Unit-1

Data Communication Components

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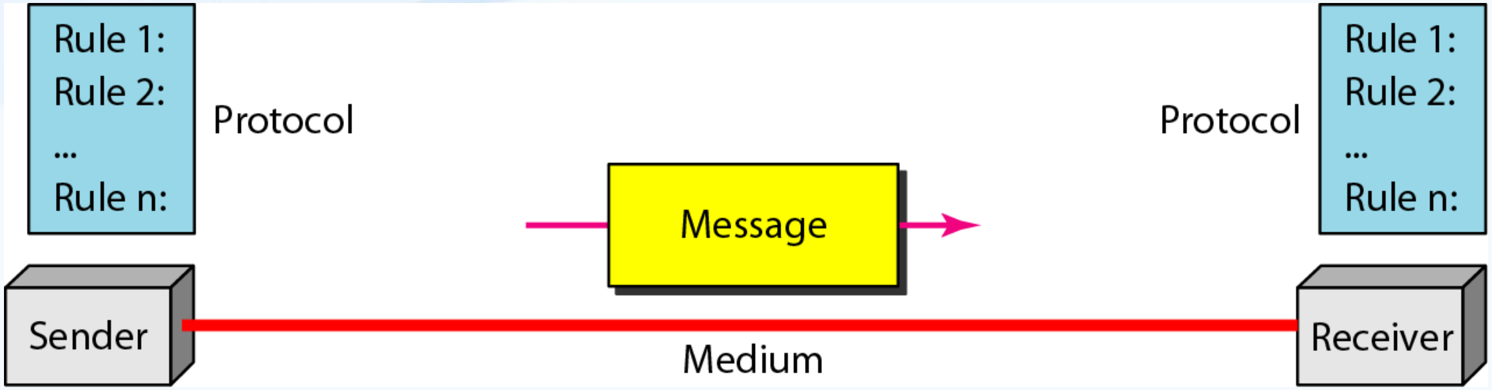
1-1 DATA COMMUNICATIONS

The term telecommunication means communication at a distance. The word data refers to information presented in whatever form is agreed upon by the parties creating and using the data. Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable. The effectiveness of data communication system depends on:-

1. Delivery. The system must deliver data to the correct destination. Data must be received by the intended device or user and only by that device or user.
2. Accuracy. The system must deliver the data accurately. Data that have been altered in transmission and left uncorrected are unusable.

3. Timeliness. The system must deliver data in a timely manner. Data delivered late are useless. In the case of video and audio, timely delivery means delivering data as they are produced, in the same order that they are produced, and without significant delay. This kind of delivery is called real-time transmission.

Components of a data communication system



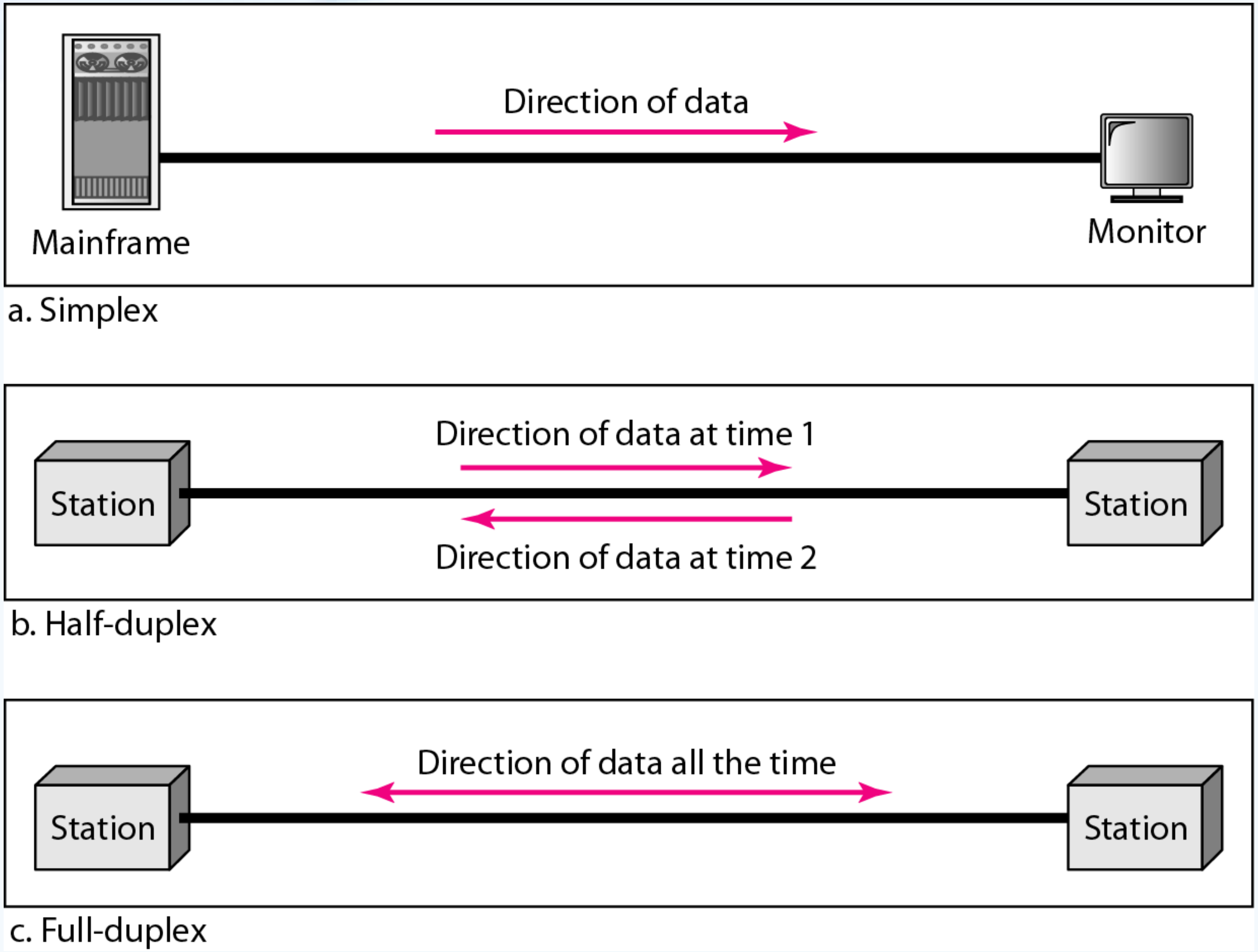
1. Message. The message is the information (data) to be communicated. It can con- sist of text, numbers, pictures, sound, or video or any combination of these.
2. Sender. The sender is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera, and so on

3. Receiver. The receiver is the device that receives the message. It can be a computer, workstation, telephone handset, television, and so on.

4. Medium. The transmission medium is the physical path by which a message travels from sender to receiver. It could be a twisted-pair wire, coaxial cable, fiber- optic cable, or radio waves (terrestrial or satellite microwave).

5. Protocol. A protocol is a set of rules that governs data communications. It represents an agreement between the communicating devices. Without a protocol, two devices may be connected but not communicating, just as a person speaking French cannot be understood by a person who speaks only Japanese.

Data flow (simplex, half-duplex, and full-duplex)



Simplex:- In simplex mode, the communication is unidirectional, as on a one-way street. Only one of the two devices on a link can transmit; the other can only receive.

Example: -Keyboards and traditional monitors are both examples of simplex devices. The keyboard can only introduce input; the monitor can only accept output.

Half-Duplex:- In half-duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive, and vice versa.

The half-duplex mode is like a one-lane road with two-directional traffic. While cars are traveling one direction, cars going the other way must wait. In a half-duplex transmission, the entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time.

Example:- Walkie-talkies and CB (citizens band) radios are both half-duplex systems.

In full-duplex mode (also called duplex), both stations can transmit and receive simultaneously. The full-duplex mode is like a two-way street with traffic flowing in both directions at the same time.

In full-duplex mode, signals going in either direction share the capacity of the link. This sharing can occur in two ways: Either the link must contain two physically separate transmission paths, one for sending and the other for receiving: or the capacity of the channel is divided between signals traveling in both directions.

Example:- One common example of full-duplex communication is the telephone network. When two people are communicating by a telephone line, both can talk and listen at the same time.

1-2 NETWORKS

A network is a set of devices (often referred to as nodes) connected by communication links. A node can be a computer, printer, or any other device capable of sending and/or receiving data generated by other nodes on the network. A link can be a cable, air, optical fiber, or any medium which can transport a signal carrying information.

Topics discussed in this section:

- **Network Criteria**
- **Physical Structures**
- **Categories of Networks**

Network Criteria

Performance:- Performance can be measured in many ways, including transit time and response time.

Transit time is the amount of time required for a message to travel from one device to another.

Response time is the elapsed time between an inquiry and a response.

The performance of a network depends on a number of factors, including the number of users, the type of transmission medium, the capabilities of the connected hardware, and the efficiency of the software.

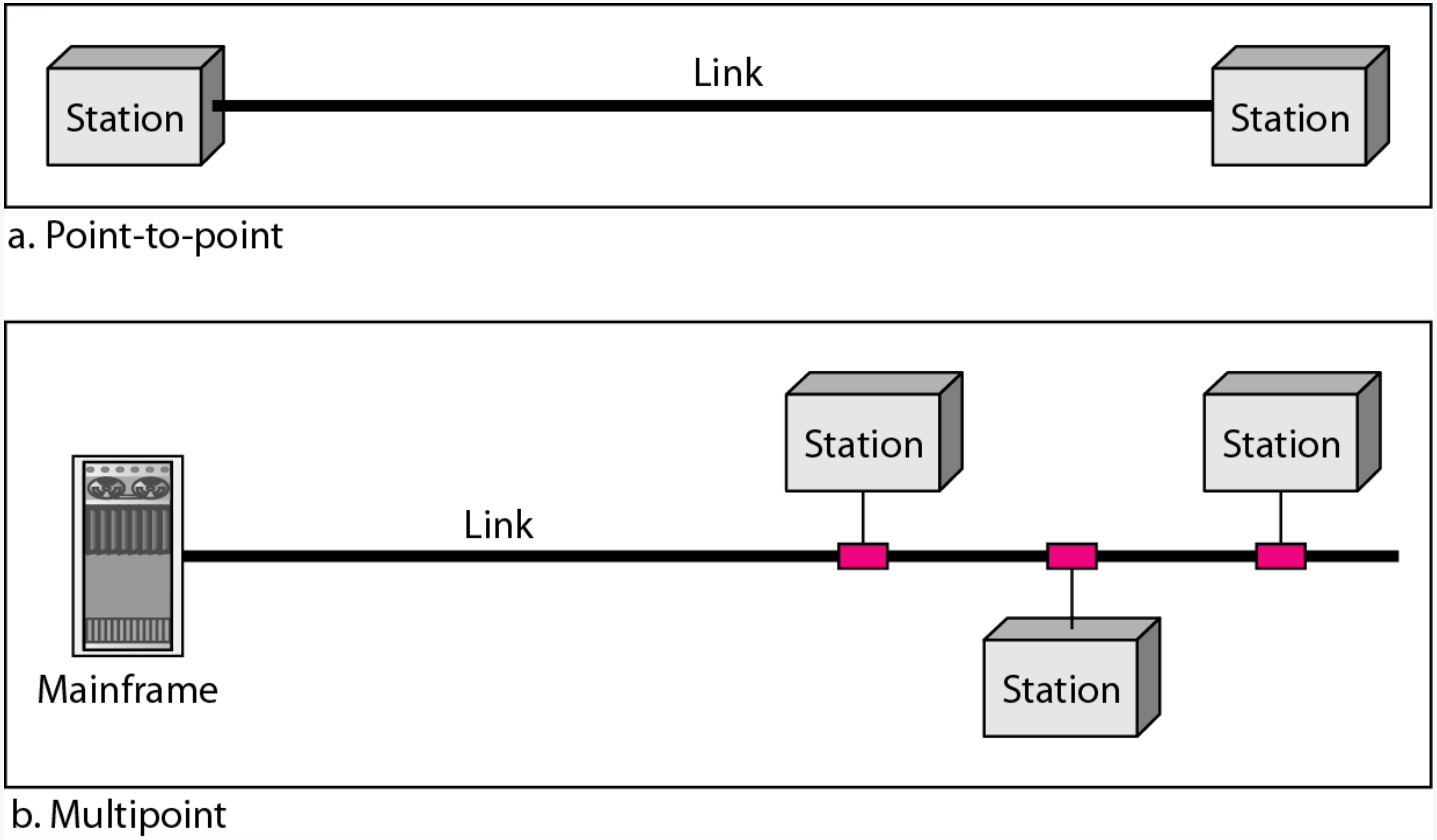
- Reliability:- In addition to accuracy of delivery, network reliability is measured by the frequency of failure, the time it takes a link to recover from a failure, and the network's robustness in a catastrophe.

- Security:- Network security issues include protecting data from unauthorized access.

Physical Structures

- Type of Connection
  - Point to Point - single transmitter and receiver
  - Multipoint - multiple recipients of single transmission
- Physical Topology
  - Connection of devices
  - Type of transmission - unicast, mulitcast, broadcast

Figure 1.3 *Types of connections: point-to-point and multipoint*



Point-to-Point:- A point-to-point connection provides a dedicated link between two devices.
The entire capacity of the link is reserved for transmission between those two devices.
Most point-to-point connections use an actual length of wire or cable to connect the two ends, but other options, such as microwave or satellite links, are also possible.

Example:- When you change television channels by infrared remote control, you are establishing a point-to-point connection between the remote control and the television's control system.

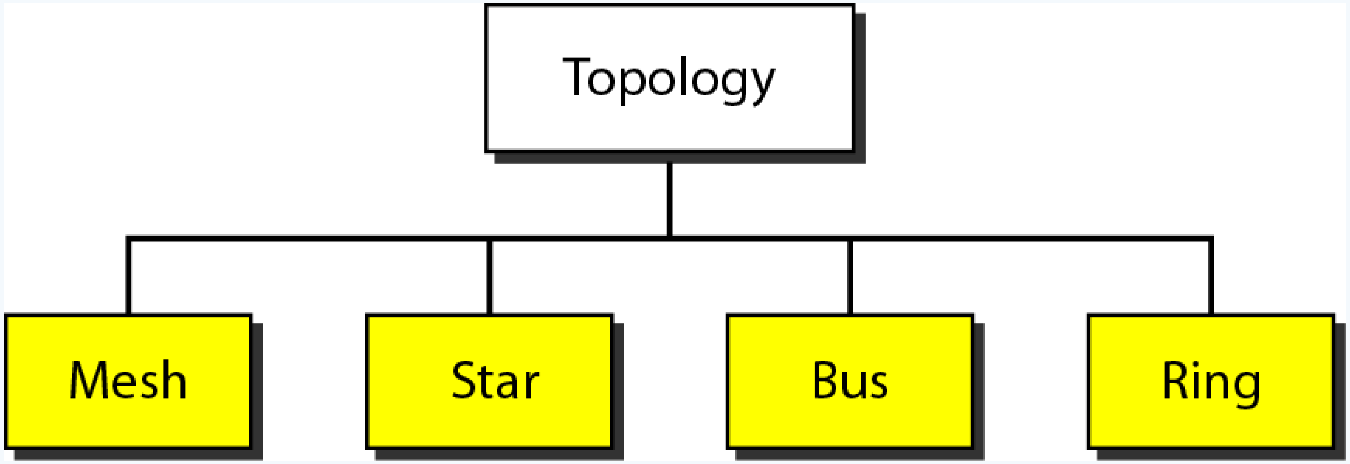
Multipoint:- A multipoint (also called multidrop) connection is one in which more than two specific devices share a single link.

In a multipoint environment, the capacity of the channel is shared, either spatially or temporally.

If several devices can use the link simultaneously, it is a spatially shared connection. If users must take turns, it is a timeshare connection.

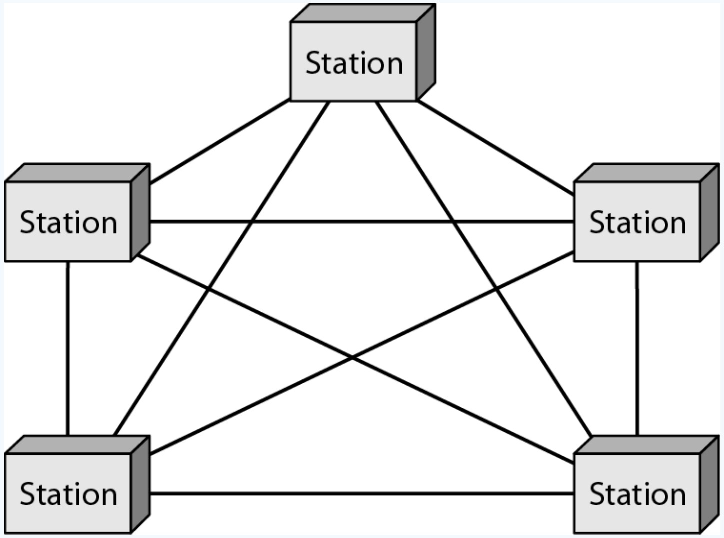
Categories of topology

The term physical topology refers to the way in which a network is laid out physically. Two or more devices connect to a link; two or more links form a topology. The topology of a network is the geometric representation of the relationship of all the links and linking devices (usually called nodes) to one another. There are four basic topologies possible: mesh, star, bus, and ring.



Mesh Topology

Mesh:- In a mesh topology, every device has a dedicated point-to-point link to every other device. The term dedicated means that the link carries traffic only between the two devices it connects. A fully connected mesh network therefore has n(n-1)/2 physical channels to link n devices.



Advantages

The use of dedicated links guarantees that each connection can carry its own data load, thus eliminating the traffic problems that can occur when links must be shared by multiple devices.

A mesh topology is robust. If one link becomes unusable, it does not incapacitate the entire system.

There is the advantage of privacy or security. When every message travels along a dedicated line, only the intended recipient sees it.

Point-to-point links make fault identification and fault isolation easy.

Disadvantages

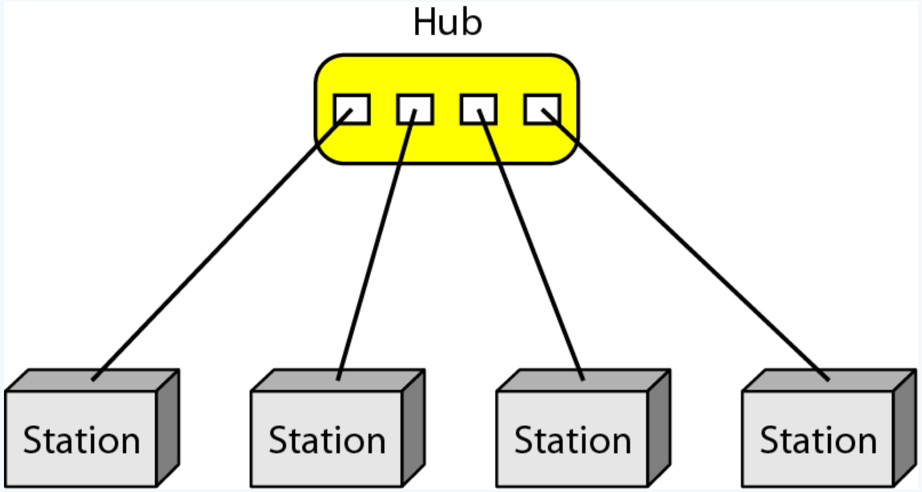
Amount of cabling and the number of I/O ports required.

The sheer bulk of the wiring can be greater than the available space (in walls, ceilings, or floors) can accommodate.

The hardware required to connect each link (I/O ports and cable) can be prohibitively expensive.

Star topology

Star:- In a star topology, each device has a dedicated point-to-point link only to a central controller, usually called a hub. The devices are not directly linked to one another. Unlike a mesh topology, a star topology does not allow direct traffic between devices. The controller acts as an exchange: If one device wants to send data to another, it sends the data to the controller, which then relays the data to the other connected device.



Advantages

A star topology is less expensive than a mesh topology. In a star, each device needs only one link and one I/O port to connect it to any number of others. This factor also makes it easy to install and reconfigure.

Far less cabling needs to be housed, and additions, moves, and deletions involve only one connection: between that device and the hub.

Other advantages include robustness. If one link fails, only that link is affected. All other links remain active.

Disadvantages

The dependency of the whole topology bon one single point, the hub. If the hub goes down, the whole system is dead.

Although a star requires far less cable than a mesh, each node must be linked to a central hub.

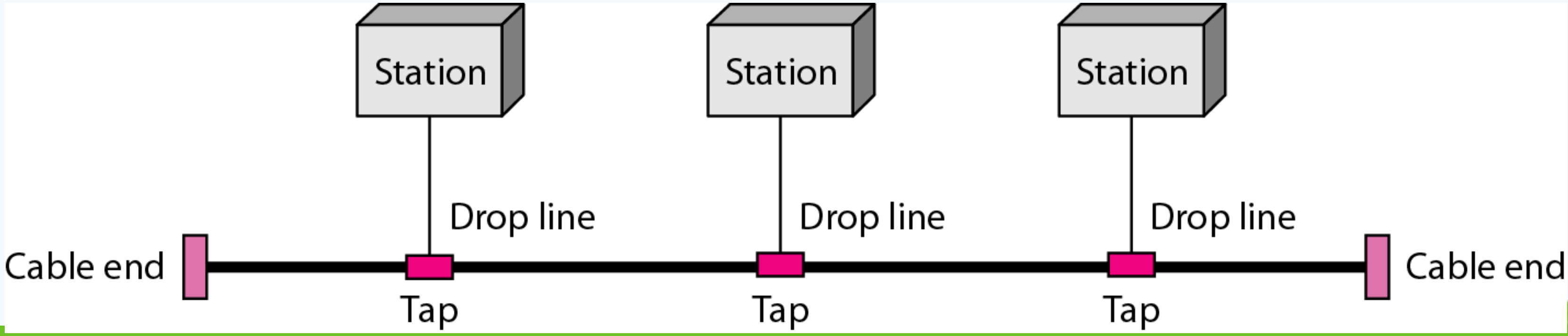
Bus topology

A bus topology, on the other hand, is multipoint. One long cable acts as a backbone to link all the devices in a network.

Nodes are connected to the bus cable by drop lines and taps.

A drop line is a connection running between the device and the main cable.

A tap is a connector that either splices into the main cable or punctures the sheathing of a cable to create a contact with the metallic core.



As a signal travels along the backbone, some of its energy is transformed into heat. Therefore, it becomes weaker and weaker as it has to travel farther and farther. For this reason there is a limit on the number of taps a bus can support and on the distance between those taps.

Advantages

Bus topology includes ease of installation.

A bus uses less cabling than mesh or star topologies.

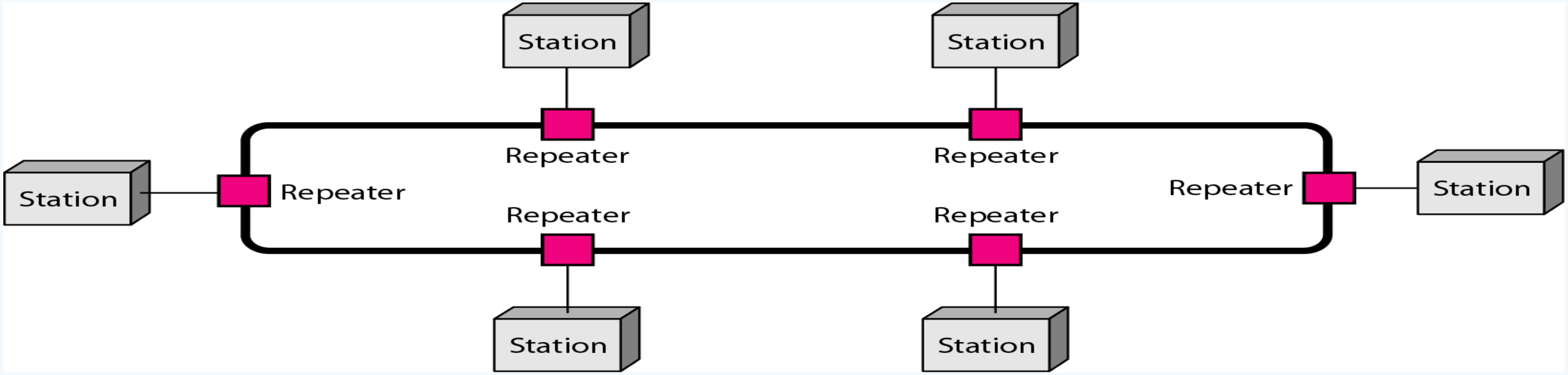
Disadvantages

Difficult reconnection and fault isolation.

A fault or break in the bus cable stops all transmission, even between devices on the same side of the problem.

Ring topology

Ring:- In a ring topology, each device has a dedicated point-to-point connection only with the two devices on either side of it. A signal is passed along the ring in one direction, from device to device, until it reaches its destination. Each device in the ring incorporates a repeater. When a device receives a signal intended for another device, its repeater regenerates the bits and passes them along .



Advantages

A ring is relatively easy to install and reconfigure.

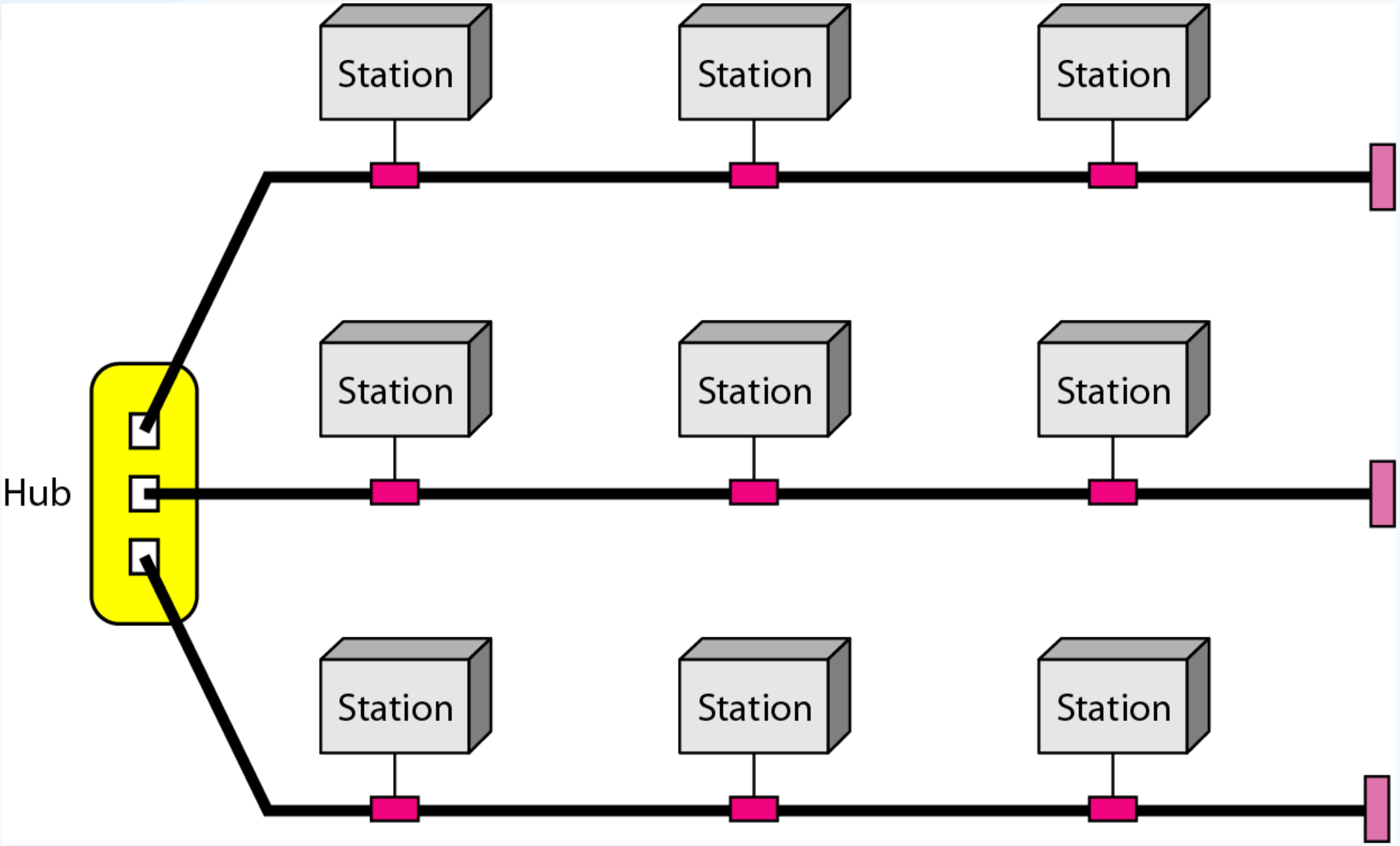
Fault isolation is simplified.

Disadvantages

Unidirectional traffic can be a disadvantage.

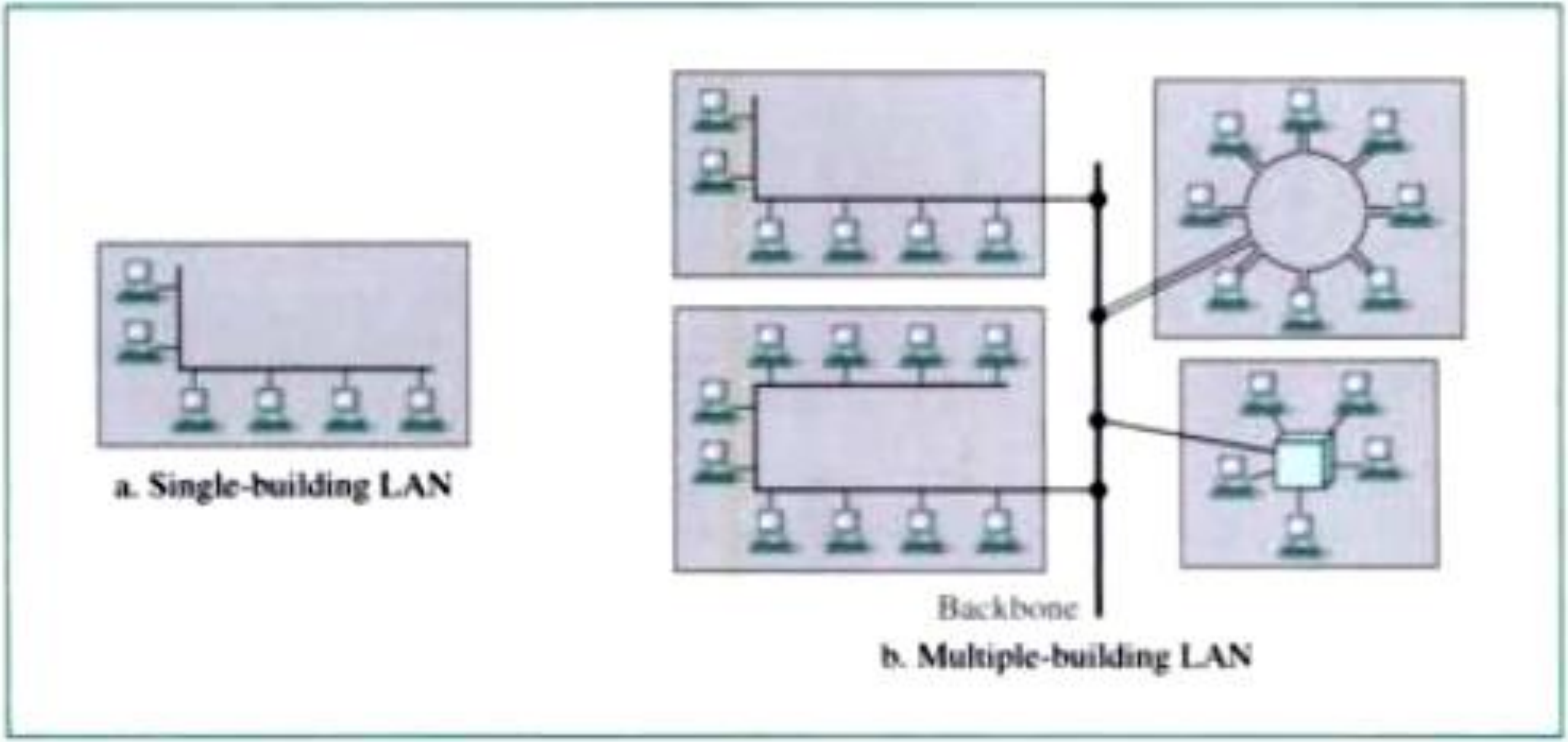
In a simple ring, a break in the ring (such as a disabled station) can disable the entire network.

Figure 1.9 *A hybrid topology: a star backbone with three bus networks*



Categories of Networks

- **Local Area Networks (LANs)**
- (LAN) is usually privately owned and links the devices in a single office, building, or campus.
- LANs are designed to allow resources to be shared between personal computers or workstations.
- The resources to be shared can include hardware (e.g., a printer), software (e.g., an application program), or data.
- A common example of a LAN, found in many business environments, links a workgroup of task-related computers, for example, engineering workstations or accounting PCs.



LAN have data rates in the range 4 to 16 MBPS. However today it reach to 100MBPS.

Wide Area Networks (WANs)

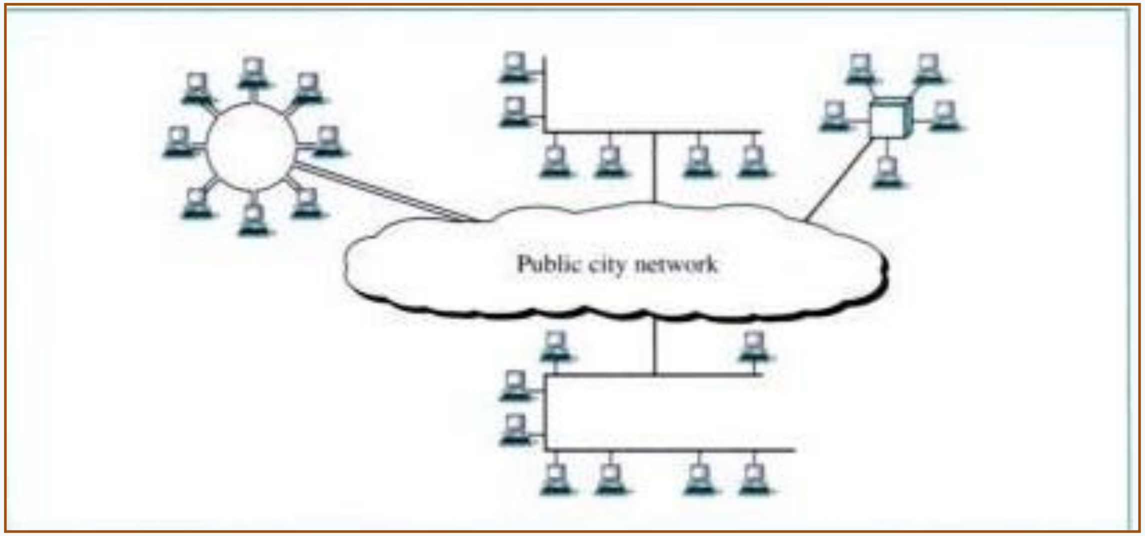
- (WAN) provides long-distance transmission of data, image, audio, and video information over large geographic areas that may comprise a country, a continent, or even the whole world.

- In contrast to LAN, WANs may utilize public, leased or private communication equipment, usually in combination.

Metropolitan Area Networks (MANs)

- A **metropolitan area network** (MAN) is a network with a size between a LAN and a WAN. It normally covers the area inside a town or a city.
- It is designed for customers who need a high-speed connectivity, normally to the Internet, and have endpoints spread over a city or part of city. A good example of a MAN is the part of the telephone company network that can provide a high-speed DSL line to the customer.

A MAN may be wholly owned and operated by a private company, or it may be a service provided by a public company, such as local telephone company or cable network.



1-4 PROTOCOLS

A protocol is synonymous with rule. It consists of a set of rules that govern data communications. It determines what is communicated, how it is communicated and when it is communicated. The key elements of a protocol are syntax, semantics and timing.

Topics discussed in this section:

- **Syntax**
- **Semantics**
- **Timing**

Elements of a Protocol

- Syntax
  - Structure or format of the data
  - Indicates how to read the bits - field delineation
  - It means first 8 bits of data represent sender address, next 8 bits of data represent destination address and remanning is data.
- Semantics
  - Interprets the meaning of the bits
  - Knows which fields define what action
- Timing
  - When data should be sent and how fast they can be sent
  - Speed at which data should be sent or speed at which it is being received.

Standards

- Standards are essential in creating and maintaining an open and competitive market for equipment manufacturers and in guaranteeing national and international interoperability of data and telecommunications technology and processes.
- They provide guidelines to manufacturers, vendors, government agencies, and other service providers to ensure the kind of interconnectivity necessary in today's marketplace and in international communications.
- Data communication standards fall into two categories: de facto (meaning "by fact" or "by convention") and de jure (meaning "by law" or "by regulation").

- De facto. Standards that have not been approved by an organized body but have been adopted as standards through widespread use are de facto standards.
- De facto standards are often established originally by manufacturers that seek to define the functionality of a new product or technology.
- De jure. Those that have been legislated by an officially recognized body are de jure standards.

Standard Organization

- International Organization for Standardization (ISO). The ISO is active in developing cooperation in the realms of scientific, technological, and economic activity.
- International Telecommunication Union-Telecommunication Standards Sector (ITU-T).
- American National Standards Institute (ANSI). Despite its name, the American National Standards Institute is a completely private, nonprofit corporation not affiliated with the U.S. federal government.
- Institute of Electrical and Electronics Engineers (IEEE). The Institute of Electrical and Electronics Engineers is the largest professional engineering society in the world.
- Electronic Industries Association (EIA). Aligned with ANSI, the Electronic Industries Association is a nonprofit organization devoted to the promotion of electronics manufacturing concerns.

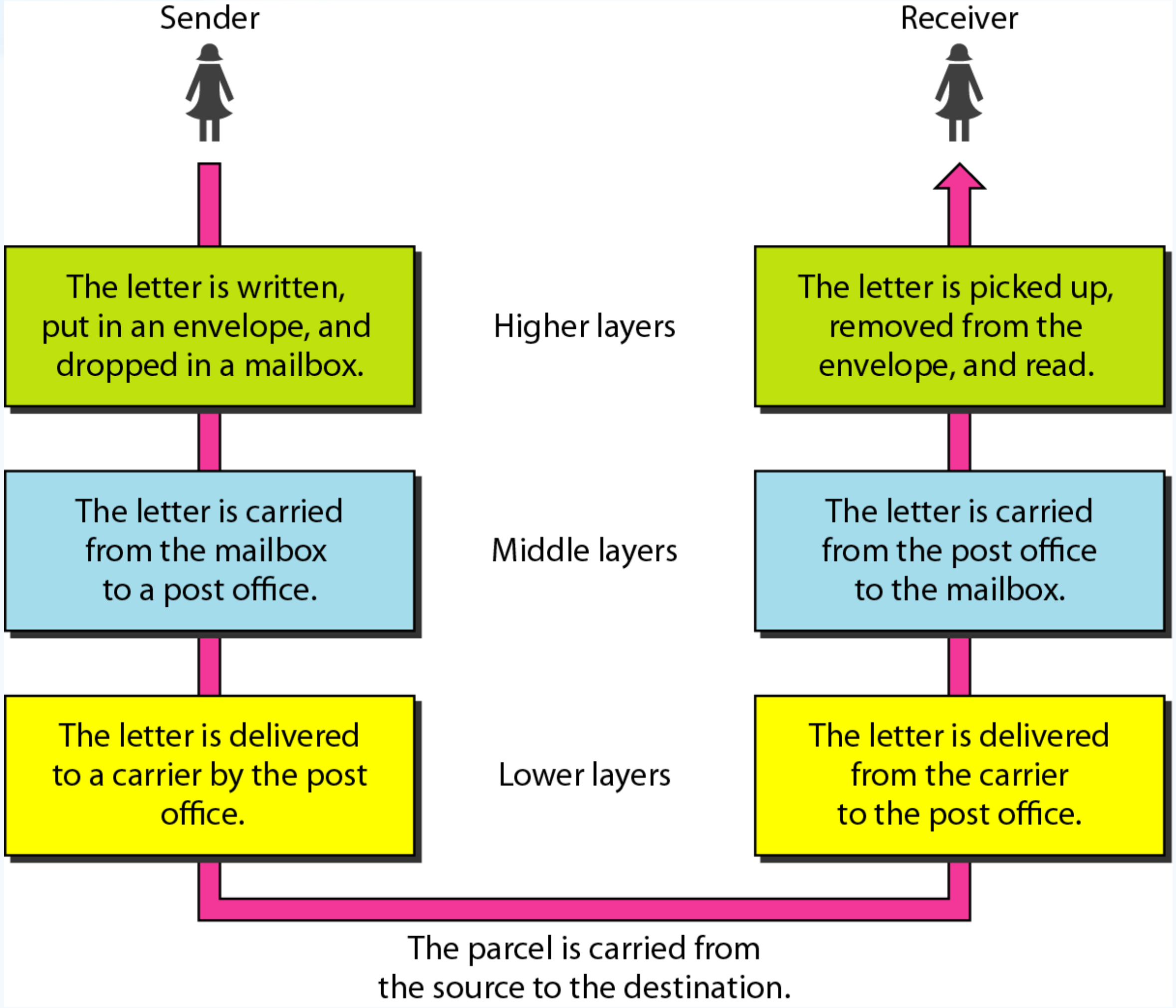
LAYERED TASKS

We use the concept of layers in our daily life. As an example, let us consider two friends who communicate through postal mail. The process of sending a letter to a friend would be complex if there were no services available from the post office.

Sender, Receiver, and Carrier

It is obvious that we have a sender, a receiver, and a carrier that transports the letter. There is a hierarchy of tasks.

Tasks involved in sending a letter



At the Sender Site

Higher layer:- The sender writes the letter, inserts the letter in an envelope, writes the sender and receiver addresses, and drops the letter in a mailbox.

Middle layer:- The letter is picked up by a letter carrier and delivered to the post office.

Lower layer:- The letter is sorted at the post office; a carrier transports the letter.

Between Process:- Transportation (train, bus or plane)

At the Receiver Site

Lower layer:- The carrier transports the letter to the post office. Middle layer:- The letter is sorted and delivered to the recipient's mailbox. Higher layer. The receiver picks up the letter, opens the envelope, and reads it.

Network Models

- A network uses a combination of hardware and software to send data from one location to another.
- The hardware consists of the physical equipment that carries signals from one point of the network to another.
- However, the services that we expect from a network are more complex than just sending a signal from a source computer to a destination computer.
- In addition to hardware, we need software.
- The task of sending an email from one point in the world to another can be broken into several tasks, each performed by a separate software package.
- This is actually performed by layer architecture in Computer Network.

THE OSI MODEL

Established in 1947, the International Standards Organization (ISO) is a multinational body dedicated to worldwide agreement on international standards. An ISO standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model. It was first introduced in the late 1970s.

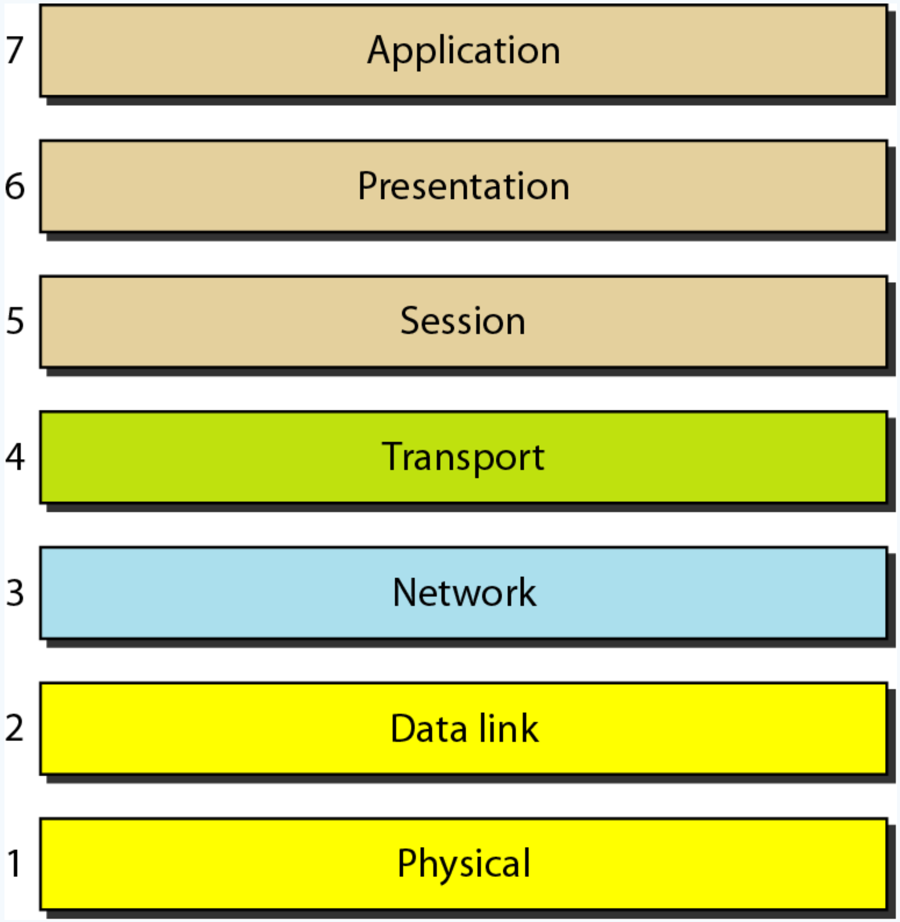
Note

ISO is the organization.
OSI is the model.

OSI Model

- An open system is a set of protocols that allows any two different systems to communicate regardless of their underlying architecture.
- The purpose of the OSI model is to show how to facilitate communication between different systems without requiring changes to the logic of the underlying hardware and software.
- The OSI model is not a protocol; it is a model for understanding and designing a network architecture that is flexible, robust, and interoperable.

Seven layers of the OSI model



gure 2.3 The interaction between layers in the OSI model

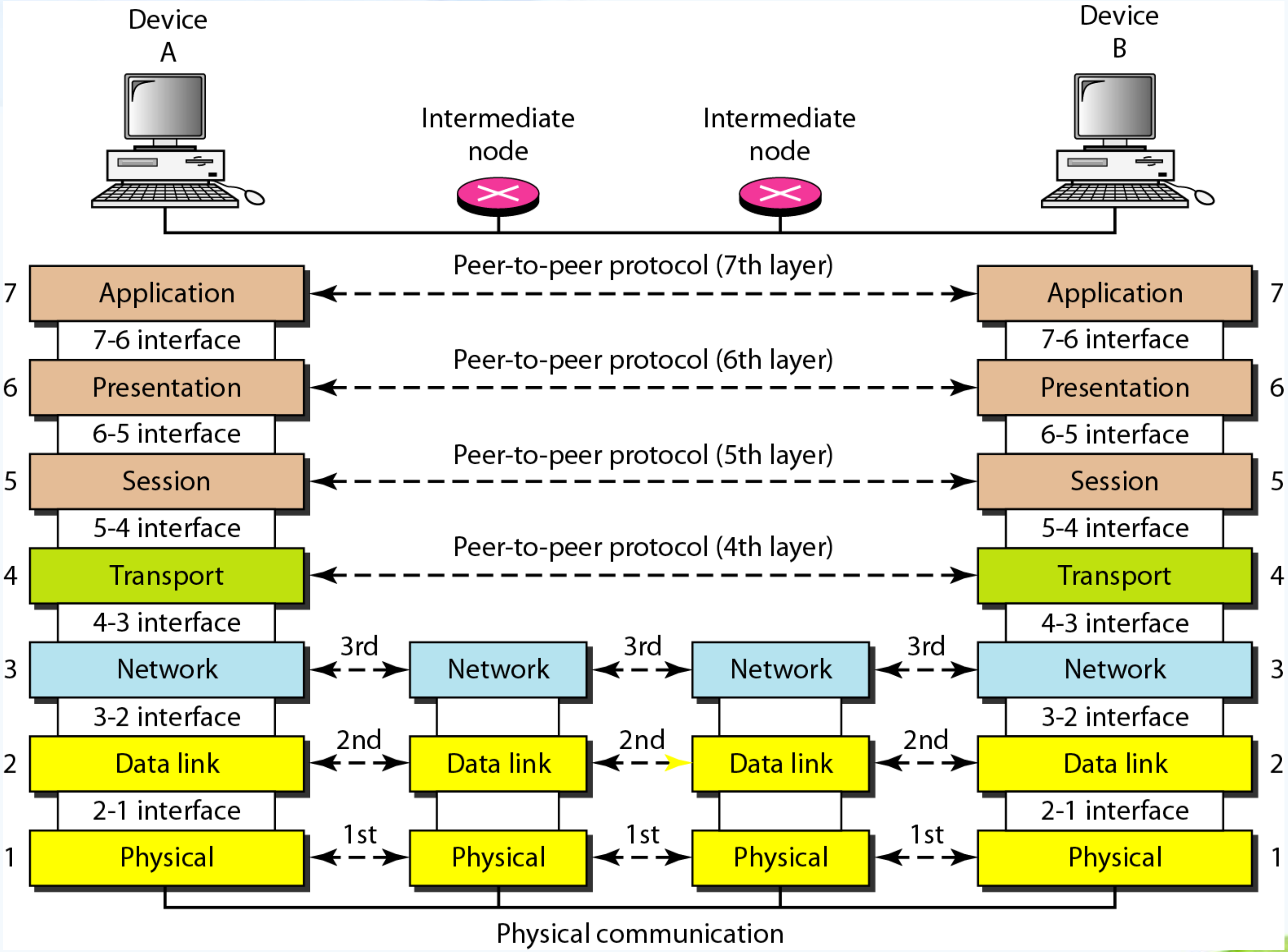
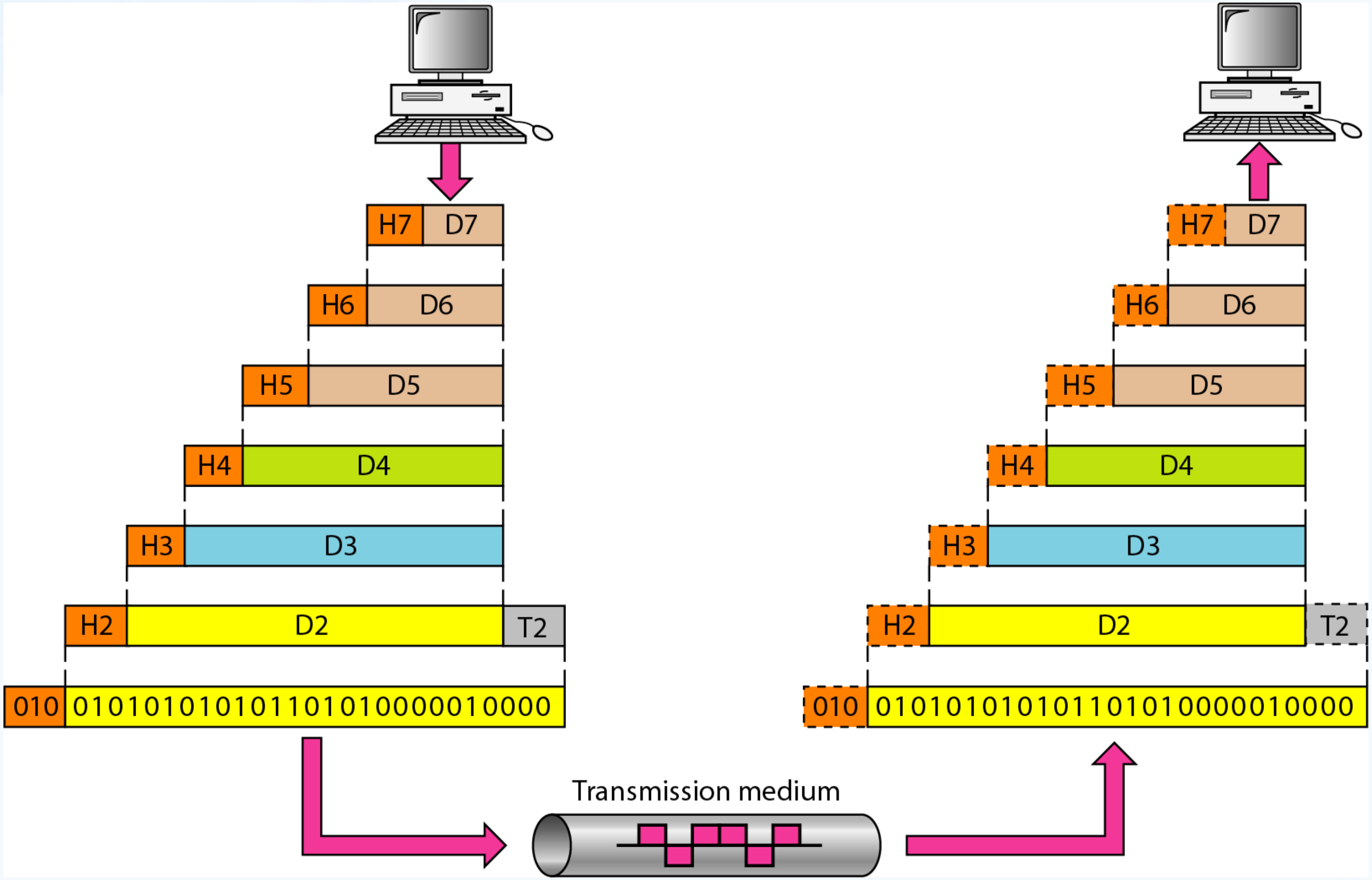


Figure 2.4 An exchange using the OSI model



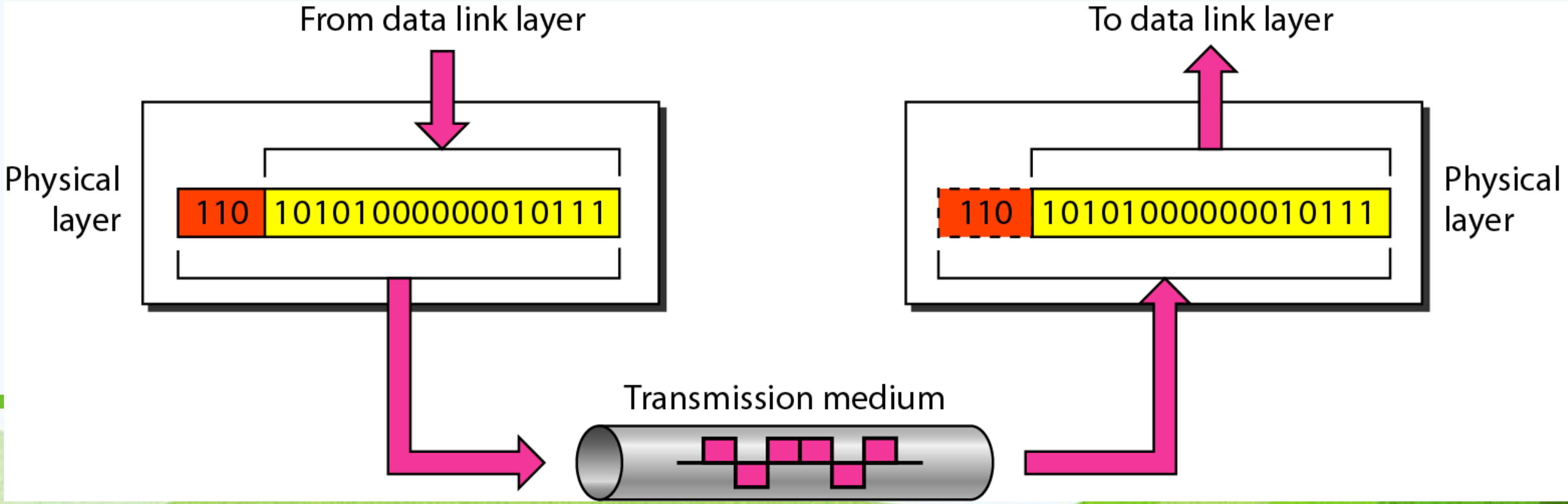
LAYERS IN THE OSI MODEL

In this section we briefly describe the functions of each layer in the OSI model.

Topics discussed in this section:

Physical Layer
Data Link Layer
Network Layer
Transport Layer
Session Layer
Presentation Layer
Application Layer

Physical layer



The major duties performed by Physical Layer are as follows:-

Physical characteristics of interfaces and medium: The physical layer defines the characteristics of the interface between the devices and the transmission medium. It also defines the type of transmission medium.

Representation of bits: The physical layer data consists of a stream of bits (sequence of 0s or 1s) with no interpretation. To be transmitted, bits must be encoded into signals-electrical or optical.

The physical layer defines the type of encoding.

Data rate: The transmission rate-the number of bits sent each second-is also defined by the physical layer. In other words, the physical layer defines the duration of a bit, which is how long it lasts.

Synchronization of bits: The sender and receiver not only must use the same bit rate but also must be synchronized at the bit level. In other words, the sender and the receiver clocks must be synchronized.

Line configuration: The physical layer is concerned with the connection of devices to the media. In a point-to-point configuration, two devices are connected through a dedicated link. In a multipoint configuration, a link is shared among several devices.

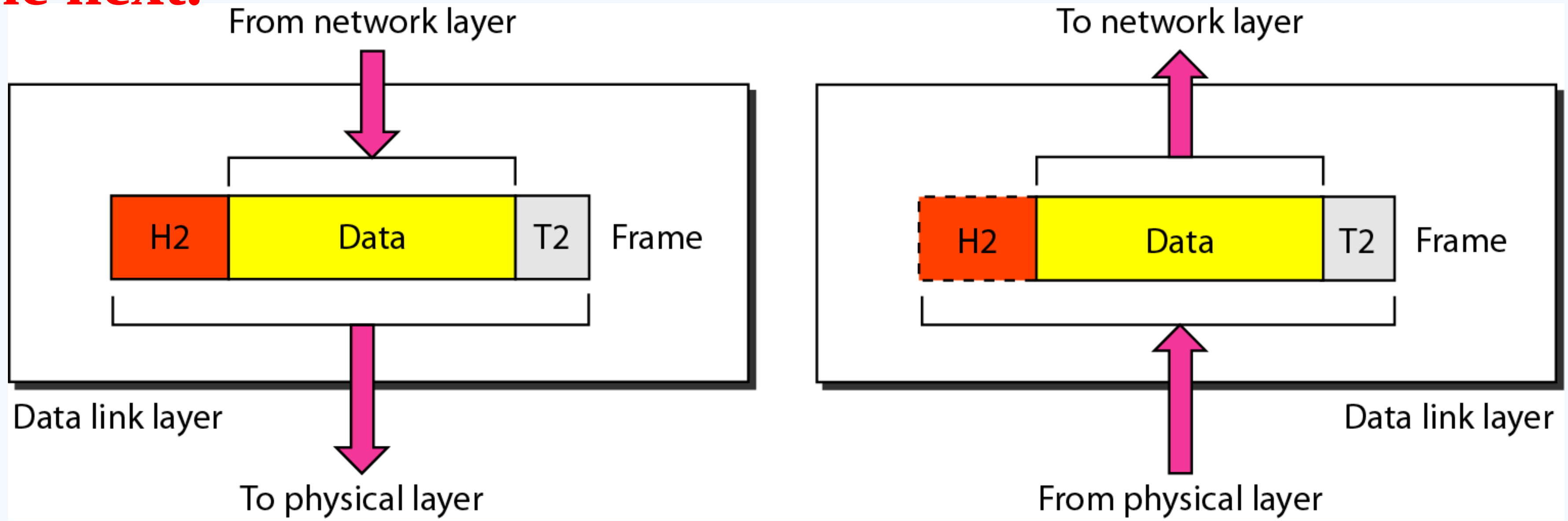
Physical topology: The physical topology defines how devices are connected to make a network.

Transmission mode: The physical layer also defines the direction of transmission between two devices: simplex, half-duplex, or full-duplex.

Data link layer

The data link layer transforms the physical layer, a raw transmission facility, to a reliable link. It makes the physical layer appear error-free to the upper layer (network layer).

Responsible for moving frames from one hop (node) to the next.



Other responsibilities of the data link layer include the following:

Framing: The data link layer divides the stream of bits received from the network layer into manageable data units called frames.

Physical addressing: If frames are to be distributed to different systems on the network, the data link layer adds a header to the frame to define the sender and/or receiver of the frame.

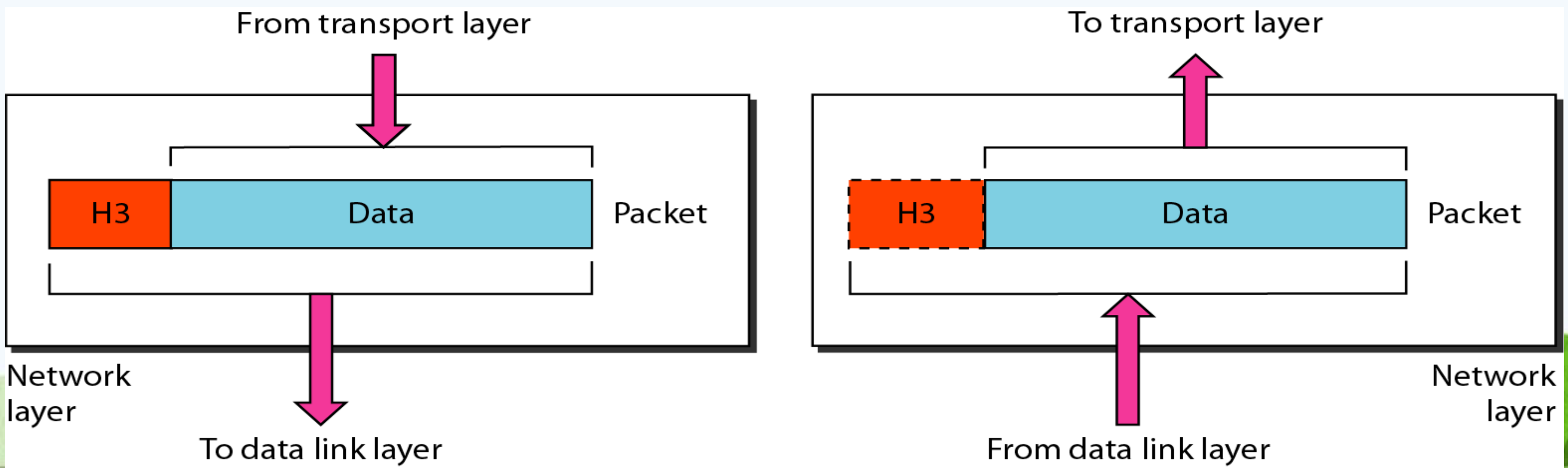
Flow control: If the rate at which the data are absorbed by the receiver is less than the rate at which data are produced in the sender, the data link layer imposes a flow control mechanism to avoid overwhelming the receiver.

Error control: The data link layer adds reliability to the physical layer by adding mechanisms to detect and retransmit damaged or lost frames. It also uses a mechanism to recognize duplicate frames. Error control is normally achieved through a trailer added to the end of the frame.

Access control: When two or more devices are connected to the same link, data link layer protocols are necessary to determine which device has control over the link at any given time.

Network layer

The network layer is **responsible for the source-to-destination delivery of a packet, possibly across multiple networks (links).** Whereas the data link layer oversees the delivery of the packet between two systems on the same network (links), the network layer ensures that each packet gets from its point of origin to its final destination.



Other responsibilities of the network layer include the following:

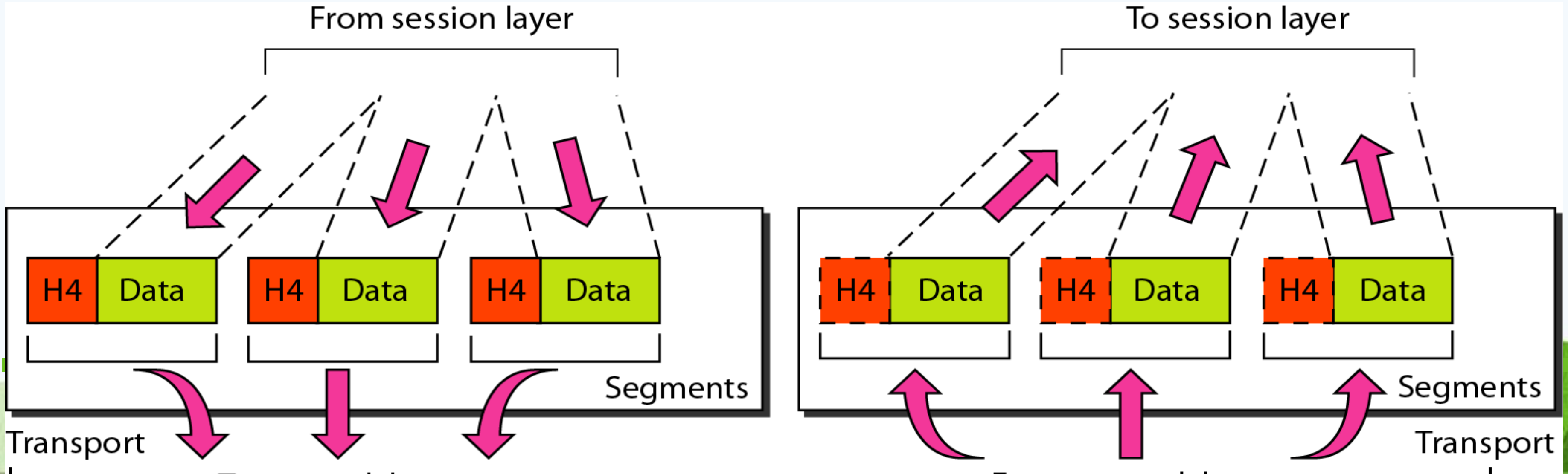
Logical addressing. The physical addressing implemented by the data link layer handles the addressing problem locally. If a packet passes the network boundary, we need another addressing system to help distinguish the source and destination systems. The network layer adds a header to the packet coming from the upper layer that, among other things, includes the logical addresses of the sender and receiver.

Routing. When independent networks or links are connected to create internetworks (network of networks) or a large network, the connecting devices (called routers or switches) route or switch the packets to their final destination. One of the functions of the network layer is to provide this mechanism.

Transport layer

The transport layer is responsible for process-to-process delivery of the entire message.

A process is an application program running on a host. Whereas the network layer oversees source-to-destination delivery of individual packets, it does not recognize any relationship between those packets.



Other responsibilities of the transport layer include the following:

Service-point addressing: Computers often run several programs at the same time. For this reason, source-to-destination delivery means delivery not only from one computer to the next but also from a specific process (running program) on one computer to a specific process (running program) on the other. The transport layer header must therefore include a type of address called a service-point address (or port address). The network layer gets each packet to the correct computer; the transport layer gets the entire message to the correct process on that computer.

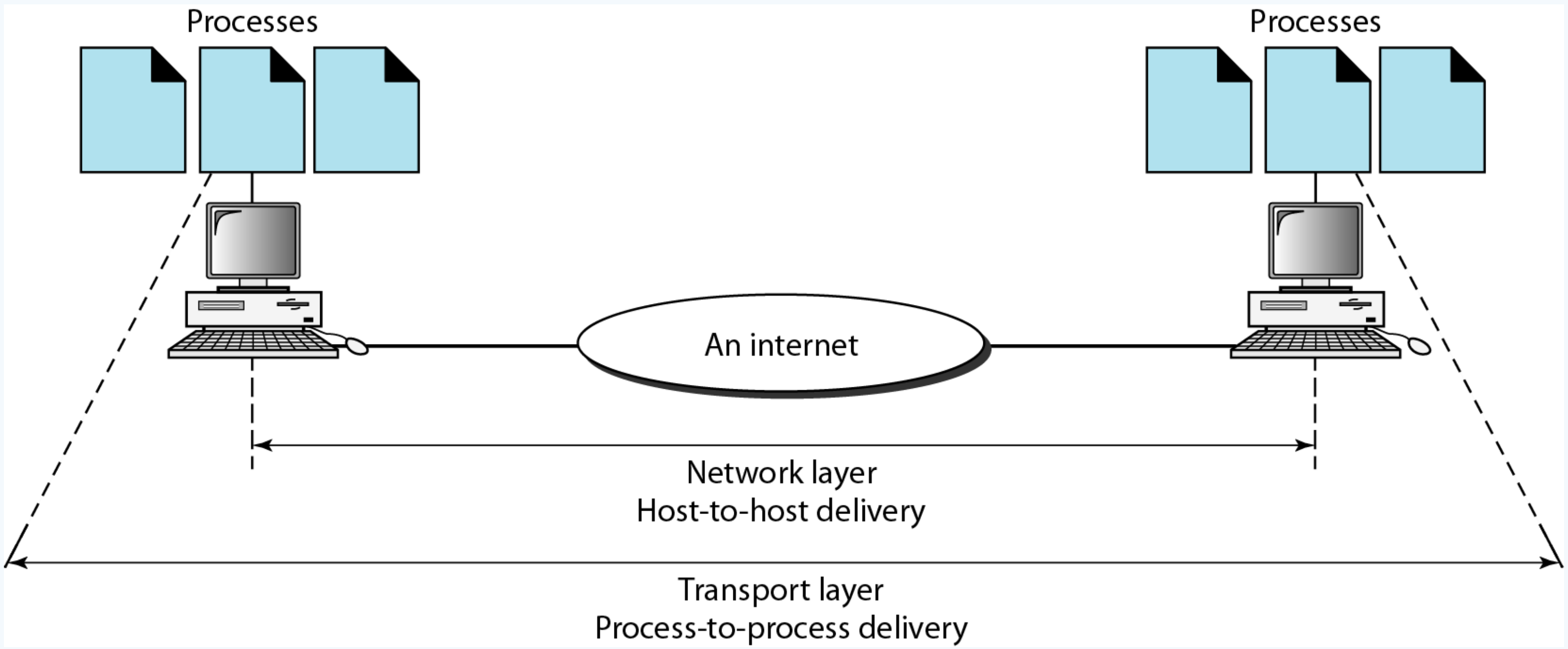
Segmentation and reassembly: A message is divided into transmittable segments, with each segment containing a sequence number. These numbers enable the transport layer to reassemble the message correctly upon arriving at the destination and to identify and replace packets that were lost in transmission.

Connection control: The transport layer can be either connectionless or connection oriented. A connectionless transport layer treats each segment as an independent packet and delivers it to the transport layer at the destination machine. A connection oriented transport layer makes a connection with the transport layer at the destination machine first before delivering the packets. After all the data are transferred, the connection is terminated.

Flow control: Like the data link layer, the transport layer is responsible for flow control. However, flow control at this layer is performed end to end rather than across a single link.

Error control: However, error control at this layer is performed process-to process rather than across a single link. The sending transport layer makes sure that the entire message arrives at the receiving transport layer without error (damage, loss, or duplication). Error correction is usually achieved through retransmission.

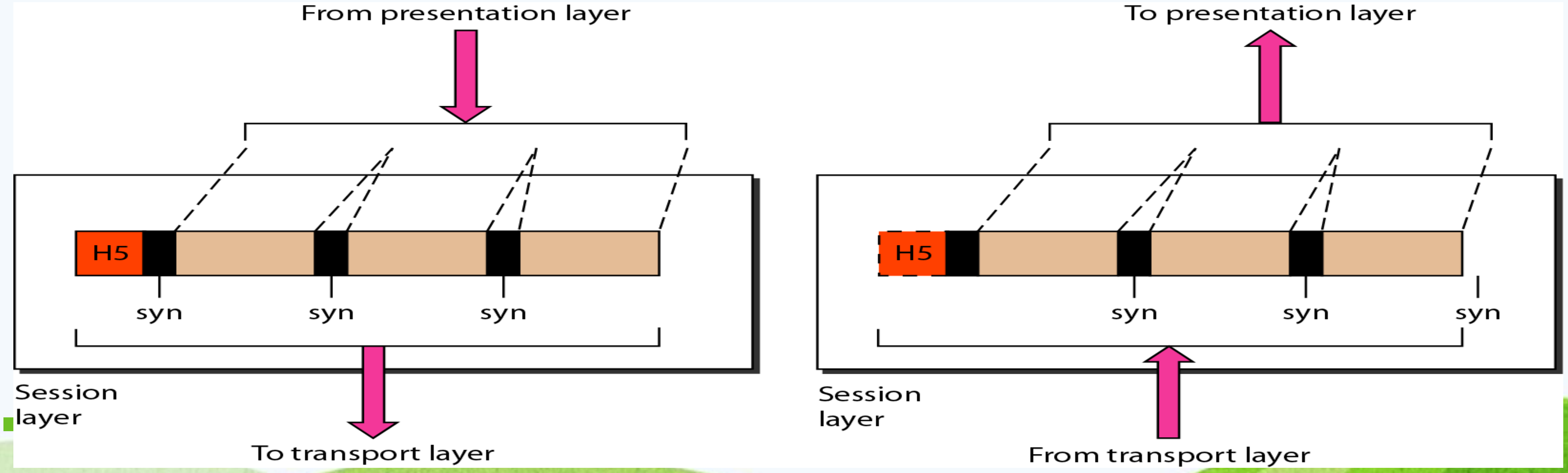
gure 2.11 Reliable process-to-process delivery of a message



Session layer

The services provided by the first three layers (physical, data link, and network) are not sufficient for some processes. The session layer is the network dialog controller. It establishes, maintains, and synchronizes the interaction among communicating systems. The session layer is responsible for dialog control and synchronization.

Also used to establish, manage and terminate sessions.



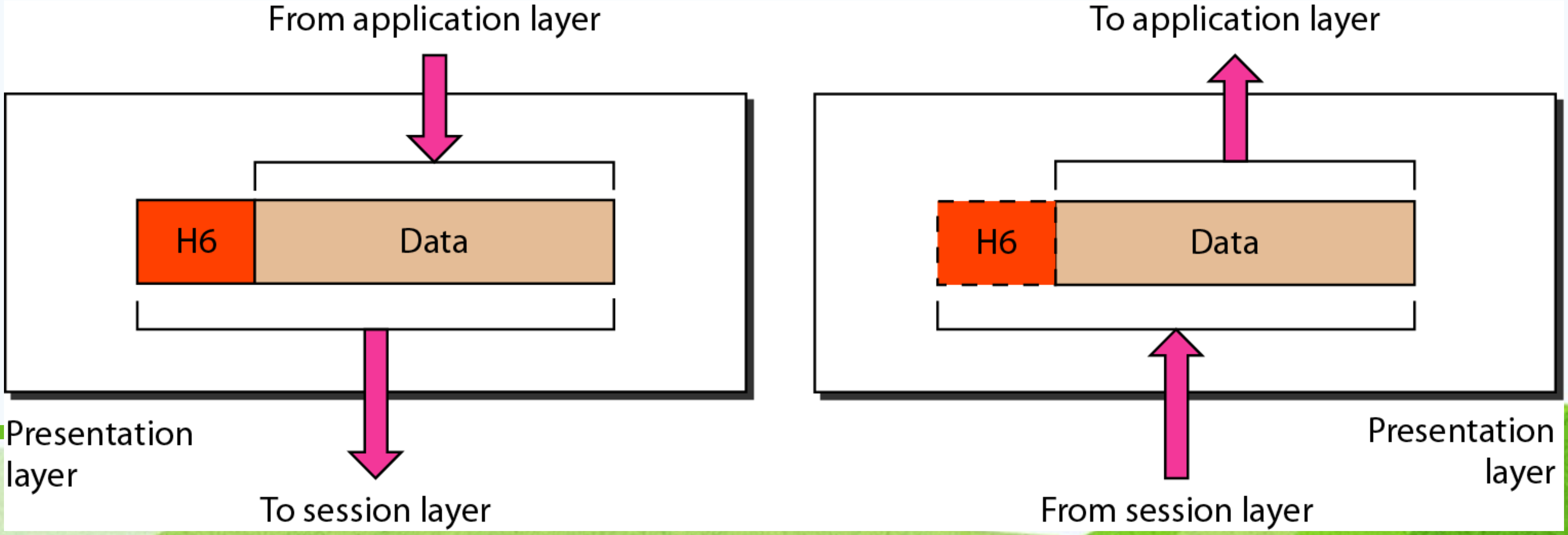
Specific responsibilities of the session layer include the following:

Dialog control: The session layer allows two systems to enter into a dialog. It allows the communication between two processes to take place in either half duplex (one way at a time) or full-duplex (two ways at a time) mode.

Synchronization: The session layer allows a process to add checkpoints, or synchronization points, to a stream of data. For example, if a system is sending a file of 2000 pages, it is advisable to insert checkpoints after every 100 pages to ensure that each 100-page unit is received and acknowledged independently. In this case, if a crash happens during the transmission of page 523, the only pages that need to be resent after system recovery are pages 501 to 523. Pages previous to 501 need not be resent.

Presentation layer

The presentation layer is concerned with the syntax and semantics of the information exchanged between two systems.



Specific responsibilities of the presentation layer include the following:

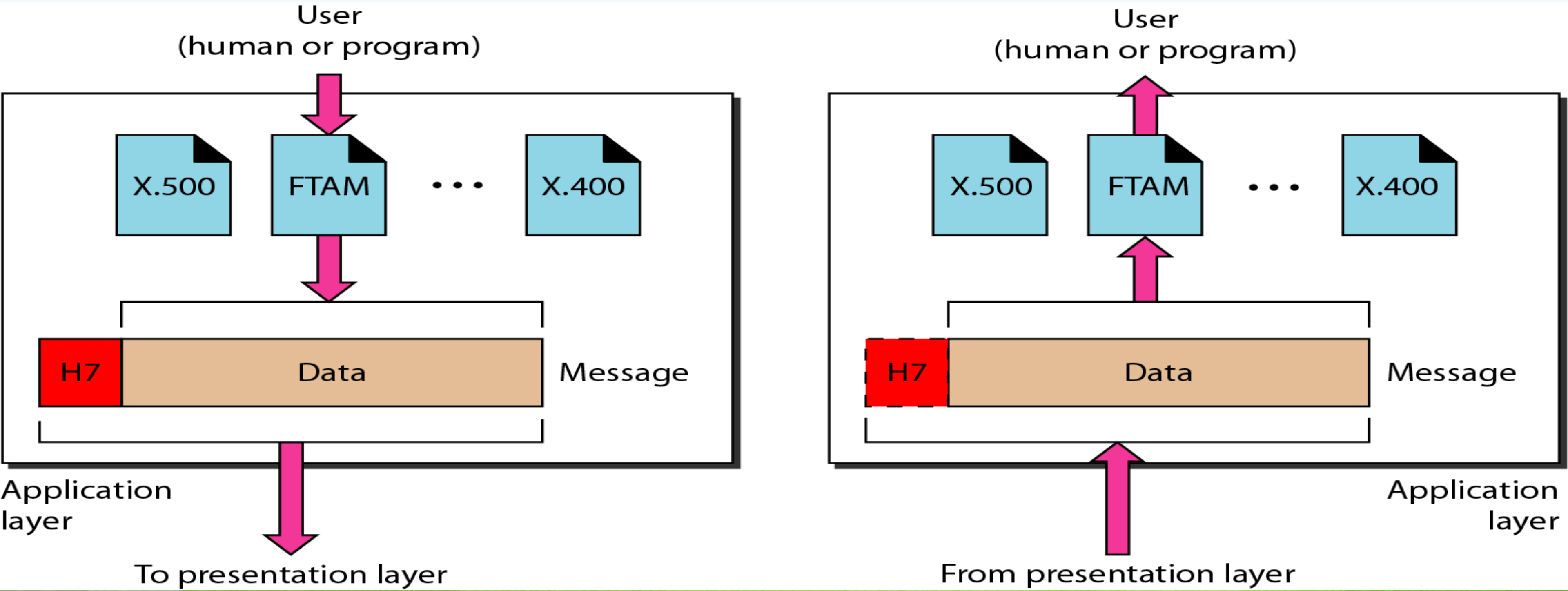
Translation: The processes in two systems are usually exchanging information in the form of character, strings, numbers, and so on. The information must be changed to bit streams before being transmitted. The presentation layer at the sender changes the information from its sender-dependent format into a common format. The presentation layer at the receiving machine changes the common format into its receiver-dependent format.

Encryption: To carry sensitive information, a system must be able to ensure privacy. Encryption means that the sender transforms the original information another form and sends the resulting message out over the network. Decryption reverses the original process to transform the message back to its original form.

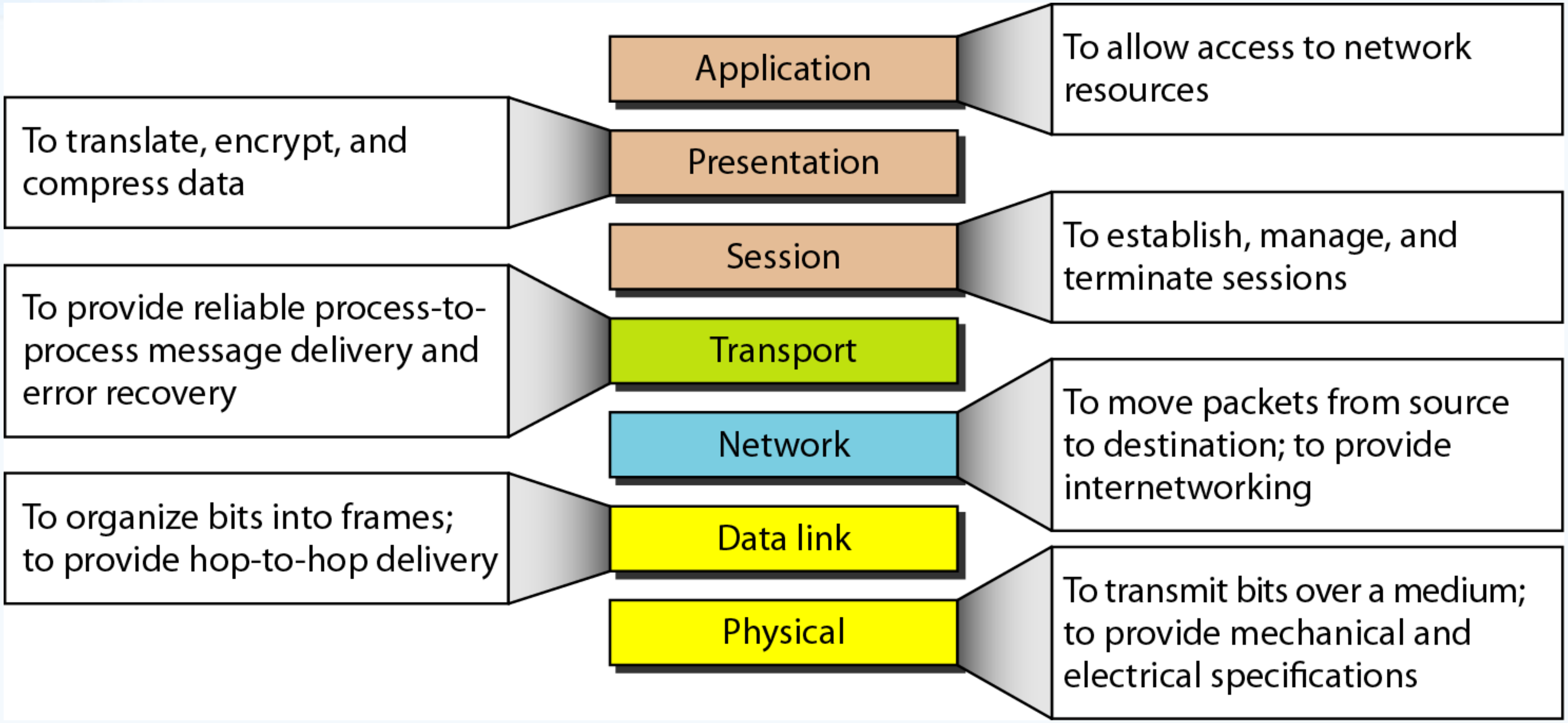
Compression: Data compression reduces the number of bits contained in the information. Data compression becomes particularly important in the transmission of multimedia such as text, audio, and video.

Application layer

The application layer enables the user, whether human or software, to access the network. It provides user interfaces and support for services such as electronic mail, remote file access and transfer, shared database management, and other types of distributed information services, ex. FTAM used for file transfer and management, X.400 for message handling and X.500 for directory services.



Summary of layers

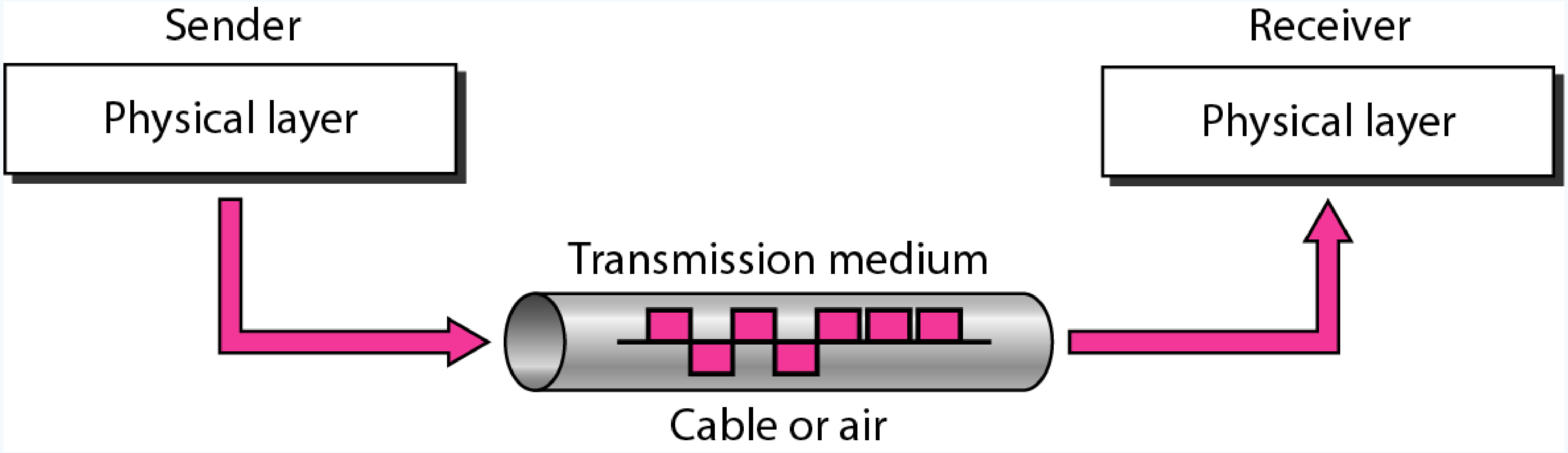


Transmission Media

A transmission **medium** can be broadly defined as anything that can carry information from a source to a destination.

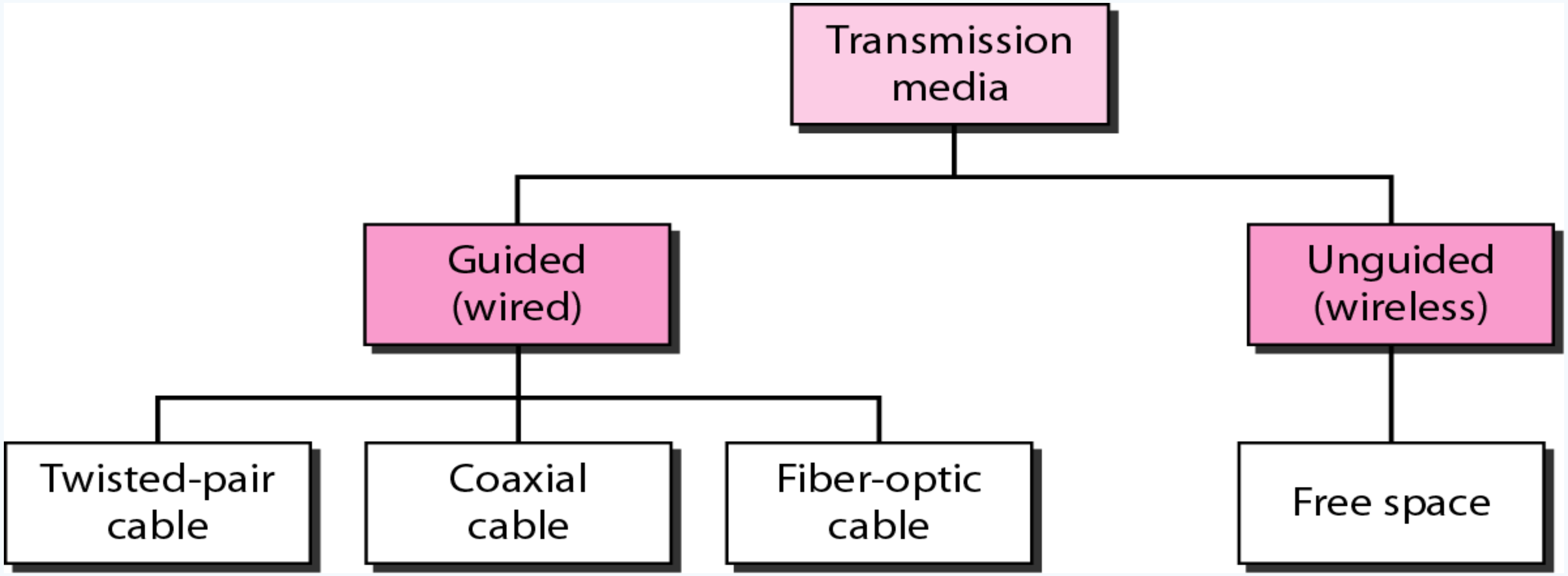
For example, the transmission medium for two people having a dinner conversation is the air.

For a written message, the transmission medium might be a mail carrier, a truck, or an airplane.



Classification of transmission media

In telecommunications, transmission media can be divided into two broad categories: **guided and unguided**. Guided media include **twisted-pair cable**, **coaxial cable**, and **fiber-optic cable**.
Unguided medium is free space. Below Figure shows this taxonomy.



7-1 GUIDED MEDIA

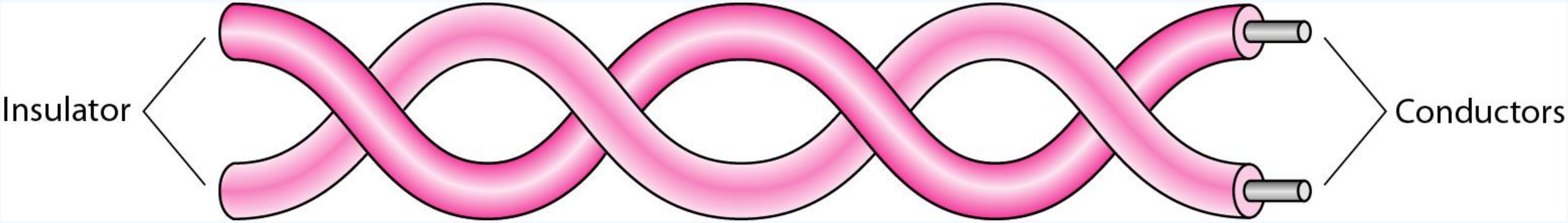
Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.

Twisted-Pair Cable
Coaxial Cable
Fiber-Optic Cable

Twisted-pair cable

A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in below figure.

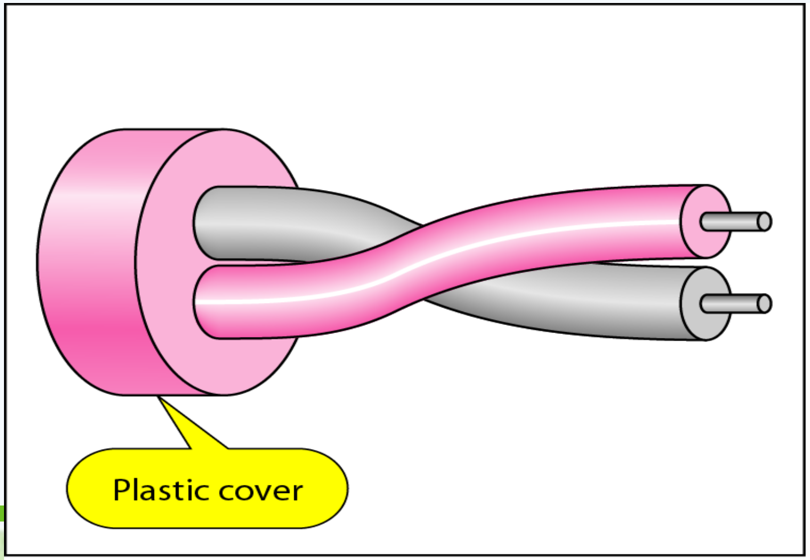
One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference. In addition to the signal sent by the sender on one of the wires, interference (noise) and crosstalk may affect both wires and create unwanted signals.



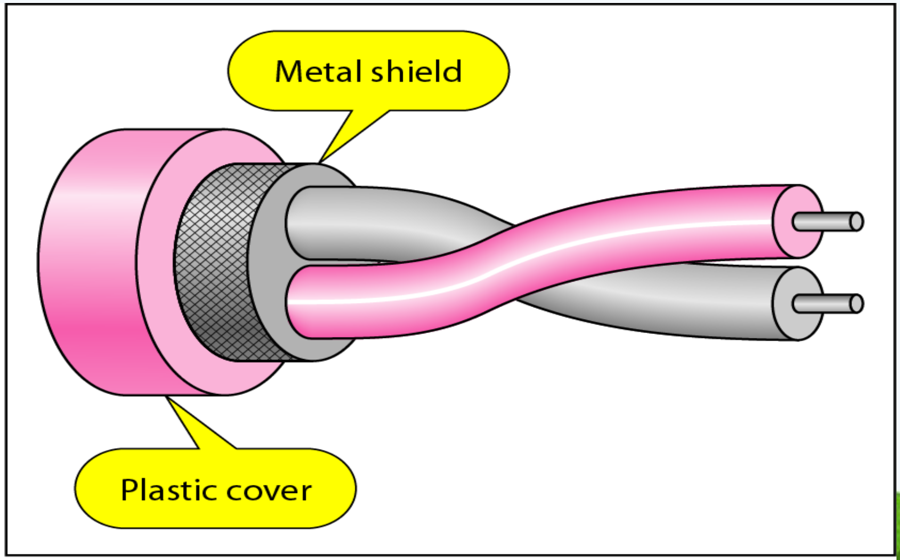
Unshielded Versus Shielded Twisted-Pair Cable *UTP and STP cables*

The most common twisted-pair cable used in communications is referred to as unshielded twisted-pair (UTP).

STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors. Although metal casing improves the quality of cable by preventing the penetration of **noise** or crosstalk, it is **bulkier** and **more expensive**.



a. UTP



b. STP

Applications

Twisted-pair cables are used in telephone lines to provide voice and data channels.

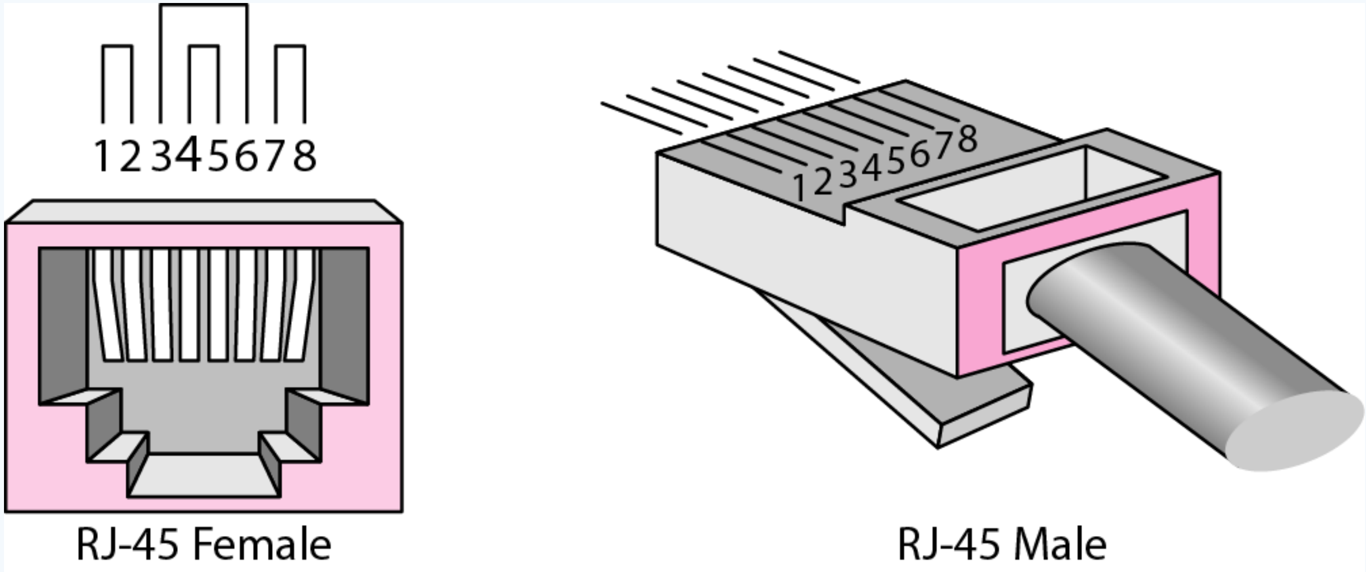
The DSL lines that are used by the telephone companies to provide high-data-rate connections also use the high-bandwidth capability of unshielded twisted-pair cables.

Table 7.1 *Categories of unshielded twisted-pair cables*

Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called SSTP (shielded screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	600	LANs

UTP connector

UTP stands for Unshielded Twisted Pair. In the mantle of a UTP cable you will find eight separate wires. All the wires are twisted in four pairs. A connector can be placed on the end of these cables. These connectors are also known as RJ45 plugs



Coaxial cable

Coaxial cable is a type of copper cable specially built with a metal shield and other components engineered to block signal interference. A coaxial -- or coax -- cable is primarily used by cable TV companies to connect their satellite antenna facilities to customer homes and businesses.

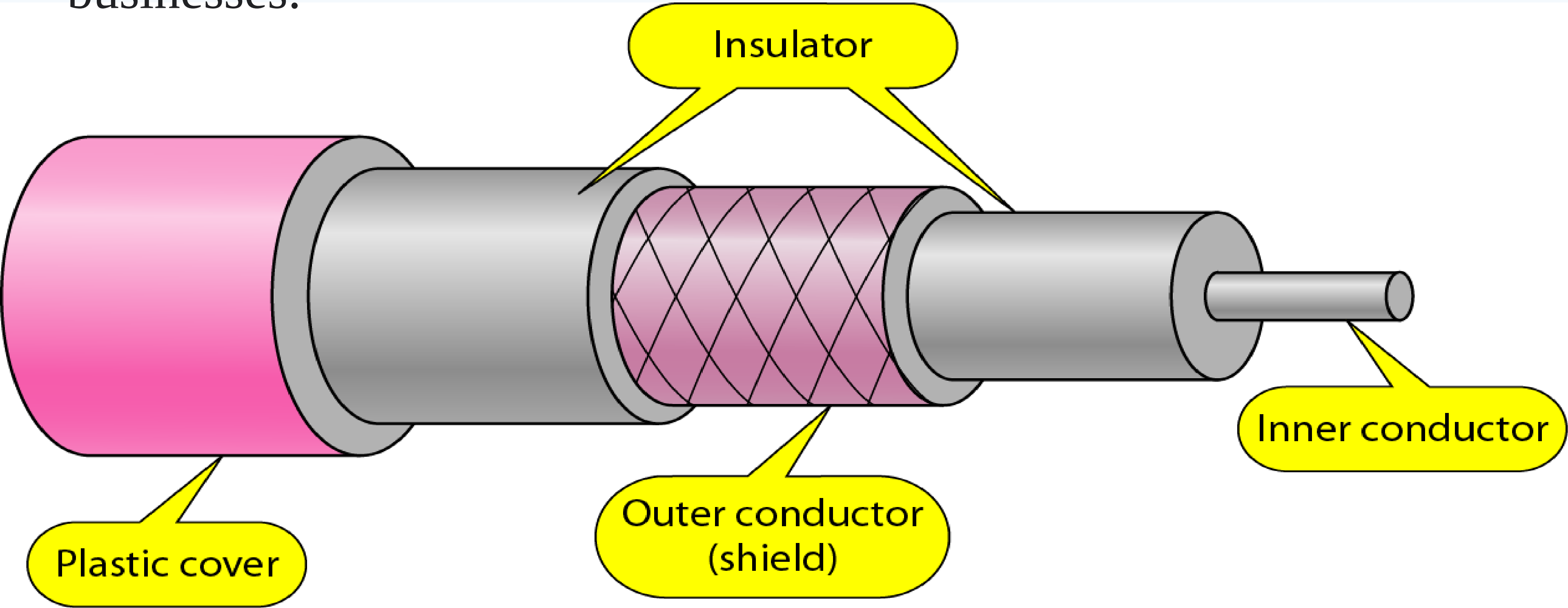
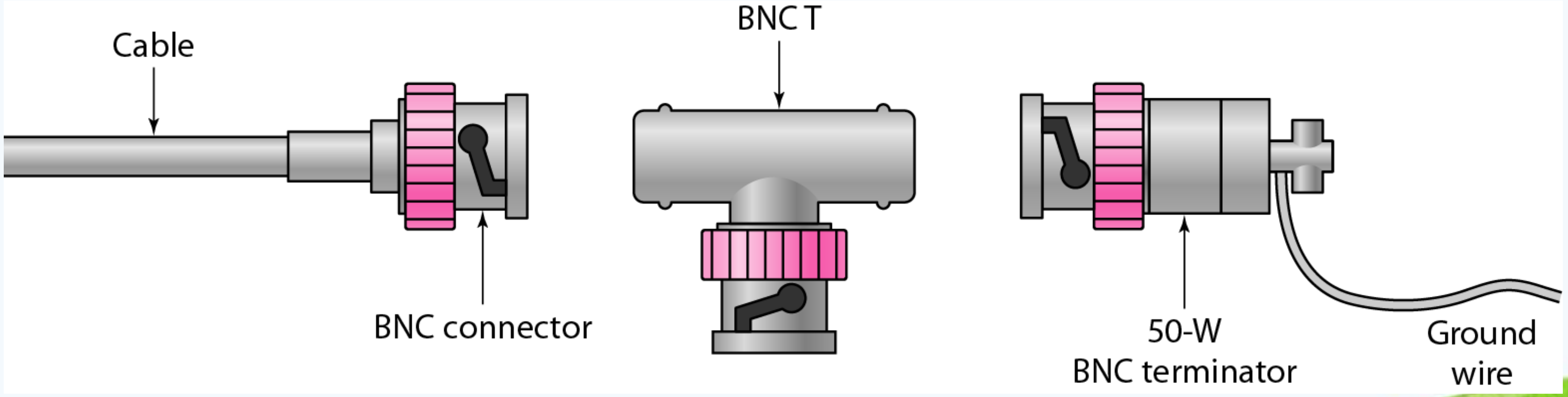


Table 7.2 *Categories of coaxial cables*

Category	*Impedance*	*Use*
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

BNC connectors

The **BNC connector** is a miniature quick connect/disconnect radio frequency connector used for coaxial cable. It is usually applied for video and radio frequency connections up to about 2 GHz and up to 500 volts.



Optical fiber

A **fiber-optic cable**, also known as an **optical-fiber cable**, is an assembly similar to an electrical cable but containing one or more optical fibers that are used to carry light. The optical fiber elements are typically individually coated with plastic layers and contained in a protective tube suitable for the environment where the cable is used.

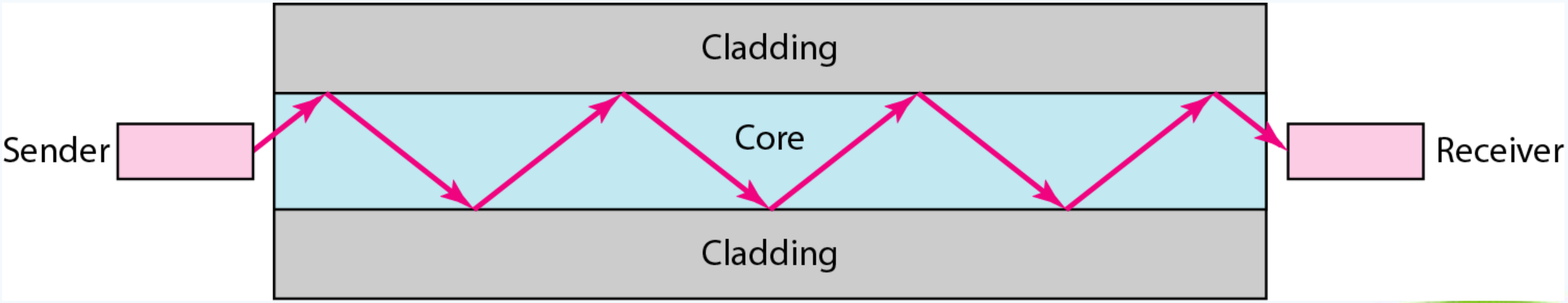


Figure 7.12 *Propagation modes*

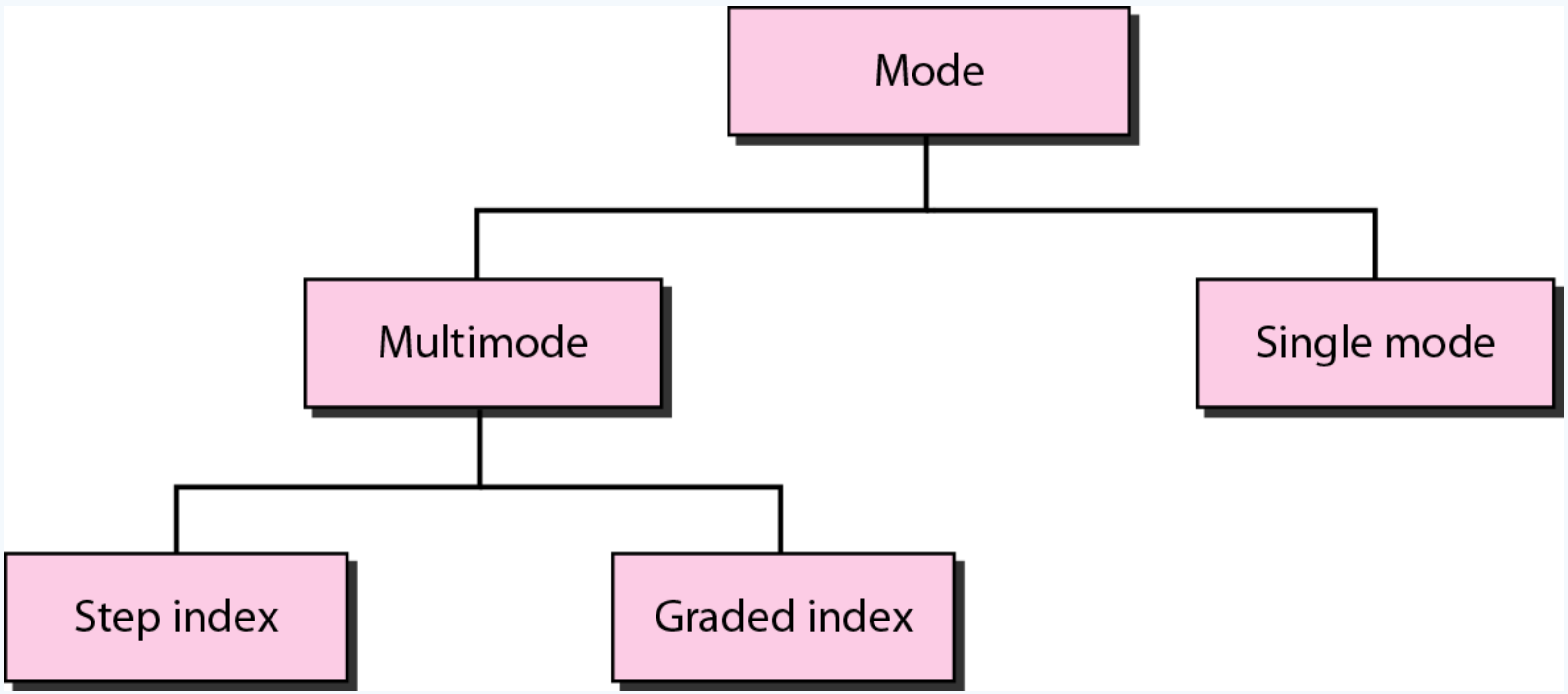
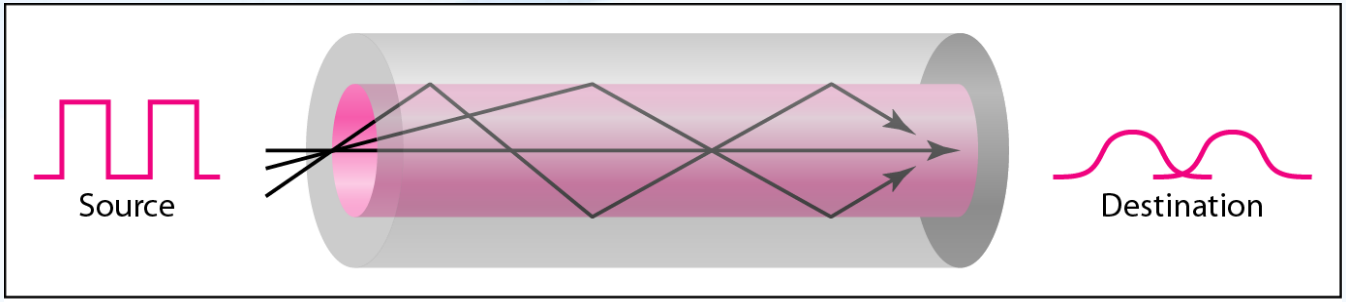
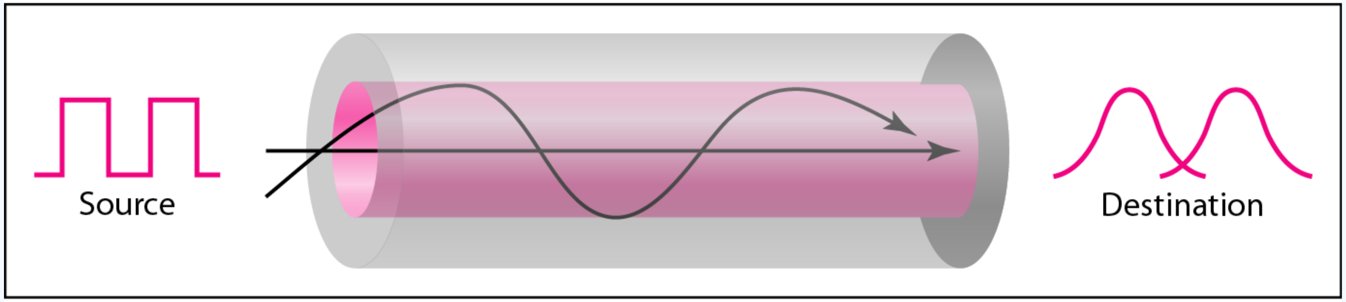


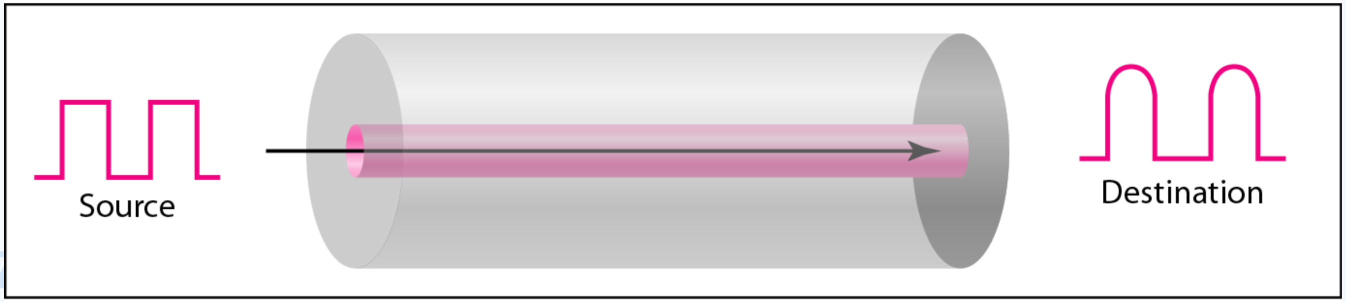
Figure 7.13 *Modes*



a. Multimode, step index

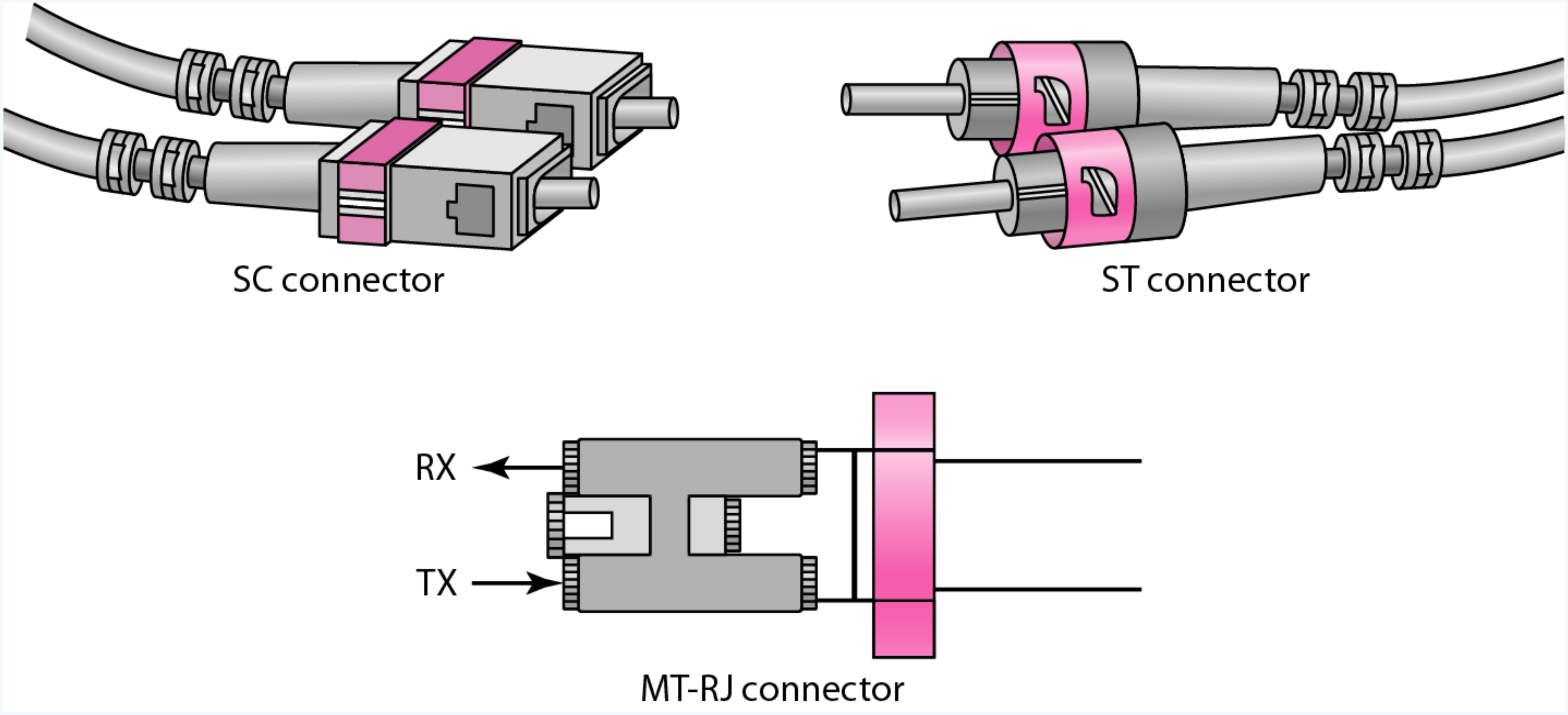


b. Multimode, graded index



c. Single mode

Figure 7.15 ***Fiber-optic cable connectors***



7-2 UNGUIDED MEDIA: WIRELESS

Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication.

Radio Waves
Microwaves
Infrared

Figure 7.17 *Electromagnetic spectrum for wireless communication*

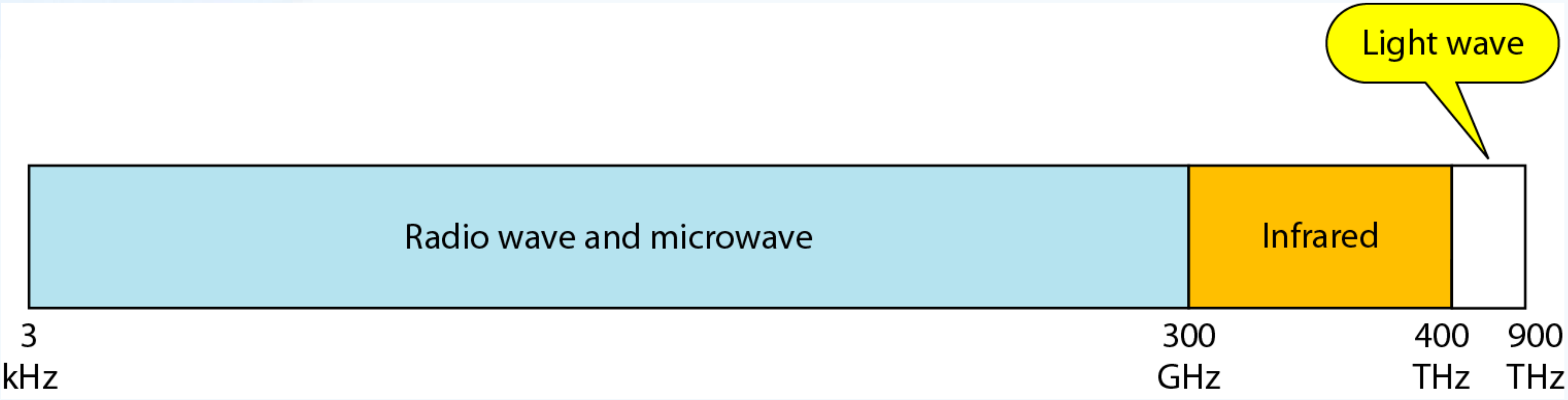
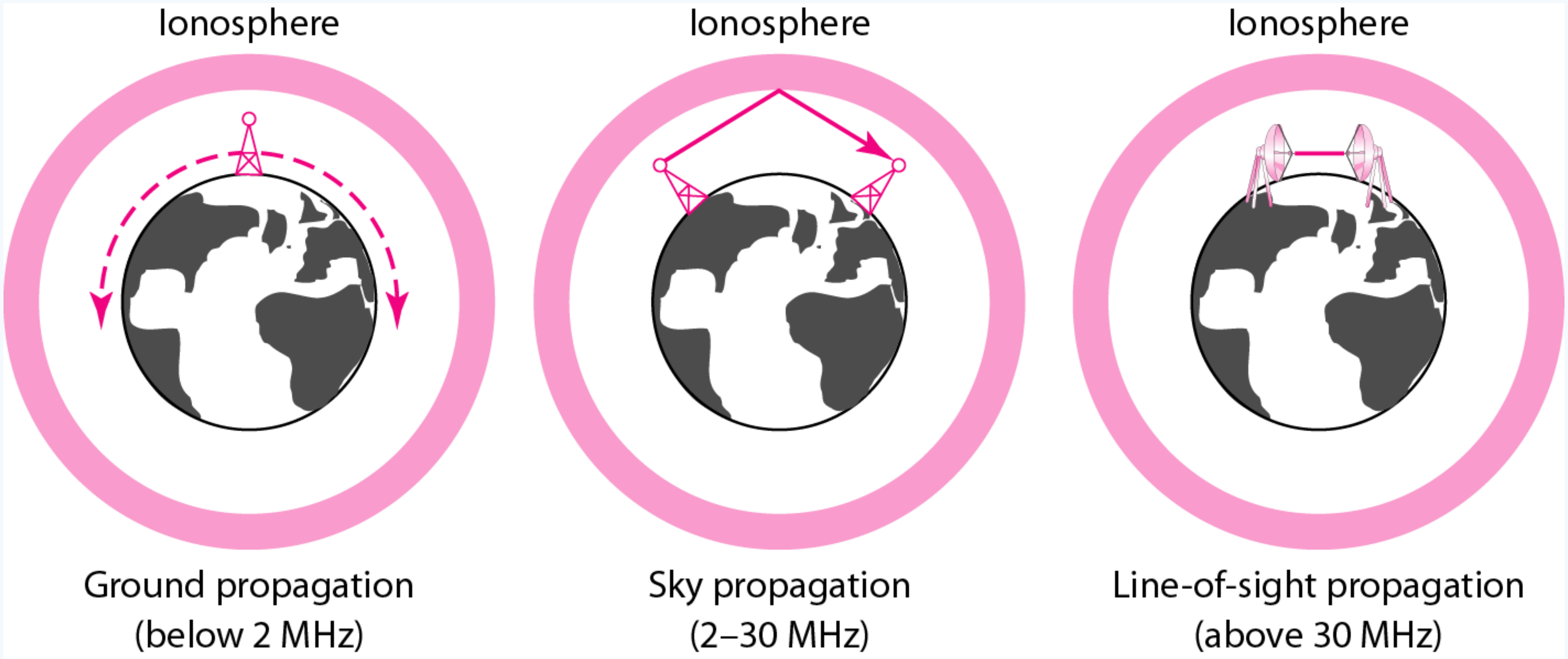


Figure 7.18 ***Propagation methods***



In **ground propagation**, radio waves travel through the lowest portion of the atmosphere, hugging the earth.

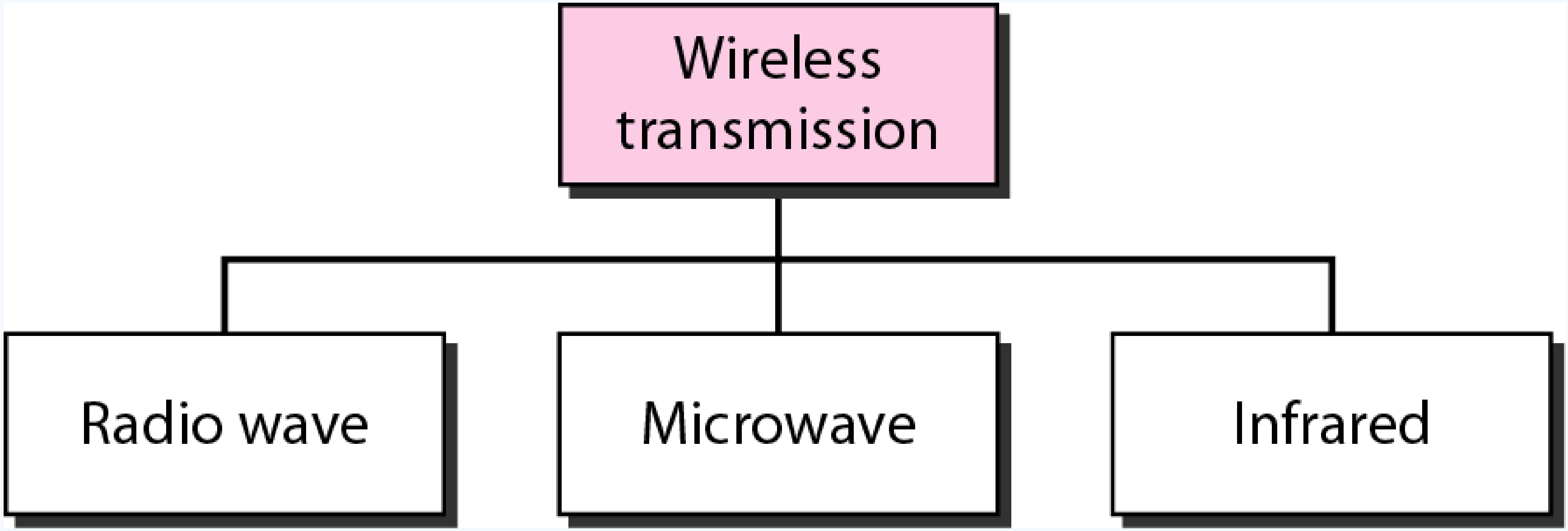
In **sky propagation**, higher-frequency radio waves radiate upward into the ionosphere (the layer of atmosphere where particles exist as ions) where they are reflected back to earth.

In **line-or-sight propagation**, very high-frequency signals are transmitted in straight lines directly from antenna to antenna.

Table 7.4 *Bands*

Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3–30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30–300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz–3 MHz	Sky	AM radio
HF (high frequency)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3–30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30–300 GHz	Line-of-sight	Radar, satellite

Figure 7.19 ***Wireless transmission waves***



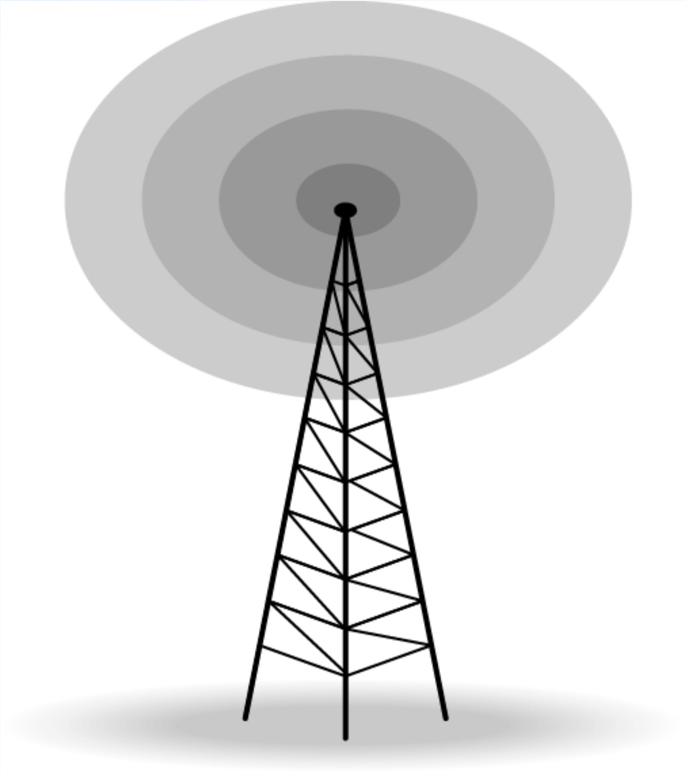
Radio Waves

Although there is no clear-cut demarcation between radio waves and microwaves, electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves; waves ranging in frequencies between 1 and 300 GHz are called microwaves.

Radio waves are used for multicast communications, such as radio and television, and paging systems. They can penetrate through walls.

Highly regulated. Use omni directional antennas

Figure 7.20 *Omnidirectional antenna*



The omni directional characteristics of radio waves make them useful for multicasting, in which there is one sender but many receivers. AM and FM radio, television, maritime radio, cordless phones, and paging are examples of multicasting.

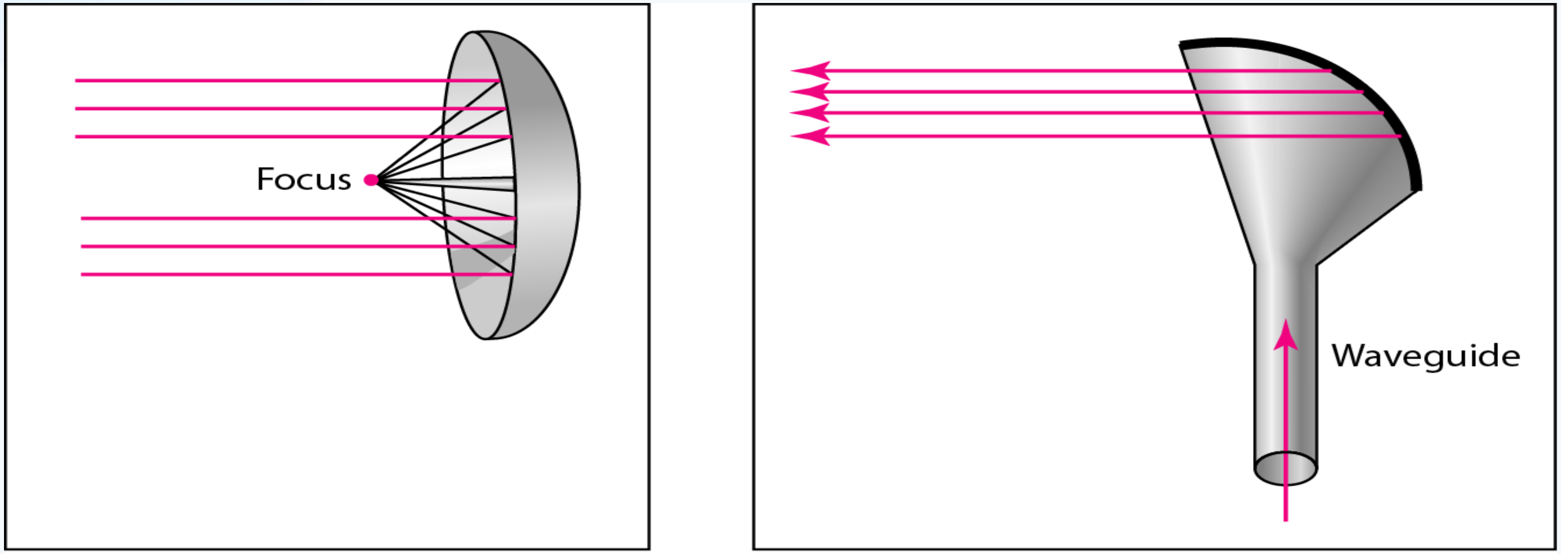
Note

Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.

Higher frequency ranges cannot penetrate walls.

Use directional antennas - point to point line of sight communications.

Figure 7.21 *Unidirectional antennas*



a. Dish antenna   b. Horn antenna

Microwaves, due to their unidirectional properties, are very useful when unicast (one-to-one) communication is needed between the sender and the receiver.
They are used in cellular phones, satellite networks and wireless LANs.

Note

Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

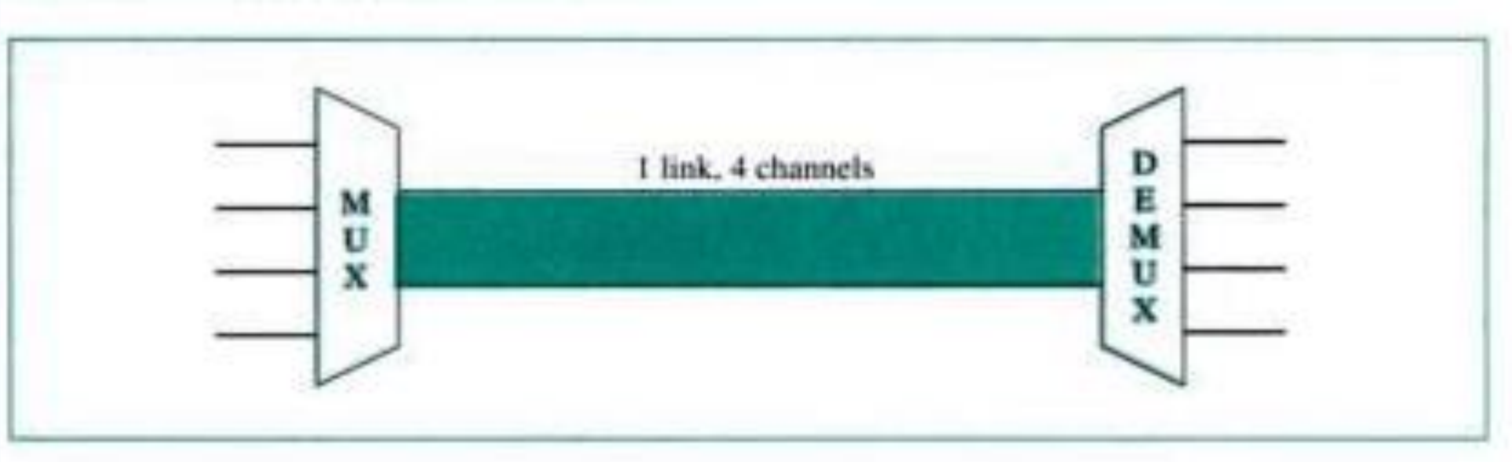
Multiplexing

Whenever the bandwidth of a medium linking two devices is greater than the bandwidth needs of the devices, the link can be shared.

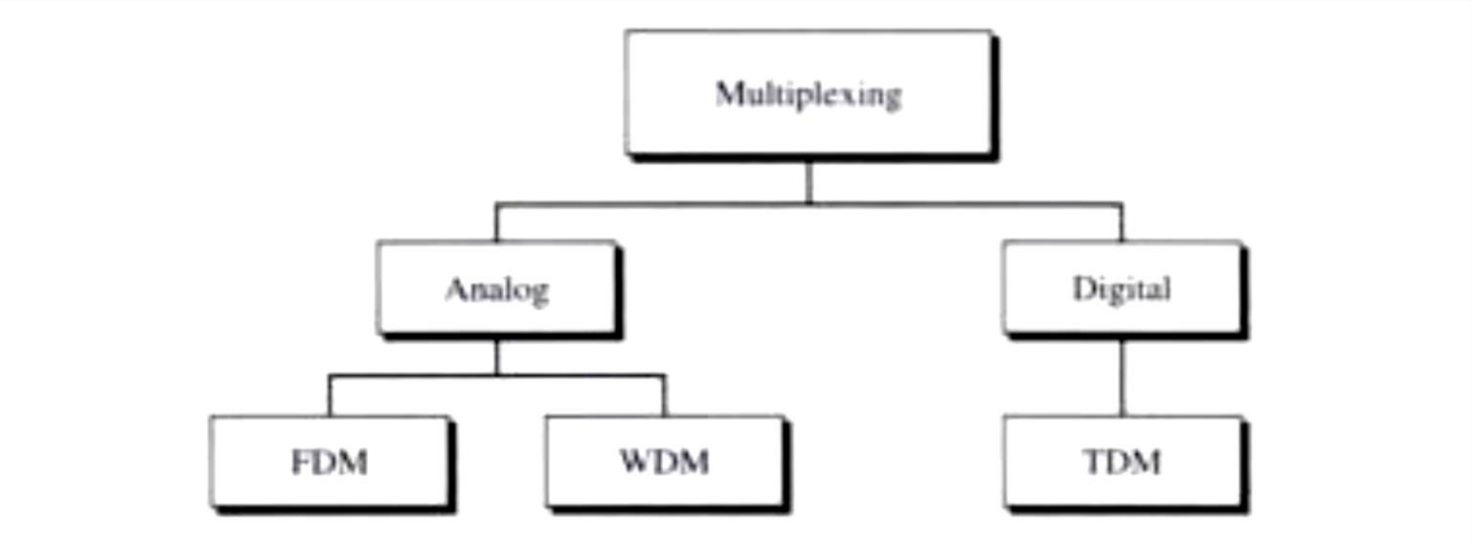
Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link.

As data and telecommunications use increases, so does traffic. We can accommodate this increase by continuing to add individual links each time a new channel is needed; or we can install higher-bandwidth links and use each to carry multiple signals.

In a multiplexed system, n lines share the bandwidth of one link. The lines on the left direct their transmission streams to a multiplexer (MUX), which combines them into a single stream (many-to-one).



There are three basic multiplexing techniques: frequency-division multiplexing, wavelength division multiplexing, and time-division multiplexing. The first two are techniques designed for analog signals, the third, for digital signals.



Frequency-Division Multiplexing

Frequency-division multiplexing (FDM) is an analog technique that can be applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted.

In FDM, signals generated by each sending device modulate different carrier frequencies. These modulated signals are then combined into a single composite signal that can be transported by the link.

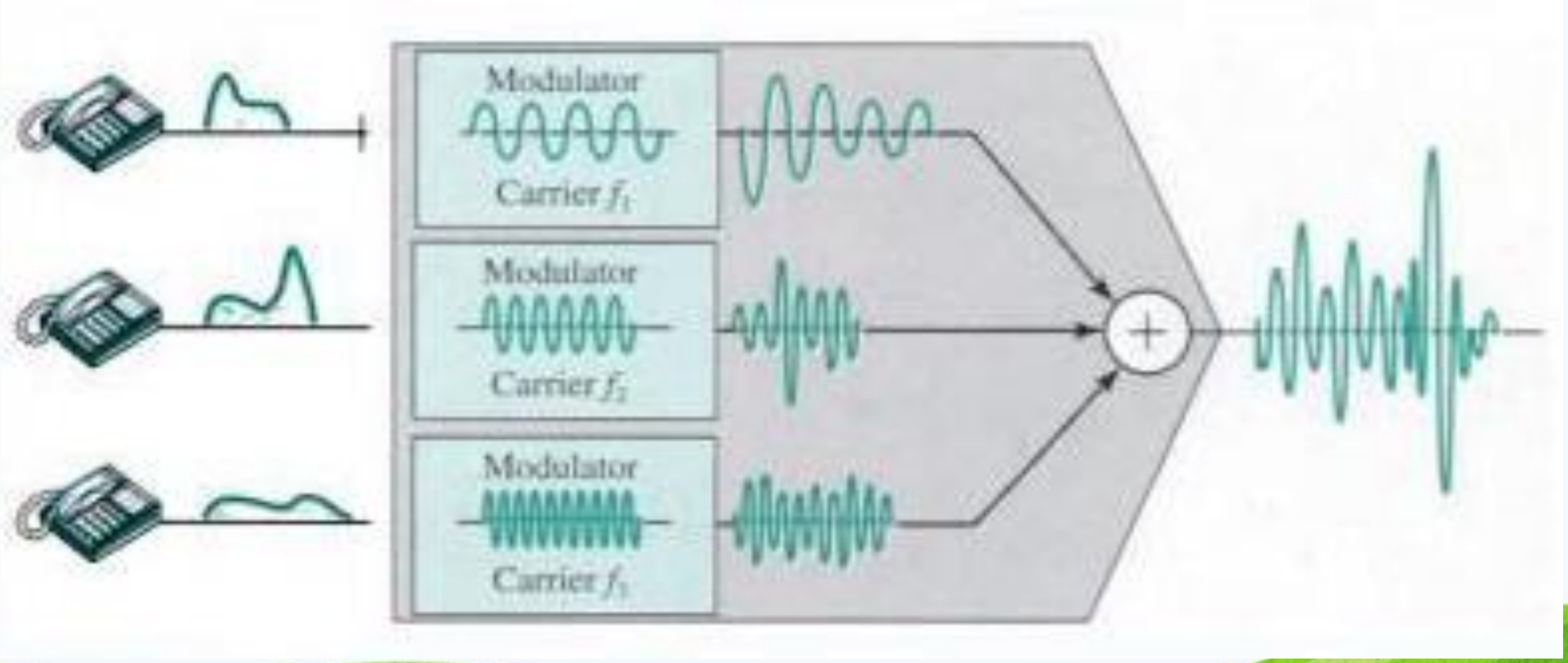
Carrier frequencies are separated by sufficient bandwidth to accommodate the modulated signal.

These bandwidth ranges are the channels through which the various signals travel. Channels can be separated by strips of unused bandwidth-guard bands-to prevent signals from overlapping.

In addition, carrier frequencies must not interfere with the original data frequencies.

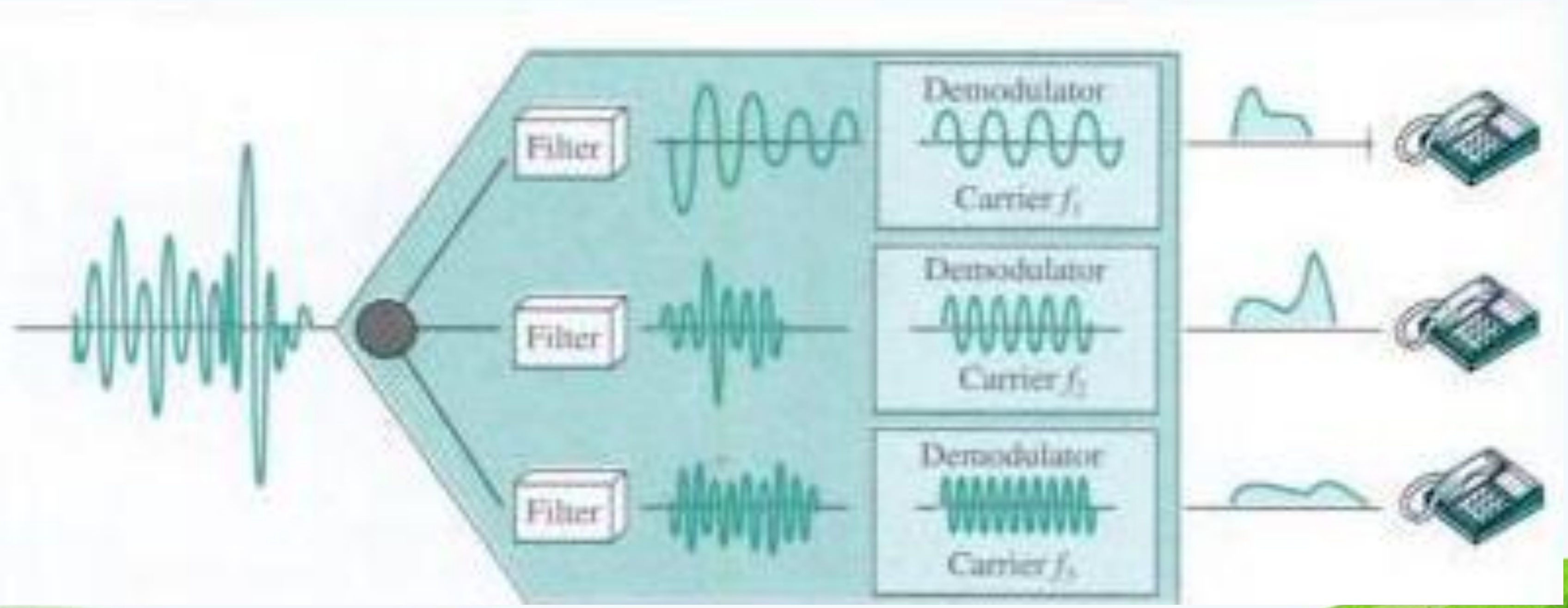
Multiplexing Process

Each source generates a signal of a similar frequency range. Inside the multiplexer, these similar signals modulate different carrier frequencies f1, f2, and f3). The resulting modulated signals are then combined into a single composite signal that is sent out over a media link that has enough bandwidth to accommodate it.



Demultiplexing Process

The de-multiplexer uses a series of filters to decompose the multiplexed signal into its constituent component signals. The individual signals are then passed to a demodulator that separates them from their carriers and passes them to the output lines.



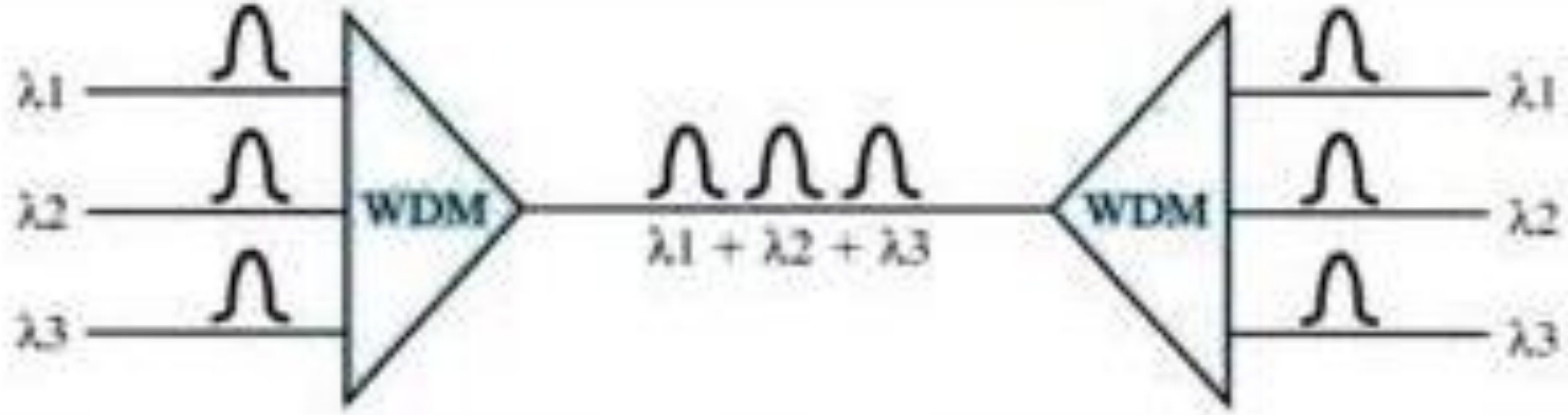
Q1. Assume that a voice channel occupies a bandwidth of 4 KHz. We need to combine three voice channels into a link with a bandwidth of 12 KHz, from 20 to 32 KHz. Show the configuration using the frequency domain without the use of guard bands.

Q2. Five channels, each with a 100-KHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 KHz between the channels to prevent interference?

Wavelength-Division Multiplexing

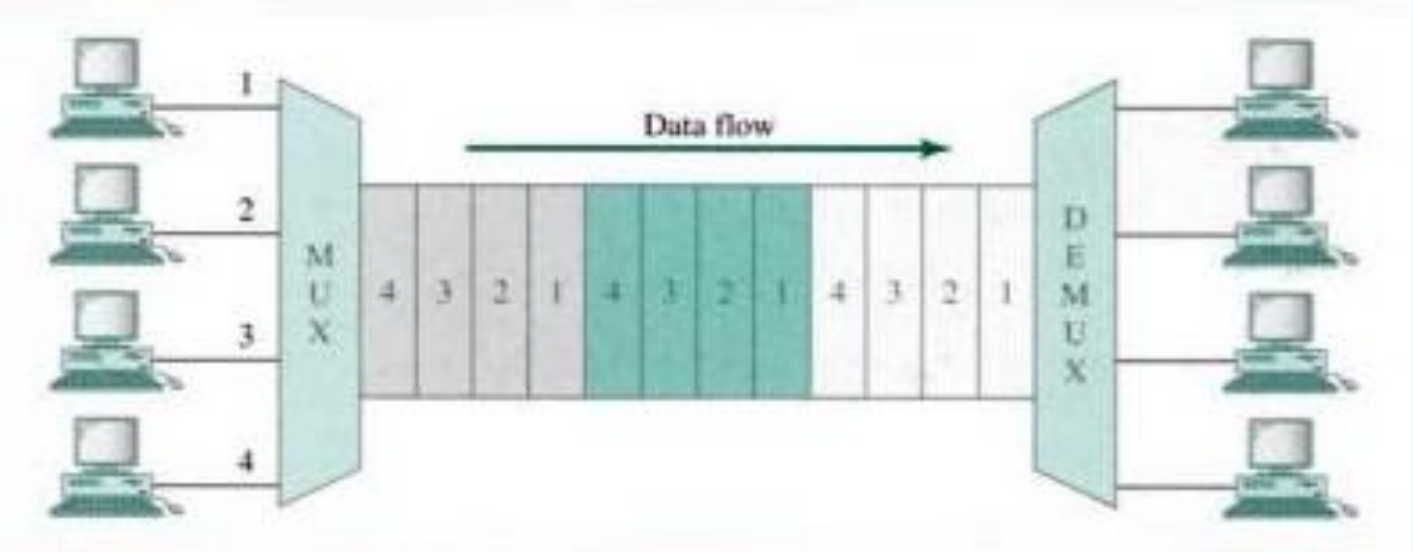
Wavelength-division multiplexing (WDM) is designed to use the high-data-rate capability of fiber-optic cable. The optical fiber data rate is higher than the data rate of metallic transmission cable. Using a fiber-optic cable for one single line wastes the available bandwidth.

WDM is conceptually the same as FDM, except that the multiplexing and de-multiplexing involve optical signals transmitted through fiber-optic channels. The idea is the same: We are combining different signals of different frequencies. The difference is that the frequencies are very high.


λ1
λ2
λ3
WDM
λ1 + λ2 + λ3
WDM
λ1
λ2
λ3

Time-Division Multiplexing

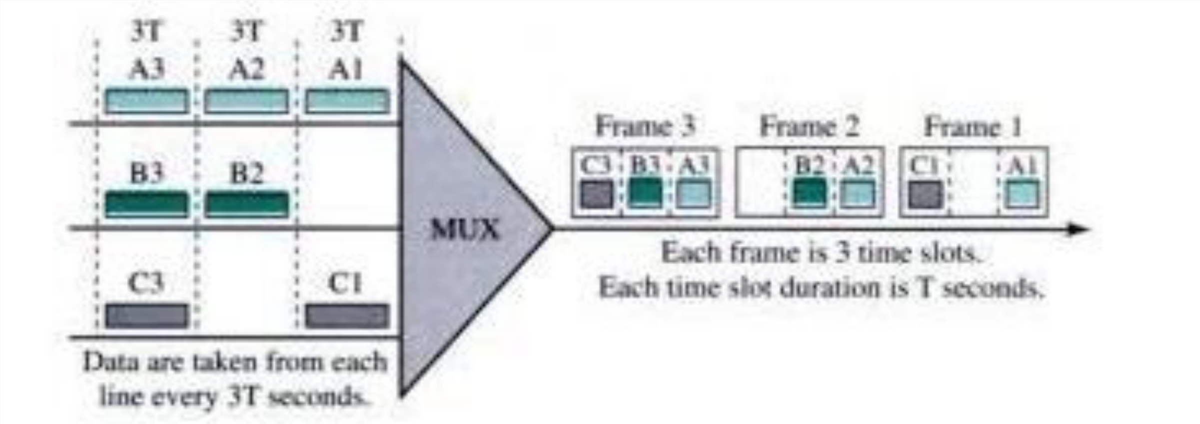
Time-division multiplexing (TDM) is a digital process that allows several connections to share the high bandwidth of a link Instead of sharing a portion of the bandwidth as in FDM, time is shared. Each connection occupies a portion of time in the link.



Time Slots and Frames

The data flow of each connection is divided into units, and the link combines one unit of each connection to make a frame. The size of the unit can be 1 bit or several bits.

For n input connections, a frame is organized into a minimum of n time slots, each slot carrying one unit from each connection.



Q1. Four 1-Kbps connections are multiplexed together. A unit is 1 bit. Find (1) the duration of 1 bit before multiplexing. (2) the transmission rate of the link. (3) the duration of a time slot, and (4) the duration of a frame?

Solution We can answer the questions as follows:

1. The duration of I bit before multiplexing is 1/1 Kbps, or 0.001 s (1 ms).
2. The rate of the link is 4 times the rate of a connection, or 4 Kbps.
3. The duration of each time slot is one-fourth of the duration of each bit before multiplexing. or 1/4 ms or 250 us. Note that we can also calculate this from the data rate of the link 4 Kbps. The bit duration is the inverse of the data rate, or 1/4 Kbps or 250 us.
4. The duration of a frame is always the same as the duration of each unit before multiplexing. or 1 ms. We can also calculate this in another way. Each frame in this case includes four time slots. So the duration of a frame is 4 times of 250 µs, or 1 ms.