Module 3

Local Area Networks - Ethernet

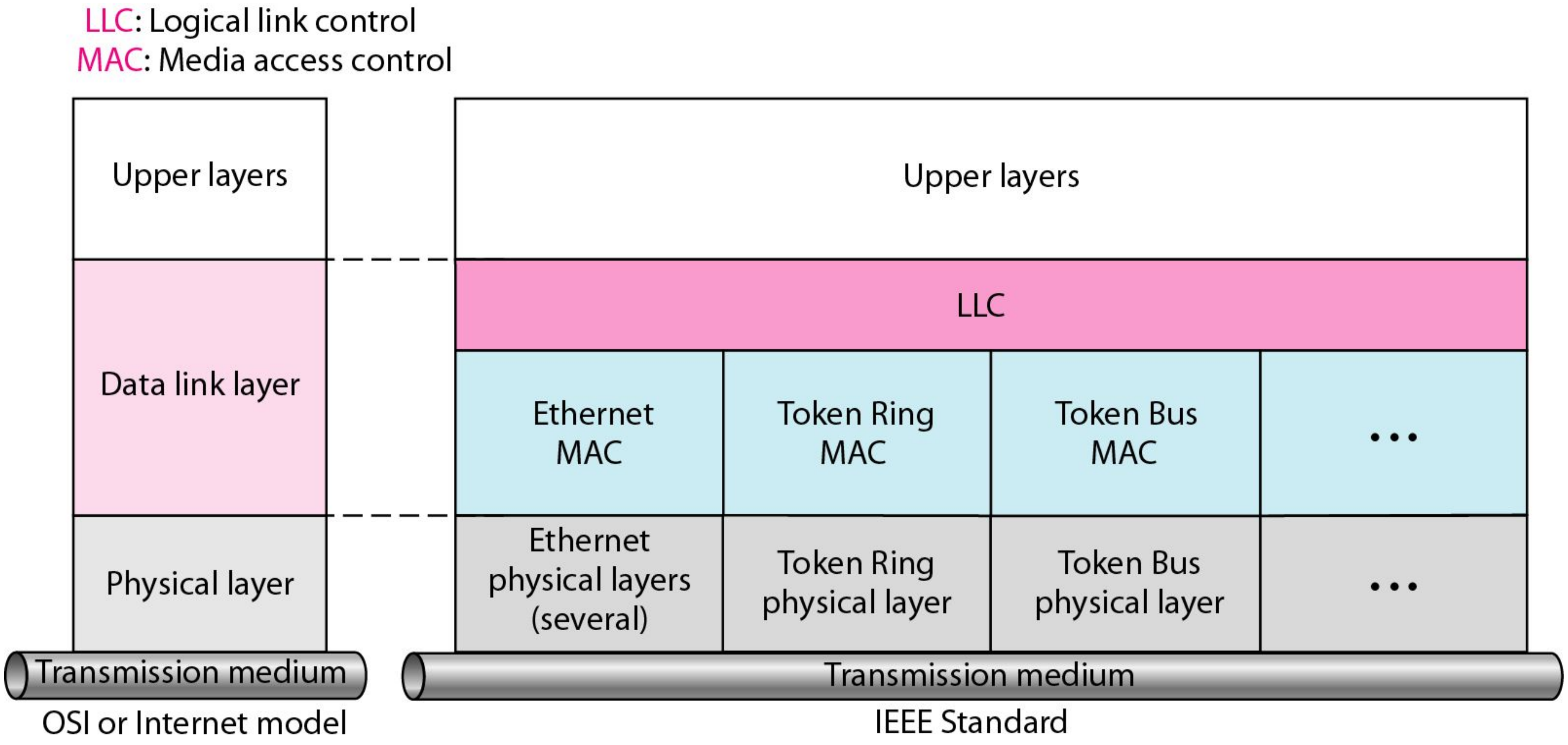
- A **local area network** (LAN) is a computer network that is designed for a limited geographic area such as a building or a campus.
- The LAN market has seen several technologies such as Ethernet, Token Ring, Token Bus, FDDI, and ATM LAN.

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.
- The standard was adopted by the American National Standards Institute (ANSI).
- In 1987, the International Organization for Standardization (ISO) also approved it as an international standard under the designation ISO 8802.

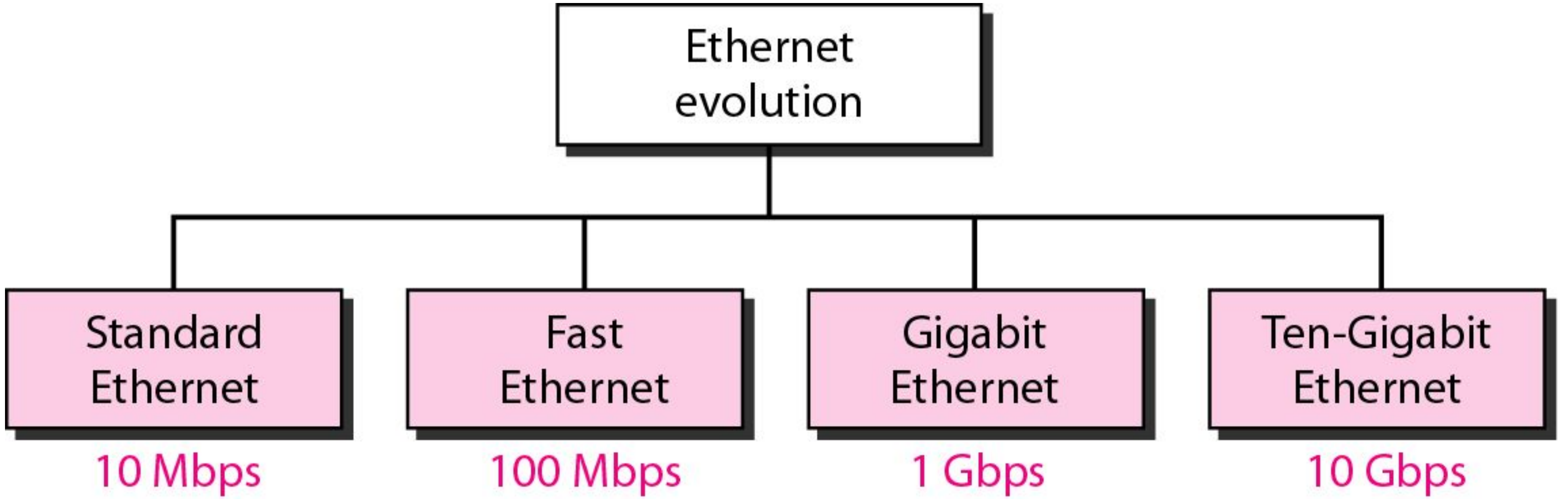
Relationship of the 802 Standard to the traditional OSI model

- The IEEE has subdivided the data link layer into two sublayers:
  - logical link control (LLC) and media access control (MAC).
- IEEE has also created several physical layer standards for different LAN protocols.



STANDARD ETHERNET

- The original Ethernet was created in 1976 at Xerox's Palo Alto Research Center (PARC).
- The 4 standards are:

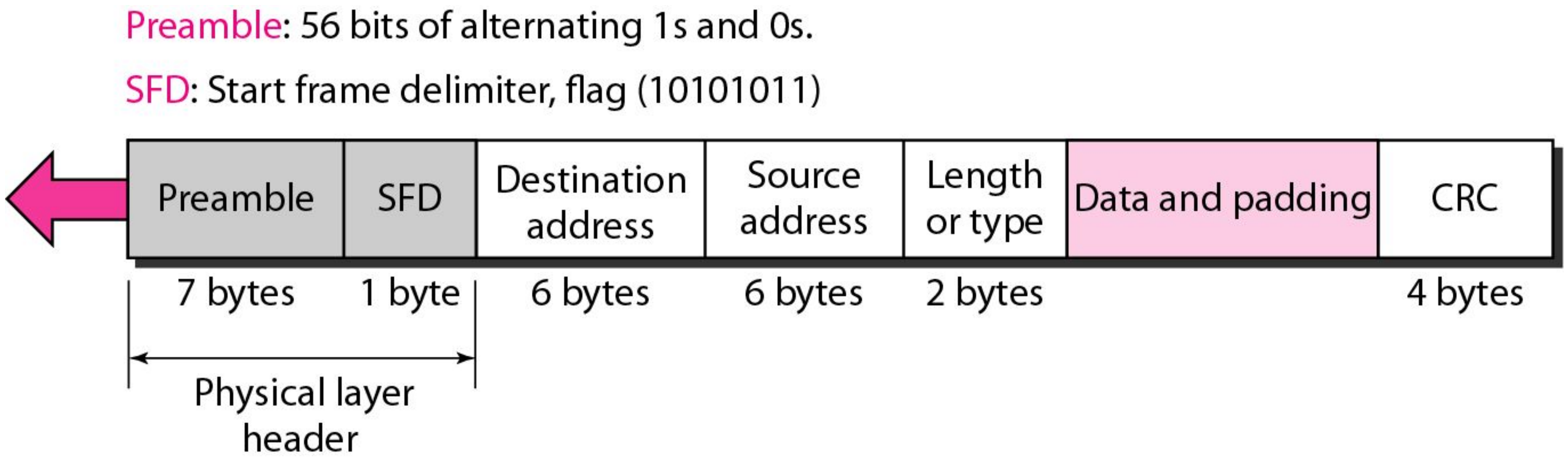


STANDARD ETHERNET

- In Standard Ethernet, the MAC sublayer governs the operation of the access method.
- It also frames data received from the upper layer and passes them to the physical layer.

Frame Format

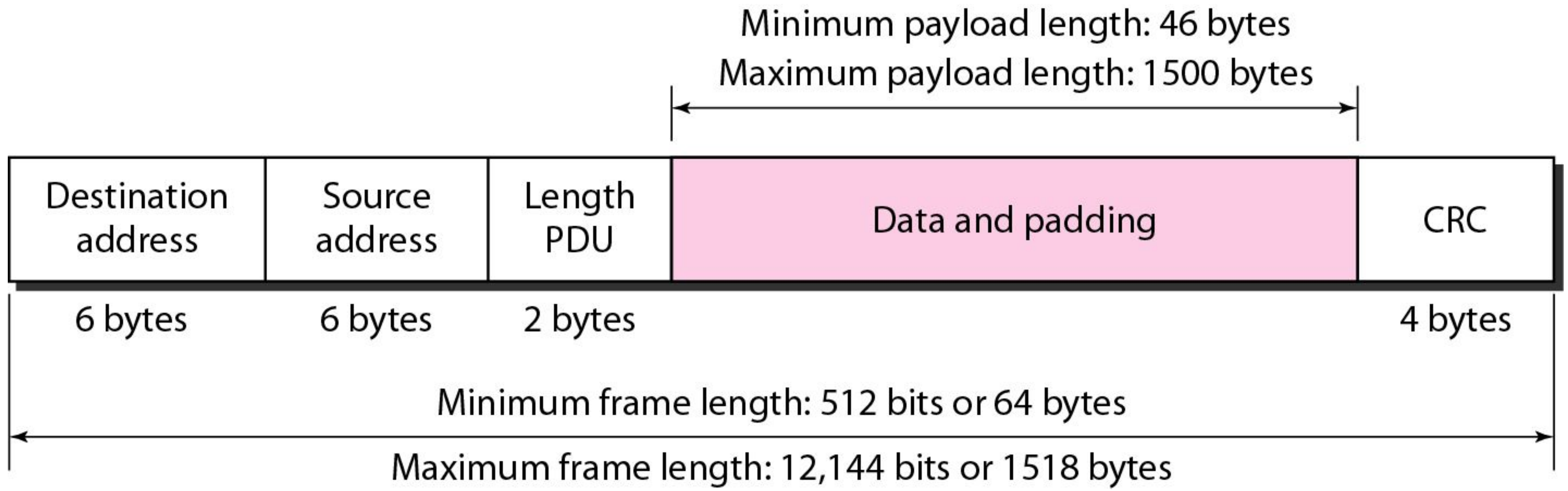
- The Ethernet frame contains seven fields:
  - preamble, SFD, DA, SA, length or type of protocol data unit (PDU), upper-layer data, and the CRC.
- Ethernet does not provide any mechanism for acknowledging received frames, making it what is known as an unreliable medium. Acknowledgments must be implemented at the higher layers.



- **Preamble:** The first field of the 802.3 frame contains **7 bytes (56 bits) of alternating 0s and 1s** that alerts the receiving system to the coming frame and enables it to synchronize its input timing. The pattern provides only an alert and a timing pulse. The preamble is actually added at the physical layer and is not (formally) part of the frame.
- **Start frame delimiter (SFD):** The second field (**1 byte: 10101011**) signals the beginning of the frame. The SFD warns the station or stations that this is the last chance for synchronization. The **last 2 bits is 11** and alerts the receiver that the next field is the **destination address**.
- **Destination address (DA):** The DA field is **6 bytes** and contains the physical address of the destination station or stations to receive the packet.
- **Source address (SA):** The SA field is also **6 bytes** and contains the physical address of the sender of the packet.
- **Length or type:** This field is defined as a type field or length field. The original Ethernet used this field as the type field to define the upper-layer protocol using the MAC frame. The IEEE standard used it as the length field to define the number of bytes in the data field.
- **Data:** This field carries data encapsulated from the upper-layer protocols. It is a **minimum of 46 and a maximum of 1500 bytes**.
- **CRC:** The last field contains error detection information, in this case a CRC-32.

Frame length

- The minimum length restriction is required for the correct operation of *CSMA/CD*
- An Ethernet frame needs to have **a minimum length of 512 bits or 64 bytes**. Part of this length is the header and the trailer. If we count 18 bytes of header and trailer (6 bytes of source address, 6 bytes of destination address, 2 bytes of length or type, and 4 bytes of CRC), then the minimum length of data from the upper layer is 64 - 18 = 46 bytes. If the upper-layer packet is less than 46 bytes, padding is added to make up the difference.
- The standard defines the **maximum length of a frame** (without preamble and SFD field) as **1518 bytes**. If we subtract the 18 bytes of header and trailer, the maximum length of the payload is 1500 bytes.



Note

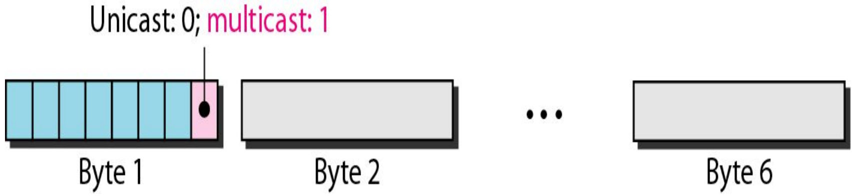
Frame length:

Minimum: 64 bytes (512 bits)

Maximum: 1518 bytes (12,144 bits)

Addressing

- Each station on an **Ethernet network** (such as a PC, workstation, or printer) has its own **network interface card** (NIC). The NIC fits inside the station and provides the station with a **6-byte physical address**.
- The Ethernet address is 6 bytes (48 bits), normally written in hexadecimal notation, with a colon between the bytes.



Unicast, Multicast, and Broadcast Addresses

- A **source address** is always a **unicast address**-the frame comes from only one station. The destination address, however, can be unicast, multicast, or broadcast. If the **least significant bit of the first byte** in a **destination address** is **0,** the address is **unicast**; otherwise, it is **multicast**.
- A **unicast destination address defines only one recipient**; the relationship between the **sender and the receiver is one-to-one**.
- A **multicast destination address** defines a **group of addresses**; the relationship between the sender and the receivers is **one-to-many**.
- The broadcast address is a special case of the multicast address; the recipients are all the stations on the LAN. A **broadcast destination address is forty-eight 1s**.

Note

**The least significant bit of the first byte defines the type of address.
If the bit is 0, the address is unicast; otherwise, it is multicast.**

Note

The broadcast destination address is a special case of the multicast address in which all bits are 1s.

Example

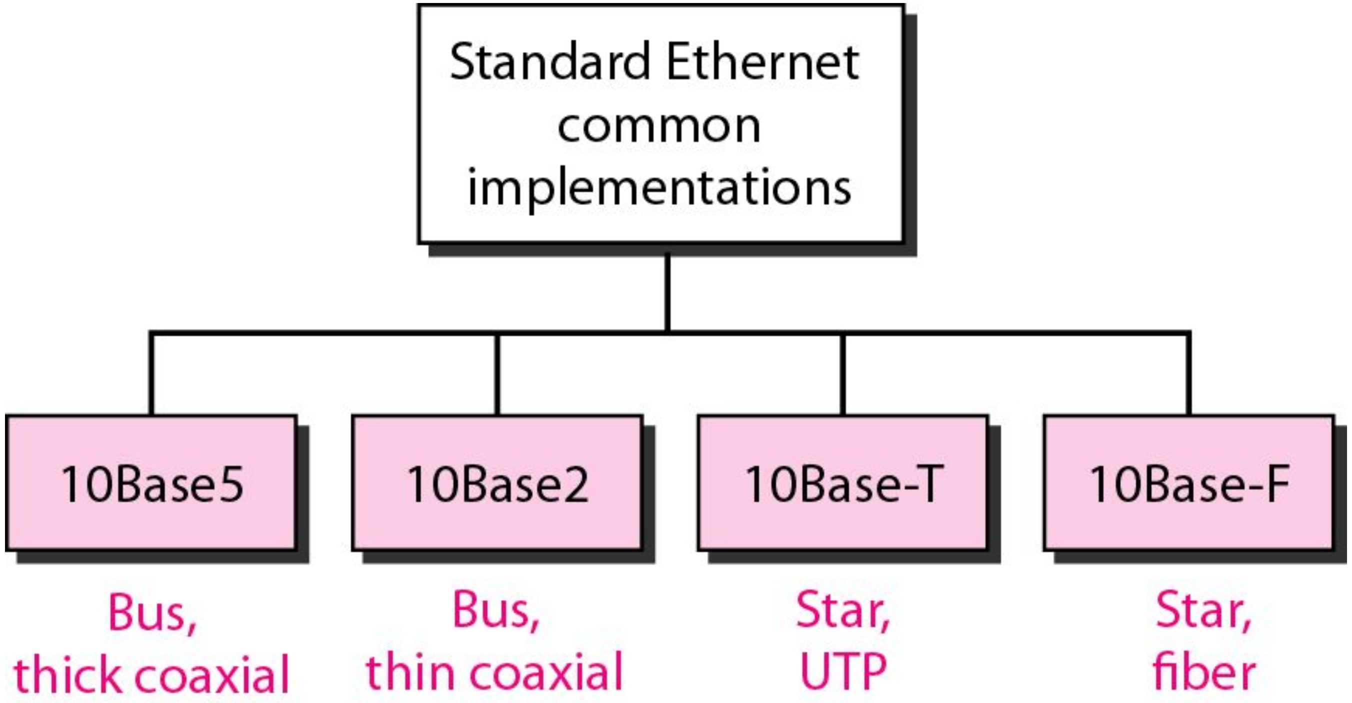
Define the type of the following destination addresses:

a. 4A:30:10:21:10:1A

b. 47:20:1B:2E:08:ED

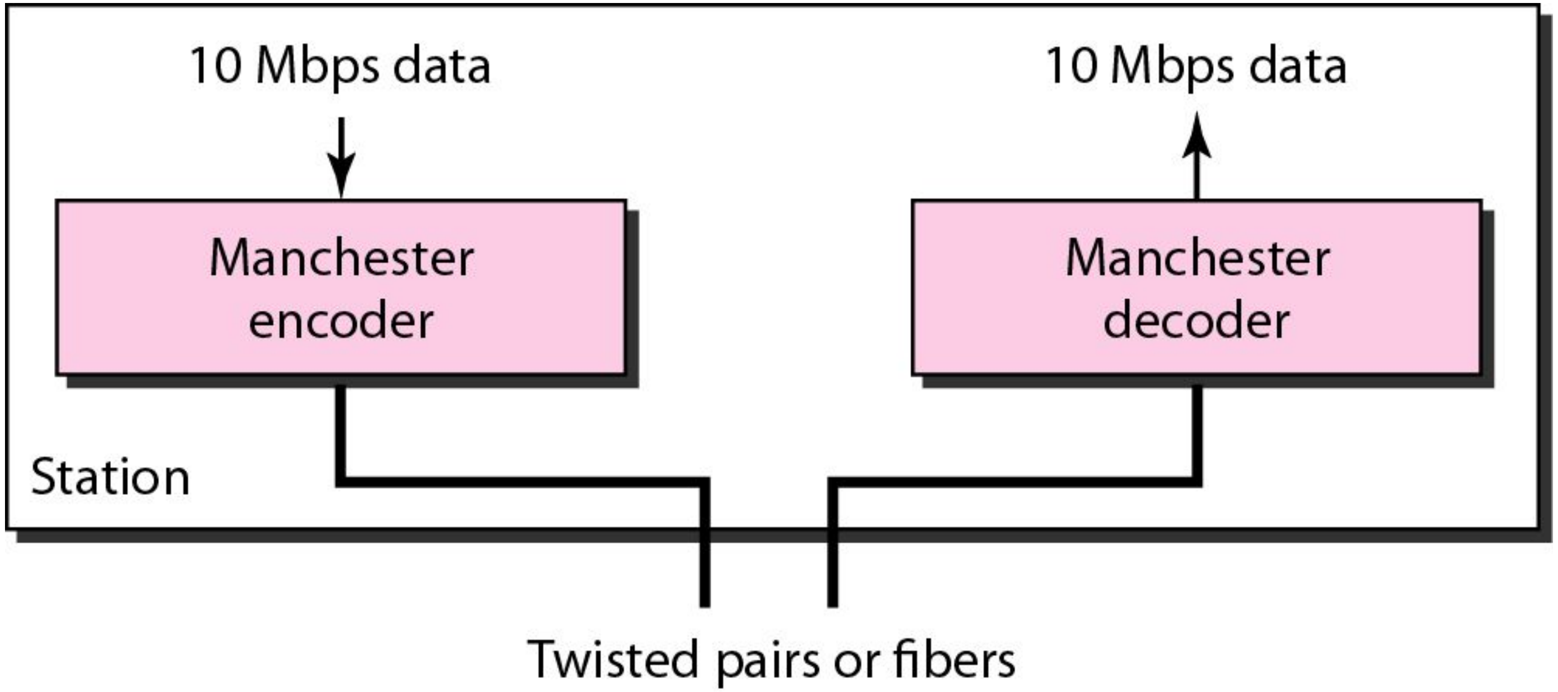
c. FF:FF:FF:FF:FF:FF

Categories of Standard Ethernet



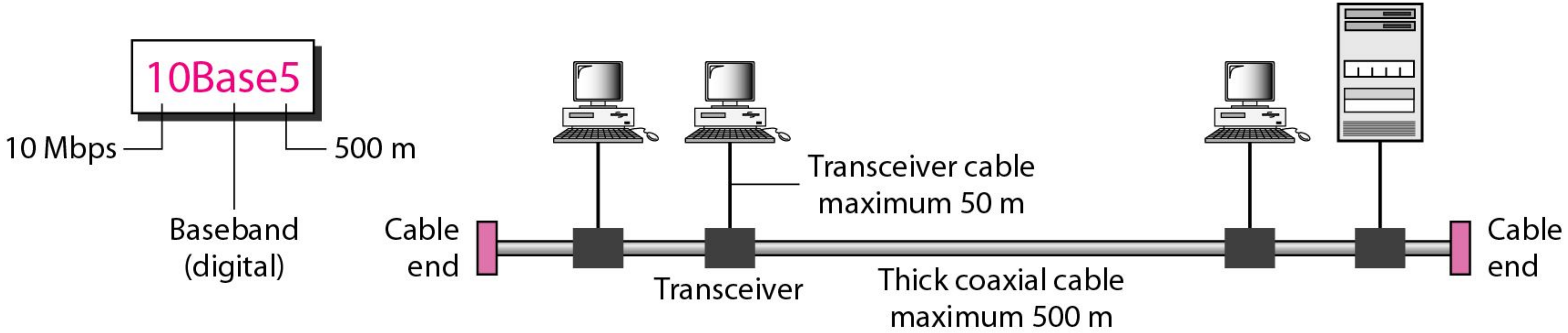
Encoding and Decoding

- All standard implementations use digital signaling (baseband) at 10 Mbps.
- At the sender, data are converted to a digital signal using the Manchester scheme; at the receiver, the received signal is interpreted as Manchester and decoded into data.
- Manchester encoding is self-synchronous, providing a transition at each bit interval.



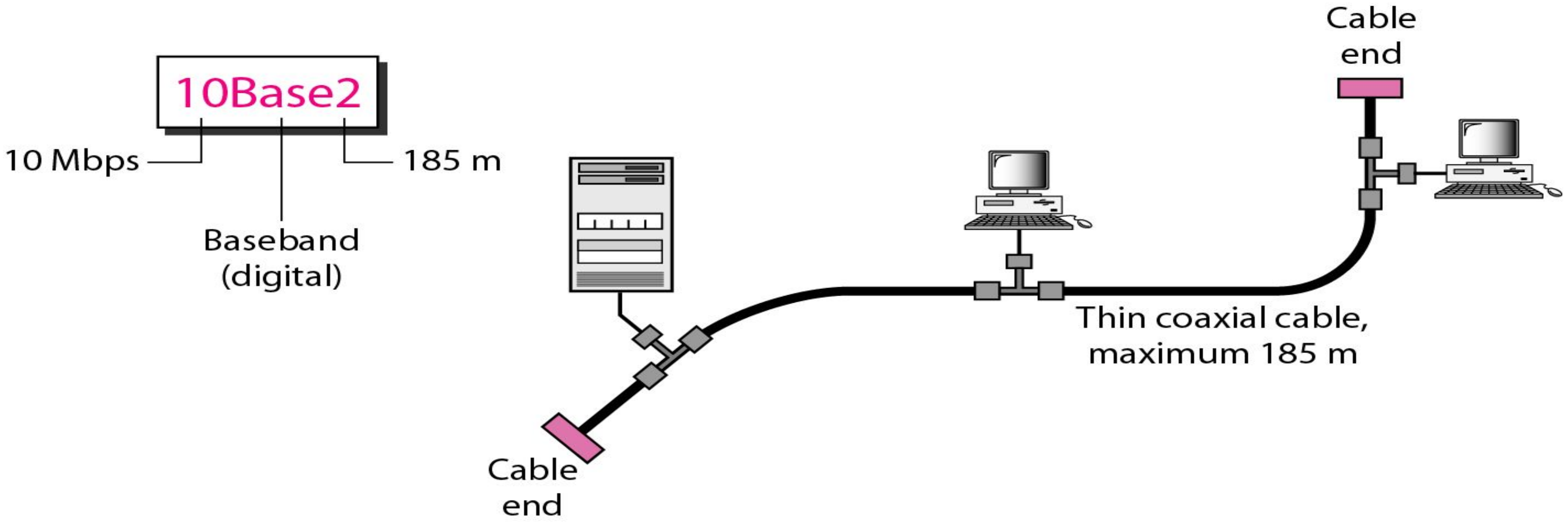
10Base5: Thick Ethernet

- The first implementation is called **10Base5, thick Ethernet, or Thicknet.**
- The nickname derives from the size of the cable, which 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.
- The **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.
- The **maximum length of the coaxial cable must not exceed 500** m, otherwise, there is excessive degradation of the signal. If a length of more than 500 m is needed, up to five segments, each a maximum of 500 meter, can be connected using repeaters.



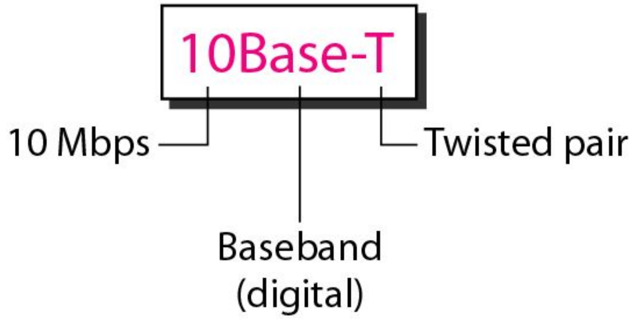
10Base2: Thin Ethernet

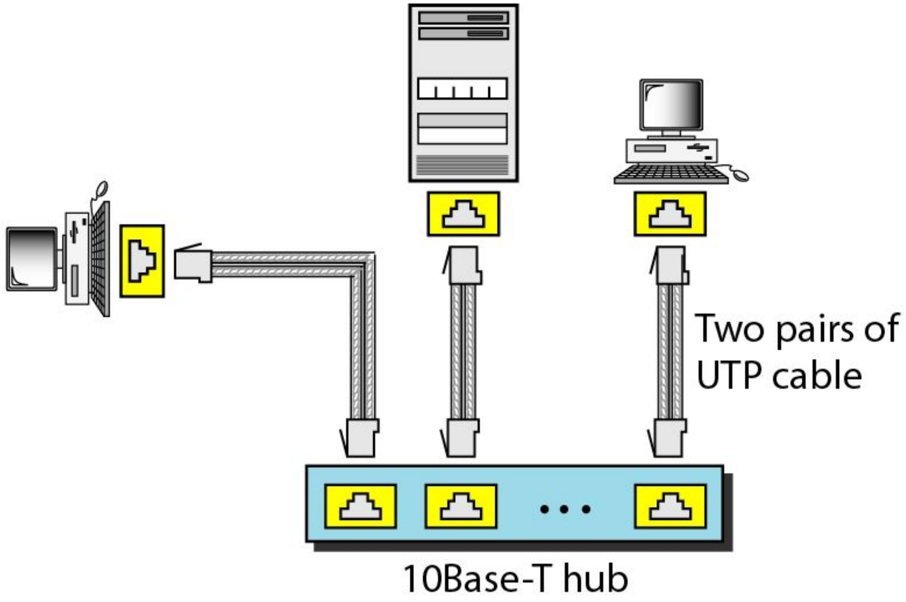
- The second implementation is called 10Base2, thin Ethernet, or Cheapernet.
- 10Base2 also uses a bus topology, but the cable is much thinner and more flexible.
- The cable can be bent to pass very close to the stations. In this case, the transceiver is normally part of the network interface card (NIC), which is installed inside the station.
- The collision occurs in the thin coaxial cable.
- This implementation is more cost effective than 10Base5 because thin coaxial cable is less expensive than thick coaxial and the tee connections are much cheaper than taps.
- Installation is simpler because the thin coaxial cable is very flexible.
- The **length of each segment cannot exceed *185* m** (close to 200 m) due to the high level of **attenuation** in thin coaxial cable.



10Base-T: Twisted-Pair Ethernet

- The third implementation is called 10Base-T or twisted-pair Ethernet.
- 10Base-T uses a physical **star topology**.
- The stations are connected to a hub via **two pairs of twisted cable**. Note that two pairs of twisted cable create two paths (one for sending and one for receiving) between the station and the hub. Any **collision here happens in the hub**.
- Compared to 10Base5 or 10Base2, the hub actually replaces the coaxial cable as far as a collision is concerned.
- The **maximum length of the twisted cable is 100 m**, to minimize the effect of attenuation in the twisted cable.





10Base-F: Fiber Ethernet

- 10Base-F uses a star topology to connect stations to a hub.
- The stations are connected to the hub using two fiber-optic cables.

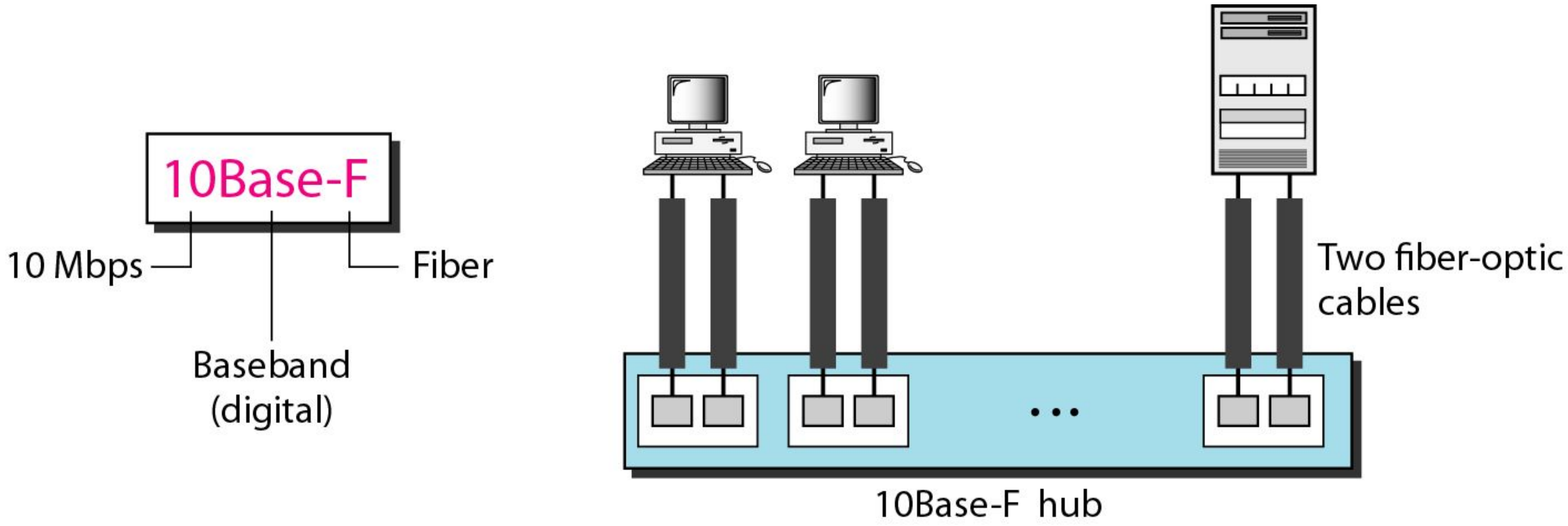
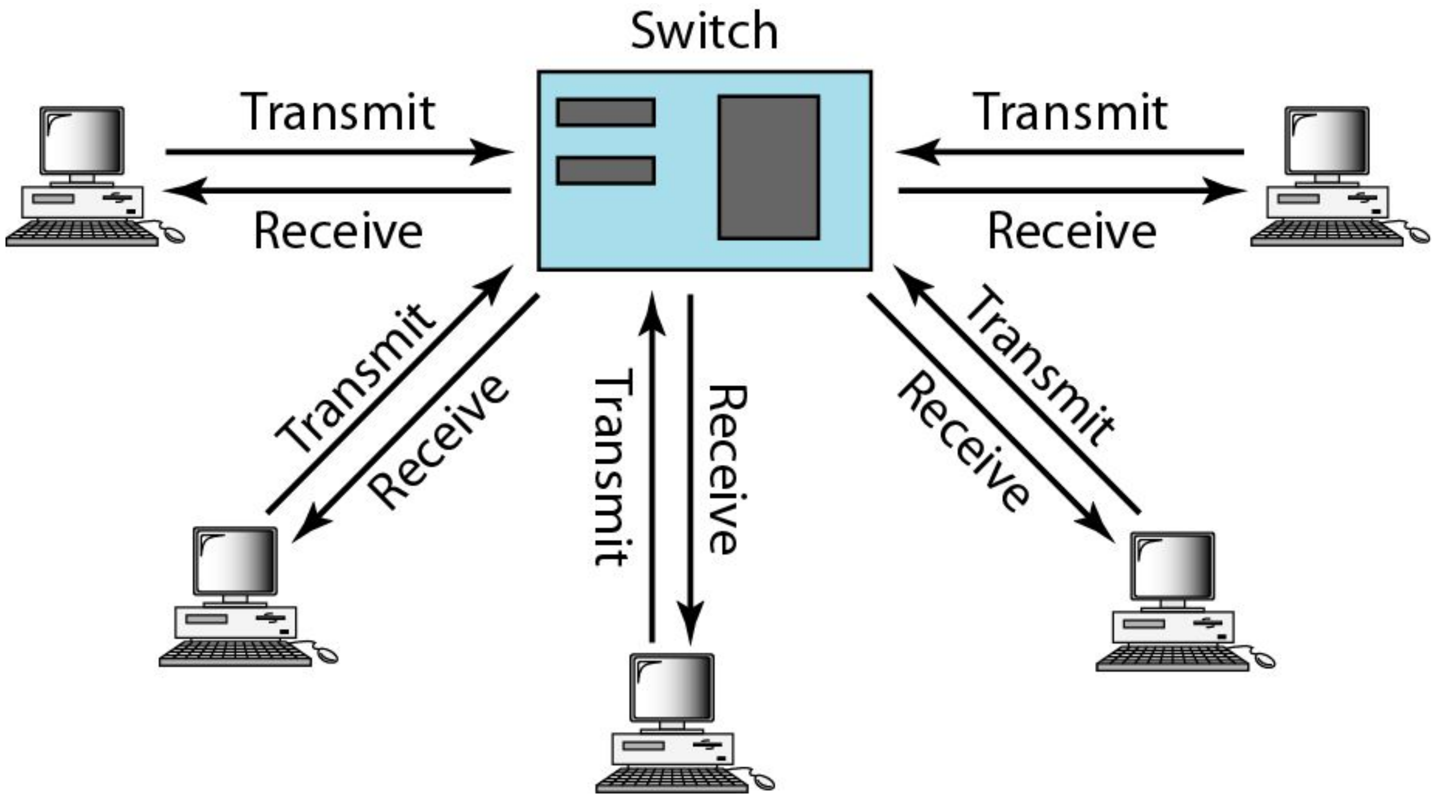


Table 13.1 ***Summary of Standard Ethernet implementations***

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

Full-duplex switched Ethernet

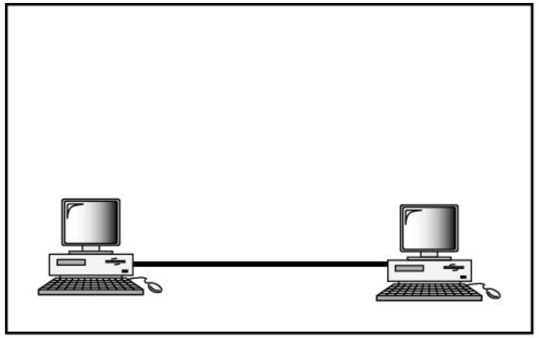


FAST ETHERNET

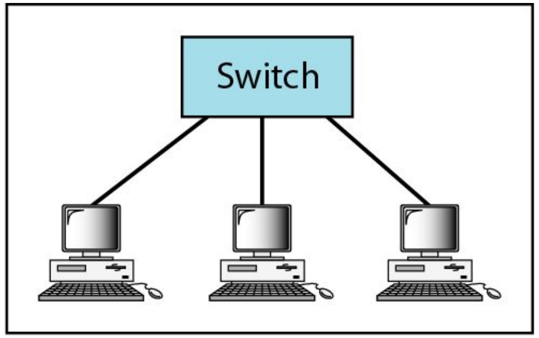
- Fast Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel.
- IEEE created Fast Ethernet under the name 802.3u.
- Fast Ethernet is backward-compatible with Standard Ethernet, but it can transmit data 10 times faster at a rate of 100 Mbps.
- The goals of Fast Ethernet can be summarized as follows:

  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.
  5. Keep the same minimum and maximum frame lengths.

- A decision was made to drop the bus topologies and keep only the star topology. For the **star topology**, there are two approaches**: half duplex and full duplex**.
- In the **half-duplex approach**, the stations are connected via a **hub**.
- In the **full-duplex approach**, the connection is made via a **switch** with buffers at each port.
- A new feature added to Fast Ethernet is called **auto negotiation**. It allows a station or a hub a range of capabilities.
- **Auto negotiation** allows two devices to **negotiate the mode or data rate of operation**. It was designed particularly for the following purposes:
  - To allow **incompatible devices to connect to one another**. For example, a device with a maximum capacity of 10 Mbps can communicate with a device with a 100 Mbps capacity (but can work at a lower rate).
  - To **allow one device to have multiple capabilities**.
  - To **allow a station to check a hub's capabilities**.
- Fast Ethernet is designed to connect two or more stations together. If there are only two stations, they can be connected **point-to-point.** Three or more stations need to be connected in a star topology with a hub or a switch at the center.



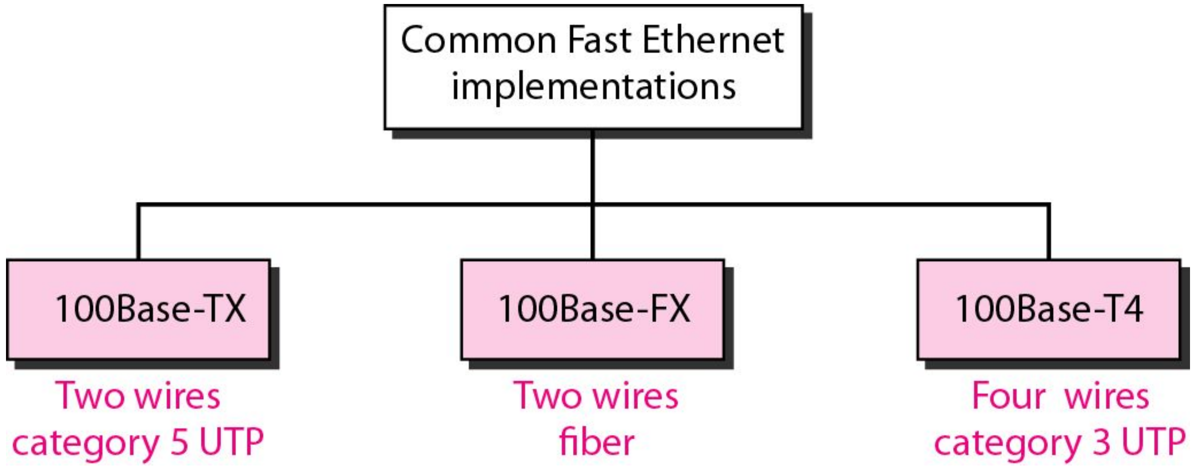
a. Point-to-point



b. Star

Fast Ethernet implementations

- Fast Ethernet implementation at the physical layer can be categorized as either two-wire or four-wire.
- The two-wire implementation can be either category 5 UTP (100Base-TX) or fiber-optic cable (100Base-FX).
- The four-wire implementation is designed only for category 3 UTP (l00Base-T4).



- **100Base-TX** uses two pairs of twisted-pair cable (either category 5 UTP or STP).
- **100Base-FX** uses two pairs of fiber-optic cables. Optical fiber can easily handle high bandwidth requirements by using simple encoding schemes. The designers of 100Base-FX selected the NRZ-I encoding scheme for this implementation. However,
- NRZ-I has a bit synchronization problem for long sequences of Os (or Is, based on the
- encoding. To overcome this problem, the designers used 4B/5B encoding.
- A new standard, called **100Base-T4,** was designed to use category 3 or higher UTP. The implementation uses four pairs of UTP for transmitting 100 Mbps.

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

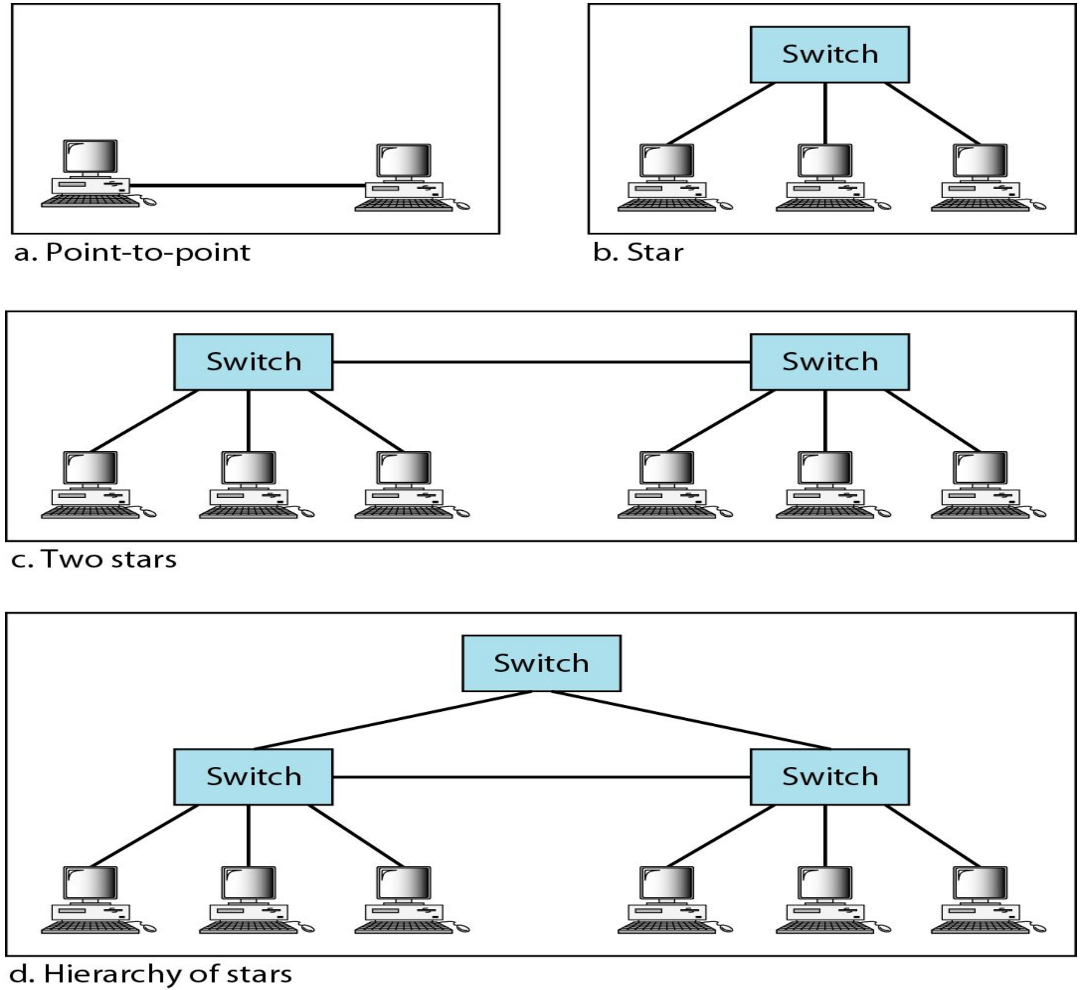
GIGABIT ETHERNET

- 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.
- The goals of the Gigabit Ethernet design can be summarized as follows:
  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. To support auto negotiation as defined in Fast Ethernet.

- Gigabit Ethernet has two distinctive approaches for medium access: half-duplex and full-duplex.
- In full-duplex mode, there is a central switch connected to all computers or other switches. In this mode, each switch has buffers for each input port in which data are stored until they are transmitted. There is no collision in this mode.
- In half-duplex mode, a switch can be replaced by a hub, which acts as the common cable in which a collision might occur. The half-duplex approach uses *CSMAlCD.*

- Three methods have been defined: traditional, carrier extension, and frame bursting.
- **Traditional:** In the traditional approach, we keep the minimum length of the frame as in traditional Ethernet (512 bits). The reduced slot time means that collision is detected 100 times earlier. This means that the maximum length of the network is 25 m. This length may be suitable if all the stations are in one room, but it may not even be long enough to connect the computers in one single office.
- **Carrier Extension:** To allow for a longer network, we increase the minimum frame length. The carrier extension approach defines the minimum length of a frame as 512 bytes (4096 bits). This means that the minimum length is 8 times longer. This method forces a station to add extension bits (padding) to any frame that is less than 4096 bits. In this way, the maximum length of the network can be increased 8 times to a length of 200 m. This allows a length of 100 m from the hub to the station.
- **Frame Bursting:** Carrier extension is very inefficient if we have a series of short frames to send; each frame carries redundant data. To improve efficiency, frame bursting was proposed. Instead of adding an extension to each frame, multiple frames are sent. However, to make these multiple frames look like one frame, padding is added between the frames (the same as that used for the carrier extension method) so that the channel is not idle. In other words, the method deceives other stations into thinking that a very large frame has been transmitted.

- Gigabit Ethernet is designed to connect two or more stations. If there are only two stations, they can be connected point-to-point. Three or more stations need to be connected in a star topology with a hub or a switch at the center. Another possible configuration is to connect several star topologies or let a star topology be part of another.



Implementation

- Gigabit Ethernet can be categorized as either a two-wire or a four-wire implementation.
- The two-wire implementations use fiber-optic cable (1000Base-SX, short-wave, or 1000Base-LX, long-wave), or STP (1000Base-CX).
- The four-wire version uses category 5 twisted-pair cable (1000Base-T).
- 1000Base-T was designed in response to those users who had already installed this wiring for other purposes such as Fast Ethernet or telephone services.

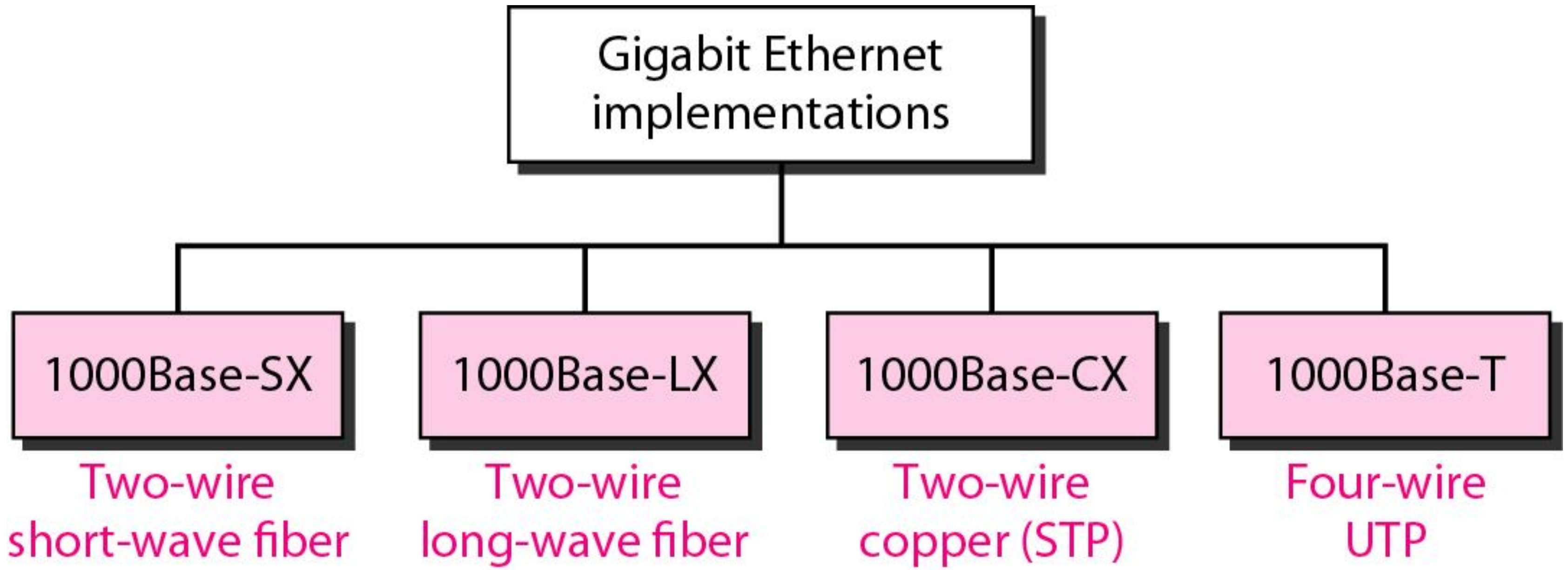


Table 13.3 *Summary of Gigabit Ethernet implementations*

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

Ten-Gigabit Ethernet

- The IEEE committee created Ten-Gigabit Ethernet and called it **Standard 802.3ae**.
- The goals of the Ten-Gigabit Ethernet design can be summarized as follows:
  - Upgrade the data rate to 10 Gbps.
  - Make it compatible with Standard, Fast, and Gigabit Ethernet.
  - Use the same 48-bit address.
  - Use the same frame format.
  - Keep the same minimum and maximum frame lengths.
  - Allow the interconnection of existing LANs into a metropolitan area network (MAN) or a wide area network (WAN).
  - Make Ethernet compatible with technologies such as Frame Relay and ATM.
- Ten-Gigabit Ethernet operates only in **full duplex mode** which means there is no need for contention.
- The physical layer in Ten-Gigabit Ethernet is designed for using fiber-optic cable over long distances.
- Three implementations are the most common: 10GBase-S, 10GBase-L, and 10GBase-E.

Ten-Gigabit Ethernet implementations

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