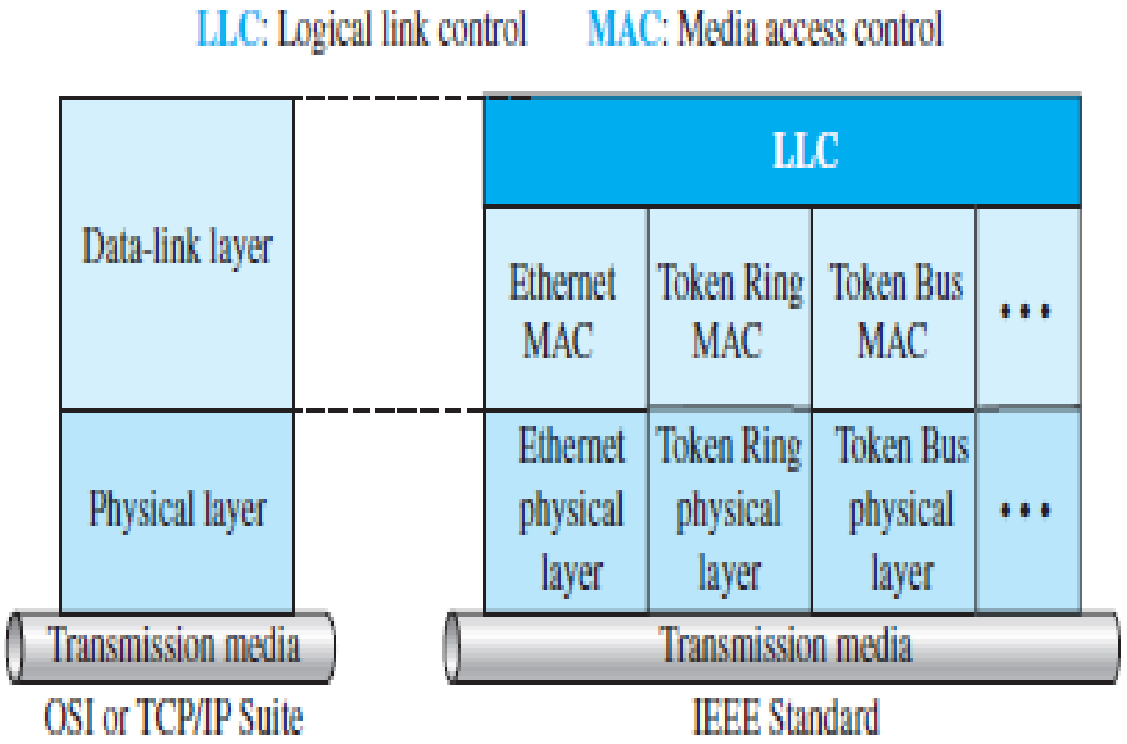
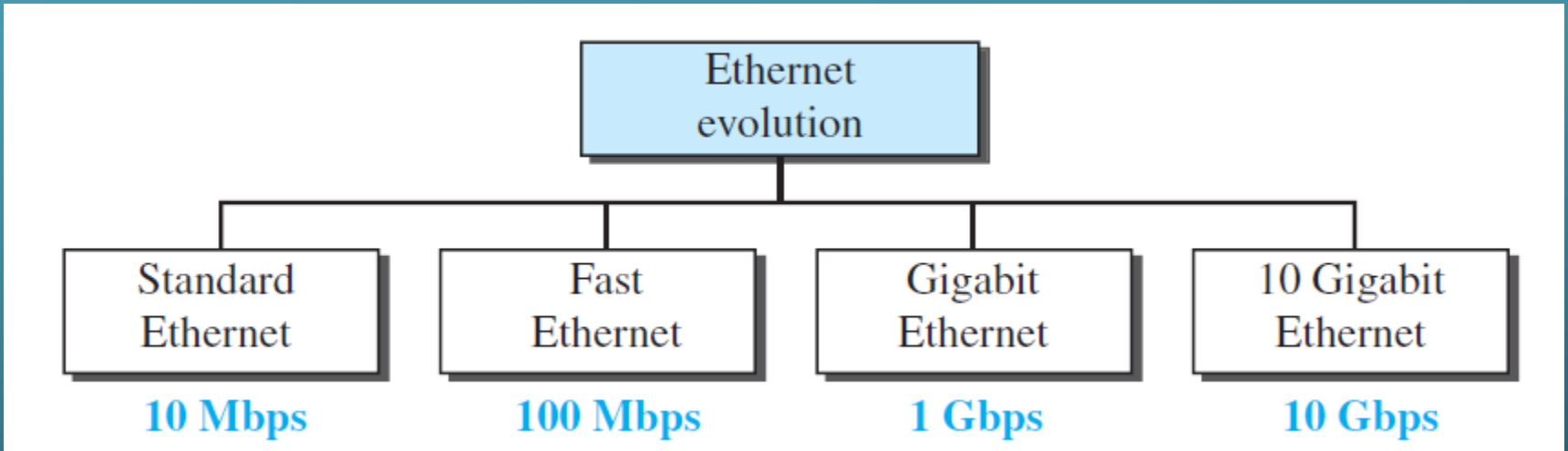
WIRED LANS: ETHERNET

ETHERNET PROTOCOL



- Project 802, to set standards to enable intercommunication among equipment from a variety of manufacturers
- LLC protocol can provide interconnectivity between different LANs because it makes the MAC sublayer transparent.

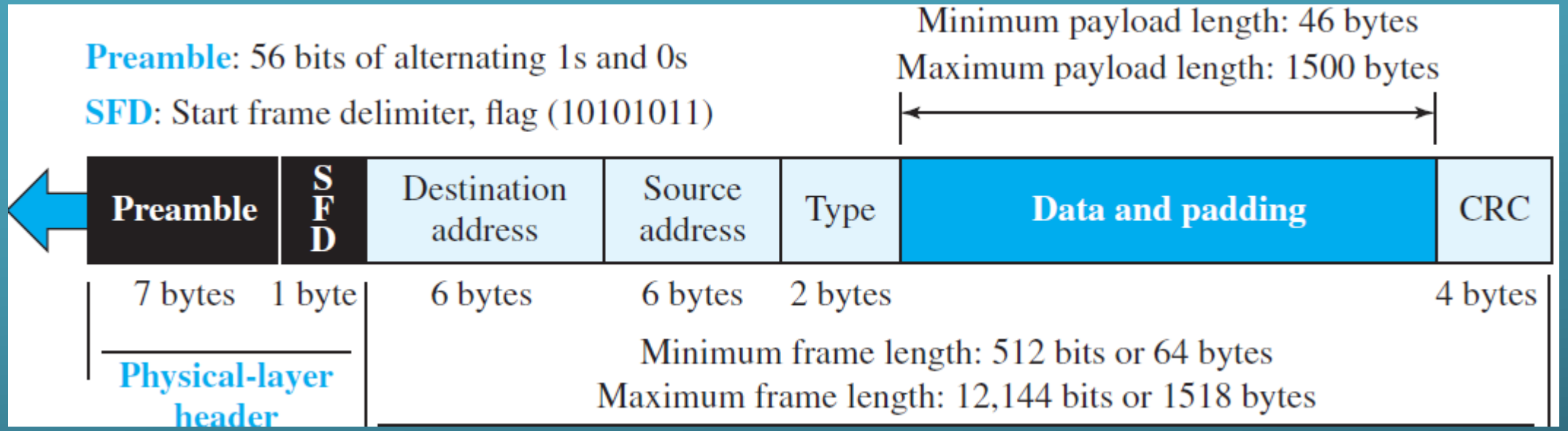
ETHERNET EVOLUTION



STANDARD ETHERNET: CONNECTIONLESS AND UNRELIABLE SERVICE

- Ethernet provides a connectionless service.
- The sender **sends a frame whenever it has** it; the receiver may or may not be ready for it. The sender may overwhelm the receiver with frames, which may result in dropping frames. If a frame drops, the sender will not know about it.
- Since IP, which is using the service of Ethernet, is also connectionless, it will not know about it either.
- If the transport layer is also a connectionless protocol, such as UDP, the frame is lost and salvation may only come from the application layer.
- However, if the transport layer is TCP, the sender TCP does not receive acknowledgment for its segment and sends it again.
- Ethernet is also **unreliable** like IP and UDP. If a frame is corrupted the receiver drops the frame silently.

FRAME FORMAT



- Preamble: This field contains 7 bytes (56 bits) of alternating 0s and 1s – synchronization - added at the physical layer.
- Start frame delimiter (SFD): This field (1 byte: 10101011) - added at the physical layer.
- ***Type:*** defines the upper-layer protocol whose packet is encapsulated in the frame. This protocol can be IP, ARP, OSPF

Minimum frame length: 64 bytes	**Minimum data length: 46 bytes**
Maximum frame length: 1518 bytes	**Maximum data length: 1500 bytes**

ADDRESSING

- Each station on an Ethernet network has its own network interface card (NIC).
- The NIC fits inside the station and provides the station with a link-layer address.
- The Ethernet address is 6 bytes (48 bits), in hexadecimal notation, with a colon between the bytes. 4A:30:10:21:10:1A

Transmission of Address Bits

- The transmission is **left to right, byte by byte**; for each byte, the **least significant bit is sent first** and the most significant bit is sent last.
- This means that the bit that defines an address as unicast or multicast arrives first at the receiver.

EXAMPLE

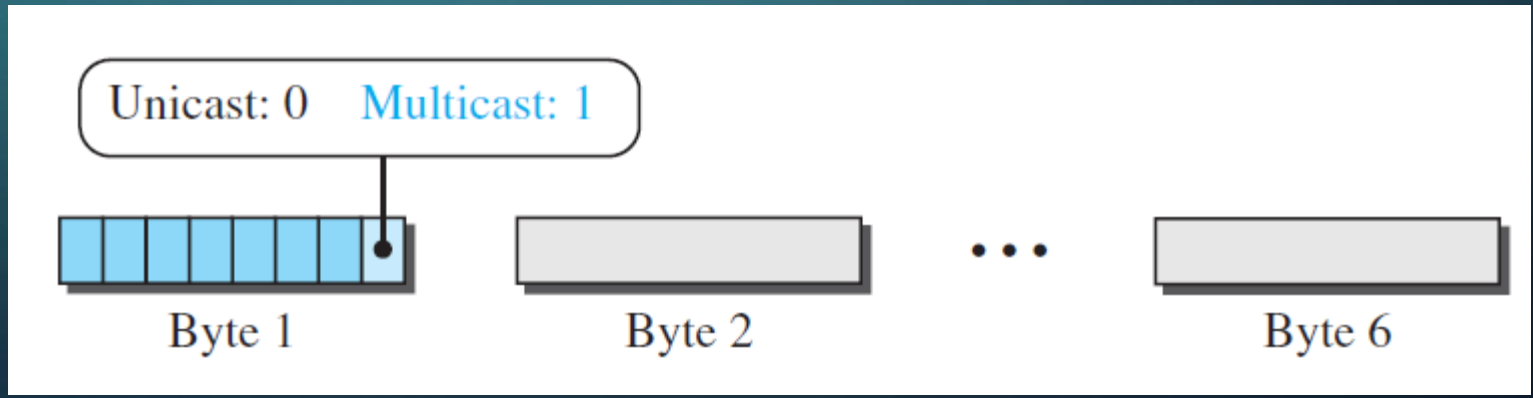
Show how the address 47:20:1B:2E:08:EE is sent out online.

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:

Hexadecimal	47	20	1B	2E	08	EE
Binarys	01000111	00100000	00011011	00101110	00001000	11101110
Transmitted ←	11100010	00000100	11011000	01110100	00010000	01110111

- If the LSB of the first byte in a destination address is 0, the address is unicast; otherwise, it is multicast. A broadcast destination address is forty-eight 1s.



PROBLEM

Define the type of the following destination addresses:

- 4A:30:10:21:10:1A
- 47:20:1B:2E:08:EE
- FF:FF:FF:FF:FF:FF

a. This is a unicast address because A in binary is 1010 (even).
b. This is a multicast address because 7 in binary is 0111 (odd).
c. This is a broadcast address because all digits are Fs in hexadecimal.

DISTINGUISH BETWEEN UNICAST, MULTICAST, AND BROADCAST TRANSMISSION

- Standard Ethernet **uses a coaxial cable** (bus topology) or a set of **twisted-pair cables** with a hub (star topology)
- Transmission in the standard Ethernet is always **broadcast**, no matter if the intention is unicast, multicast, or broadcast
- Bus topology: when station A sends a frame to station B, all stations will receive it. In the star topology, when station A sends a frame to station B, the hub will receive it.
- In a **unicast transmission**, all stations will receive the frame, the intended recipient keeps and handles the frame; the **rest discard it**.
- In a **multicast transmission**, all stations will receive the frame, the stations that are members of the group keep and handle it; **the rest discard it**.
- In a **broadcast transmission**, all stations (except the sender) will receive the frame and **all stations** (except the sender) **keep and handle** it.

ACCESS METHOD, EFFICIENCY

- The standard ethernet chose **CSMA/CD with 1-persistent method**
- The efficiency of the ethernet is defined as the **ratio of the time used by a station to send data to the time the medium is occupied by this station**.

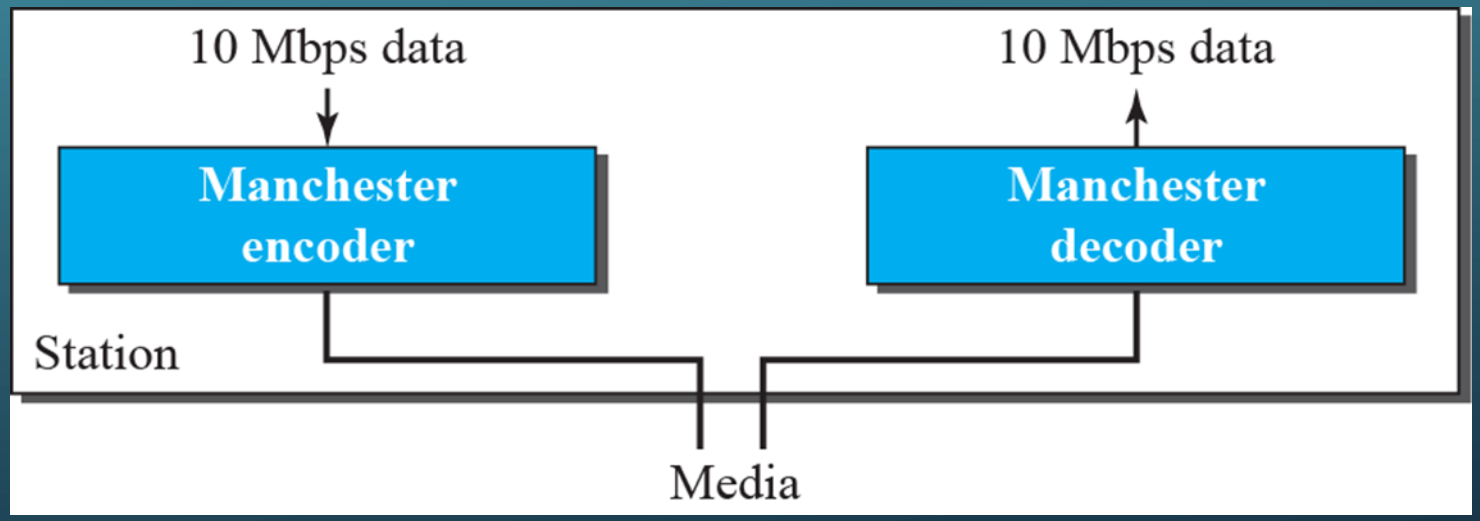
$$\text{Efficiency} = 1 / (1 + 6.4 \times a)$$

- Parameter "***a***" is the number of frames that can fit on the medium.
- It can be calculated as ***a*** = (propagation delay)/(transmission delay)
- If the length of the media is shorter or the frame size longer, the efficiency increases. In the ideal case, ***a*** = 0 and the efficiency is 1.

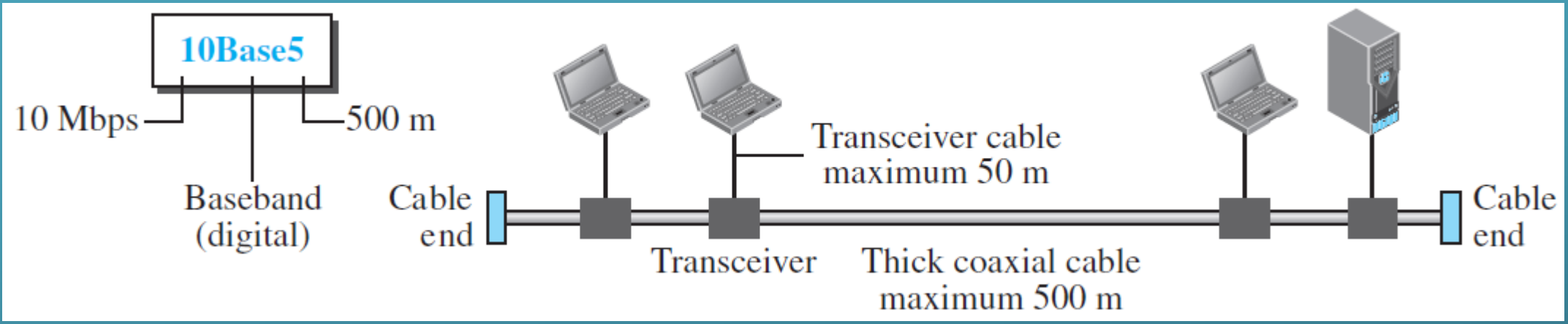
IMPLEMENTATION

Implementation	*Medium*	*Medium Length*	*Encoding*
10Base5	Thick coax	500 m	Manchester
10Base2	Thin coax	185 m	Manchester
10Base-T	2 UTP	100 m	Manchester
10Base-F	2 Fiber	2000	Manchester

Encoding and Decoding



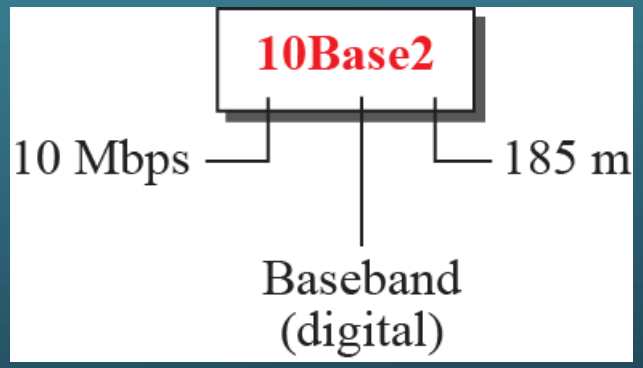
10BASE5: THICK ETHERNET

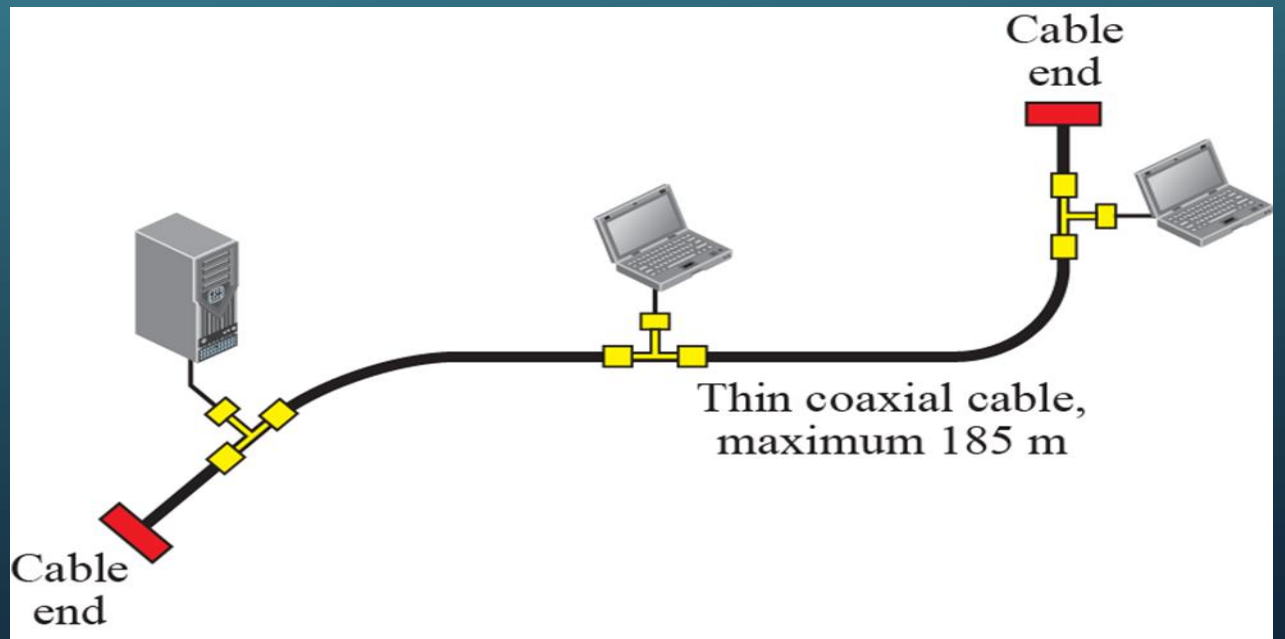


- Size of the cable is roughly the size of a garden hose and too stiff to bend with your hands.
- 10Base5 was the first Ethernet specification **to use a bus topology** with an external transceiver (transmitter/receiver) connected via a tap to a thick coaxial cable
- transceiver is responsible for **transmitting, receiving, and detecting collisions**.
- The transceiver is connected to the station via a transceiver cable that provides separate paths for sending and receiving. This means that collision can only happen in the coaxial cable
- use **repeaters when length > 500 m to avoid degradation**

10BASE2: THIN ETHERNET OR CHEAPERNET

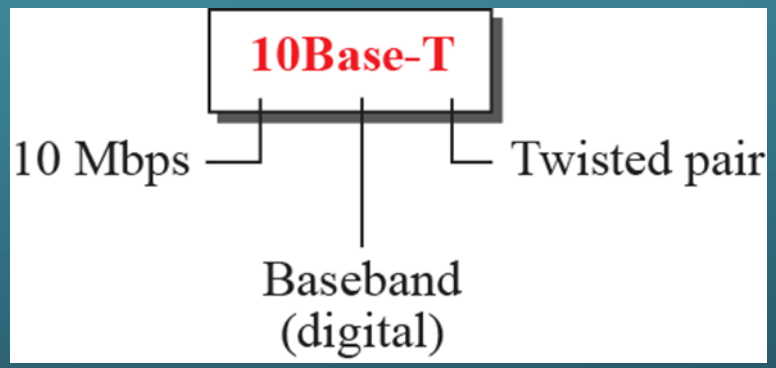
- also uses a bus topology, but the cable is much thinner and more flexible.
- The cable can be bent to pass very close to the stations.
- In this case, the transceiver is normally part of the network interface card (NIC), which is installed inside the station
- the tee connections are much cheaper than taps

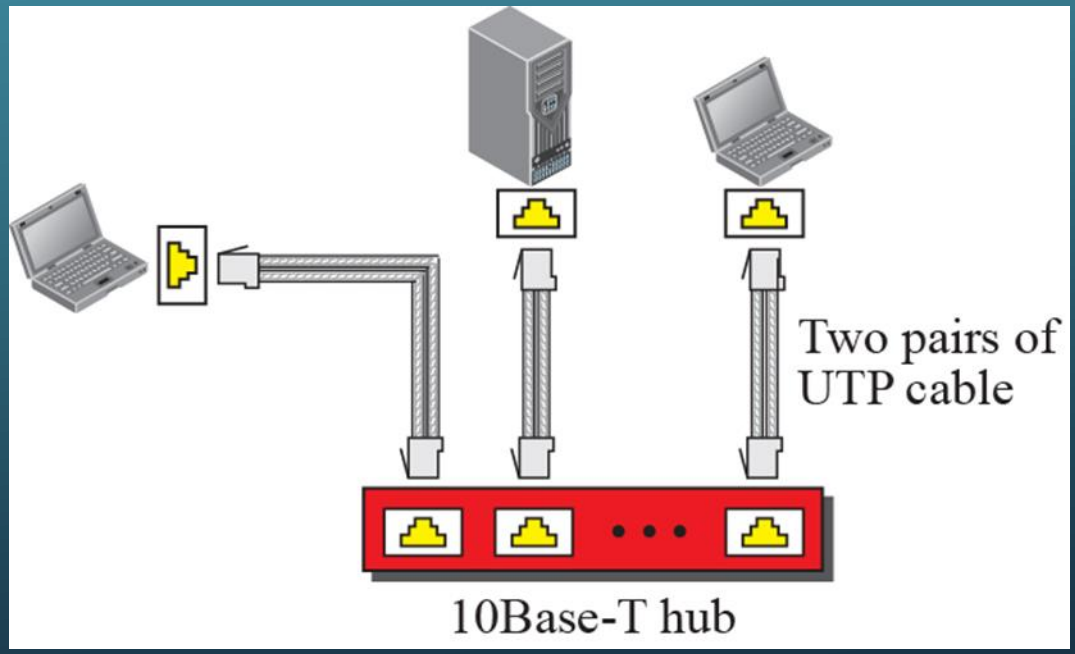




10BASE-T: TWISTED-PAIR ETHERNET

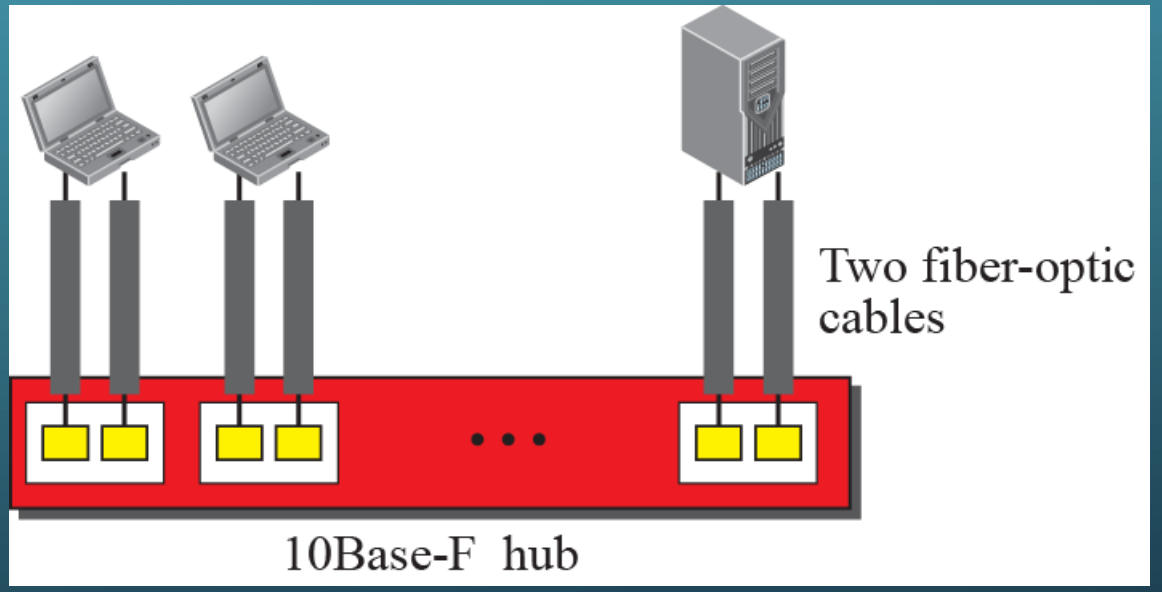
- Uses a **physical star topology**, stations are connected to a hub via two pairs of twisted cable.
- Any **collision here happens in the hub**
- The **maximum length** of the twisted cable :as **100 m, to minimize attenuation**

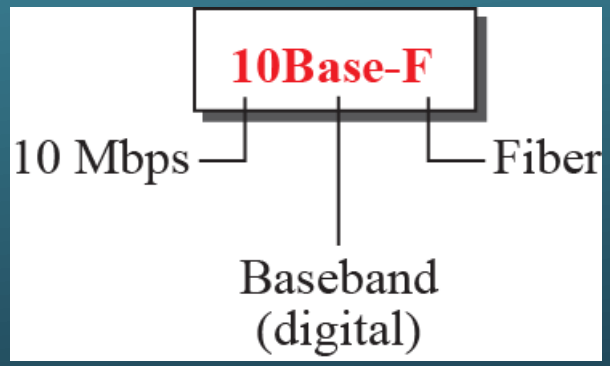




10BASE-F: FIBER ETHERNET

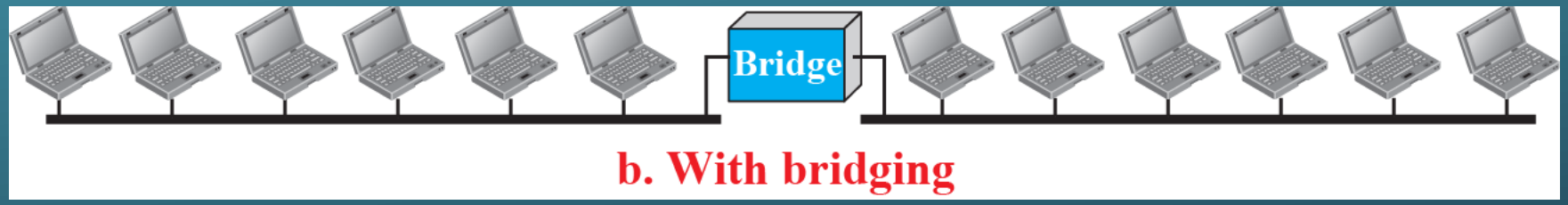
- uses a star topology to connect stations to a hub
- The stations are connected to the hub using two fiber-optic cables





CHANGES IN THE STANDARD: *BRIDGED ETHERNET*

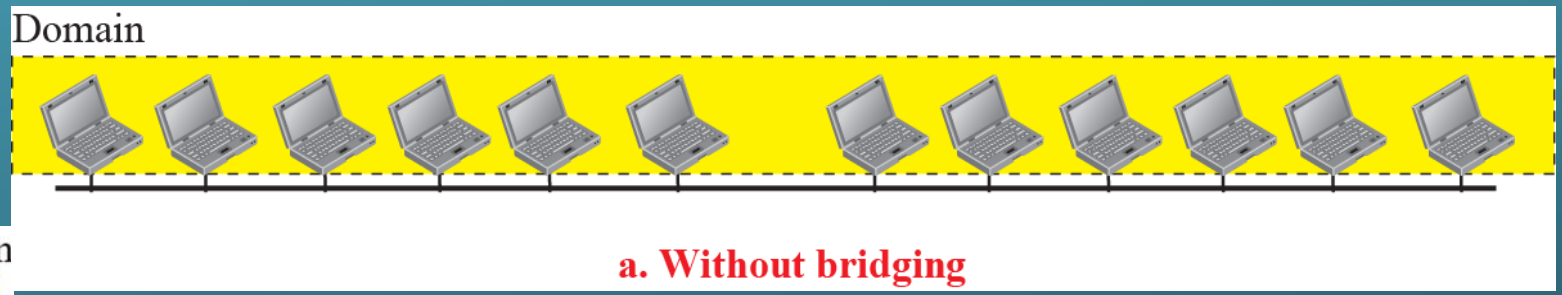
- division of a LAN by bridges.
- This has two effects : They raise the bandwidth and they separate collision domains



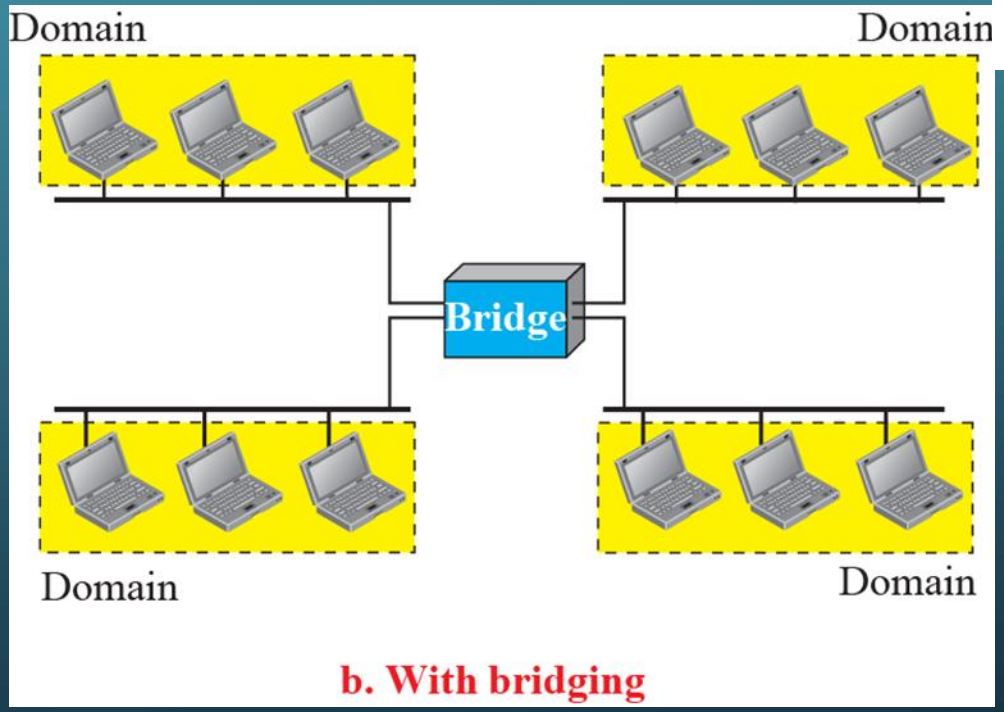
- network with 12 stations is divided into two networks, each with 6 stations.
- each network has a capacity of 10 Mbps.
- The 10-Mbps capacity in each segment is now shared between 6 stations

SEPARATING COLLISION DOMAINS

- **collision domain becomes much smaller** and the probability of collision is reduced
- Without bridging, 12 stations contend for access to the medium; with bridging only 3 stations contend for access to the medium.



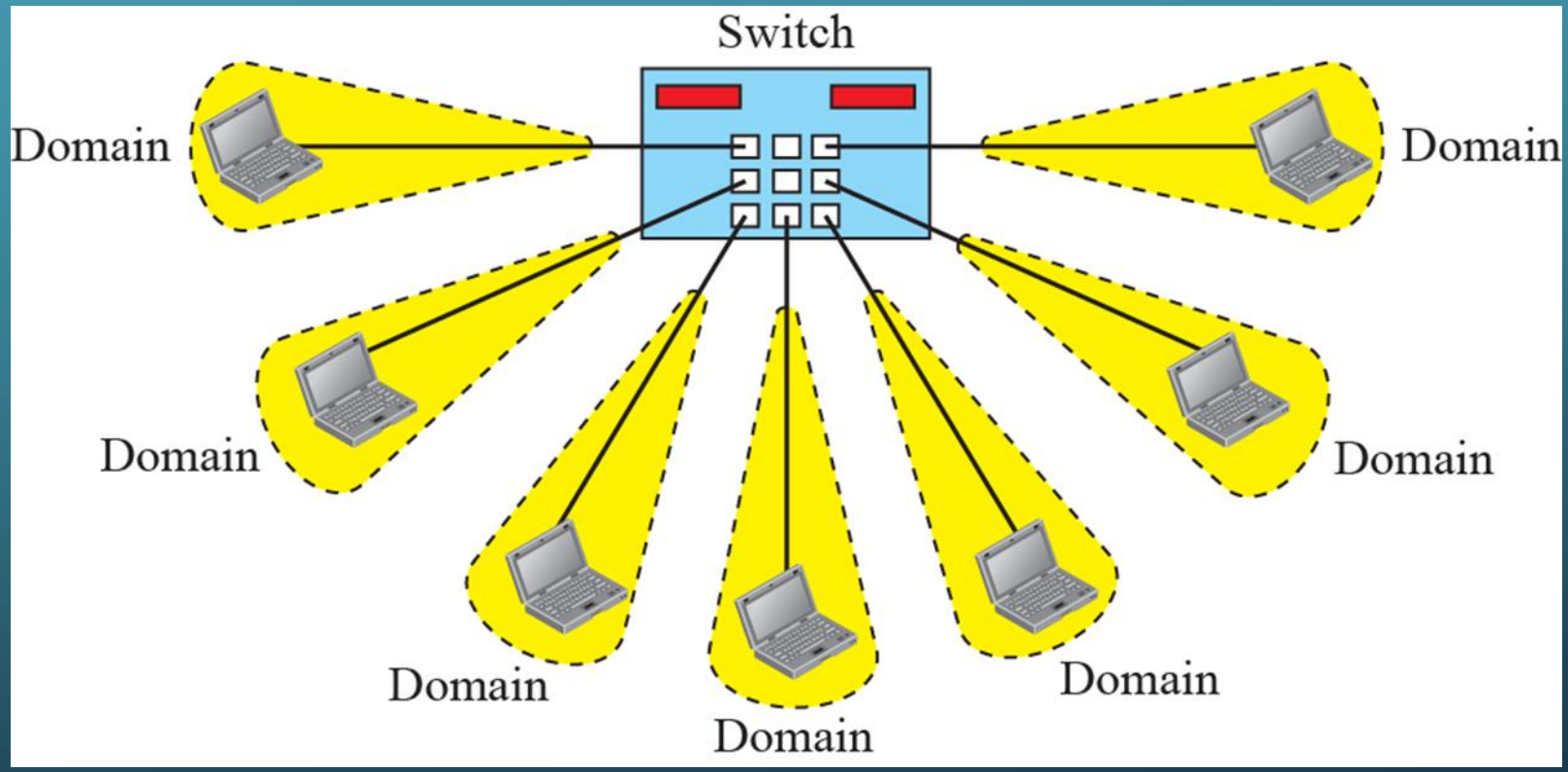
a. Without bridging



b. With bridging

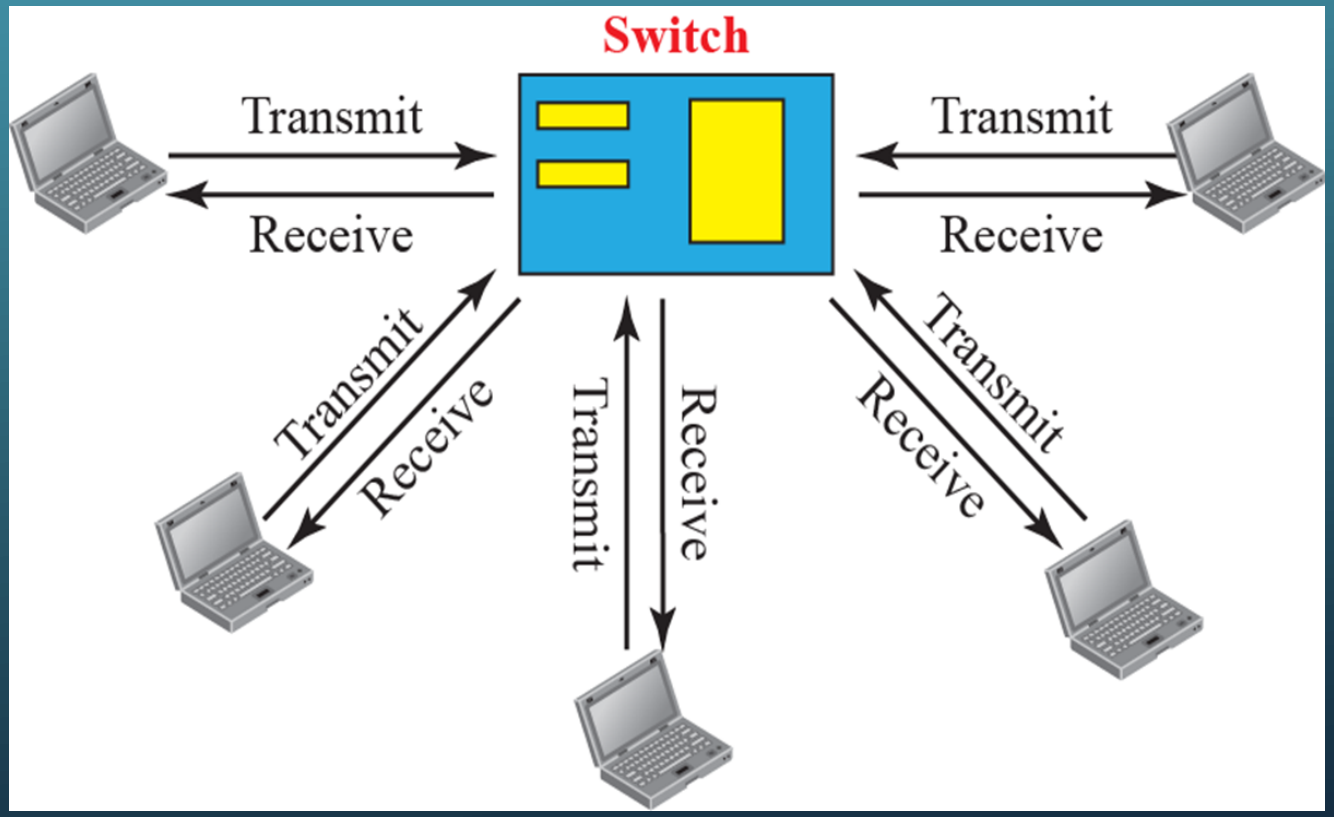
SWITCHED ETHERNET

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



FULL-DUPLEX ETHERNET

- Communication is **half-duplex in 10base5 and 10base2**
- **Switched ethernet is full-duplex** :the capacity of each domain from 10 to 20 mbps
- No need for the CSMA/CD



FAST ETHERNET (100 MBPS)

- MAC sublayer was left unchanged, →the frame format and the maximum and minimum size could also remain unchanged.
- By increasing the transmission rate, features of the Standard Ethernet that depend on the transmission rate, access method, and implementation had to be reconsidered.
- The goals of Fast Ethernet
  1. Upgrade the data rate to 100 Mbps.
  2. Make it compatible with Standard Ethernet.
  3. Keep the same 48-bit address.
  4. Keep the same frame format.

ACCESS METHOD

First solution

- Drop the bus topology and use a **passive hub and star topology**
- Make the **maximum size of the network 250 meters** instead of 2500 meters as in the standard ethernet.
- This approach is kept for compatibility with the standard ethernet.

Second solution

- Use a **link-layer switch--** has a buffer to **store frames and a full-duplex** connection to each host to make the transmission medium private for each host
- Shared medium is **changed to many point to- point media** → no need for contention.

AUTONEGOTIATION

- allows two devices to negotiate the mode or data rate of operation.
- It was designed particularly for these purposes:
  - To allow incompatible devices to connect to one another.
  - To allow one device to have multiple capabilities.
  - To allow a station to check a hub’s capabilities.

PHYSICAL LAYER

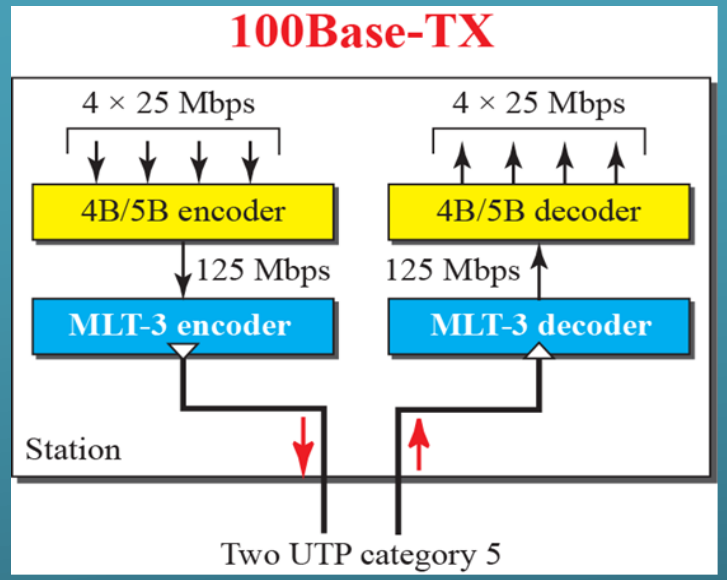
Topology

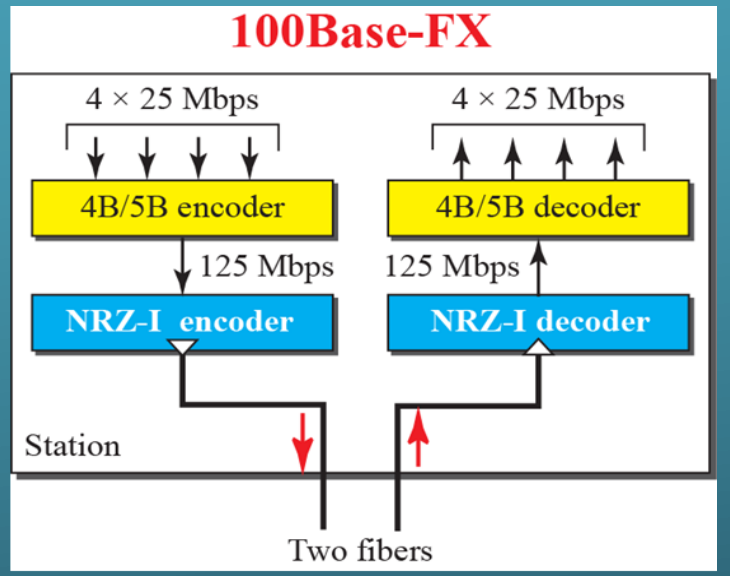
- designed to connect two or more stations.
- If there are only two stations → **point-to-point. Three or more** stations need to be connected in a **star topology with a hub or a switch**

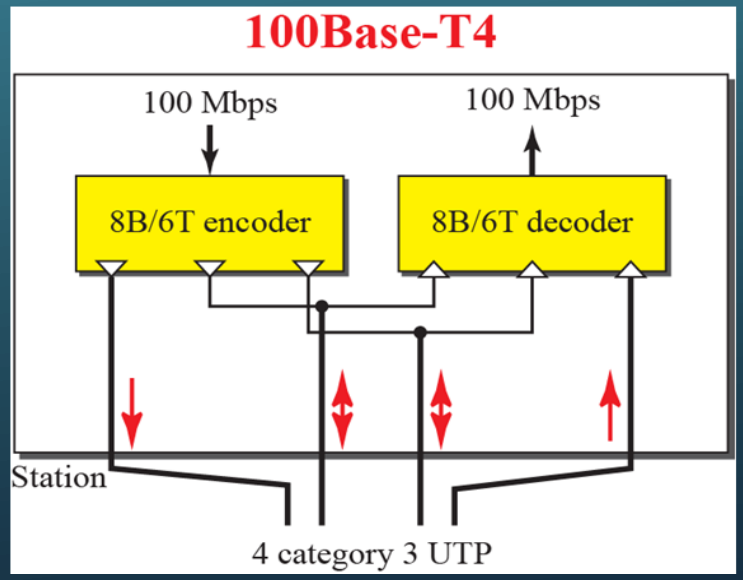
Encoding

- three different encoding schemes were chosen

ENCODING FOR FAST ETHERNET







100BASE-TX

- 100Base-TX uses two pairs of twisted-pair cable (either category 5 UTP or STP).
- **MLT-3 scheme** was selected since it has good bandwidth performance, **4B/5B block coding** is used to provide bit synchronization by preventing the occurrence of a long sequence of 0s and 1s.
- This creates a **data rate of 125 Mbps**, which is fed into MLT-3 for encoding

100BASE-FX

- 100Base-FX uses two pairs of **fiber-optic cables.**
- Optical fiber can easily **handle high bandwidth requirements** by using simple encoding schemes.
- **NRZ-I** encoding scheme
- Designers used **4B/5B block encoding**
- The block encoding increases the bit rate from 100 to 125 Mbps, which can easily be handled by fiber-optic cable.

100BASE-TX

- A 100Base-TX network can provide a data rate of 100 Mbps requires the use of category 5 UTP or STP cable.
- 100Base-T4, was designed to use **category 3 or higher UTP**.
- The implementation uses **four pairs of UTP** for transmitting 100 Mbps.
- Encoding/decoding in 100Base-T4 is more complicated.
- Uses only **(6/8) × 100 Mbps, or 75 Mbaud.**

Summary of Fast Ethernet

Implementation	*Medium*	*Medium Length*	*Wires*	*Encoding*
100Base-TX	STP	100 m	2	4B5B + MLT-3
100Base-FX	Fiber	185 m	2	4B5B + NRZ-I
100Base-T4	UTP	100 m	4	Two 8B/6T

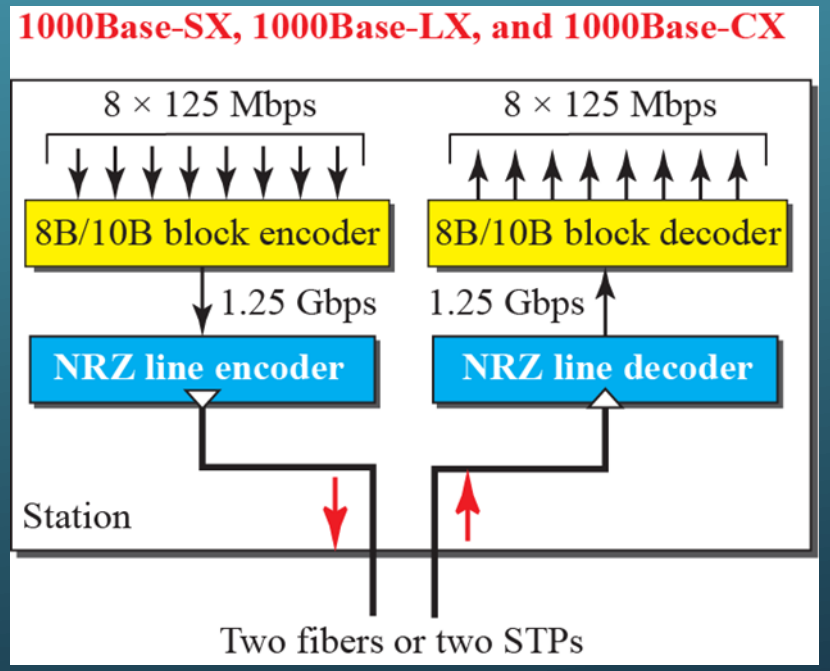
GIGABIT ETHERNET

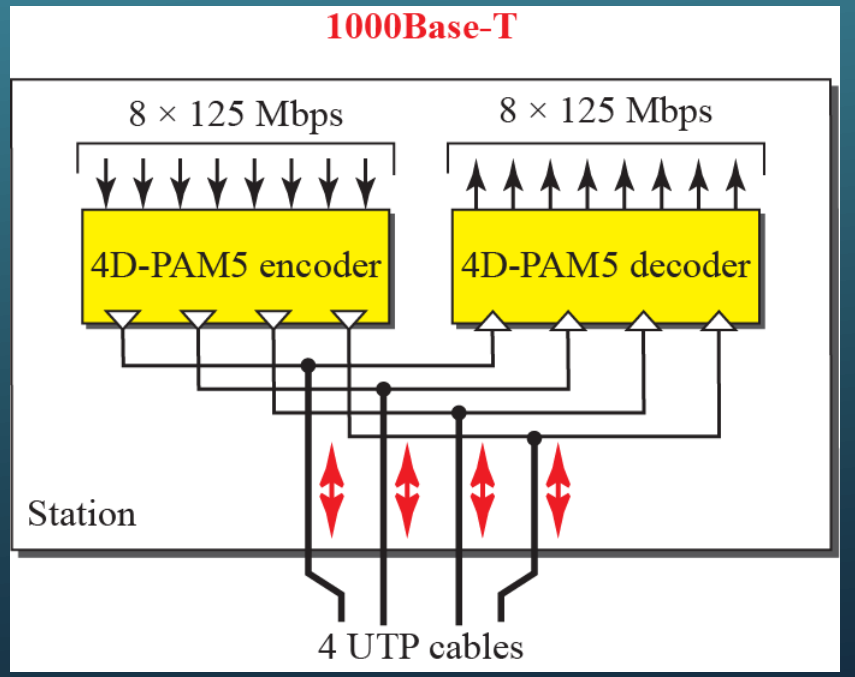
- IEEE committee calls it the Standard 802.3z
  1. Upgrade the data rate to 1 Gbps.
  2. Make it compatible with Standard or Fast Ethernet.
  3. Use the same 48-bit address.
  4. Use the same frame format.
  5. Keep the same minimum and maximum frame lengths.
  6. Support autonegotiation as defined in Fast Ethernet.
- Gigabit Ethernet follow the full-duplex approach→There is no collision;
- The maximum length of the cable is determined by the signal attenuation in the cable.

GIGABIT ETHERNET

- the minimum length of a frame as 512 bytes

Implementation	*Medium*	*Medium Length*	*Wires*	*Encoding*
1000Base-SX	Fiber S-W	550 m	2	8B/10B + NRZ
1000Base-LX	Fiber L-W	5000 m	2	8B/10B + NRZ
1000Base-CX	STP	25 m	2	8B/10B + NRZ
1000Base-T4	UTP	100 m	4	4D-PAM5





10 GIGABIT ETHERNET

Implementation	*Medium*	*Medium Length*	*Number of wires*	*Encoding*
10GBase-SR	Fiber 850 nm	300 m	2	64B66B
10GBase-LR	Fiber 1310 nm	10 Km	2	64B66B
10GBase-EW	Fiber 1350 nm	40 Km	2	SONET
10GBase-X4	Fiber 1310 nm	300 m to 10 Km	2	8B10B

SUMMARY

- Ethernet is the most widely used local area network protocol
- Common implementations of 10-Mbps Ethernet are 10Base5 (thick Ethernet), 10Base2 (thin Ethernet), 10Base-T (twisted-pair Ethernet), and 10Base-F (fiber Ethernet).
- Fast Ethernet has a data rate of 100 Mbps
- Gigabit Ethernet has a data rate of 1000 Mbps
- The latest Ethernet standard is 10 Gigabit Ethernet

TEST YOUR UNDERSTANDING

- Why is there no need for CSMA/CD on a full-duplex Ethernet LAN?
- How is the preamble field different from the SFD field?
- How does the Ethernet address 1A:2B:3C:4D:5E:6F appear on the line in binary?