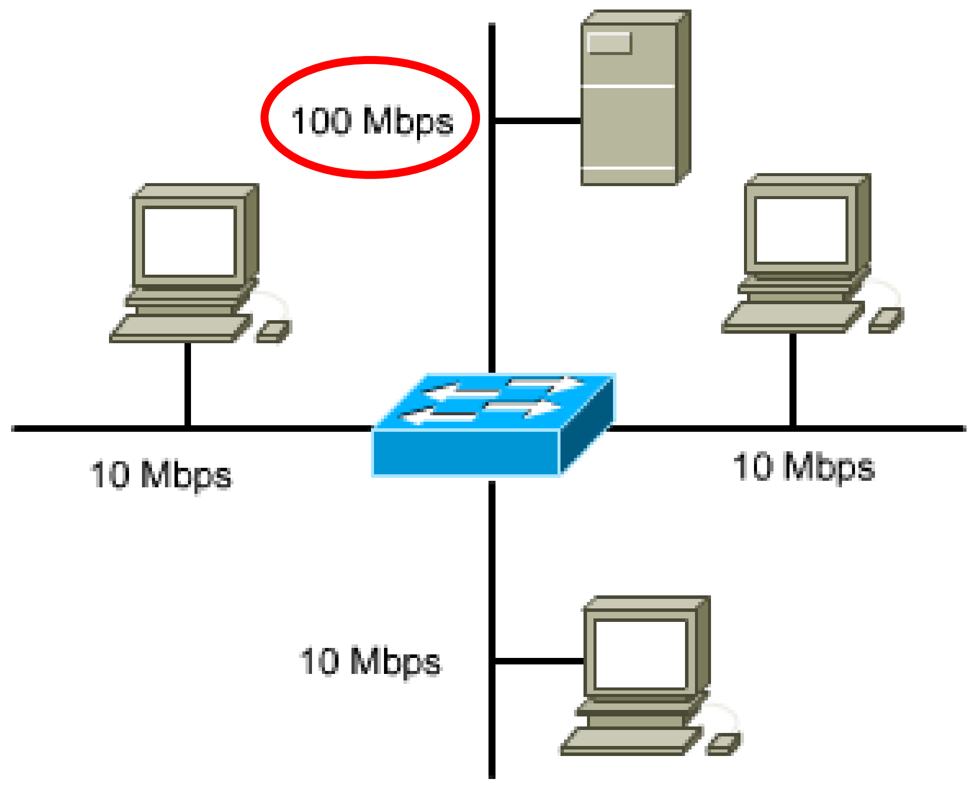
# Symmetric Switching

- symmetric switching provides switched connections between ports with the same bandwidth (10/10 Mbps or 100/100 Mbps)
- can cause bottlenecks as users try to access servers on other segments.



# Asymmetric Switching

- asymmetric switching reduces the likelihood of a potential bottleneck at the server by attaching the segment with the server to a higher bandwidth port (100 Mbps)
- asymmetric switching requires memory buffering in the switch



# Memory Buffering

- Area of memory in a switch where destination and transmission data are stored until it can be switched out the correct port.
  - Port-based memory buffering
    - packets are stored in a queue on each port
    - possible for one packet to delay transmission of other packets because of a busy destination port
  - Shared memory buffering
    - common memory buffering shared by all ports
    - allows packets to be RX on one port and TX out another port without changing it to a different queue.

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# Switching Methods

- Store-and-Forward
  - The switch receives the entire frame, calculating the CRC at the end, before sending it to the destination
- Cut-through
  - A switch adds latency. It can be reduced by using cut-through switching method
  - Fast forward switching--only checks the destination MAC before immediately forwarding the frame
  - Fragment Free--reads the first 64 bytes to reduce errors before forwarding the frame

# Two Switching Methods

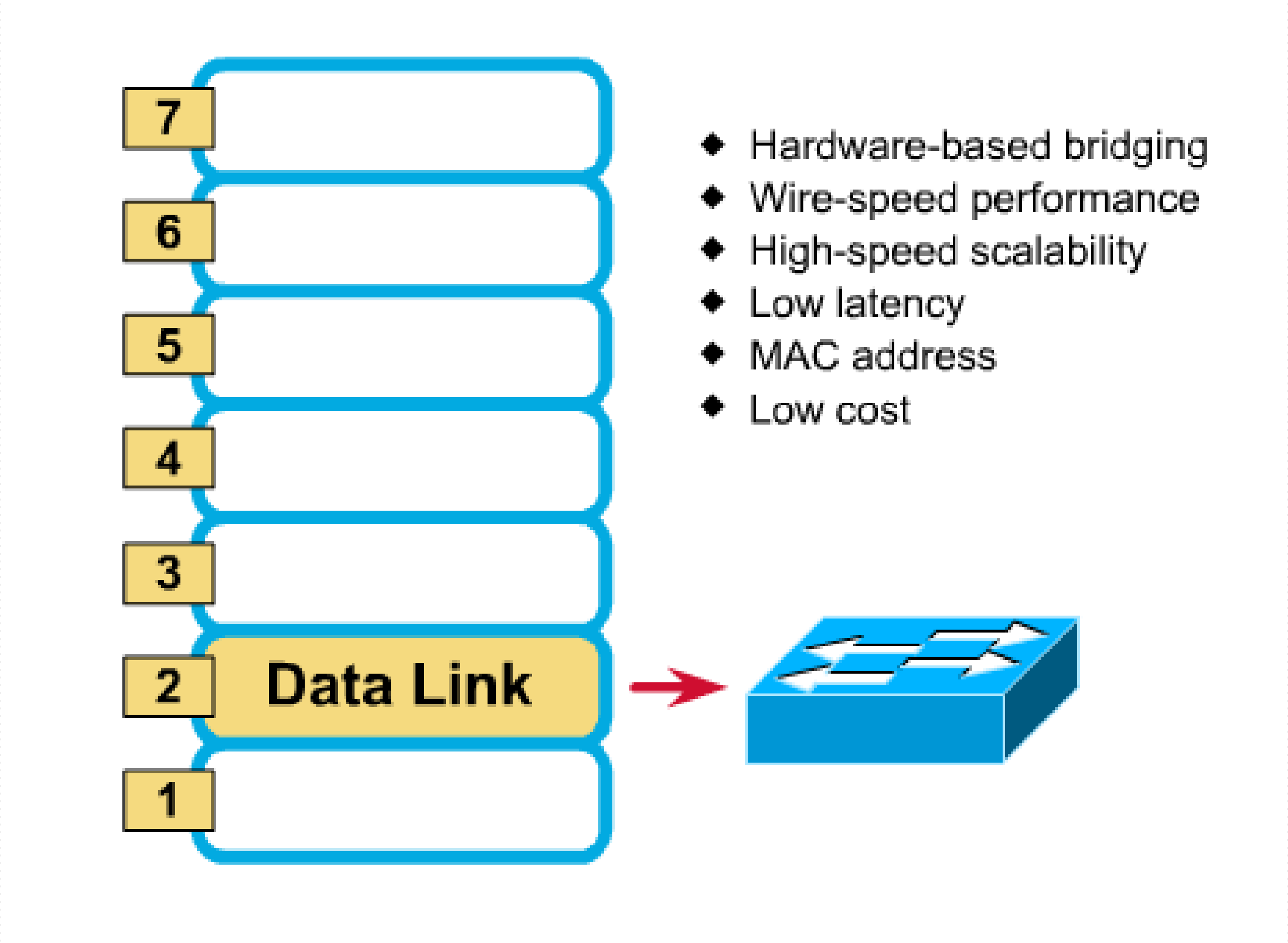
| 7 bytes | 1 byte | 6 bytes | 6 bytes | 2 bytes | Max 1500 bytes | 4 bytes |
|---|---|---|---|---|---|---|
| Preamble | SFD | Dest. Address | Source Address | Length | Data | FCS |

Fast Forward
Lowest Latency
No error checking
(Default)

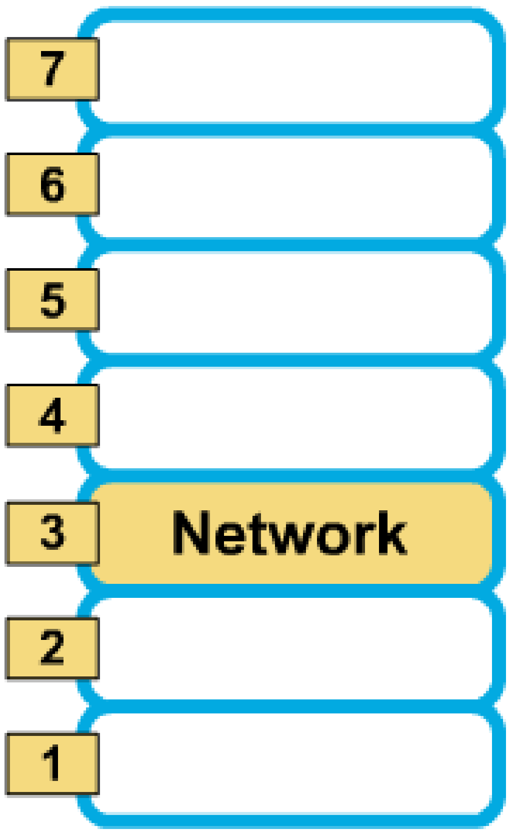
Fragment Free
Low Latency
Checks for collisions
(Filters most errors)

Store-and-Forward
Highest Latency
All errors filtered

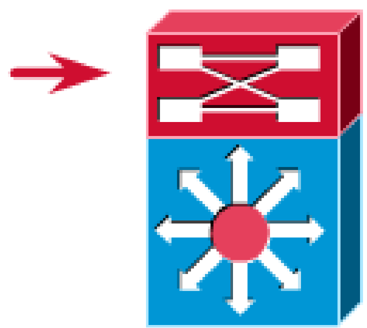
# Layer 2 Switching



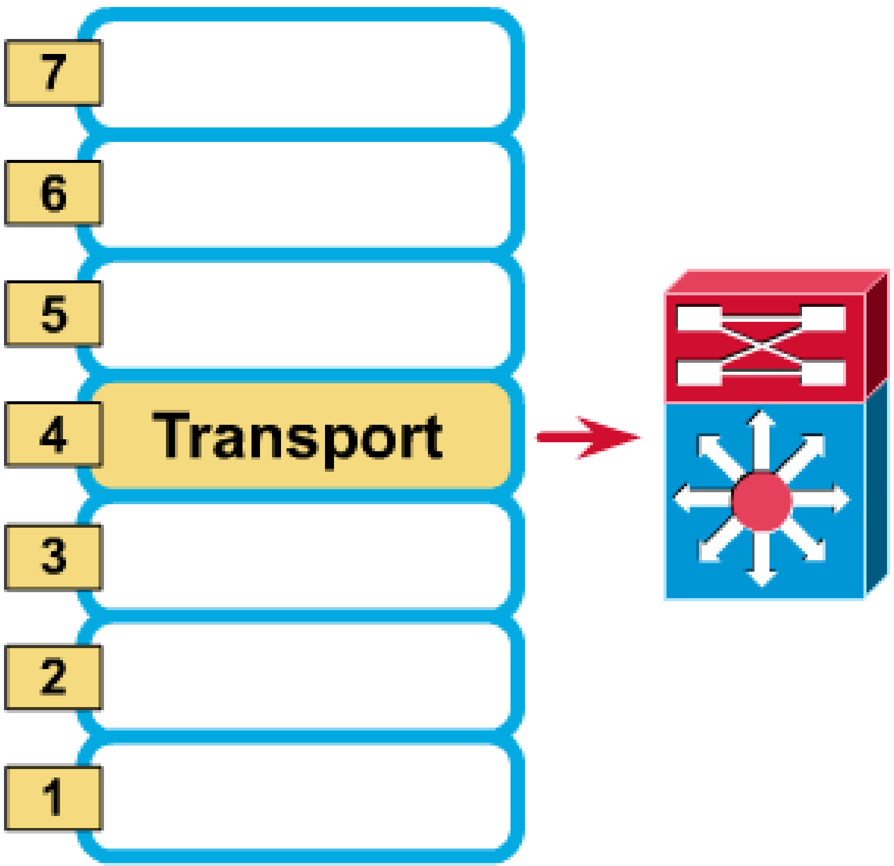
# Layer 3 Switching




- Hardware-based packet forwarding
- High-performance packet switching
- High-speed scalability
- Low latency
- Lower per-port cost
- Flow accounting
- Security
- QoS



# Layer 4 Switching




- Based on Layer 3
- Based on application-related information
- TCP fields
- UDP fields
- QoS
- Granular Traffic Control

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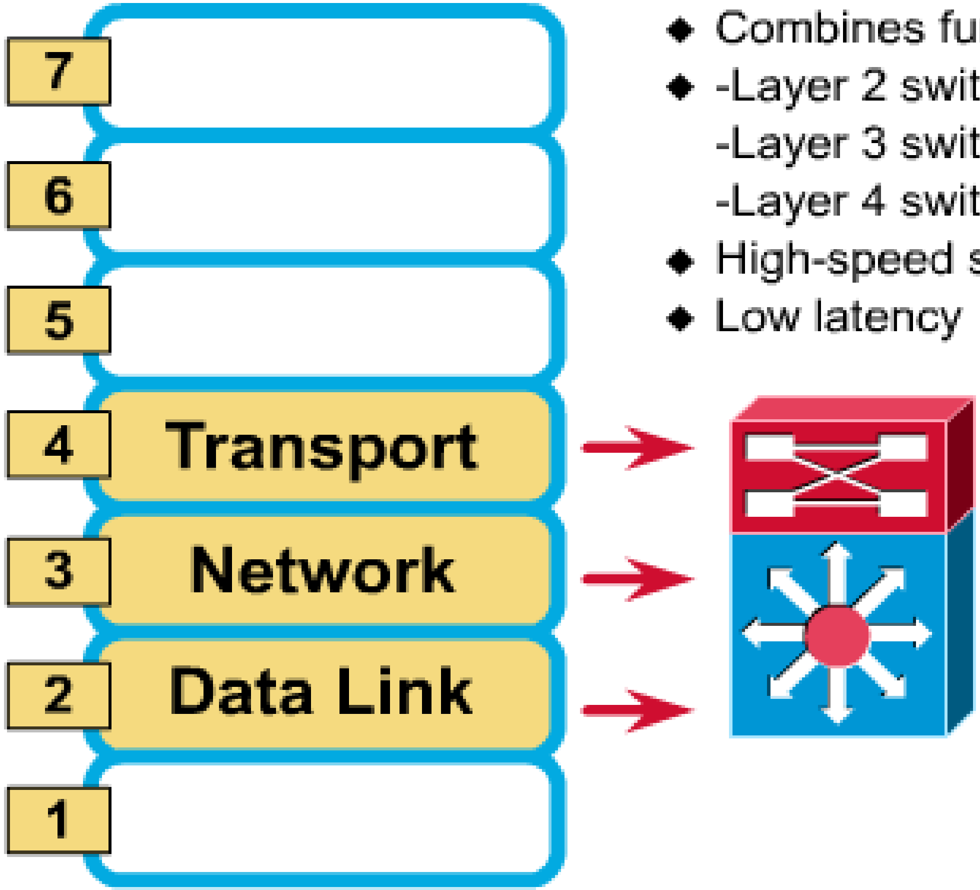
# Multilayer Switching




- Combines functionality of:
- -Layer 2 switching
  -Layer 3 switching
  -Layer 4 switching
- High-speed scalability
- Low latency

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- Switching
- The Spanning-Tree Protocol
- VLAN
  - Introduction of VLAN
  - VLAN Architecture
  - VLAN Implementation
  - Routing Between VLANs

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# Bridging Loops

- Loops may occur in a network for a variety of reasons.
  - Usually loops in networks are the result of a deliberate attempt to provide redundancy.
  - Can also occur by configuration error
    - Two primary reasons loops can be absolutely disastrous in a bridged network:
      - broadcast loops
      - bridge-table corruption

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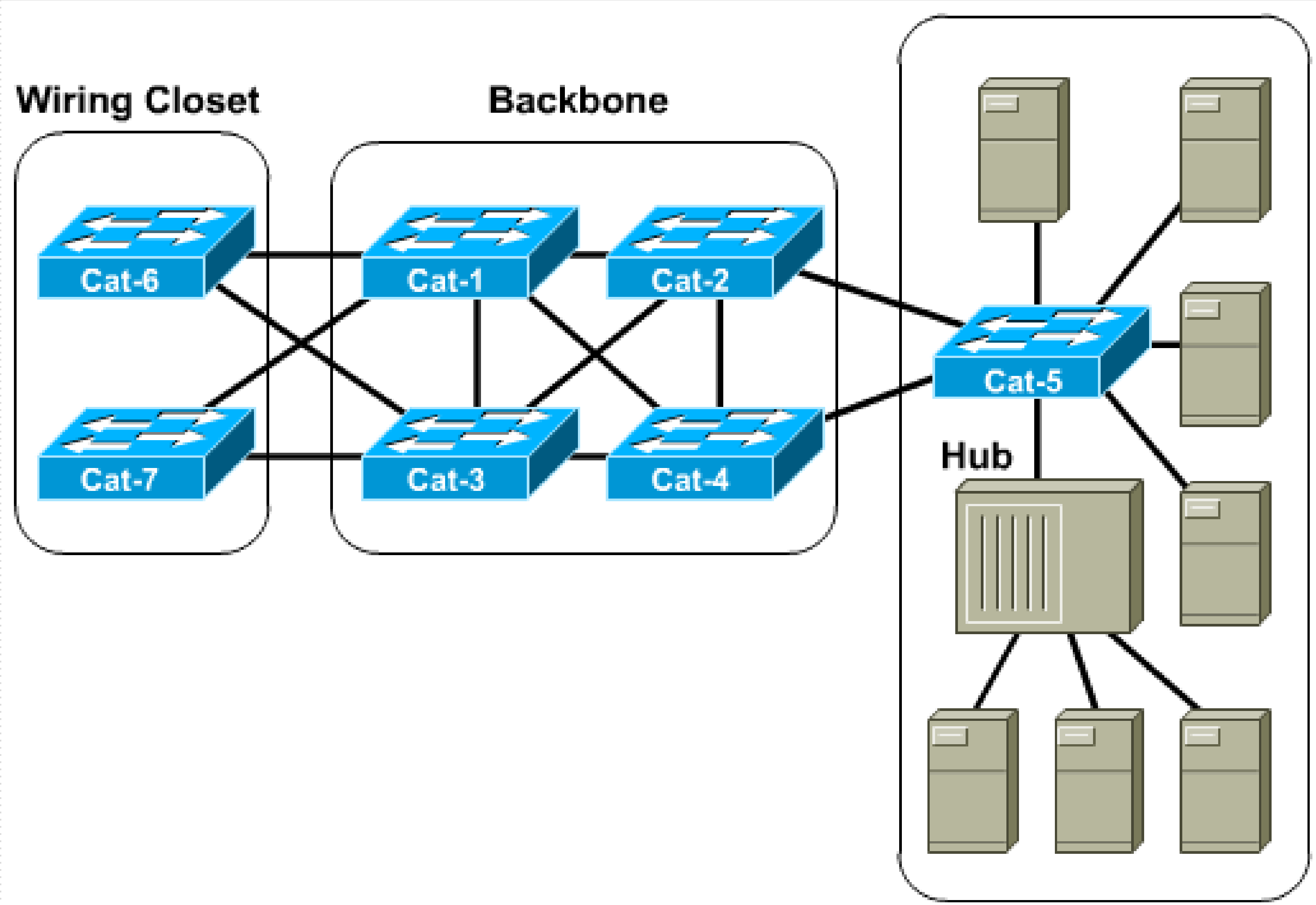
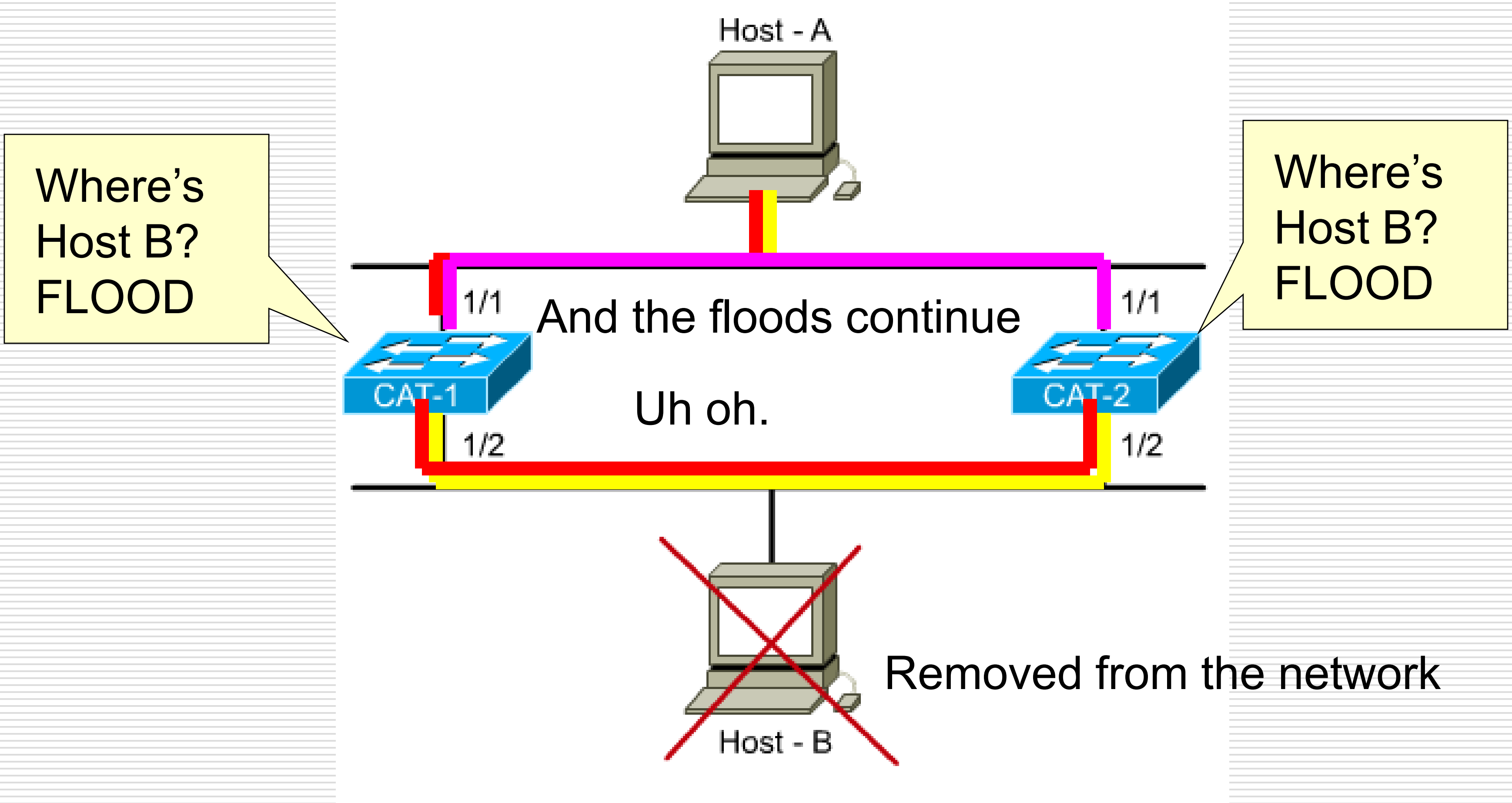
# Redundancy Creates Loops



# L2 Loops

- Broadcasts and Layer 2 loops can be a dangerous combination.
- Ethernet frames have no TTL field
- After an Ethernet frame starts to loop, it will probably continue until someone shuts off one of the switches or breaks a link
- The switches will flip flop the bridging table entry for Host A (creating extremely high CPU utilization).

# L2 Loops - Flooded unicast frames



# Overview of STP

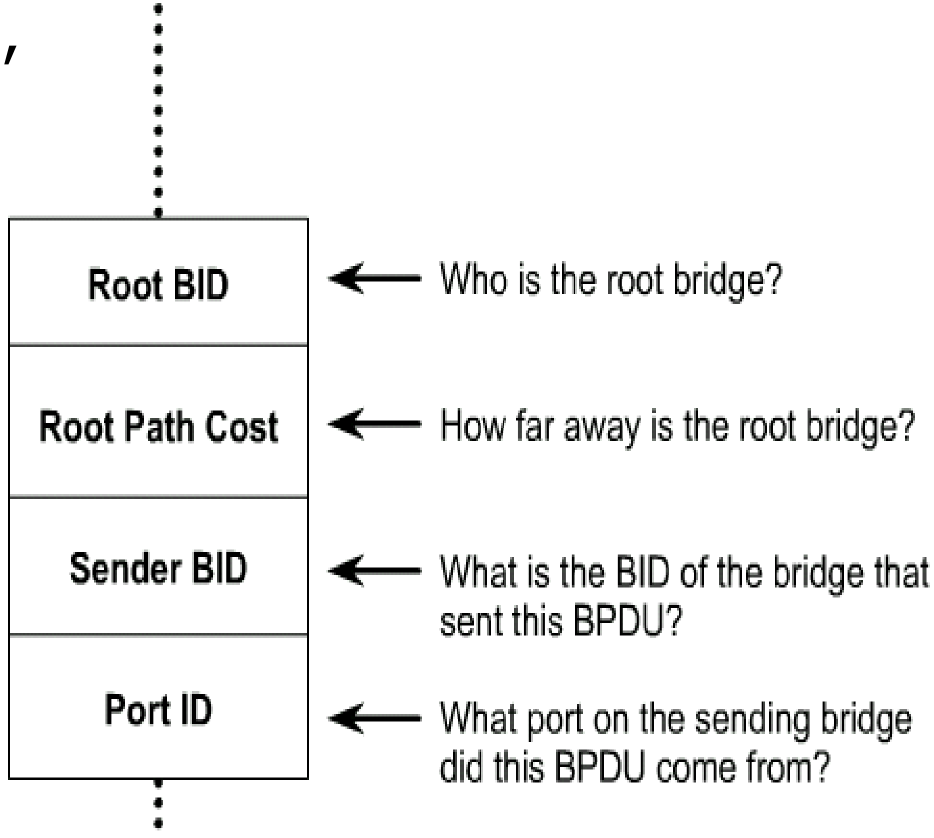
- Elements of the Spanning Tree Protocol
  - Main function: allow redundant paths in a switched/bridged network without incurring latency from the effects of loops.
  - STP prevents loops by calculating a stable spanning-tree network topology
  - Spanning-tree frames (called bridge protocol data units--BPDUs) are used to determine the spanning-tree topology

# STP Decision Sequence

- Spanning Tree always uses the same four-step decision sequence:
  - Lowest root BID (Bridge Identification)
  - Lowest path cost to root bridge
  - Lowest sender BID
  - Lowest port ID

# BPDUs

- STP establishes a root node, called the root bridge
- The resulting tree originates from the root bridge.
- Redundant links that are not part of the shortest path tree are blocked.
- Data frames received on blocked links are dropped.
- The message that a switch sends, allowing the formation of a loop free logical topology, is BPDU




**BPDUs are switch-to-switch traffic; they do not carry end-user traffic.**

# STP BPDU

BPDU 字段

| 字段编号 | 字节数 | 字段 |
|---|---|---|
| 4 | 2 | 协议 ID |
| | 1 | 版本 |
| | 1 | 消息类型 |
| | 1 | 标志 |
| 8 | 8 | 根 ID |
| | 4 | 路径开销 |
| | 8 | 网桥 ID |
| | 2 | 端口 ID |
| 12 | 2 | 消息老化时间 |
| | 2 | 最大老化时间 |
| | 2 | Hello 时间 |
| | 2 | 转发延迟 |

# Bridge Identification/BID

- A Bridge ID (BID): 8 bytes
  - The high-order BID subfield(2 bytes): bridge priority
    - $2^{16}$ possible values: 0-65,535 (default: 32,768)
    - Typically  expressed in a decimal format
  - The low-order subfield(6 bytes): a MAC address assigned to the switch
    - Expressed in hexadecimal format
- *STP cost values:* ***lower costs are better.***

# Electing the Root Switch

- The switches elect a single root switch by looking for the switch with the lowest BID (often referred to as a root war).
- If all the switches are using the default bridge priority of 32,768, the lowest MAC address serves as the tie-breaker.

# Path Cost

| Bandwidth | STP Cost |
|---|---|
| 4 Mbps | 250 |
| 10 Mbps | 100 |
| 16 Mbps | 62 |
| 45 Mbps | 39 |
| 100 Mbps | 19 |
| 155 Mbps | 14 |
| 622 Mbps | 6 |
| 1 Gbps | 4 |
| 10 Gbps | 2 |

**Bridges use the concept of cost to evaluate how close they are to other bridges.**

# Five STP States

- States are established by configuring each port according to policy
- Then the STP modifies the states based on traffic patterns and potential loops
- The default order of STP states are:
  - Blocking--no frames forwarded, BPDUs heard
  - Listening--no frames forwarded, listening for data frames
  - Learning--no frames forwarded, learning addresses
  - Forwarding--frames forwarded, learning addresses
  - Disabled--no frames forwarded, no BPDUs heard

blocking
20s
15s
15s
forwarding

# Initial STP Convergence

- When the network first starts, all the bridges flood the network with a mix of BPDU information.
- Immediately, they apply the decision sequence allowing them to hone in on the set of BPDUs that form a single spanning tree for the entire network.

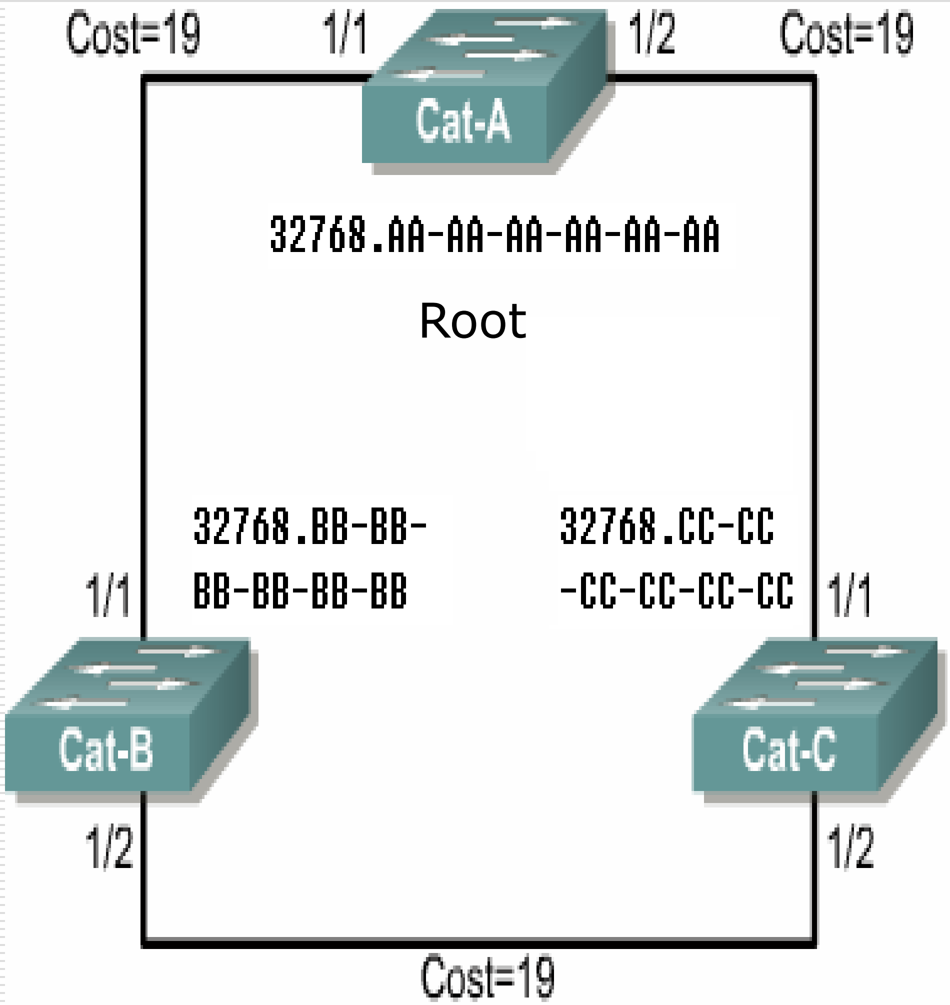
**(Step 1) *Root switch decision:* A single root bridge is elected to act as the central point of this network**

**(Step 2) *Electing the root ports:* All the remaining bridges calculate a set of root ports**

**(Step 3) *Electing the designated ports:* All the remaining bridges calculate a set of designated ports**

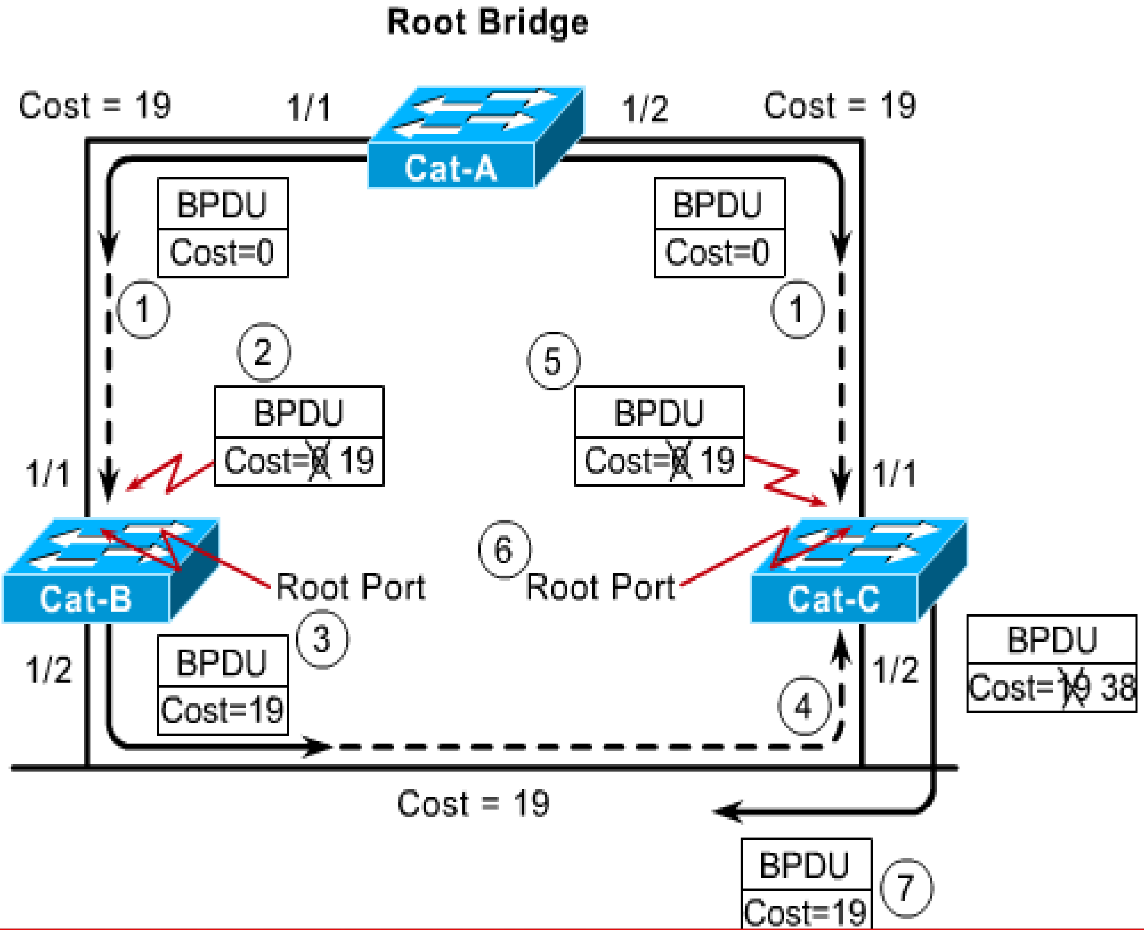
# Step1: Root Switch Decision

- Announce itself as the root
- Checking all BPDUs received on the port as well as the BPDU that would be sent on that port
- For each arrived BPDU, if it is lower in value than the existing BPDU saved for the port
  - The old value is replaced
  - The sender of BPDU is accepted as the new root



# Step2: Electing the Root Ports

- Every non-root bridge must select one root port.
  - The root port of a bridge is the port that is closest to the root bridge.
  - The root path cost is the cumulative cost of all links to the root bridge.



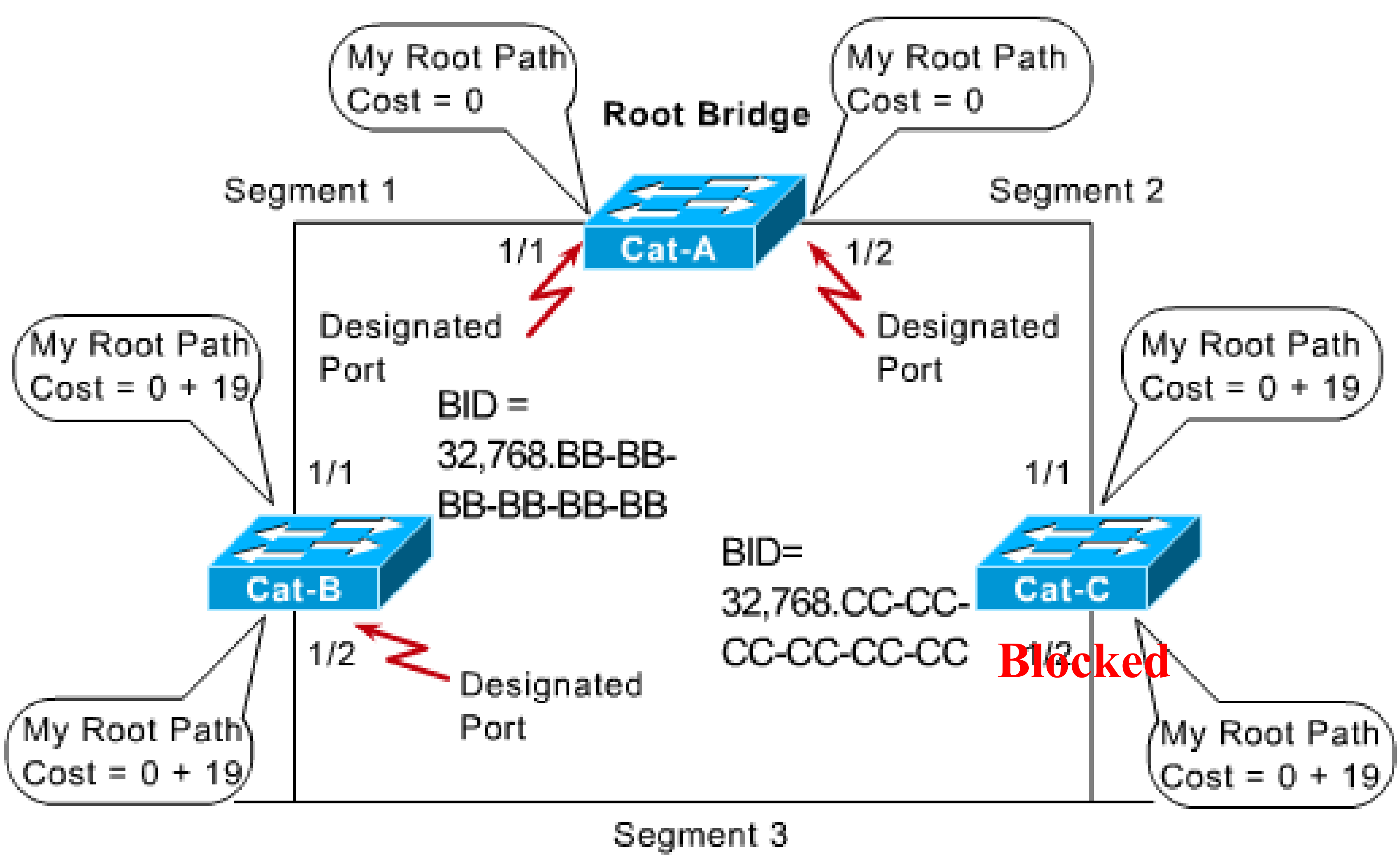

STP costs are incremented as BPDUs are received on a port, not as they are sent out a port.

# Step3: Electing Designated Ports(I)

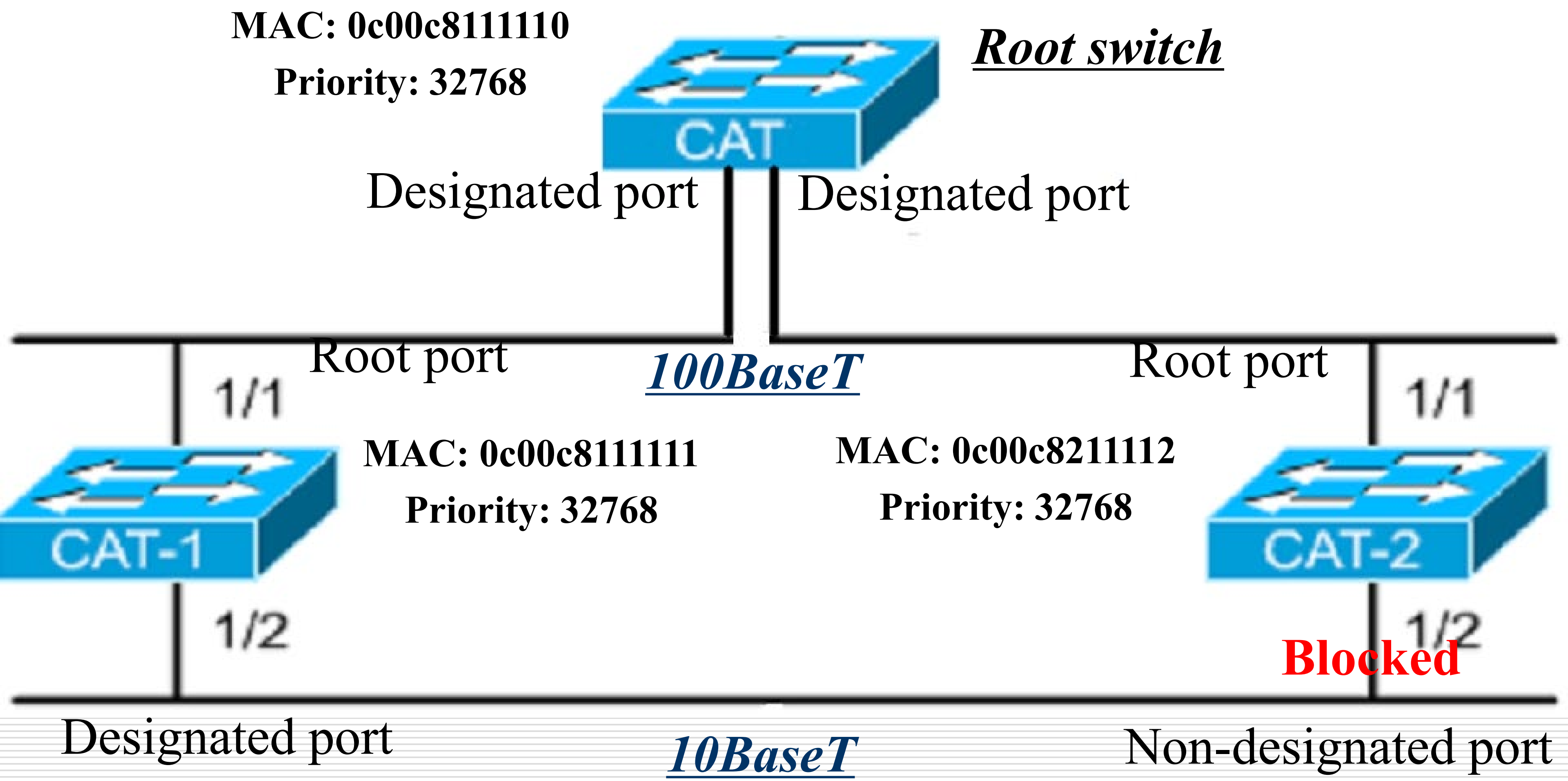
- Each segment has one designated port
  - Functions as the single bridge /switch port that both sends and receives traffic to and from that segment and the root bridge.
- The bridge/switch containing the designated port for a given segment is referred to as the *designated bridge* for that segment.
- All the bridges/switches will block the non-designated ports on them

**Every active port on the root bridge becomes a designated port**

# Step3: Electing Designated Ports(II)



# An Example of STP



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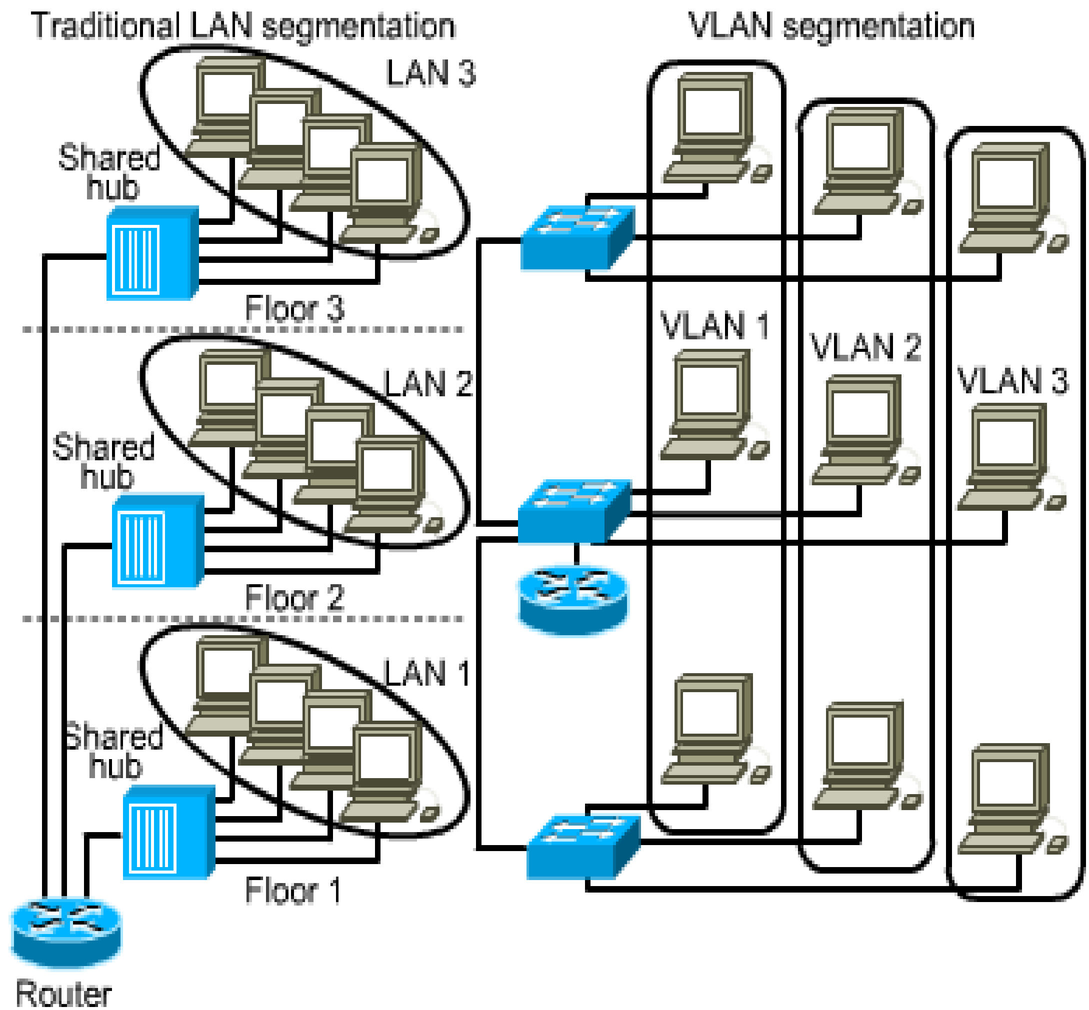
# Existing Shared LAN Configurations

- In a typical shared LAN...
  - Users are grouped physically based on the hub they are plugged into
  - Routers segment the LAN and provide broadcast firewalls
- In VLANs...
  - you can group users logically by function, department or application in use
  - configuration is done through proprietary software

# Differences between LANs & VLANs

- VLANs...
  - work at Layer 2 & 3
  - control network broadcasts
  - allow users to be assigned by net admin.
  - provide tighter network security. How?



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# VLANs (IEEE 802.1q)

- Characteristics
  - A logical grouping of network devices or users that are not restricted to a physical switch segment.
  - The devices or users in a VLAN can be grouped by function, department, application, and so on, regardless of their physical segment location.
  - A VLAN creates a single broadcast domain that is not restricted to a physical segment and is treated like a subnet.
  - VLAN setup is done in the switch by the network administrator using the vendor's software.

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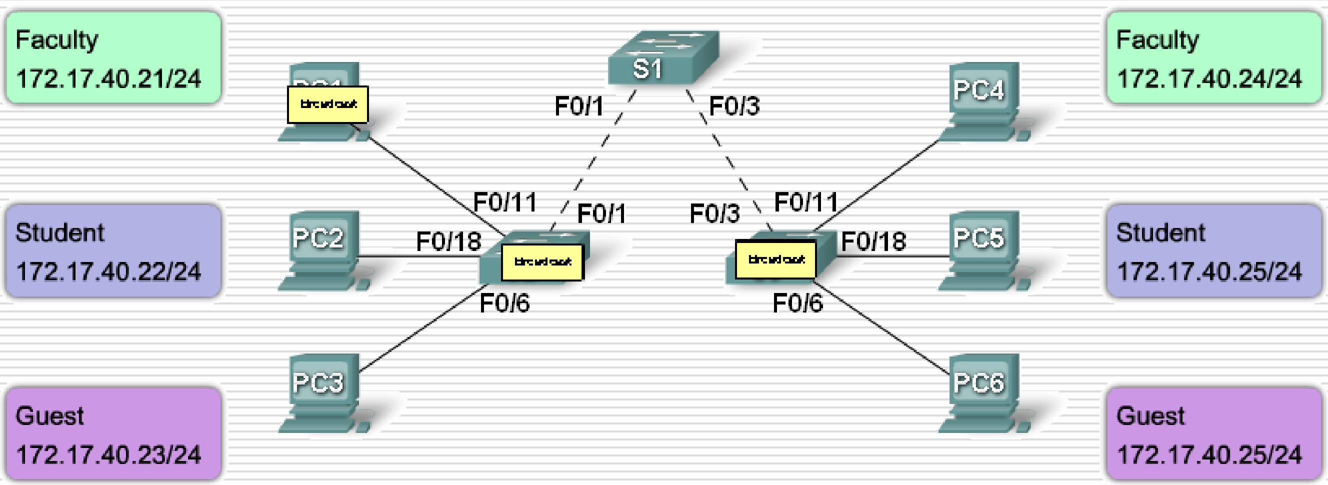
# Grouping Users

- VLANs can logically segment users into different subnets (broadcast domains)
- Broadcast frames are only switched between ports on the switch or switches with the same VLAN ID.
- Users can be logically group via software based on:
  - port number
  - MAC address
  - protocol being used
  - application being used

# 没有VLAN 时的网络广播



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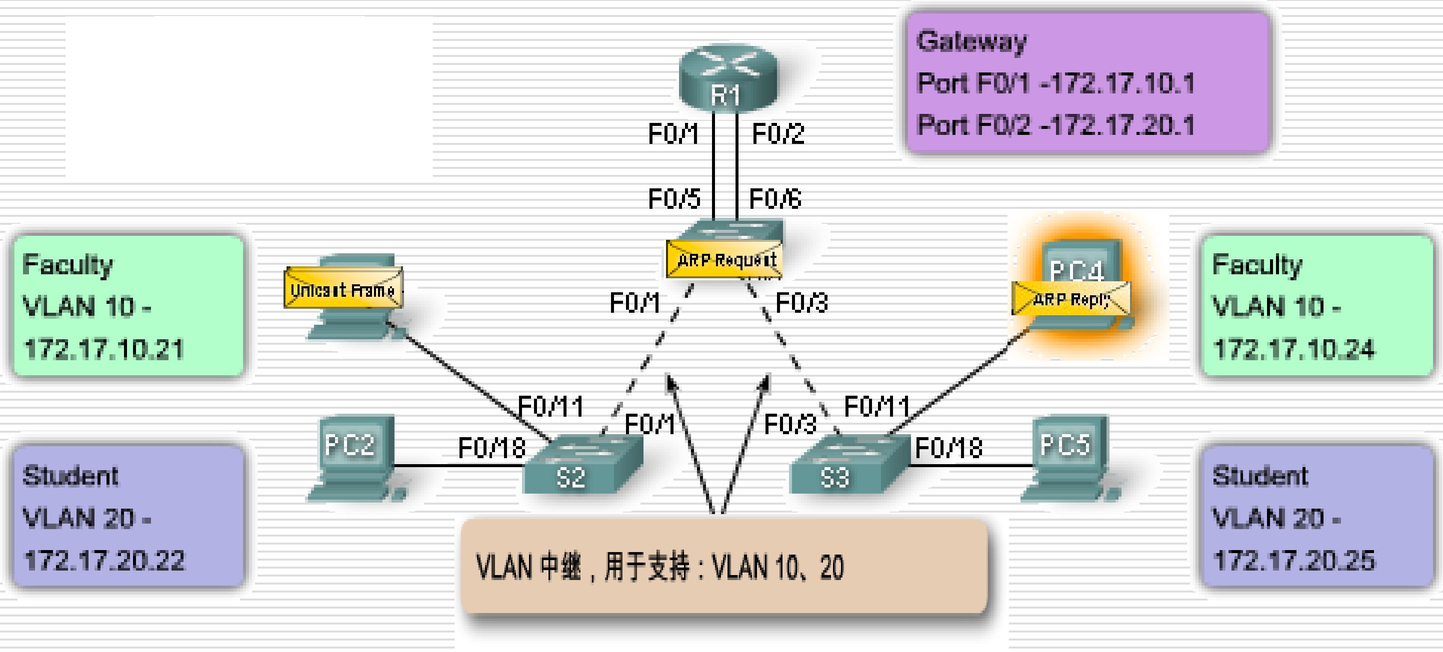
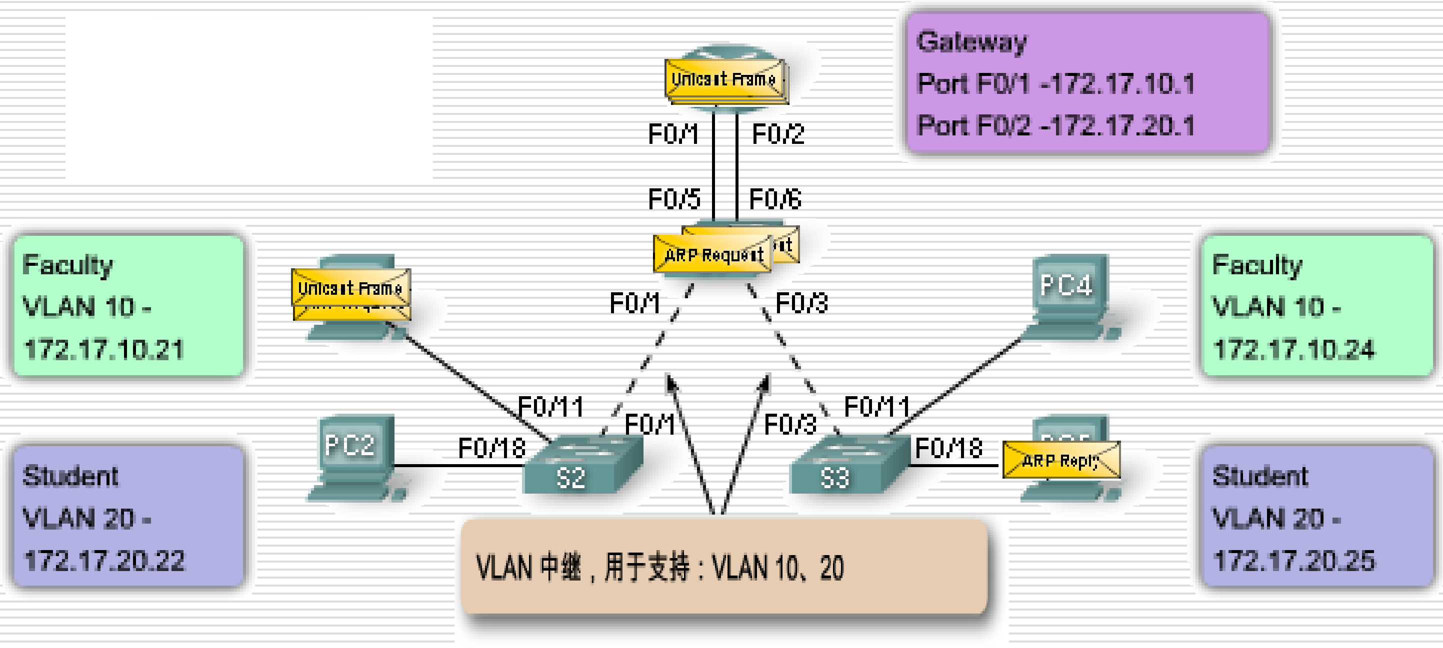
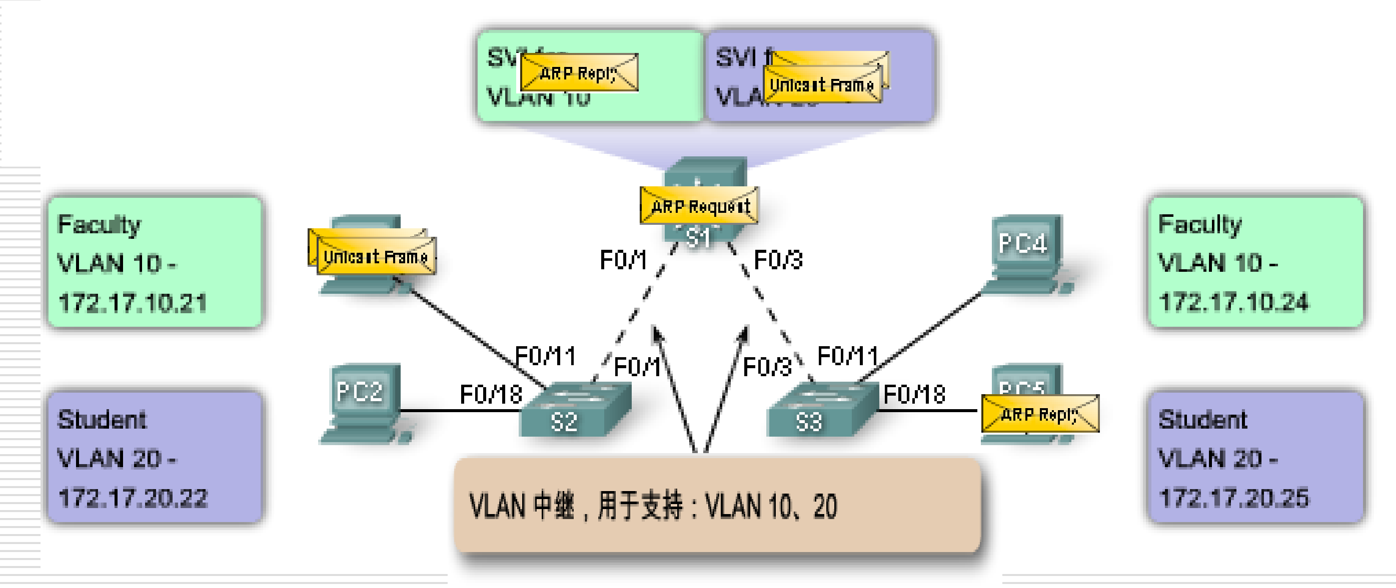
# 划分了VLAN的网络广播



# VLAN 间通信


Gateway
Port F0/1 -172.17.10.1
Port F0/2 -172.17.20.1
Unicast Frame
F0/1
F0/2
F0/5
F0/6
ARP Request
Faculty
VLAN 10 -
172.17.10.21
Unicast Frame
F0/1
F0/3
PC4
Faculty
VLAN 10 -
172.17.10.24
F0/11
F0/1
F0/3
F0/11
PC2
F0/18
S2
S3
F0/18
ARP Reply
Student
VLAN 20 -
172.17.20.22
Student
VLAN 20 -
172.17.20.25
VLAN 中继，用于支持：VLAN 10、20

# VLAN 和第 3 层转发来控制广播域



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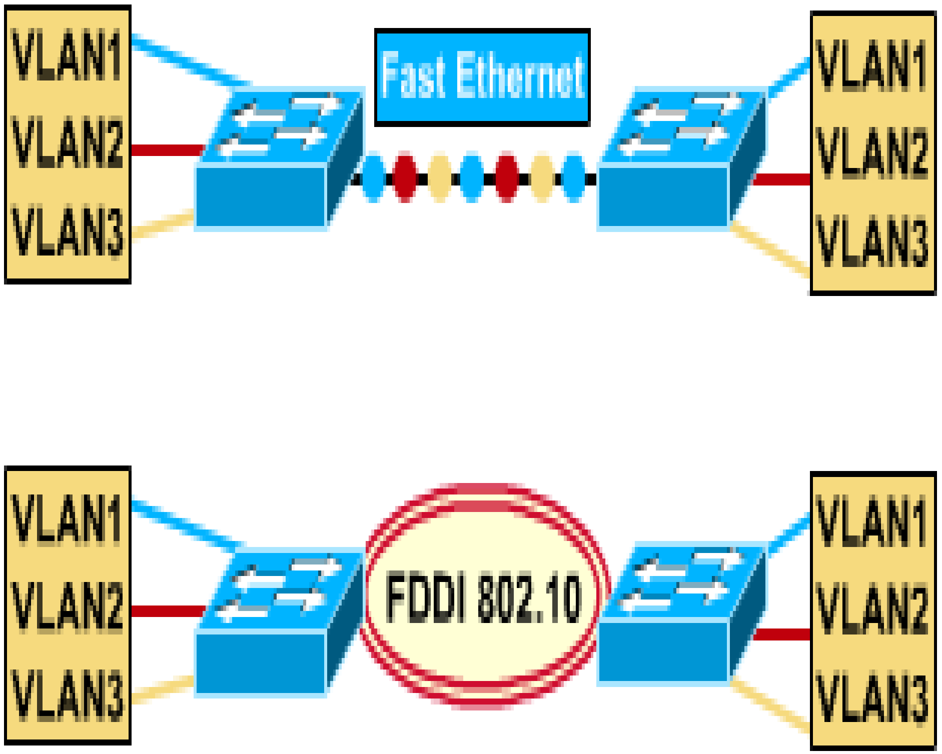
# VLANs Across the Backbone

- VLAN configuration needs to support backbone transport of data between interconnected routers and switches.
- The backbone is the area used for inter-VLAN communication
- The backbone should be high-speed links, typically 100Mbps or greater



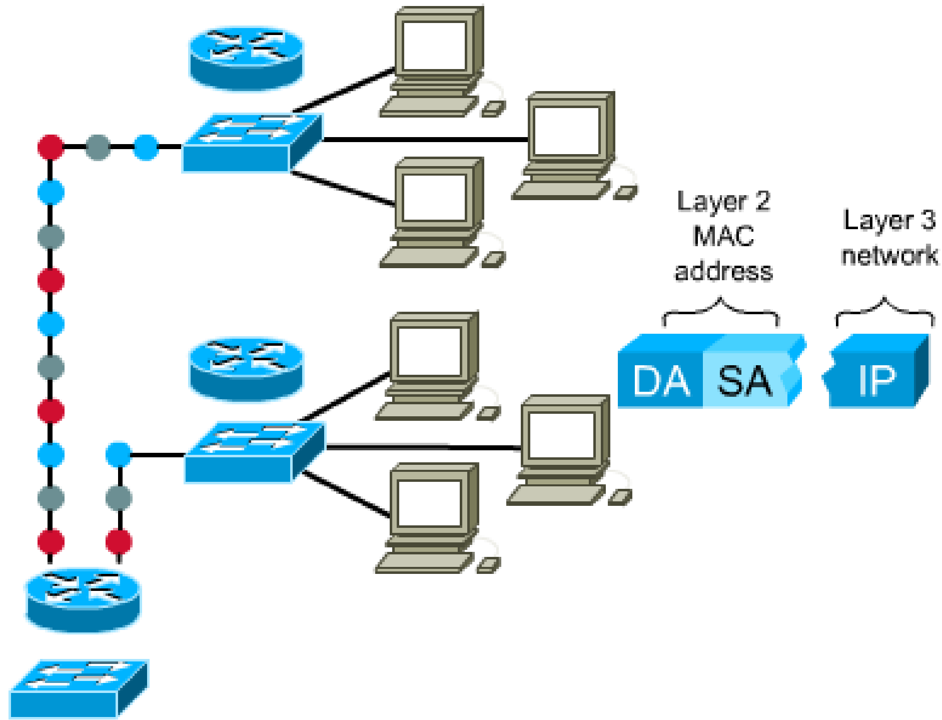
# Router's Role in a VLAN

- A router provides connection between different VLANs
- For example, you have VLAN1 and VLAN2.
  - Within the switch, users on separate VLANs cannot talk to each other (benefit of a VLAN!)
  - However, users on VLAN1 can email users on VLAN2 but they need a router to do it.

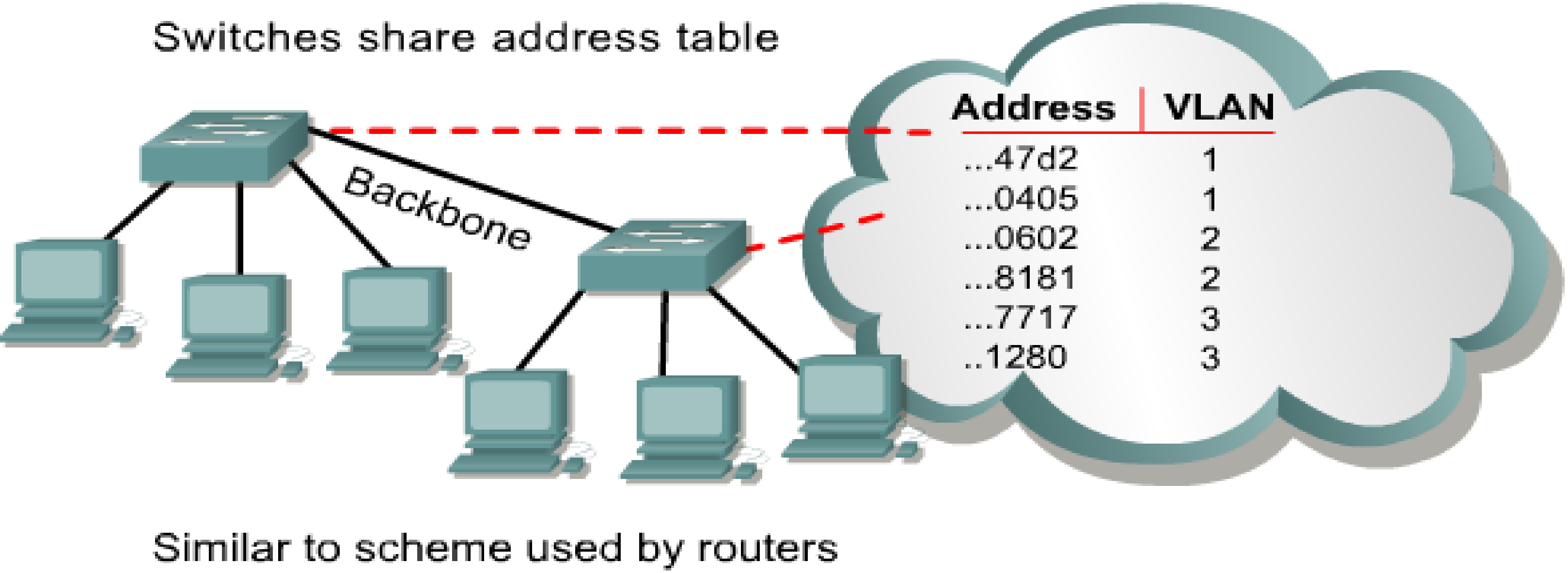
# How Frames are Used in a VLAN

- Switches make filtering and forwarding decisions based on data in the frame.
- There are two techniques used.
  - Frame Filtering--examines particular information about each frame (MAC address or layer 3 protocol type)
  - Frame Tagging--places a unique identifier in the header of each frame as it is forwarded throughout the network backbone.

## VLAN Switching and Filtering



# Frame Filtering

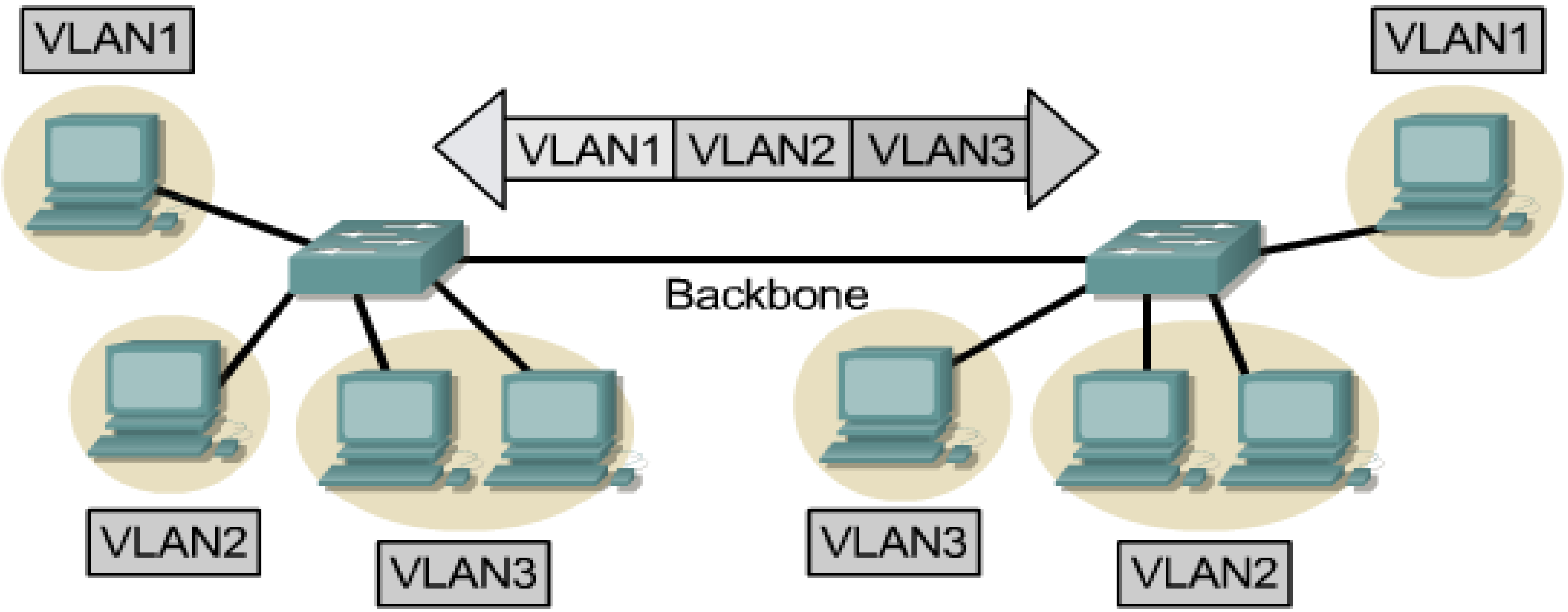



A filtering table is developed for each switch. Switches share address table information. Table entries are compared with the frames. Switch takes appropriate action.

# Frame Tagging

- Frame tagging implementation process:
  - Places a VLAN identifier in the header of each frame as it is forwarded throughout the network backbone.
  - The identifier is understood and examined by each switch.
  - When the frame exits the network backbone, the switch removes the identifier before the frame is transmitted to the target end station.
- Frame tagging functions at Layer 2 and requires little processing or administrative overhead.

# Frame Tagging



# Frame Tagging– IEEE802.1Q and ISL

- IEEE802.1Q
  - IEEE Standard, insert a label of VLAN to the header to identify the VLAN belonging to. (Frame Tagging)。
- ISL(Inter-Switch Link)
  - Cisco proprietary. ISL add a header of 26 bytes in front of the data frame, and appends a CRC(4 byte) at the end.

| Name | Encapsulation | Label | Media |
|---|---|---|---|
| 802.1Q | No | Yes | Ethernet |
| ISL | Yes | No | Ethernet |

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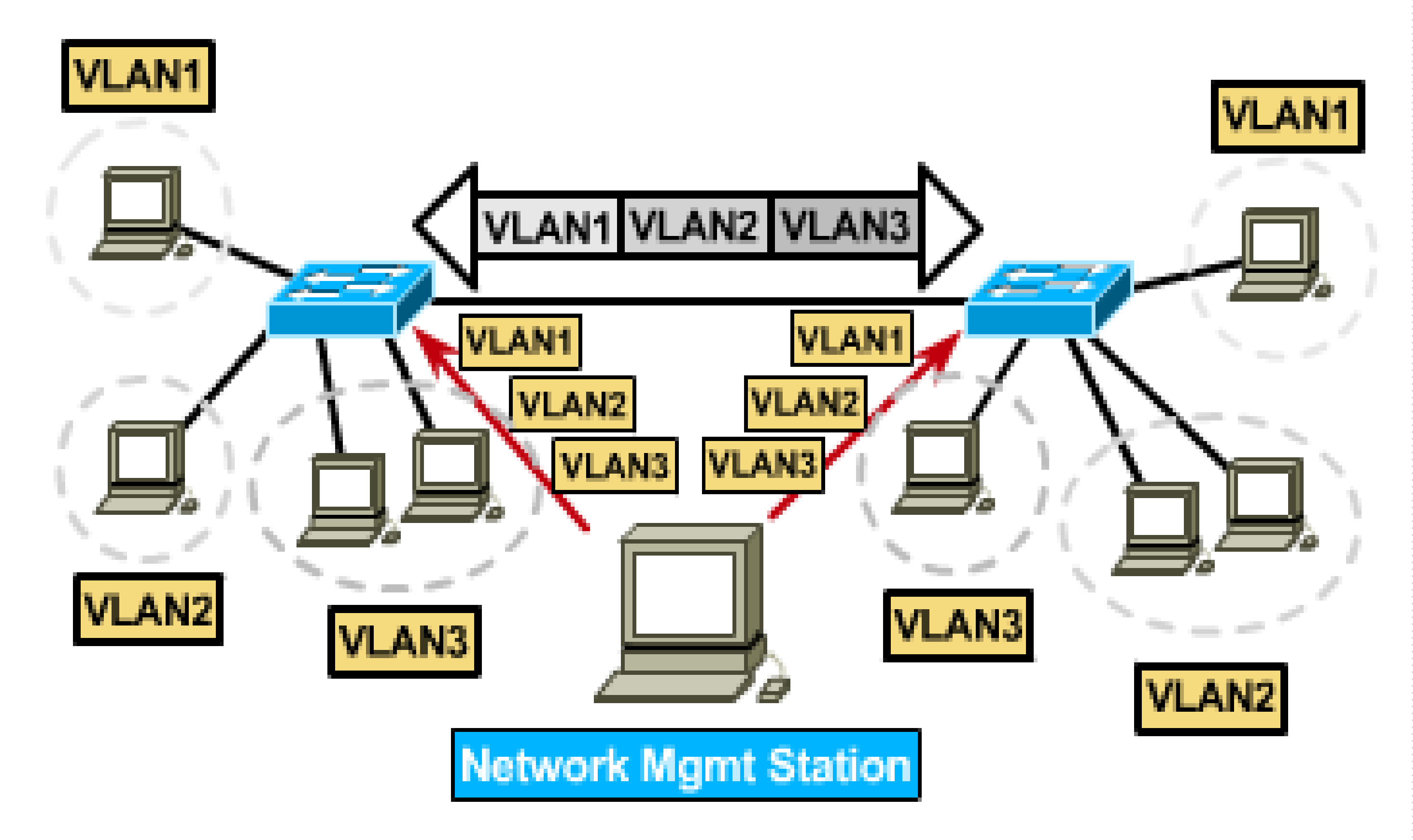
# Ports, VLANs, and Broadcasts

- Methods for implementing VLANs
  - Static
  - Dynamic
- Each switched port can be assigned to a VLAN. This…
  - ensures ports that <u>do not</u> share the same VLAN <u>do not</u> share broadcasts.
  - ensures ports that <u>do</u> share the same VLAN <u>will share</u> broadcasts.

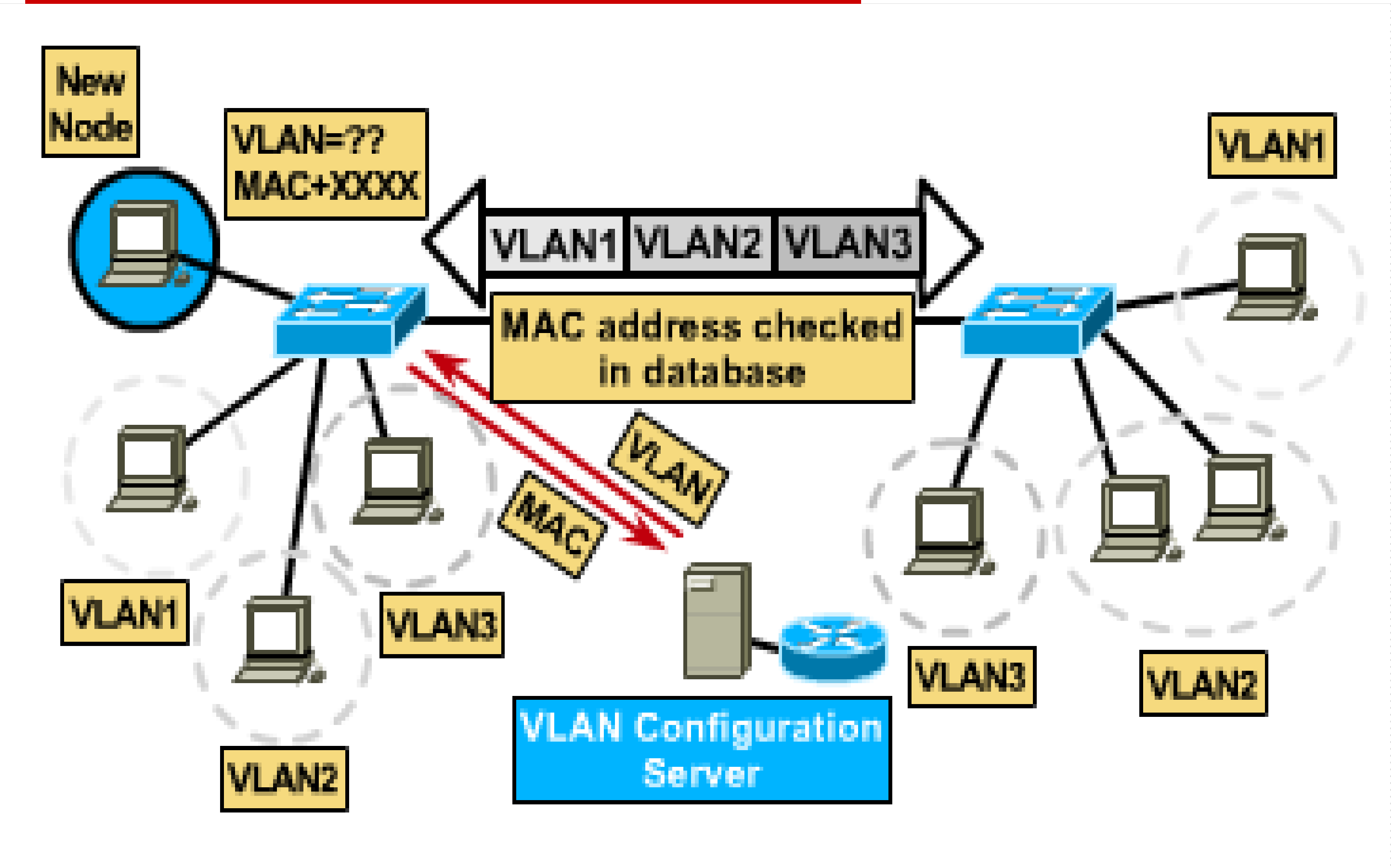
# Static VLANs



# Static VLANs

- Defined
  - Static VLANs are when ports on a switch are administratively assigned to a VLAN
- Benefits
  - secure, easy to configure and monitor
  - works well in networks where moves are controlled

# Dynamic VLANs



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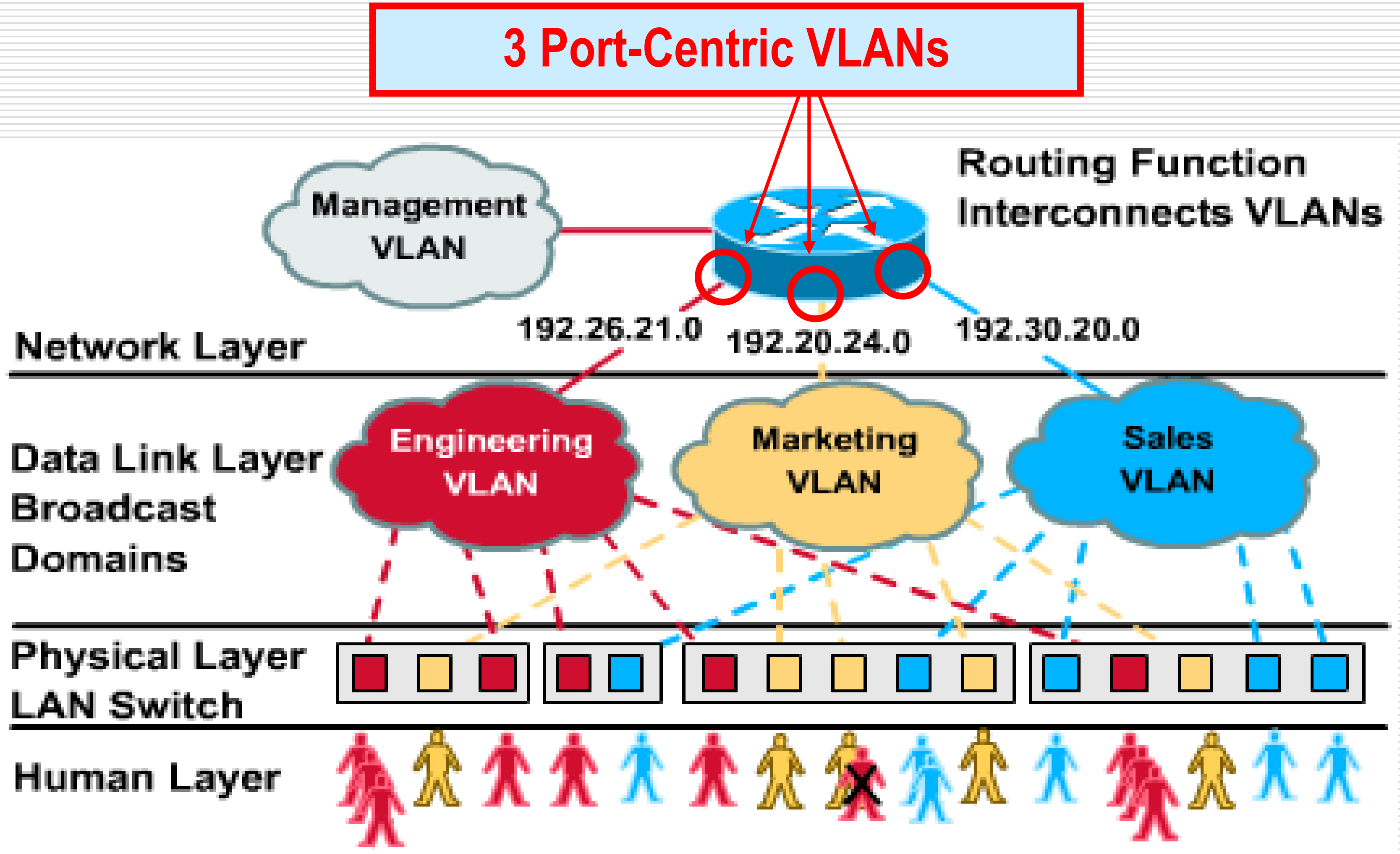
# Dynamic VLANs

- When a station is initially connected to an unassigned port, the switch checks an entry in the table and dynamically configures the port with the right VLAN
- Benefits
  - less administration (more upfront) when users are added or move
  - centralized notification of unauthorized user

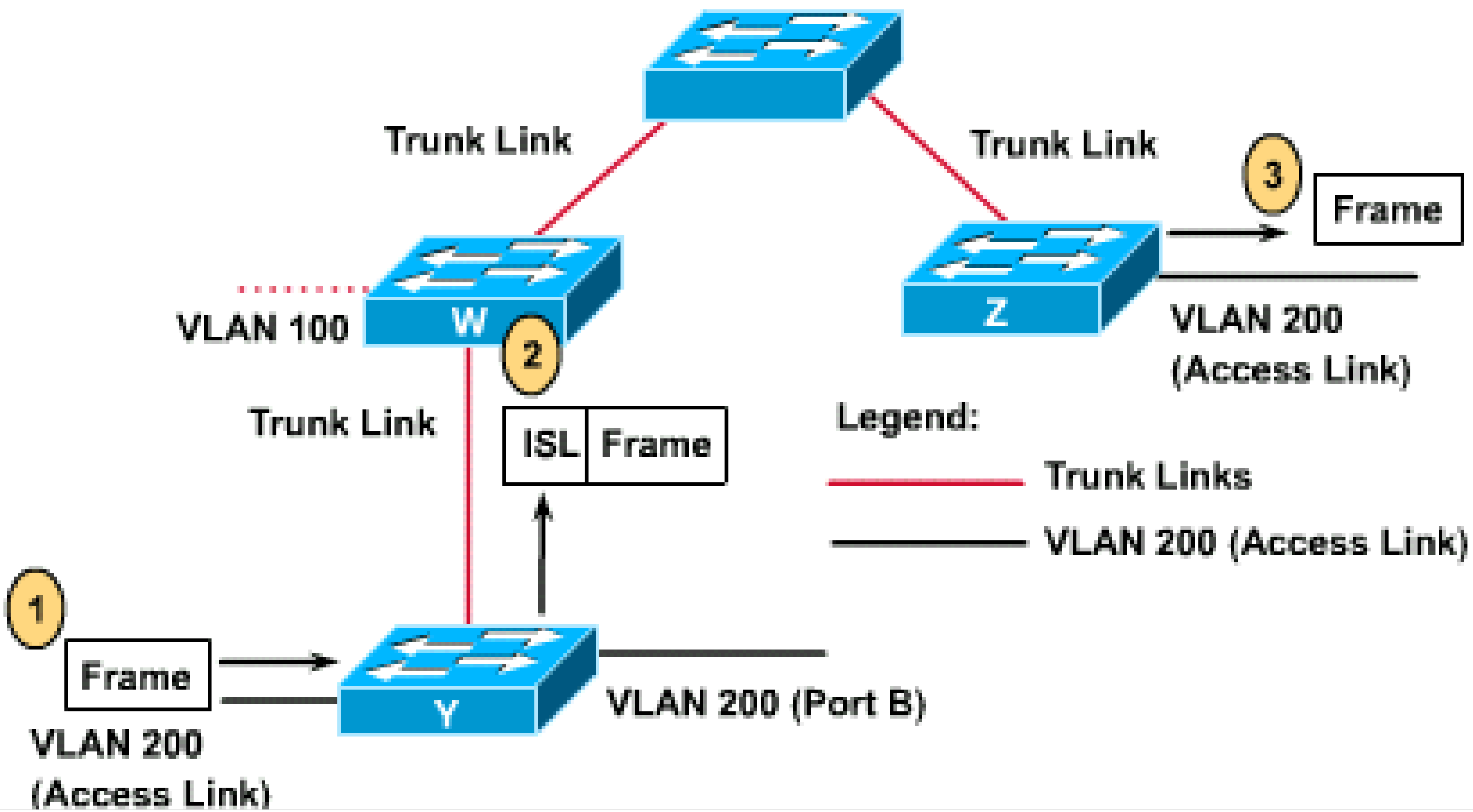
# Port-Centric VLANs



# Benefits of Port-Centric VLANs

- All nodes in the same VLAN are attached to the same router interface
- Makes management easier because...
  - Users are assigned by router port
  - VLANs are easy to admin.
  - provides increased security
  - packets do not “leak” into other domains

# Access and Trunk Links



# Access Links

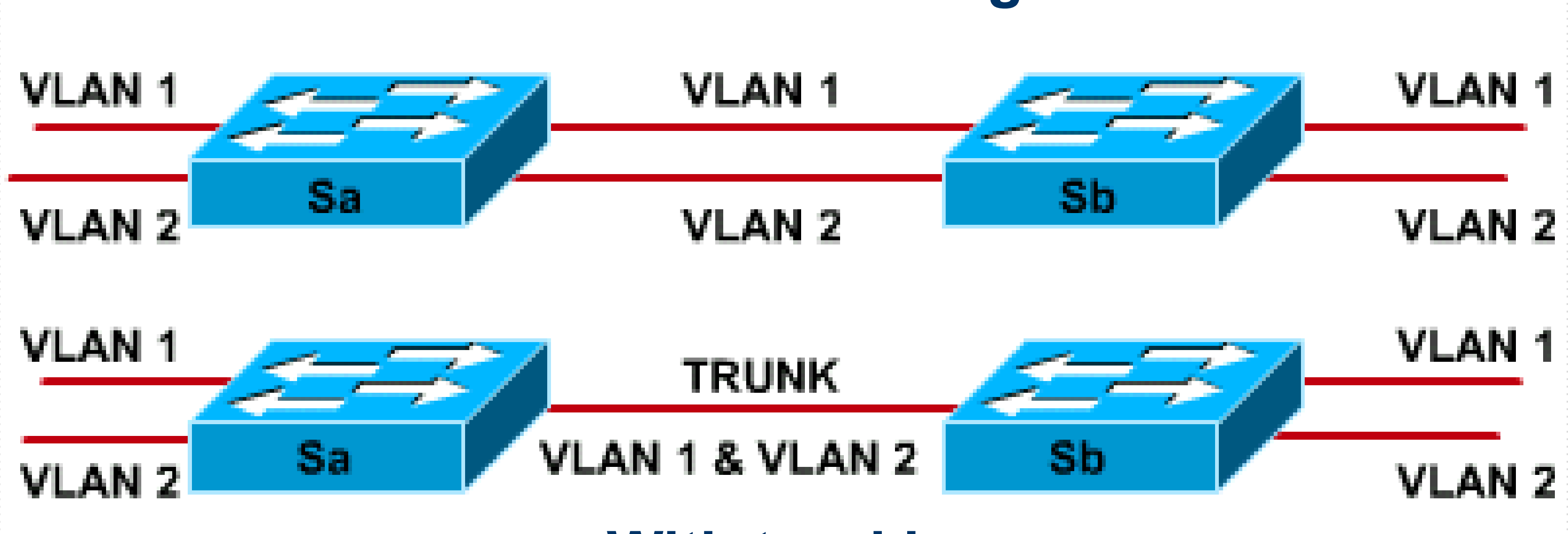
- An access link is a link on the switch that is a member of only one VLAN.
- This VLAN is referred to as the *native VLAN* of the port.
  - Any device that is attached to the port is completely unaware that a VLAN exists.

# Trunk Links

- A trunk link is capable of supporting multiple VLANs.
- Trunk links are typically used to connect switches to other switches or routers.
- Switches support trunk links on both Fast Ethernet and Gigabit Ethernet ports.
- Access and trunk links exist, too

# Trunk Links

**Without trunking**




**With trunking**

- **A trunk is a point-to-point link that supports several VLANs**
- **A trunk is to saves ports when creating a link between two devices implementing VLANs**

# Trunk Links

- A trunk link does not belong to a specific VLAN.
  - Acts as a conduit for VLANs between switches and routers.
- The trunk link can be configured to transport all VLANs or to transport a limited number of VLANs.
- A trunk link may, however, have a native VLAN.
  - The native VLAN of the trunk is the VLAN that the trunk uses if the trunk link fails for any reason.

# Configuration in Switch 29xx

- The following guidelines must be followed when configuring VLANs on Cisco 29xx switches:
  - The maximum number of VLANs is switch dependent.
  - VLAN 1 is one of the factory-default VLANs.
  - VLAN 1 is the default Ethernet VLAN.
  - Cisco Discovery Protocol (CDP) and VLAN Trunking Protocol (VTP) advertisements are sent on VLAN 1.
  - The Catalyst 29xx IP address is in the VLAN 1 broadcast domain by default.

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# VLAN Configuration

**Step1: The steps necessary to create the VLAN. A VLAN name may also be configured, if necessary.**

**Switch# vlan database**
**Switch(vlan)# vlan *vlan_number***
**Switch(vlan)# exit**

**Step2: Assign the VLAN to one or more interfaces:**

**Switch(config)# interface fastethernet 0/9**
**Switch(config-if)# switchport access vlan *vlan_number***

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# Adding a VLAN Example

**cat2950#vlan database**

**cat2950(vlan)#vlan 9 name switchlab90**

**VLAN 9 added:**

**Name: switchlab90**

**cat2950(vlan)#?**

**VLAN database editing buffer manipulation commands:**

**abort Exit mode without applying the changes**

**apply Apply current changes and bump revision number**

**exit Apply changes, bump revision number, and exit mode**

**reset Abandon current changes and reread current database**

***cat2950(config)#interface fa 0/2***

***cat2950(config-if)# switchport access vlan 9***

# Verifying a VLAN

**Switch# show vlan [*vlanid*]**

```
cat2950#sh vlan

VLAN Name                              Status       Ports
---- --------------------------------  ------------ ------------
1   Default                            active         Fa0/1, Fa0/3
9     switchlab90                      active         Fa0/2
1002 fddi-default                      active
1003 token-ring-default                active
1004 fddinet-default                   active
1005 trnet-default                     active
```

# Deleting VLANs

- When a VLAN is deleted any ports assigned to that VLAN become inactive. The ports will, however, remain associated with the deleted VLAN until assigned to a new VLAN.

**switch(vlan)# no vlan *vlanid* [name *vlan-name*]**

```
cat2950(vlan)#no vlan 9
Deleting VLAN 9...
cat2950(vlan)#exit
APPLY completed.
Exiting....
cat2950#
```

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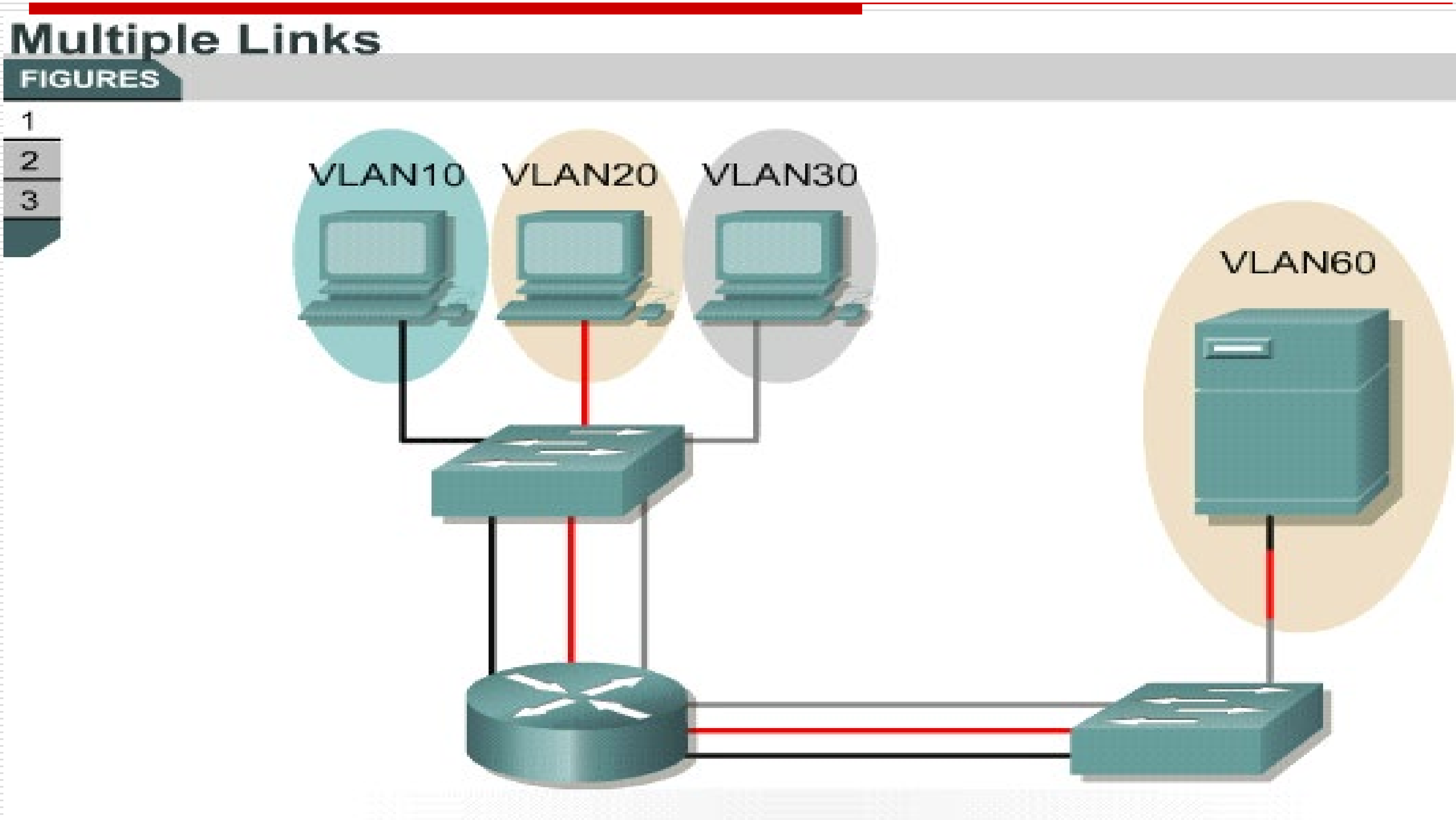
# Routing Between VLANs






The router supports one VLAN per interface.

# Routing Between VLANs

## Trunk-Connected Routers

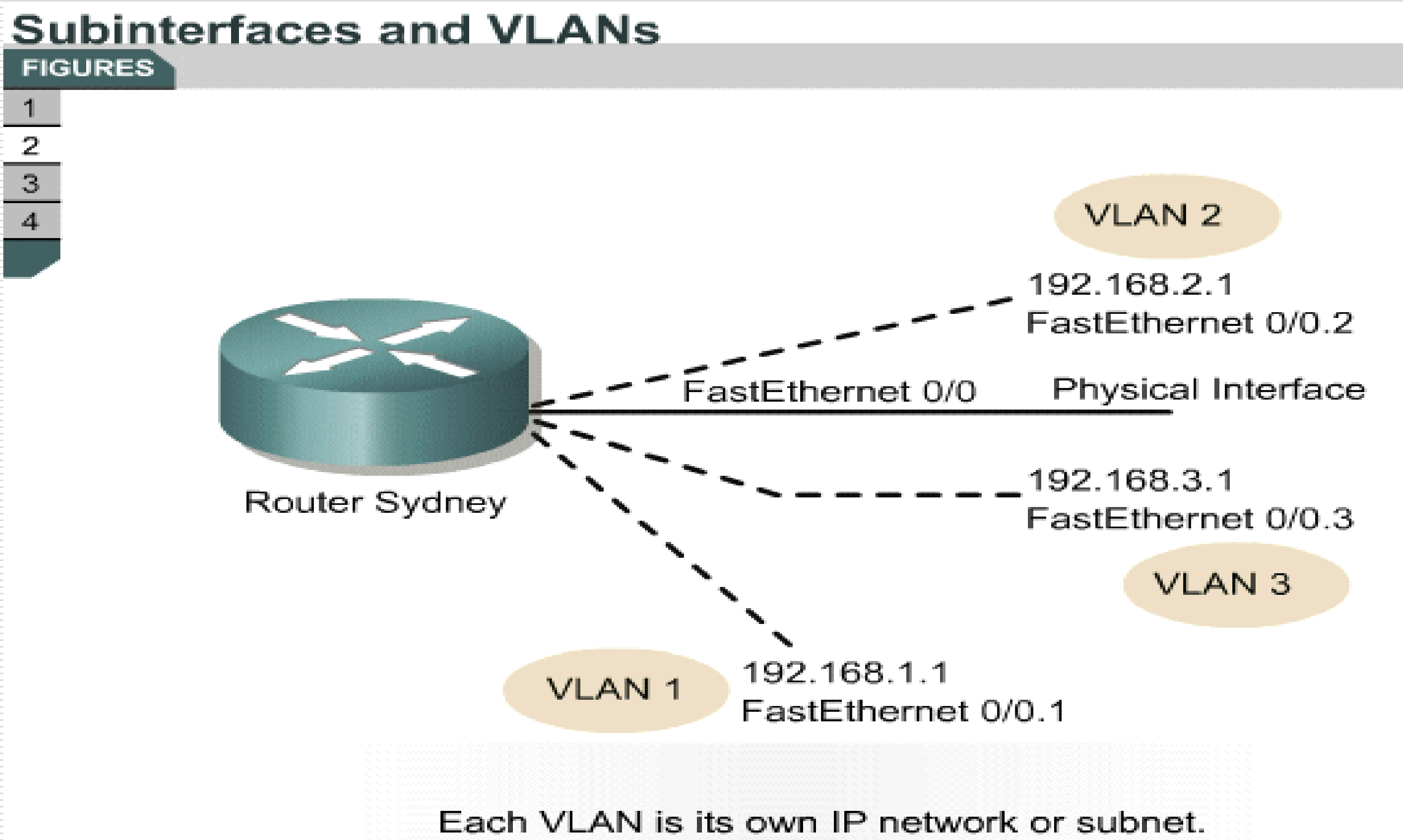
FIGURES

### 路由器物理接口和子接口对比

| 物理接口 | 子接口 |
|---|---|
| 每个 VLAN 占用一个物理接口 | 多个 VLAN 占用一个物理接口 |
| 无带宽争用 | 带宽争用 |
| 连接到接入模式交换机端口 | 连接到中继模式交换机端口 |
| 成本高 | 成本低 |
| 连接配置较复杂 | 连接配置较简单 |

An ISL or 802.1q-enabled interface on the router connects to a trunk port on the switch.

# Subinterfaces



# Configuring Inter-VLAN Routing

**Step1: Identify the interface.**

**Router(config)#interface fastethernet** *port-number. subinterface-number*

**Step2: Define the VLAN encapsulation.**

**Router(config-if)#encapsulation dot1q** *vlan-number*

**Step3: Assign an IP address to the interface**

**Router(config-if)#ip address** *ip-address subnet-mask*

# Configuring Inter-VLAN Routing

- Sydney(config)#interface FastEthernet 0/0
- Sydney(config-if)#full duplex
- Sydney(config-if)#no shut

- Sydney(config-if)#interface FastEthernet 0/0.1
- Sydney(config-subif)#encapsulation 802.1q 1
- Sydney(config-subif)#ip address 192.168.1.1 255.255.255.0

- Sydney(config-if)#interface FastEthernet 0/0.2
- Sydney(config-subif)#encapsulation 802.1q 20
- Sydney(config-subif)#ip address 192.168.2.1 255.255.255.0

- Sydney(config-if)#interface FastEthernet 0/0.3
- Sydney(config-subif)#encapsulation 802.1q 30
- Sydney(config-subif)#ip address 192.168.3.1 255.255.255.0

谢 谢！