Ethernet
Week 2

Module : Computer Networks

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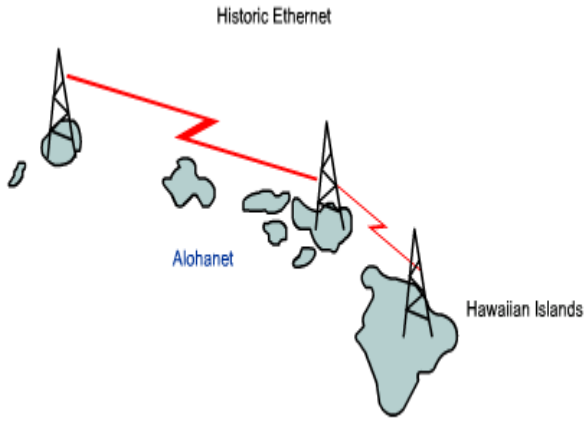
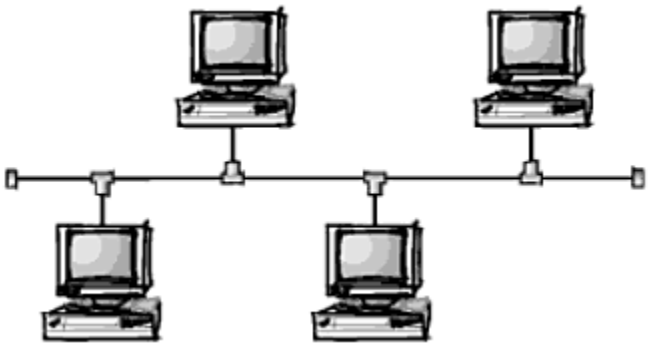
Many Slides courtesy of Tony Chen

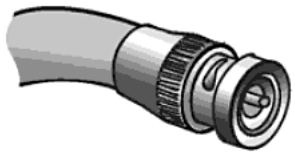
Historic Ethernet

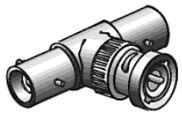
- The foundation for Ethernet technology was first established in 1970 with a program called Alohanet.
  - –Alohanet was a digital radio network designed to transmit information over a shared radio frequency between the Hawaiian Islands.
  - –Alohanet required all stations to follow a protocol in which an unacknowledged transmission required re-transmitting after a short period of waiting.
- The techniques for using a shared medium in this way were later applied to wired technology in the form of Ethernet.
  - –Ethernet was designed to accommodate multiple computers that were Interconnected on a shared bus topology.
- The first version of Ethernet incorporated a media access method known as **Carrier Sense Multiple Access with Collision Detection (CSMA/CD).**
  - –CSMA/CD managed the problems that result when multiple devices attempt to communicate over a shared physical medium.

Ethernet's shared media and collision detection techniques were adapted from the Alohanet radio network.



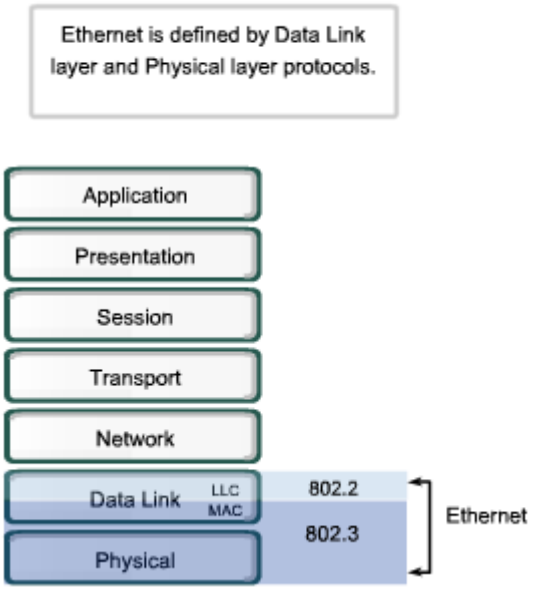


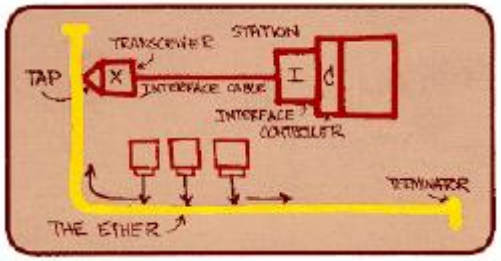

BNC (bayonet connector) plug


BNC T connector

Ethernet – Standard and Implementation

- Ethernet operates in the lower two layers of the OSI model: the Data Link layer and the Physical layer.
- Robert Metcalfe and his coworkers at Xerox designed the 1st Ethernet LAN more than thirty years ago.
  - –The first Ethernet standard was published in 1980 by a consortium of Digital Equipment Corporation, Intel, and Xerox (DIX).
- In 1985, the Institute of Electrical and Electronics Engineers (IEEE) standards committee for Local and Metropolitan Networks published standards for LANs.
  - –These standards start with the number 802.
  - –The standard for Ethernet is 802.3.
  - –The IEEE wanted to make sure that its standards were compatible with those of the International Standards Organization (ISO) and OSI model.
  - –The IEEE 802.3 standards address the needs of Layer 1 and the lower portion of Layer 2 of the OSI model.





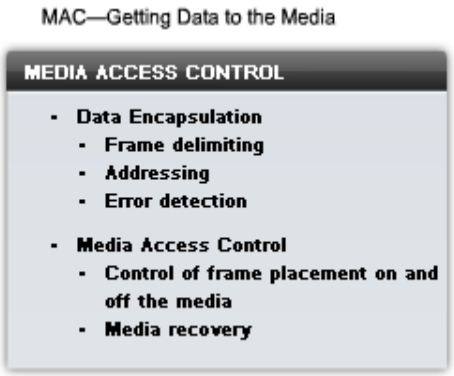
Ethernet – Layer 1 and Layer 2

- Ethernet operates across 2 layers of the OSI model.
  - –The Physical layer.
    - •Ethernet at Layer 1 involves signals, bit streams that travel on the media, physical components that put signals on media, and various topologies.
    - •Ethernet Layer 1 performs a key role in the communication that takes place between devices.
  - –Ethernet is actually implemented in the lower half of the Data Link layer, which is known as the Media Access Control (MAC) sublayer,
    - •Ethernet at Layer 2 addresses the limitations in layer 1.
    - •The MAC sublayer is concerned with the physical components that will be used to communicate the information and prepares the data for transmission over the media.
- The Logical Link Control (LLC) sublayer remains relatively independent of the physical equipment that will be used for the communication process.

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

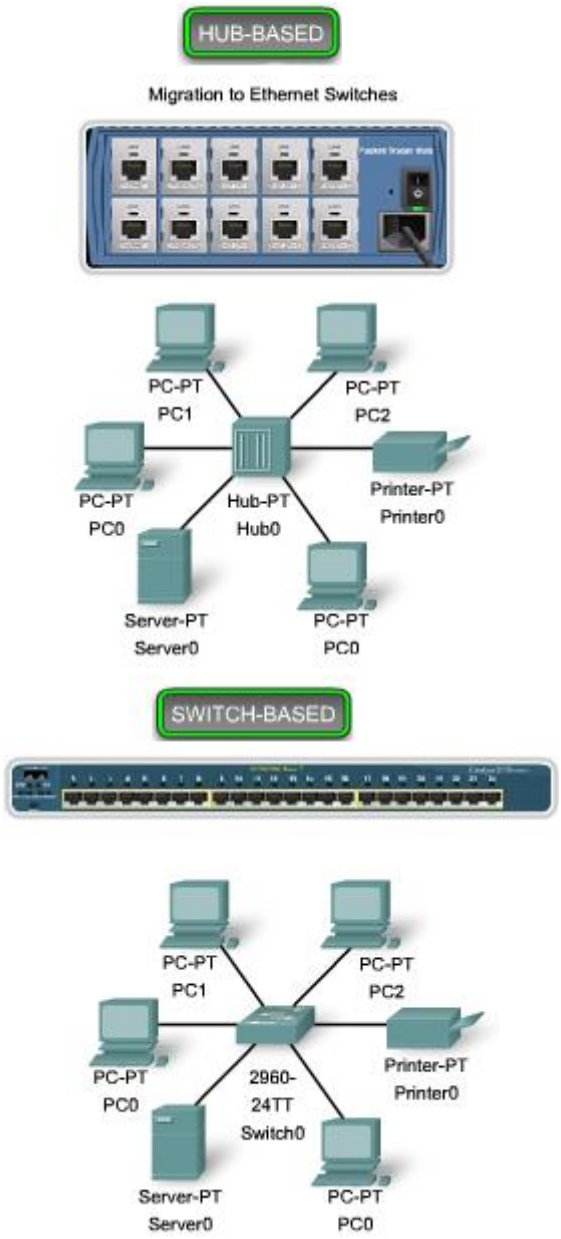
MAC – Getting Data to the Media

- The Ethernet MAC sublayer has two responsibilities:
  - –Data Encapsulation
    - •Frame delimiting
      - –The MAC layer adds a header and trailer to the Layer 3 PDU.
      - –It aids the grouping of bits at the receiving node.
      - –It provides synchronization between the transmitting and receiving nodes.
    - •Addressing
      - –Each header contains the physical address (MAC address) that enables a frame to be delivered to a destination node.
    - •Error detection
      - –Each trailer contains a CRC. After reception of a frame, the receiving node creates a CRC to compare to the one in the frame. If these two CRC calculations match, the frame can be trusted to have been received without error.
  - –Media Access Control
    - •The MAC sublayer controls the placement of frames on the media and the removal of frames from the media.
      - –This includes the initiation of frame transmission and recovery from transmission failure due to collisions.
    - •The media access control method for Ethernet is CSMA/CD.
      - –All the nodes in that network segment share the medium.
      - –All the nodes in that segment receive all the frames transmitted by any node on that segment.



Ethernet Collision Management

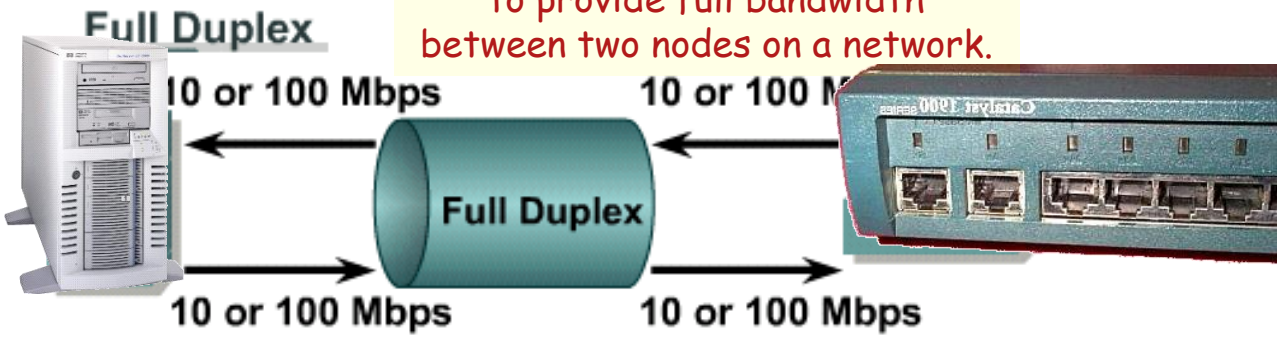
- Legacy Ethernet (Hub and half-duplex)
  - –In 10BASE-T networks, typically the central point of the network segment was a hub. This created a shared media.
  - –Because the media is shared, only one station could successfully transmit at a time.
  - –This type of connection is described as a half-duplex.
  - –As more devices were added to an Ethernet network, the amount of frame collisions increased significantly.
- Current Ethernet (switch and full-duplex)
  - –To enhanced LAN performance, switch was introduced to replace hubs in Ethernet-based networks.
  - –This corresponded with the development of 100BASE-TX.
  - –Switches can isolate each port and sending a frame only to its proper destination (if the destination is known), rather than send frame to every device.
  - –This, and the later introduction of full-duplex communications (having a connection that can carry both transmitted and received signals at the same time), has enabled the development of 1Gbps Ethernet and beyond.



Switch operation

- Full Duplex
  - –Another capability emerges when only two nodes are connected.
  - –In a network that uses twisted-pair cabling, one pair is used to carry the transmitted signal. A separate pair is used for the return or received signal. It is possible for signals to pass through both pairs simultaneously.
  - –The capability of communication in both directions at once is known as full duplex.
  - –Most switches are capable of supporting full duplex, as are most network interface cards (NICs).
  - –In full duplex mode, there is no contention for the media. Thus, a collision domain no longer exists.
  - –Theoretically, the bandwidth is doubled when using full duplex.

A switch uses full-duplex mode to provide full bandwidth between two nodes on a network.

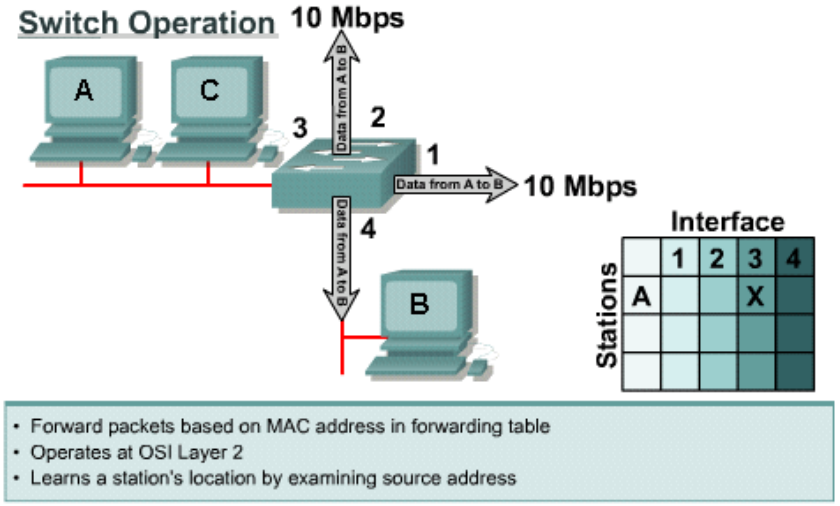


- Doubles bandwidth between nodes
- Collision-free transmission
- Two 10- or 100- Mbps data paths

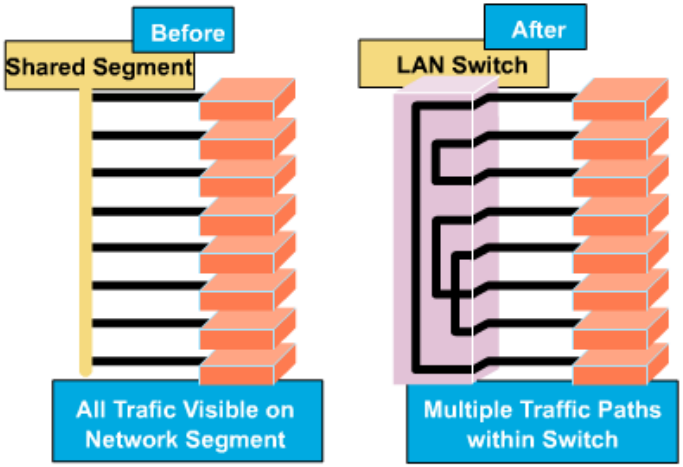
Switch operation

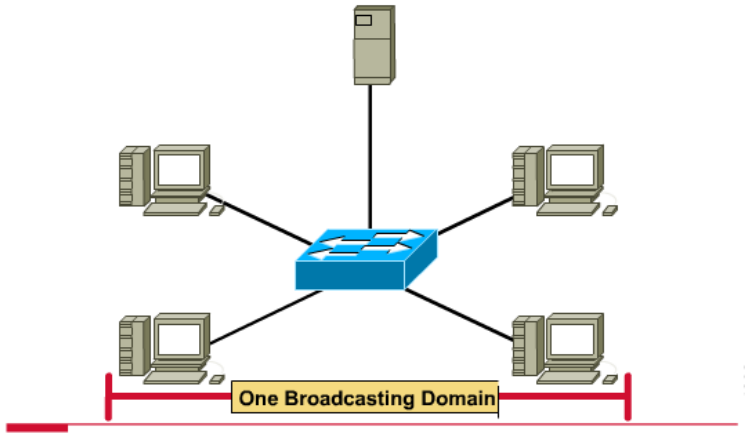
- Microsegments
  - –When only one node is connected to a switch port, the collision domain on the shared media contains only two nodes.
  - –These small physical segments are called microsegments.

A bridge or switch increase the number of collision domains but have no impact on broadcast domains



- Forward packets based on MAC address in forwarding table
- Operates at OSI Layer 2
- Learns a station's location by examining source address





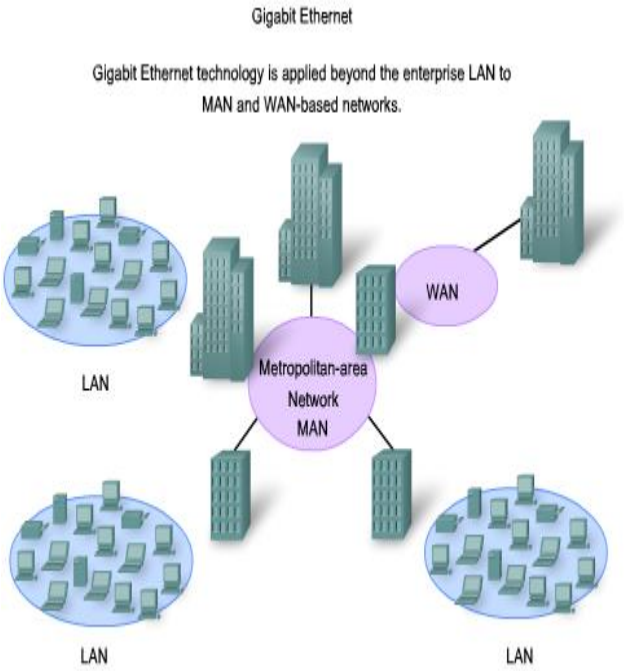
- Enables dedicated access
- Eliminates collisions and increases capacity
- Supports multiple conversations at a time

Moving to 1Gbps and Beyond

- The applications that cross network links on a daily basis tax even the most robust networks.
  - –For example, the increasing use of Voice over IP (VoIP) and multimedia services requires connections that are faster than 100 Mbps Ethernet.
- The increase in network performance is significant when throughput increases from 100 Mbps to 1 Gbps and above.
  - –Gigabit Ethernet is used to describe bandwidth of 1000 Mbps (1 Gbps) or greater.
  - –This capacity has been built on the full-duplex capability and the UTP and fiber-optic media technologies of earlier Ethernet.
- Upgrading to 1 Gbps Ethernet does not always mean that the existing network infrastructure of cables and switches has to be completely replaced.
  - –Some of the equipment and cabling in modern, well-designed and installed networks may be capable of working at the higher speeds with only minimal upgrading.

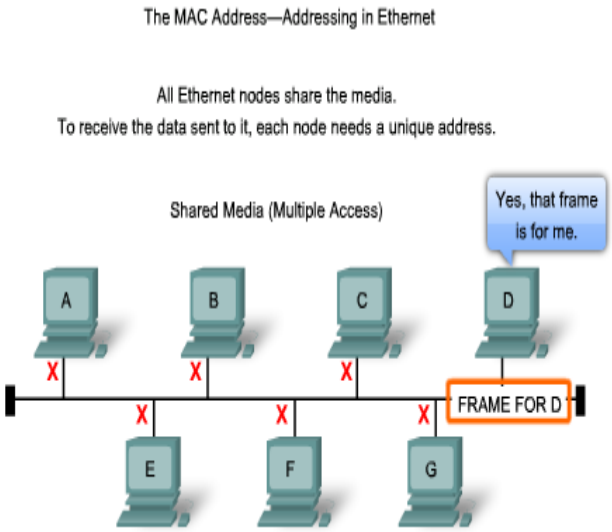
Ethernet Beyond the LAN

- Ethernet was initially limited to LAN cable systems within single buildings, and then extended to between buildings. It can now be applied across a city in what is known as a Metropolitan Area Network (MAN).
  - –The increased cabling distances enabled by the use of fiber-optic cable in Ethernet-based networks has resulted in a blurring of the distinction between LANs and WANs.



The Ethernet MAC Address

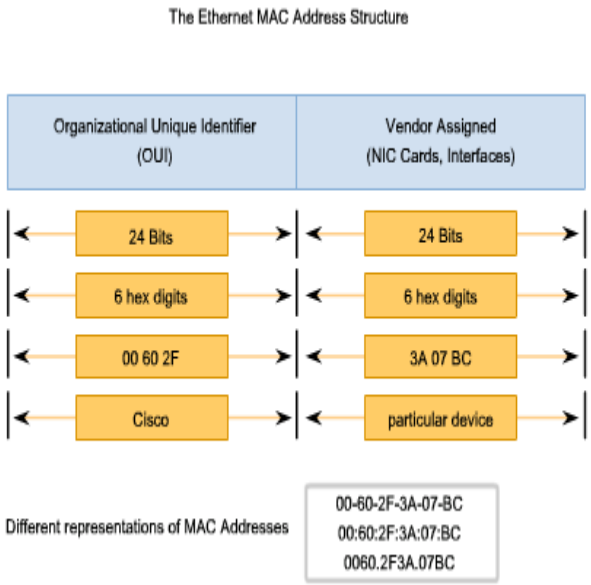
- A unique identifier called a Media Access Control (MAC) address was created to assist in determining the source and destination address within an Ethernet network.
  - –It provided a method for device identification at a lower level of the OSI model.
  - –As you will recall, MAC addressing is added as part of a Layer 2 PDU.
  - –An Ethernet MAC address is a 48-bit binary value expressed as 12 hexadecimal digits.




```
C:\Windows\system32\cmd.exe
H:\>ipconfig /all

Windows IP Configuration

        Host Name . . . . . . . . . . . . : MaryHanney
        Primary Dns Suffix  . . . . . . . : ballfoundation.org
        Node Type . . . . . . . . . . . . : Hybrid
        IP Routing Enabled. . . . . . . . : No
        WINS Proxy Enabled. . . . . . . . : No
        DNS Suffix Search List. . . . . . : ballfoundation.org
                                            ballfoundation.org

Ethernet adapter Local Area Connection:

        Connection-specific DNS Suffix  . : ballfoundation.org
        Description . . . . . . . . . . . : Intel(R) PRO/100 VM Network Connecti
on
        Physical Address. . . . . . . . . : 00-08-02-90-C9-52
        Dhcp Enabled. . . . . . . . . . . : Yes
        Autoconfiguration Enabled . . . . : Yes
        IP Address. . . . . . . . . . . . : 10.214.252.84
        Subnet Mask . . . . . . . . . . . : 255.255.255.0
        Default Gateway . . . . . . . . . : 10.214.252.41
        DHCP Server . . . . . . . . . . . : 10.214.252.5
        DNS Servers . . . . . . . . . . . : 10.214.252.5
                                            10.214.252.6
        Lease Obtained. . . . . . . . . . : Tuesday, June 03, 2008 8:26:32 AM
        Lease Expires . . . . . . . . . . : Wednesday, September 10, 2008 8:26:3
2 AM

H:\>_
```

MAC Address Structure

- IEEE require any vendor that sells Ethernet devices to register with IEEE and to follow two simple rules:
  - –All MAC addresses assigned to a NIC must use that vendor's assigned OUI as the first 3 bytes.
  - –All MAC addresses with the same OUI must be assigned a unique value in the last 3 bytes.
- The MAC address is often referred to as a burned-in address (BIA) because it is burned into ROM (Read-Only Memory) on the NIC.
  - –However, when the computer starts up, the NIC copies the address into RAM. When examining frames, it is the address in RAM that is used as the source address to compare with the destination address.
- When the device forwarding the message to an Ethernet network, each NIC in the network see if the MAC address matches its address.
  - –If there is no match, the device discards the frame.
  - –If there is a match, the NIC passes the frame up the OSI layers, where the decapsulation process take place.

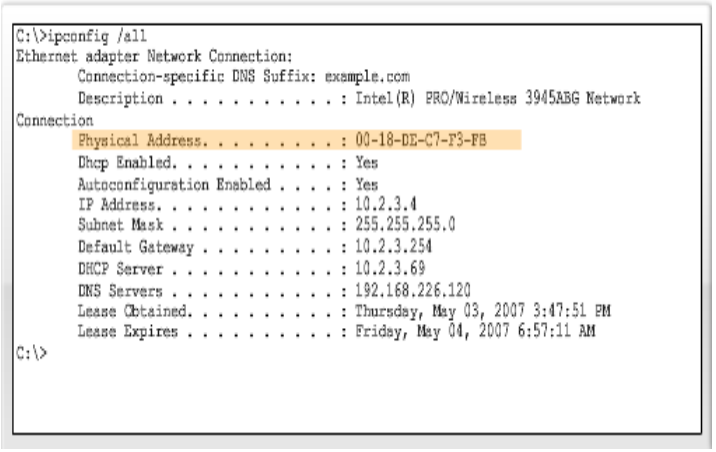


http://standards.ieee.org/regauth/oui/oui.txt

Viewing the MAC

- Hexadecimal is used to represent Ethernet MAC addresses and IP Version 6 addresses.
- A tool to examine the MAC address of our computer is the ipconfig /all or ifconfig.
- You may want to research the OUI of the MAC address to determine the manufacturer of your NIC.

Viewing the MAC Address



Key takeaways so far…

- MAC Address bits ?
- OUI ?

- CSMA/CD
- Switched Ethernet

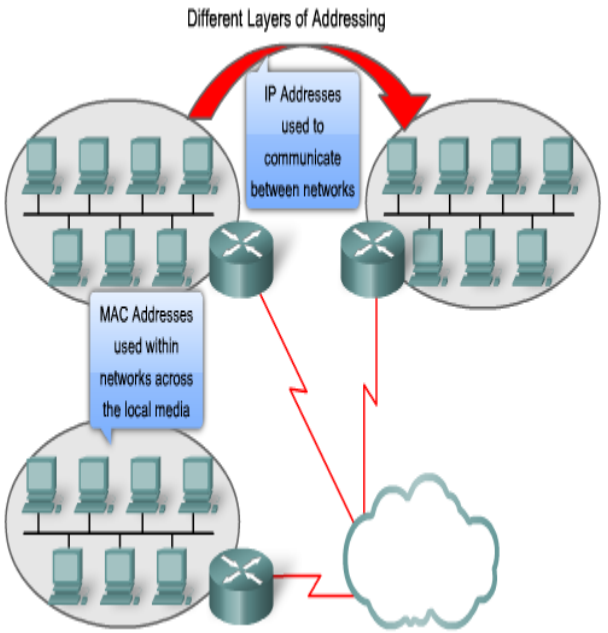
- CSMA/CA – Wifi

- Hubs v Switches

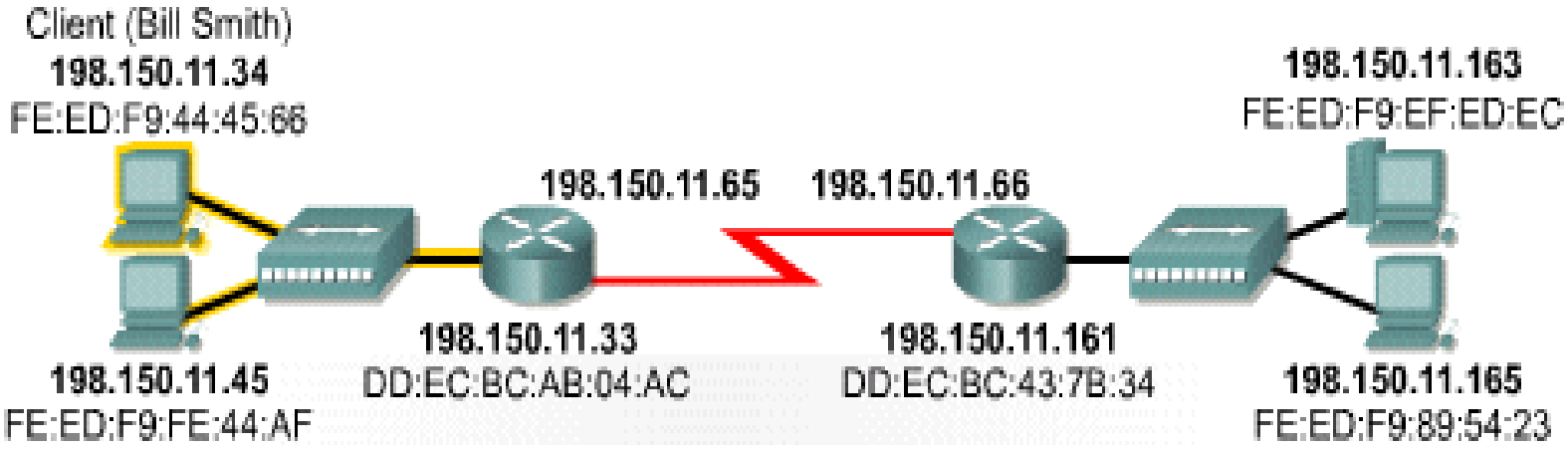
- Simplex
- Half-Duplex
- Full Duplex

Another Layer of Addressing

- Data Link Layer
  - –OSI Data Link layer (Layer 2) physical addressing, implemented as an Ethernet MAC address, is used to transport the frame across the local media.
  - –They are non-hierarchical. They are associated with a particular device regardless of its location or to which network it is connected.
- Network Layer
  - –Network layer (Layer 3) addresses, such as IPv4 addresses, provide the ubiquitous, logical addressing that is understood at both source and destination.
  - –To arrive at its eventual destination, a packet carries the destination Layer 3 address from its source.
- In short:
  - –The Network layer address enables the packet to be forwarded toward its destination.
  - –The Data Link layer address enables the packet to be carried by the local media across each segment.



Another Layer of Addressing

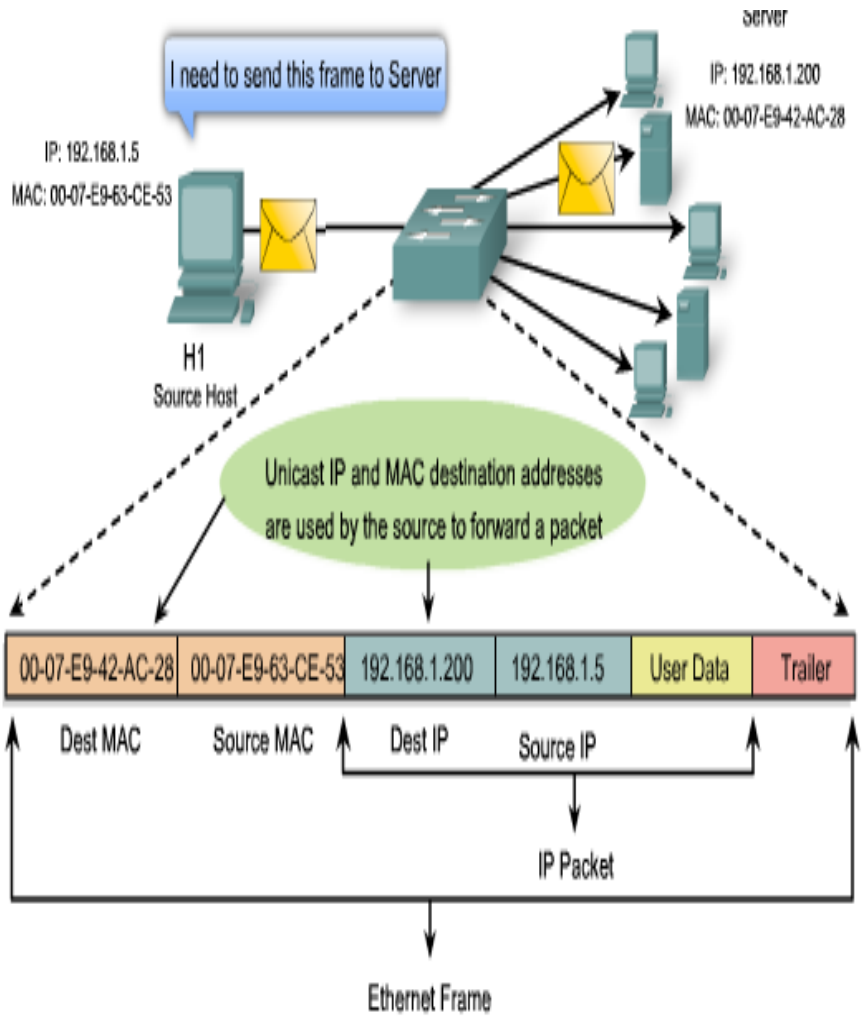


Frame Header		Network Header		Data	Frame Trailer
Destination	Source	Source	Destination		
DD:EC:BC:AB:04:AC	FE:ED:F9:44:45:66	198.150.11.34	198.150.11.163	Email Data	CRC-32

The data frames are then transmitted on the Ethernet segment. All stations pick up the packet and check to see if the packet is for them. All devices except for the Router discard the packet.

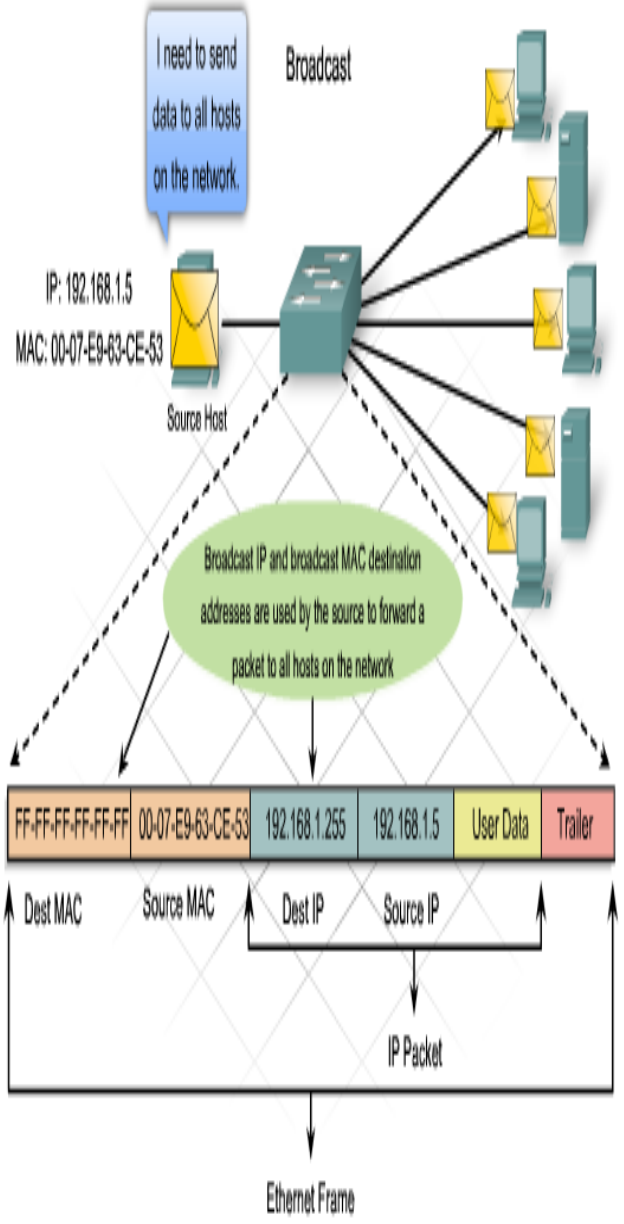
Ethernet Unicast, Multicast & Broadcast

- A unicast MAC address is the unique address used when a frame is sent from a single transmitting device to single destination device.
- In the example shown in the figure, a host with IP address 192.168.1.5 (source) requests a web page from the server at IP address 192.168.1.200.
  - –For a unicast packet to be sent and received, a destination IP address must be in the IP packet header.
  - –A corresponding destination MAC address must also be present in the Ethernet frame header.
  - –The IP address and MAC address combine to deliver data to one specific destination host.



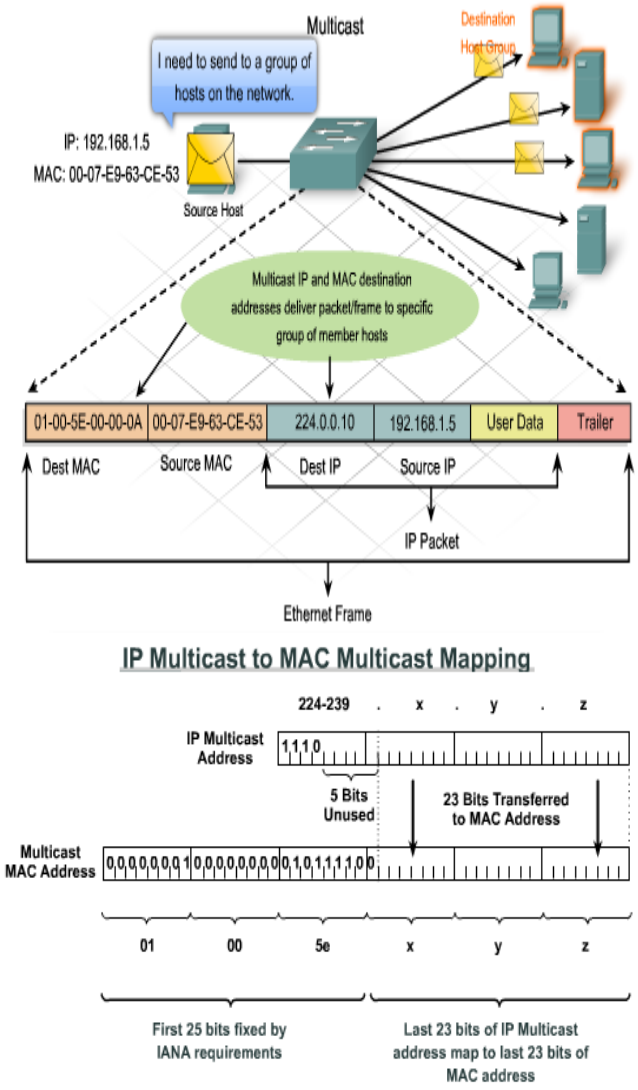
Ethernet Unicast, Multicast & Broadcast

- With a broadcast, the packet contains a destination IP address that has all ones (1s) in the host portion.
  - –Direct broadcast
    - •This numbering in the address means that all hosts on that local network (broadcast domain) will receive and process the packet.
  - –Limited broadcast
    - •All 32 bits address are all 1s
- Many network protocols, such as Dynamic Host Configuration Protocol (DHCP) and Address Resolution Protocol (ARP), use broadcasts.
- As shown in the figure, a broadcast IP address for a network needs a corresponding broadcast MAC address in the Ethernet frame.
- On Ethernet networks, the broadcast MAC address is 48 ones displayed as Hexadecimal FF-FF-FF-FF-FF-FF.



Ethernet Unicast, Multicast & Broadcast

- Multicast addresses allow a source device to send a packet to a group of devices.
  - –Devices that belong to a multicast group are assigned a multicast group IP address.
  - –The range of multicast addresses is from 224.0.0.0 to 239.255.255.255.
  - –Multicast addresses represent a group of addresses, they can only be used as the destination of a packet.
  - –The source will always have a unicast address.
- As with the unicast and broadcast addresses, the multicast IP address requires a corresponding multicast MAC address to actually deliver frames on a local network.
  - –The multicast MAC address is a special value that begins with 01-00-5E in hexadecimal.
  - –The value ends by converting the lower 23 bits of the IP multicast group address into the remaining 6 hexadecimal characters of the Ethernet address.
  - –The remaining bit in the MAC address is always a "0".



Summary

- Ethernet is the most widely used LAN technology used today.
- Ethernet standards define both the Layer 2 protocols and the Layer 1 technologies.
- The Ethernet frame structure adds headers and trailers around the Layer 3 PDU to encapsulate the message being sent.
- As an implementation of the IEEE 802.2/3 standards, the Ethernet frame provides MAC addressing and error checking.
- Replacing hubs with switches in the local network has reduced the probability of frame collisions in half-duplex links.
- The Layer 2 addressing provided by Ethernet supports unicast, multicast, and broadcast communications.