Computer Networks (CS30006)

Spring Semester (2021-2022)

LAN and Ethernet

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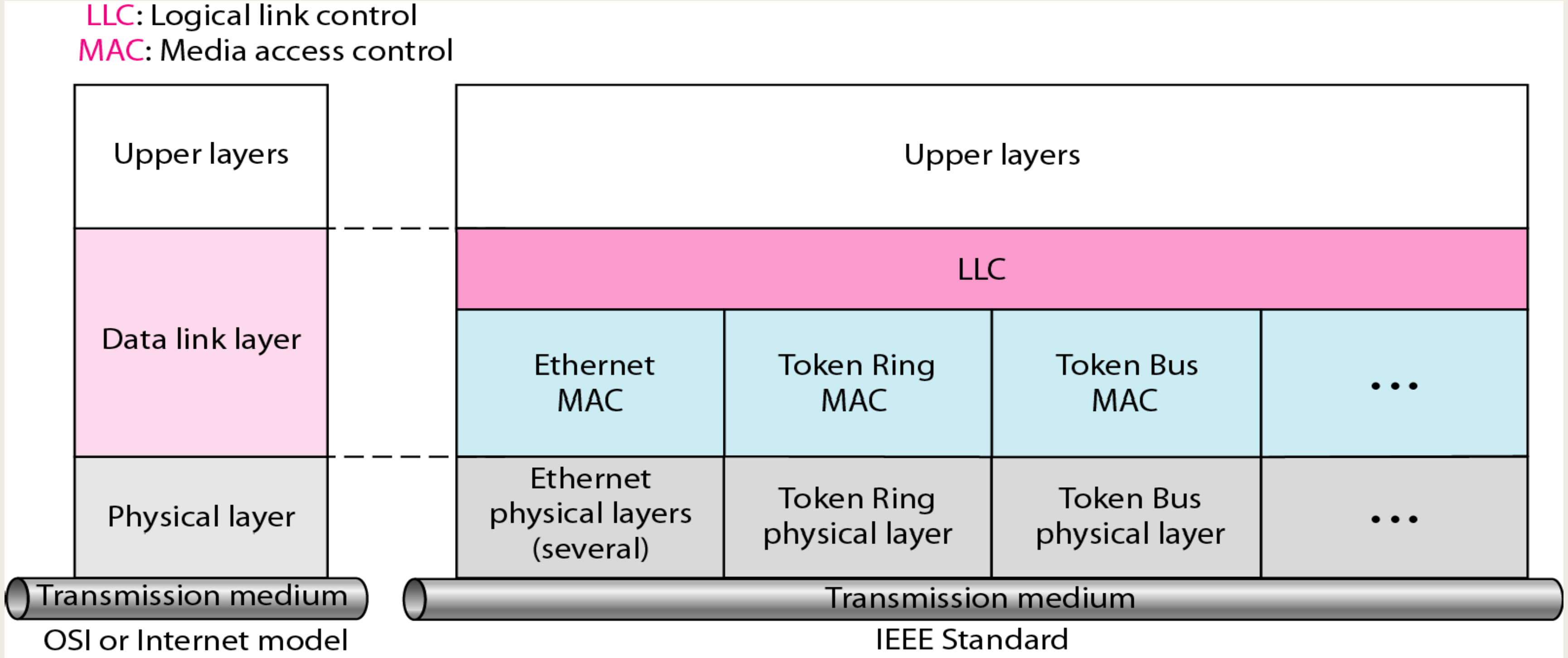
IEEE Standards

- 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.



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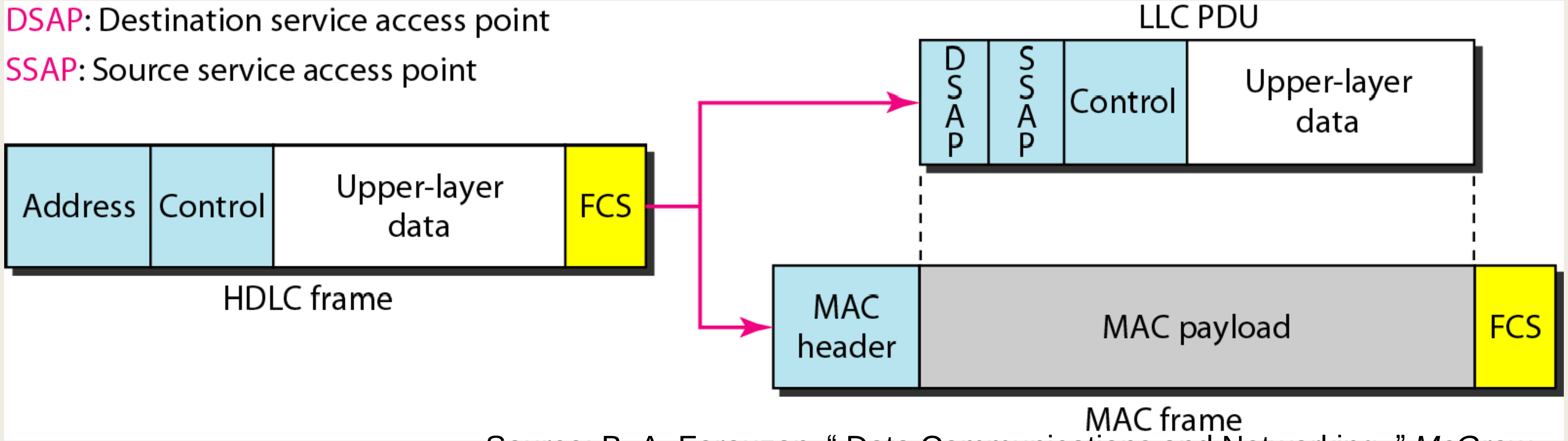
Physical Layer

- The physical layer is dependent on the implementation and type of physical media used.
- IEEE defines detailed specifications for each LAN implementation.
- **For example,** although there is only one MAC sublayer for Standard Ethernet, there is a different physical layer specifications for each Ethernet implementation.

Data Link Layer

- The data link layer in the IEEE standard is divided into two sublayers:
- **Logical Link Layer (LLC):** Flow control, error control, and part of the framing duties are collected into one sublayer called the logical link control.
- **Media Access Control (MAC):** Framing is handled in both the LLC sublayer and the MAC sublayer.
- Framing: LLC defines a protocol data unit (PDU) which is used for flow and error control. The two other header fields define the upper-layer protocol at the source and destination that uses LLC.



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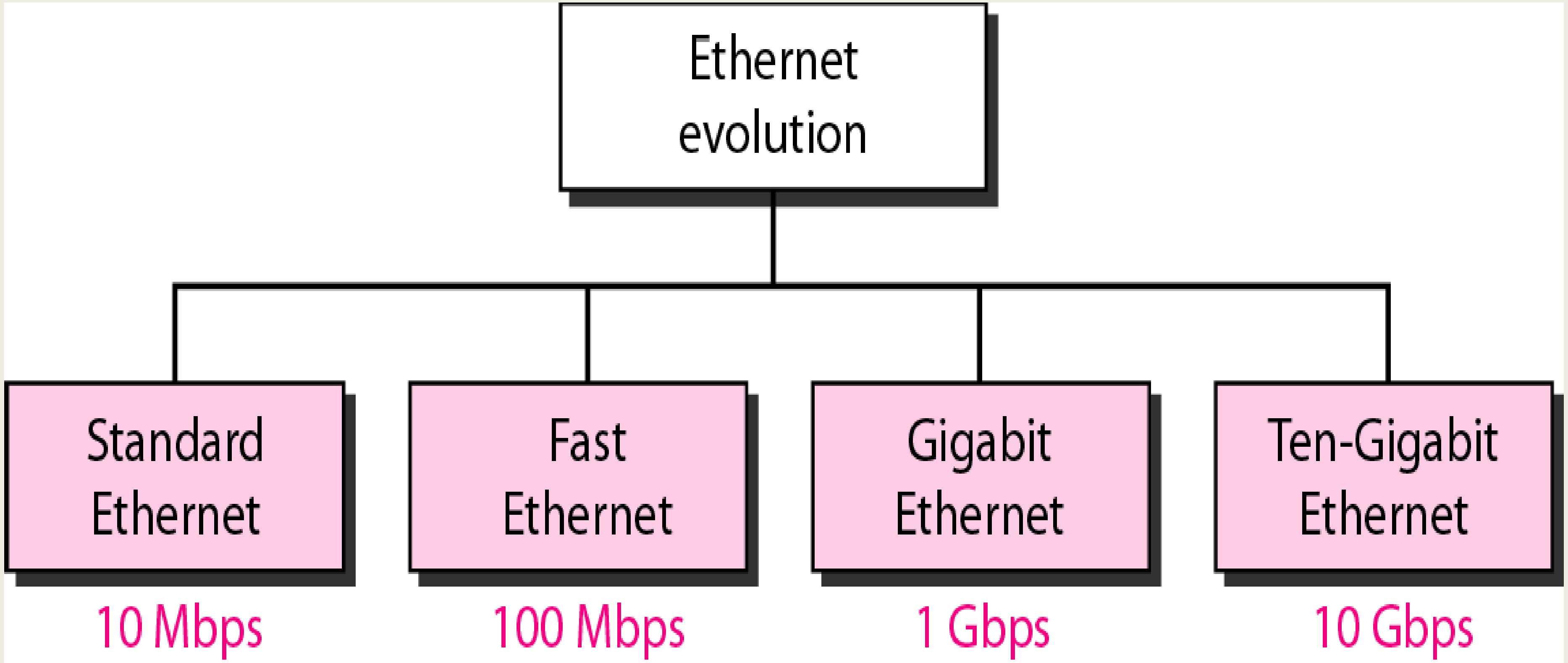
LAN as a Broadcast Domain

- A **broadcast domain** is a collection of network devices that receive broadcast traffic from each other.
- Logical division of a computer network, in which all nodes can reach each other by broadcast at the data link layer.
- In simple Ethernet (without switches or bridges), data frames are transmitted to all other nodes on a network.
- Each receiving node checks the destination address of each frame, and simply ignores any frame not addressed to its own MAC address or the broadcast address.
- Can be within the same LAN segment or it can be bridged to other LAN segments.

Evolution of Ethernet



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Standard Ethernet

- Standard Ethernet uses I-persistent CSMA/CD
- Slot Time in an Ethernet network, the round-trip time required for a frame to travel from one end of a maximum-length network to the other plus the time needed to send the jam sequence is called the slot time.

Slot time =round-trip time + time required to send the jam seq

Logical Link Control layer (IEEE 802.2)

- Defines a programming interface between that part of the communications software that controls the network interface card (the Media Access Control and Physical Medium Dependent components).

- Creates a reliable data transfer mechanism at the Data Link Layer.

- Provides multiplexing mechanisms that make it possible for several network protocols (e.g. IP, IPX, Decnet and Appletalk) to coexist within a multipoint network.

- Provide flow control and automatic repeat request (ARQ) error management mechanisms.

- The 802.2 header includes two eight-bit address fields, called **service access points** (SAP)

802.2 LLC Header			Information
DSAP address	SSAP address	Control	
8 bits	8 bits	8 or 16 bits	multiple of 8 bits

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- SSAP (Source SAP) is an 8-bit long field that represents the logical address of the network layer entity that has created the message.

- DSAP (Destination SAP) is an 8-bit long field that represents the logical addresses of the network layer entity intended to receive the message.

- The LPDU control field contains command, response, and sequence number information.

- Data field contains the encapsulated protocol.

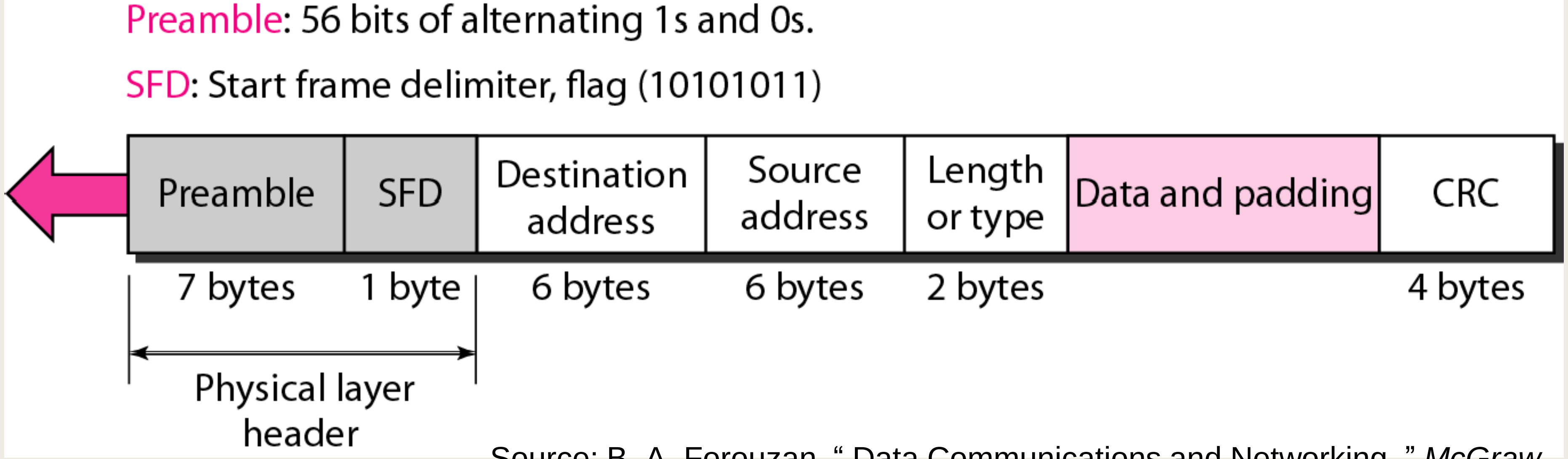
Popular 802.x Standards

- 802.1: Bridging
- 802.2: Logical Link
- 802.3: Ethernet
- 802.4: Token Bus
- 802.5: Token Ring
- 802.11: WiFi
- 802.15: Wireless Personal Area Network
- 802.15.1: Bluetooth
- 802.15.4: Zigbee

- For more details refer: https://www.techtarget.com/searchnetworking/reference/IEEE-802-Wireless-Standards-Fast-Reference

MAC Sublayer (IEEE 802.3)

- 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.
- 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.



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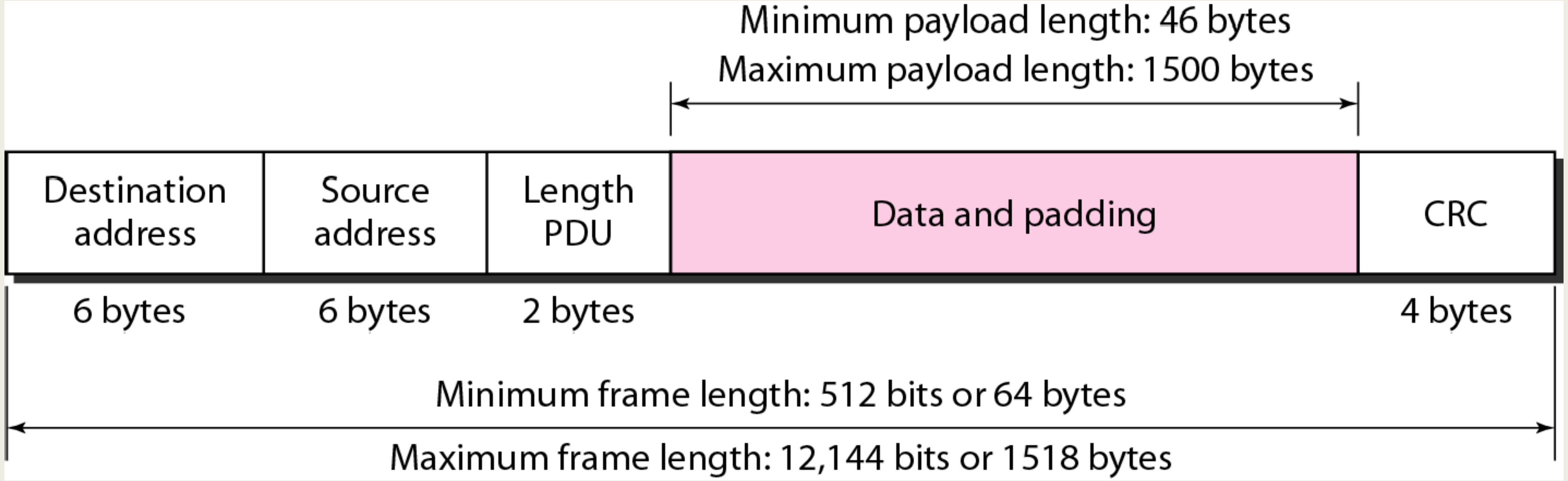
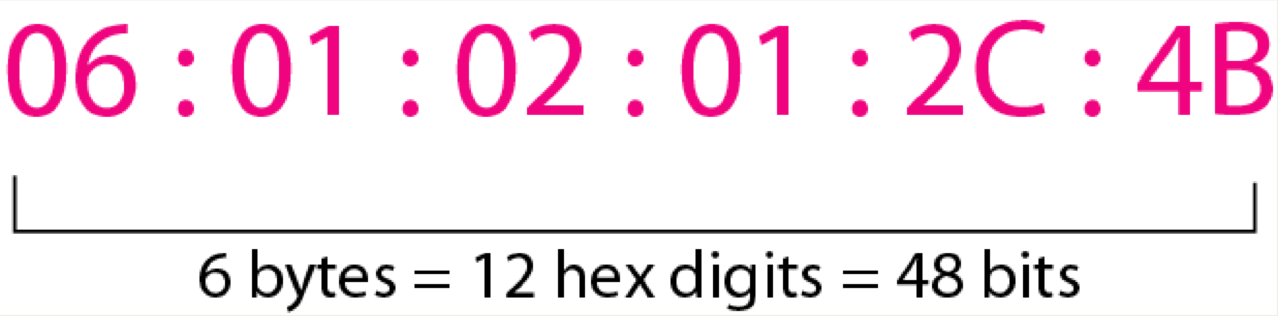
- **Preamble. The first field of the 802.3 frame contains 7 bytes (56 bits) of alternating OS and Is that alerts the receiving system to the coming frame and enables it to synchronize its input timing. The pattern provides only an alert and a timing pulse. The 56-bit pattern allows the stations to miss some bits at the beginning of the frame. The preamble is actually added at the physical layer and is not (formally) part of the frame.**
- **Start frame delimiter (SFD). The second field (l 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. We will discuss addressing shortly.**
- **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. Both uses are common today.**
- **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

- Ethernet has imposed restrictions on both the minimum and maximum lengths of a frame.



Example of Ethernet address:



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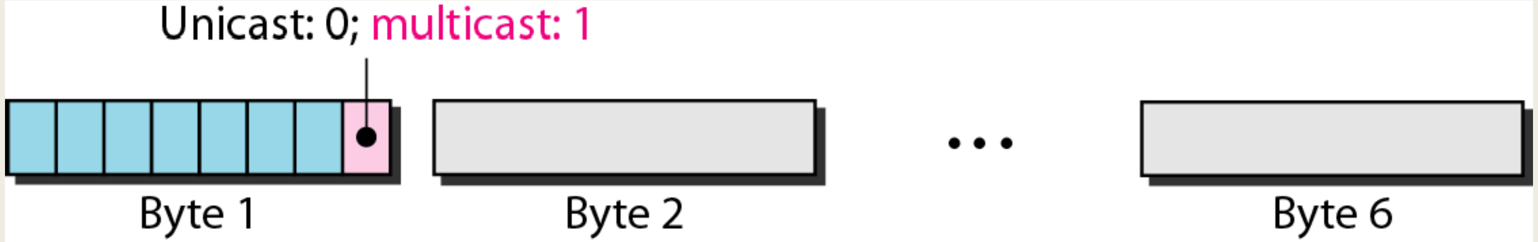
Unicast, Multicast, and Broadcast Addresses

- If the least significant bit of the first byte in a destination address is 0, the address is unicast; otherwise, it is multicast.

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



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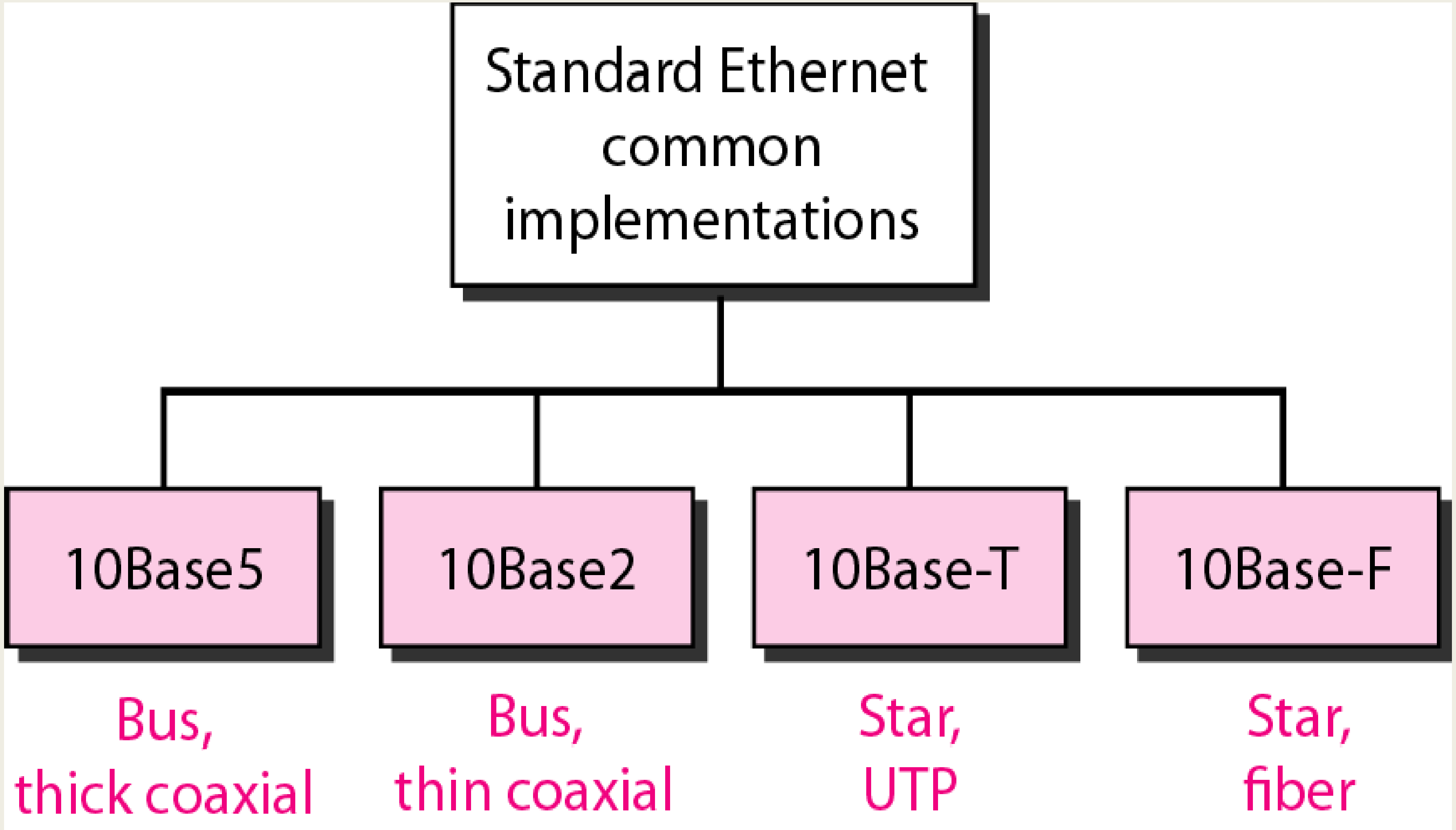
Categories of Standard Ethernet



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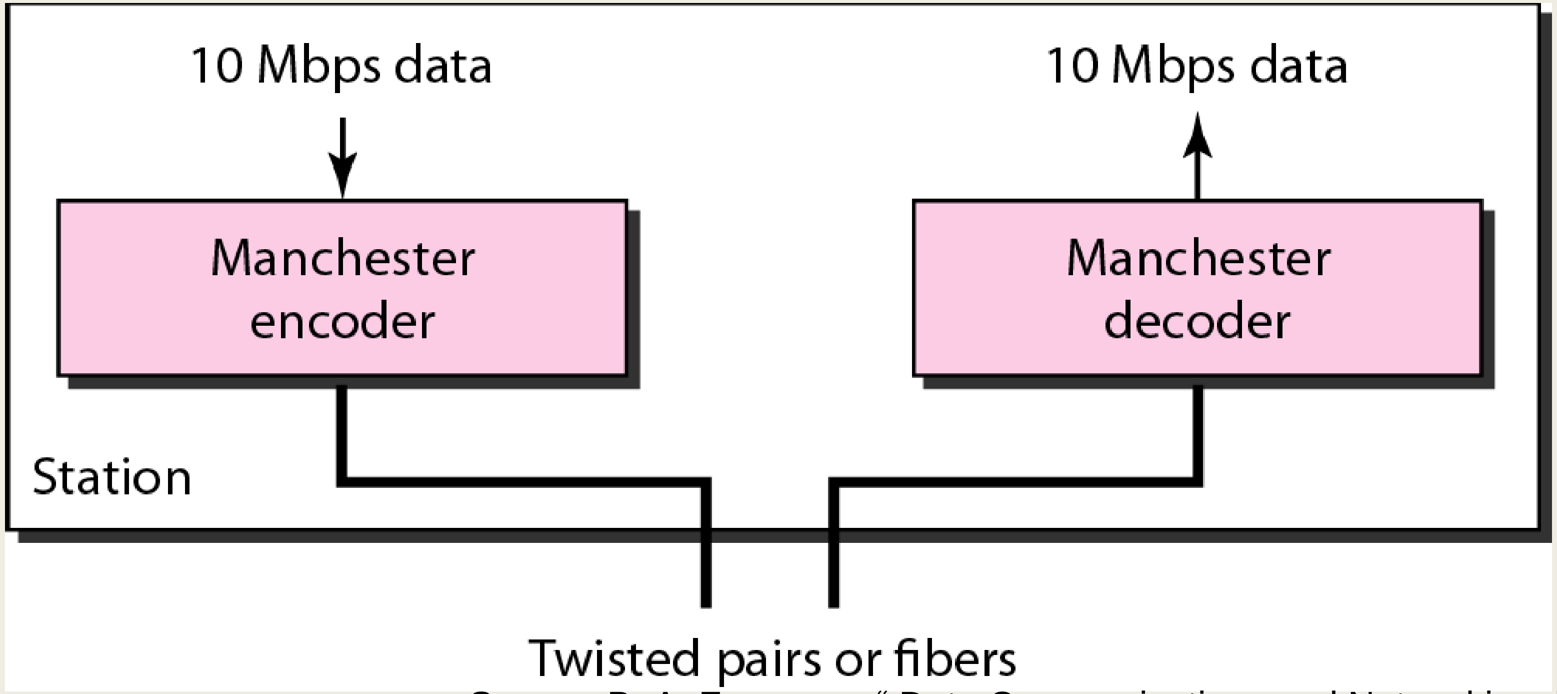
Encodings and Decodings

- 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.



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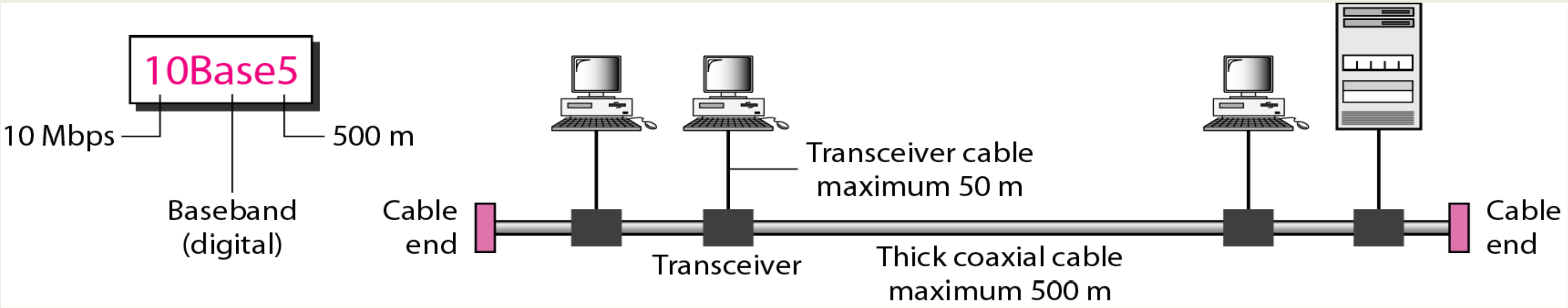
10Base5: Thick Ethernet

- The first implementation is called **10Base5, thick Ethernet, or Thicknet.**
- l0Base5 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.



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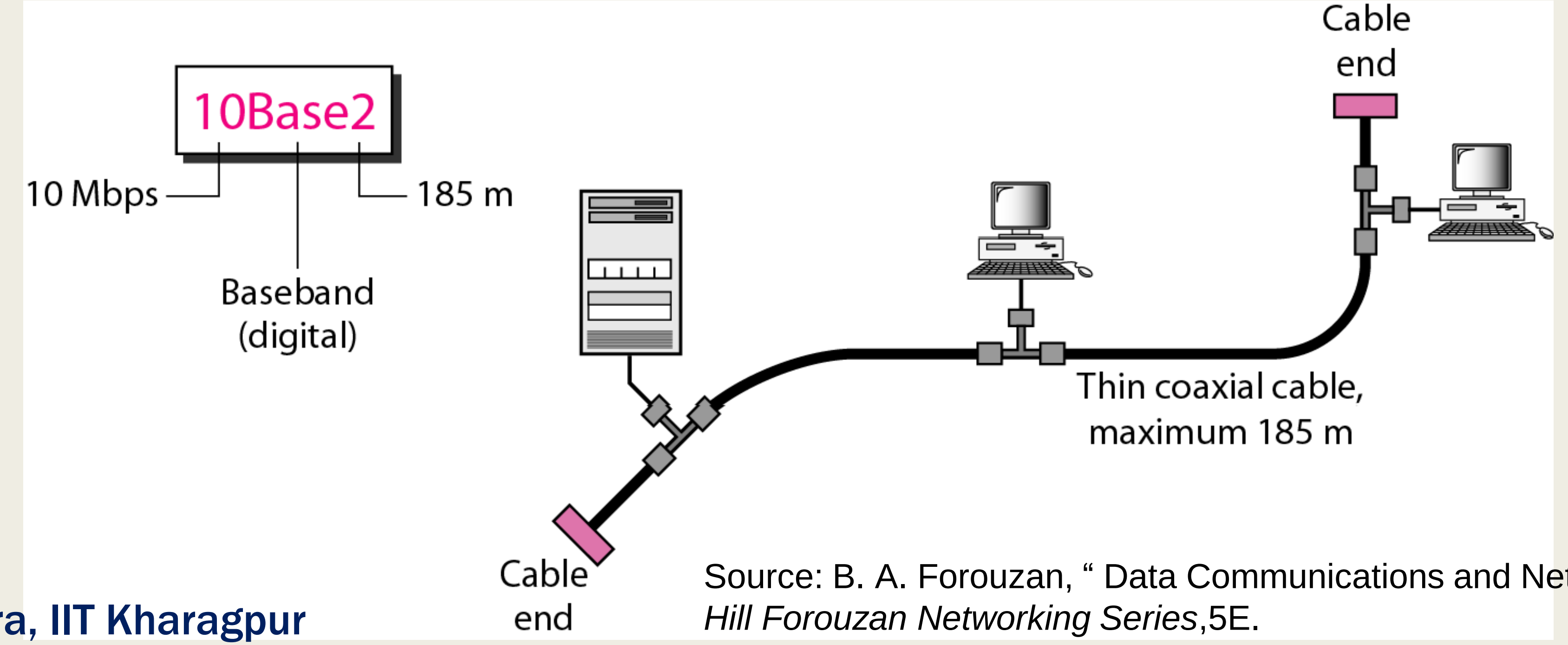
10Base2: Thin Ethernet

- The second implementation is called l0Base2, **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.



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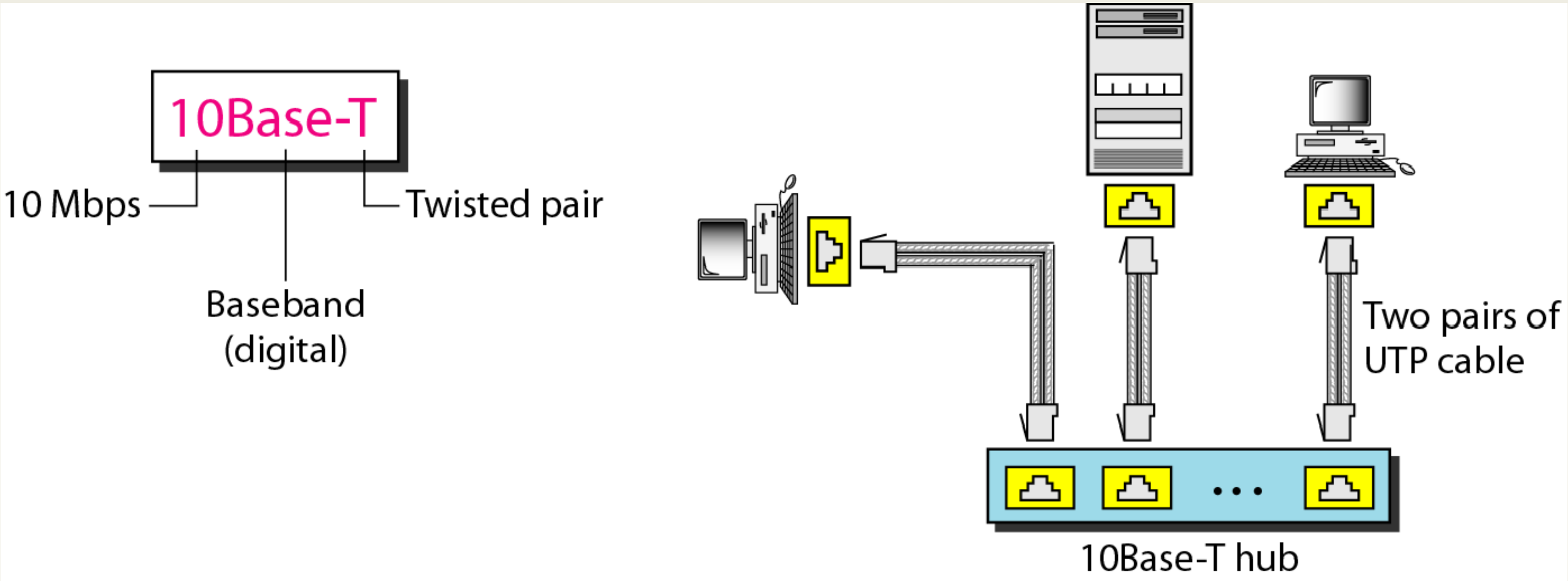
10BaseT: Twisted Pair Ethernet

- 10Base-T uses a physical star topology.
- The 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 here is defined as 100 m, to minimize the effect of attenuation in the twisted cable.



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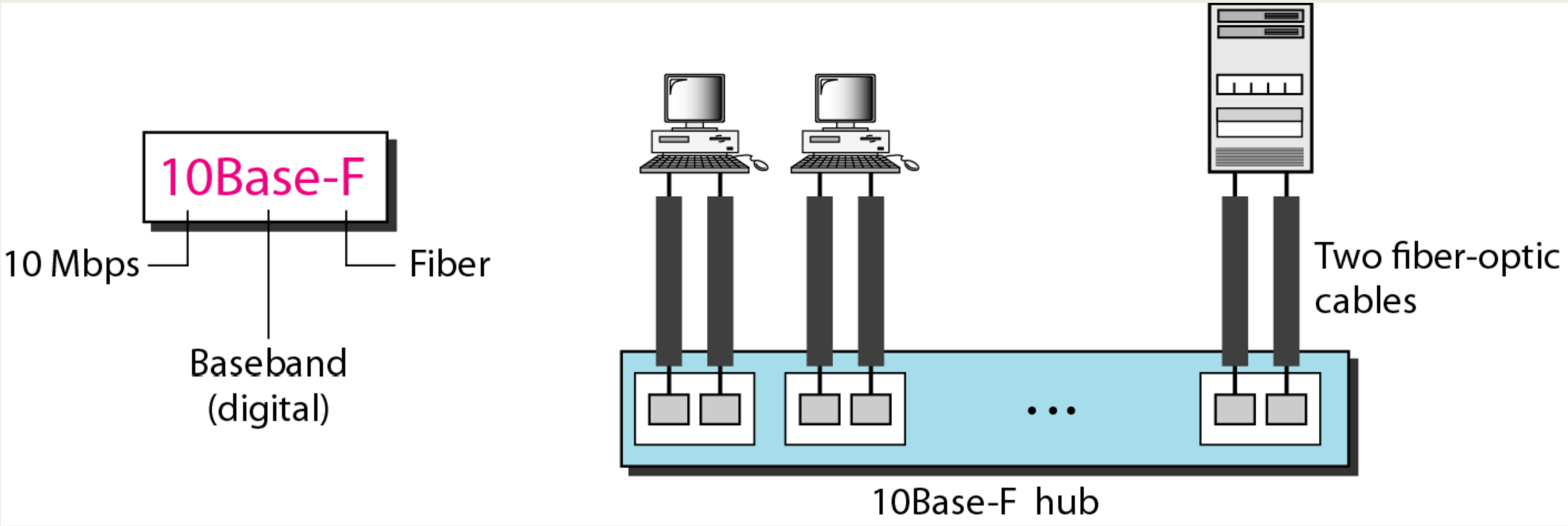
10BaseF: Fiber Ethernet

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



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Summary

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

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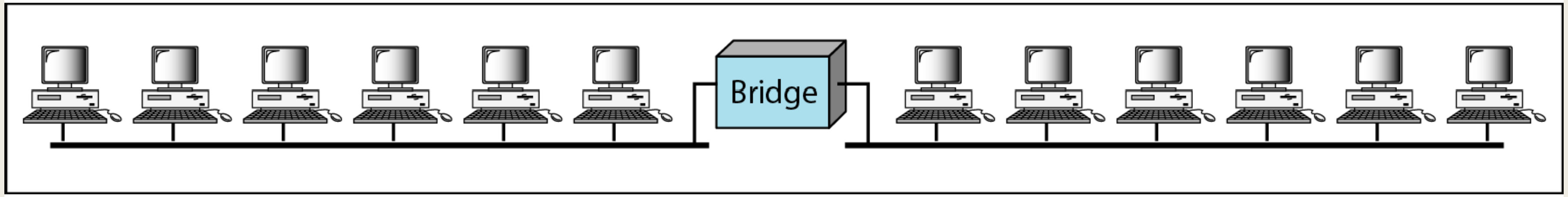
Bridged Ethernet

Bridges have two effects on an Ethernet LAN: They raise the bandwidth and they separate collision domains.

A bridge divides the network into two or more networks.

Bandwidth-wise, each network is independent.


a. Without bridging



b. With bridging

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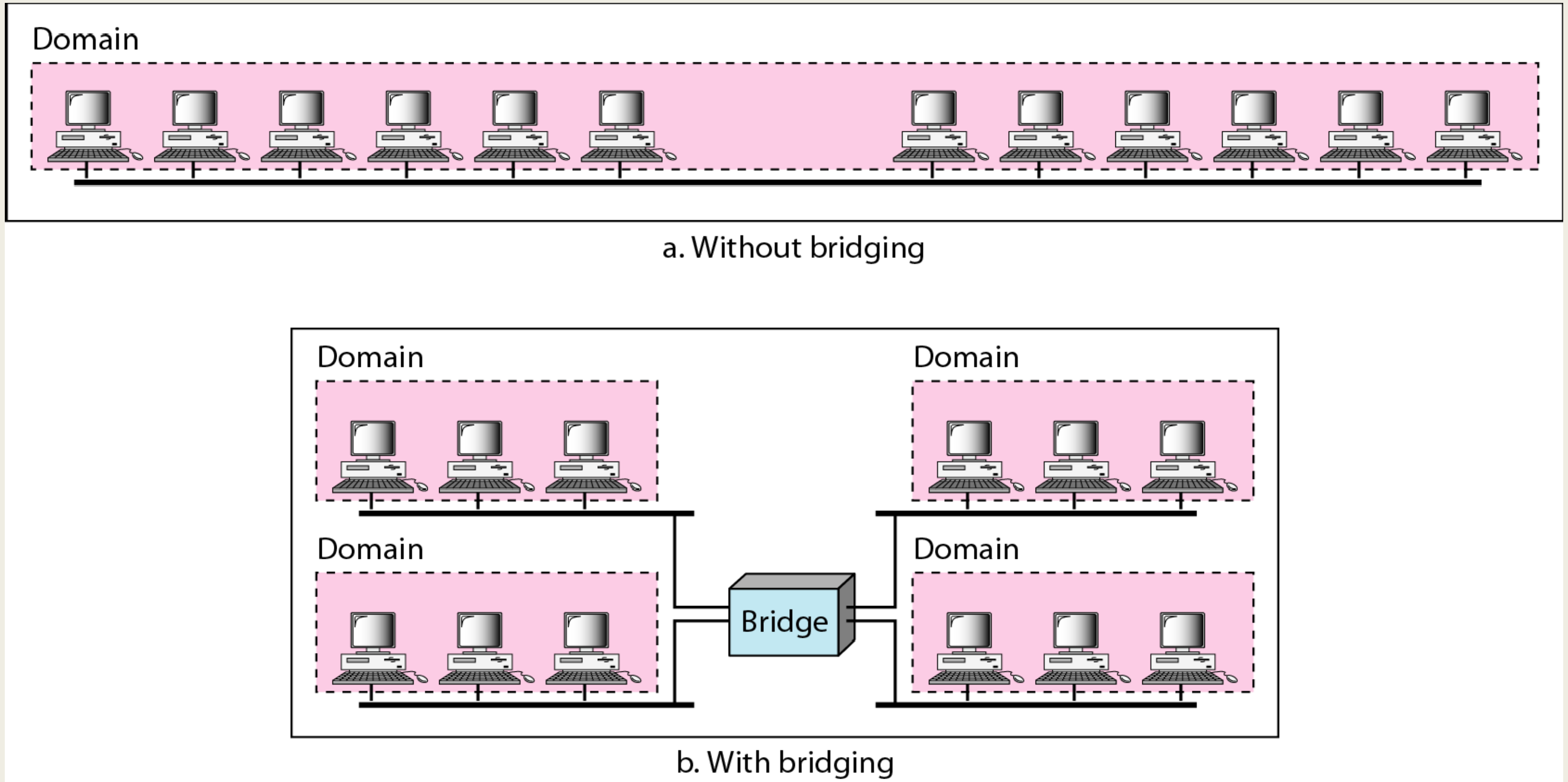
Bridged Ethernet: Collision Domain

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



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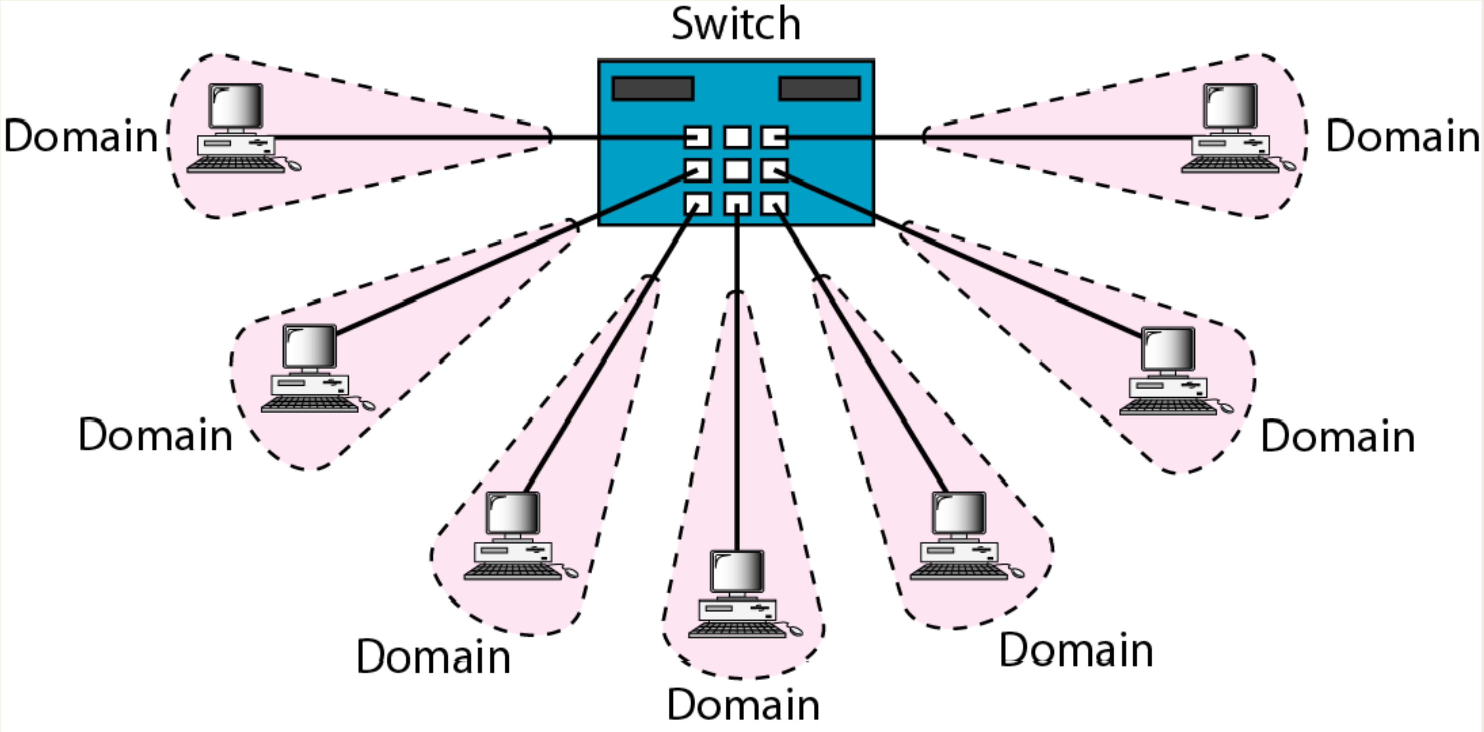
Switched Ethernet

- Allows faster handling of the packets.



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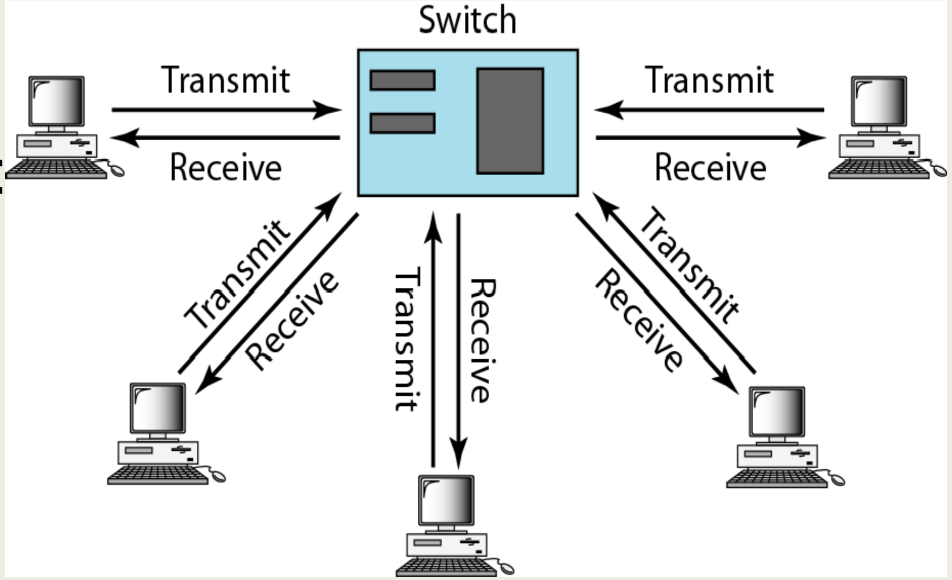
Switched Ethernet

- The full-duplex mode increases the capacity of each domain from 10 to 20 Mbps.
- Instead of using one link between the station and the switch, the configuration uses two links: one to transmit and one to receive.
- In full-duplex switched Ethernet, there is no need for the CSMA/CD method.
- In a full duplex switched Ethernet, each station is connected to the switch via two separate links.
- Each station or switch can send and receive independently without worrying about collision.



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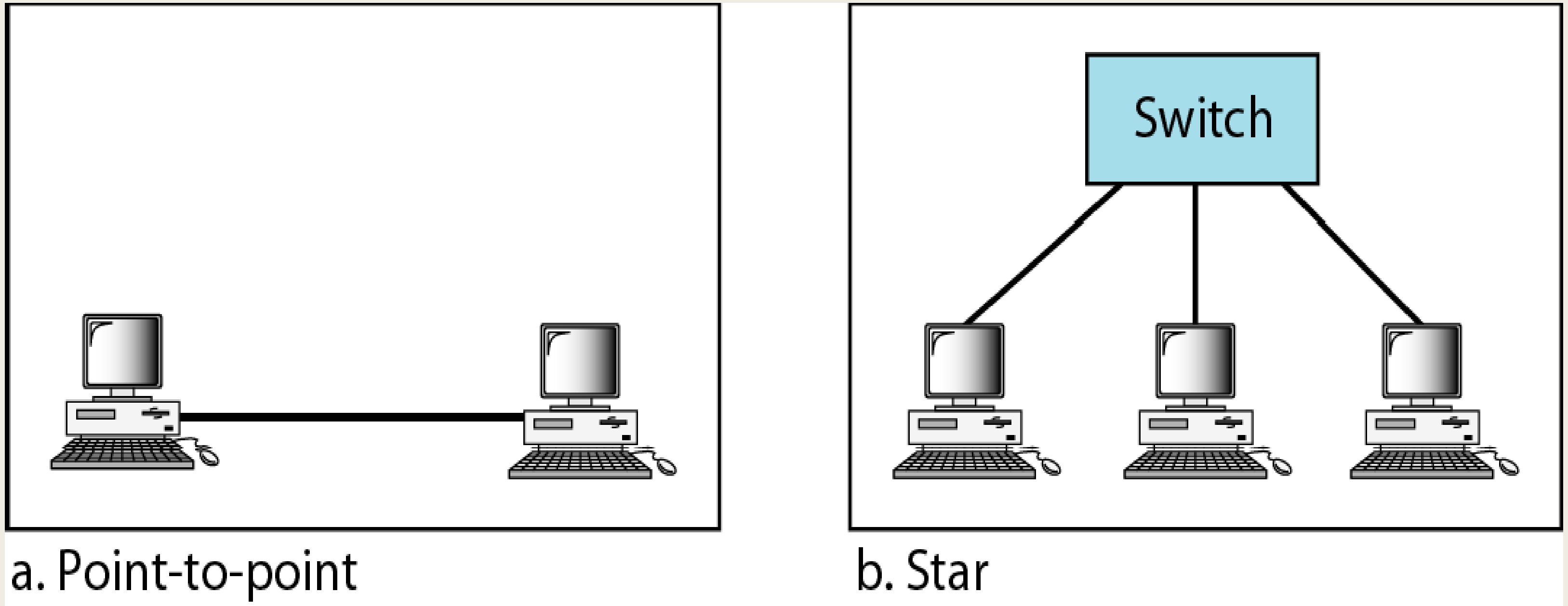
Fast Ethernet

- Fast Ethernet was designed to compete with LAN protocols such as FDDI or Fiber Channel.

- 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.

Fast Ethernet: Topology

- 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.



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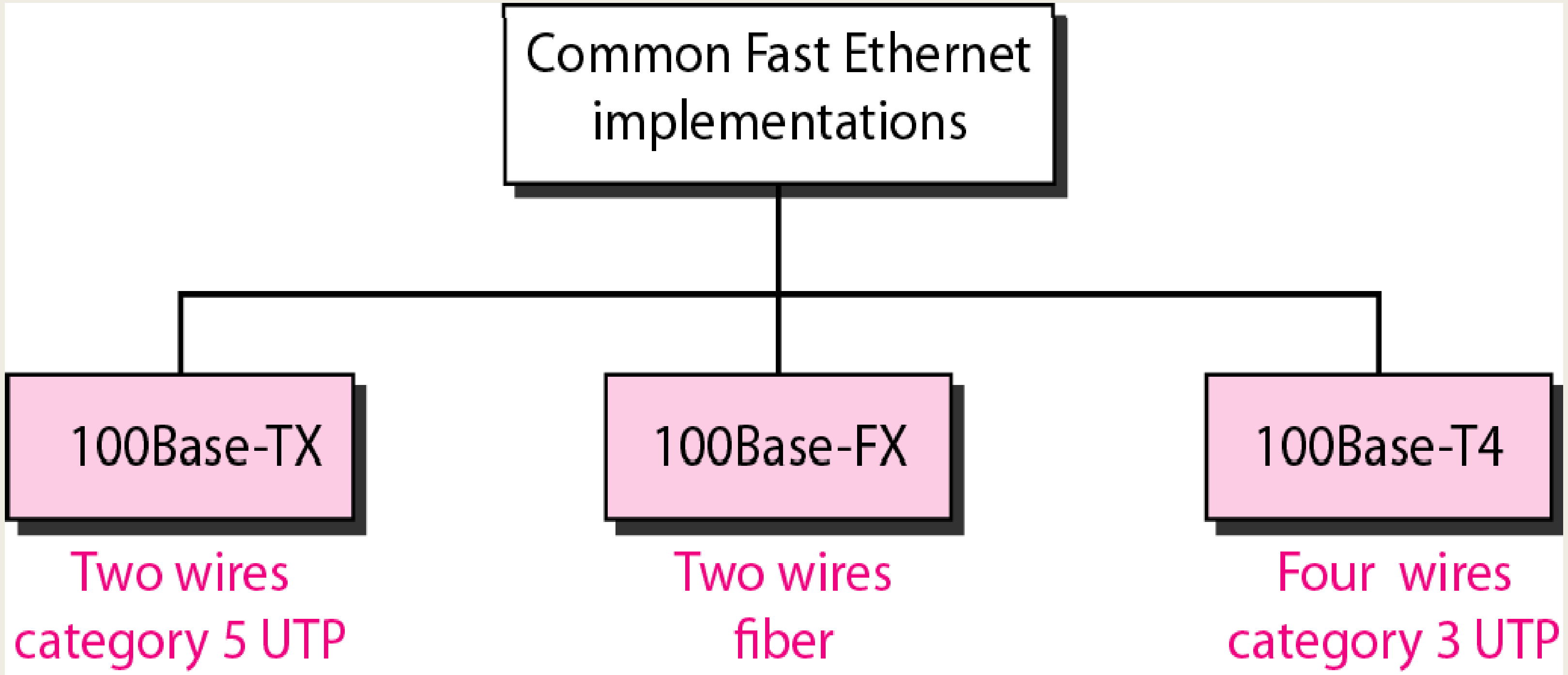
Fast Ethernet: Implementation

- 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 (l00Base-TX) or fiber-optic cable (l00Base-FX).
- The four-wire implementation is designed only for category 3 UTP (l00Base-T4).



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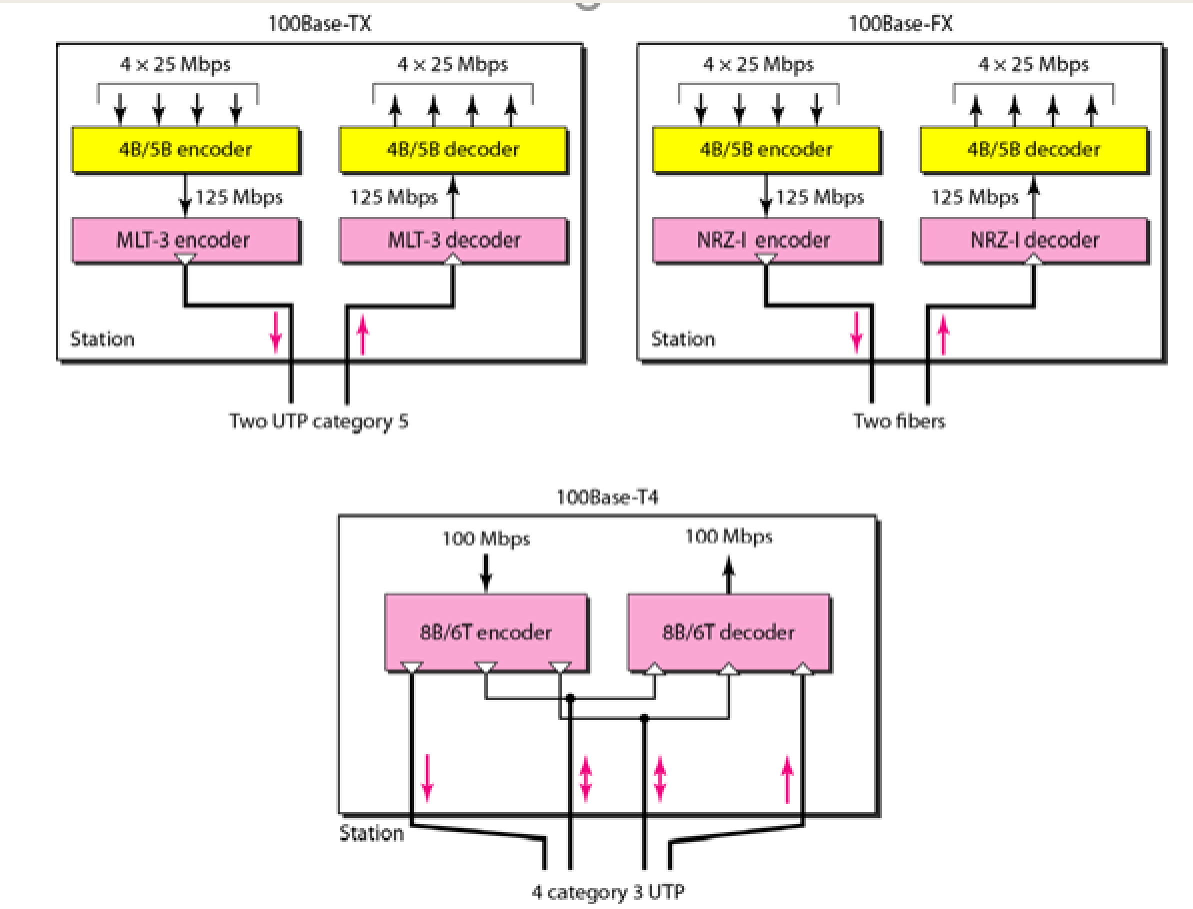
Fast Ethernet: Encoding

- Manchester encoding needs a 200-Mbaud bandwidth for a data rate of 100 Mbps, which makes it unsuitable for a medium such as twisted-pair cable.
- three different encoding schemes were chosen:
- **l00Base-TX** uses MLT-3 scheme since it has good bandwidth performance.
- **100Base-FX** uses the NRZ-I encoding scheme
- **100 Base-T4** uses 8B/6T scheme



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Summary

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

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Gigabit Ethernet

The need for an even higher data rate resulted in the design of the Gigabit Ethernet protocol (1000 Mbps).

The goals of Fast Ethernet 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.

Cont...

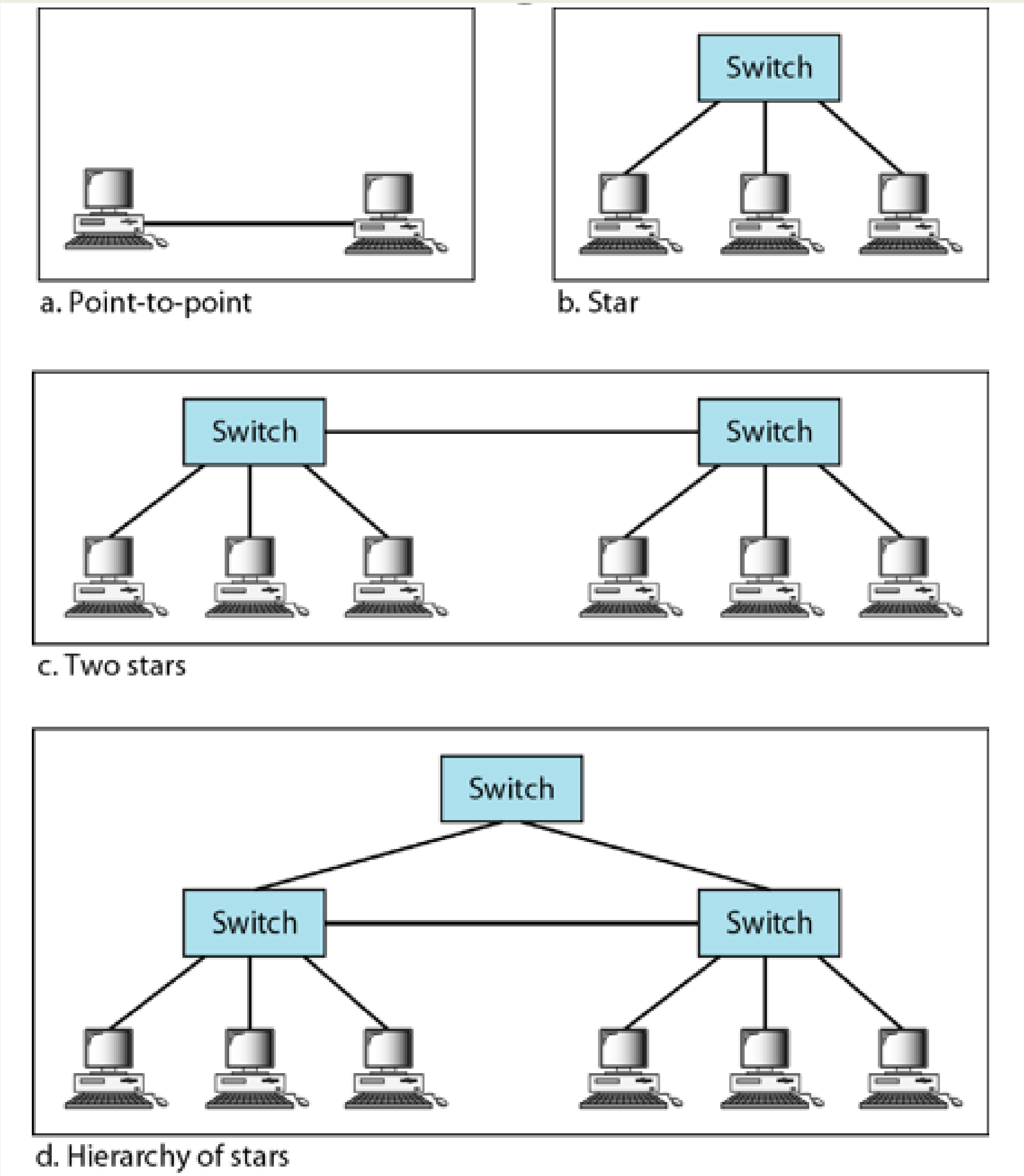
Gigabit Ethernet has two distinctive approaches for medium access: half-duplex and full-duplex.

Full Duplex Mode: In the full-duplex mode of Gigabit Ethernet, there is no collision; the maximum length of the cable is determined by the signal attenuation in the cable.

Half Duplex Mode: In this case, 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 *CSMA/CD.*

Gigabit Ethernet: Topologies

- 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.



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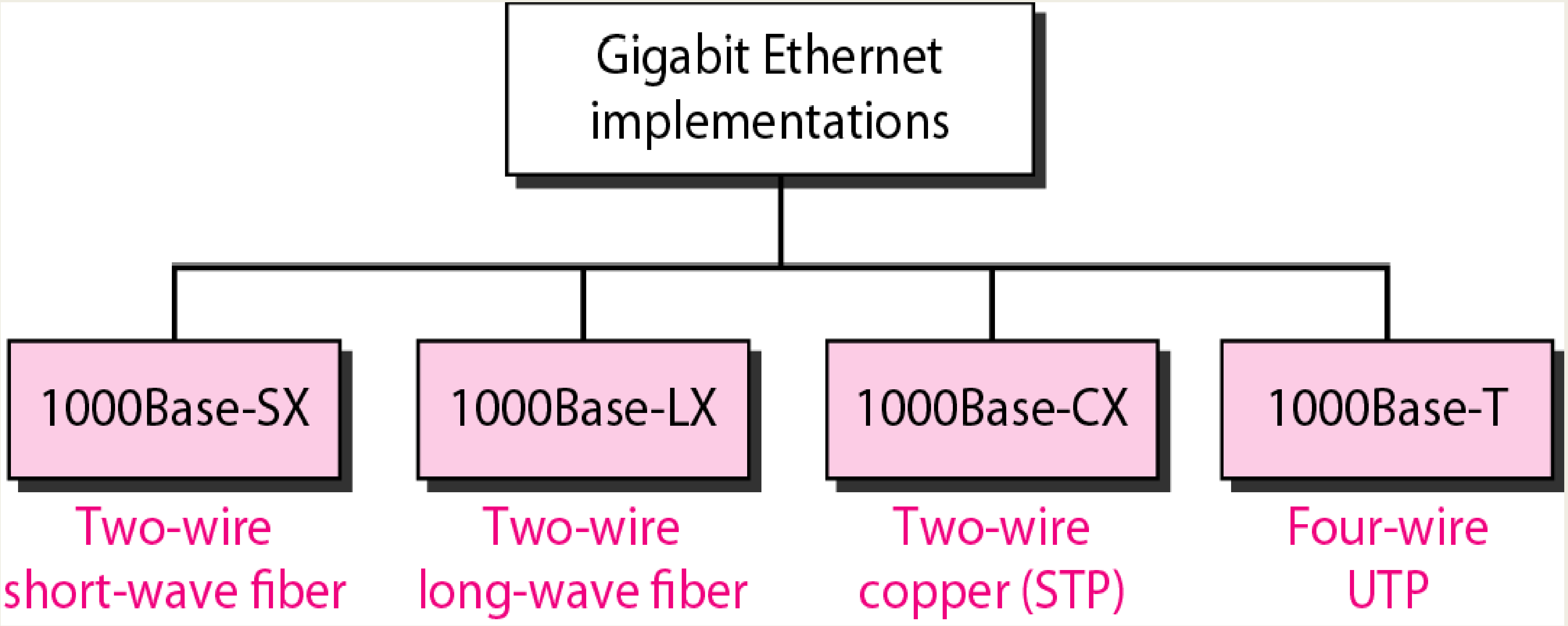
Gigabit Ethernet: Implementations



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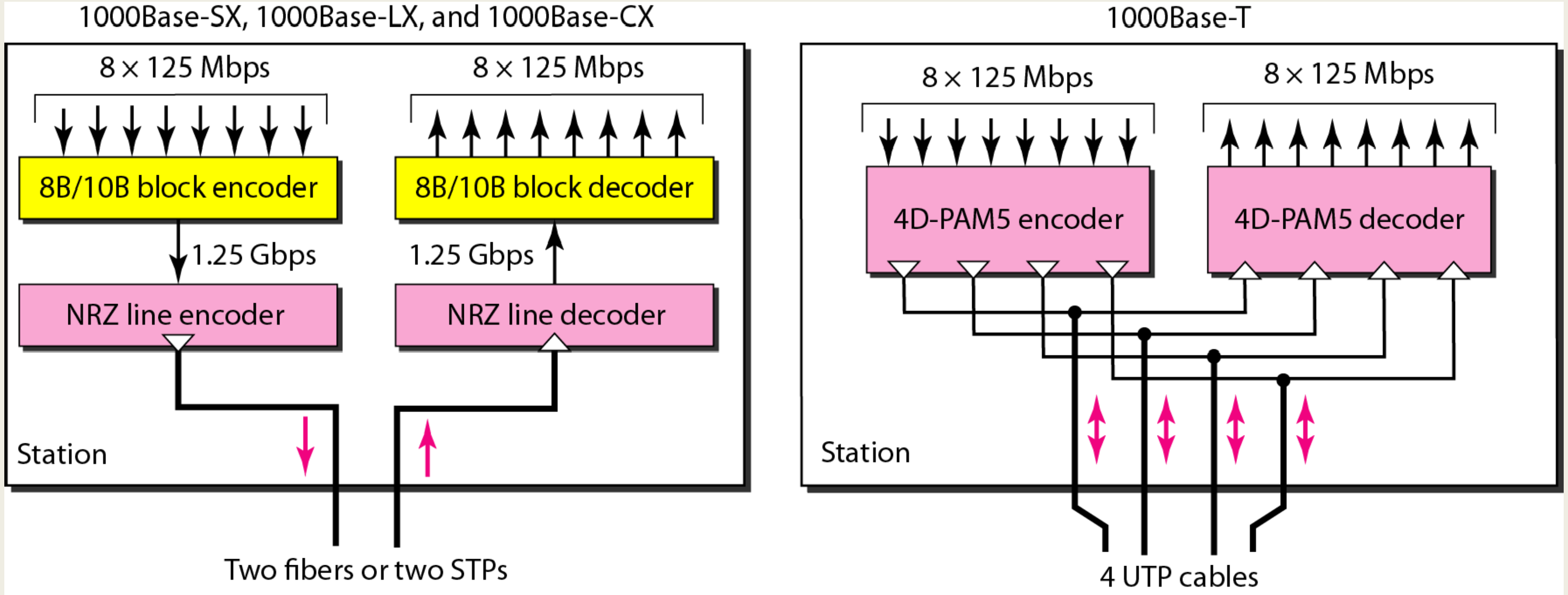
Gigabit Ethernet: Implementations

- Gigabit Ethernet cannot use the Manchester encoding scheme because it involves a very high bandwidth (2 GBaud).
- The two-wire implementations use an NRZ scheme, but NRZ does not self-synchronize properly.
- To synchronize bits, particularly at this high data rate, 8B/10B block encoding is used.



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10-Gigabit Ethernet

The goals of the Ten-Gigabit Ethernet design can be summarized as follows:

1. Upgrade the data rate to 10 Gbps.

2. Make it compatible with Standard, Fast, and Gigabit Ethernet.

3. Use the same 48-bit address.

4. Use the same frame format.

S. Keep the same minimum and maximum frame lengths.

6. Allow the interconnection of existing LANs into a metropolitan area network (MAN) or a wide area network (WAN).

7. Make Ethernet compatible with technologies such as Frame Relay and ATM.

10-Gigabit Ethernet: Implementations

Three implementations are the most common: 10GBase-S, 10GBase-L, and 10GBase-E.

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

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Difference between 802.3 and Ethernet

802.3 is a standard, Ethernet is the implementation.

Ethernet is a set of technologies and protocols that are used primarily in LANs whereas IEEE 802.3 defines the physical layer and the medium access control (MAC) sub-layer of the data link layer for wired Ethernet networks.

IEEE 802.3 is original standard given for 10BASE-5.

Hubs and Switches

A Network Switch

- It takes packets and sends them in the right direction.
- Improve network performance compared to hubs, by providing dedicated bandwidth to each end device, supporting full-duplex connectivity, utilizing the MAC address table to make forwarding decisions.

A Network hub

- A Network Hub is a dumb thing that just replicates traffic from one port to all of the ports.
- Sometimes causing "Collisions" which causes data loss.

Difference between Hub and Switch

Hub	Switch
Hub is operated on Physical layer of OSI model.	While switch is operated on Data link layer of OSI Model.
Hub is a broadcast type transmission.	While switch is a Unicast, multicast and broadcast type transmission.
Hub is a half duplex transmission mode.	While switch is a full duplex transmission mode.
In hub, Packet filtering is not provided.	While in switch, Packet filtering is provided.

Difference between Hub and Switch

Hub	Switch
Hub cannot be used as a repeater.	While switch can be used as a repeater.
Hub is not an intelligent device that sends message to all ports hence it is comparatively inexpensive.	While switch is an intelligent device that sends message to selected destination so it is expensive.
Hub is simply old type of device and is not generally used.	While switch is very sophisticated device and widely used.
Hacking of systems attached to hub is complex.	Hacking of systems attached to switch is little easy.

https://www.geeksforgeeks.org/difference-between-hub-and-switch/

Spanning Tree Protocol

Link management protocol designed to support redundant links that stops switching loops.

It is a Layer 2 protocol that runs on bridges and switches, which should be enabled on the switch interfaces.

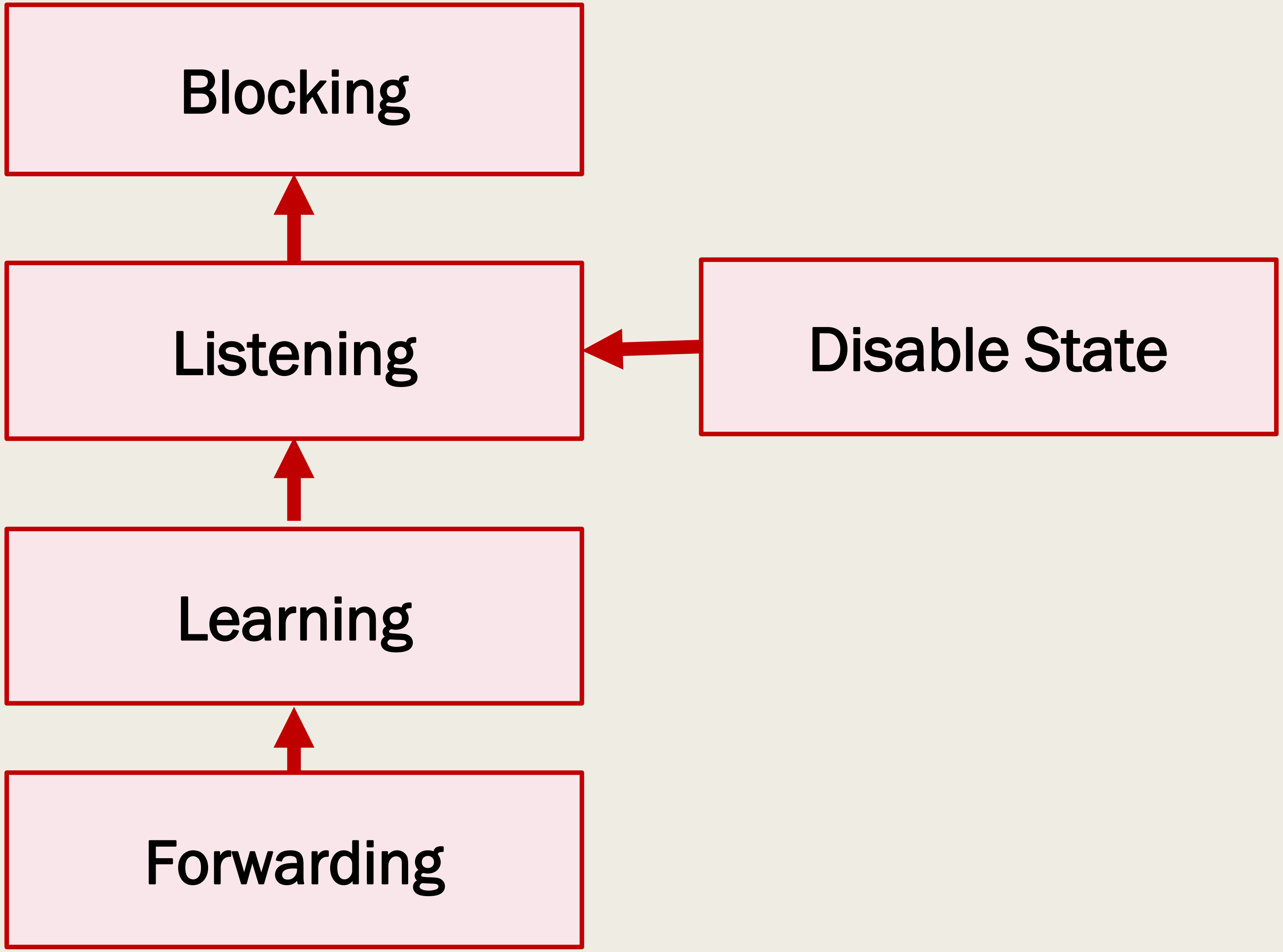
Need:

- The reliability (fault tolerance) of the network is increase exponentially by the introduction of redundancy.
- Switches flood traffic out all ports, when the traffic needs to be sent to a destination that is not yet known.
- Broadcast and multicast traffic is forwarded out to every port, apart from the port on which the traffic arrived.
- The Spanning-Tree Protocol is used to create a loop-free logical topology from a physical topology that has loops.

Working

- Spanning trees use an algorithm to search for the redundant links in the LAN and select the best paths.
- It is mainly used to put all links in either forwarding or blocking.
- After this process, all the links without a redundant link is likely to be in the forwarding state.
- The redundant links that were not as good as the selected links would be blocking.
- Spanning Tree never uses multiple links to the same destination. There is no load-sharing feature with Spanning Tree.

Stages of STP



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Blocking State

Block state is a non-designated port, and it is never participating in frame forwarding.
Its time limit is 20 sec or unlimited.
An interface always enters the blocking state when you enable STP.

Listening State

The listening state is the first state.
It is an interface that is entered after the blocking state.
The interface helps to determine that the interface that should participate in frame forwarding.

The listening state performs the following functions:

- Discards frames received on the port
- Does not learn addresses
- Receives BPDUs

Cont...

Learning State

Learning state helps to prepare for participating in frame forwarding.
The interface allows to enter the learning state from the listening slate.
Learning state performs the following functions:

- Discards frames received on the port
- Receives BPDUs
- Learns addresses

Forwarding State

An interface in the forwarding state form the forward frames.
This interface enters the forwarding state from the learning state which performs the following functions:

- Receives and forwards frames which is received on the port
- Learns addresses
- Receives BPDUs

Cont...

Disabled State

This state does not participate in the Spanning Tree loop because the port is administratively disabled, and its timing is also unlimited.

A disabled interface performs the following functions:

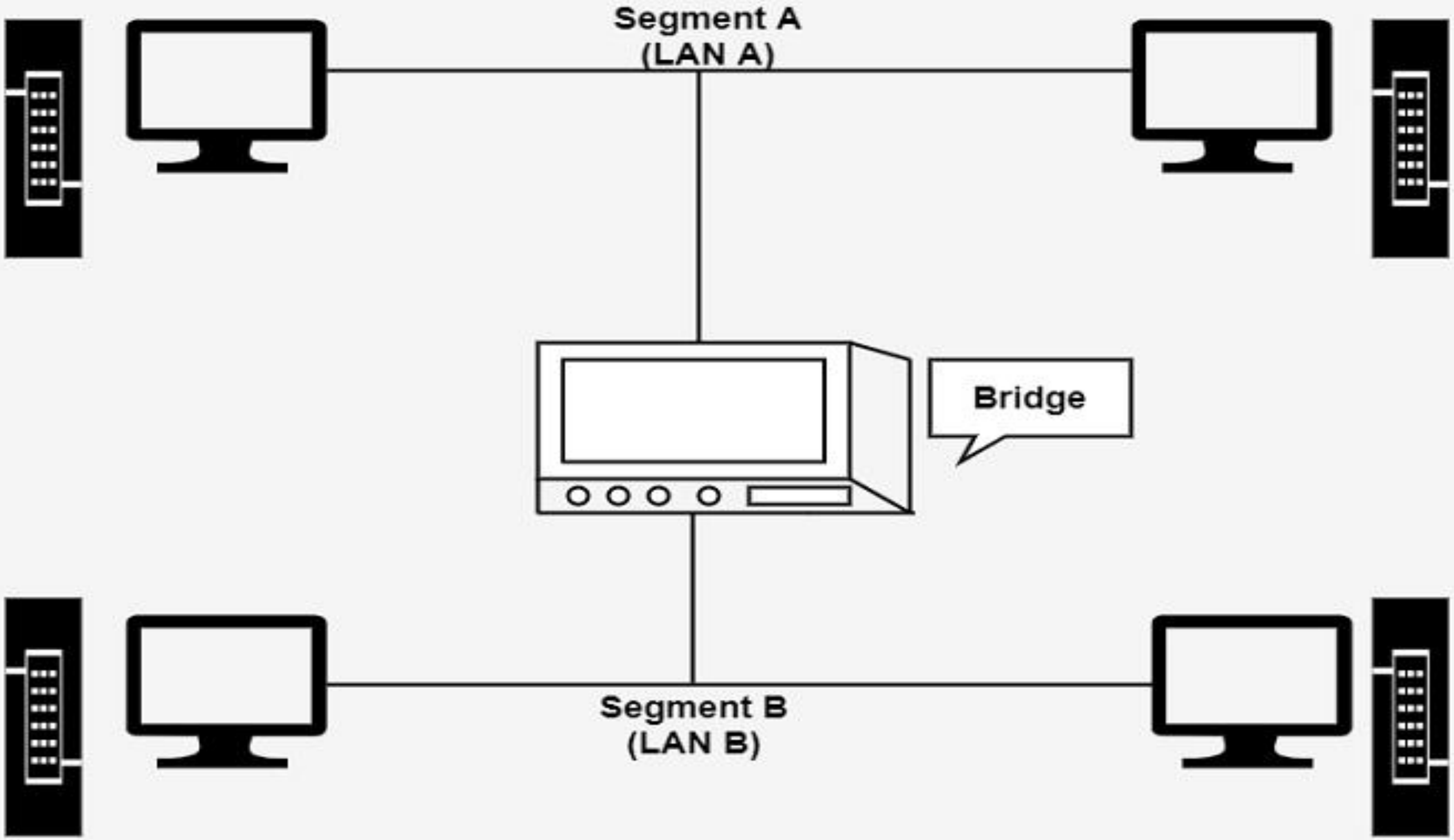
- Discards frames received on the port
- Does not learn addresses
- Does not receive BPDUs

Bridge

- In telecommunication networks, a bridge is a product that connects a local area network (LAN) to another local area network that uses the same protocol (for example, Ethernet or Token Ring).

- Can envision a bridge as being a device that decides whether a message from you to someone else is going to the local area network in your building or to someone on the local area network in the building across the street.

- A bridge examines each message on a LAN, "passing" those known to be within the same LAN, and forwarding those known to be on the other interconnected LAN (or LANs).



Source: Tutorialspoint, “What Are Bridges”, [Online], Available:
https://www.tutorialspoint.com/what-are-bridges-in-computer-network

Cont…

Root Bridge (RB)

- It is the bridge that offers an interconnection point for all segments.
- All the bridges in a LAN have a path to the root.
- STP allows you to select the root bridge automatically.
- However, if the STP network admin wants, he or she can change the RB according to the network.

Non-Root Bridge (NRB)

- A noon-root Bridge is any bridge that is not the root bridge.

Today’s Ethernet

40 Gigabit Ethernet (**40GbE**) and **100 Gigabit Ethernet** (**100GbE**) are groups of computer networking technologies for transmitting Ethernet frames at rates of 40 and 100 gigabits per second (Gbit/s), respectively.

The common reasons to adopt these technologies are:

- to reduce the number of optical wavelengths used and the need to light new fiber.
- to utilize bandwidth more efficiently than 10 Gbit/s link aggregate groups.
- to provide cheaper wholesale, internet peering and data center connectivity.
- to skip the relatively expensive 40 Gbit/s technology and move directly from 10 to 100 Gbit/s.

Thank You!!!