NET 363
Introduction to LANs

Network Devices

Greg Brewster
DePaul University

Network Intermediary Devices (NIDs)

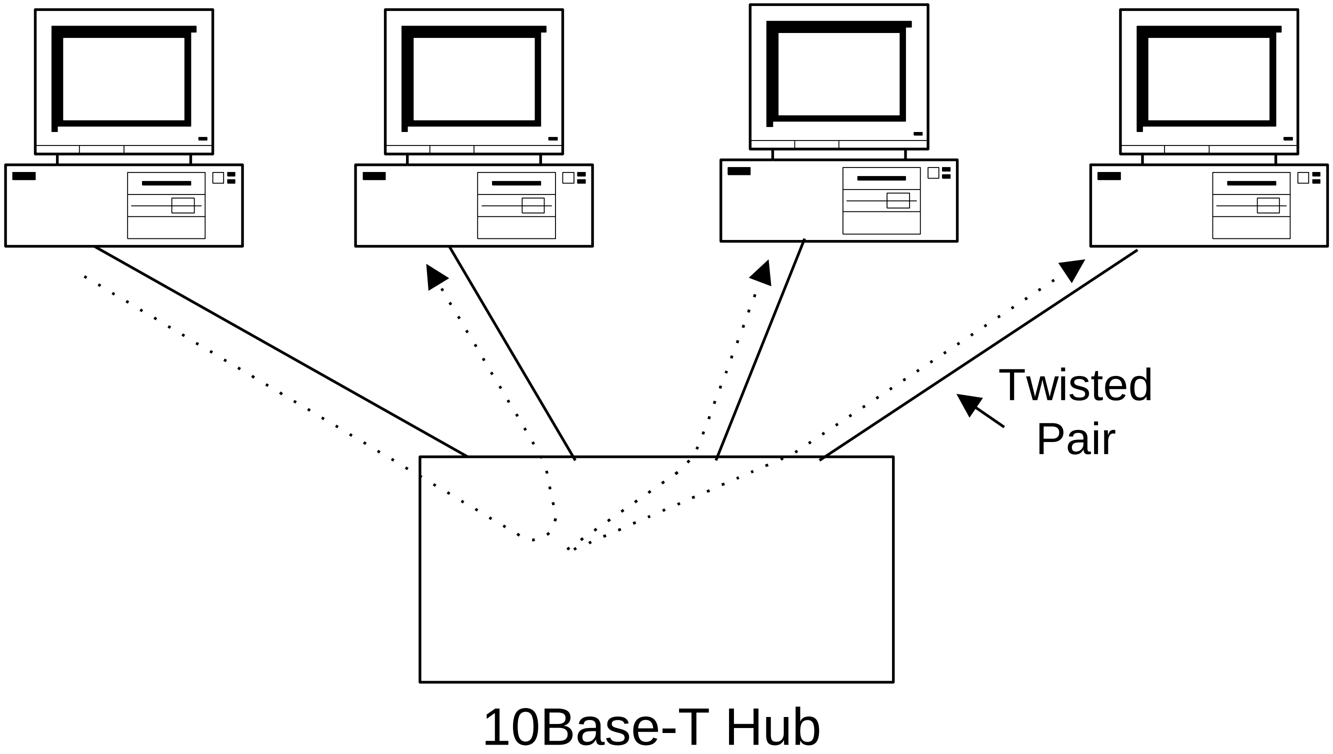
- **Hubs, Access Points, Switches and Routers** are multi-port NIDs.
  - Each port (interface) connects this NID to another device (either end-user device or another NID).
- NIDs forward data packets
  - Data packet is received on one port (interface)
  - The same packet (possibly with some header modifications) is sent out other port(s)

Hub

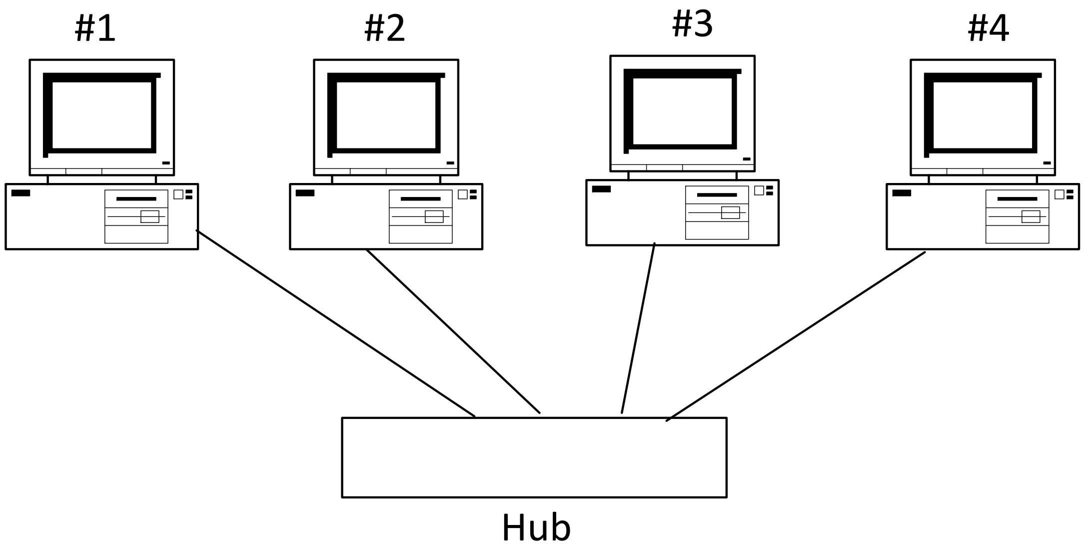
- Operates at Layer 1
- Each bit received on any port is immediately retransmitted out all other ports (physical broadcast device).
- If bits are received on more than 1 port at the same time, this is a **collision** event, all communications will be shut down and a **jam signal** sent out all ports.
- All devices connected to a hub are in the same **collision domain**
  - Definition: <u>Collision domain</u> = a set of devices where every device receives every bit transmitted by any other device. If 2 devices in same collision domain transmit at same time, <u>collision</u> occurs.
- All devices connected to a hub are in the same **broadcast domain**
  - Definition: <u>Broadcast domain</u> = a set of devices where every device receives every <u>Layer 2 broadcast frame</u> sent by any other device in the domain.
  - <u>Layer 2 broadcast</u> is Ethernet frame w/ dest. = FF:FF:FF:FF:FF:FF

Shared Ethernet

Data delivery by broadcast



Data Delivery through Hub



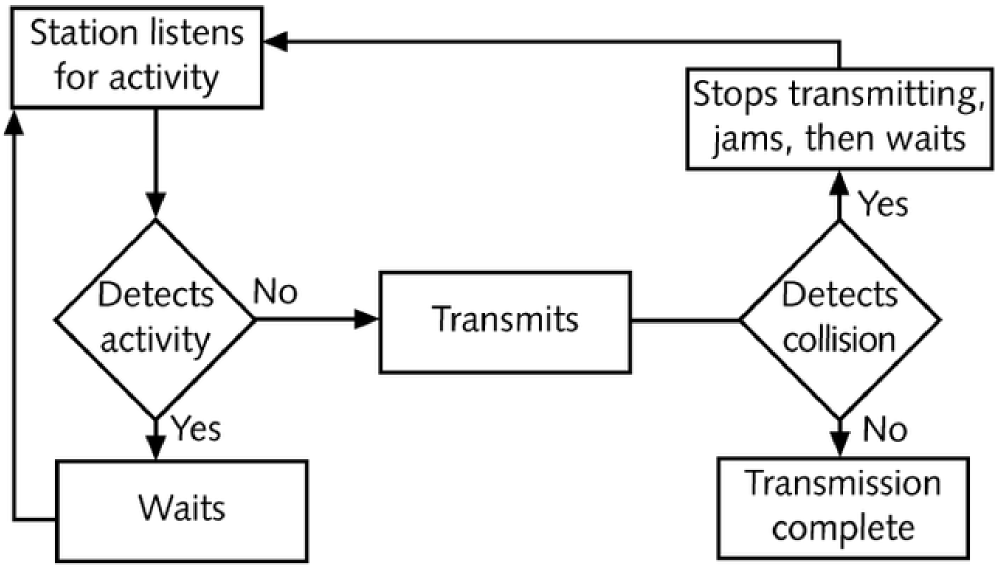
- Example: PC #1 puts MAC address "#2" into Destination Address field of Ethernet header and transmits data frame to Hub
- Hub broadcasts the frame to #2, #3 and #4
- #2 copies frame while #3 and #4 ignore it (not their address)

Carrier Sense Multiple Access with Collision Detection

- Only 1 station can transmit data through a hub at any one time
- CSMA/CD protocol is used to resolve contention if multiple stations want to transmit at the same time.
- Not needed in Switched Ethernets, in which the central switch stores data if multiple stations send at same time.

CSMA/CD

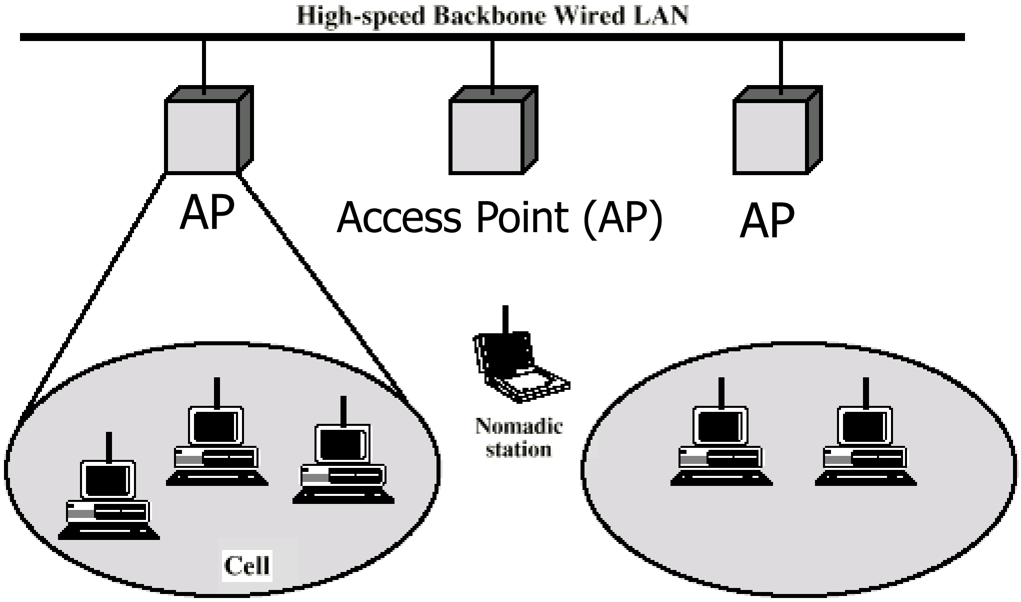
- Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
  - Used in wired hub-based Ethernet networks
  - Different version (CSMA/CA) used with Wi-Fi LANs



Wi-Fi APs ≈ Hubs

- WiFi – "Wireless Fidelity" industry alliance
  - http://www.wifialliance.com
- IEEE 802.11 committee has created multiple standards for transmitting wireless data.
- **Access Points** act like hubs for all WiFi devices that join a common SSID (Service Set Identifier).
  - Each wireless packet sent by any wireless client is received by every other wireless client within the Wi-Fi LAN.
  - Wireless LAN is a single collision domain. Only 1 device can send at a time.

Wireless LAN
(more details later)



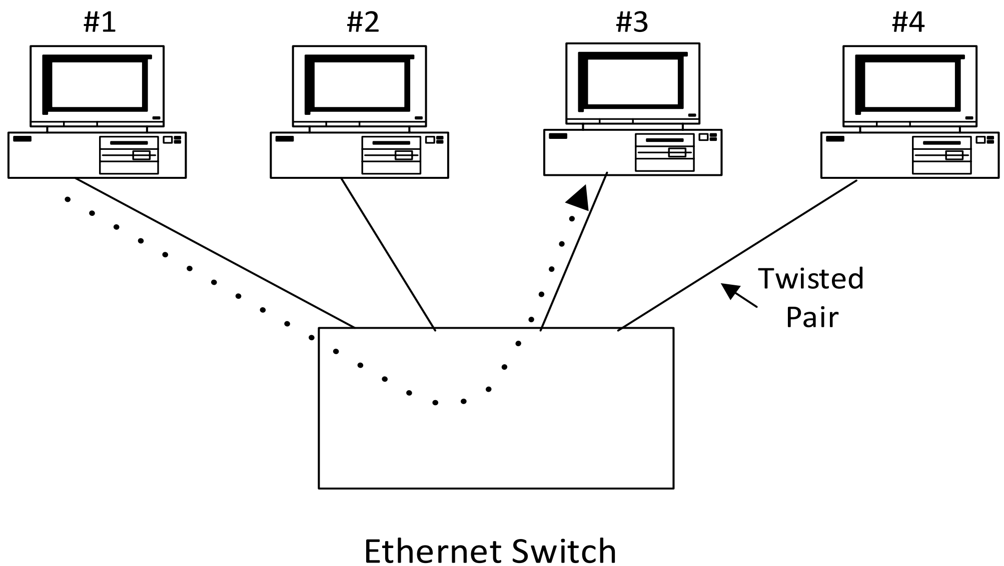
(a) Infrastructure Wireless LAN

Layer 2 Ethernet Switch

- Operates at Layers 1 and 2
- Ethernet frames received on any port are stored temporarily in a memory buffer (cut-through or store-and-forward) and sent out a port determined by the destination MAC address in Ethernet header.
  - MAC addresses are mapped to outgoing ports in the **Forwarding Table**
  - If an address is not found in the Forwarding Table, then the frame is broadcast out all ports (that is, switch reverts to acting like a hub).
- If frames are received on more than 1 port at the same time, this is no problem. Each is buffered and forwarded individually.
- Ports on a switch are in different **collision domains**
  - Each switch port defines a separate collision domain
- Ports on a switch are in the same **broadcast domain**
  - Switch will forward a layer 2 broadcast frame out every port except the one it came in on.

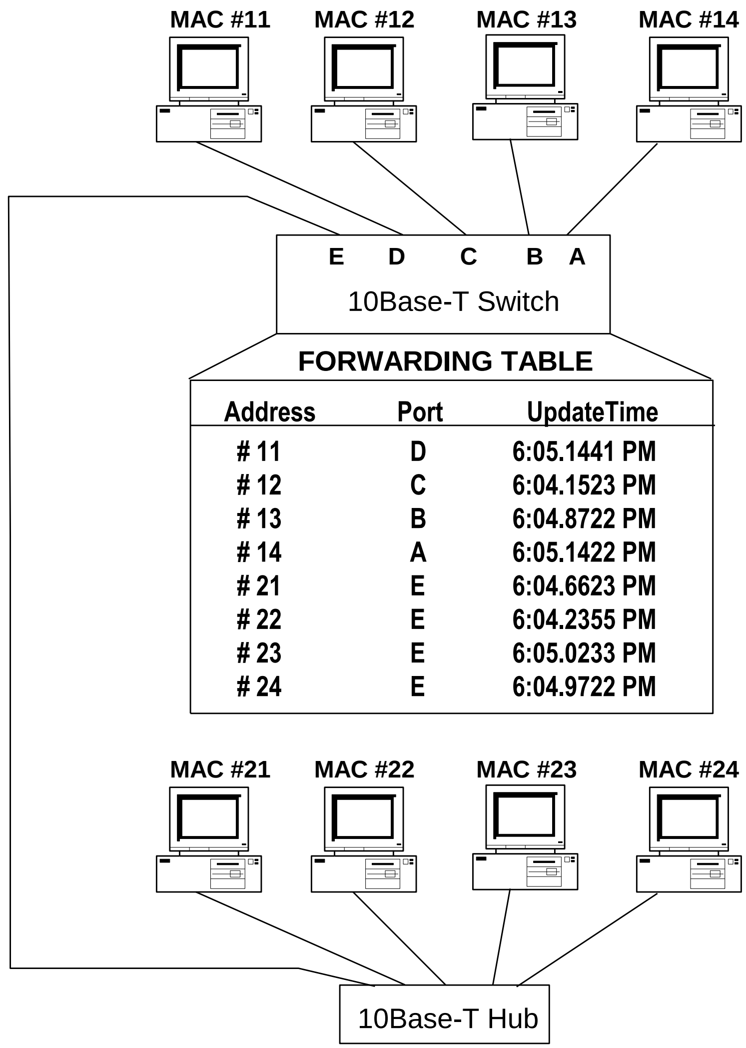
Switched Ethernet

Data delivery via intelligent switch



- Example: PC #1 puts MAC address "#2" into Destination Address field of Ethernet header and transmits data frame to Switch
- Switch checks its MAC Forwarding Table and ONLY transmits data frame to #2.

Switch Forwarding Table



Address	Port	UpdateTime
# 11	D	6:05.1441 PM
# 12	C	6:04.1523 PM
# 13	B	6:04.8722 PM
# 14	A	6:05.1422 PM
# 21	E	6:04.6623 PM
# 22	E	6:04.2355 PM
# 23	E	6:05.0233 PM
# 24	E	6:04.9722 PM

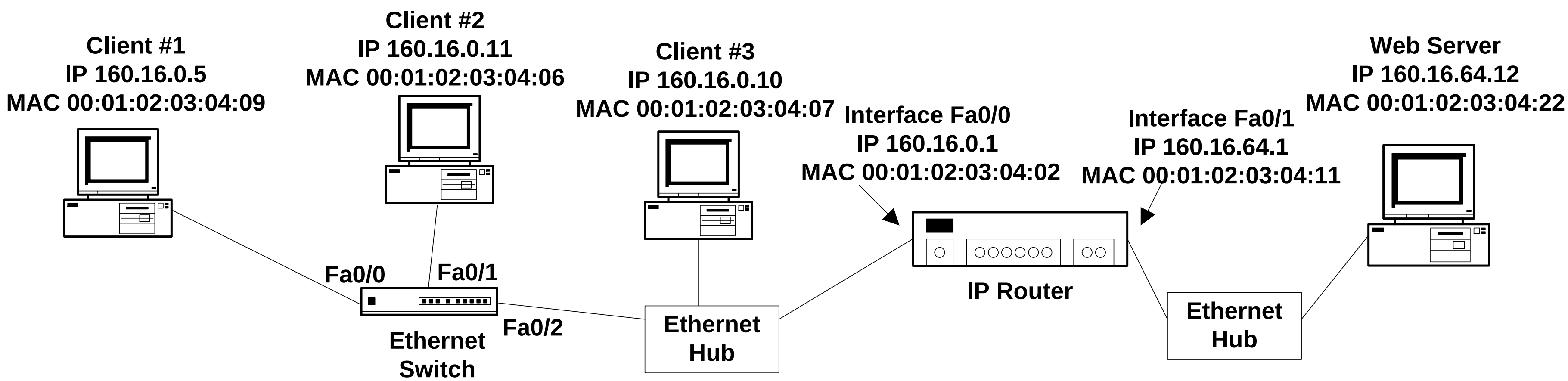
IP Router

- Operates at Layers 1, 2 and 3
- IP packets received on any port are stored temporarily in a memory buffer and sent out an interface determined by the destination IP address in the packet's IP header.
  - IP subnets are mapped to outgoing interfaces in the **Routing Table**
  - If an address is not found in the Routing Table, then
    - If there is a <u>default route</u>, then the packet is forwarded based on this route.
    - If no default route, the packet is dropped and an ICMP error message sent back to the sender.
- If frames are received on more than 1 port at the same time, this is no problem. Each is buffered and forwarded individually.
- Devices connected out different router ports are in <u>different</u> collision domains and <u>different</u> broadcast domains
  - Routers <u>do not forward layer 2 broadcast frames</u>

What's a Router?

- A router has multiple network interfaces.
- Each interface connects router to a ***subnet*** of devices
- Each interface has its own IP address
  - Interface IP must be <u>assignable</u> IP from the attached subnet
- Router forwards packets:
  - Receives packets on an interface, removes MAC header
  - Looks up packet's IP destination address in **Routing Table**
  - Creates a <u>new MAC header</u> for outgoing packet with MAC destination corresponding to Next Hop IP from Routing Table.
  - Retransmits the packet out another interface to get it closer to its destination.

Forwarding Example:
Client #1 sends to Web Server



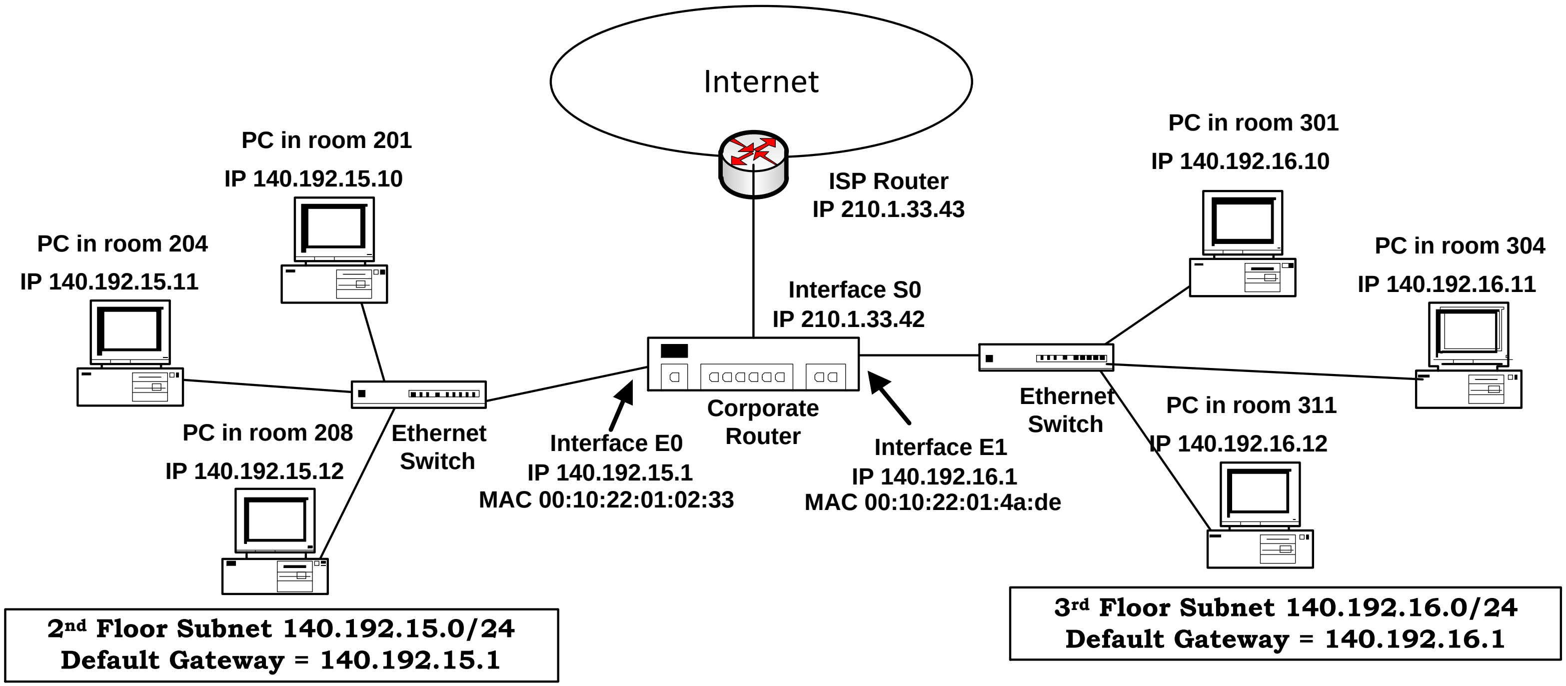
What do routers do?

- Store and Forward packets based on their destination IP address
- Provide a gateway between different physical networks.
- Provide a boundary for network security, management and auditing
- Packet filtering and security services
- Special routing services (MPLS, virtual private networks, etc.)

What's a subnet?

- A subnet is a group of devices that can all send packets to each other <u>without</u> going through a router.
- An Ethernet LAN is an example of a subnet.
  - PCs that can send packets to each other through any combination of Ethernet hubs and switches are members of the same subnet.
- Every device in a subnet is allocated an IP address from a group of addresses called the **IP subnet.**
  - **Example:** IP addresses 140.192.35.1, 140.192.35.2, … 140.192.35.255 might all be in the same IP subnet, written as **140.192.35.0/24.**
    - "/24" means the first 24 bits of all addresses in the subnet are the same.

Example



- This Corporate Router has 3 interfaces – 2 Ethernet and 1 point-to-point.
- Each router interface has its own IP address
- Devices in each subnet keep track of the IP address of the router interface in their subnet, called the <u>default gateway</u> address.

What’s in a Routing Table?

- Important entries in a routing table :
  - **Destination Subnet ID** – this is an identifier that represents a group (subnet) of IP addresses
  - **Outgoing Interface** – the router interface the packet should be sent out to deliver it to the particular IP subnet.
  - **Next Hop** – the IP address of the incoming interface of the next router this packet needs to go through, if it has to go through another router.
- Plus some other stuff we will examine later.

Routing Table for Corporate Router in Example

IP Subnet	Interface	Next Hop
140.192.15.0 / 24	E0	--
140.192.16.0 / 24	E1	--
0.0.0.0 / 0	S0	210.1.33.43

Note: "0.0.0.0/0" is the notation for the default route. If the IP destination address in an arriving packet does not match any other entries in the routing table, then this route will be taken.

Cisco Routing Table

- IOS Command: **show ip route**

```
it263s11@linux05:~
Router6>show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

Gateway of last resort is not set

C    192.168.10.0/24 is directly connected, Ethernet0/0
R    192.168.11.0/24 [120/1] via 192.168.10.7, 00:00:00, Ethernet0/0
C    192.168.1.0/24 is directly connected, Ethernet0/1
R    192.168.2.0/24 [120/2] via 192.168.10.7, 00:00:00, Ethernet0/0
```

Code (how route was learned)

IP Subnet

[Admin Distance / Metric]

Next Hop

Time since last route update received

Outgoing Interface

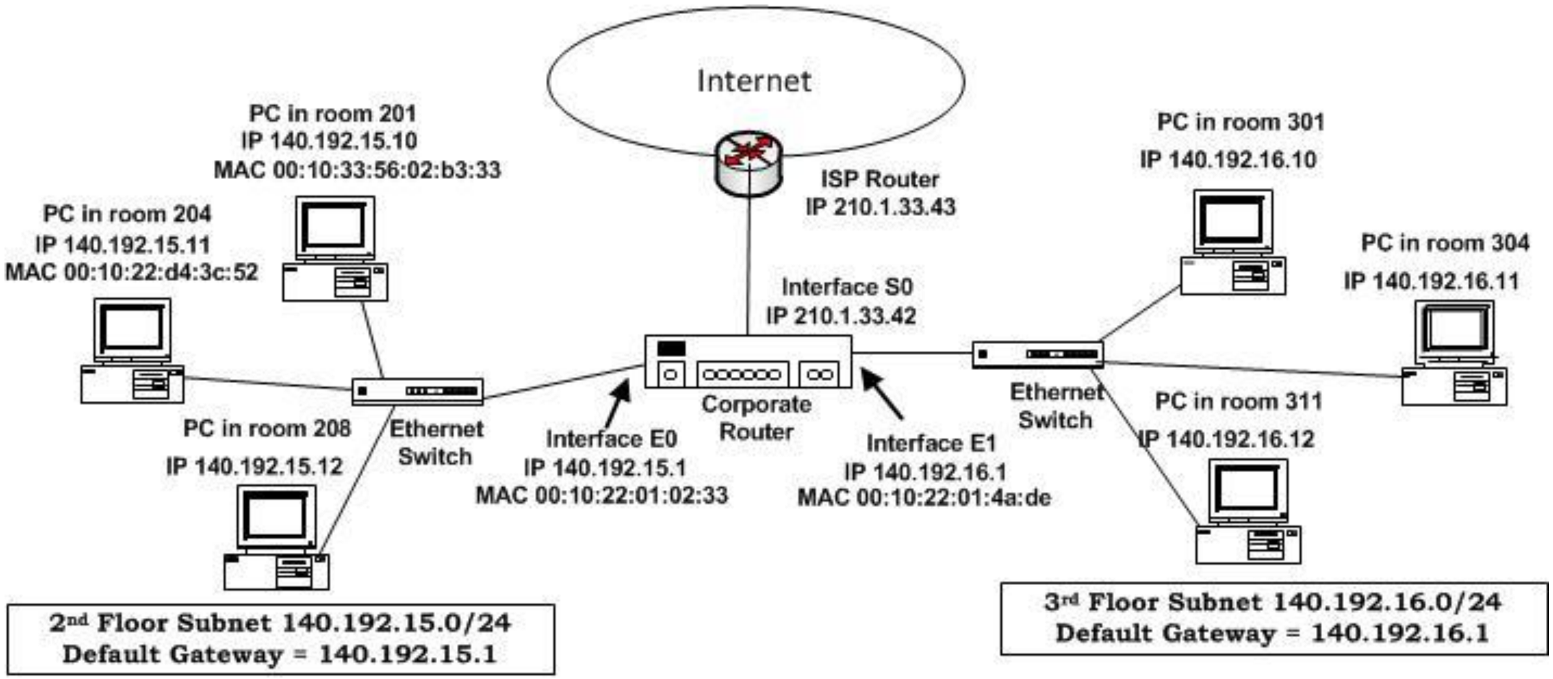
How a PC sends an IP Packet

- PC must first determine whether the Destination IP is on the <u>same subnet</u> as the sending PC or on a <u>different subnet</u>
  - If destination is on the <u>same subnet</u>, then PC adds an Ethernet header with ***Destination PC's MAC address*** in the Ethernet Destination field.
  - If destination is on a <u>different IP subnet</u>, then PC adds an Ethernet header with the ***MAC address of the default gateway*** in the Ethernet Destination field.

Router Forwarding

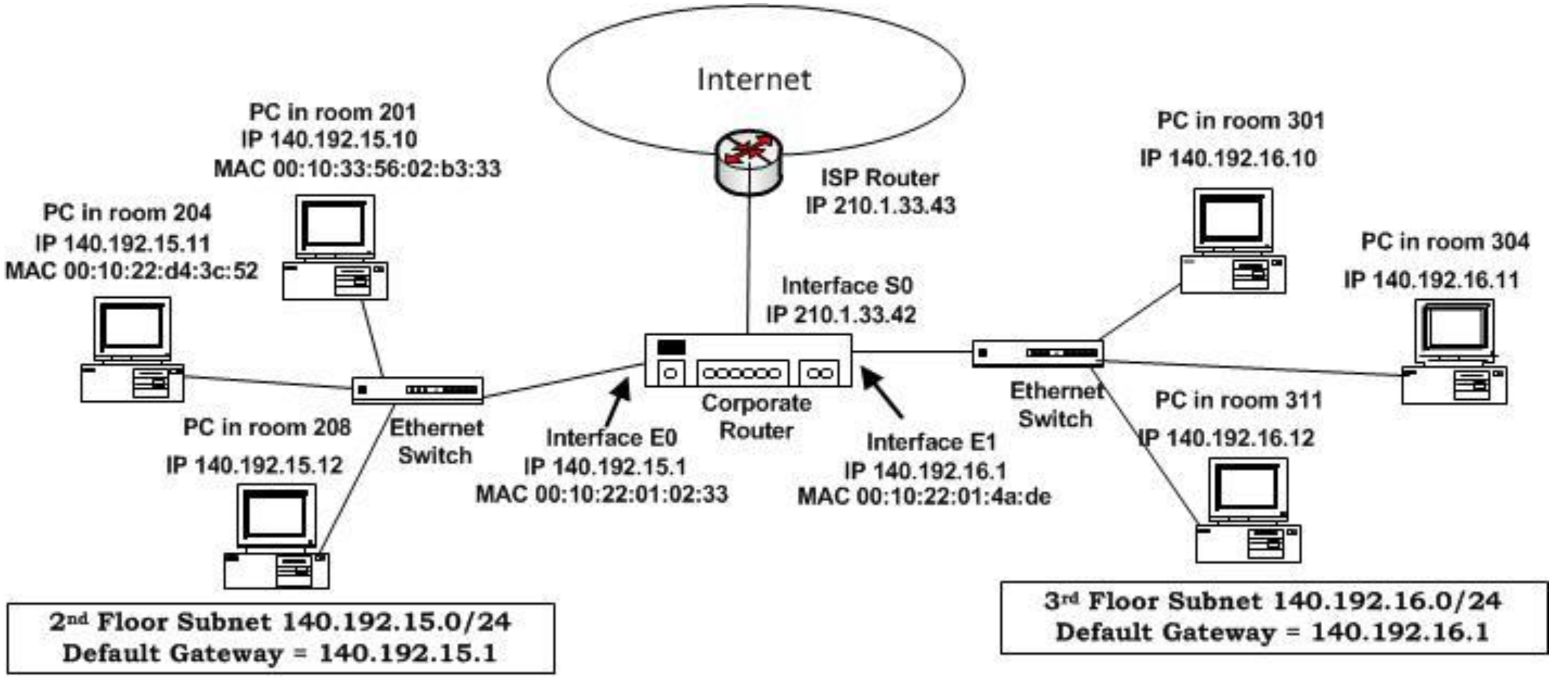
- For each arriving packet, the router will:
  - Remove the MAC header from arriving packet
  - Look up the Destination IP address from the packet in the Routing Table to determine (a) Outgoing Interface (b) Next Hop IP address (if present)
  - Create a new MAC header of the appropriate type for the outgoing Interface.
  - If there is a Next Hop IP address then
    - If Ethernet interface, look in ARP table to find MAC address corresponding to Next Hop IP address and put that into Destination field of the new MAC header.
  - If there is no Next Hop value (directly connected)
    - Look in ARP table to find MAC address corresponding to Dest IP in packet and put that into Destination field of the new MAC header.

Example: same subnet



- For packet sent from Room 201 PC to Room 204 PC, transmitted packet:
  - In IP header:
    - Source = 140.192.15.10, Dest = 140.192.15.11
  - In Ethernet header:
    - Source = 00:10:33:56:02:b3:33, Dest = 00:10:22:d4:3c:52
  - Ethernet switch will deliver this to the Room 204 PC

Example: different subnet



- For packet going from Room 201 PC to Room 301 PC, transmitted packet:
  - In IP header:
    - Source = 140.192.15.10, Dest = 140.192.16.10
  - In Ethernet header:
    - Source = 00:10:33:56:02:b3:33, Dest = 00:10:22:01:02:33 (router)
  - But how does the Router deliver it from there?