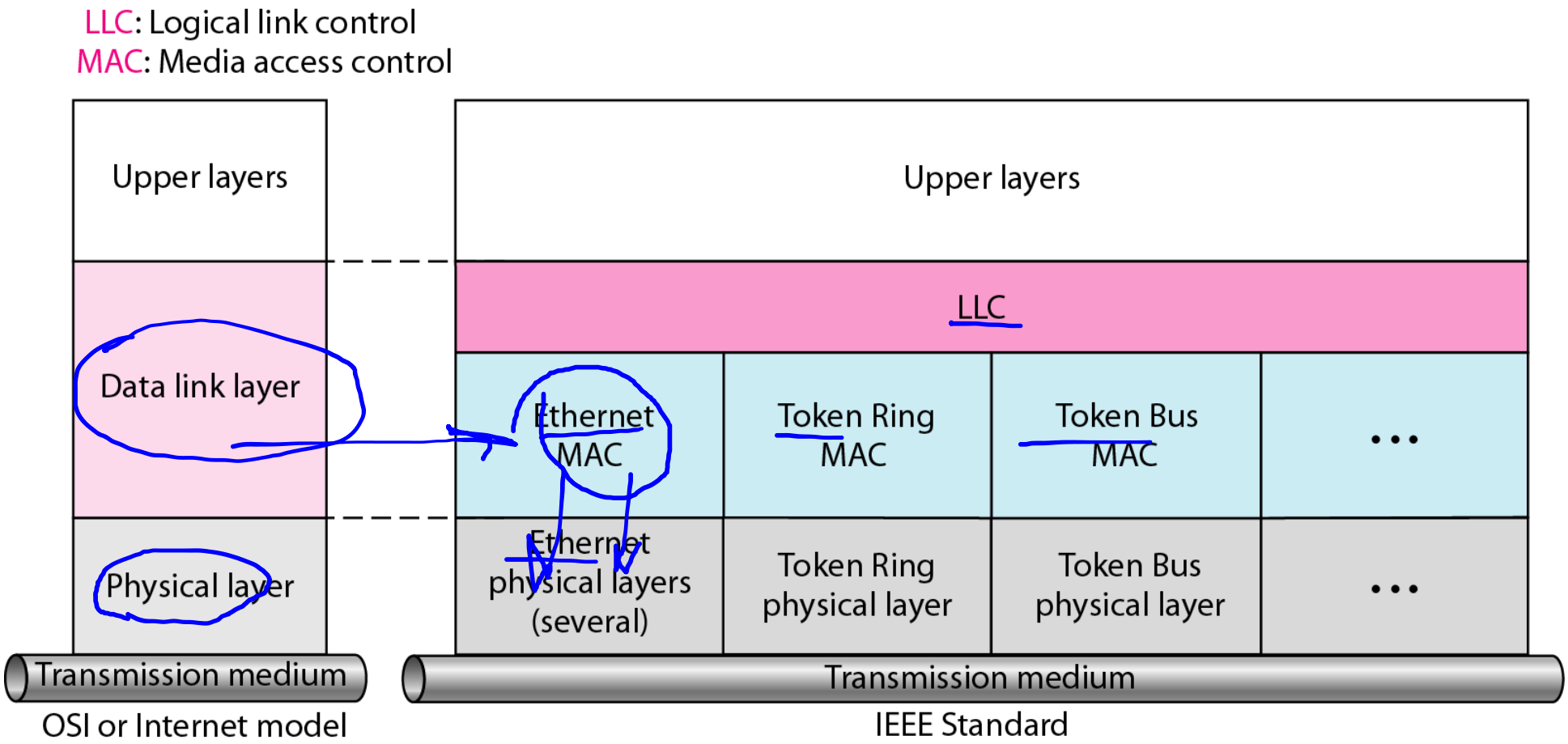
Wired LANs: Ethernet

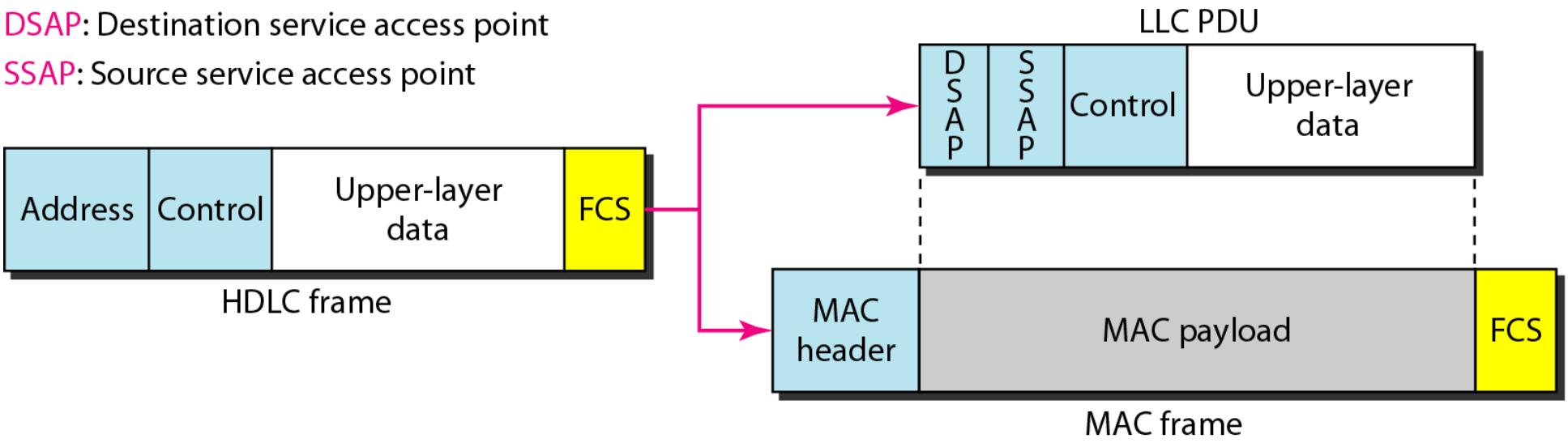
IEEE Standards

- *In 1985, the Computer Society of the IEEE started a project, called Project 802, to set standards to enable intercommunication among equipment from a variety of manufacturers.*
- *Project 802 is a way of specifying*
  - *functions of the physical layer and*
  - *the data link layer of major LAN protocols.*

IEEE standard for LANs



HDLC frame compared with LLC and MAC frames

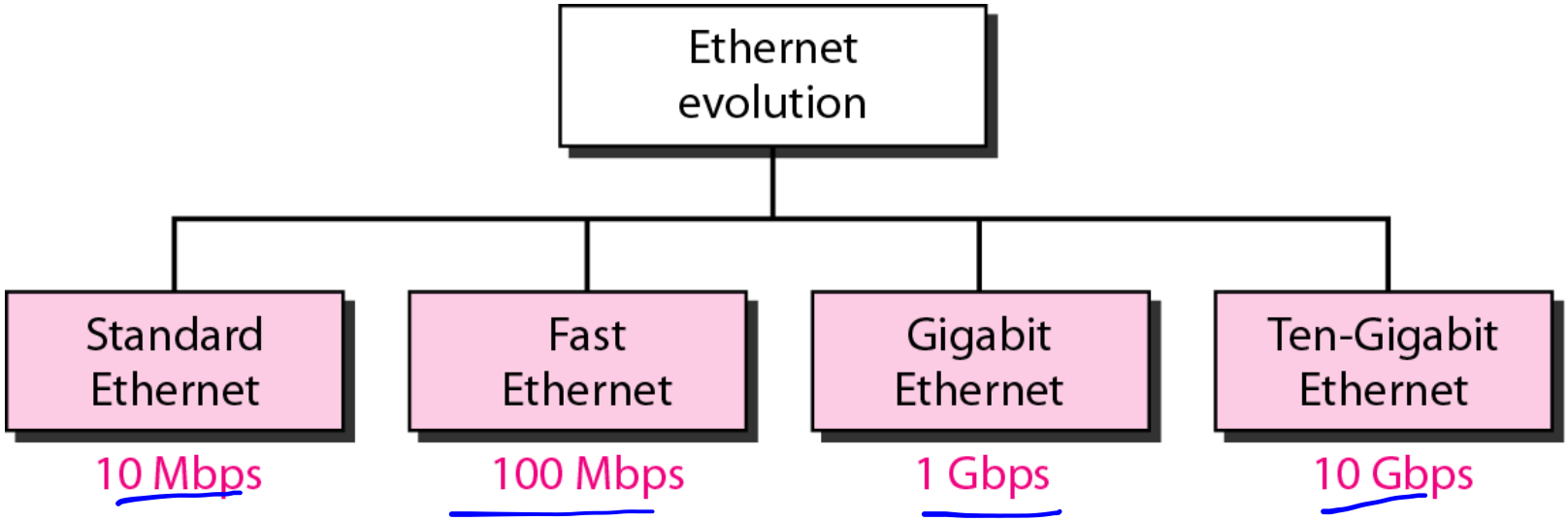


Standard Ethernet

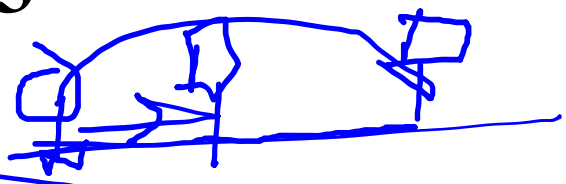
- *The original Ethernet was created in 1976 at Xerox's Palo Alto Research Center (PARC).*

- *Since then, it has gone through four generations.*
  - *Standard Ethernet (10 Mbps)*
  - *Fast Ethernet (100 Mbps)*
  - *Gigabit Ethernet (1 Gbps)*
  - *10 Gigabit Ethernet (10 Gbps)*

Ethernet evolution through four generations

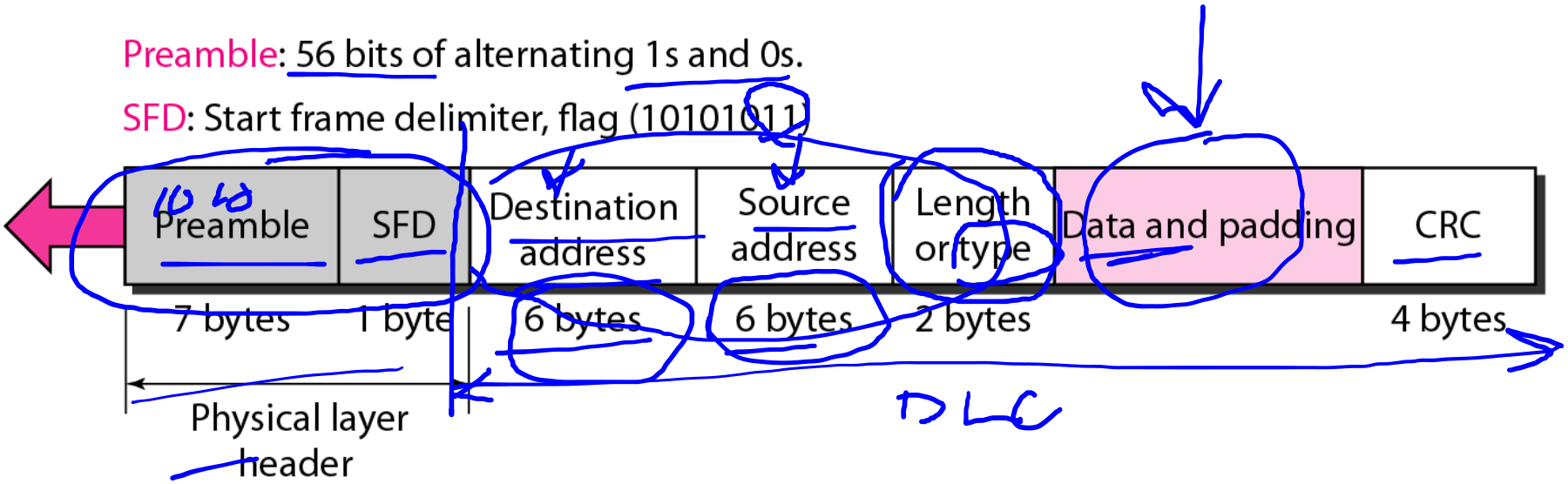


Standard Ethernet : 802.3



- **Characteristics:**
  - Provides a connectionless service
  - Sender sends the frame whenever it has it
    - But the receiver may not be ready to accept
  - If a frame drops, sender will not know about it
  - As it is connectionless, it is unreliable.

Standard Ethernet: 802.3 MAC frame format



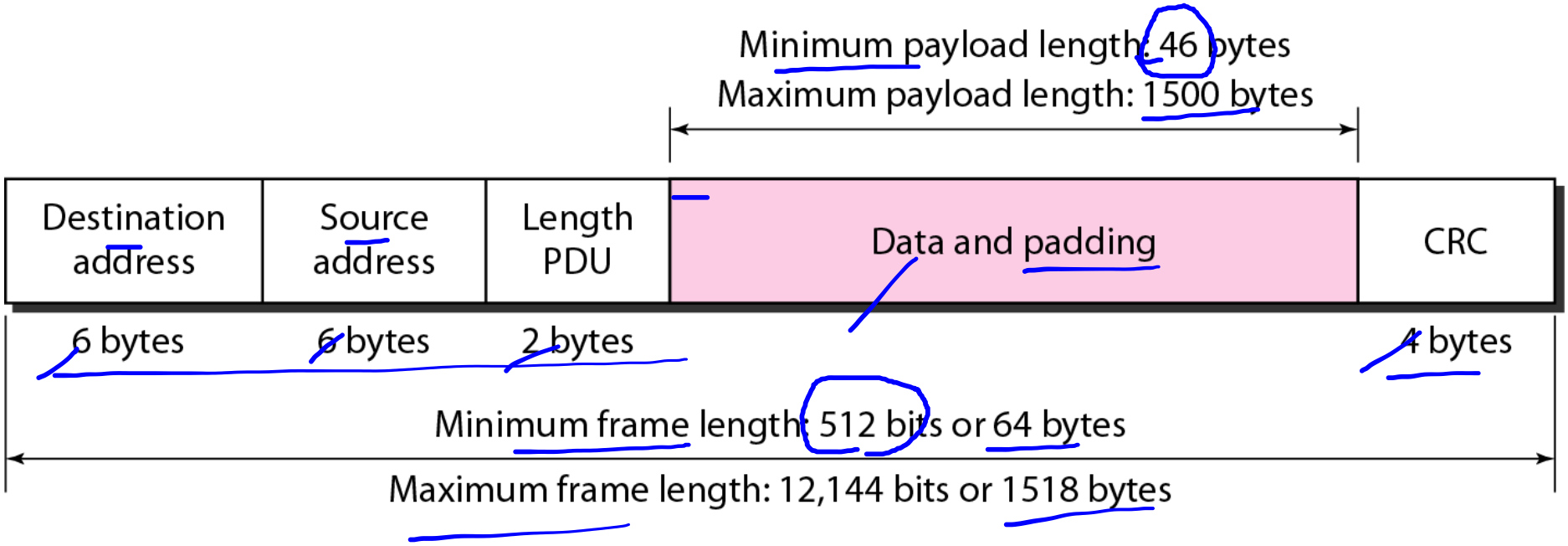
- **Preamble:**
  - Alert the receiving system about coming frame and enable it to synchronize.
  - This is actually added at the physical layer and is not part of the frame
- **SFD:**
  - Signals the beginning of the frame.
  - It warns the station that this is the last chance to synchronize
  - The last two bits of SFD $(11)_2$ alert the receiver that next field is destination address

Standard Ethernet: 802.3 MAC frame format

- **Type:**
  - Defines the upper-layer protocol whose packet is encapsulated
    - Ex: Packet like IP, ARP, OSPF etc.

- **Data:**
  - Variable size

Minimum and maximum lengths



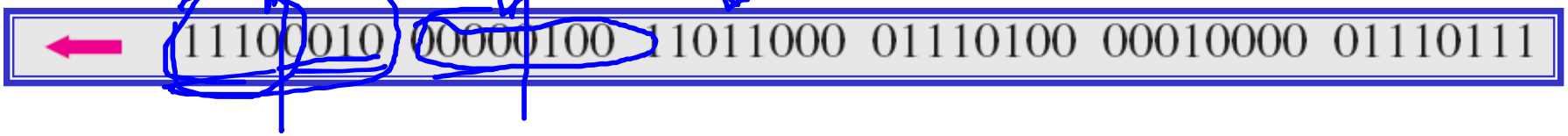
- **If the upper layer data is less than 46 bytes, padding is added to make up the difference**

Transmission of Address Bits

It shows how the address 47:20:1B:2E:08:EE is sent out on line.

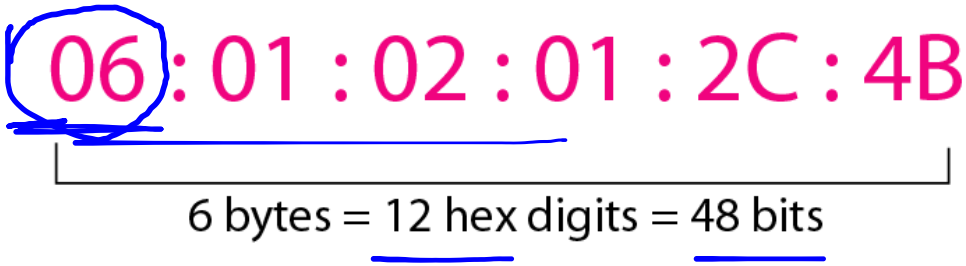
Solution:

- The address is sent left-to-right, byte by byte; for each byte, it is sent right-to-left, bit by bit, as shown below:

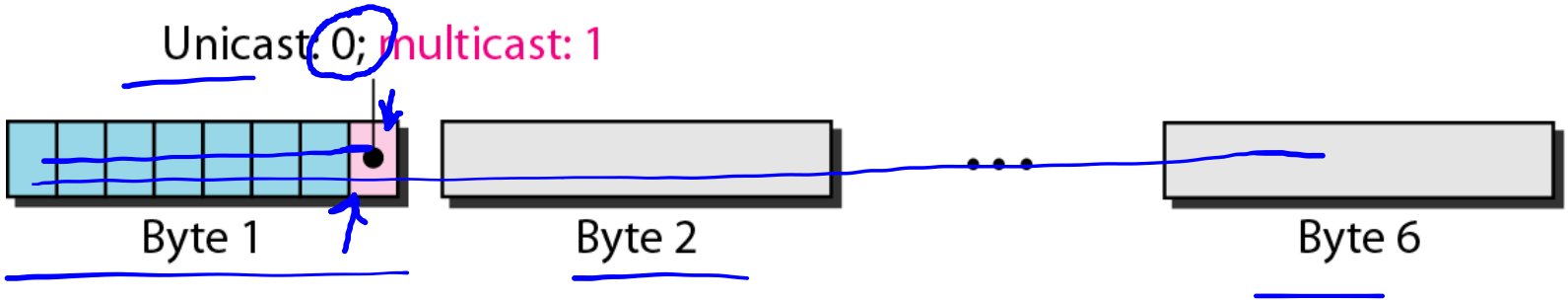


Ethernet address :

- Each station on an Ethernet Network has its own network Interface Card (NIC), which provides the station with a link layer address
- It is a 48 bit address, normally written in a hexadecimal notation.



Unicast and multicast addresses



- A source address is always *unicast address* – the frames comes from one station
- The destination address, can be *unicast, multicast or broadcast*
- The broadcast destination address is a special case of the multicast address in which all bits are 1s.

Example

Define the type of the following destination addresses:

a. 4A:30:10:21:10:1A **b. 47:20:1B:2E:08:EE**

c. FF:FF:FF:FF:FF:FF

Solution

- To find the type of the address, we need to look at the second hexadecimal digit from the left.
- If it is even, the address is unicast.
- If it is odd, the address is multicast.
- If all digits are F's, the address is broadcast.
- Therefore, we have the following:
    a. This is a unicast address because A in binary is 1010.
    b. This is a multicast address because 7 in binary is 0111.
    c. This is a broadcast address because all digits are F's.

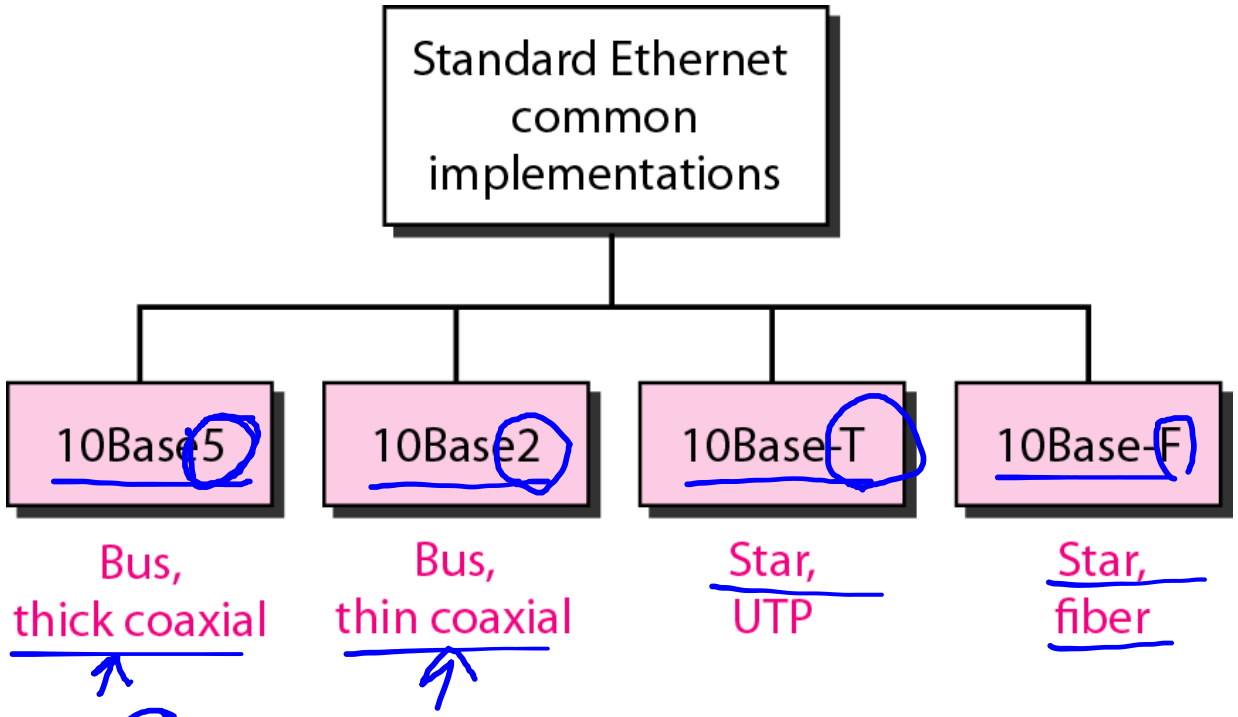
Standard Ethernet

- Transmission in the standard Ethernet is ***always broadcast***, no matter if the intention is unicast, multicast, or broadcast

- **Access method:**
  - The standard ethernet chose CSMA/CD with 1-persistent method.

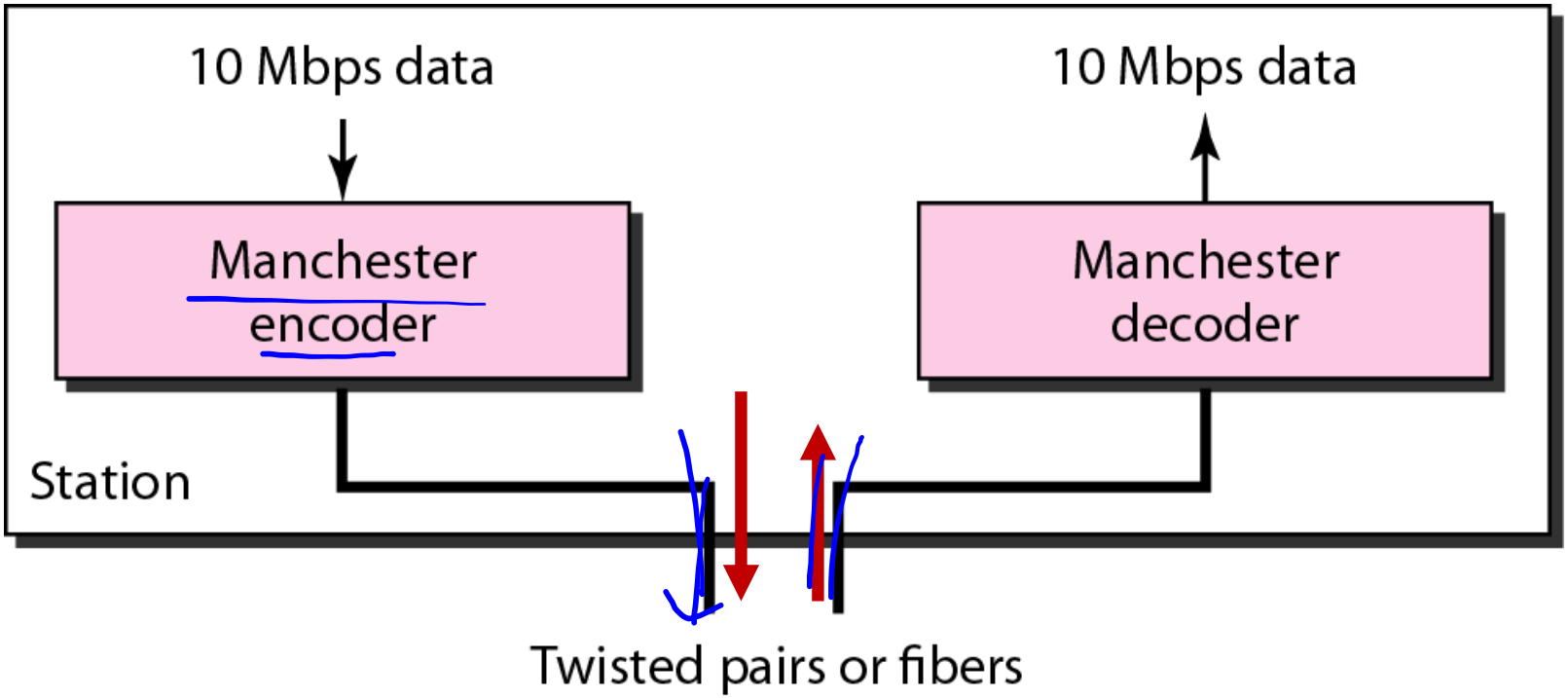
- **Efficiency:**
  - *Already discussed for CSMA/CD*

Implementation: Categories of Standard Ethernet

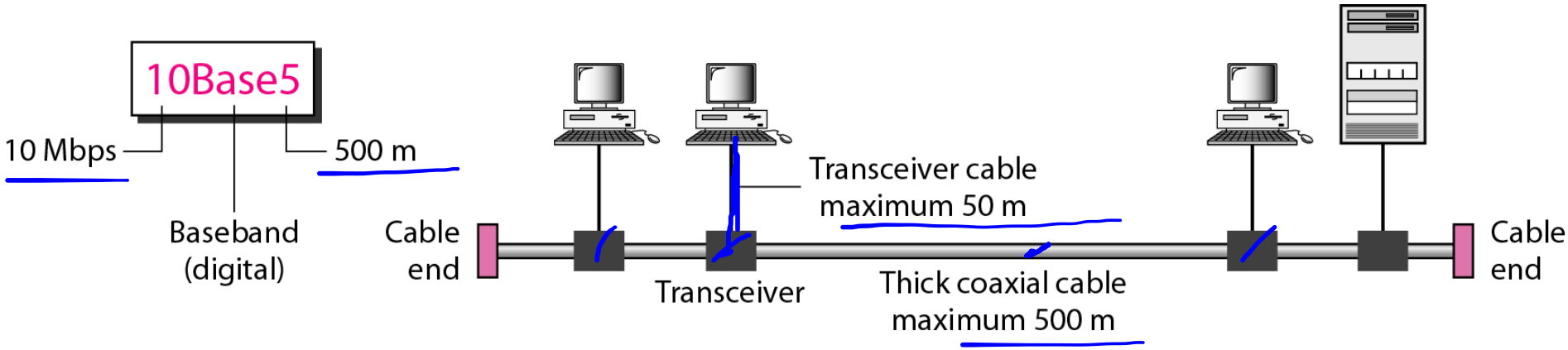


- **10BaseX:**
  - **10 :** Defines the data rate (10 Mbps)
  - **Base:** Defines baseband (digital) signal
  - **X:** Approximately defines either the maximum size of the cable in 100 meters or type of the cable

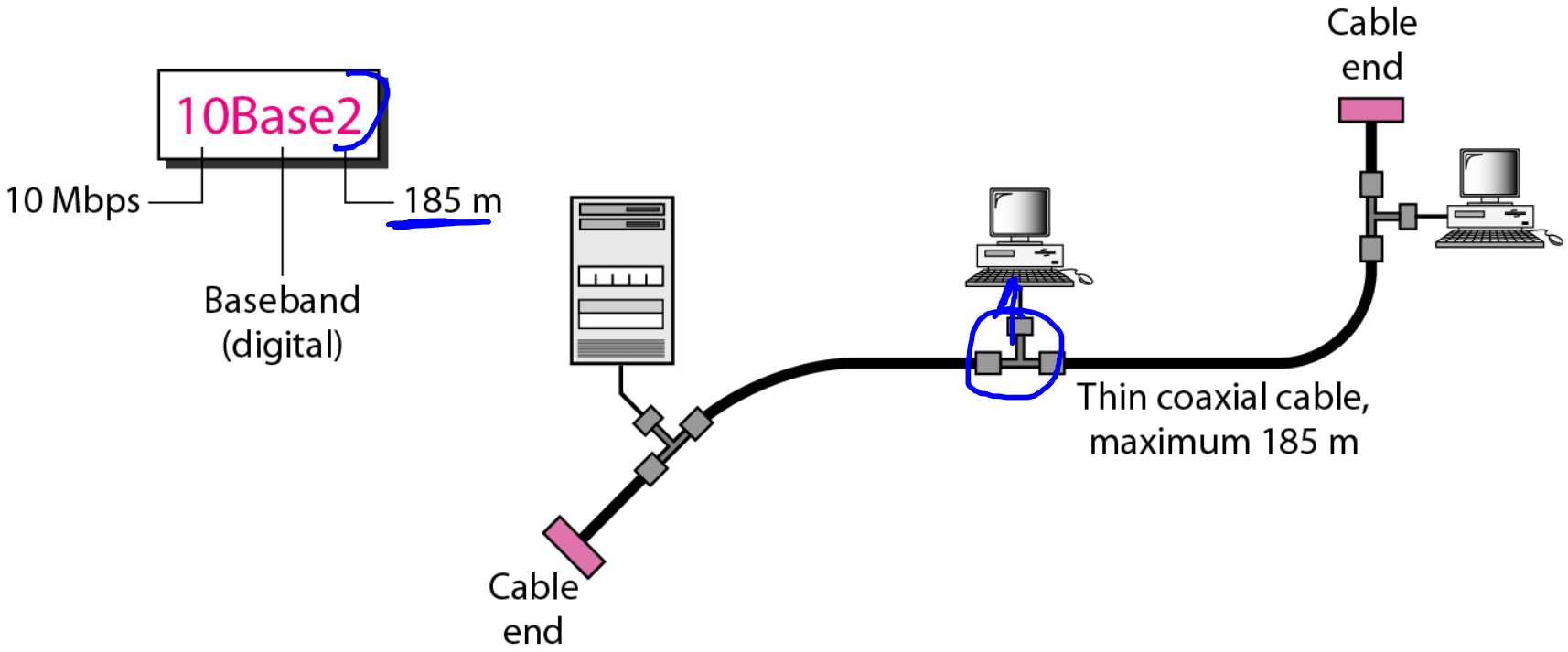
Encoding in a Standard Ethernet implementation



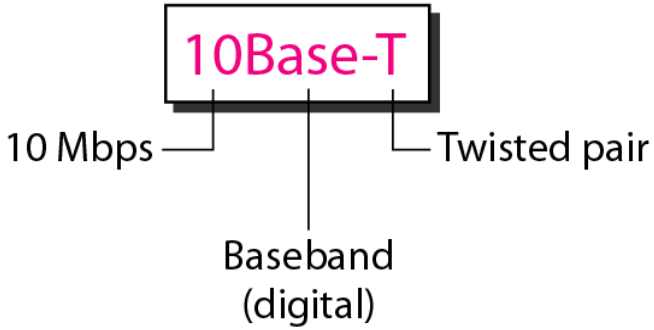
10Base5: Thick Ethernet or Thicknet implementation

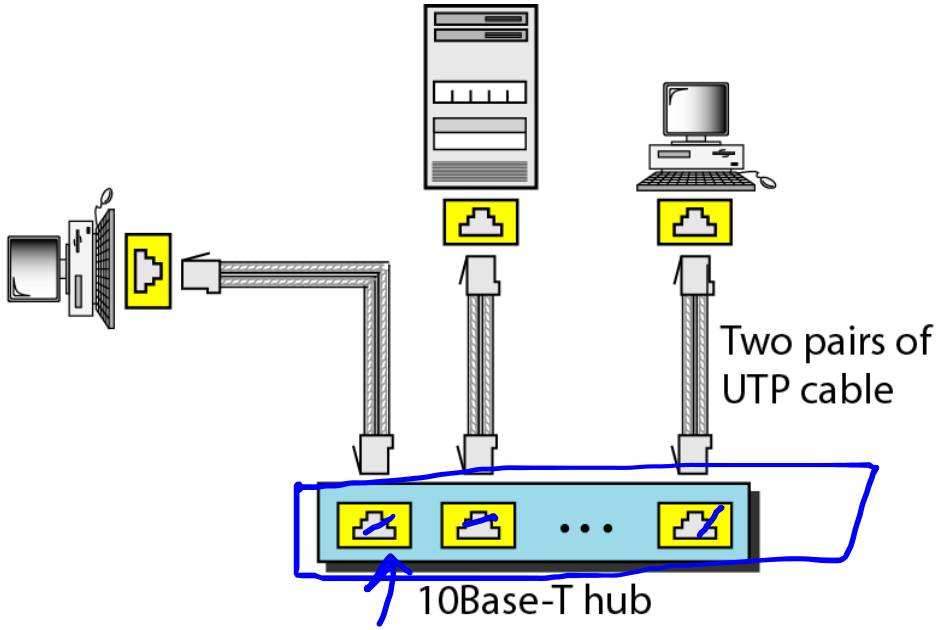


10Base2: thin Ethernet or Cheapernet implementation



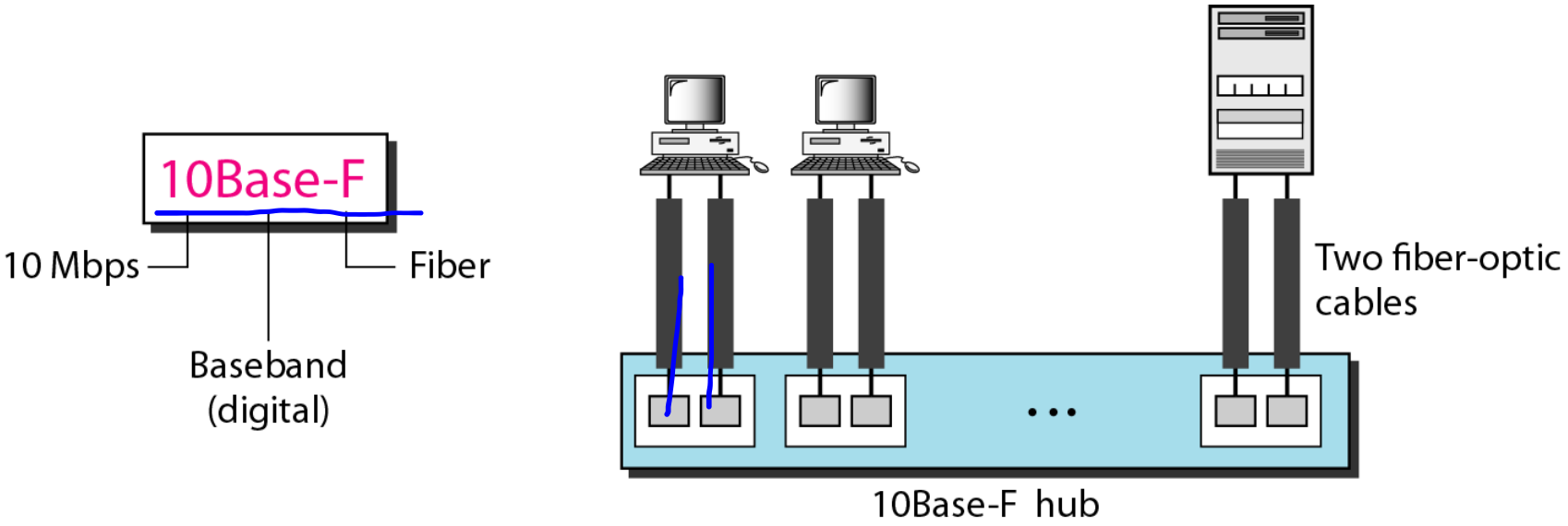
10Base-T: Twisted-Pair Ethernet implementation





Maximum length of the Twisted pair cable is 100m

10Base-F implementation



Two fiber optic cable is used to connect the stations to a hub and star topology is used

Table ***Summary of Standard Ethernet implementations***

Characteristics	*10Base5*	*10Base2*	*10Base-T*	*10Base-F*
Media	Thick coaxial cable	Thin coaxial cable	2 UTP	2 Fiber
Maximum length	500 m	185 m	100 m	2000 m
Line encoding	Manchester	Manchester	Manchester	Manchester

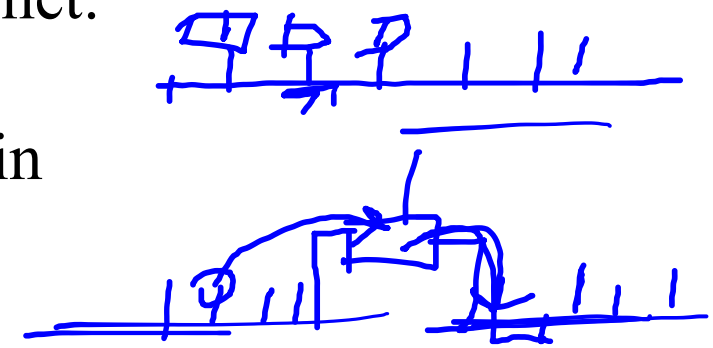
Changes in the Standard

- The 10-Mbps Standard Ethernet has gone through several changes before moving to the higher data rates.
- These changes actually opened the road to the evolution of the Ethernet to become compatible with other high-data-rate LANs.

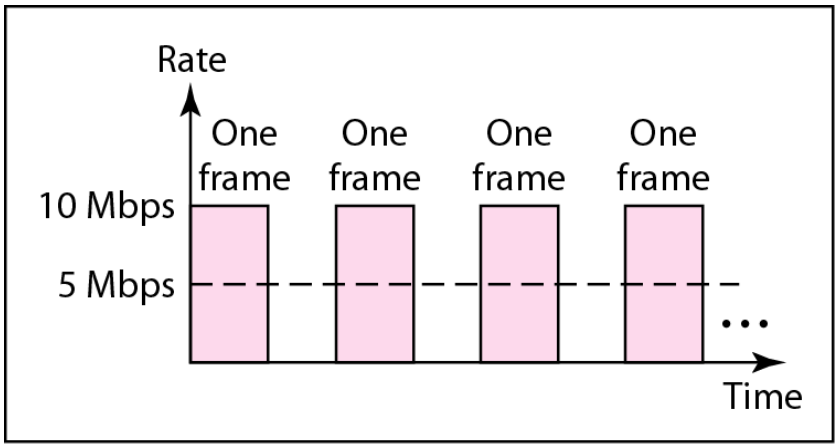
  - **Bridged Ethernet**
  - **Switched Ethernet**
  - **Full-Duplex Ethernet**

Bridged Ethernet

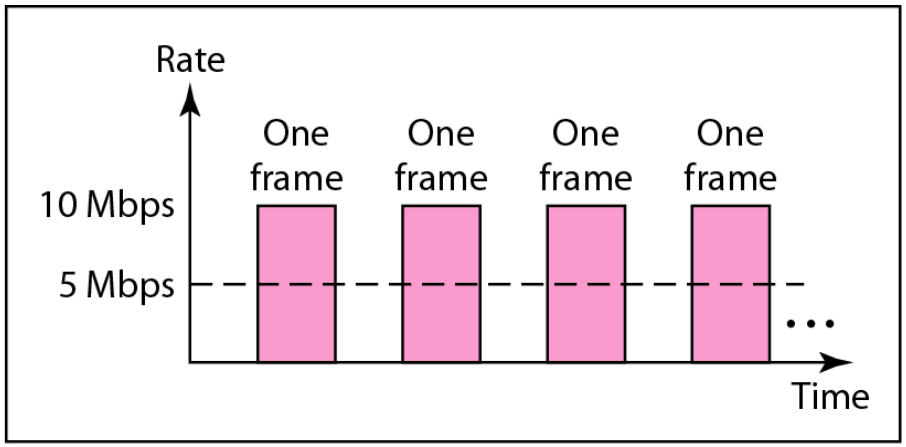
- This divides the LAN using *bridges*
- Bridges have two effects on ethernet:
  - They raise the bandwidth
  - They separate collision domain



Sharing bandwidth

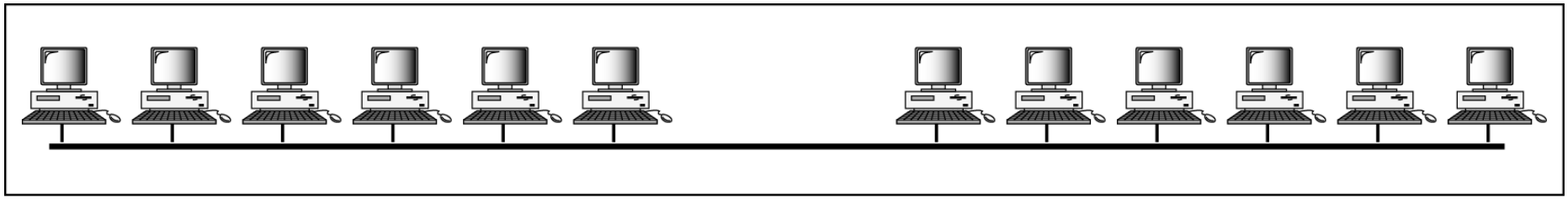


a. First station

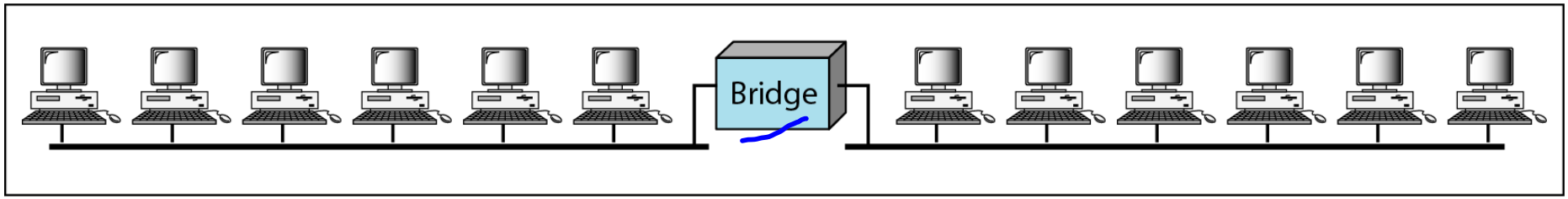


b. Second station

A network with and without a bridge

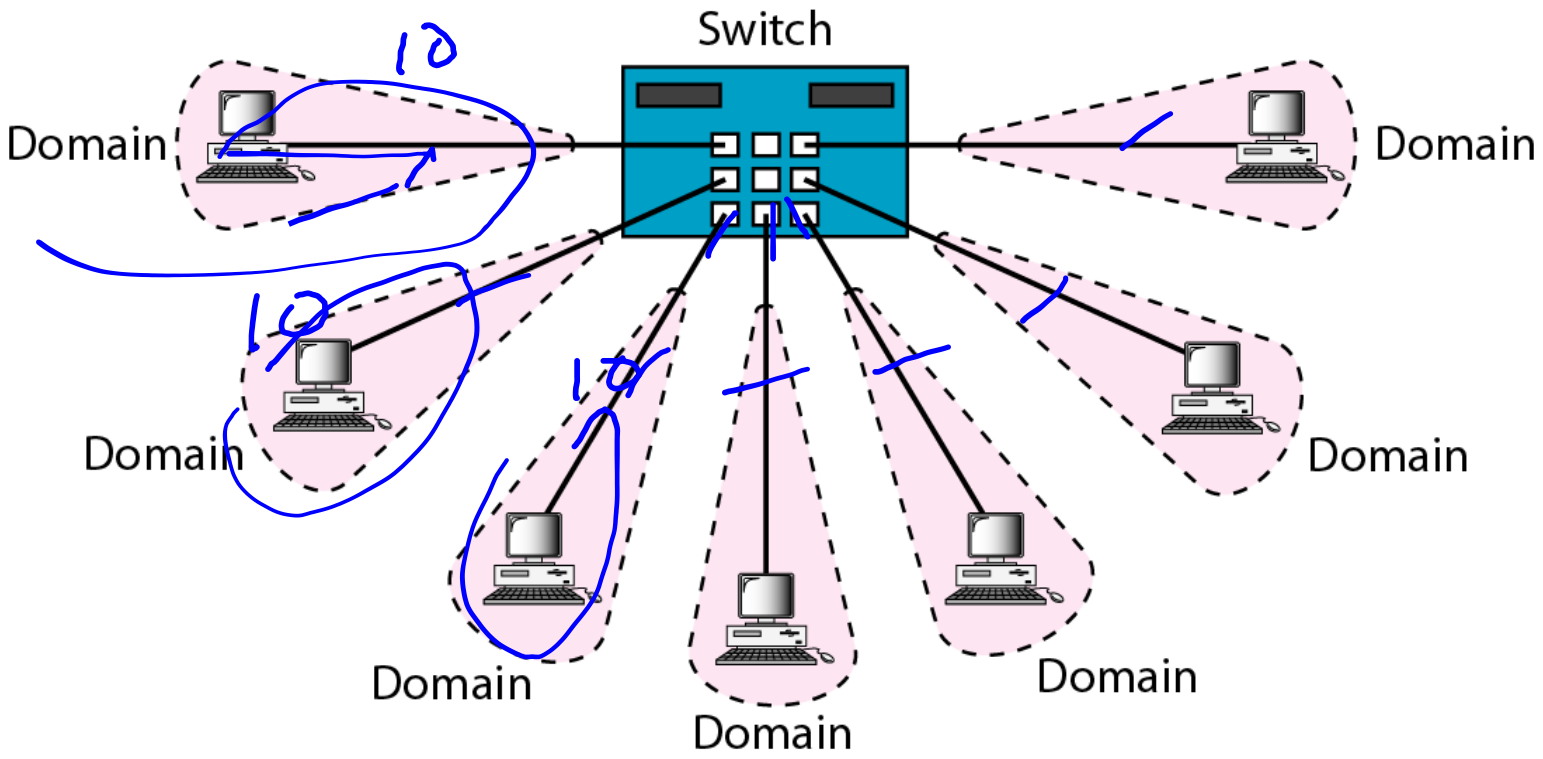


a. Without bridging



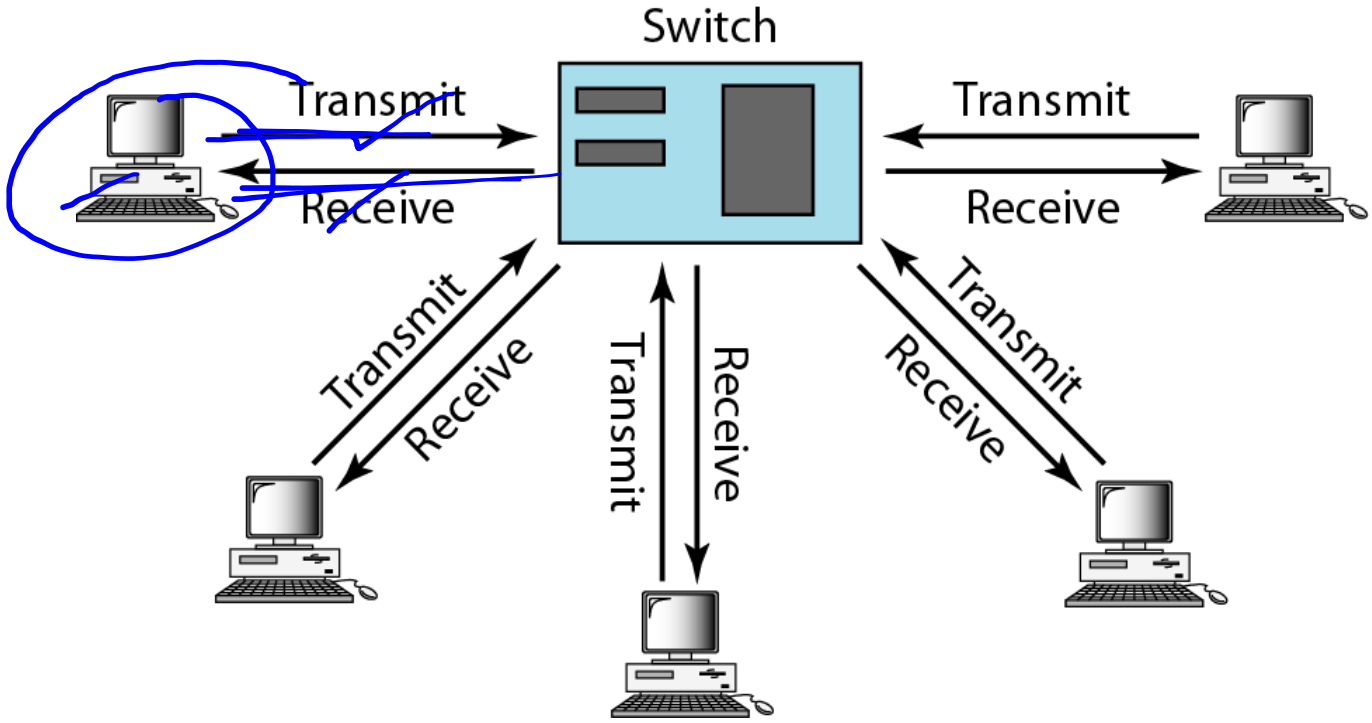
b. With bridging

Switched Ethernet



- A layer 2-switch is an N-port bridge with additional sophistication that allows faster handling of the packets

Full-duplex switched Ethernet



- Full-duplex mode increases the capacity of each domain by 10 to 20Mbps
- Uses two links: one to transmit and one to receive
- No need for CSMA/CD, as each link is a point-to-point dedicated path between the station and the switch

Standard Ethernet

- It was designed as a connectionless protocol in MAC sublayer
- There is *no explicit flow control or error control* to inform the sender that the frame has arrived at the destination without error
- When the receiver receives the frame, it does not send any positive or negative acknowledgment
- To provide the flow and error control in full-duplex switched ethernet, a new sublayer called *MAC control*, is added between LLC and MAC sublayer

Fast Ethernet

- *Fast Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel.*
- *IEEE created Fast Ethernet under the name 802.3u.*
- *Fast Ethernet is backward-compatible with Standard Ethernet, but it can transmit data 10 times faster at a rate of 100 Mbps.*
- *Change is done based on the modification in*
    - **MAC Sublayer and**
    - **Physical Layer**

Fast Ethernet

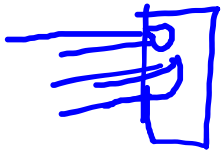
- **Goals:**
  - Upgrade the data rate to 100Mbps
  - Make it compatible with Standard Ethernet
  - Keep the same 48 bit address
  - Keep the same frame format

Fast Ethernet: Access Method

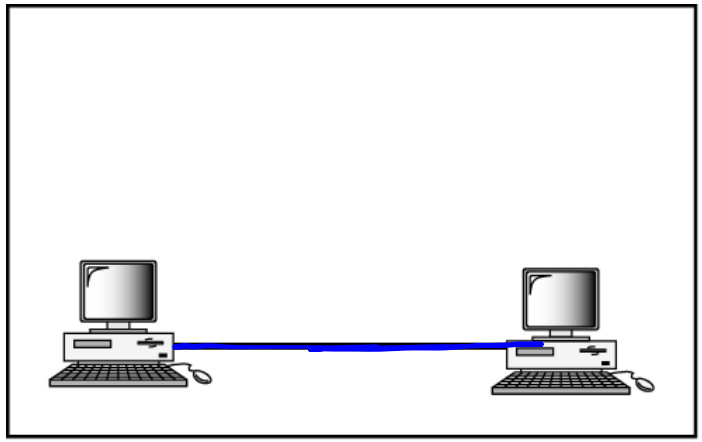
- Efficiency of CSMA/CD depends on the transmission rate, the minimum size of the frame and the maximum network length
- If the minimum frame size is kept same then network length should be changed
- Keeping minimum size frame length and data rate 10 time faster than standard ethernet means collision is detected 10 times sooner
    - This implies length of the network should be 10 times shorter

Fast Ethernet: Access Method

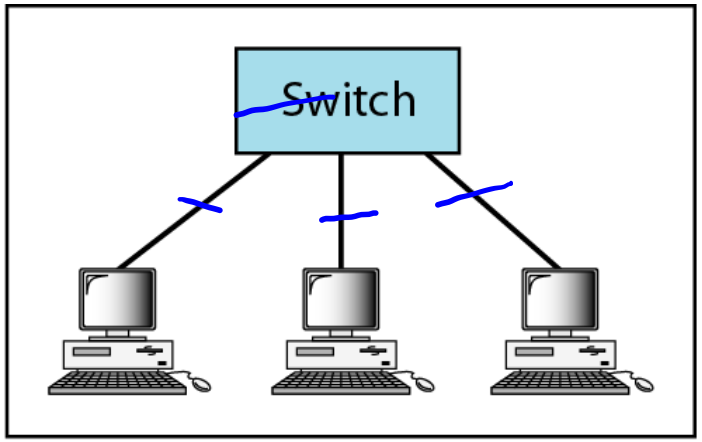
- So fast ethernet comes with two solutions:
  - **First:**
    - ❖ Totally drop the bus topology
    - ❖ Use a passive hub and star topology
    - ❖ Make the maximum size network as 250m
  - **Second:**
    - ❖ Use a link-layer switch with a buffer to store frames and a full duplex connection to each host



Fast Ethernet: Topology

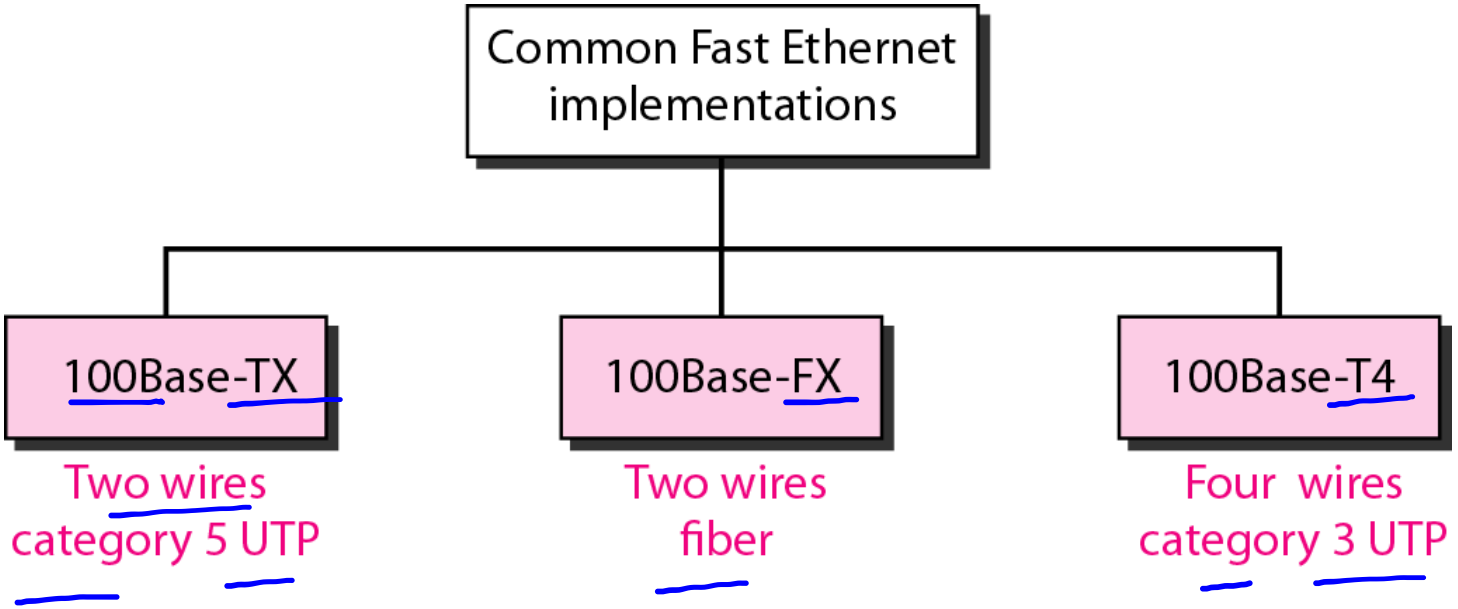


a. Point-to-point

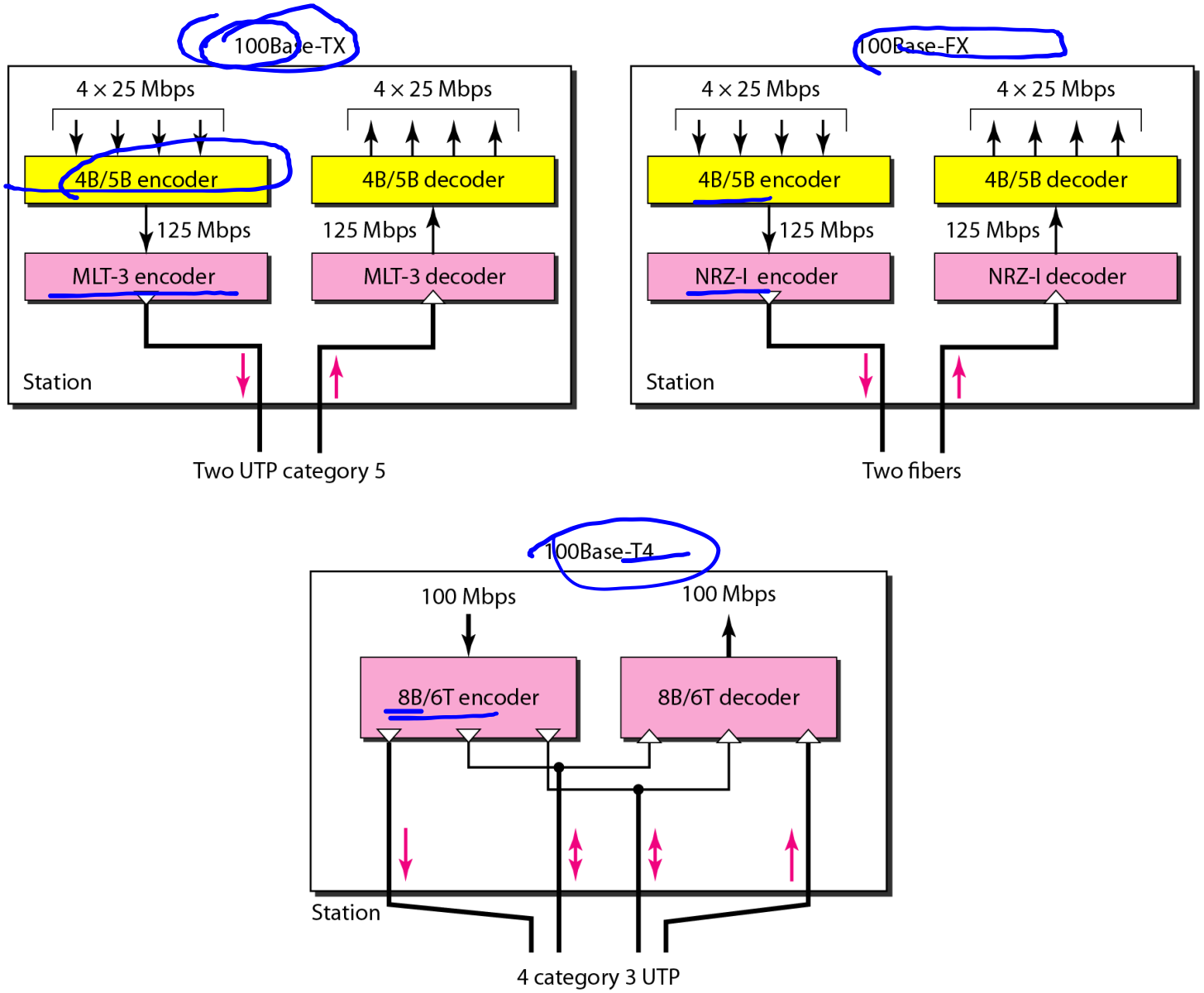


b. Star

Fast Ethernet implementations



Fast Ethernet : Encoding



Summary of Fast Ethernet implementations

Characteristics	*100Base-TX*	*100Base-FX*	*100Base-T4*
Media	Cat 5 UTP or STP	Fiber	Cat 4 UTP
Number of wires	2	2	4
Maximum length	100 m	100 m	100 m
Block encoding	4B/5B	4B/5B	
Line encoding	MLT-3	NRZ-I	8B/6T

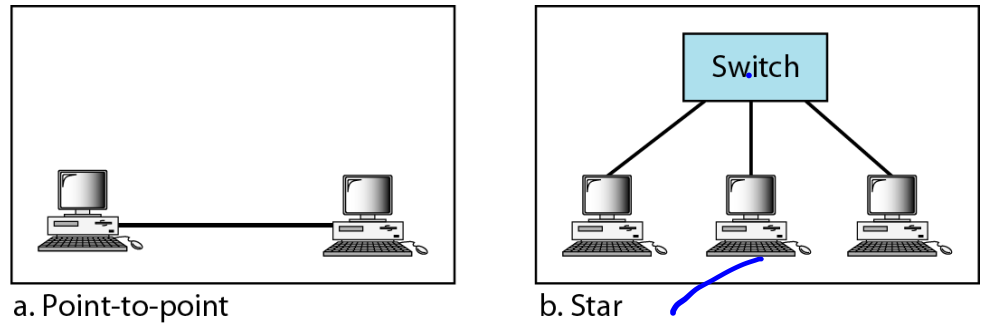
Gigabit Ethernet

- *The need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps).*
- *The IEEE committee calls the standard 802.3z.*
- *This is obtained by doing changes in*
    - **MAC Sublayer**
    - **Physical Layer and**

Gigabit Ethernet

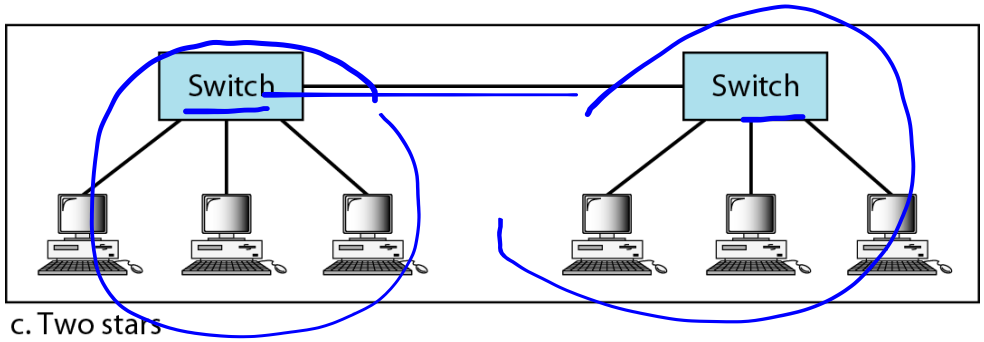
- **Goals:**
  - Upgrade the data rate to 1 Gbps
  - Make it compatible with Standard and Fast Ethernet
  - Use the same 48-bit address
  - Keep the same minimum and maximum frame lengths
  - Support auto-negotiation

Topologies of Gigabit Ethernet

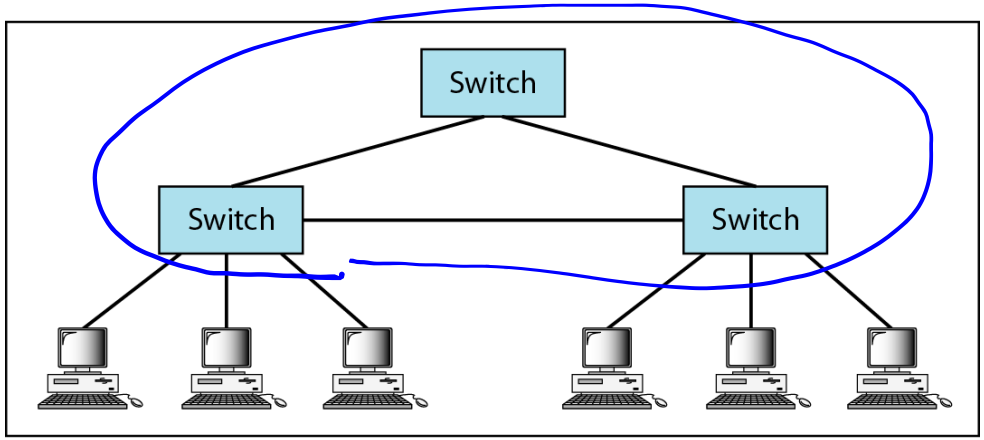


a. Point-to-point

b. Star

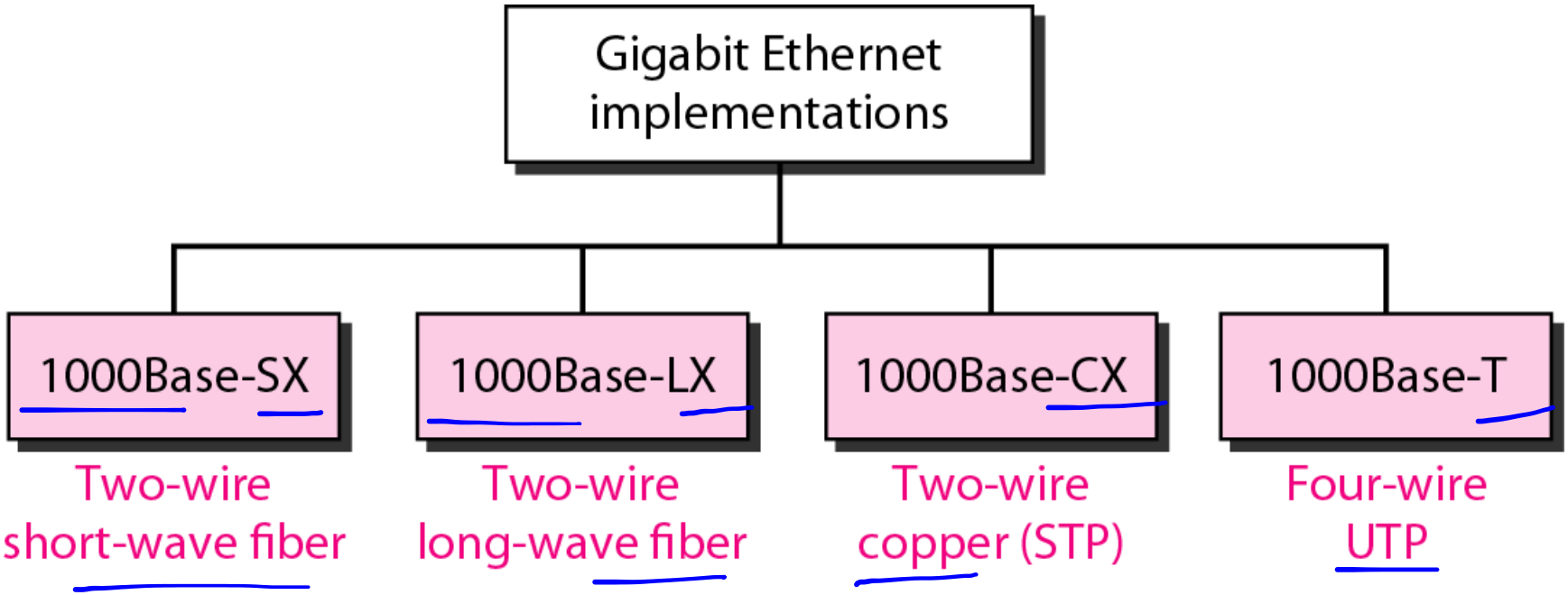


c. Two stars

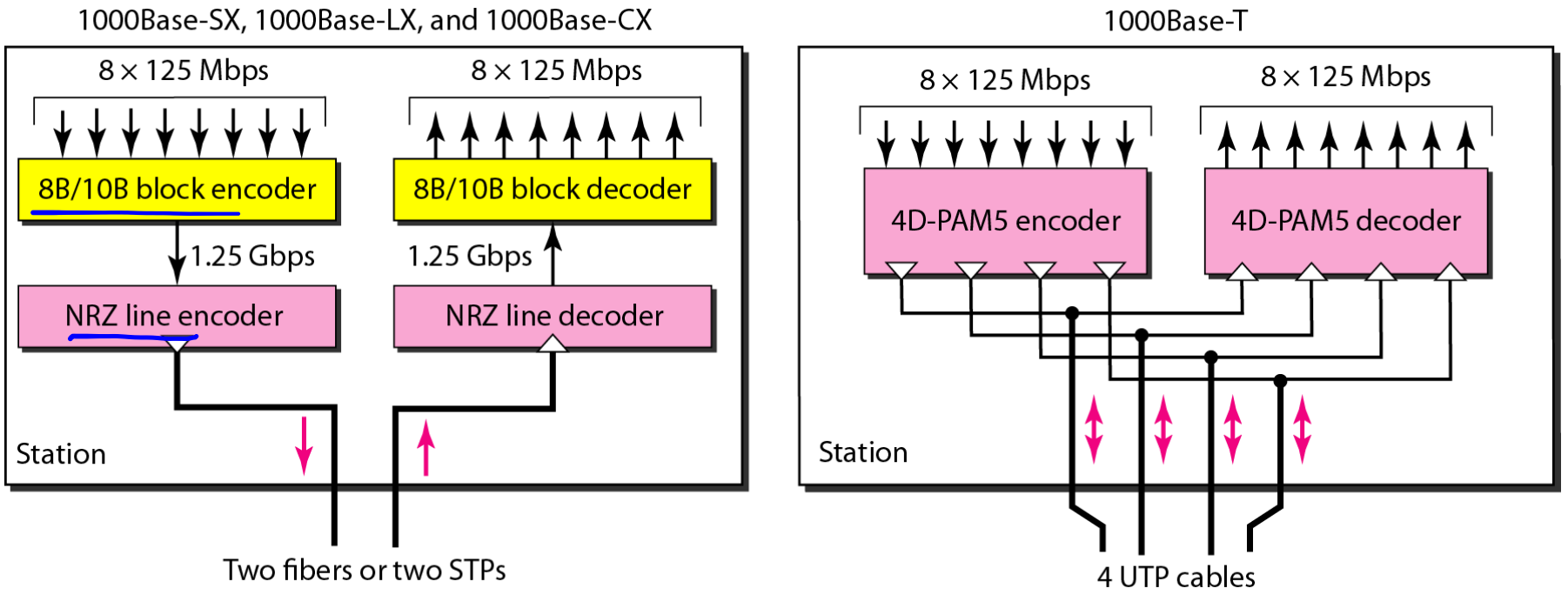


d. Hierarchy of stars

Gigabit Ethernet implementations



Encoding in Gigabit Ethernet implementations



Summary of Gigabit Ethernet implementations

Characteristics	*1000Base-SX*	*1000Base-LX*	*1000Base-CX*	*1000Base-T*
Media	Fiber short-wave	Fiber long-wave	STP	Cat 5 UTP
Number of wires	2	2	2	4
Maximum length	550 m	5000 m	25 m	100 m
Block encoding	8B/10B	8B/10B	8B/10B	
Line encoding	NRZ	NRZ	NRZ	4D-PAM5

Characteristics	*10GBase-S*	*10GBase-L*	*10GBase-E*
Media	Short-wave 850-nm multimode	Long-wave 1310-nm single mode	Extended 1550-mm single mode
Maximum length	300 m	10 km	40 km