HO CHI MINH CITY UNIVERSITY OF SCIENCE
FACULTY OF ELECTRONICS AND TELECOMMUNICATIONS
DEPARTMENT OF TELECOMMUNICATIONS AND NETWORKS

COURSE

COMPUTER NETWORK

Chapter 02

Ethernet

Reference: Peter L Dordal, "An Introduction to Computer Networks," Feb 05, 2022

Lecturer: Nguyen Viet Ha, Ph.D. Email: nvha@fetel.hcmus.edu.vn

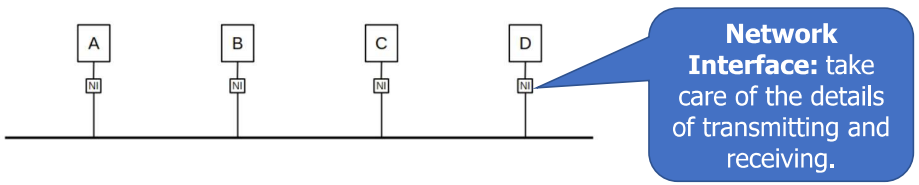
1. 10-*Mbps* Classic Ethernet

❖**Ethernet: IEEE 802.3** (FYI: WiFi: 802.11, WiMAX: 802.16)

❖**Broadcast bus**

➢Consisted of a long piece of cable (possibly spliced by **repeaters**).

➢Data went everywhere along that cable.



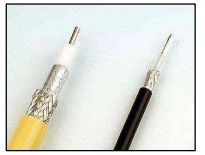
1 10-*Mbps* Classic Ethernet

1. 10-*Mbps* Classic Ethernet

❖There were three physical formats for 10 Mbps Ethernet cable.

➢Thick coax (10BASE-5)
(max: 500 meters)

➢Thin coax (10BASE-2)
(max: 500 meters)



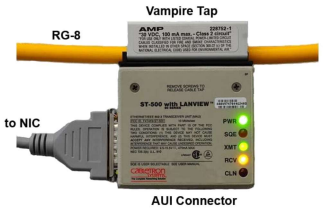
10BASE-5 vs 10BASE-2

➢Twisted pair (10BASE-T)
(max: 100 meters)

1. 10-*Mbps* Classic Ethernet

❖There were three physical formats for 10 Mbps Ethernet cable.

- ➢**thick-coax** cabling, connections were made via **taps**, often literally drilled into the coax central conductor.
- ➢**Thin coax** allowed the use of **T-connectors** to attach hosts.
- ➢**Twisted-pair** does not allow mid-cable attachment; it is only used for **point-to-point links**.



Tap, T-connector,and RJ-45

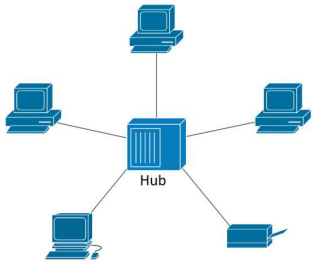
1. 10-*Mbps* Classic Ethernet

❖Repeaters

- ➢Signal amplifier (might attempt to clean up a noisy signal).
- ➢Process each bit individually and did no buffering.

❖Hub

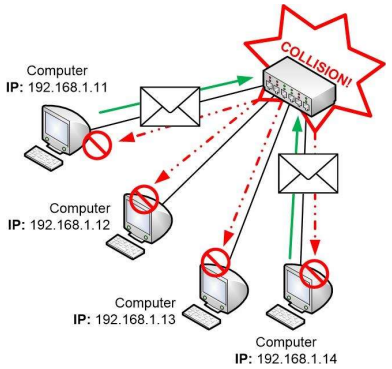
- ➢A repeater with more than two ports.
- ➢**Star topologies** in which each host connects directly to the hub rather than to one long run of coax.
- ➢Twisted-pair cable.



1. 10-*Mbps* Classic Ethernet

❖Bridge – later known as Switch

- ➢Not bit. Reads in and forwards an entire packet.
- ➢Can determine to where the packet is forwarded. (Using MAC address)
- ➢Note:
  - ○Hubs propagate collisions;
  - ○Switches do not.



1. 10-*Mbps* Classic Ethernet

❖Two stations transmitted at the same time, the signals would **collide**.

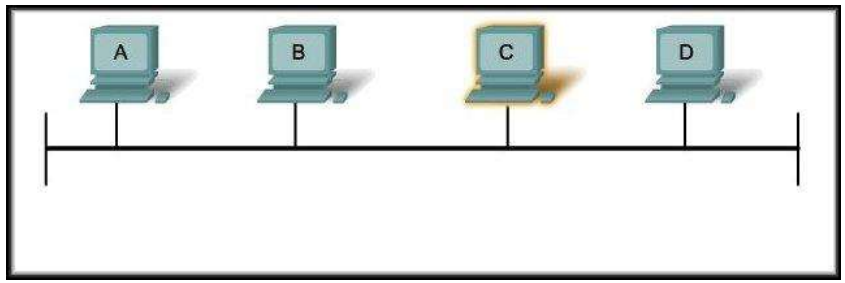
❖**CSMA/CD (Carrier Sense, Multiple Access, Collision Detect)**

- ➢Before transmission, wait for the line to become quiet.
- ➢While transmitting, continually monitor the line for signs that a collision has occurred; if a collision is detected, cease transmitting.
- ➢If a collision occurs, use a backoff-and-retransmit strategy.

1. 10-*Mbps* Classic Ethernet

❖CSMA/CD (Carrier Sense, Multiple Access, Collision Detect)

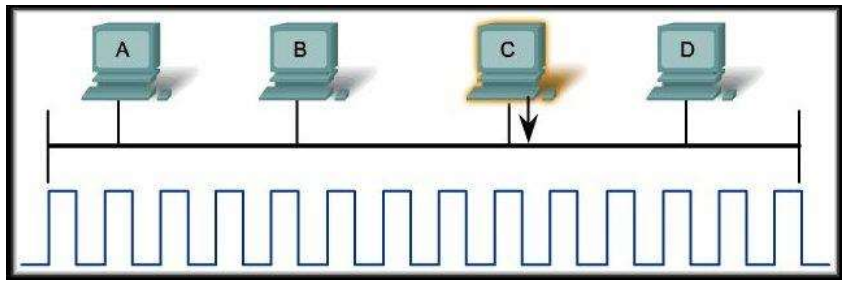
- To transmit, each host will listen on the media.
  - If a signal from another device is present, it will wait for a specific amount of time and listen again.
  - If no signal is present, it will transmit.



1. 10-*Mbps* Classic Ethernet

❖CSMA/CD (Carrier Sense, Multiple Access, Collision Detect)

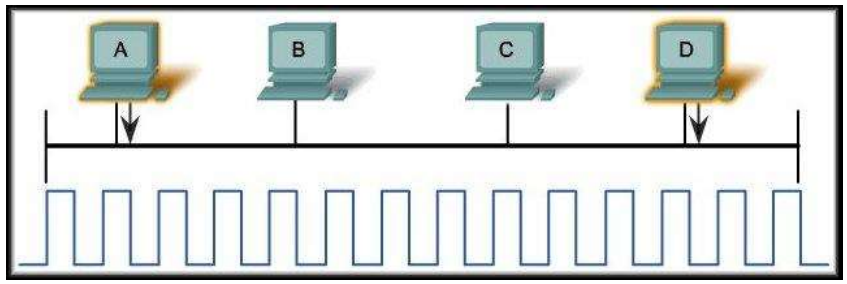
- To transmit, each host will listen on the media.
  - If a signal from another device is present, it will wait for a specific amount of time (e.g., 9.6 μs for 10-Mbps Ethernet) and listen again.
  - If no signal is present, it will transmit.



1. 10-*Mbps* Classic Ethernet

❖CSMA/CD (Carrier Sense, Multiple Access, Collision Detect)

- It can happen that two devices will determine that it is safe to transmit at exactly the same time.
  - In that case, both will transmit their frame.



1. 10-*Mbps* Classic Ethernet

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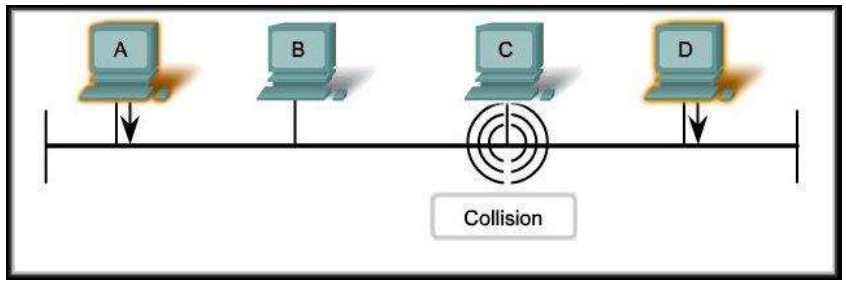
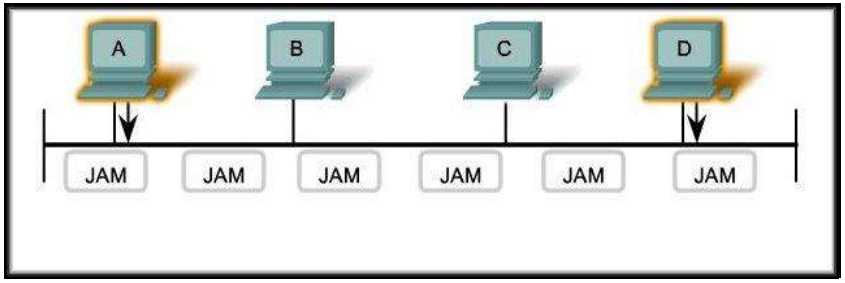


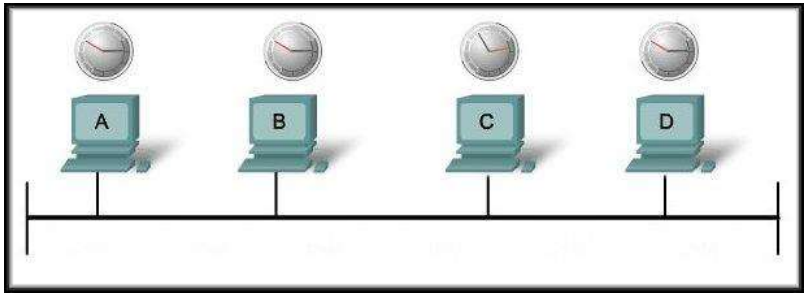
❖CSMA/CD (Carrier Sense, Multiple Access, Collision Detect)

- ➢ Both devices detect the collision and send out a jamming signal.
  - ○ The jamming signal is detected by all devices and all devices now know that a collision has occurred on the network.



❖CSMA/CD (Carrier Sense, Multiple Access, Collision Detect)

- ➢ Each device to invoke a backoff algorithm.
  - ○ Devices wait a random amount of time before returning to listening mode.
  - ○ The random time ensures that the original devices that caused the collision won't repeat it.



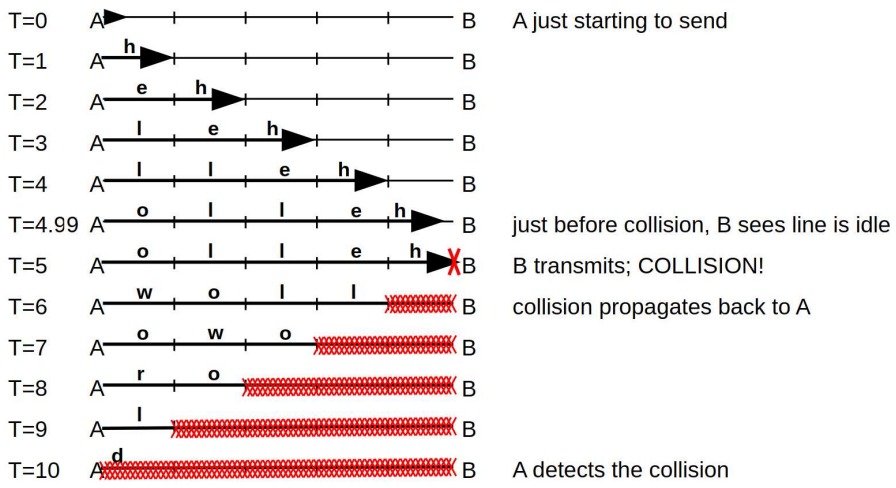
❖The Slot Time and Collisions

- ➢The **diameter** of an Ethernet is the maximum distance between any pair of stations.
  - ○Measured in bits.
  - ○Maximum: 232 bits.
- ➢**Jam signal:** 32 bits (up to 48 bits)
  - ○16 times → 512 bits (or 64 bytes)
    - ▪ Also, be the **minimum of the frame size**.
- ➢**A slot time** = 512 bits
  - ○The time to send 512 bits of Jam signal.
- ➢**Time intervals** are often described in bit times but in conventional time units the slot time is **51.2 µsec**.

❖The Slot Time and Collisions

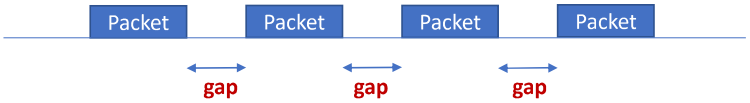
- ➢One slot time is enough time for any other station to have realized that the first station has started transmitting and wait for the first station to finish.
- ➢Ethernet has a **minimum packet size** = a slot time.
  - ○If a collision were to occur, the sender would detect it.
  - ○If we need to send less than 46 bytes of data, the Ethernet packet must be padded out to the minimum length.
    - ▪ All protocols running on top of Ethernet need to provide some way to specify the actual data length, as it cannot be inferred from the received packet size.

❖The Slot Time and Collisions



❖Interpacket gap (IPG)

- ➢Also known as interframe spacing, or interframe gap.
- ➢A delay or time gap between CSMA/CD packets intended to provide interframe recovery time for other CSMA/CD sublayers and for the Physical Medium.
- ➢The standard minimum interpacket gap for transmission is 96 bit.



Ethernet variant	Minimum transmitted IPG
10 Mbit/s Ethernet	9.6 µs
100 Mbit/s (Fast) Ethernet	0.96 µs
Gigabit Ethernet	96 ns
2.5 Gigabit Ethernet	38.4 ns
5 Gigabit Ethernet	19.2 ns
10 Gigabit Ethernet	9.6 ns

❖Exponential Backoff Algorithm

- ➢Range from which the backoff value is chosen is doubled after every successive collision involving the same packet.
- ➢If a collision does occur, send the jam signal, choose a backoff time as follows:
  - ○For *N-th* transmission (*N=0* represents the original attempt):
    - ▪If $1 \le N \le 10$, choose ***k*** randomly with $0 \le k < 2^N$.
    - ▪If $11 \le N \le 15$, choose ***k*** randomly with $0 \le k < 1024$.
  - ○Wait ***k*** slot times (***k*** × *51.2* µsec).
  - ○If reach *N=16* (16 transmission attempts), give up.

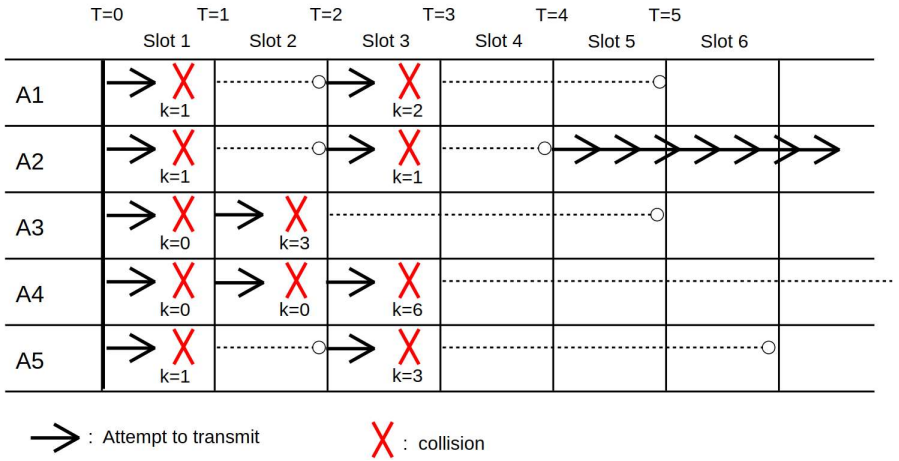
❖Exponential Backoff Algorithm

- ➢A maximum of **1024 hosts** is allowed on an Ethernet.
  - ○(k<1024).
  - ○If there are 1024 hosts simultaneously trying to send.
    - ▪Once the backoff range has reached k<1024 (N=10),
    - ▪It is a good chance that one station will succeed in seizing the channel,
      - That is; the minimum value of all the random k's chosen will be unique.

1. 10-*Mbps* Classic Ethernet

❖ **Exponential Backoff Algorithm**

? A2 will occupy the entire bandwidth

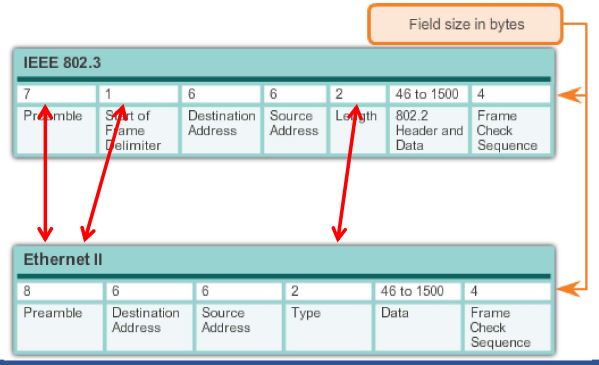


1. 10-*Mbps* Classic Ethernet

❖ There are two styles of Ethernet framing:

- **IEEE 802.3 Ethernet standard** which has been updated several times to include new technologies
- **The DIX Ethernet standard** which is now referred to Ethernet II

Ethernet II is the Ethernet frame format used in TCP/IP networks.



1. 10-*Mbps* Classic Ethernet

❖ **The address** is often referred to as a **burned-in address** (BIA)

- Burned in ROM.
- Unique.

❖ **Preamble:** for synchronization: a block of 1 bits followed by a 0.

❖ **Type:** Identifies the Layer 3 protocol in the data field.

- E.g., 0x0800=IP, 0x8137=IPX, 0x0806=ARP

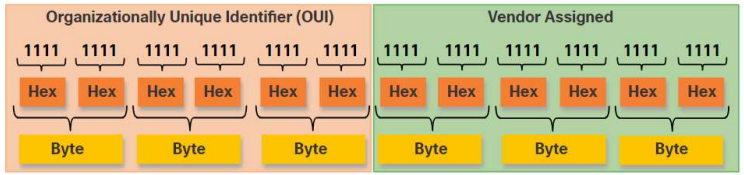
❖ Maximum Ethernet length: 1500 bytes

1. 10-*Mbps* Classic Ethernet

❖ **The address** is often referred to as a **burned-in address** (BIA)

- Burned in ROM.
- Unique.

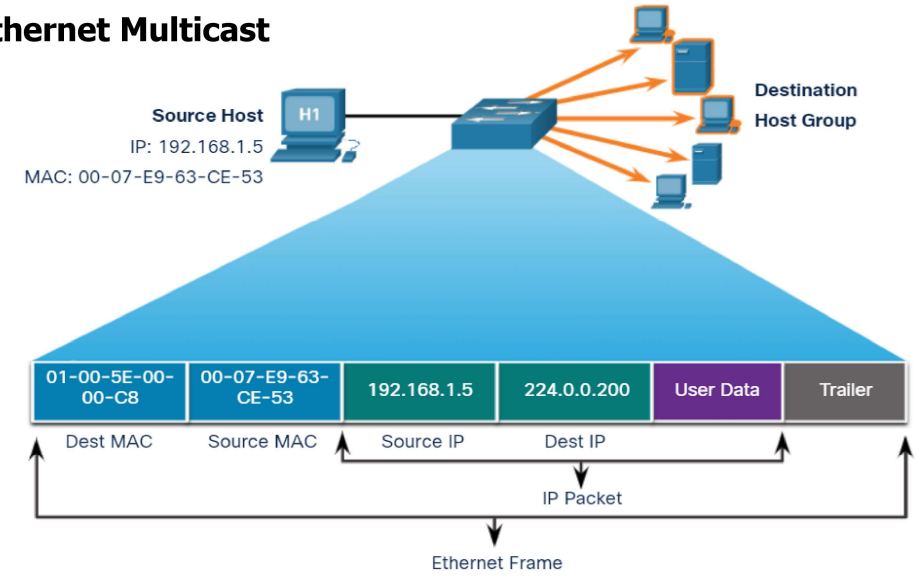
- The **first three bytes** of the physical address have been assigned to the manufacturer.
- The **subsequent three bytes** are a serial number assigned by that manufacturer.

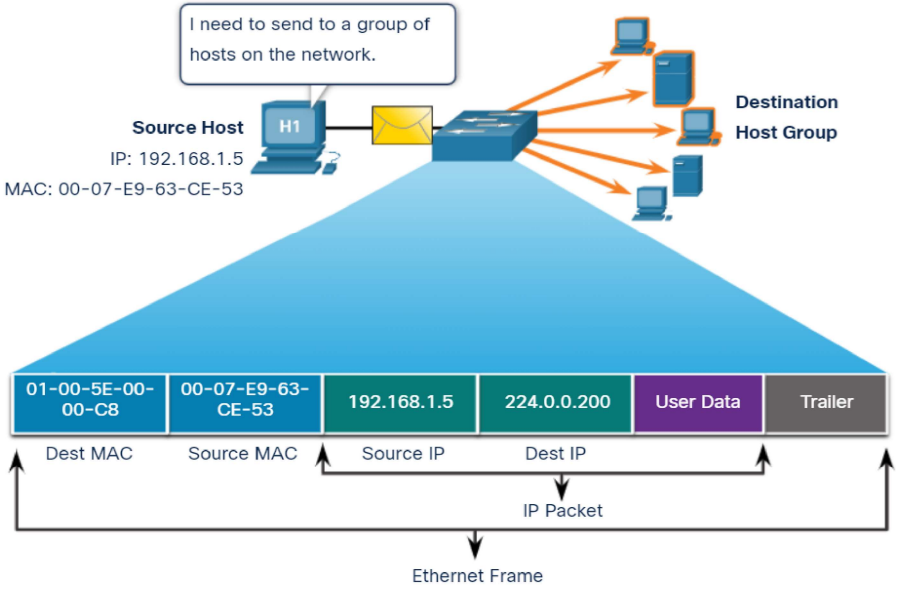


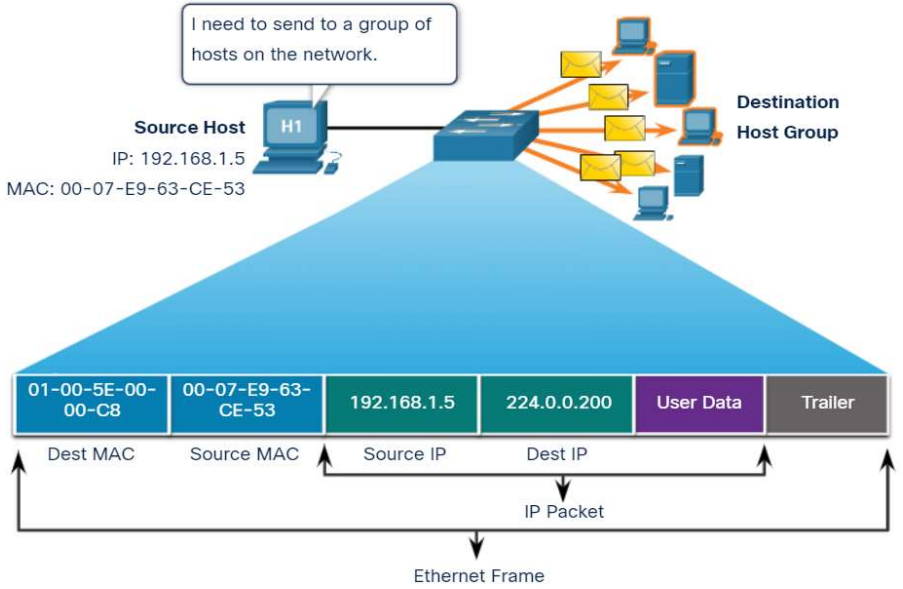
❖ **Ethernet Multicast**

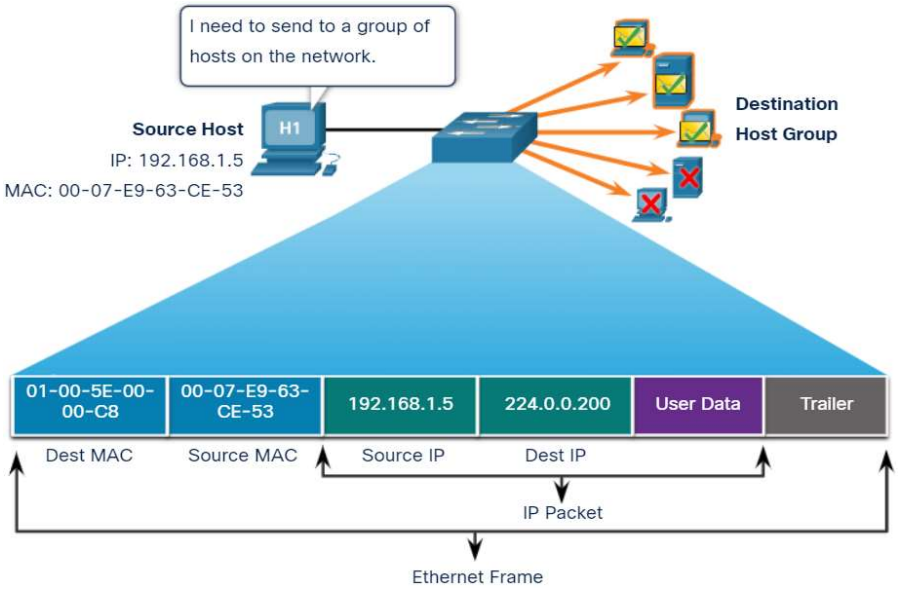
- Transmit to a set of stations; streaming video to multiple simultaneous viewers.
- IPv4 multicast → MAC address: **01-00-5E**-??-??-??
- IPv6 multicast → MAC address: **33-33**-??-??-??-??
- It is flooded out all Ethernet switch ports except the incoming port, unless the switch is configured for **multicast snooping**.

❖ **Ethernet Multicast**



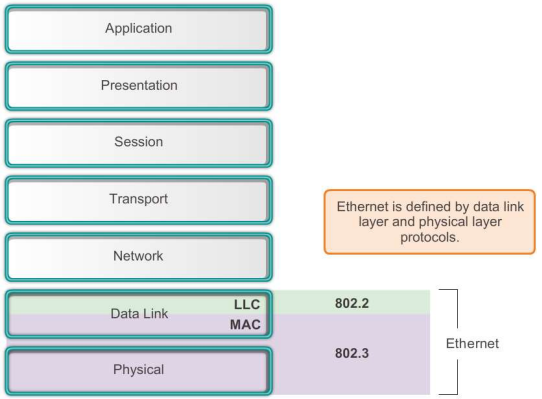






❖**LLC and MAC Sublayers**

➢In IEEE protocols, the LAN layer is divided into the **media access control**, or MAC, sublayer and a higher **logical link control.**



❖**LLC and MAC Sublayers**

➢**LLC**

- Takes the network protocol data and adds control information to help deliver the packet to the destination.
- Implemented in **software.**

➢**MAC**

- Data encapsulation
- Media access control
- Implemented by **hardware**, typically in the computer NIC.

2 100 Mbps (Fast) Ethernet

2. 100 Mbps (Fast) Ethernet

❖100 Mbps Ethernet is officially known as **100BASE-TX.**

➢Operates over twisted-pair cable.

➢Instead of increasing the minimum packet size, the decision was made to ensure collision detectability by reducing the network diameter.

- The network diameter: 400 meters (10 Mbps Ethernet: up to 2500 meters).
  - Using optical-fiber-based 100BASE-FX in half-duplex mode, but this is not common.
- The network diameter: 200 meters
  - Using 100BASE-TX network diameter – with hubs.
    - maximum cable length 100 meters.

2. 100 Mbps (Fast) Ethernet

❖Switch partition an Ethernet into separate "collision domains".

➢Each collision domain is simply a single twisted-pair link, subject to the 100-meter maximum length.

❖**Full-duplex Ethernet**:

➢Two twisted pairs could be used, one for each direction.

- Collision-free.

➢100BASE-FX with full-duplex can up to 2,000 meters.

- Links between buildings

3 Gigabit Ethernet

2. Gigabit Ethernet

❖The problem of scaling Ethernet to handle collision detection gets harder as the transmission rate increases.

➢If maintain the 51.2 μsec slot time but raise the transmission rate to 1000 Mbps, the maximum network diameter would be 20-40 meters.

➢Gigabit Ethernet moved to a **4096-bit (512-byte, or 4.096 μsec)** slot time for the twisted-pair versions.

- Increase the minimum frame size to 512 bytes.
- Short frames need to be padded, but this padding is done by the hardware.

2. Gigabit Ethernet

❖Gigabit Ethernet mostly works with full-duplex.

➢Collision-free.

➢10 Gigabit Ethernet has officially abandoned any pretense of supporting collisions; everything must be full-duplex.

❖Gigabit Ethernet 1000Base-T uses PAM-5 encoding (vs. 4B/5B encoding of 100Base-TX)

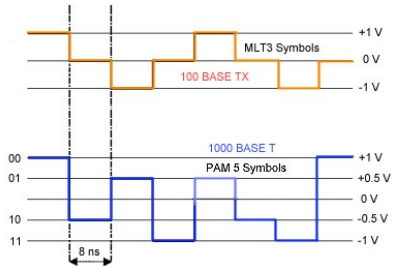
2. Gigabit Ethernet

❖The most common gigabit Ethernet over copper wire is **1000BASE-T**.

➢For 1000BASE-T, all four twisted pairs in the cable are used.

➢Each pair transmits at **250 Mbps**, and each pair is bidirectional, thus supporting full-duplex communication.

➢On any one cable pair, there are five signaling levels. These are used to transmit two-bit symbols at a rate of 125 symbols/μsec, for a data rate of 250 bits/μsec.



➢The target bit error rate (BER) for 1000BASE-T is 10^{-10}

4 Ethernet Switches

4. Ethernet Switches

❖Switches join separate physical Ethernets.

❖A switch has two or more Ethernet interfaces.

➢When a packet is received on one interface it is retransmitted on one or more other interfaces.

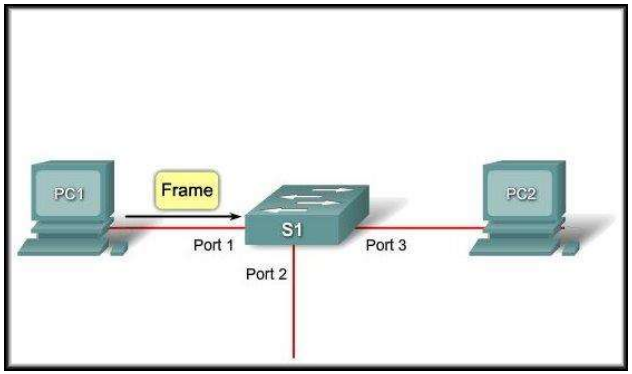
❖Only valid packets are forwarded; collisions are not propagated.

❖Ethernet also offers much more resistance to eavesdropping than a non-switched (e.g., hub-based) Ethernet.

❖**Ethernet Learning Algorithm**

➢**Example Step 1:**

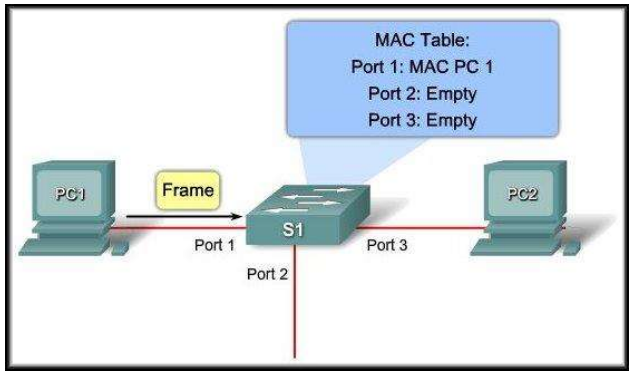
➢The switch receives a frame from PC 1 on Port 1 to PC2.



❖**Ethernet Learning Algorithm**

➢**Example Step 2: (learning)**

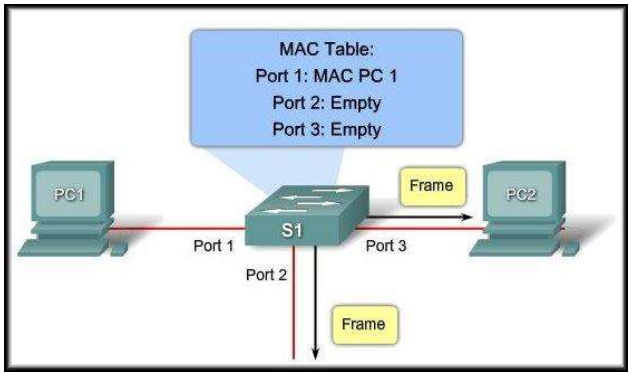
➢The switch enters the source MAC address and the switch port that received the frame into the address table.



❖**Ethernet Learning Algorithm**

➢**Example Step 3: (flooding)**

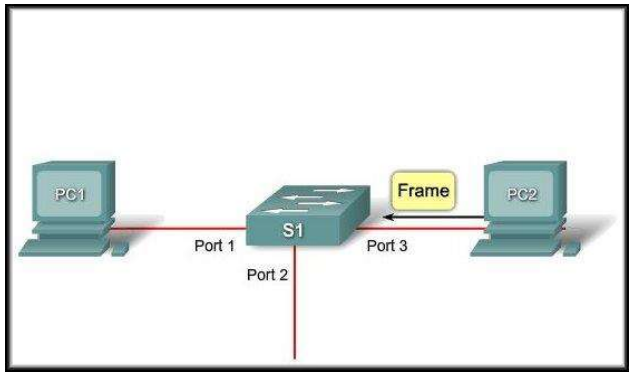
➢Because the destination address is a broadcast, the switch floods the frame to all ports, except the port on which it received the frame.



❖**Ethernet Learning Algorithm**

➢**Example Step 4:**

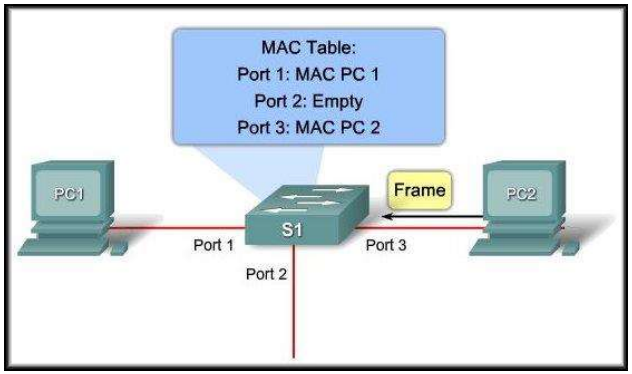
➢The destination device replies to the broadcast with a unicast frame addressed to PC 1.



❖Ethernet Learning Algorithm

➢Example Step 5:

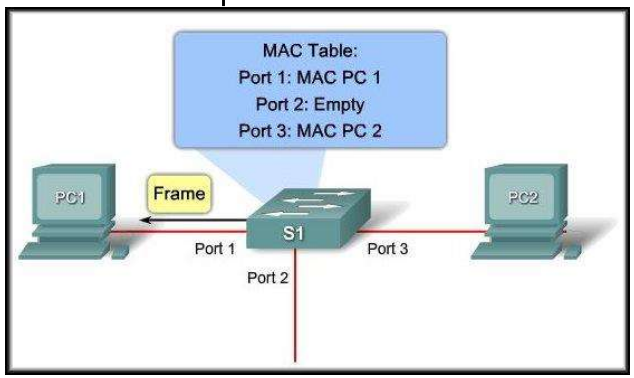
➢The switch enters the source MAC address of PC 2 and the port number of the switch port that received the frame into the address table.



❖Ethernet Learning Algorithm

➢Example Step 6:

➢The switch can now forward frames between source and destination devices because it has entries in the address table that identify the associated ports.



❖Switch Hardware

➢One of the differences between an inexpensive Ethernet switch and a pricier one is the degree of internal parallelism it can support.

➢The worst-case load, for a switch with *2N* ports, is for packets to arrive continuously on *N* ports, and depart on a different *N* ports.

❖Switch Hardware

➢Shared-memory.

- Consists of a single CPU, single memory, peripheral busses, and multiple Ethernet cards.
- When a packet arrives:
  - The CPU must copy the packet from the arrival interface into RAM
  - Determine the forwarding
  - Copy the packet to the output interface.
- To keep up with one-at-a-time 100 Mbps transmission, the internal transfer rate must therefore be at least 200 Mbps.

❖**Switch Hardware**

➢**Shared-memory.**

- The maximum speed of such a device depends on the speed of the **peripheral-to-RAM bus**.
- Ex: USB 3.0 bus operates at 5 Gbps. At an Ethernet speed of 100 Mbps
  - USB 3.0 bus can transfer 25 packets in and out in the time → supporting up to 50 ports total.
  - BUT. Gigabit Ethernet, only two packets can be handled.
- In datacenters: 10 Gbps, 40 Gbps Ethernet is now common.

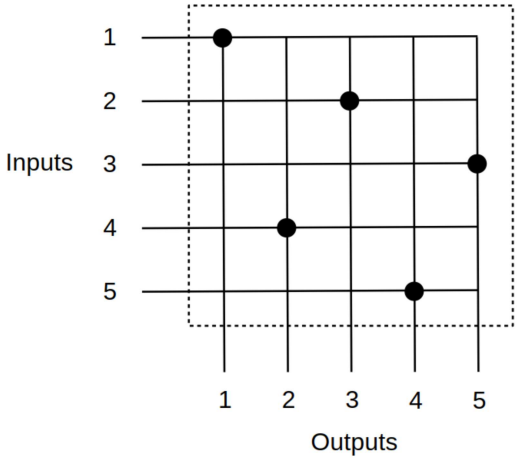
❖**Switch Hardware**

➢**Switch fabrics.**

- In datacenters: 10 Gbps, 40 Gbps Ethernet is now common.
- Switch 24 ports is a bare minimum.
  - Shared-memory not a suitable.
- Crossbar switch fabric:
  - Consisting of a grid of *N x N* normally open switch nodes that can be closed under CPU control.
  - Packets travel, via a connected path through the crossbar, directly from one Ethernet interface to another.

❖**Switch Hardware**

➢**Switch fabrics.**



5×5 crossbar with 5 parallel connections
1→1, 2→3, 3→5, 4→2, 5→4

❖**Switch Hardware**

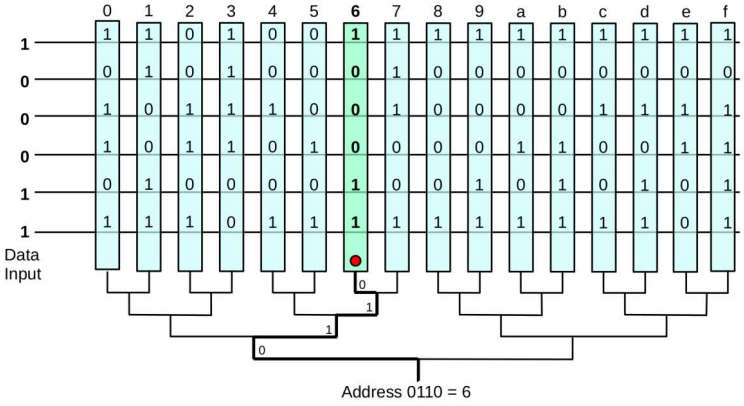
➢**Content-Addressable Memory (CAM)**

- Allows for the search of the forwarding table in **a single** memory load.
  - vs. several tens of memory loads in shared-memory switch.
- CAM memory consists of a large number *N* of memory registers all attached to a common data-input bus.
  - For Ethernet switching, the data width of the bus and registers needs to be at least as large as the 48-bit address size.

4. Ethernet Switches

❖Switch Hardware

➢Content-Addressable Memory (CAM)



QA

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