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

COURSE

# COMPUTER NETWORKS

Chapter 02

# Ethernet

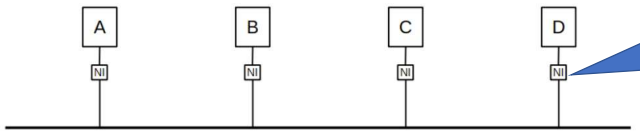
Reference: Peter L Dordal, "An Introduction to Computer Networks," Jul 26, 2019

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

# 1 10-*Mbps* Classic Ethernet

## 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.




**Network Interface:** take care of the details of transmitting and receiving.



## 1. 10-*Mbps* Classic Ethernet

- There were three physical formats for 10 Mbps Ethernet cable.
  - Thick coax (10BASE-5) (max: 500 meters)

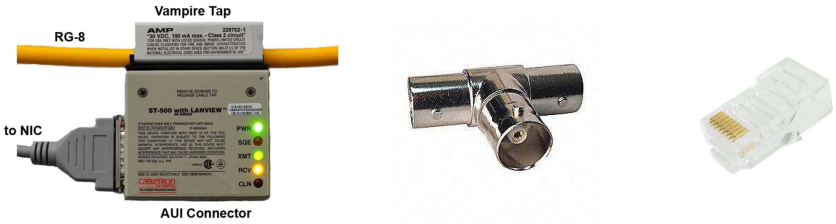
  - Thin coax (10BASE-2) (max: 500 meters)

*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**.

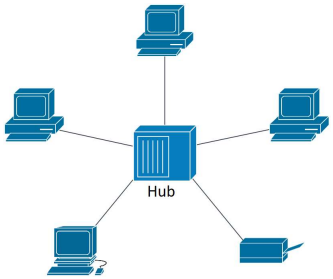



*Tap, T-connector,and RJ-45*



## 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.



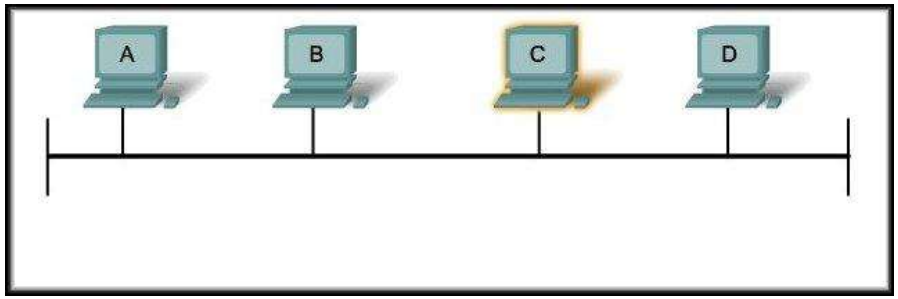
## 1. 10-*Mbps* Classic Ethernet

- 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

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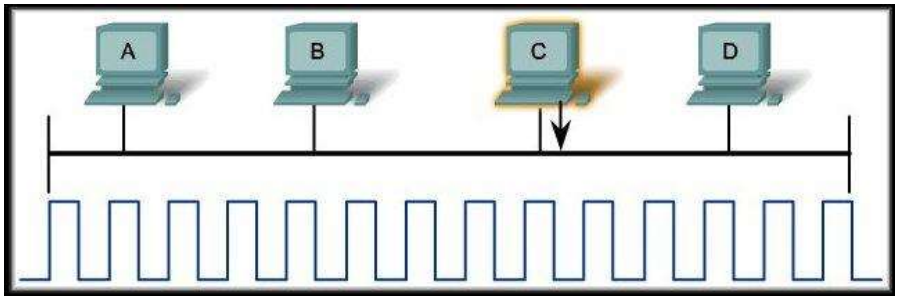
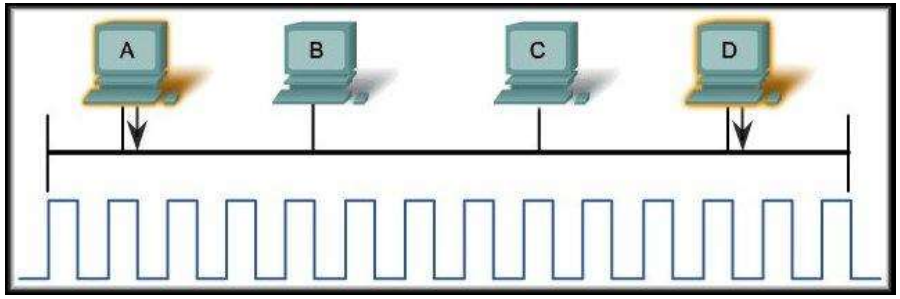





## 1. 10-*Mbps* Classic Ethernet

❖**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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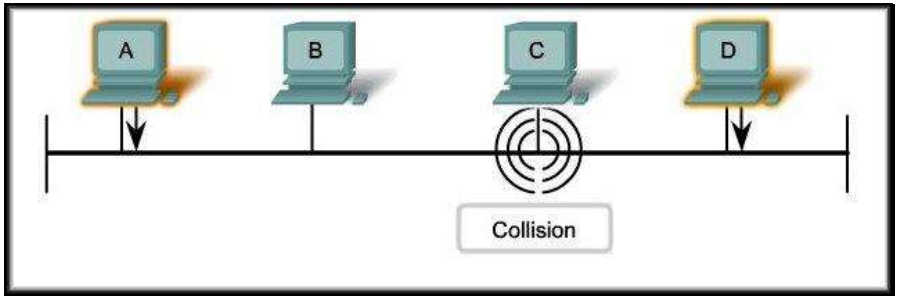
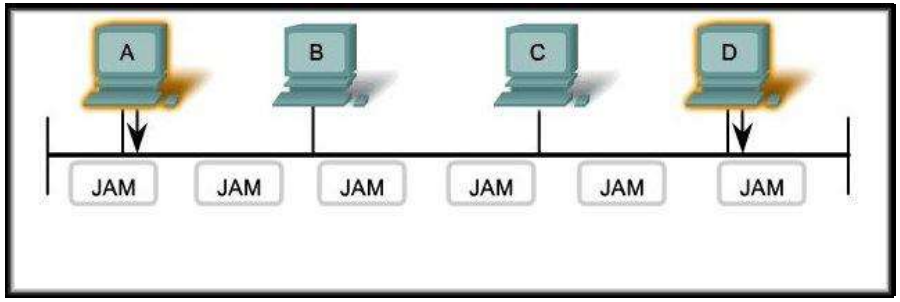


## 1. 10-*Mbps* Classic Ethernet

❖**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.

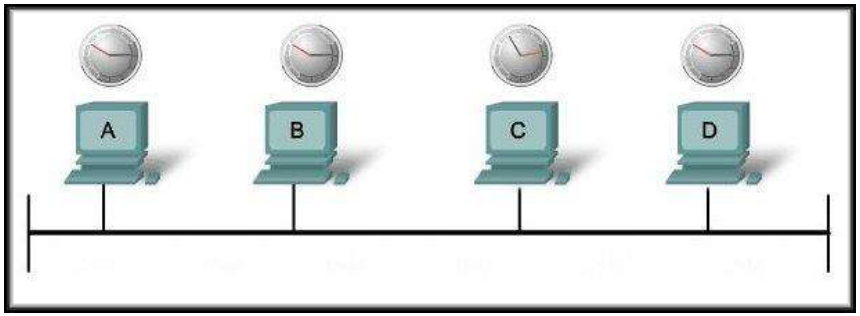





## 1. 10-*Mbps* Classic Ethernet

❖**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.






## 1. 10-*Mbps* Classic Ethernet

❖**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**.



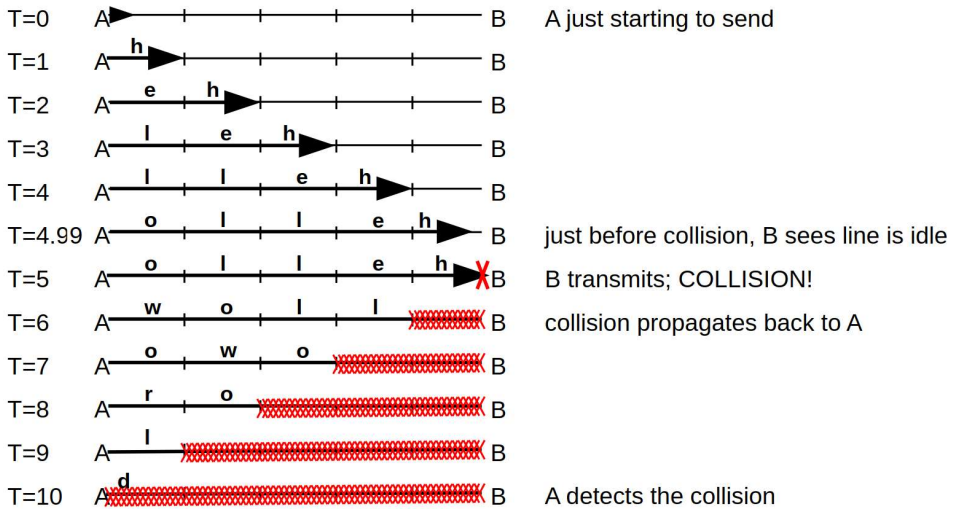
## 1. 10-*Mbps* Classic Ethernet

❖**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

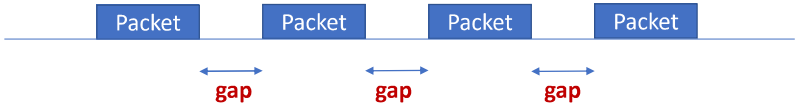







## ❖Interpacket gap

- ➢If line is busy, wait for sender to stop and then wait an additional **9.6 microseconds** (96 bits).
  - ○Is the **gap** between packets








## ❖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.



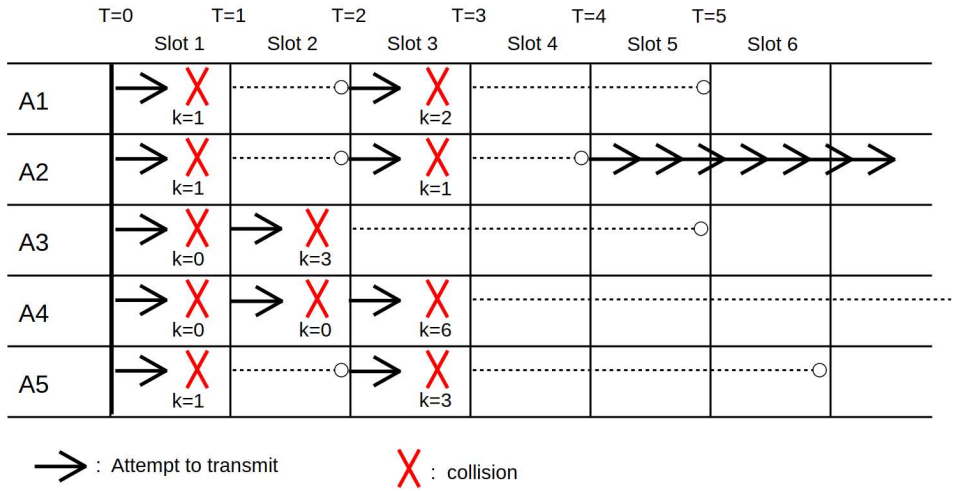


## ❖Exponential Backoff Algorithm

- ➢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.

❖ **Exponential Backoff Algorithm**

*? A2 will occupy the entire bandwidth*

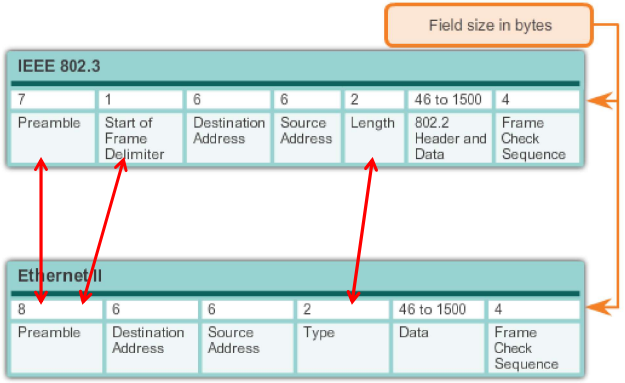







❖ There are two styles of Ethernet framing:

- **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.*





❖ **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

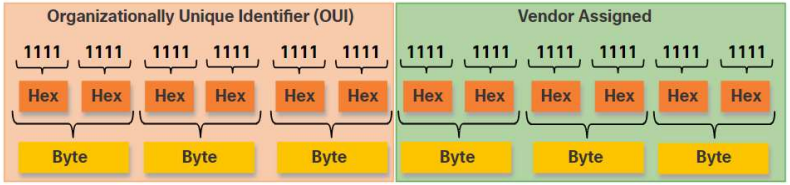




❖ **The address** is often referred to as a **burned-in address** (BIA) – burned in ROM.

- 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.



## 1. 10-*Mbps* Classic Ethernet

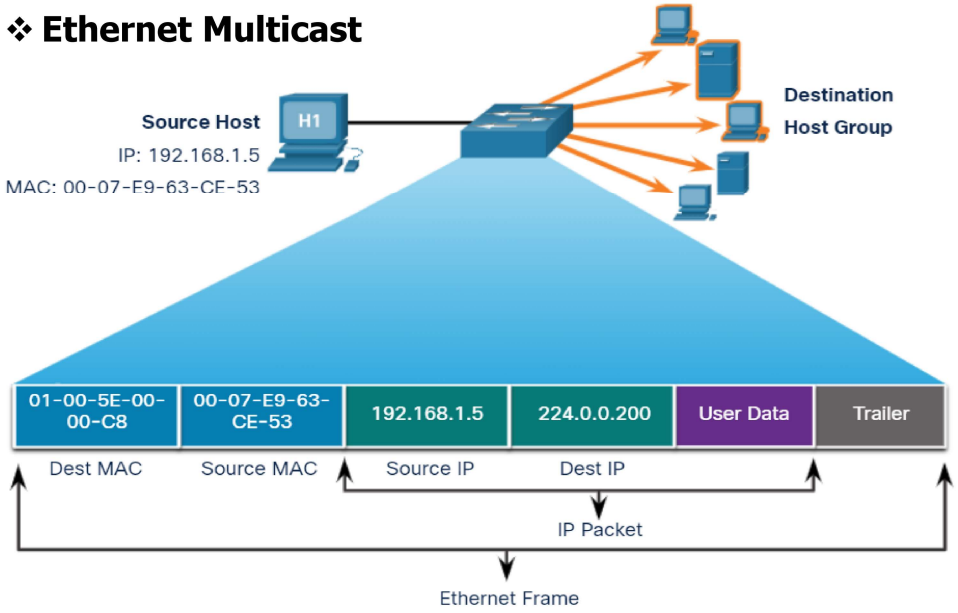
❖ **Ethernet Multicast**

- 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.**



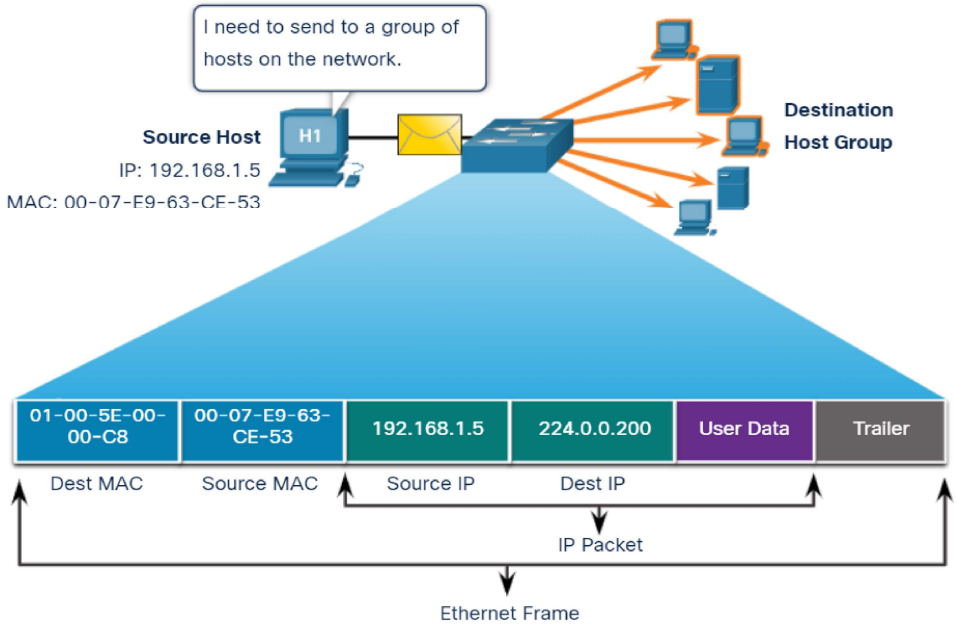
## 1. 10-*Mbps* Classic Ethernet

❖ **Ethernet Multicast**



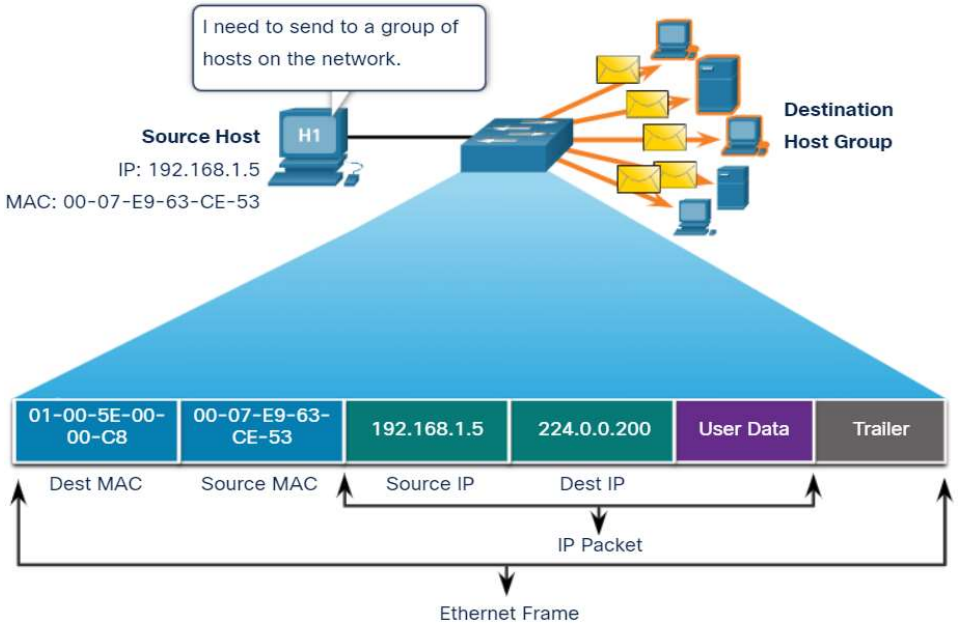



## 1. 10-*Mbps* Classic Ethernet

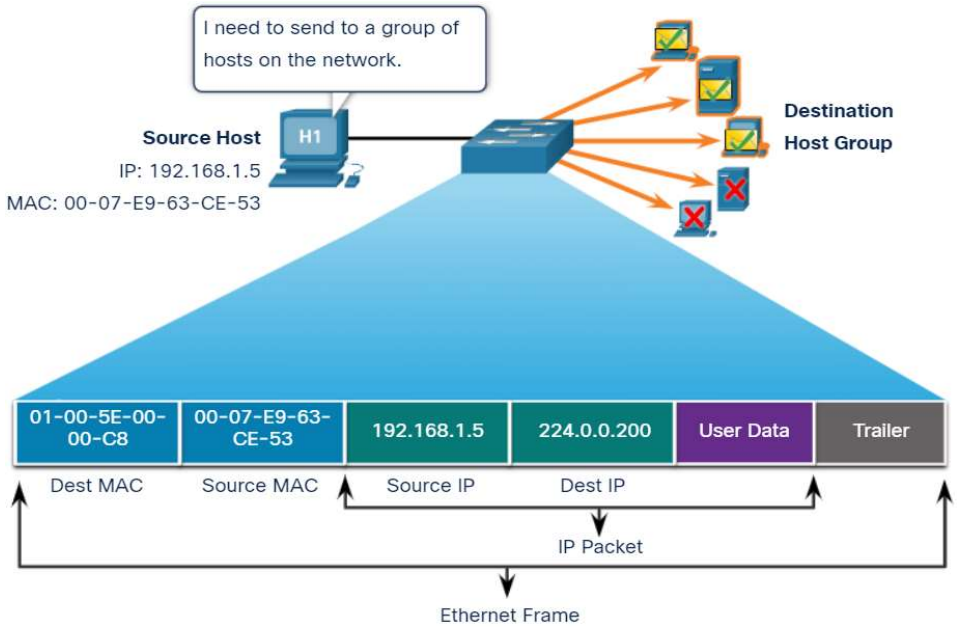





## 1. 10-*Mbps* Classic Ethernet



## 1. 10-*Mbps* Classic Ethernet

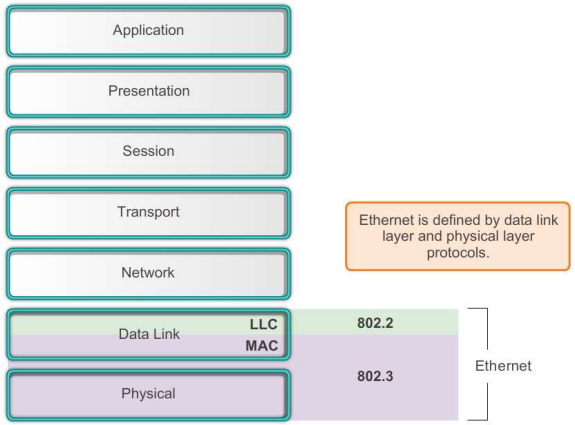





## 1. 10-*Mbps* Classic Ethernet

❖**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.**






## 1. 10-*Mbps* Classic Ethernet

❖**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.

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

## 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.



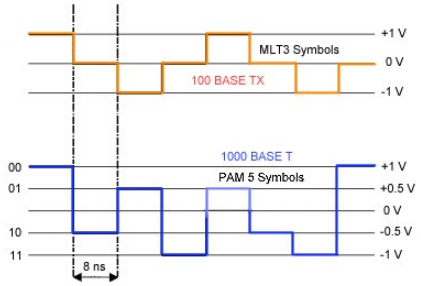
## 2. Gigabit Ethernet

❖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.

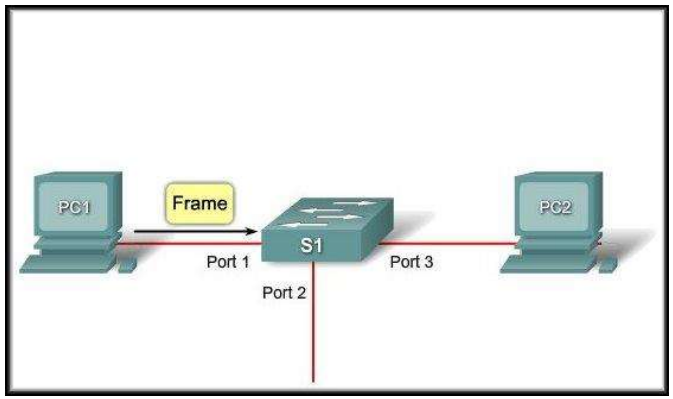
❖Ethernet also offers much more resistance to eavesdropping than a non-switched (e.g., hub-based) Ethernet.

## 4. Ethernet Switches

❖Ethernet Learning Algorithm

➢**Example Step 1:**

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



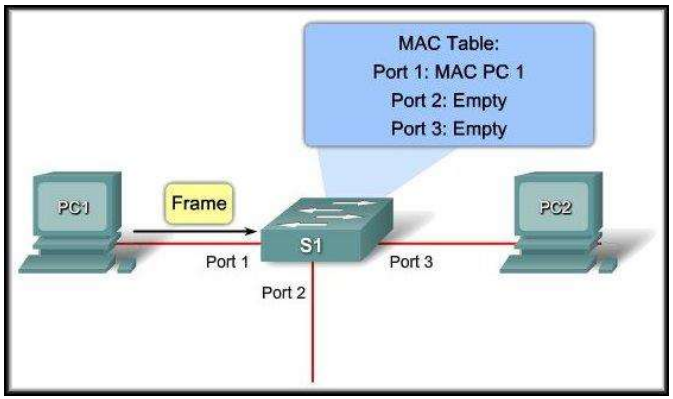



## 4. Ethernet Switches

❖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.



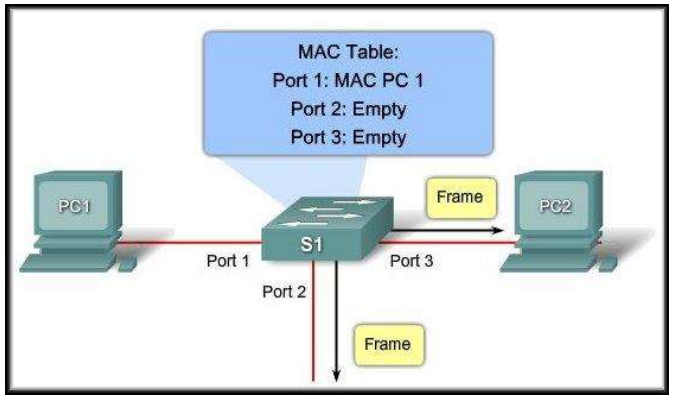



## 4. Ethernet Switches

❖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.



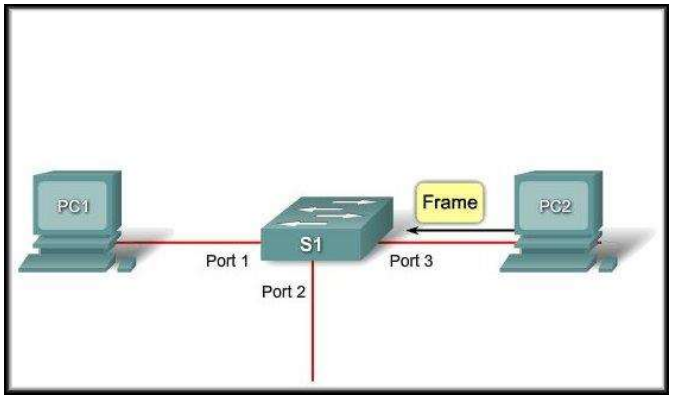



## 4. Ethernet Switches

❖Ethernet Learning Algorithm

➢**Example Step 4:**

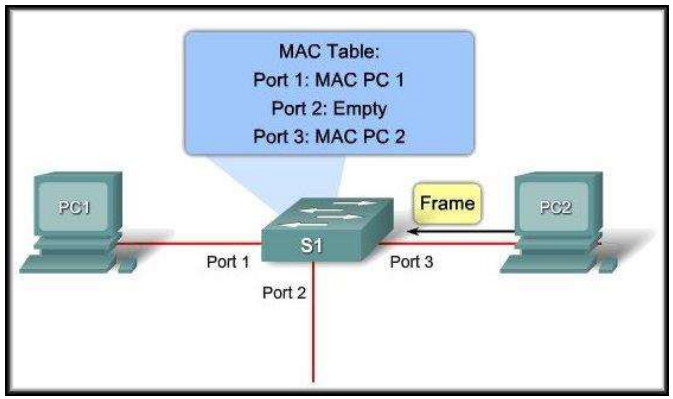
➢The destination device replies to the broadcast with a unicast frame addressed to PC 1.



❖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.



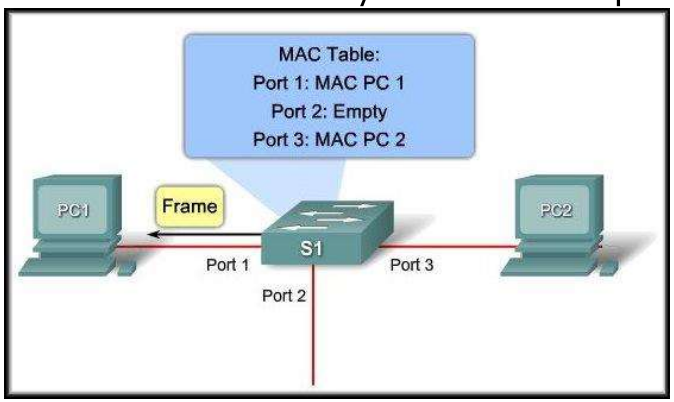





❖Ethernet Learning Algorithm

➢**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 and 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.**

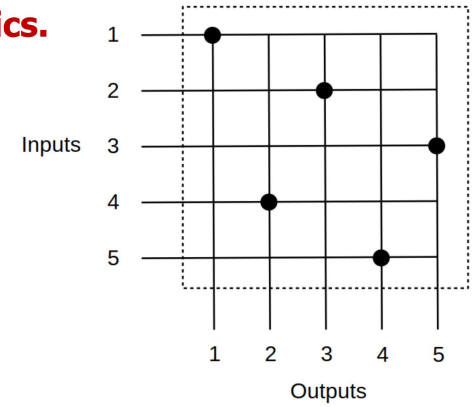
- In datacenters: 10 Gbps, 40 Gbps Ethernet is now common.
- Switch 24 ports is a bare minimum.
  - Shared-memory not a suitable.
- Crossbar switch fabric:
  - Consisting of a grid of *N x N* normally open switch nodes that can be closed under CPU control.
  - Packets travel, via a connected path through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

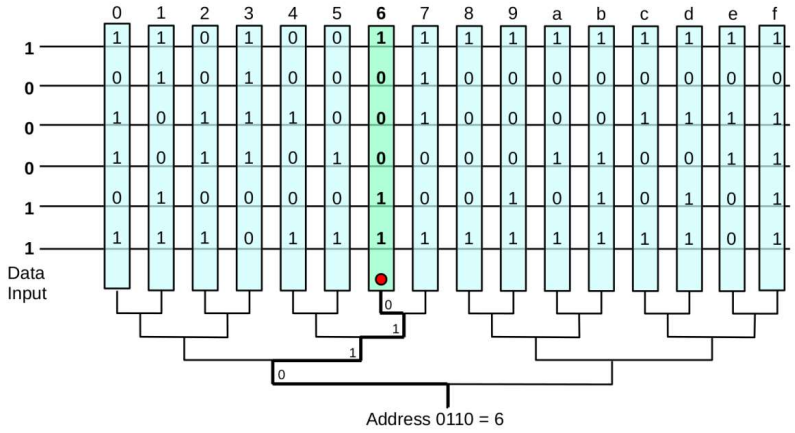
➢**Content-Addressable Memory (CAM)**

- 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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