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Ethernet, Switching, Cabling, and VLANs

ICT169

Foundations of Data Communications

Admin

- Lecture recording issue fixed; Echo360 should only show actual lectures now
- Access to the Routing & Switching Essentials course should now be available
- Mid-Semester Test will run **next week** during your regular lab session
    - Covers topics from lectures, labs and readings of sessions 1—5 (includes this lecture)
    - **Must** attend the lab session you are enrolled in
    - 90 minute LMS-based test; no extra time if you are late
    - No aids allowed except note paper (provided)
    - Example of question and test format on LMS (under Topic 6)

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Mid-Semester Test – Possible Question Topics (1)

- Describe the difference between packet switched and circuit switched networks
- Describe why data networks break communications into packets
- Define network convergence, and identify challenges associated with it
- Describe a communications medium, giving three examples
- Differentiate between a LAN and a WAN
- Describe the purpose of the OSI model
- Name the layers of the OSI model and TCP/IP models
- Name some networking devices, and identify which layer of the OSI model they operate at

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Mid-Semester Test – Possible Question Topics (2)

- Define the term ‘protocols’ and describe their purpose in data communications.
- Differentiate between units used to define network speeds and data storage
- Convert between units used to define network speeds and data storage
- Describe the Client/Server and Peer-to-Peer architectures
- Describe the purpose and operation of some widely used application layer protocols (eg. DNS, HTTP, FTP, DHCP)
- Describe the purpose of the OSI Transport layer
- Define ports with respect to the Transport layer

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Mid-Semester Test – Possible Question Topics (3)

- Describe the operation of the Transmission Control Protocol and User Datagram Protocol
- Identify when it is appropriate to use each transport layer protocol
- Describe the purpose of the network layer
- Describe the operation of IPv4 (key properties and header fields)
- Describe the packet forwarding process
- Describe the different types of IP transmissions (unicast, multicast, broadcast)
- Describe the purpose of the subnet mask and subnetting
- Apply VLSM to subnet IP networks (and related questions):
    - Subnetting problems (see lab handout)
    - Size of subnets given subnet mask
    - Identify whether IP addresses belong to the same subnet
    - Convert between dotted decimal and slash notation

Mid-Semester Test – Possible Question Topics (4)

- Describe the role of the Data Link layer and the division of functions between the Logical Link Control (LLC) and Media Access Control (MAC) sublayers
- Describe the difference between Point-to-Point and Multi-Access links
- Differentiate between different approaches to MAC (CSMA/CD, TDMA, Token Ring)
- Describe the role and use of MAC addressing in data communications
    - End-to-end and hop-to-hop addressing
- Identify data link layer protocols
- Describe the purpose of the physical layer
- Identify different forms of physical media (copper, fibre, air) and the distances these mediums are used for
- Medium, medium access and topology for Ethernet, ADSL, Cable/DOCSIS

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Mid-Semester Test – Possible Question Topics (5)

- List different topologies used by Ethernet networks
- Describe the operation of CSMA/CD
- Describe the role of MAC addresses in Ethernet networks
- Describe the operation of Ethernet switches
- Describe the role and operation of ARP
- Define and identify Collision and Broadcast domains
- Differentiate between a straight-through and crossover cable
- Identify the suitable cable type for connecting network devices
- Describe the Hierarchical Network Model
- Describe the role of Virtual Local Area Networks (VLANs) in switched networks
- Describe how traffic from different VLANs is identified and isolated
- Describe the purpose of a trunk link
- Describe the purpose of Spanning Tree Protocol

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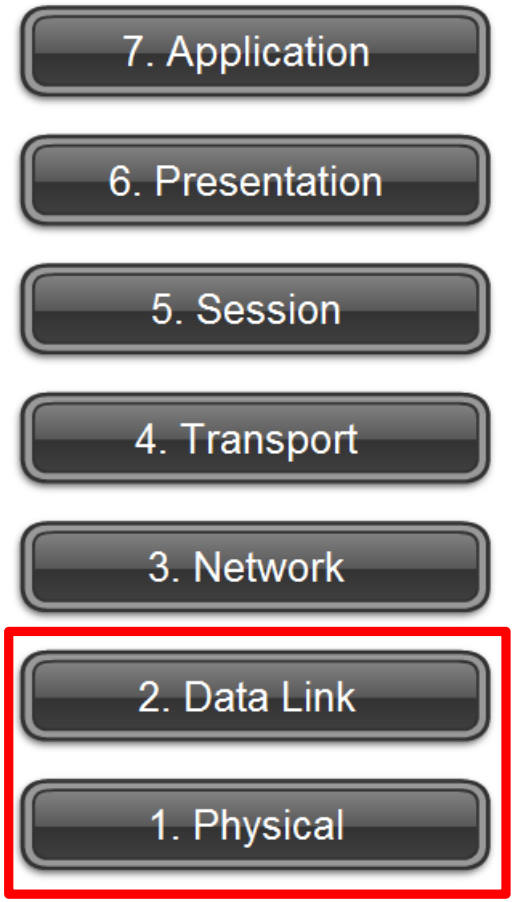
Last Week

- We finished our look at the OSI model with the Data Link and Physical layers
    - Sub-layers of the Data Link Layer
- Link layer technologies and media access
- Media access in shared environments
- Link layer addressing and differences to the upper layers
- Communications media and media access
- Current broadband technologies



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Lecture Overview

- A closer look at Ethernet and related technologies
  - Brief recap of history
  - MAC addressing
  - Cabling
  - Hubs and switches
- Broadcast and collision domains
- Switched network design
- Virtual Local Area Networks (VLANs) and Inter-VLAN routing

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Ethernet

- Overtook competing technologies like Token Ring to become one of the most dominant LAN technologies
    - WiFi (802.11) is quickly catching up
- Became favoured wired technology because of cost, scalability, and flexible cabling options
- Like many protocols developed in the early days of computer networks, is showing its age; lacking security options

Ethernet Protocols

- Actually consists of two protocols: IEEE 802.2 and IEEE 802.3
- 802.2 is the specification for the Logical Link Control (LLC)
- 802.3 is the "Ethernet" specification, defining the MAC sub-layer functions as well as cables and connectors

Layer 1 Limitations	Layer 2 Functions
Cannot communicate with upper layers	Connects to upper layers via Logical Link Control (LLC)
Cannot identify devices	Uses addressing schemes to identify devices
Only recognizes streams of bits	Uses frames to organize bits into groups
Cannot determine the source of a transmission when multiple devices are transmitting	Uses Media Access Control (MAC) to identify transmission sources

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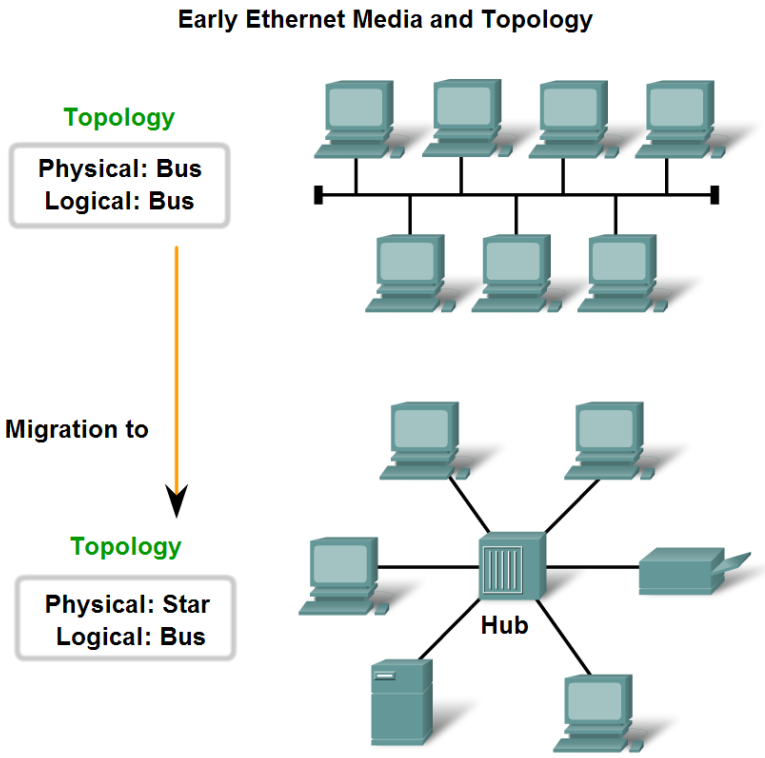
Ethernet – A Brief History

- The original Ethernet specification was published by DEC, Intel and Xerox in 1980
- Several iterations since then:
  - 10Base2 – Bus topology using Coaxial cable
  - 10Base5
  - 10BaseT – Physical star topology using UTP
- Used Ethernet hubs to connect devices



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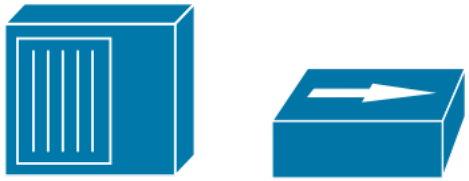
Ethernet Hubs

- Early versions used hubs for 10Mbps and 100Mbps
- Hubs rebroadcast transmissions to all other ports, meaning that every other device will see the packets
- Only the intended recipient should keep the packet
    - No way to enforce this behaviour; security issue
- Networks using hubs are **half-duplex** and require **CSMA/CD**



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CSMA/CD Revisited

- Contention-based media access control used by Ethernet
- CSMA/CD process is:
  - Listen for other transmissions before transmitting
  - If no other transmissions heard, send data
  - Otherwise, wait for current transmission to end
  - Collisions generate a JAM signal, which prompts devices to back-off and wait for a random period of time
  - Once the timer expires, try to resend
- Now unnecessary in modern networks because of prevalence of switches

Switched Ethernet Networks

- Modern Ethernet networks use switches to connect hosts
- Switches allow for full-duplex transmission by placing every device in its own **collision domain**
- Only forward packets to the intended recipient based on MAC addresses
- Current switches usually allow for 100Mbps or 1Gbps Ethernet with higher speed links for the network backbone
- Can also provide 10Gbps (still using copper), or 40–100Gbps over fibre

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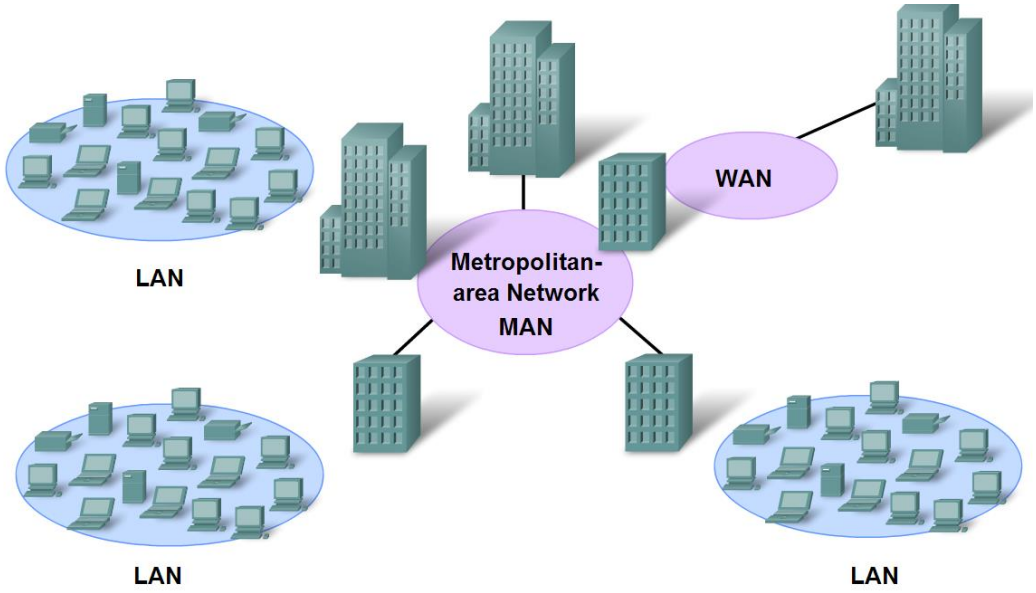
Ethernet in the WAN

- In addition to being commonly used as a LAN technology, Ethernet can also be used in WANs
- Displaces more traditional WAN technologies like Frame Relay and ATM
- Usually uses fibre in these deployments (due to distance)



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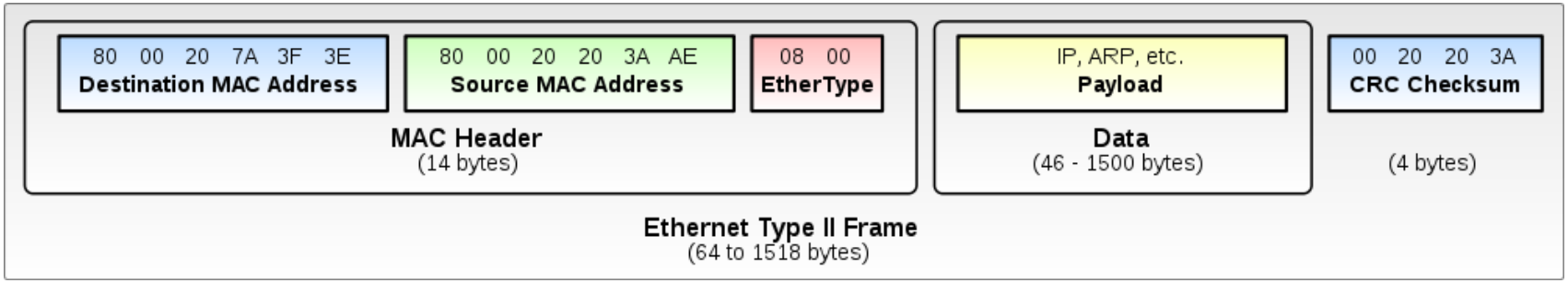
Ethernet Headers

- Ethernet headers are very simple, only containing 5 fields (plus preamble and trailer)
- Uses MAC addresses to identify intended recipient
    - Note that the destination address comes first
- EtherType field used to specify protocol encapsulated

```
▼ Ethernet II, Src: Tp-LinkT_7b:9c:e9 (64:66:b3:7b:9c:e9), Dst: Apple_ab:c4:03 (70:56:81:ab:c4:03)
  ▶ Destination: Apple_ab:c4:03 (70:56:81:ab:c4:03)
  ▶ Source: Tp-LinkT_7b:9c:e9 (64:66:b3:7b:9c:e9)
    Type: IP (0x0800)
```

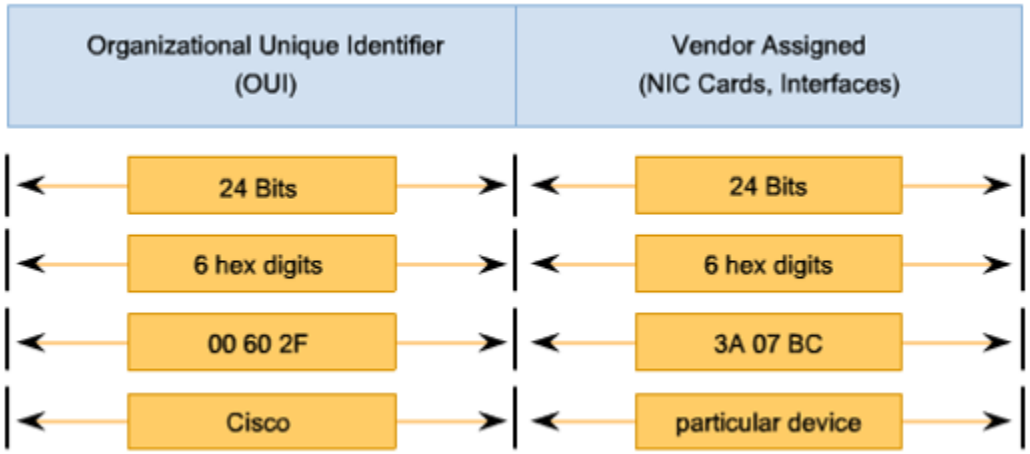


MAC Addresses

- Remember that Ethernet is a multi-access network and needs an addressing scheme: MAC addresses
- 48-bit address represented in hexadecimal (0—9, A—F)
- MAC Addresses are usually unique, but are only significant within the local network segment
- Flat structure (not hierarchical like IP)
- Common representations of MAC addresses:
    - 12:34:56:78:9A:BC
    - 12-34-56-78-9A-BC
    - 1234.5678.9ABC

MAC Addresses (cont.)

- MAC addresses are assigned to network interfaces by the manufacturer and shouldn't be changed
- MAC addresses can be split into two halves:
  - Organisational Unique Identifier (OUI) – An identifier specific to the manufacturer / vendor
  - NIC Specific – Assigned by the manufacturer / vendor



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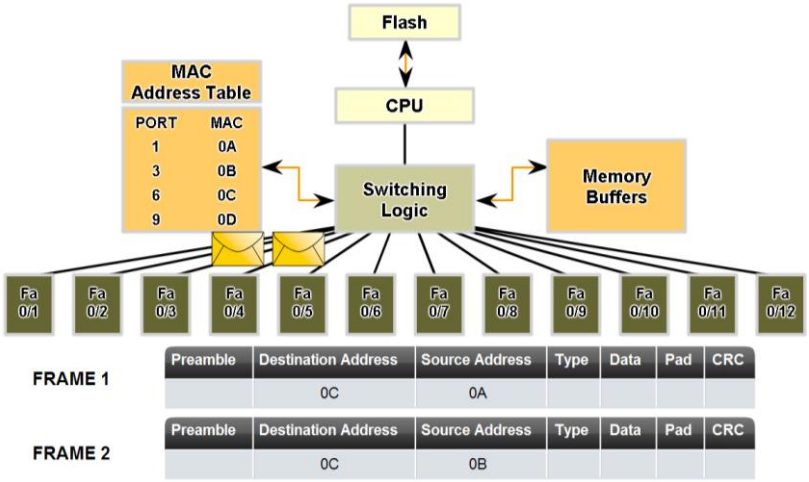
Ethernet Switching

- Remember that Ethernet switches forward frames only to the intended recipient (identified using MAC addresses)
- Stores MAC addresses in a **MAC address table** which maps addresses of connected devices to ports on the switch
- Mappings are usually created based on the source address of received frames
- If a frame is received for an unrecognized host, it will be flooded out all but the incoming port instead



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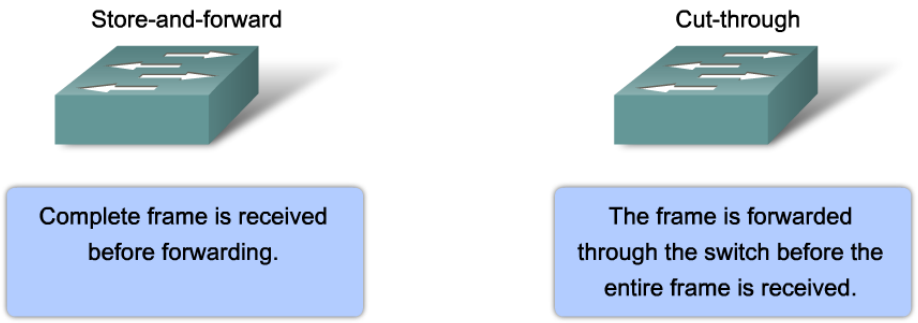
Ethernet Switching (cont.)

- **Store and forward** switching
  - Read entire frame into memory (**store**) before forwarding
  - Variable (but usually higher) latency as the frame must be received in entirety
- **Cut-through**
  - Begin sending frame as soon as the destination is known
  - Lower latency but can result in errors (corrupt packets will still be forwarded)



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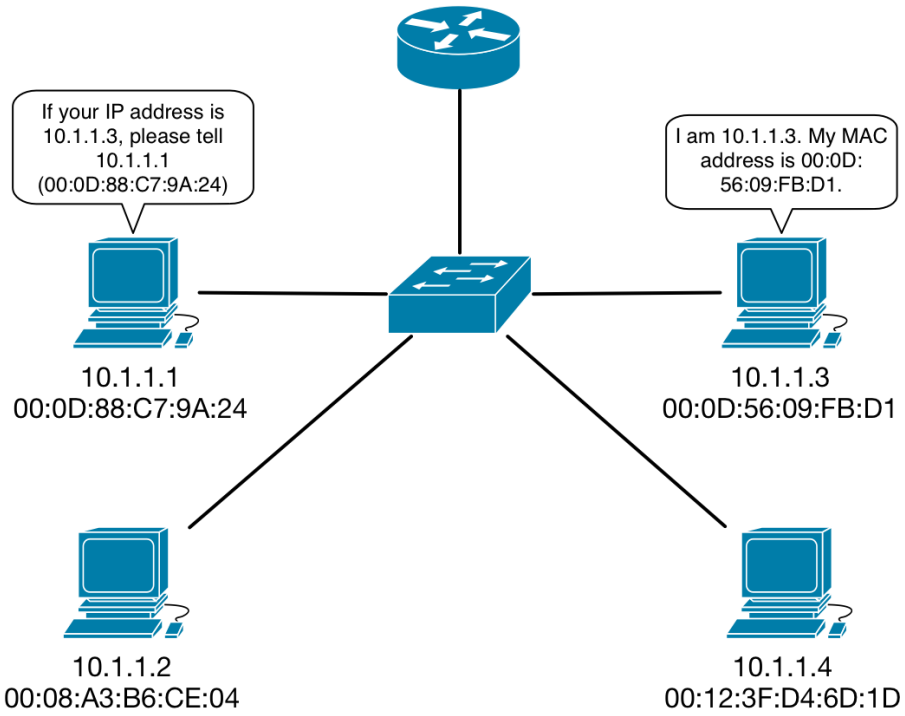
Address Resolution Protocol (ARP)

- Hosts transmitting over the local network are responsible for mapping IP addresses to MAC addresses
- ARP creates and maintains a list of mappings in the **ARP table** (sometimes called the ARP cache)
- Hosts check their ARP table before transmitting packets bound for the local network
- If no mapping exists, an **ARP request** will be generated

ARP Operation

- The host with the IP address in the ARP request will transmit an ARP reply
- Only the requesting host will receive the reply



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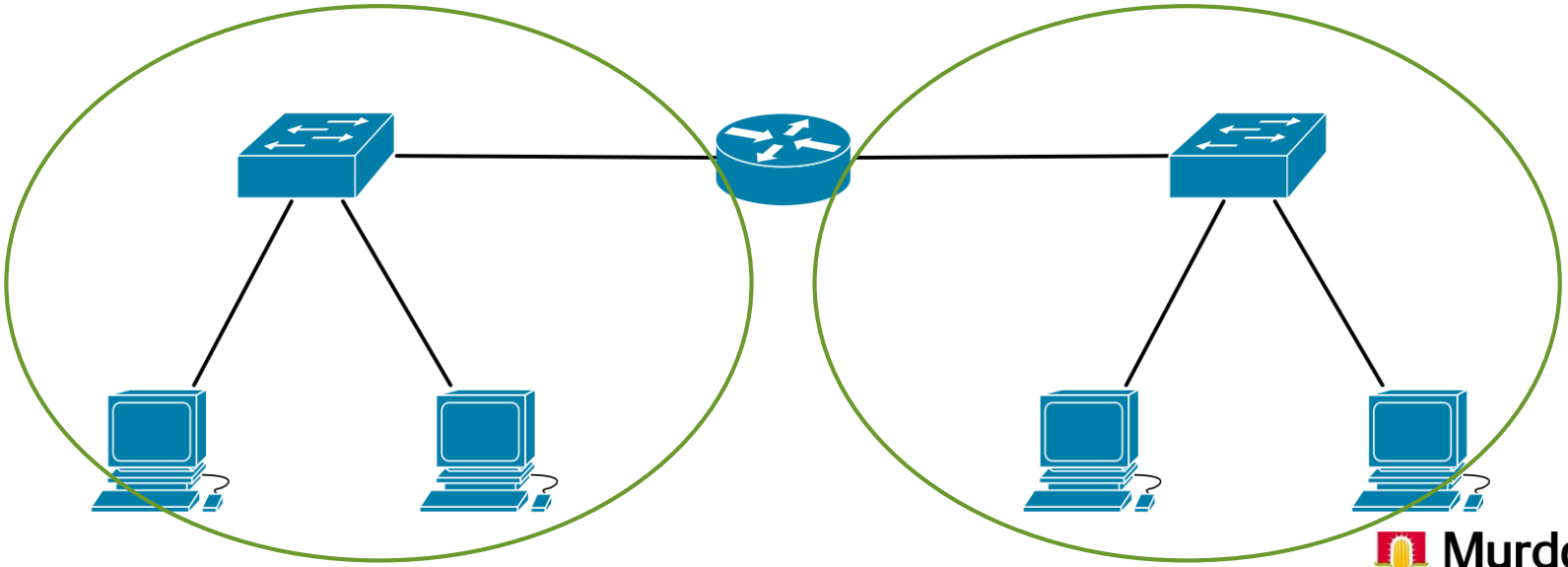
Types of Transmissions

- The three types of transmissions for packets also apply to Ethernet frames: Unicast, Multicast and Broadcast
- Unicast transmissions are used to transmit frames to a single device using the recipient's MAC address
- Multicast transmissions allow a device to transmit to a group of devices using multicast addresses (usually beginning with 01:00:5E)
- Broadcasts are sent to all devices within the broadcast domain, using the broadcast MAC address (FF:FF:FF:FF:FF:FF)

Broadcast Domains

- Logical network boundary inside which all devices can be reached by a Layer 2 broadcast
- Broadcast domains are separated by **routers**
- Broadcast domains are **extended by switches and hubs**



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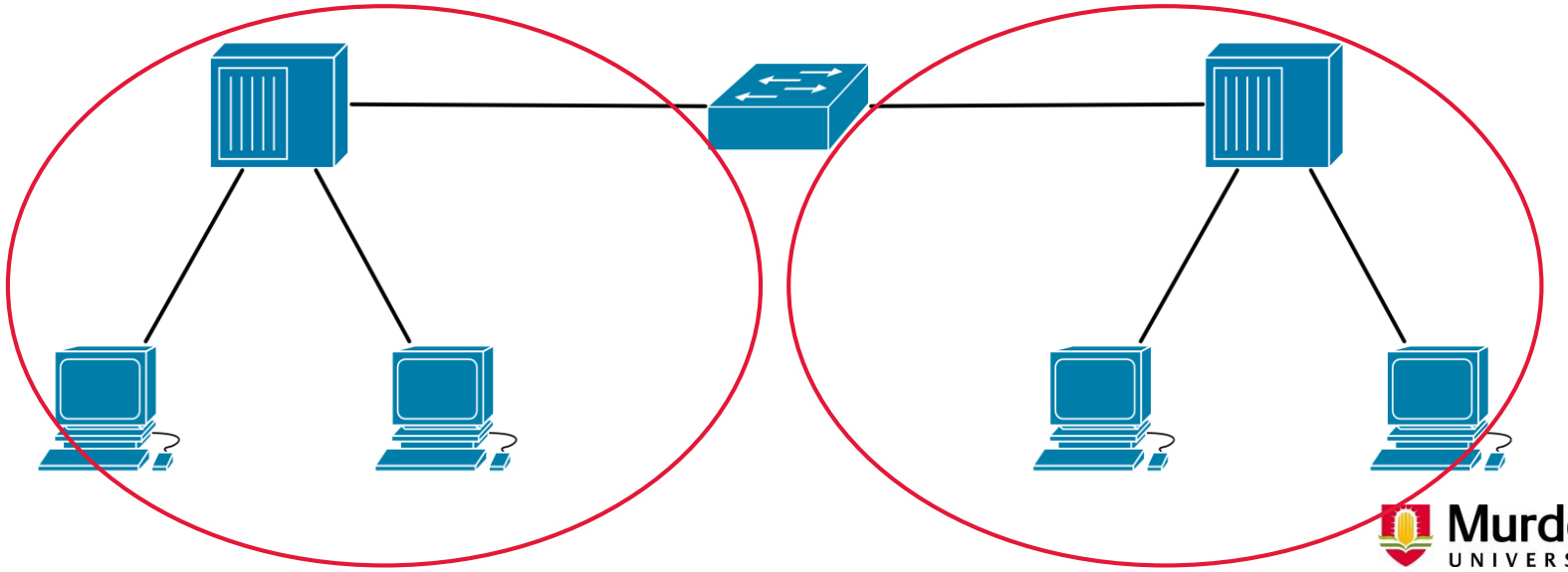
Collision Domains

- Logical network boundary inside which transmissions occurring simultaneously will collide
- Collision domains are **separated by switches**, which create a separate domain per port
- Collision domains are **extended by hubs**



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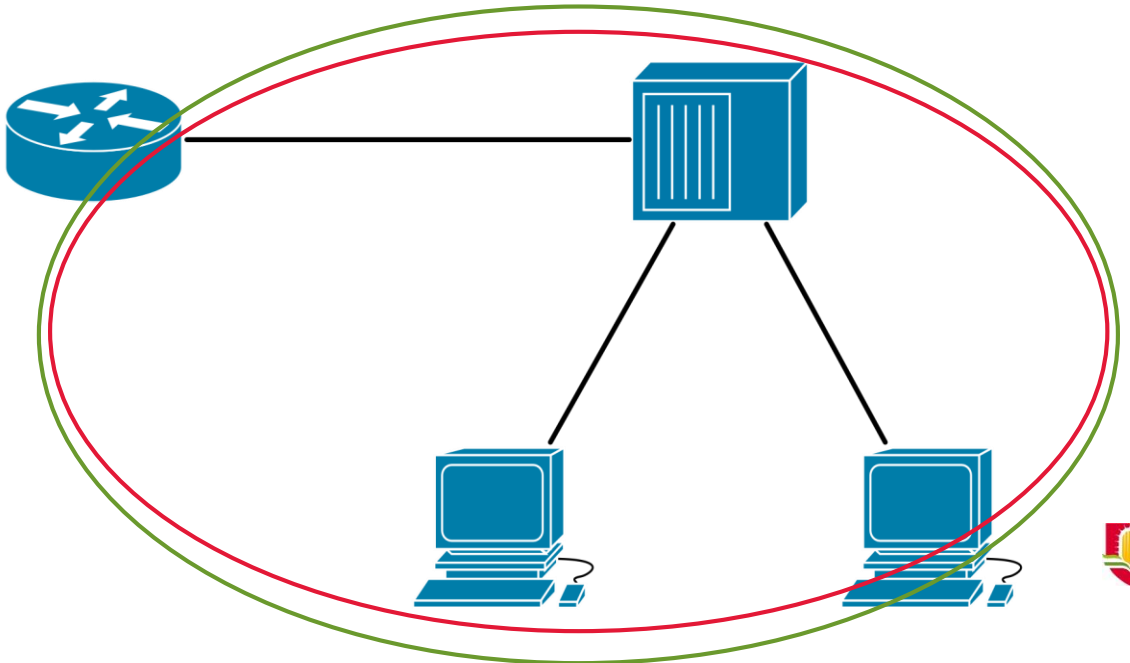
Identifying Broadcast and Collision Domains

How many broadcast domains are in this topology? **1**

How many collision domains? **1**



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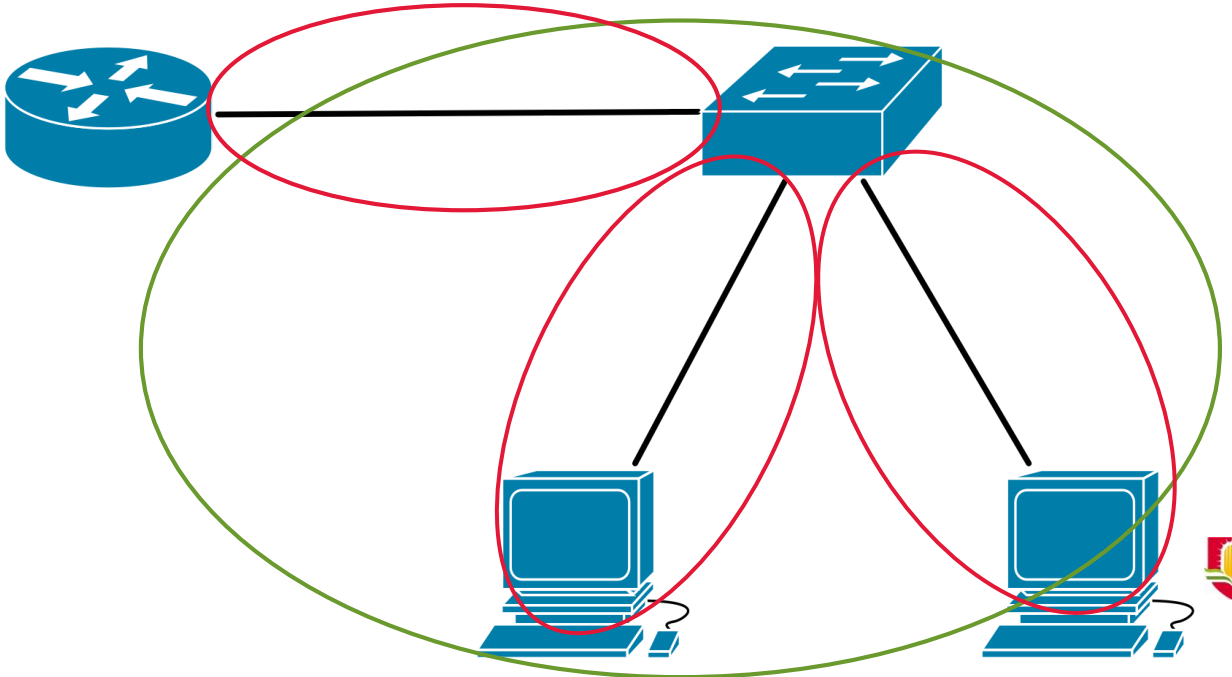
Identifying Broadcast and Collision Domains (cont.)

How many broadcast domains are in this topology? **1**

How many collision domains? **3**



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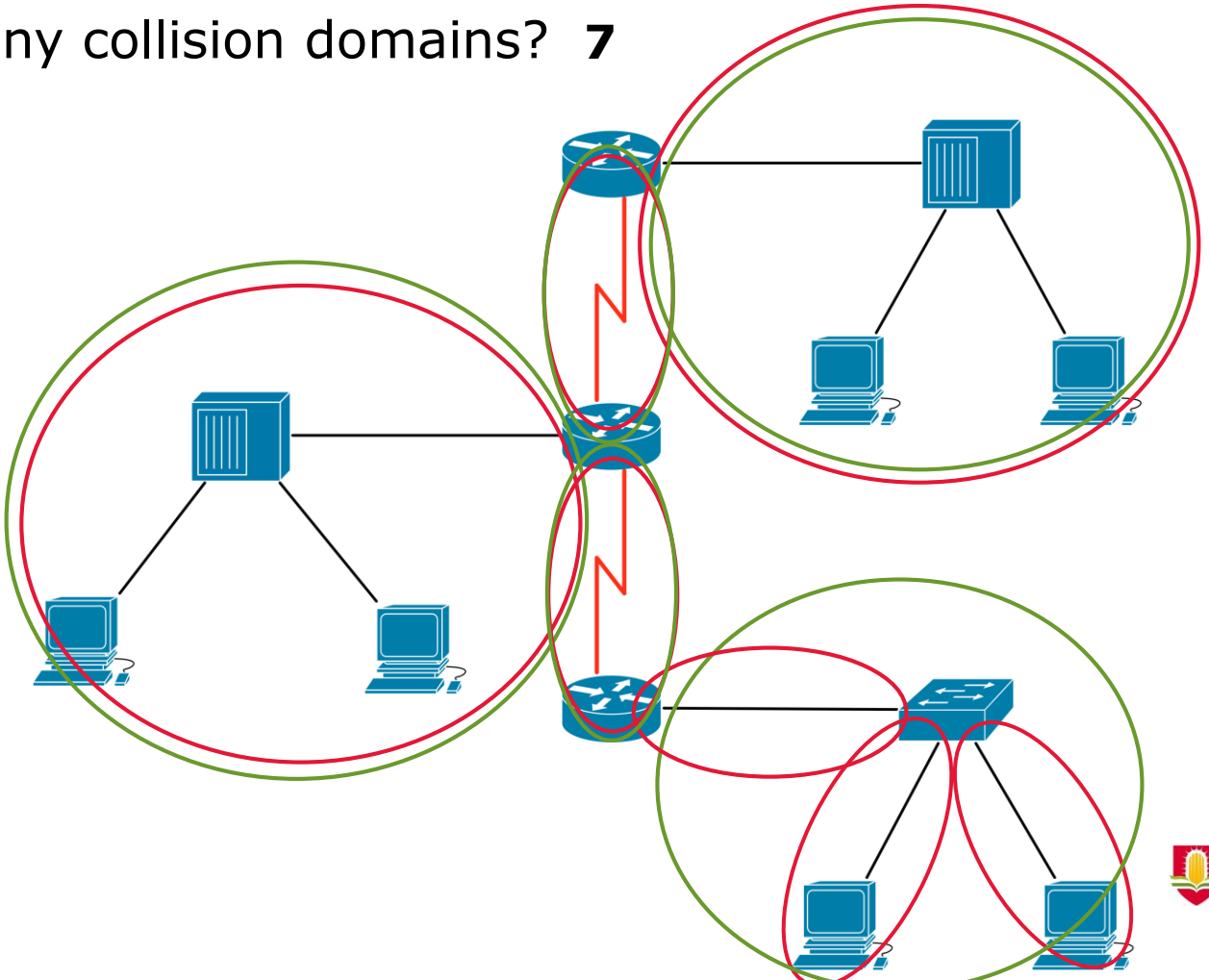
Identifying Broadcast and Collision Domains (cont.)

How many broadcast domains are in this topology? **5**

How many collision domains? **7**



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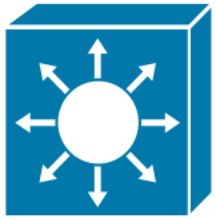
Multilayer Switching

- Switches are generally thought of as Layer 2 devices, but some support routing (a Network layer concept)
- Multilayer switches use Layer 2 information and optimisations to route at high speed
- Usually Ethernet-based, but some support other WAN technologies
- Often used in inter-VLAN routing
- Reduces the need for routers within an organisation, but not at the edge of the network



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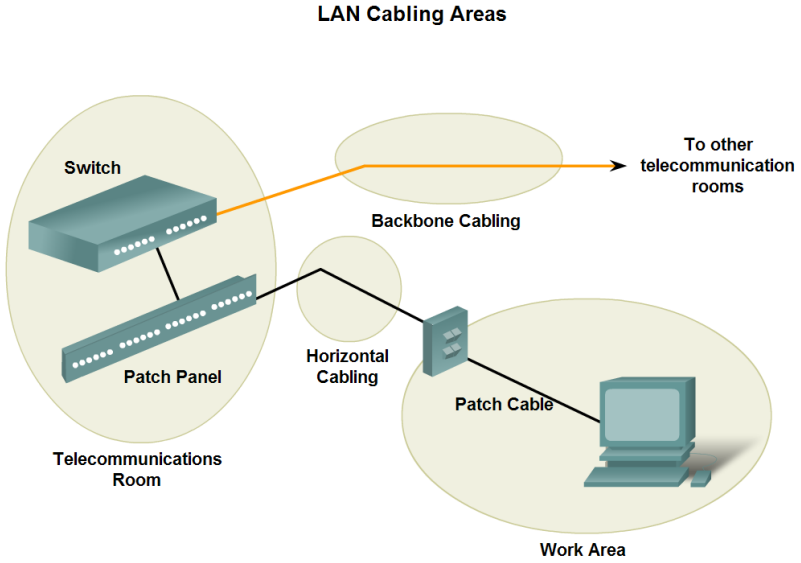
Cabling

- Structured cabling is broken into three main components:
  - Horizontal cabling – cables running between PC and local switch (usually via a patch panel)
  - Patch panels – physical layer devices that provide cable extension
  - Vertical / Backbone cabling – cables running between telecommunications closets (usually between intermediary devices)



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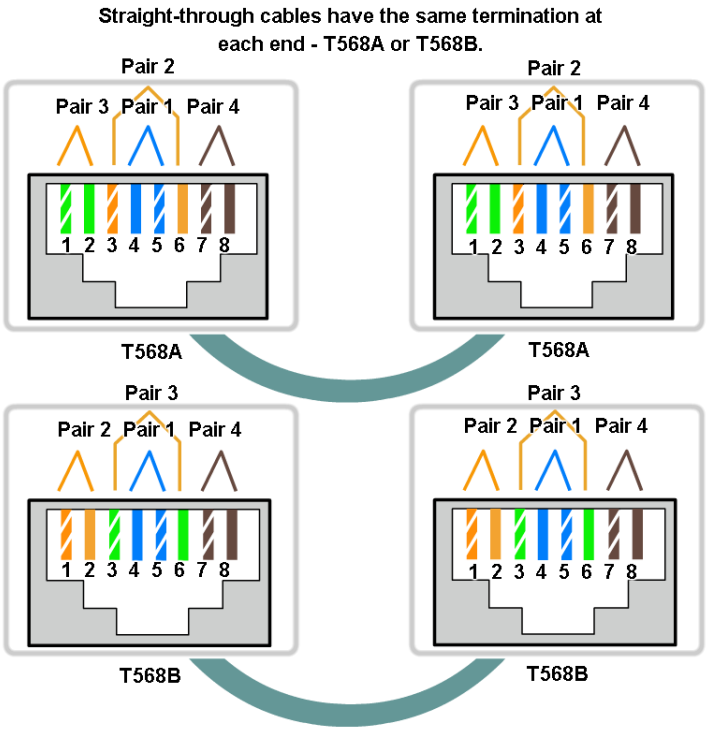
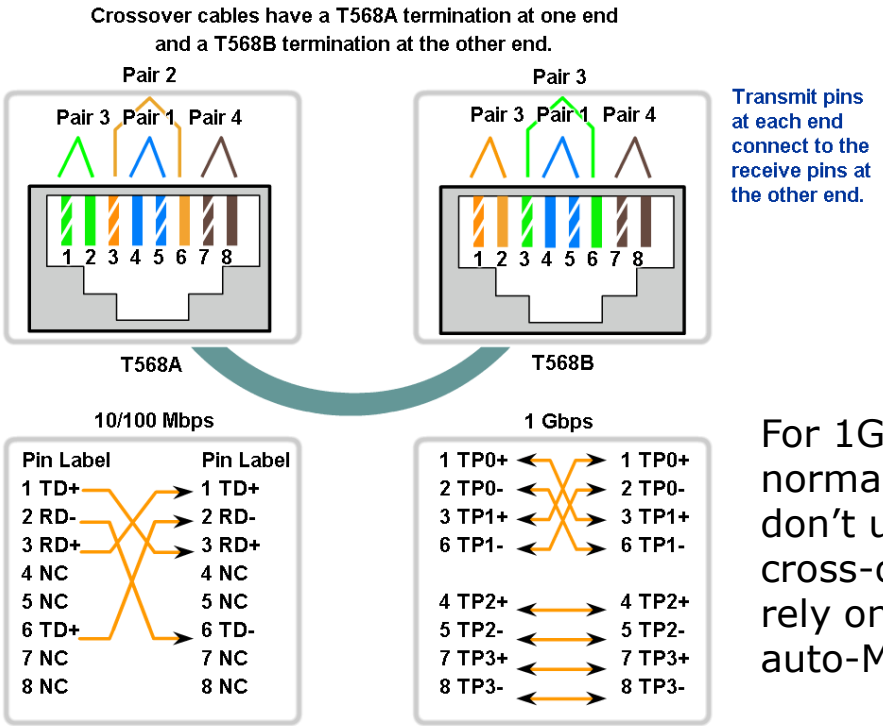
Ethernet Cabling

- Important that you can differentiate **straight-through cables** and **crossover cables**
- Defined by ordering of pins; pairs 2 and 3 swapped on one end





For 1Gbps normally don't use cross-over; rely on auto-MDIX

Break

When we return: Virtual Local Area Networks and Switched Network Design

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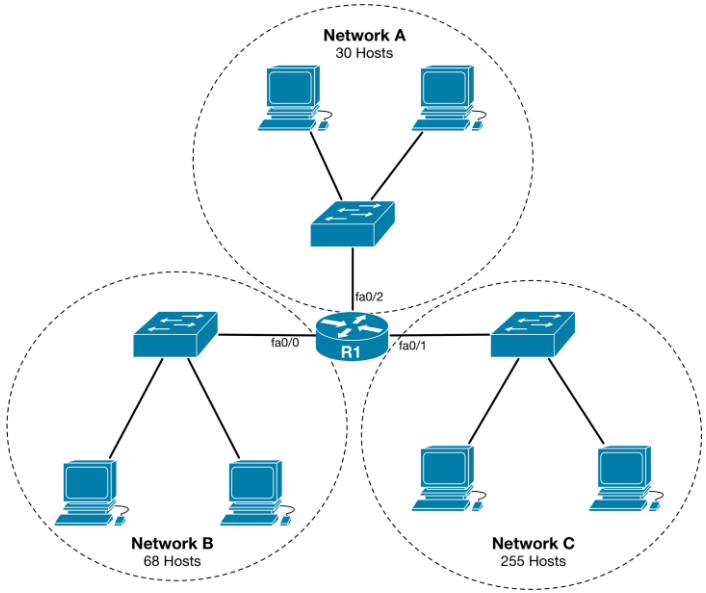
Local Area Networks and Subnets Revisited

- Remember, a LAN describes a network serving a single home, building or campus
- Subnetting is the process of sub-dividing an existing IP network into smaller logical networks
- Networks are usually understood to be divided into subnets based on location



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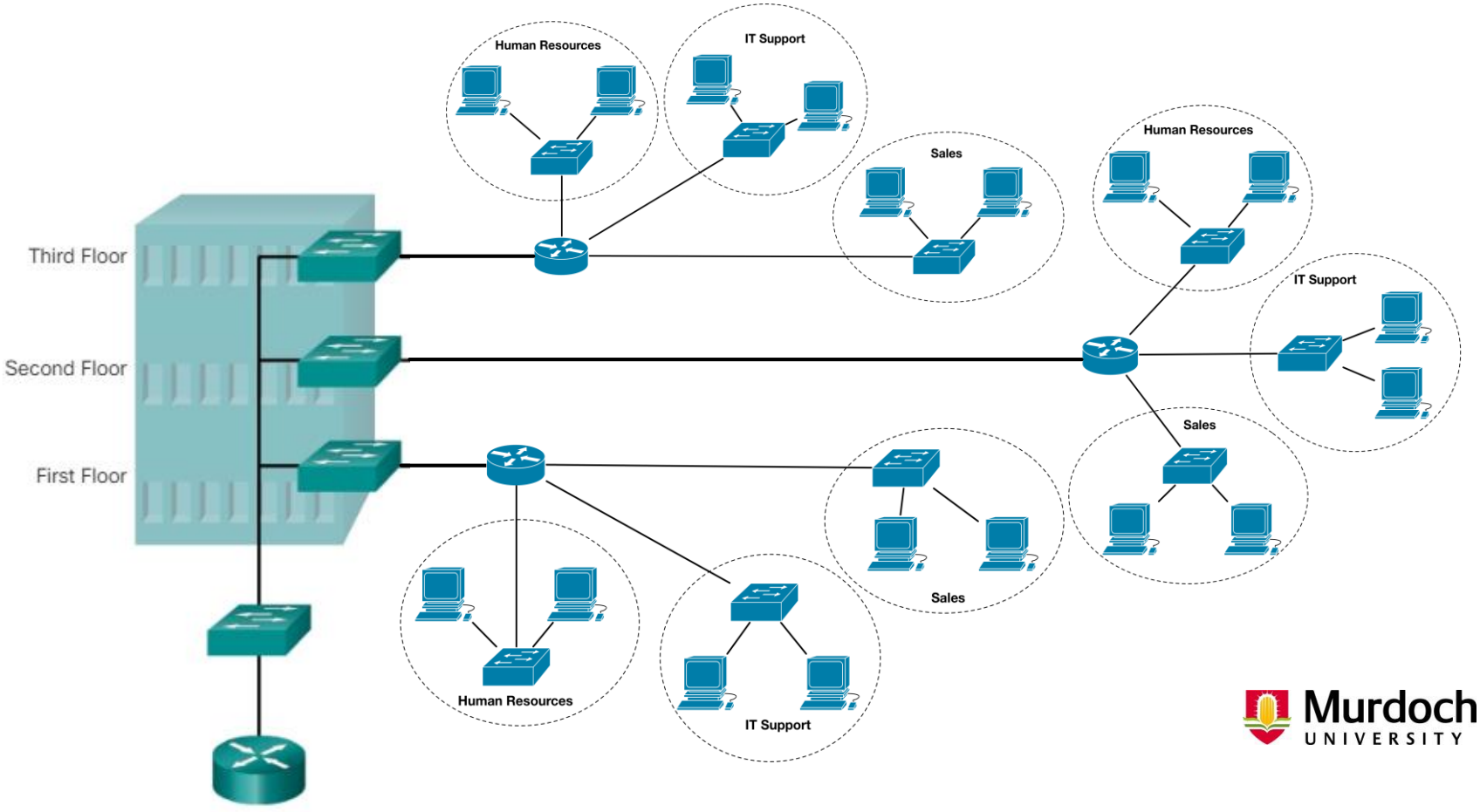
LANs and Subnets – An Example

- Imagine a company network like the one below
- Each department is distributed across all floors



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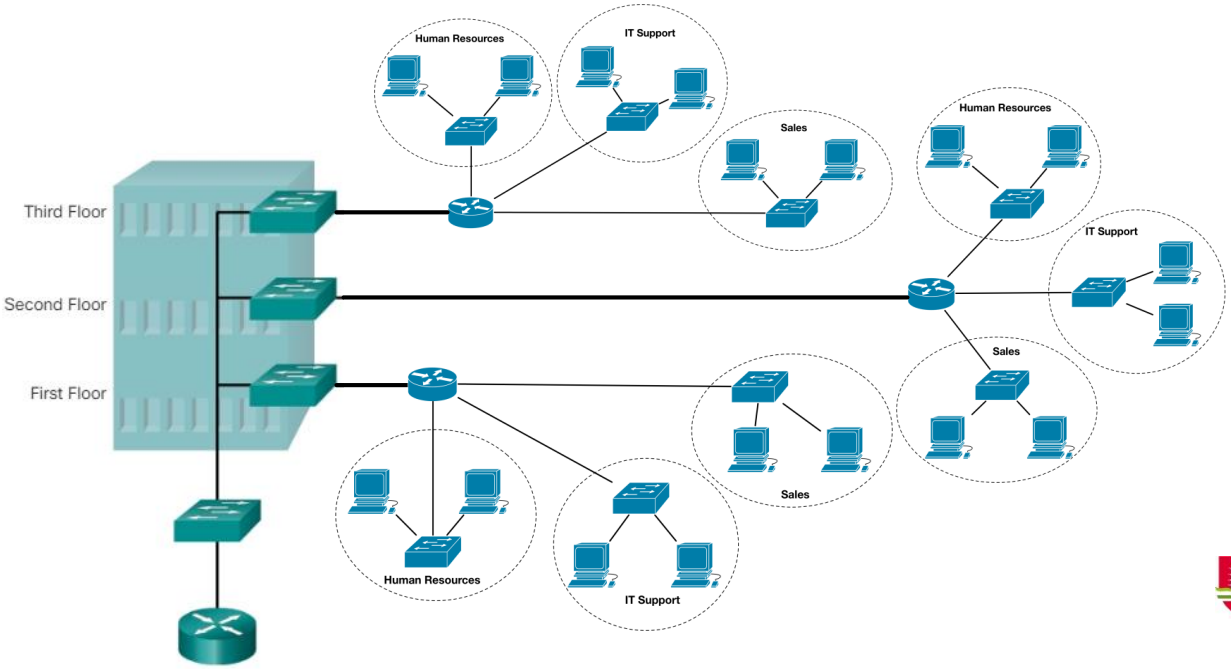
LANs and Subnets – An Example (cont.)

- To separate the different departments, we would need a subnet for each
- How many subnets, routers, and switches are required?



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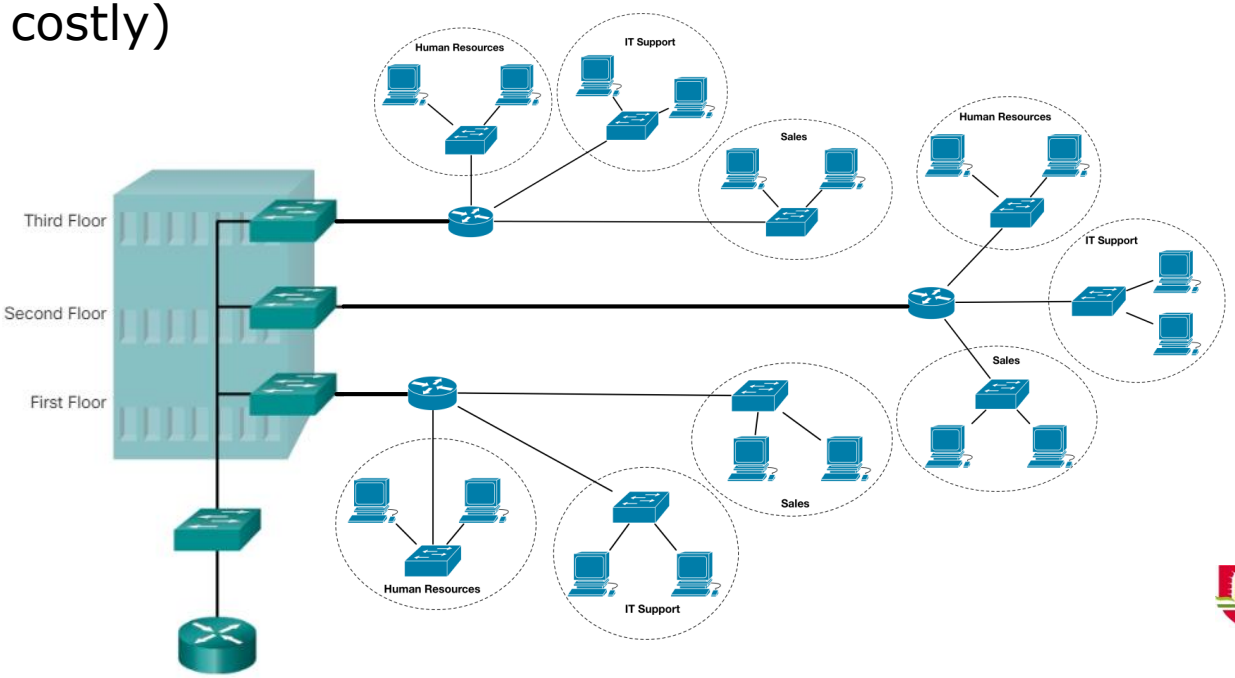
LANs and Subnets – An Example (cont.)

- We could try to reduce the number of switches and routers by having a single switch per department
- Cabling problem:
  - Cat5/6 runs max out at 100m
  - Cabling between floors would be messy (and probably costly)



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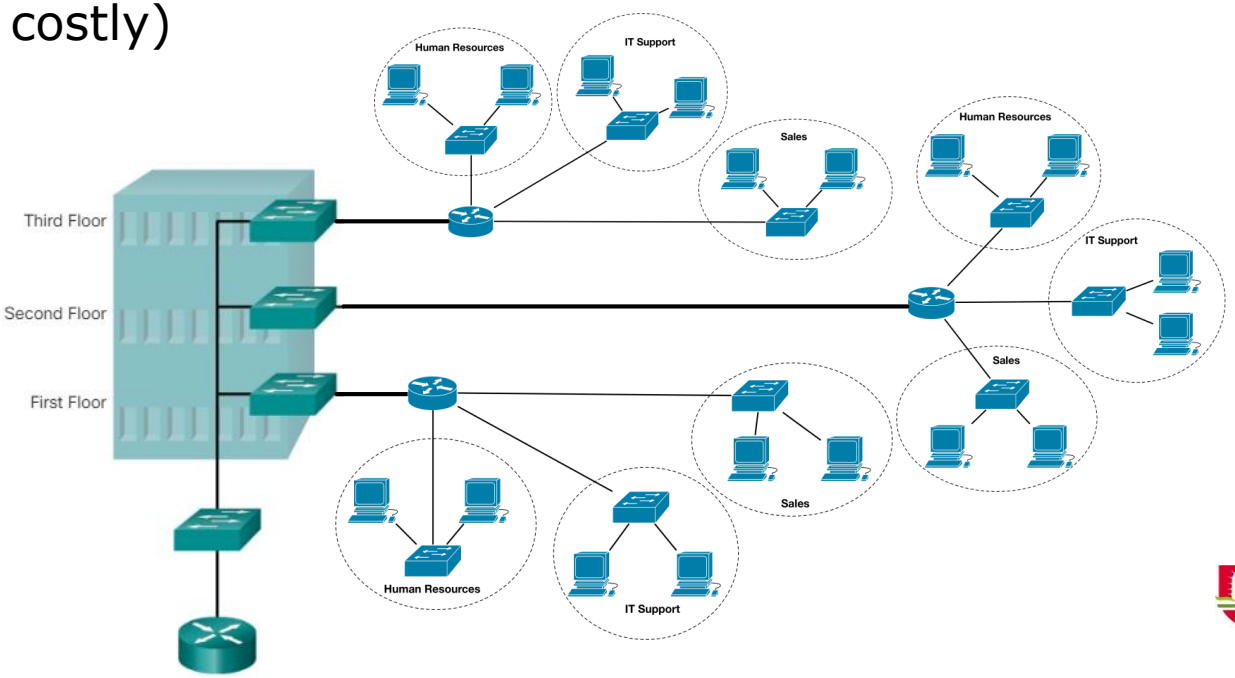

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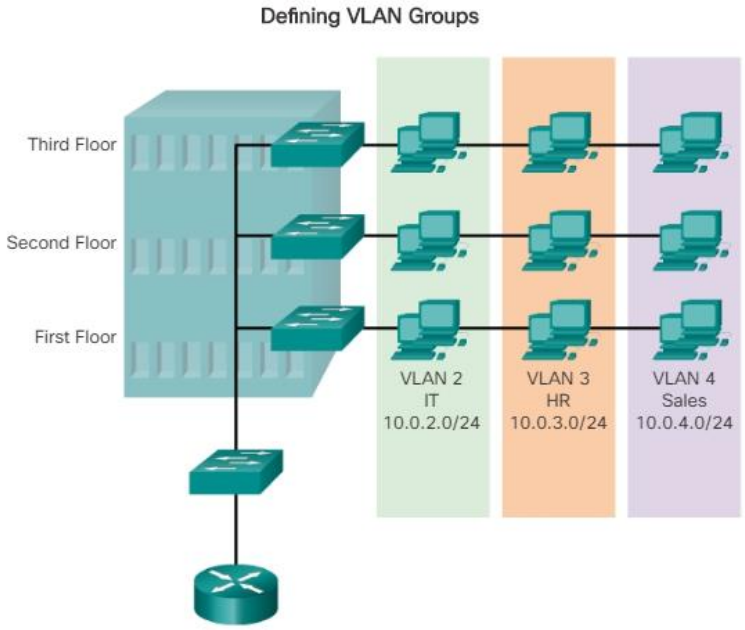
Virtual LANs

- Logical networks that enable hosts in different physical locations to communicate as though they were on the same network segment
- Using VLANs enables the network administrator to create a number of smaller networks on a single switch



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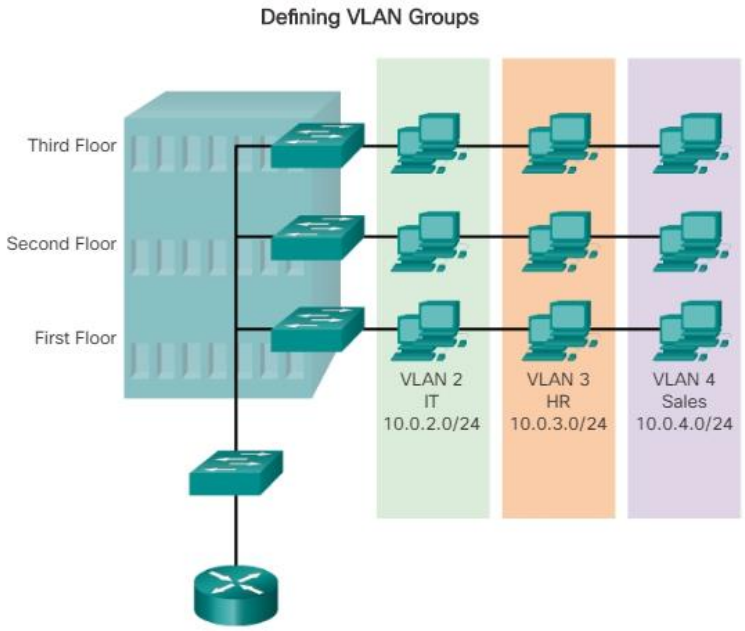
Virtual LANs (cont.)

- Each VLAN becomes a different logical network (and its own broadcast domain)
- Distinguish between VLANs using a VLAN ID



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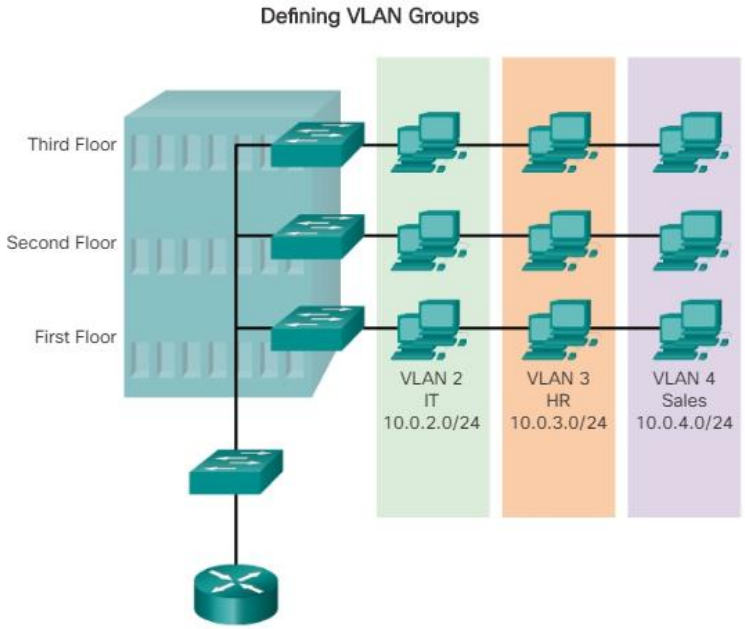
Virtual LANs (cont.)

- Each VLAN becomes a different logical network with it's own IP subnet and broadcast domain
- Distinguish between VLANs using:
  - VLAN ID – An arbitrary number assigned for identification
  - Name – A description of the VLAN's purpose



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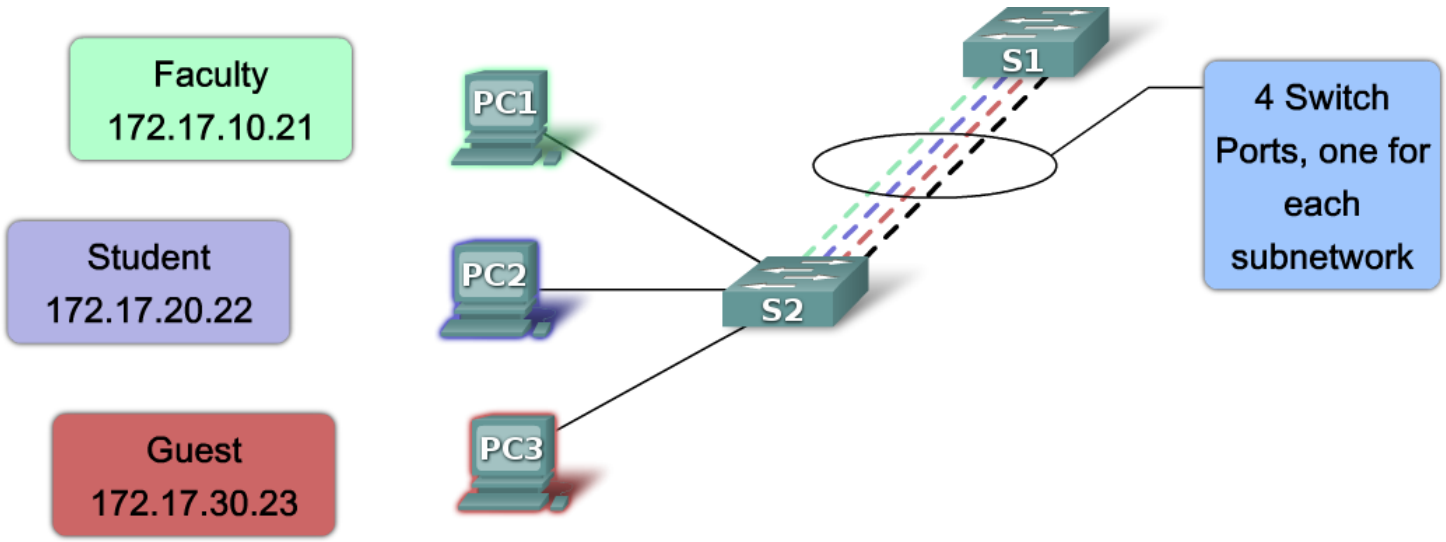
Benefits of VLANs

- Reduced equipment cost – a single switch can now be used for multiple networks
- Improved security – traffic can be isolated based on VLAN tags
- Reduced performance overheads – broadcasts are contained within a VLAN
- Simplified network management – configuration changes can be applied to all users on a VLAN as they share similar requirements / roles

VLAN Operation

- Normally, any given link would only be able to carry data for a single VLAN
- In the example below, that would mean four links are needed between each switch
- How would this scale for an organisation with hundreds of VLANs?



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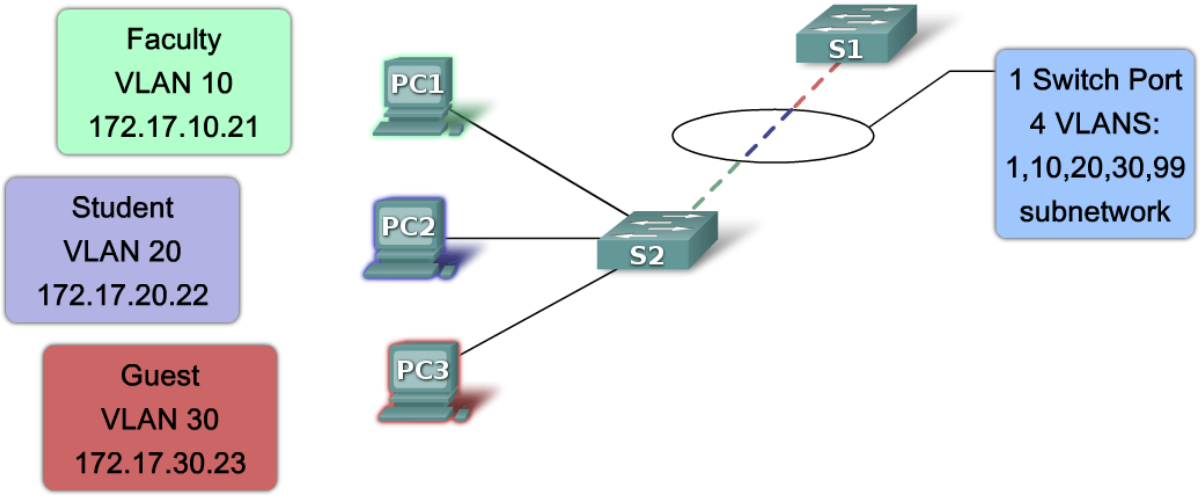
VLAN Trunking

- VLAN trunk links solve this problem; a trunk can carry traffic for multiple VLANs
- Ethernet frames must be tagged so that switches can identify which VLAN they belong to
- Tagging is done using 802.1Q
- Cisco had a competing standard (Inter-switch Link) which is now largely deprecated



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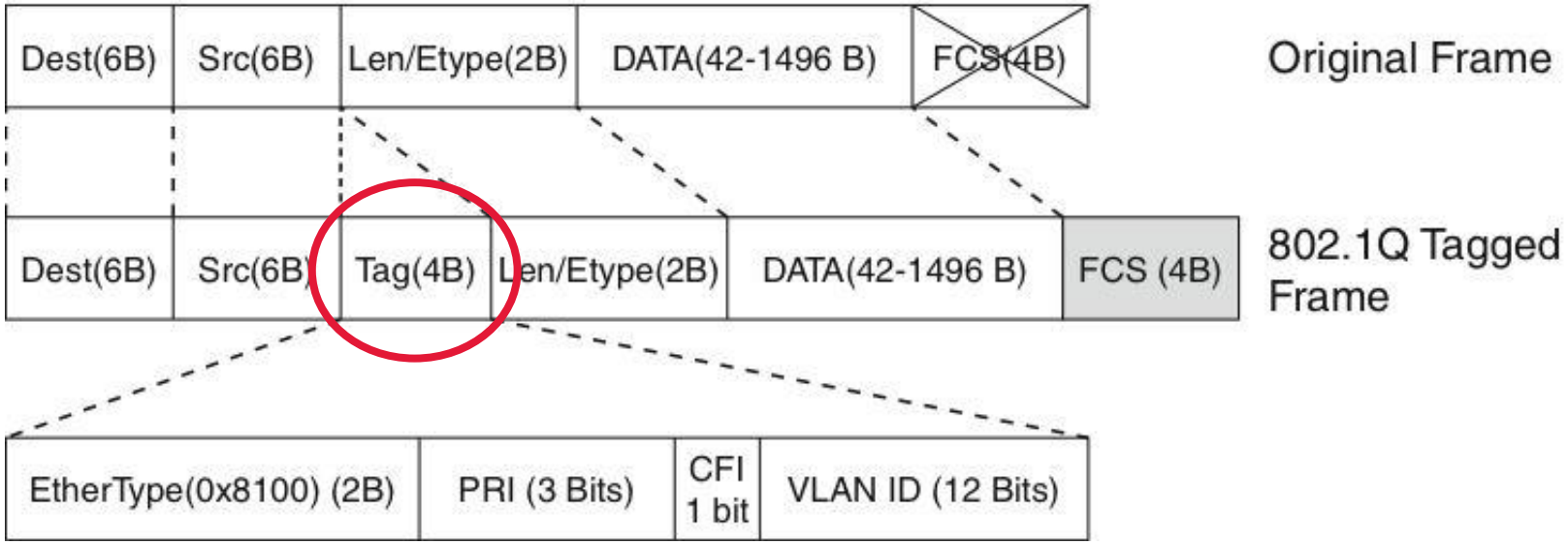
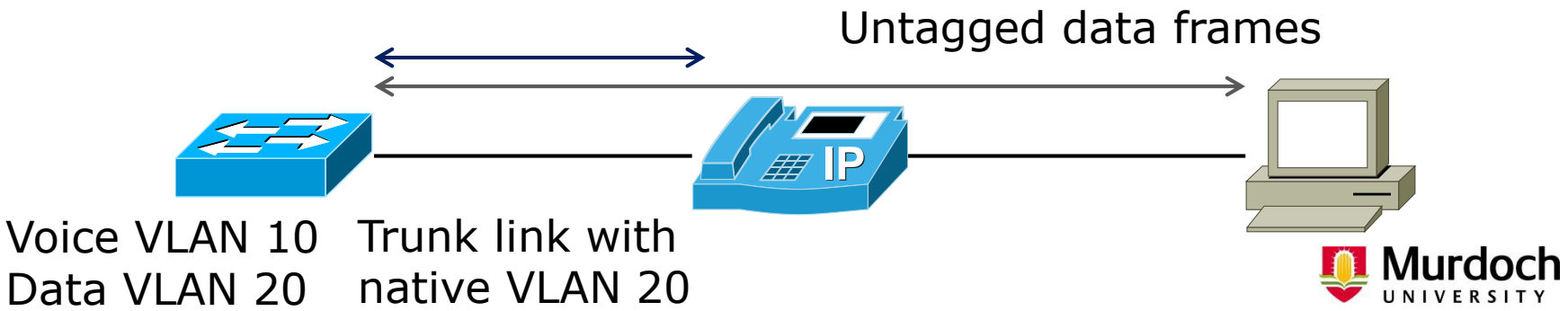
VLAN Tagging using 802.1Q

- 802.1Q is an open standard for VLAN tagging
- Adds 4 bytes to the standard Ethernet header
- VLAN ID is a 12 bit value (maximum of 4095 VLANs)
- VLAN tags are only applied to traffic traversing between switches



Default and Native VLANs

- By default, all ports on a switch are assigned to the **default VLAN** (usually VLAN 1)
- Any untagged traffic traversing a trunk link is treated as traffic from the **native VLAN** (also VLAN 1 by default)
- The Native VLAN provides compatibility with legacy switches that do not support 802.1Q
- Native VLAN also allows multiple devices to be connected to the same switch port (like IP phones)



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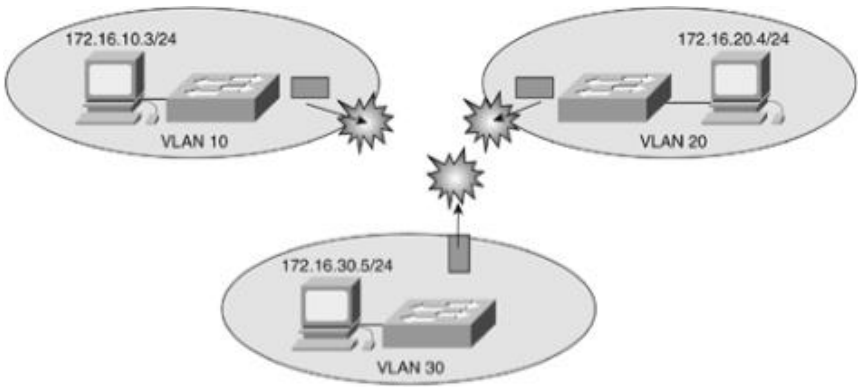
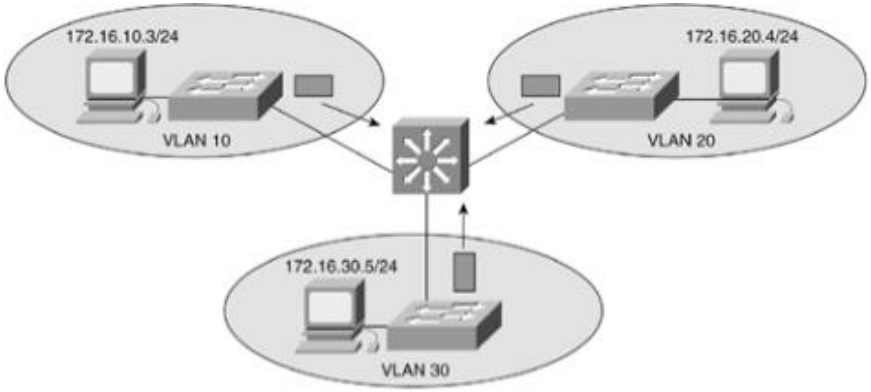
Routing Between VLANs

- VLANs are individual IP subnets, so hosts on different VLANs can't normally communicate with one another
- At least, not without the use of a router
- This concept is referred to as **Inter-VLAN routing**

Isolated VLANs…



… needs router



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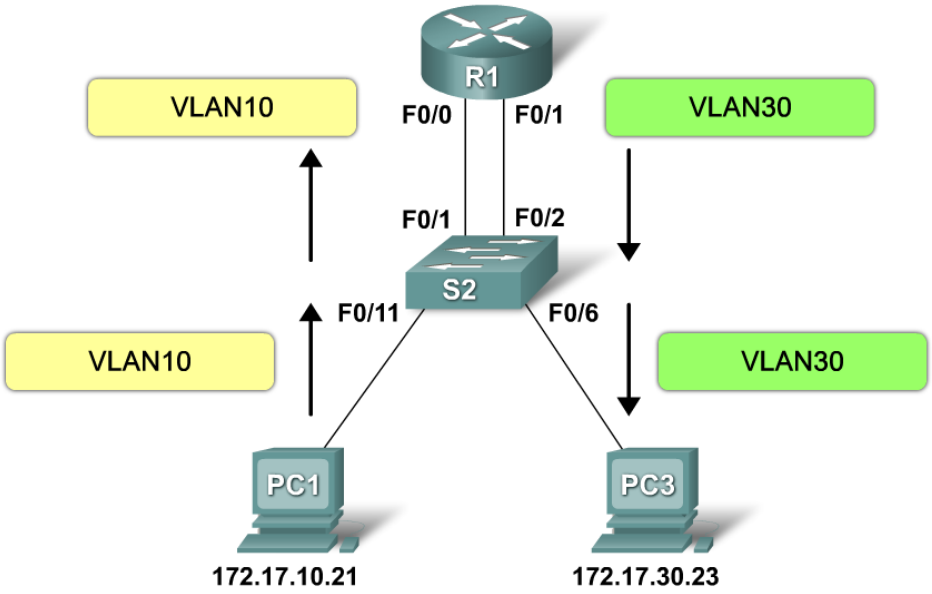
Inter-VLAN Routing

- Historically, inter-VLAN routing would require one switch (and router) interface per VLAN
- This approach isn't scalable, but there are alternatives:
  - Router-on-a-Stick
  - Multilayer switching



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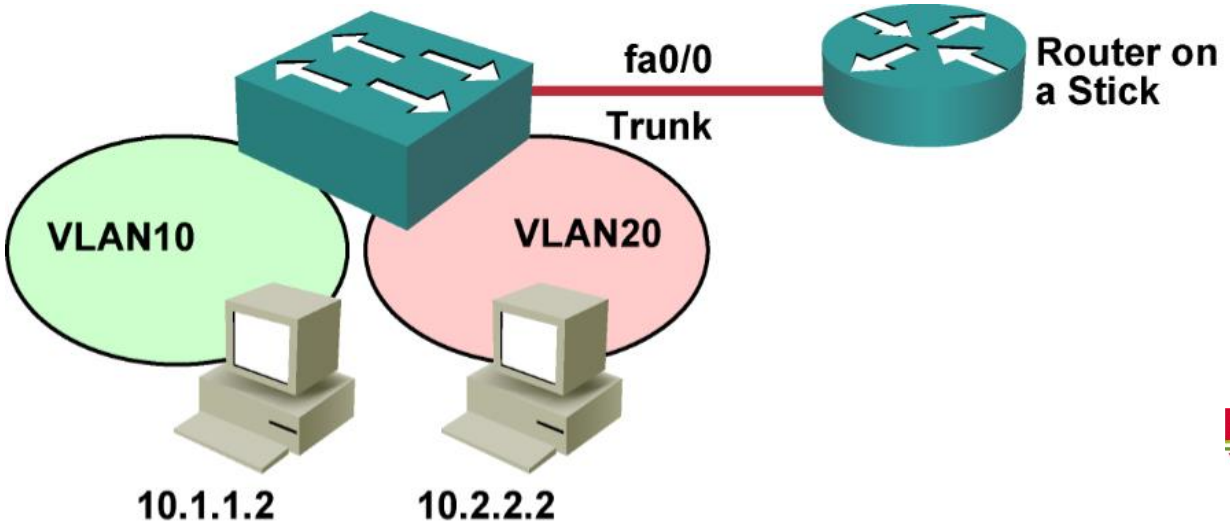
Router-on-a-Stick

- Single trunk link carries traffic for multiple VLANs between a switch and router
- Router uses 802.1Q tags to determine how packets should be routed
- Each VLAN gets a virtual sub-interface on a router
    - Fa0/0 could be broken into Fa0/0.10 and Fa0/0.20
    - Each sub-interface is configured with a different IP address



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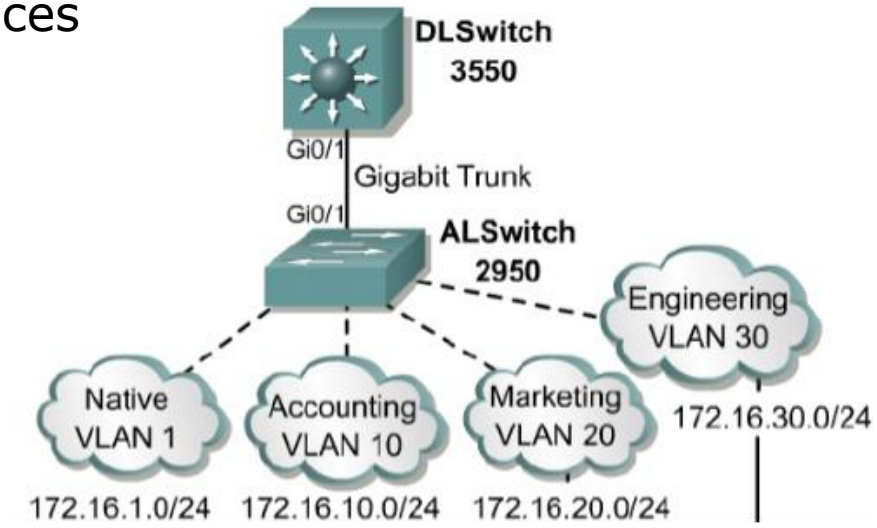
Multilayer Switching

- Multilayer switches can also be configured to perform inter-VLAN routing
- Most enterprise networks use multilayer switches to achieve higher forwarding rates (hardware switching)
- In this arrangement, a **switch virtual interface (SVI)** is assigned to each VLAN
    - SVIs are assigned IP addresses, just like router sub-interfaces



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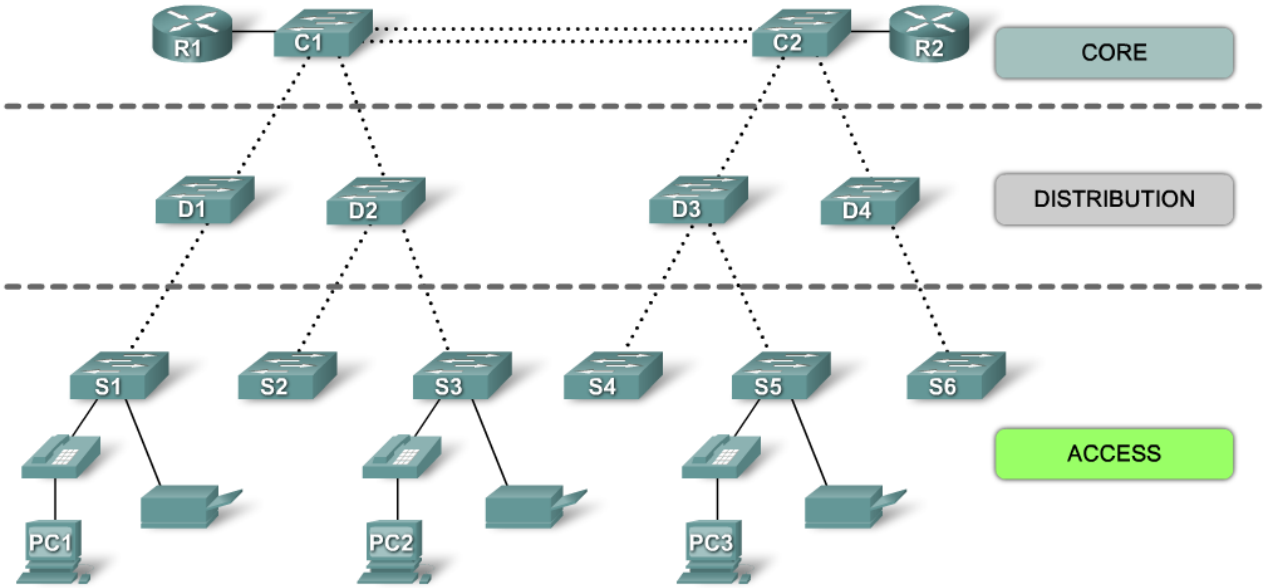
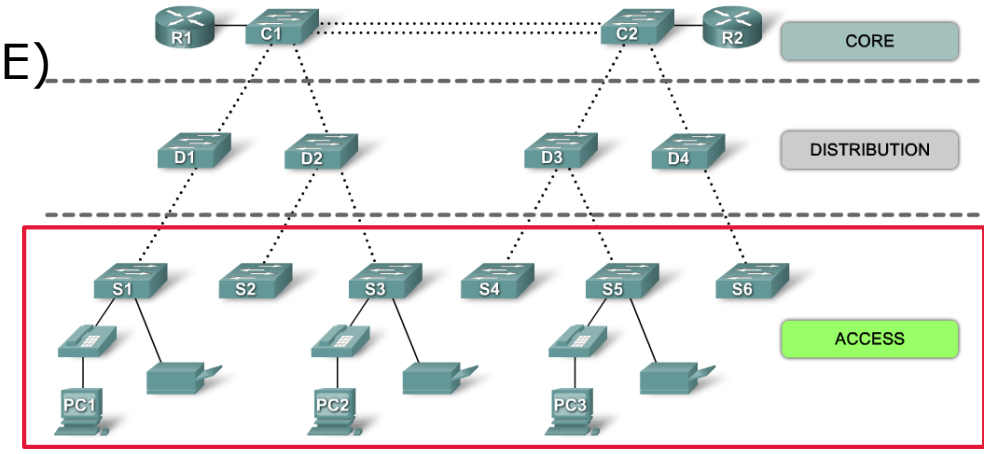
Switched Network Design

- Networks are often designed around the hierarchical model
- Divides the network into three layers: Core, Distribution and Access
    - Distribution and core layers can be merged



Access Layer

- Provides connectivity to end-devices (eg. workstations, printers, mobile devices)
- Includes 100Mbps / 1Gbps Ethernet and WiFi
- Implemented at the Access Layer:
  - Port Security
  - Virtual LANs
  - Power over Ethernet (PoE)
  - Quality of Service (QoS)



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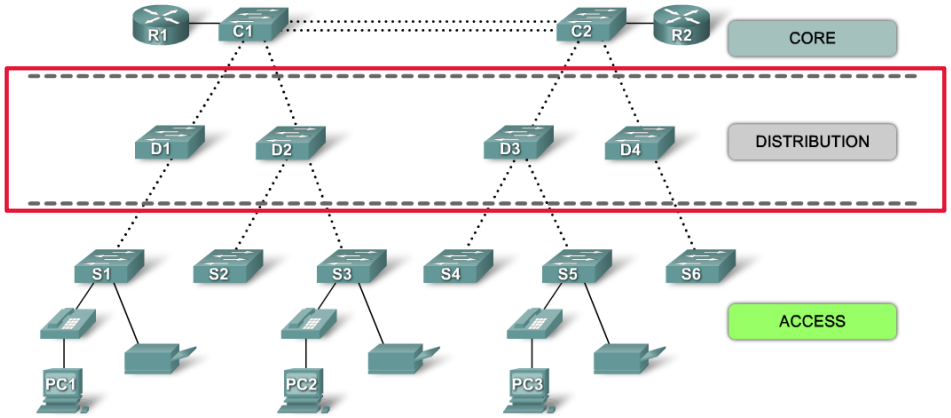
Distribution Layer

- Aggregates data received from the access layer, and segments access layer networks
- Usually has high speed (1Gbps—10Gbps) links to the core Implemented at the Distribution Layer:
  - Link Aggregation
  - Redundancy
  - Security Policies (Access Control Lists)
  - Quality of Service (QoS)



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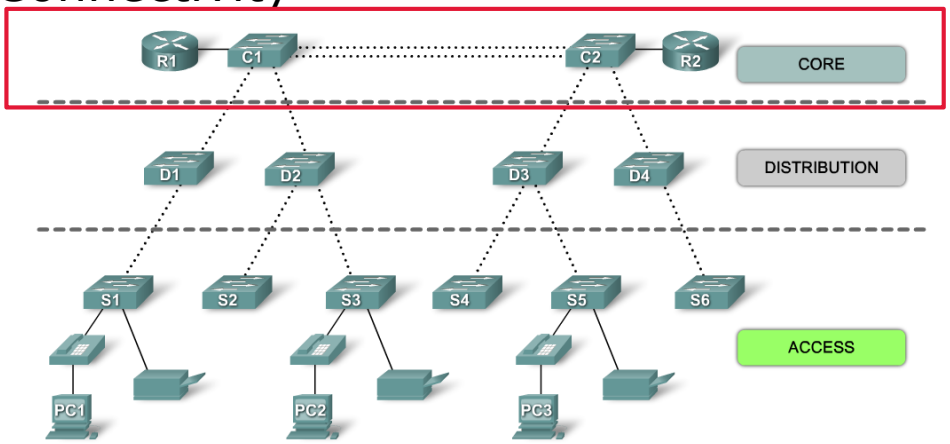
Core Layer

- Backbone of the network, provides connectivity between distribution layer devices and access to the WAN
- Designed to switch packets as fast as possible
- Critical for connectivity, so must provide high level of availability and adapt to changes quickly
- Implemented at the Core Layer:
  - Routing
  - WAN Connectivity



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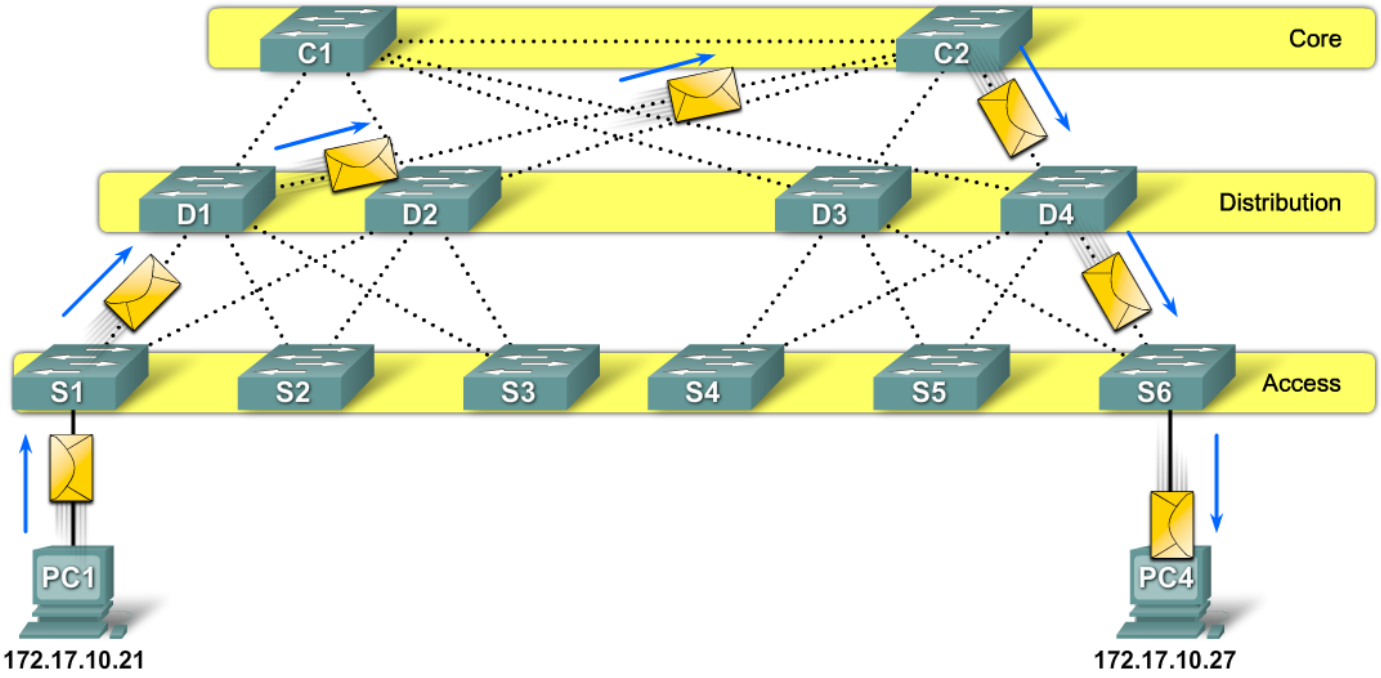
Redundancy

- Networks should be designed with fault tolerance in mind
- Redundant links between switches are used so that the fewest users are effected by any outage



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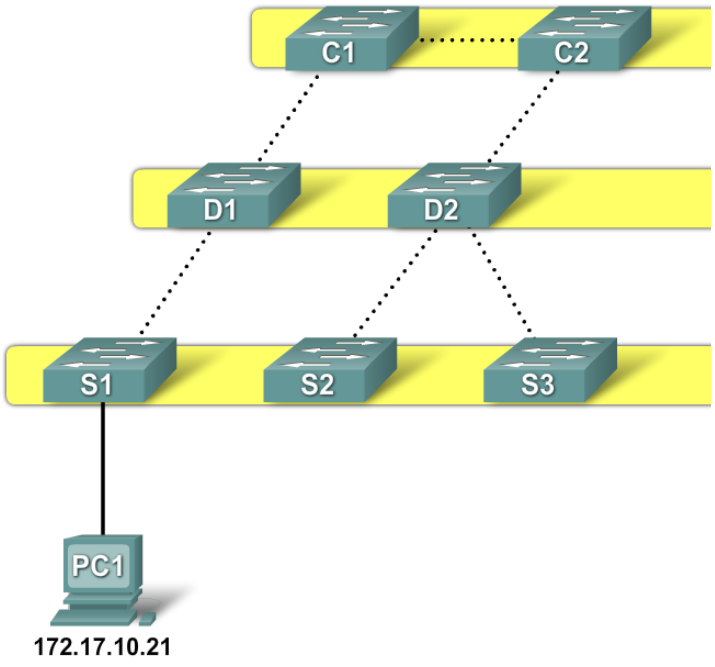
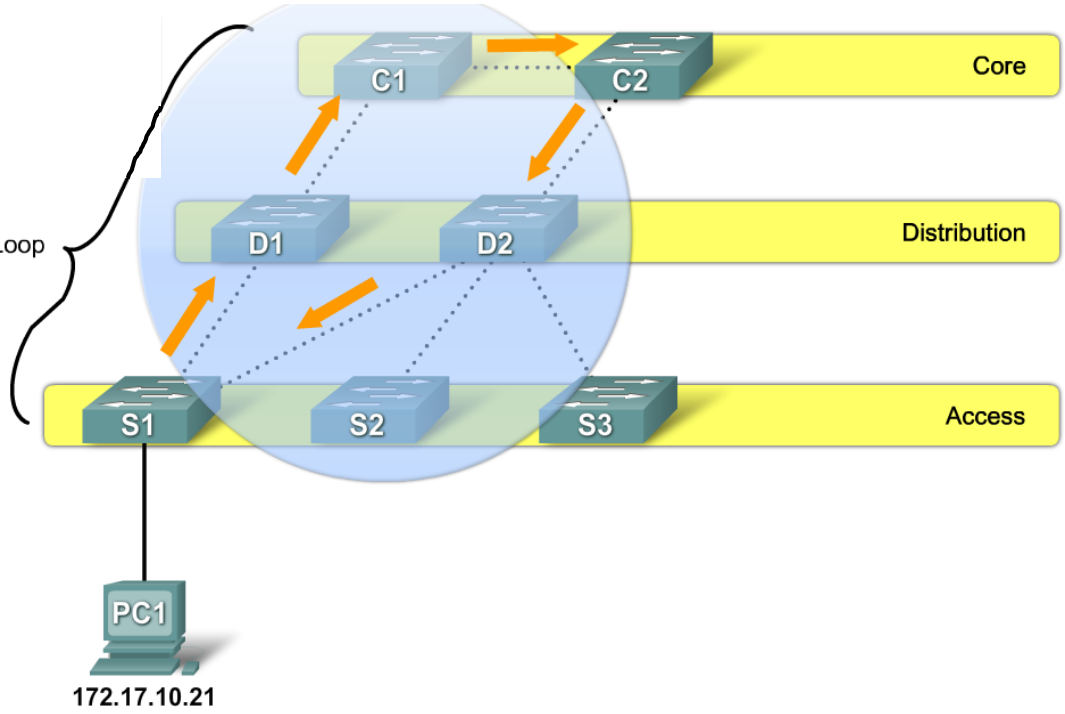
Redundancy Creates Loops

- Redundancy creates loops in switched networks (usually deliberately)
- However, Ethernet doesn't have any built in loop prevention

No redundancy, **loop free**

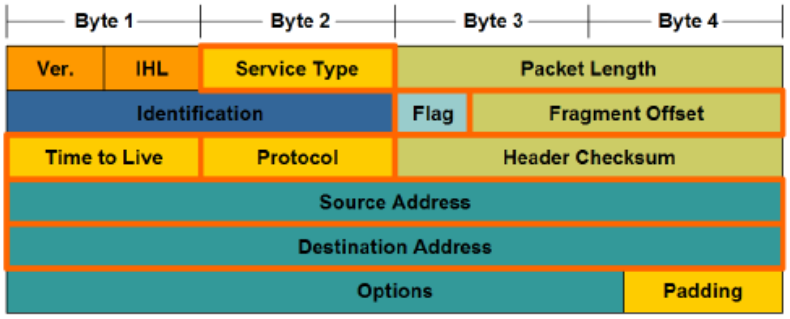


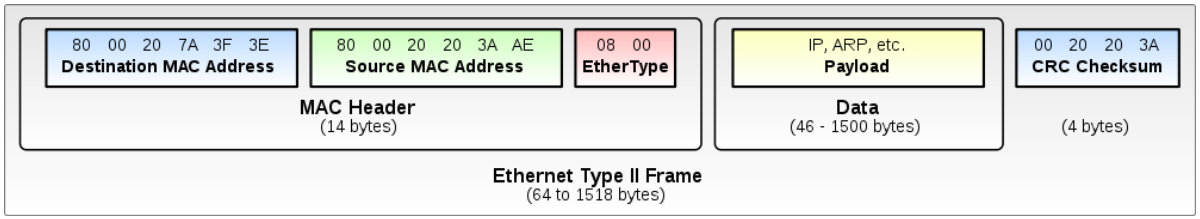
With redundancy, **with loop**



Layer 2 Loops

- Ethernet frames don't have any concept of a Time to Live field (used by IP to prevent loops)
- In networks with redundant links, frames could be transmitted in a loop indefinitely
- If enough frames become stuck in switching loops, these transmissions could consume all of the available bandwidth





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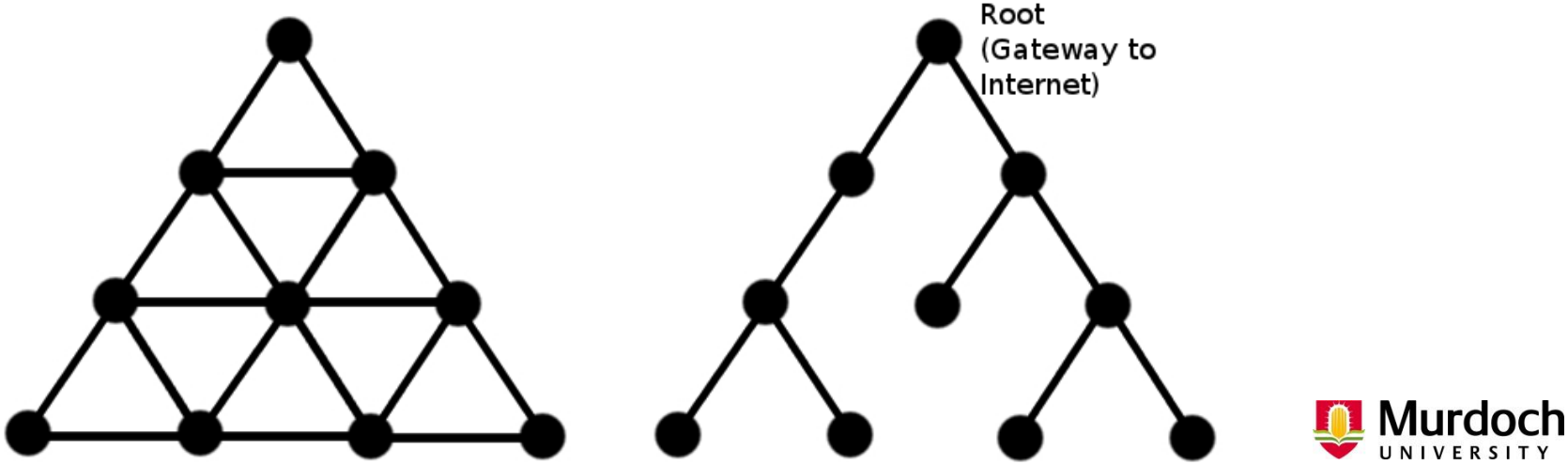
Preventing Loops using Spanning Tree Protocol

- Spanning Tree Protocol (STP) is a Layer 2 protocol designed allow for redundancy in switched networks
- Prevents switching loops by disabling redundant links until they are needed
- Creates a logical tree structure consisting of loop-free leaves and branches



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Lecture Objectives

You should now be able to:

- List different topologies used by Ethernet networks
- Describe the operation of CSMA/CD
- Describe the role of MAC addresses in Ethernet networks
- Describe the operation of Ethernet switches
- Describe the role and operation of ARP
- Define and identify Collision and Broadcast domains
- Differentiate between a straight-through and crossover cable
- Identify the suitable cable type for connecting network devices
- Describe the Hierarchical Network Model
- Describe the role of Virtual Local Area Networks (VLANs) in switched networks
- Describe how traffic from different VLANs is identified and isolated
- Describe the purpose of a trunk link
- Describe the purpose of Spanning Tree Protocol

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Lecture Summary and the Week Ahead

- Today's lecture started our look at individual technologies with Ethernet, with some discussion of VLANs and switched network design
- The readings for this week are Routing and Switching Essentials – Chapters 1, 2, 3 and 5
- In the labs: configuring VLANs and Inter-VLAN routing

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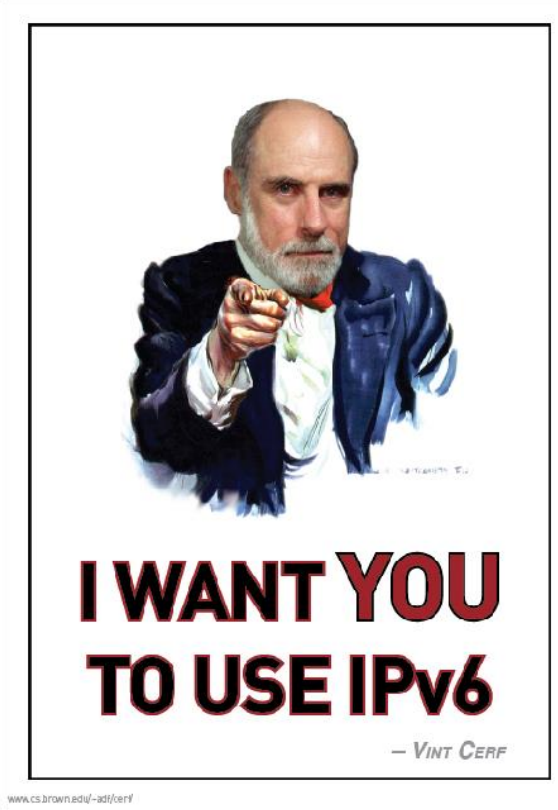
Next Week

- The IPv4 address space is finite (and depleted), so we'll look at two technologies designed to mitigate this problem:
    - Network Address Translation (NAT)
    - Internet Protocol version 6 (IPv6)
- Mid-Semester Test in the labs next week, make sure you're ready!



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