DATA COMMUNICATIONS AND COMPUTER NETWORKS

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UNIT 1

COURSE OBJECTIVE

Understand the fundamental concepts of computer networks, know the role of various layers and protocols and security policies

COURSE OUTCOMES

1. Familiarize data communication components, network models and physical layer issues.
2. Learn the detection of error and correction methods and describe MAC layer protocols.
3. Choose appropriate routing algorithms and understand network layer services and applying various IP Protocols.
4. Apply the transport layer protocols and understand the various congestion control mechanisms.
5. Understand different application layer protocols and their utilization in the real time applications.

UNIT I:

Introduction: Data communication, network applications, Data flow, network types, topologies, Protocols and standards, OSI and TCP/IP Protocol Suite.

Physical Layer: Introduction to Data and Signals, Transmission media (wired and wireless), Switching.

UNIT II:

Data Link Layer: Design issues, framing, error detection and correction, parity, LRC, CRC, hamming code, elementary data link protocols- Stop-and-wait, sliding window protocols.

Medium Access sublayer: ALOHA, CSMA/CD, LAN Standards: IEEE 802.3, IEEE 802.11.

UNIT III:

Network Layer: Network layer design issues, routing algorithms- Shortest Path Routing, Flooding, Distance Vector Routing, Link State Routing, IPV4, IPV6, Internet, Internet Control protocols - ARP, RARP, DHCP.

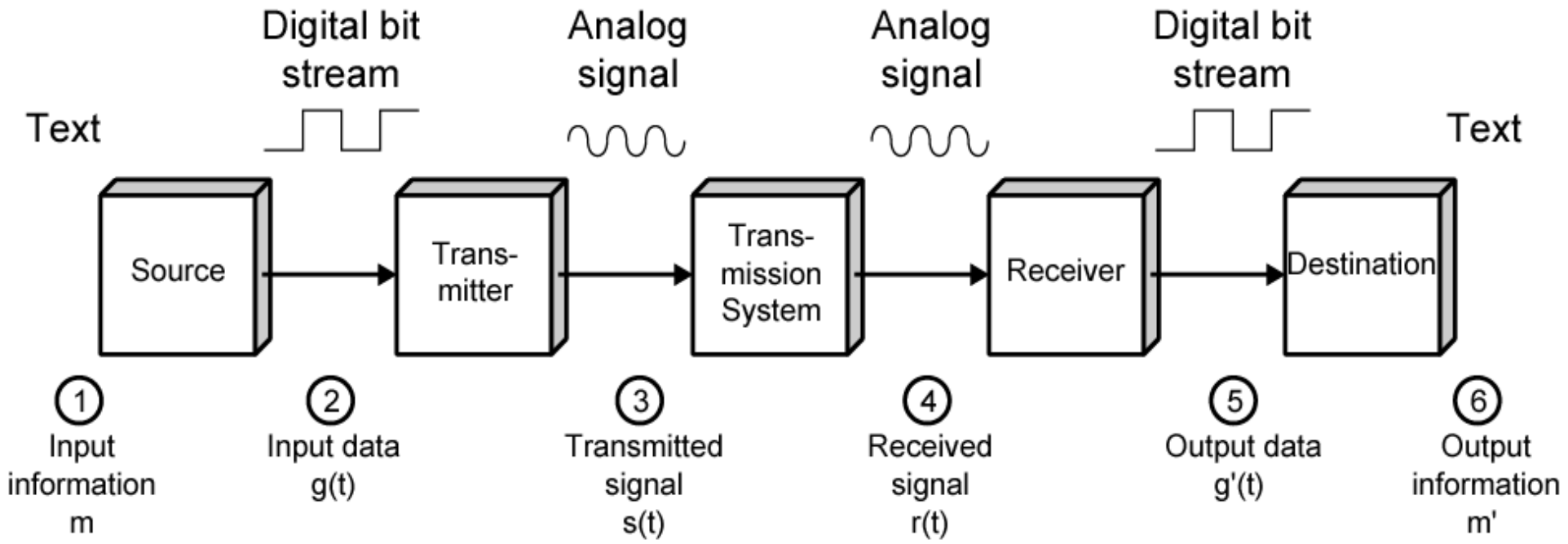
UNIT IV:

Transport Layer: Process to Process Communication, User Datagram Protocol (UDP), Transmission Control Protocol (TCP), Congestion control algorithms, Quality of Service.

UNIT V:

Application Layer: Domain Name System (DNS), EMAIL, File Transfer Protocol (FTP), WWW, HTTP, SNMP.

Data Communications Model



Source

- The source generates the information or data that will be transmitted to the destination. Popular forms of information include **text, numbers, pictures, audio, video**, or a **combination of any of these**.
- Information is put together in analog or digital form.

Transmitter

- The transmitter a device used to convert the data as per the destination requirement.
- **For example**, a **modem** converts the analog (telephonic) signal to digital (computer) signals and alternatively digital to analog.

Transmission medium

- The transmission medium is the physical path by which data travels from the transmitter to the receiver.
- For Example of such channels are **copper wires, optical fibers**, and **wireless** communication channels, etc.

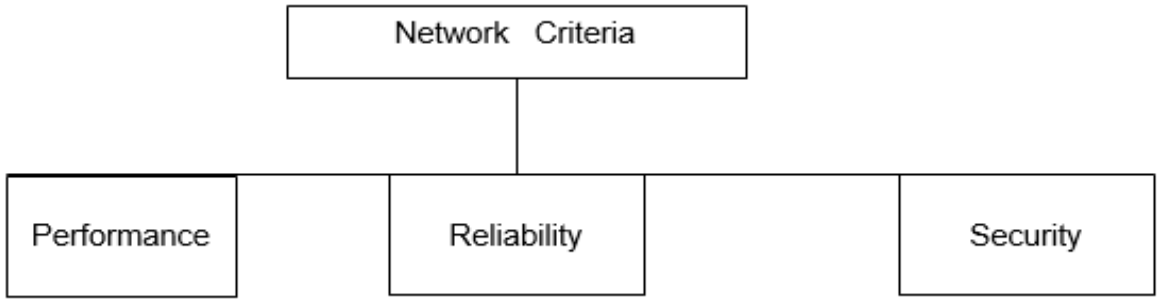
Receiver

- This receives the signals from the transmission medium and converts it into a form that is suitable to the destination device.
- **For example**, a modem accepts an analog signal from a transmission channel and transforms it into digital bit stream which is acceptable by the computer system.

Destination

- It is simply a device for which source device sends the data.

Network Criteria



Performance:

The performance can be measured in many ways and depends on number of factors.

- Number of users
- Type of transmission medium
- Hard ware & Soft ware

Reliability

This is measured by the following factors

- Frequency of failure
- Recovery time of a network after a failure.

Security

Network security issues include protecting data from the following

- Unauthorized access
- Viruses

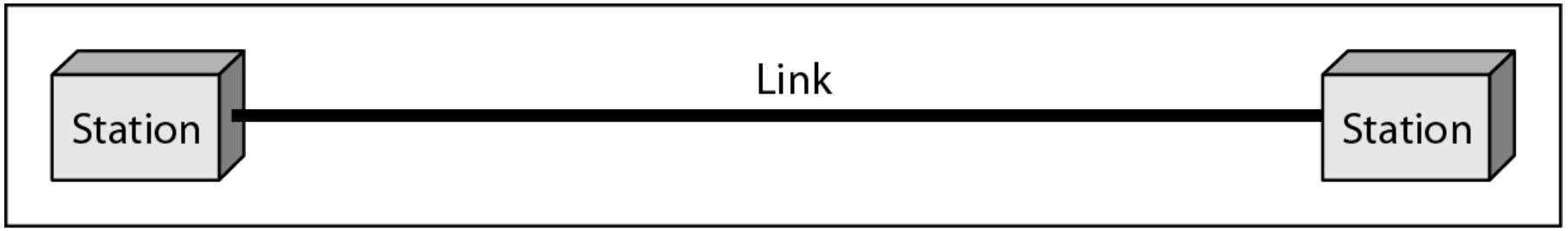
Applications

- Accessing Remote databases
- Accessing Remote programs
- Value added communication facility
- Marketing and sales
- Financial services
- Manufacturing
- Electronic message
- Directory services
- Information services
- Teleconferencing
- Cellular telephone

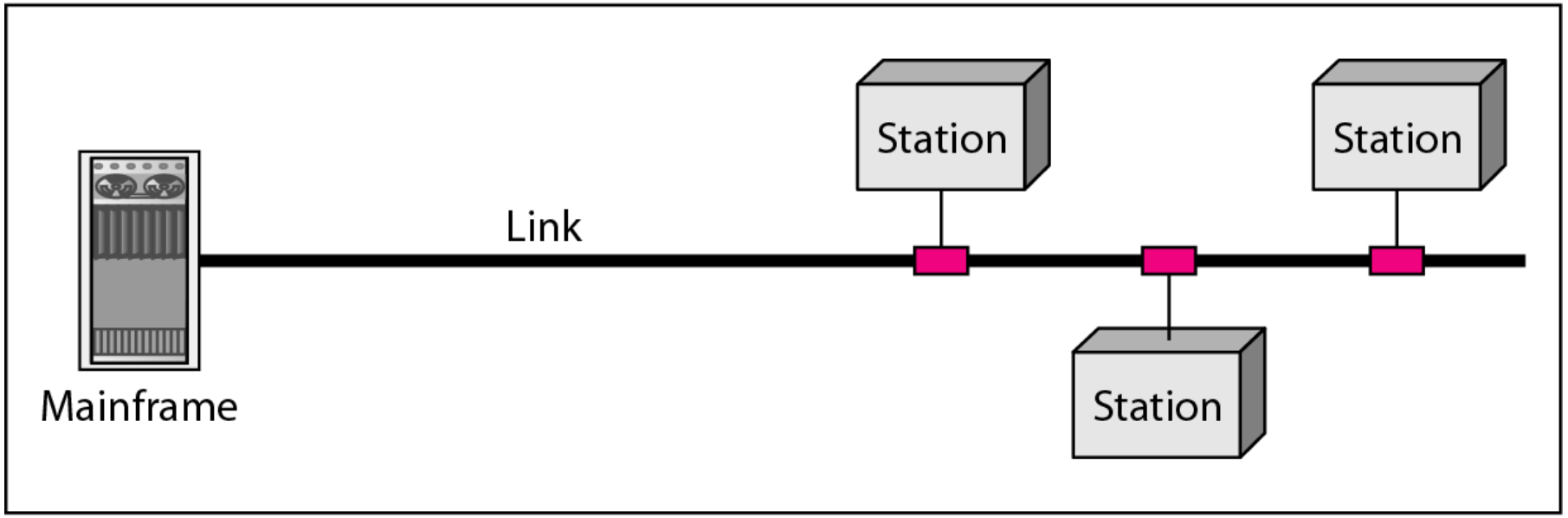
Physical Structures

- 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

Types of connections: point-to-point and multipoint

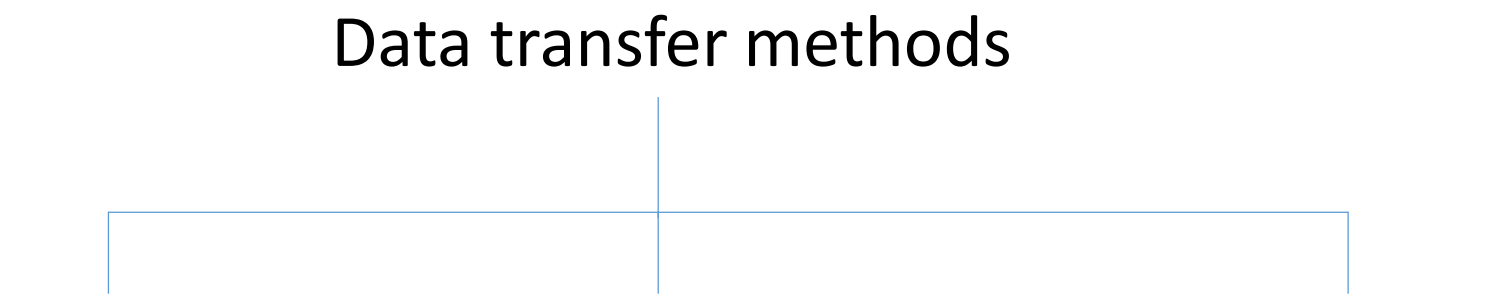


a. Point-to-point



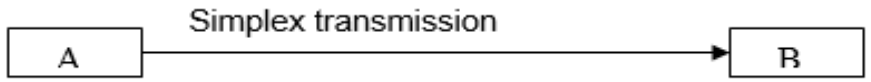
b. Multipoint

Data Flow- Data transfer methods



Simplex communication:

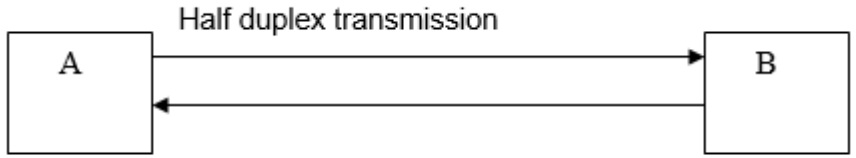
Data will be transferred in one direction only.



Ex Key Board

Half -- duplex communication:

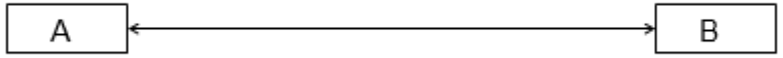
Data will be transferred in both the directions, but not simultaneously.



Ex: One way bridge with two directional traffic.

Full – duplex communication(Duplex)

Data will be transferred in both the directions simultaneously.



Ex: Two-way road, where traffic will be there in both the directions.

Net Work -Topology

- A Network Topology is the arrangement with which computer systems or network devices are connected to each other.
- Topologies may define both physical and logical aspect of the network.
- Both logical and physical topologies could be same or different in a same network.

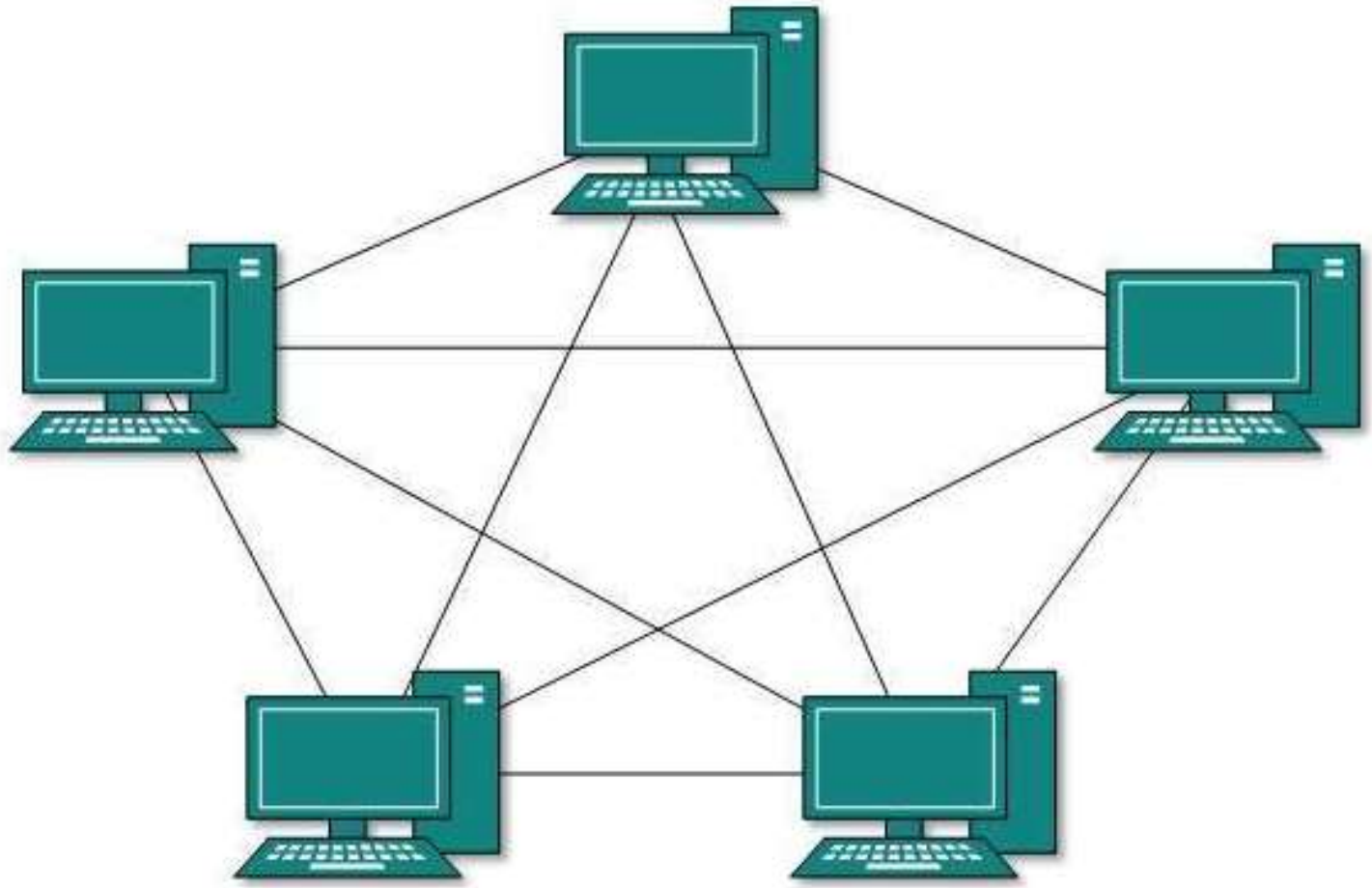
TOPOLOGY

- The term topology refers to the way a network laid out, either physically or logically.
- Two or more devices connect to a link, two or more links form a topology.
- Is a geometric representation of the relationship of all the links and linking devices(nodes) to each other.

Types of Topologies

1. Mesh(Fully Connected)
2. Star
3. Bus
4. Ring
5. Tree
6. Hybrid

MESH



MESH TOPOLOGY

- Every device has a dedicated point-point link to every other device.
- To link *n* devices n(n-1)/2 physical channels & (n-1) I/O ports required.

Advantages

1. Use of dedicated line guarantees that each line carry its own data load.
2. Eliminates traffic problems that will occur with shared line.
3. If one link fails, does not incapacitate the entire system.
4. Privacy and security is more.
5. Fault identification easy.

Disadvantage

1. Amount of cable and I/O ports required are more.

MESH TOPOLOGY

Ex. A fully connected mesh topology has 08 devices. Find out the no of

a) I/O devices required

b) No of cables or links required.

no of devices = n = 8

no of I/O =(n-1) = 8-1 = 7

no of links = n(n-1)/2 = (8*7)/2 =28

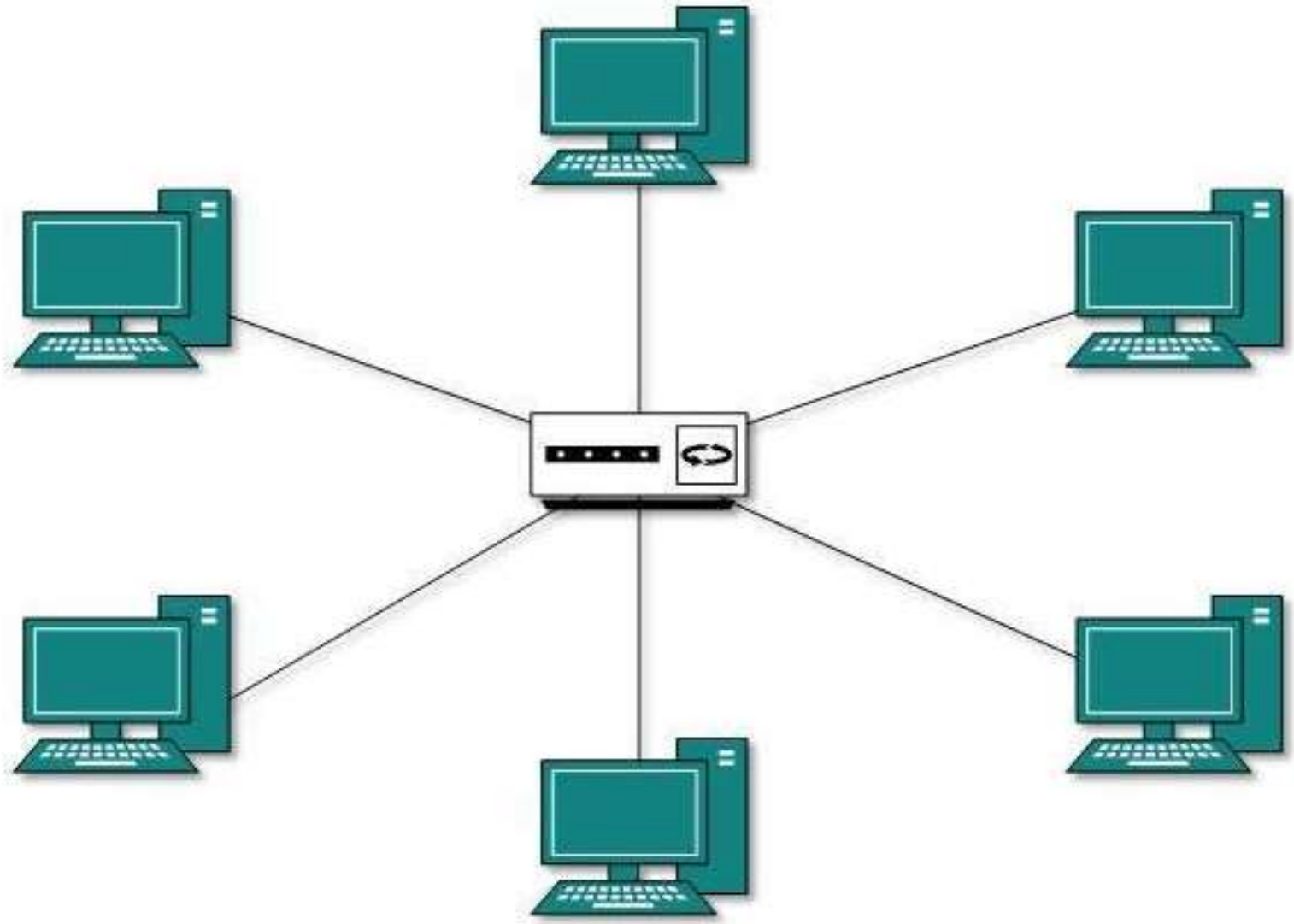
Ex. A fully connected mesh topology has 20 devices. Find out the no of I/O devices and No of cables or links required.

- n = 20

no of links = n(n-1)/2 = (20 x 19)/2= 190

no of I/O = (n-1) = 19

STAR



STAR TOPOLOGY

- Each device has a dedicated point –to- point link to a central controller, usually called a HUB (switch)
- Does not allow traffic between devices directly.
- Data will be routed through a controller to another device.

ADVANTAGES

1. Less cable required, hence less expensive compared to Mesh.
2. Needs one I/O port & one link to connect any no of others.
3. Additions, Deletions and moves are easy.
4. If one link fails only that link is affected.

DISADVANTAGE

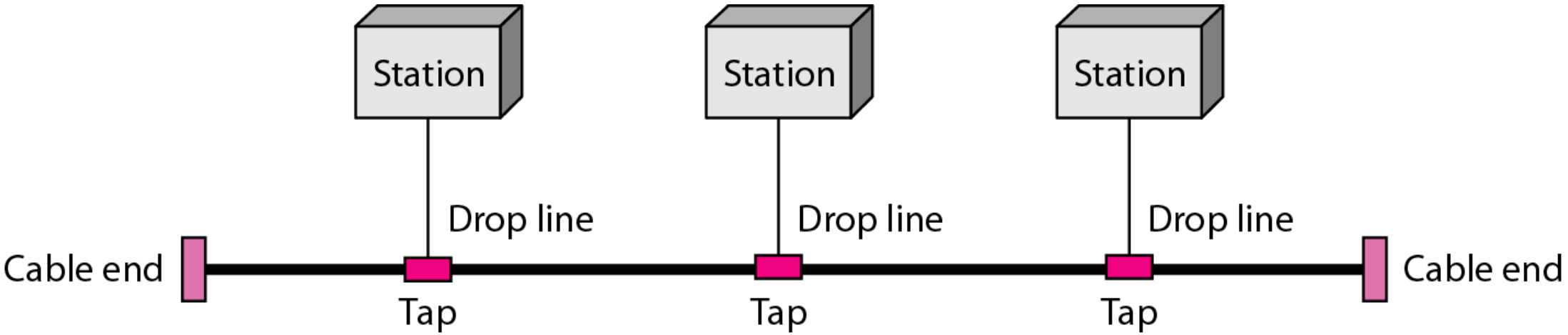
1. More cable is required compared with Bus, Ring and Tree.

1.21

- ..\Hub, Switch, & Router Explained - What's the difference_.mp4

https://www.youtube.com/watch?v=1z0ULvg_pW8

BUS


Station
Station
Station
Drop line
Drop line
Drop line
Cable end
Cable end
Tap
Tap
Tap

Bus Topology

- Multipoint configuration.
- One long cable act as backbone to connect all the devices in the network.
- Nodes are connected by Drop lines and Taps.

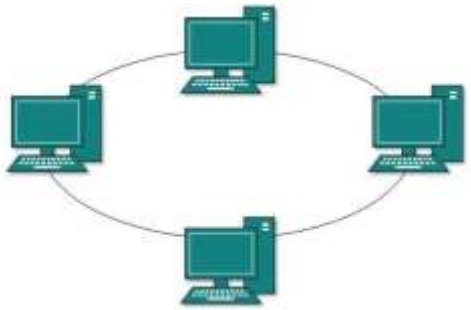
ADVANTAGES

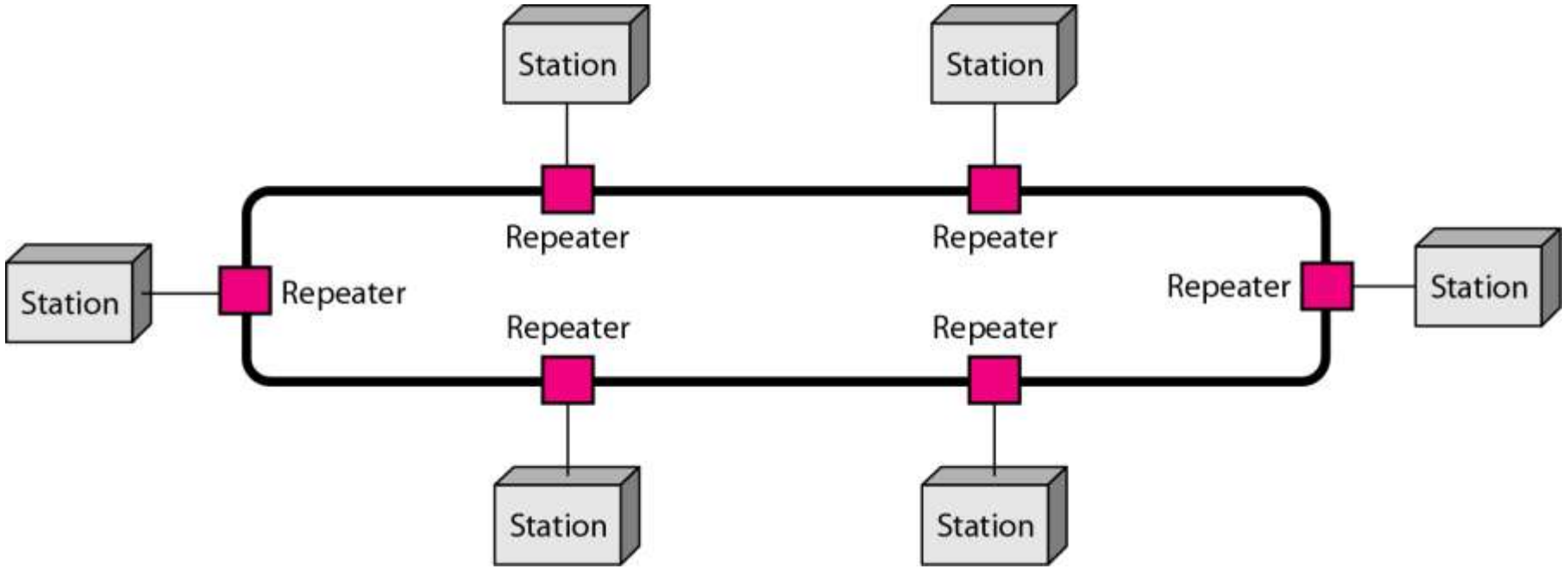
1. Ease to install.
2. Uses less cable than Mesh, Tree and star topologies.

Disadvantages

1. Fault recognition is difficult.
2. Difficult to add new devices.
3. A fault or break will stop all transmissions.
4. Heat will be generated in the cable causes signal to become weak.
5. Limitation in the no of taps per cable.

RING




Station
Station
Repeater
Repeater
Station
Repeater
Repeater
Repeater
Station
Repeater
Repeater
Station
Station

RING TOPOLOGY

- Each device has a dedicated point to point line with only two devices on either side.
- Signal will pass in one direction until it reaches the destination.
- Each device in ring contains a repeater.

Advantages

1. Easy to install and reconfigure.
2. Fault isolation is simplified.

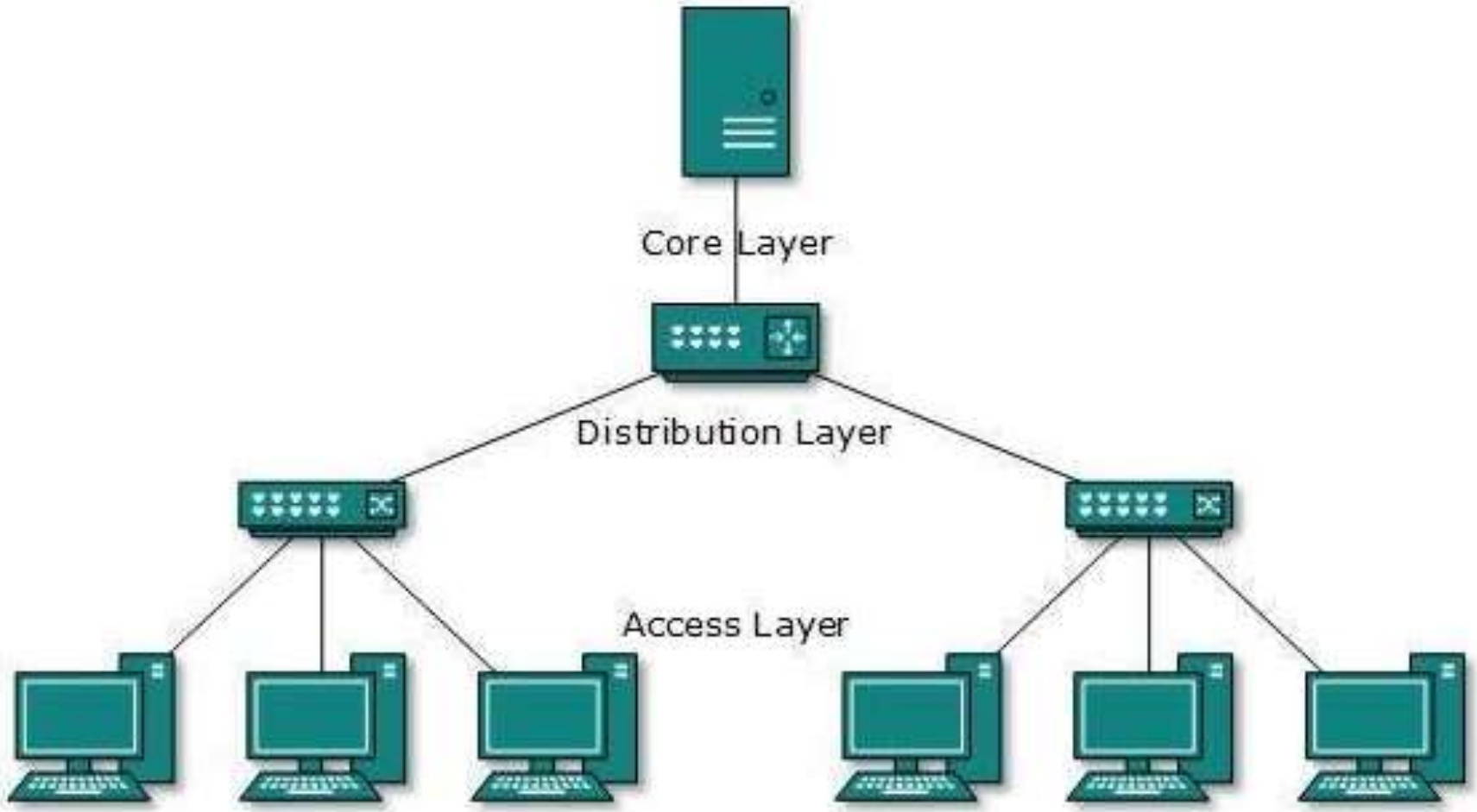
DISADVANTAGES

1. Unidirectional traffic.
2. A break in the cable causes disable entire network.

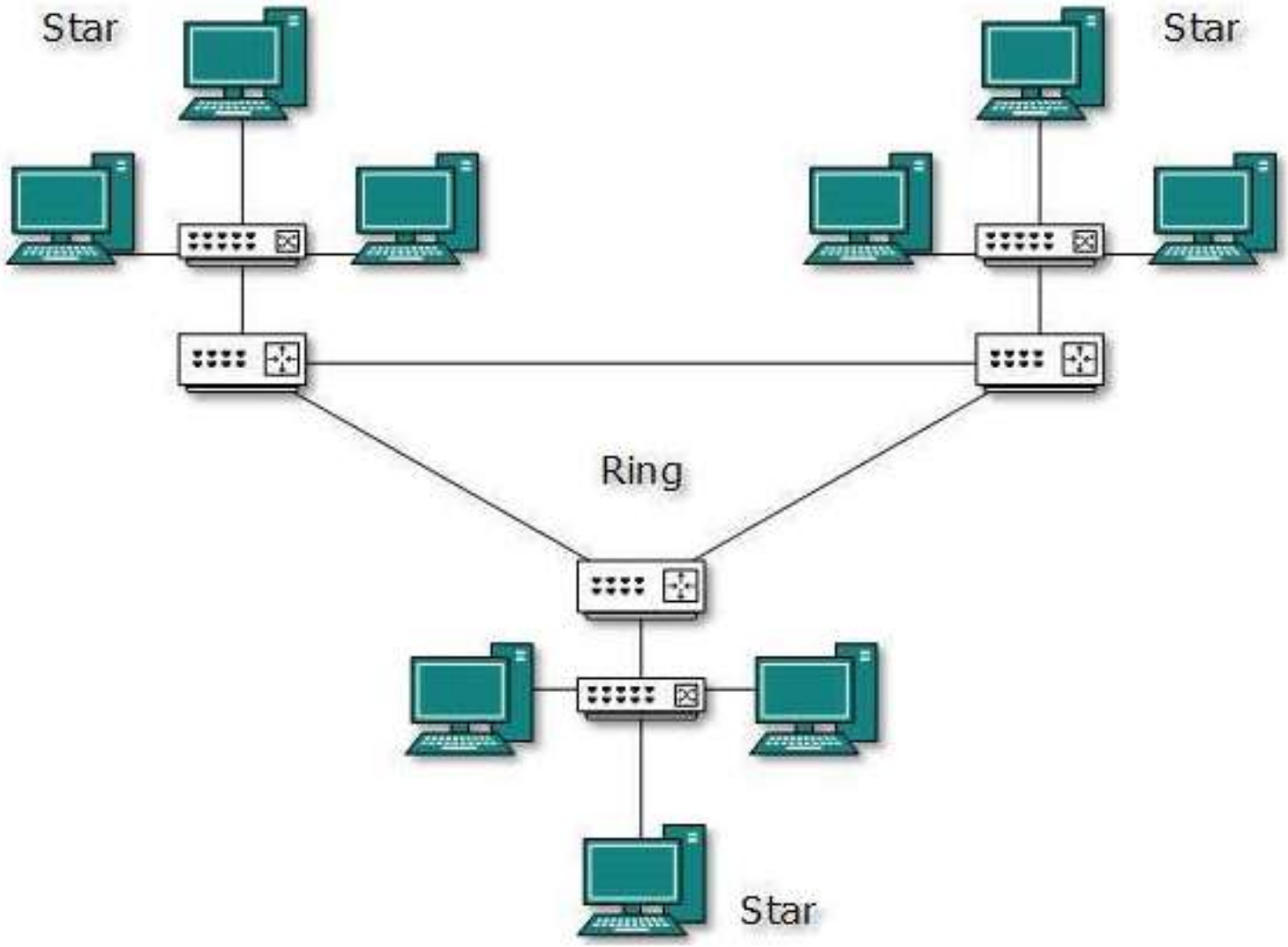
DIASY CHAIN

- This topology connects all the hosts in a linear fashion.
- Similar to Ring topology, all hosts are connected to two hosts only, except the end hosts.
- Means, if the end hosts in daisy chain are connected then it represents Ring topology.

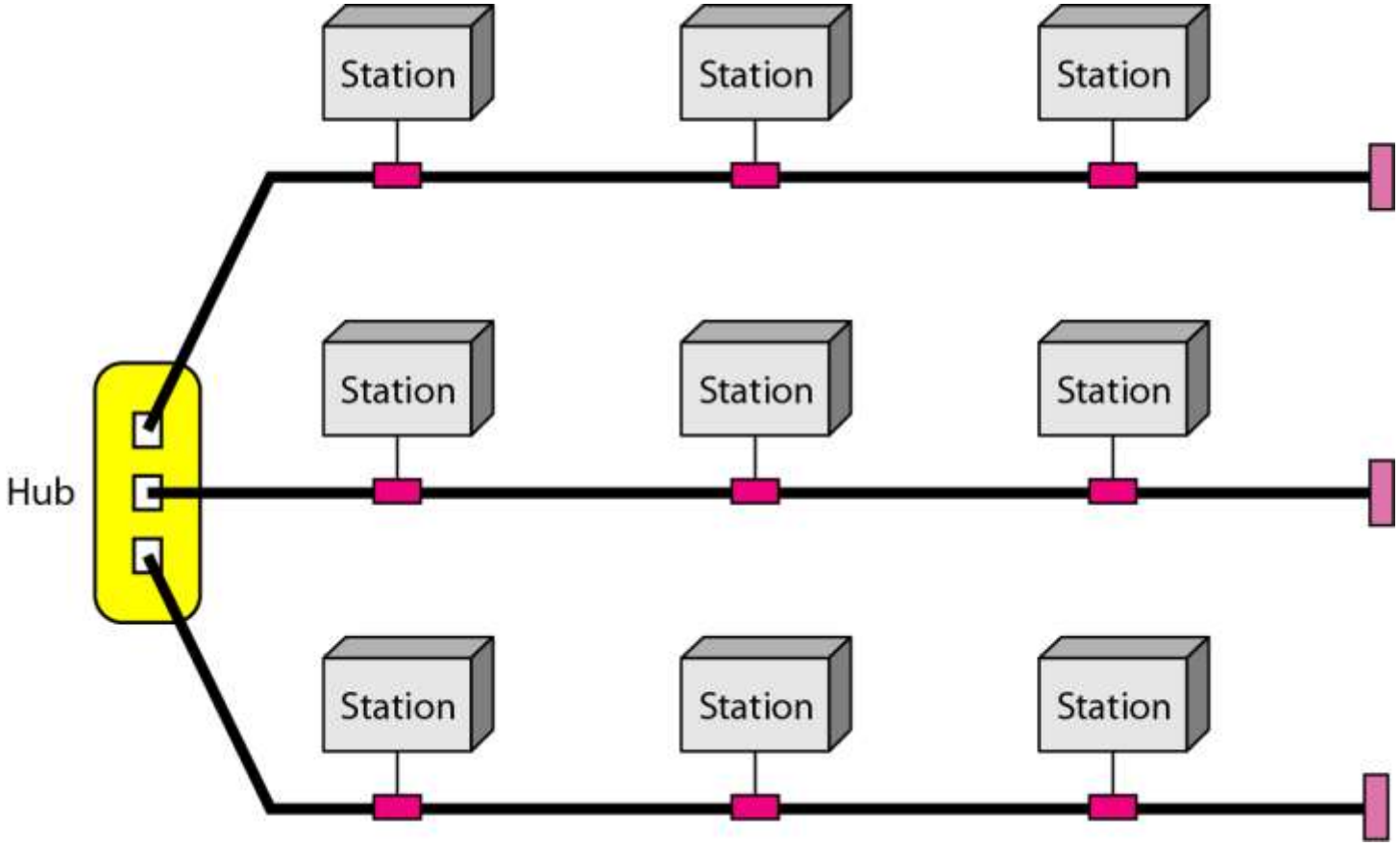
TREE



HYBRID



A hybrid topology: a star backbone with three bus networks



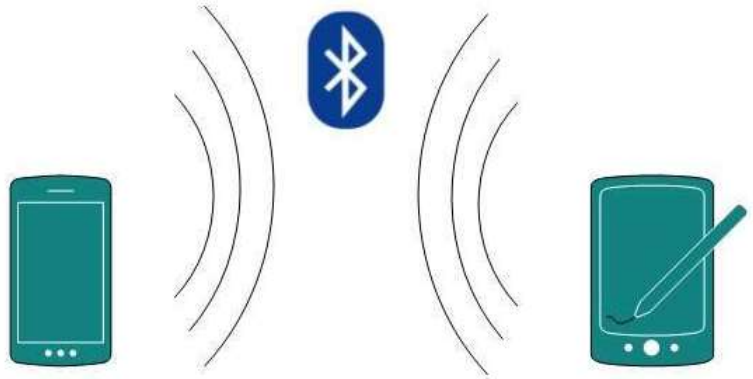
Computer Network Types

PAN,LAN,MAN,WAN

Categories of Networks

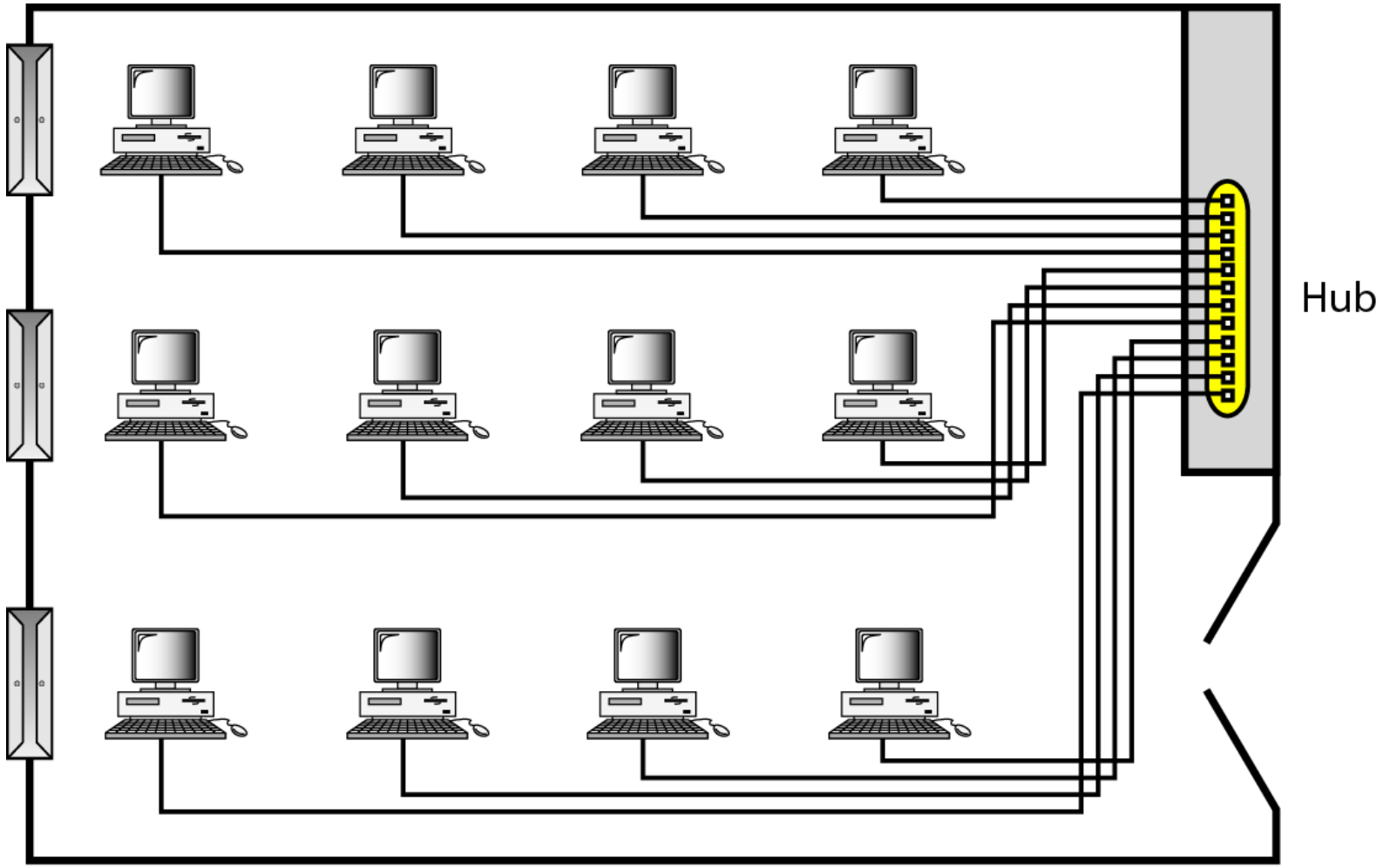
- Personal Area Network(PAN)
- Local Area Networks (LANs)
  - Short distances
  - Designed to provide local interconnectivity
- Wide Area Networks (WANs)
  - Long distances
  - Provide connectivity over large areas
- Metropolitan Area Networks (MANs)
  - Provide connectivity over areas such as a city, a campus

Personal Area Network
PAN



- A Personal Area Network (PAN) is smallest network which is very personal to a user.
- This may include Bluetooth enabled devices or infra-red enabled devices.
- PAN has connectivity range up to 10 meters.
- PAN may include wireless computer keyboard and mouse, Bluetooth enabled headphones, wireless printers and TV remotes.

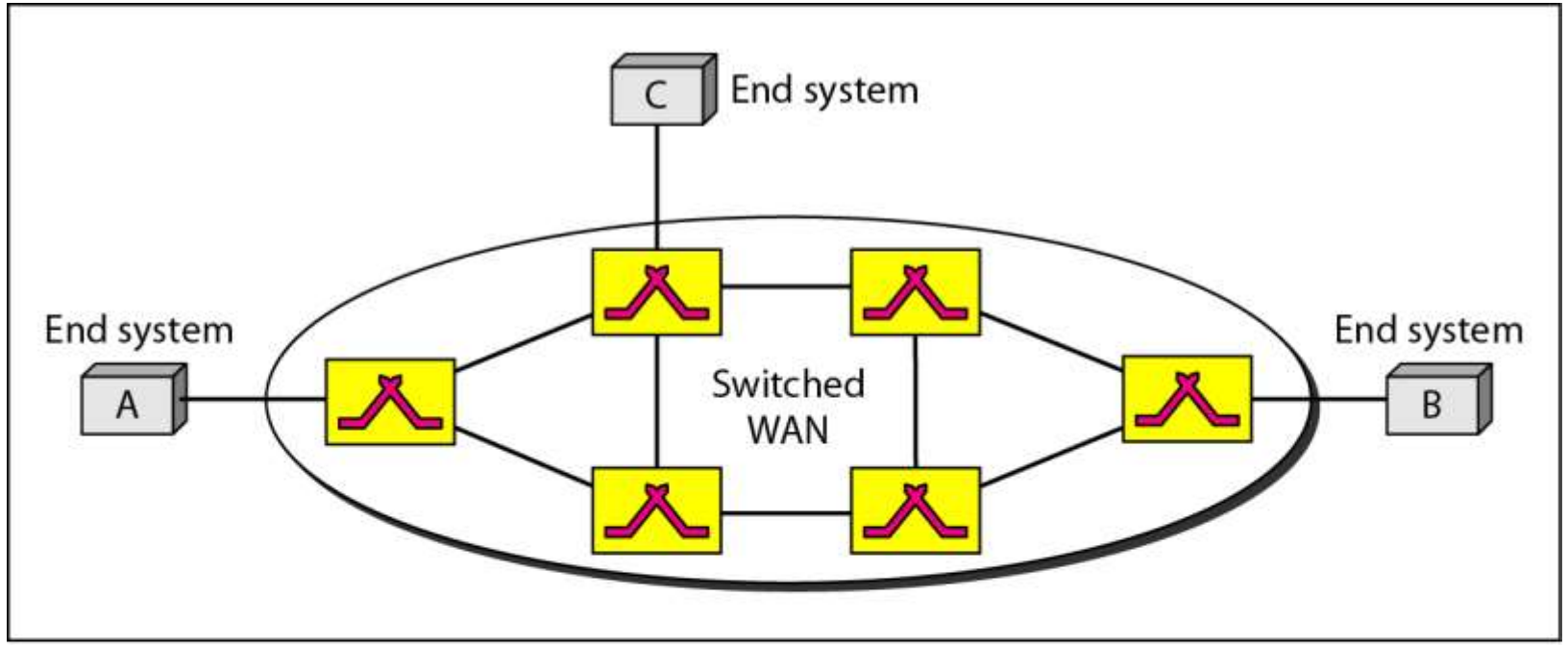
An isolated LAN connecting 12 computers to a hub in a closet



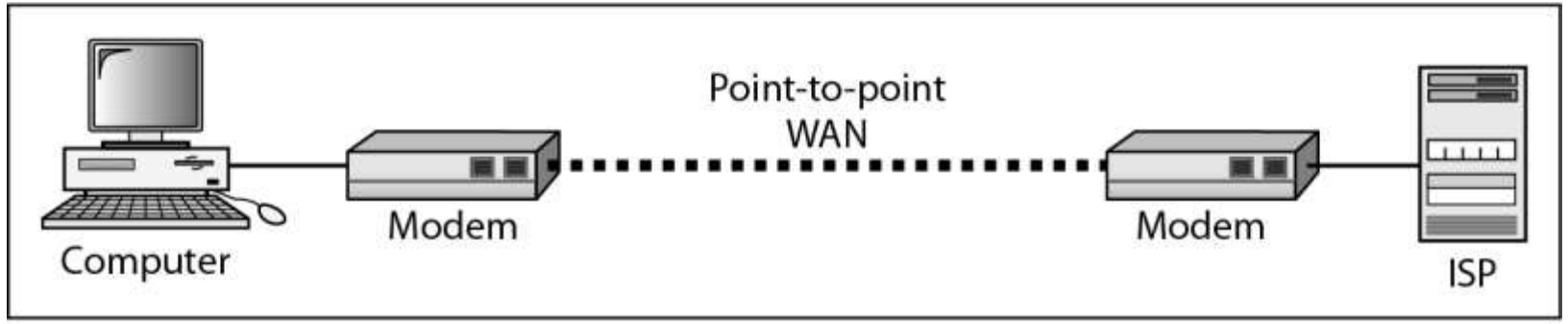
Local Area Network- LAN

- A computer network spanned inside a building and operated under single administrative system is generally termed as Local Area Network (LAN).
- Usually, LAN covers an organization' offices, schools, colleges or universities.
- Number of systems connected in LAN may vary from as least as two to as much as 16 million.
- LAN provides a useful way of sharing the resources between end users.
- The resources such as printers, file servers, scanners, and internet are easily sharable among computers.
- LAN can be wired, wireless, or in both forms at once.

WANs: a switched WAN and a point-to-point WAN

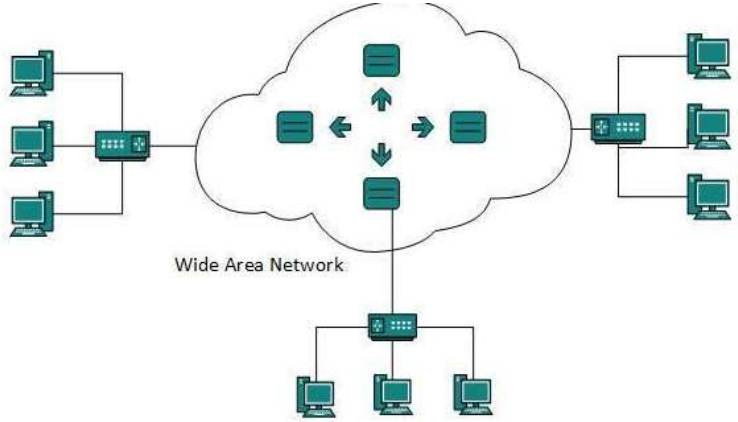


a. Switched WAN



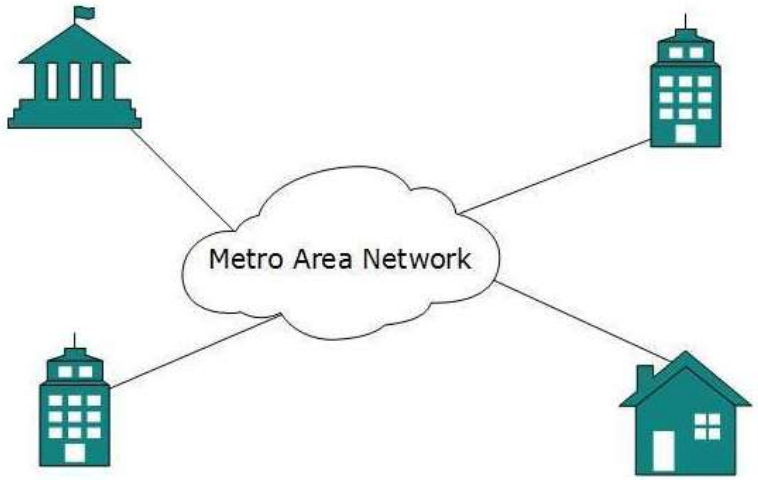
b. Point-to-point WAN

Wide Area Network -WAN



- As the name suggests, the Wide Area Network (WAN) covers a wide area which may span across provinces and even a whole country.
- Generally, telecommunication networks are Wide Area Network.
- These networks provide connectivity to MANs and LANs.
- Since they are equipped with very high speed backbone, WANs use very expensive network equipment.

Metropolitan Area Network -MAN



- The Metropolitan Area Network (MAN) generally expands throughout a city such as cable TV network.
- It can be in the form of Ethernet, Token-ring, ATM, or Fiber Distributed Data Interface (FDDI).
- Backbone of MAN is high-capacity and high-speed fiber optics.
- MAN works in between Local Area Network and Wide Area Network.
- MAN provides uplink for LANs to WANs or internet.

Internetwork

- A network of networks is called an internetwork, or simply the internet.
- It is the largest network in existence on this planet.
- The internet hugely connects all WANs and it can have connection to LANs and Home networks.
- Internet uses very high speed backbone of fiber optics.
- To inter-connect various continents, fibers are laid under sea known to us as submarine communication cable.

https://www.tutorialspoint.com/data_communication_computer_network/computer_network_topologies.htm

BASIS OF COMPARISON	LAN	MAN	WAN
Expands to	Local Area Network	Metropolitan Area Network	Wide Area Network
Meaning	A network that connects a group of computers in a small geographical area.	It covers relatively large region such as cities, towns.	It spans large locality and connects countries together. Example Internet.
Ownership of Network	Private	Private or Public	Private or Public
Design and maintenance	Easy	Difficult	Difficult
Congestion	Less	More	More
Used for	College, School, Hospital.	Small towns, City.	Country/Continent.

Computer NetWork

- An interconnected collection of **autonomous** computers is called a computer network.
- Two computers are said to be interconnected if they are able to exchange the information.
- If one computer can forcibly start, stop and control another one, the computers are not autonomous.
- A system with one control unit and many slaves is not a network, nor is a large computer with remote printers and terminals.

Distributed System

- In a **Distributed system**, the existence of multiple autonomous computers is transparent (i.e., not visible) to the user.
- He can type a command to run a program and it runs.
- It is up to the operating system to select the best processor, find and transport all the files to that processor, and put the results in the appropriate place.

- With a network, users must explicitly log onto one machine, explicitly submit jobs remotely, explicitly move files around and generally handle all the network management personally.
- The distinction between Network and distributed system lies with software (OS) rather than software.
- In a network user invokes, in distributed system the system invokes.

Applications

- Accessing Remote databases
- Accessing Remote programs
- Value added communication facility
- Marketing and sales
- Financial services
- Manufacturing
- Electronic message
- Directory services
- Information services
- Teleconferencing
- Cellular telephone

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

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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**
- **Semantics**
  - **Interprets the meaning of the bits**
  - **Knows which fields define what action**
- **Timing**
  - **When data should be sent and what**
  - **Speed at which data should be sent or speed at which it is being received.**

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.

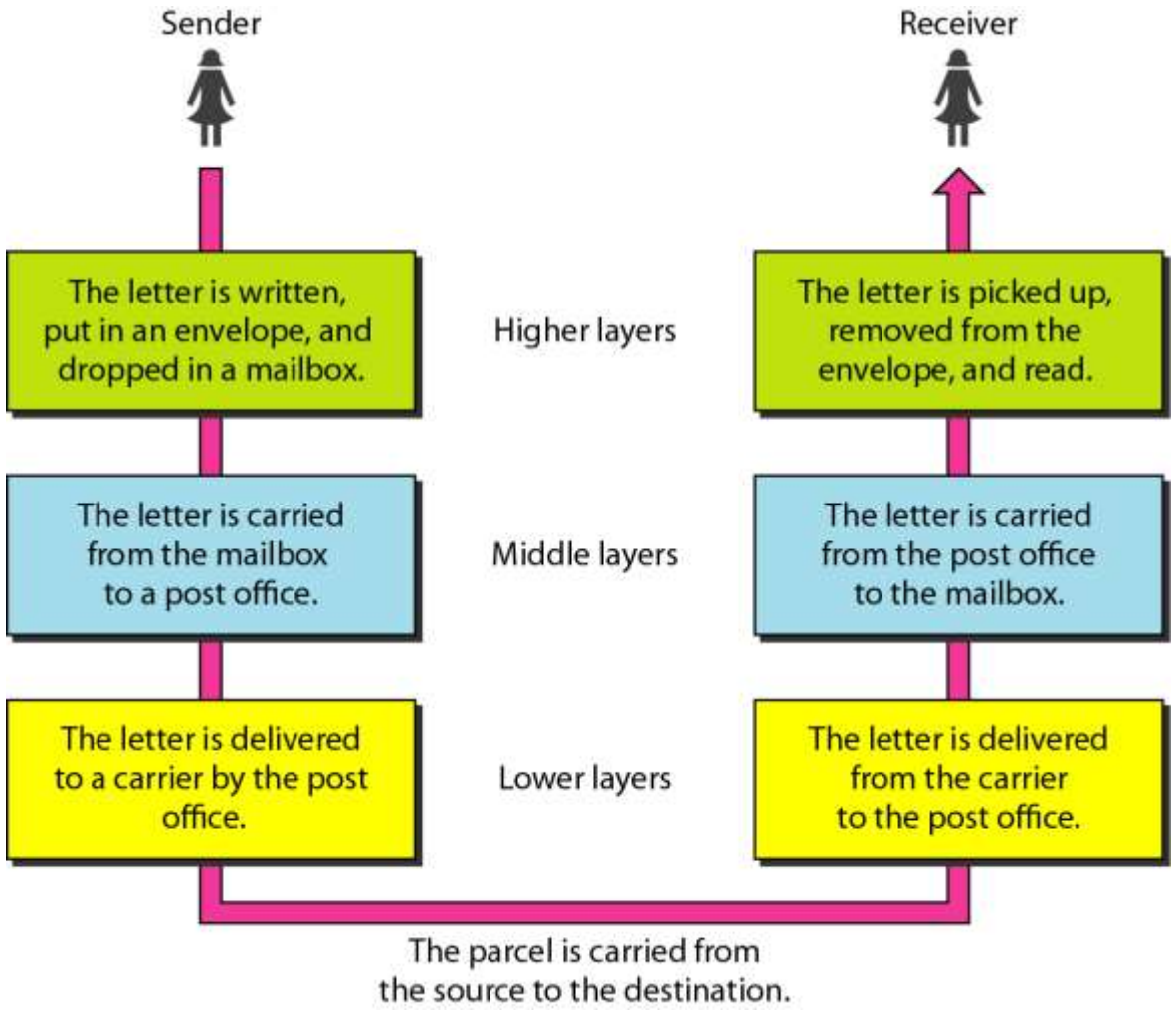
Topics discussed in this section:

Sender, Receiver, and Carrier
Hierarchy

NET WORK MODELS

ISO OSI & TCP/IP

Figure Tasks involved in sending a letter



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.

Topics discussed in this section:

Layered Architecture
Peer-to-Peer Processes
Encapsulation

Note

ISO is the organization.
OSI is the model.

Figure *Seven layers of the OSI model*

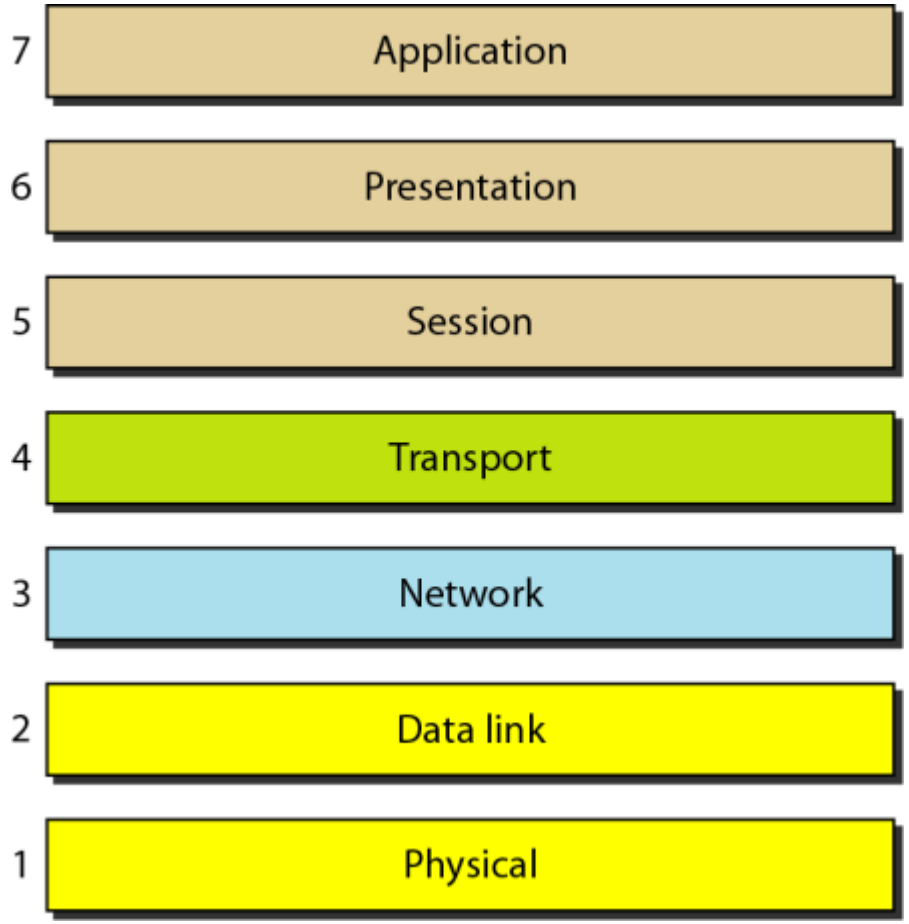


Figure *The interaction between layers in the OSI model*

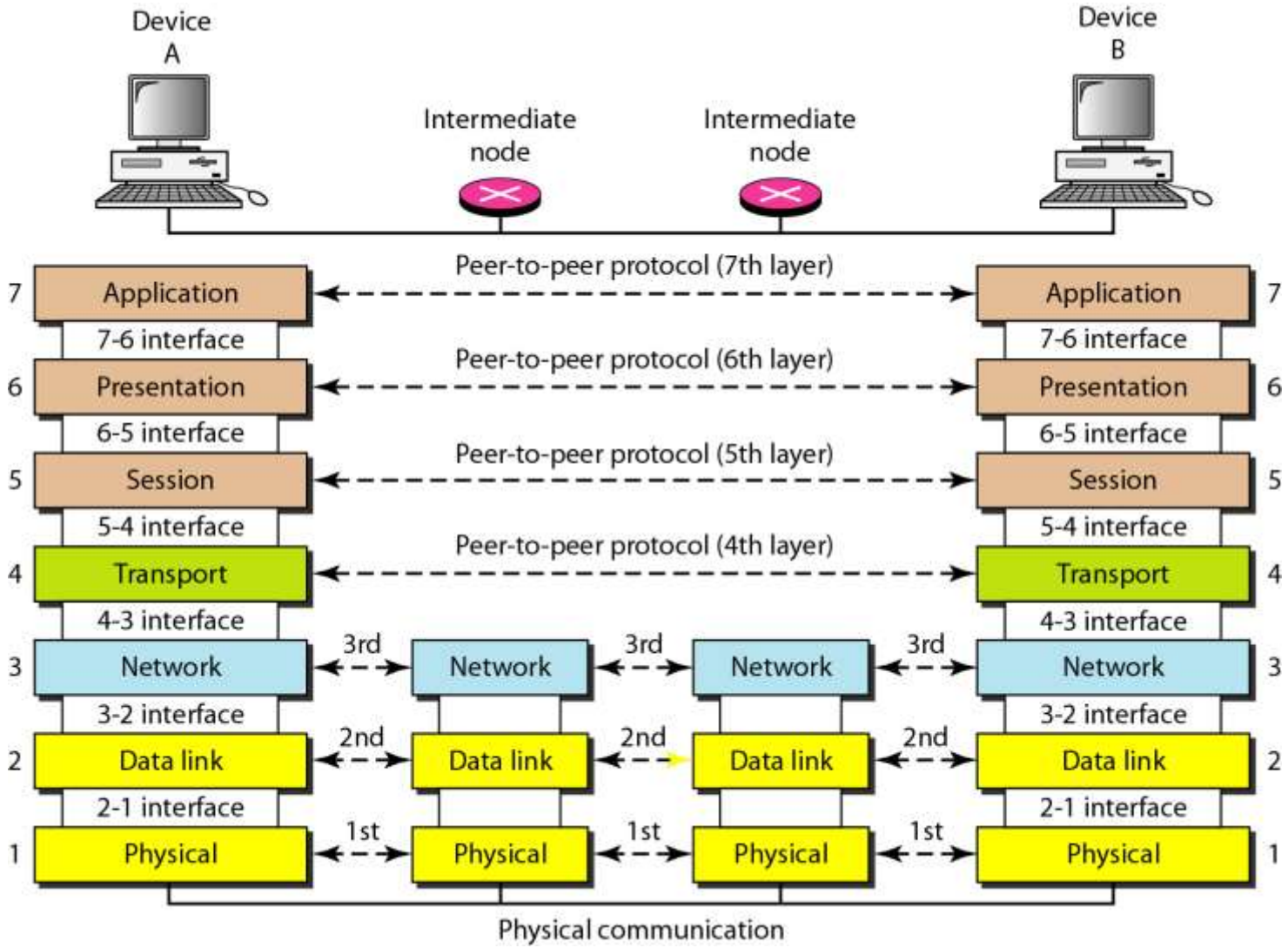
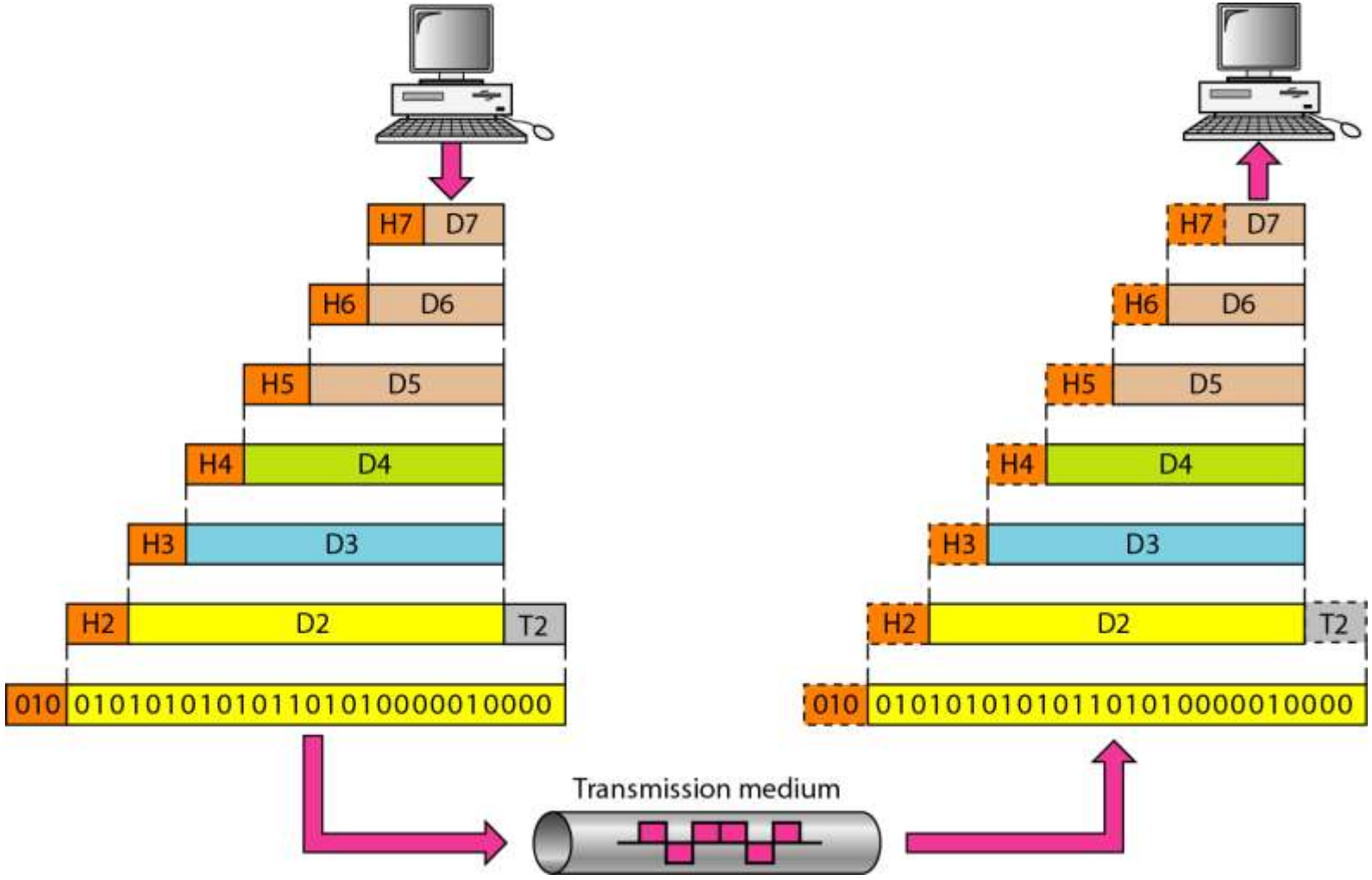


Figure *An exchange using the OSI model*



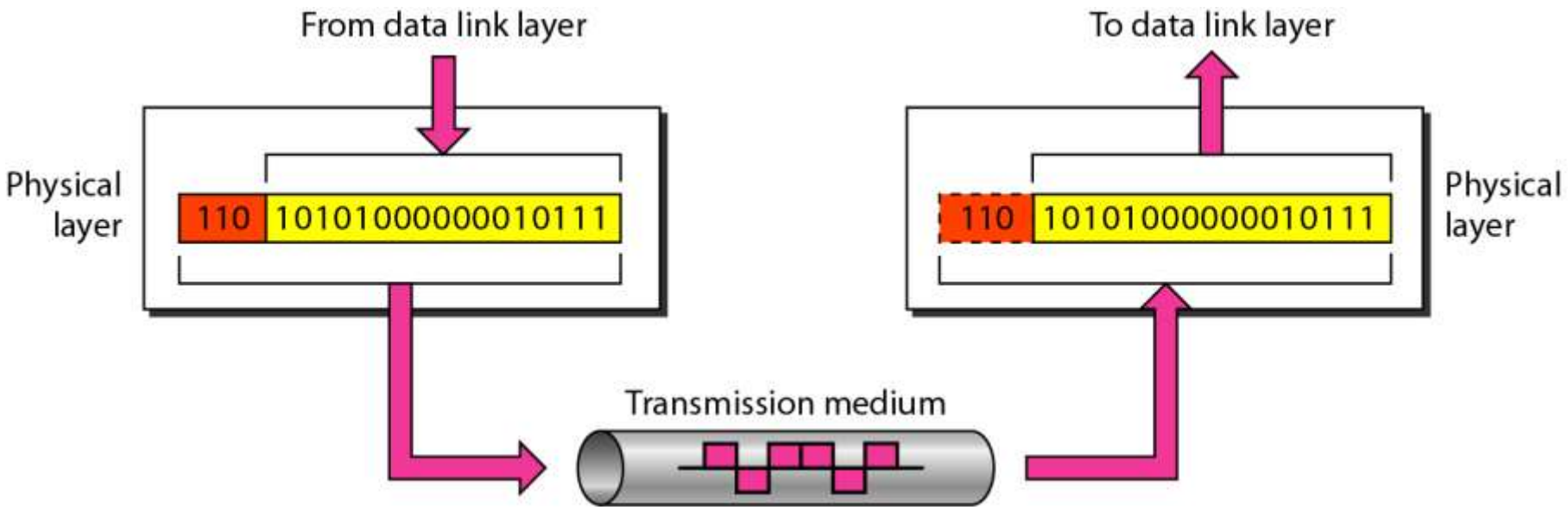
LAYERS IN THE OSI MODEL

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

Figure *Physical layer*



Functions of the Layers

Physical Layer :

- Physical characteristics of interfaces and media
- Representation of bits.
- Data rate
- Synchronization of bits
- Line configuration (point to point or multipoint)
- Transmission Mode
- Physical Topology

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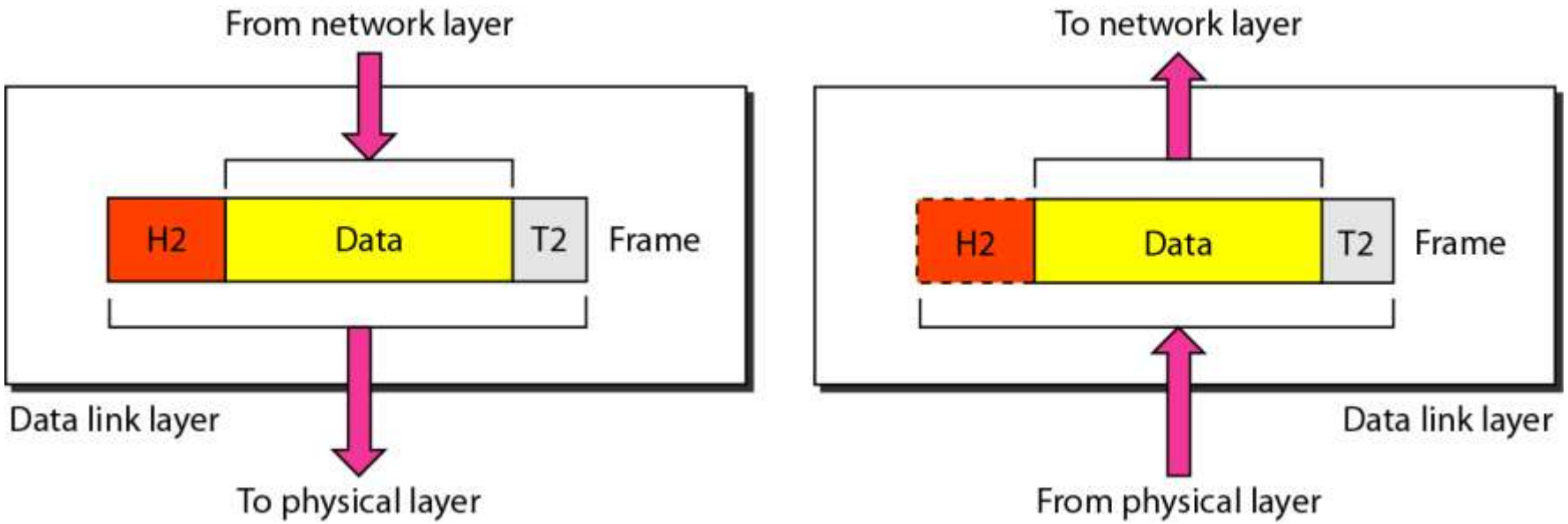
Note

The physical layer is responsible for movements of individual bits from one hop (node) to the next.

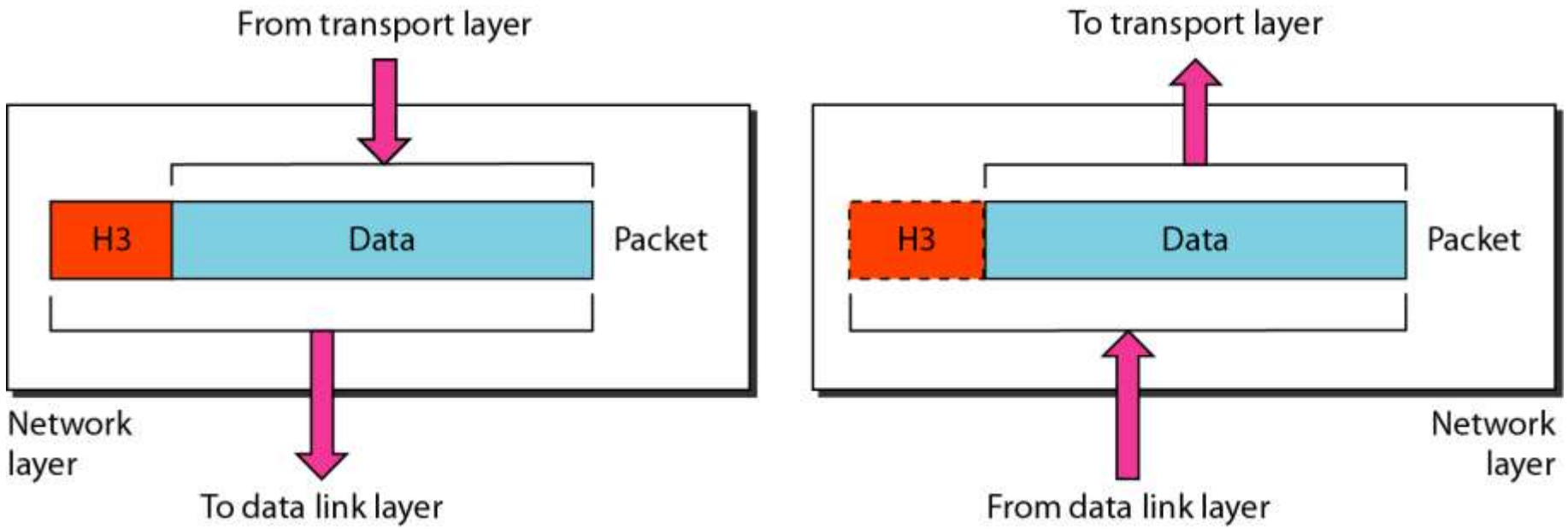
Figure *Data link layer*



Data Link Layer :

- Framing
- Physical addressing
- Error control
- Flow control

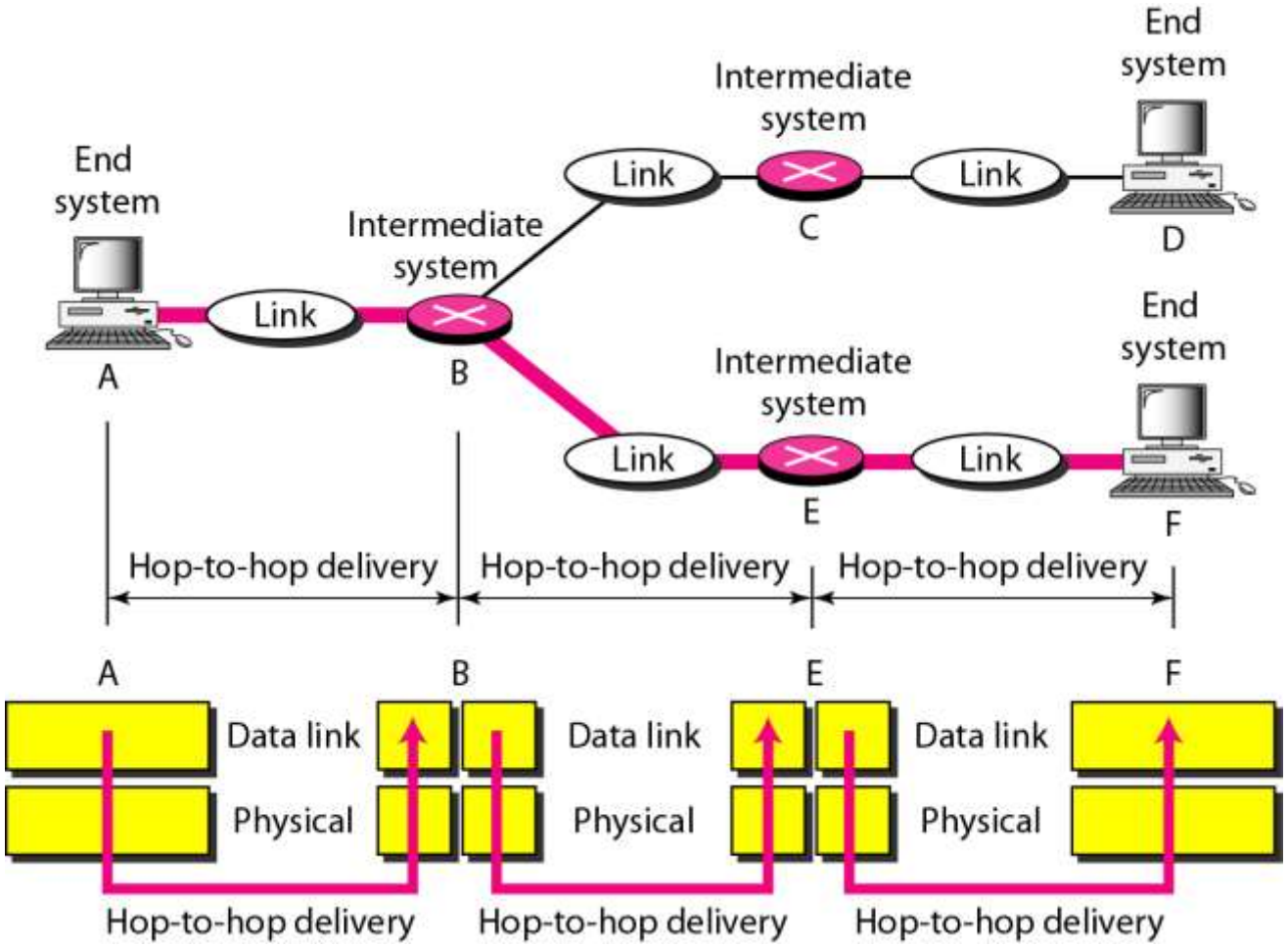
Figure *Network layer*



Note

The data link layer is responsible for moving frames from one hop (node) to the next.

Figure *Hop-to-hop delivery*



Network Layer :

- Routing
- Congestion control
- Billing

Note

The network layer is responsible for the delivery of individual packets from the source host to the destination host.

Figure *Source-to-destination delivery*

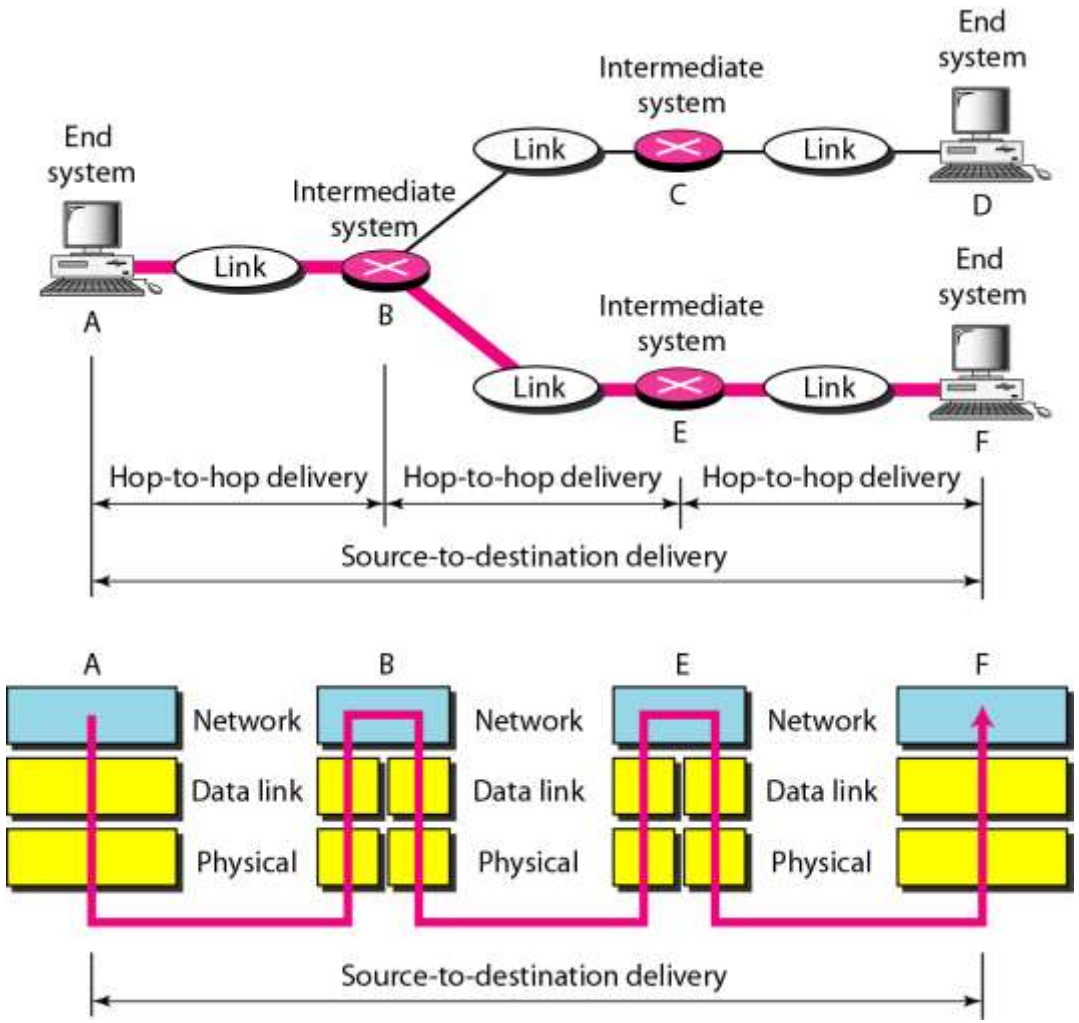
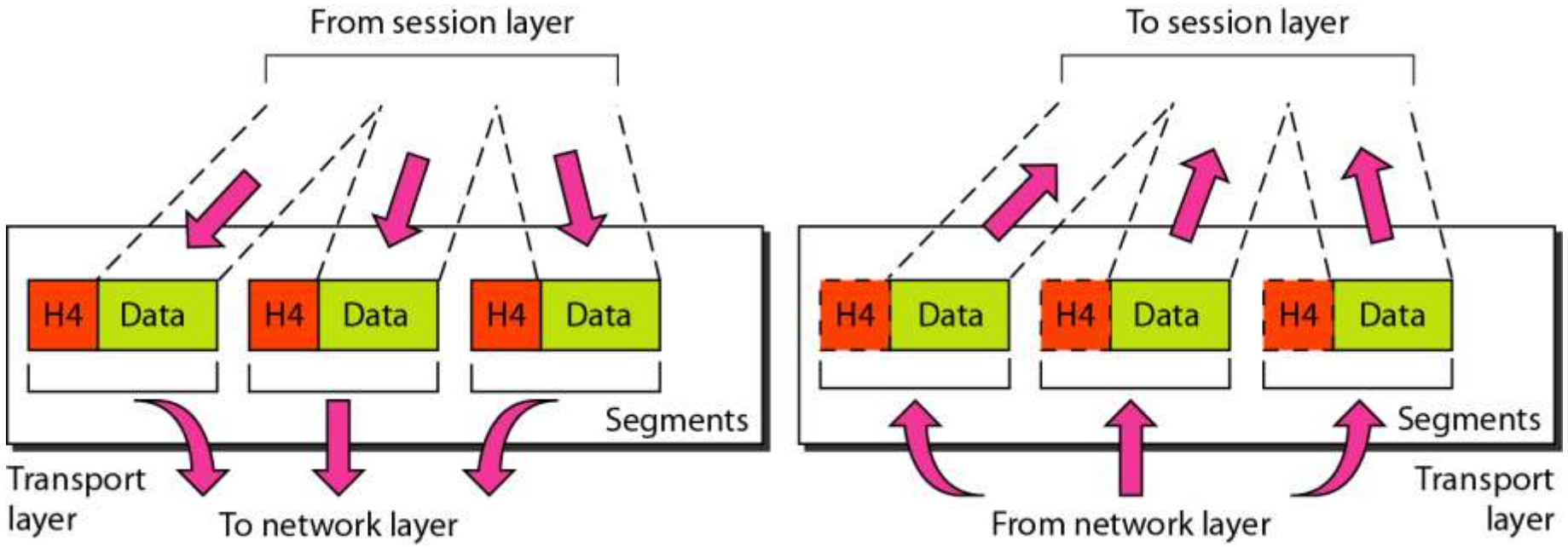


Figure *Transport layer*



Transport Layer :

- Service – Point addressing
- Segmentation and reassembly
- Flow control
- Error control

Note

The transport layer is responsible for the delivery of a message from one process to another.

Figure *Reliable process-to-process delivery of a message*

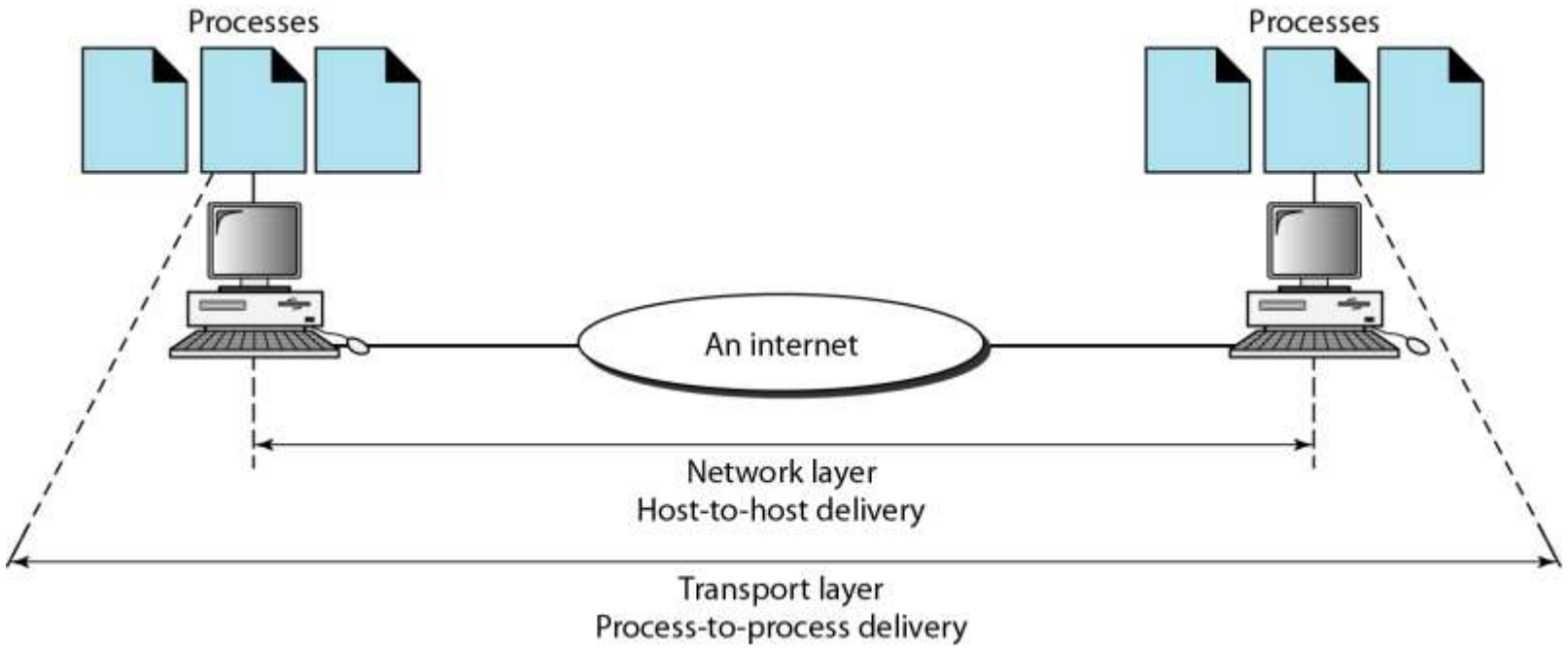
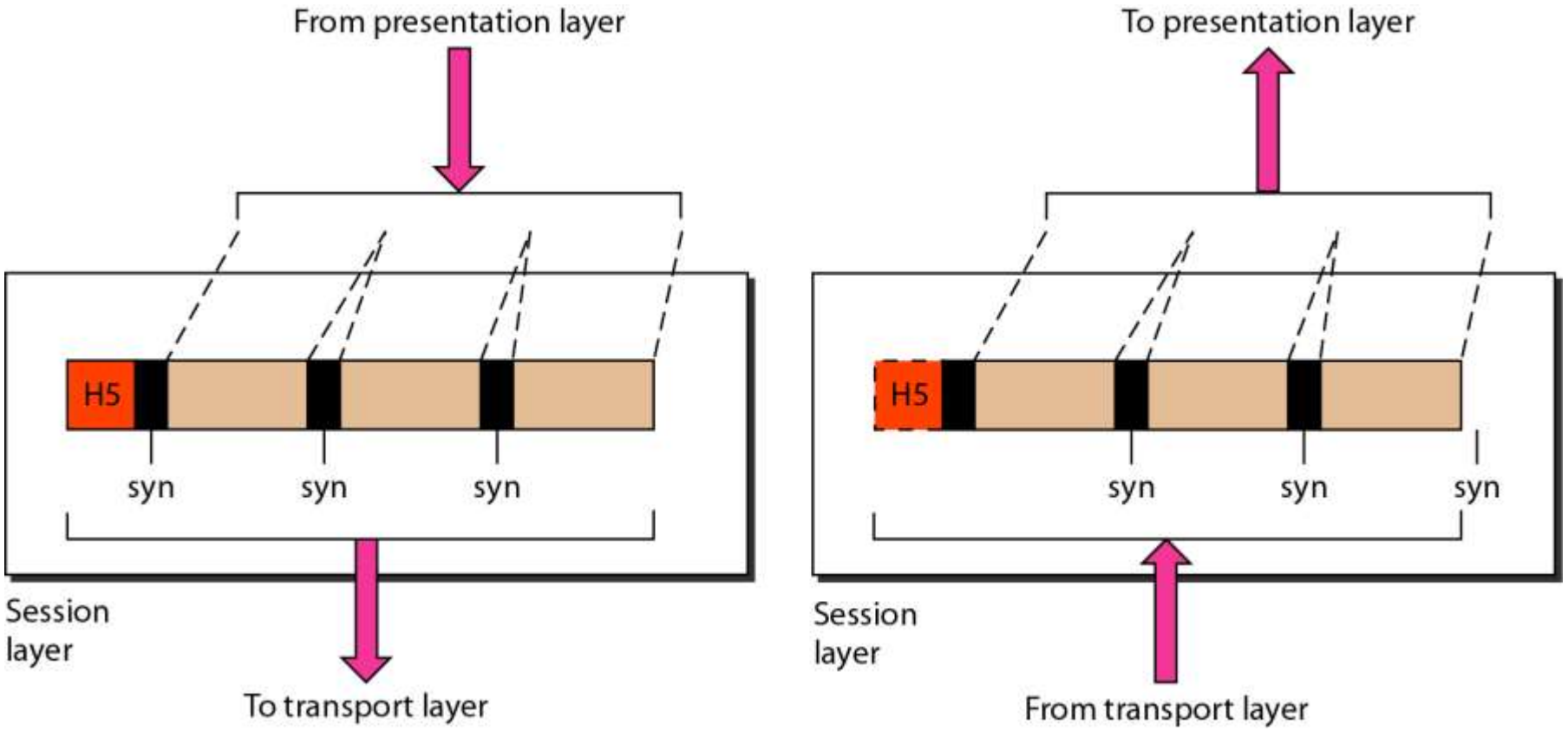


Figure *Session layer*



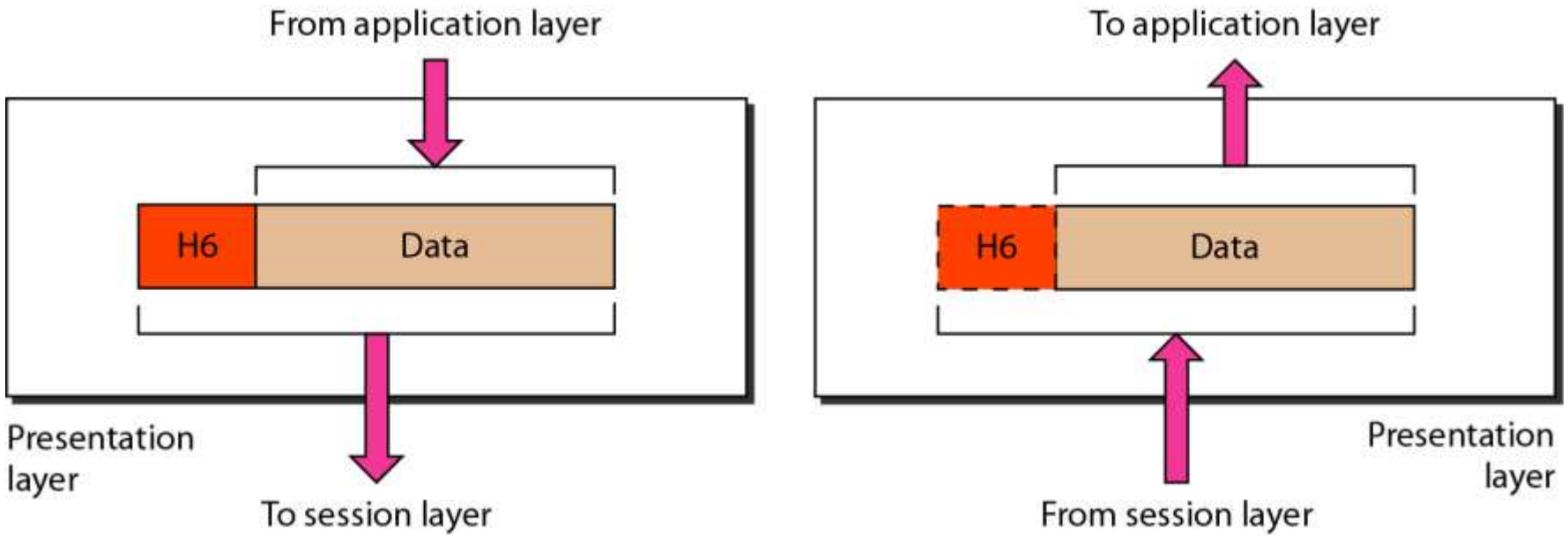
Session Layer :

-Dialog control

-Synchronization

The session layer is responsible for dialog control and synchronization.

Figure *Presentation layer*

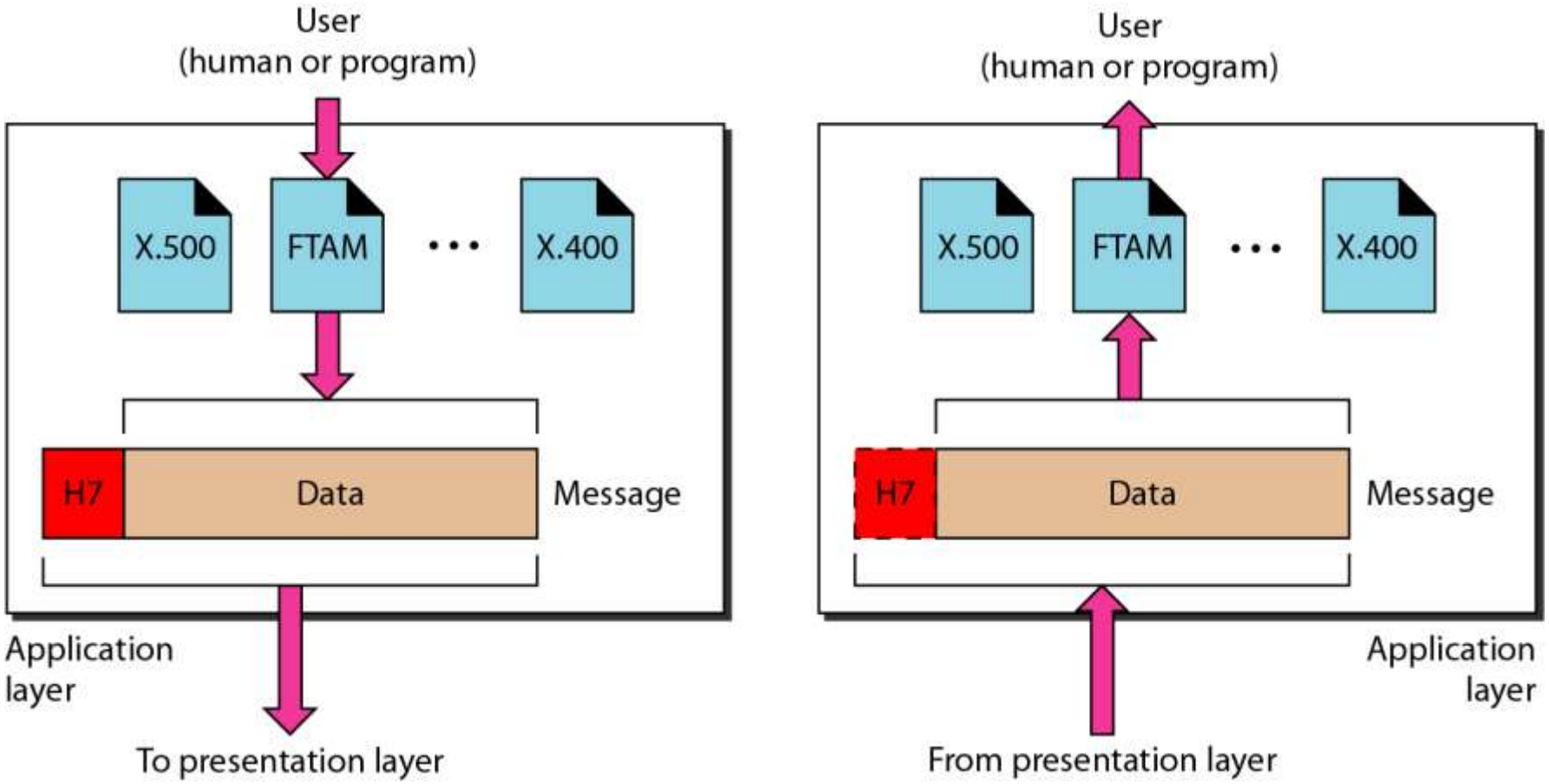


Presentation Layer :

- Data encoding
- Encryption
- Compression

The presentation layer is responsible for translation, compression, and encryption.

Figure *Application layer*



Application Layer :

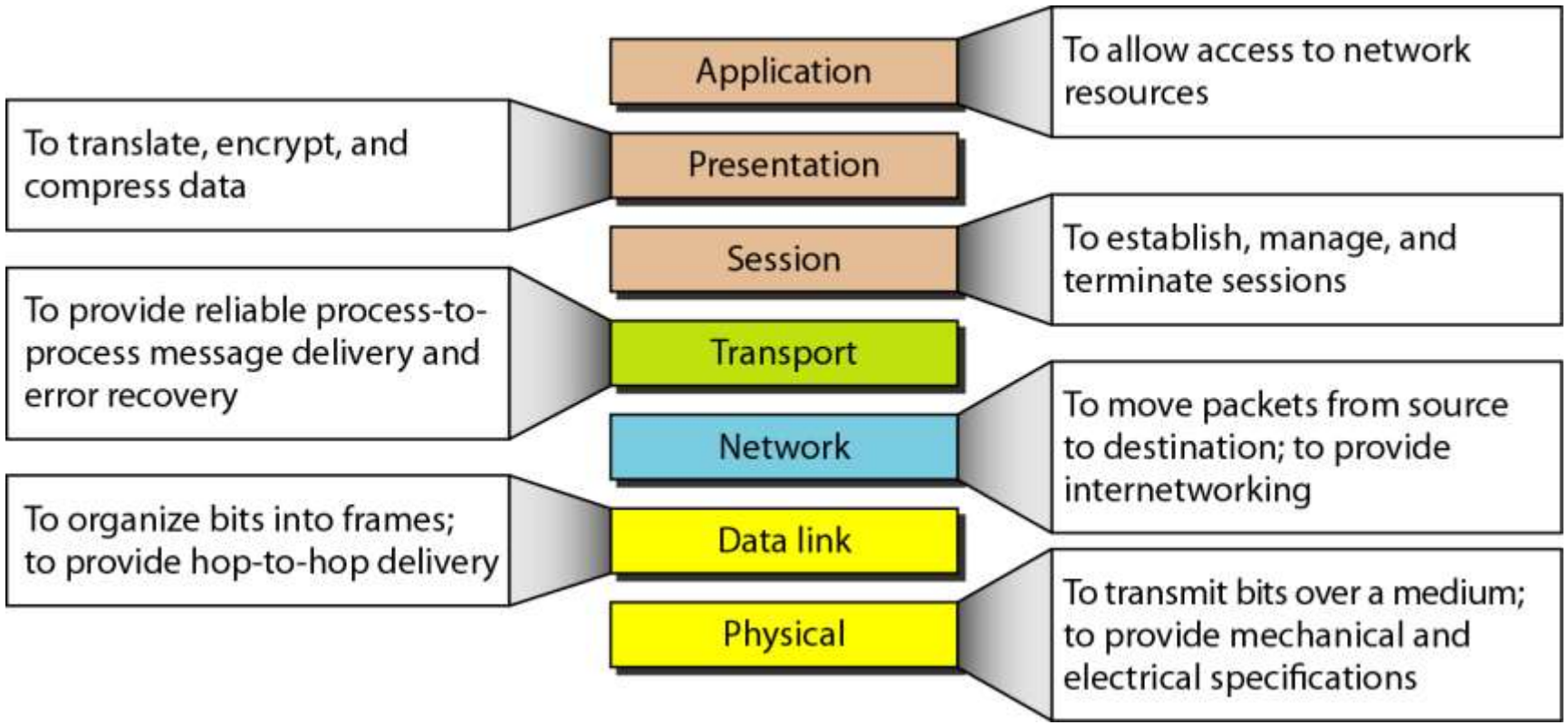
- File Transfer
- Mail services
- Directory services

Note

The application layer is responsible for providing services to the user.

OSI ISO VIDEO

Figure 2.15 *Summary of layers*



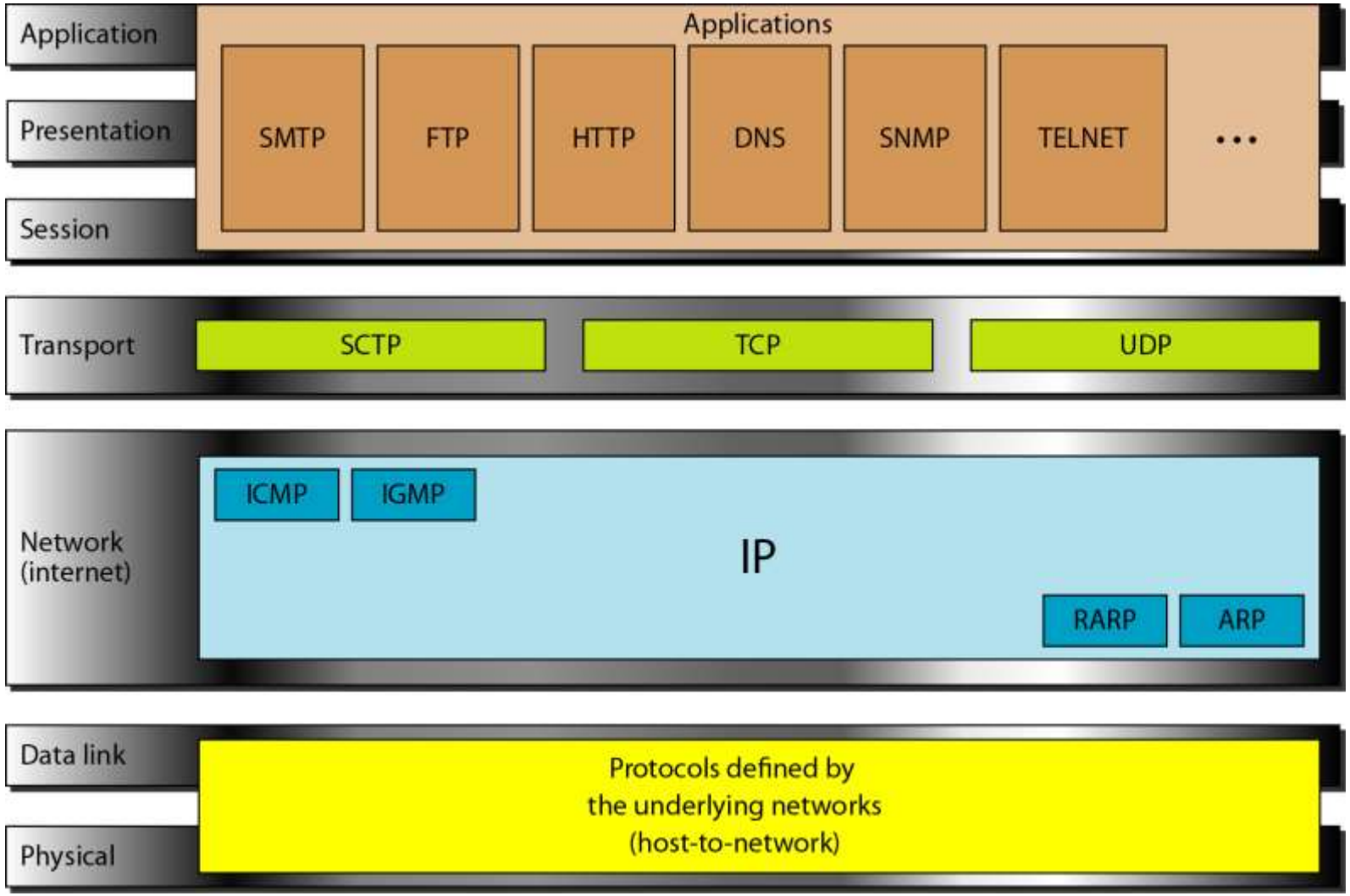
TCP/IP PROTOCOL SUITE

The layers in the TCP/IP protocol suite do not exactly match those in the OSI model. The original TCP/IP protocol suite was defined as having four layers: host-to-network, internet, transport, and application. However, when TCP/IP is compared to OSI, we can say that the TCP/IP protocol suite is made of five layers: physical, data link, network, transport, and application.

Topics discussed in this section:

Physical and Data Link Layers
Network Layer
Transport Layer
Application Layer

Figure *TCP/IP and OSI model*



TCP, IP & UDP

Internetworking Protocol(IP)

- It is the Transmission mechanism used by the TCP/IP protocol.
- An unreliable and connectionless protocol
- A best-effort delivery service : No error checking or Tracking.
- Transports data in packets called Datagrams, independently.

Transmission Control Protocol (TCP)

- It is a reliable stream transport protocol & Connection oriented.
- Divides data into smaller units called.
- TCP includes mechanisms to solve many of the problems that arise from packet-based messaging,

  such as lost packets,

  out of order packets,

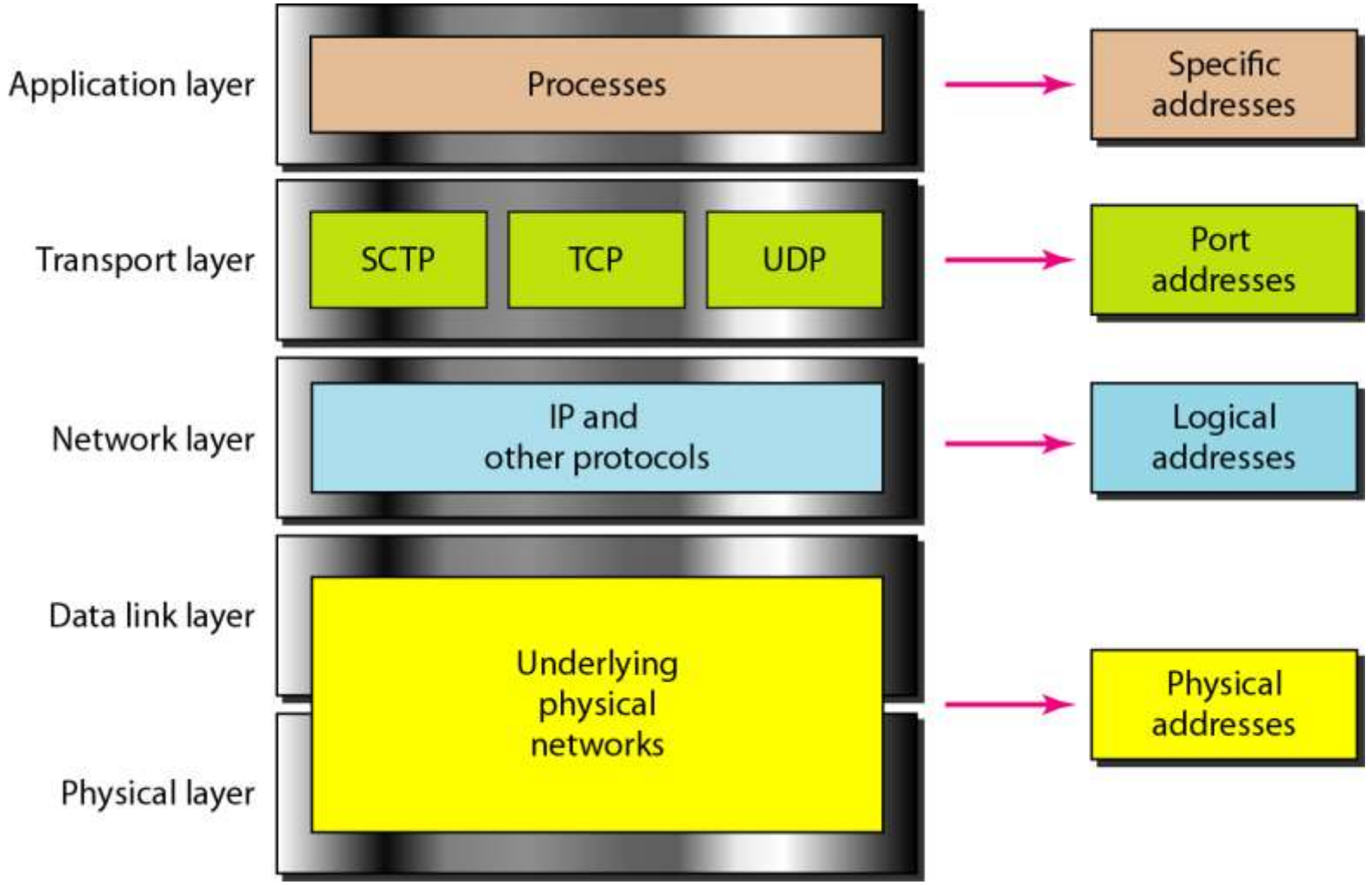
  duplicate packets, and

  corrupted packets.

User Datagram Protocol (UDP)

- User Datagram Protocol defines a robust way to transmit real-time data bits (like voice and video) from one place to another in the form of individual datagrams--a data packet which has no acknowledgment features associated with it.
- UDP is fast, but unreliable in nature, means when data bits are transferred via UDP, their reception acknowledgment cannot be attained in an automated fashion

Figure *Relationship of layers and addresses in TCP/IP*



BASIS FOR COMPARISON	TCP/IP MODEL	OSI MODEL
Expands To	TCP/IP- Transmission Control Protocol/ Internet Protocol	OSI- Open system Interconnect
Meaning	It is a client server model used for transmission of data over the internet.	It is a theoretical model which is used for computing system.
No. Of Layers	4 Layers	7 Layers
Developed by	Department of Defense (DoD)	ISO (International Standard Organization)
Tangible	Yes	No
Usage	Mostly used	Never used

Comparison Chart

TCP/IP VIDEO

https://www.youtube.com/watch?v=_FmDKQ3hlYs

2-5 ADDRESSING

Four levels of addresses are used in an internet employing the TCP/IP protocols: physical, logical, port, and specific.

Topics discussed in this section:

Physical Addresses
Logical Addresses
Port Addresses
Specific Addresses

Figure *Addresses in TCP/IP*

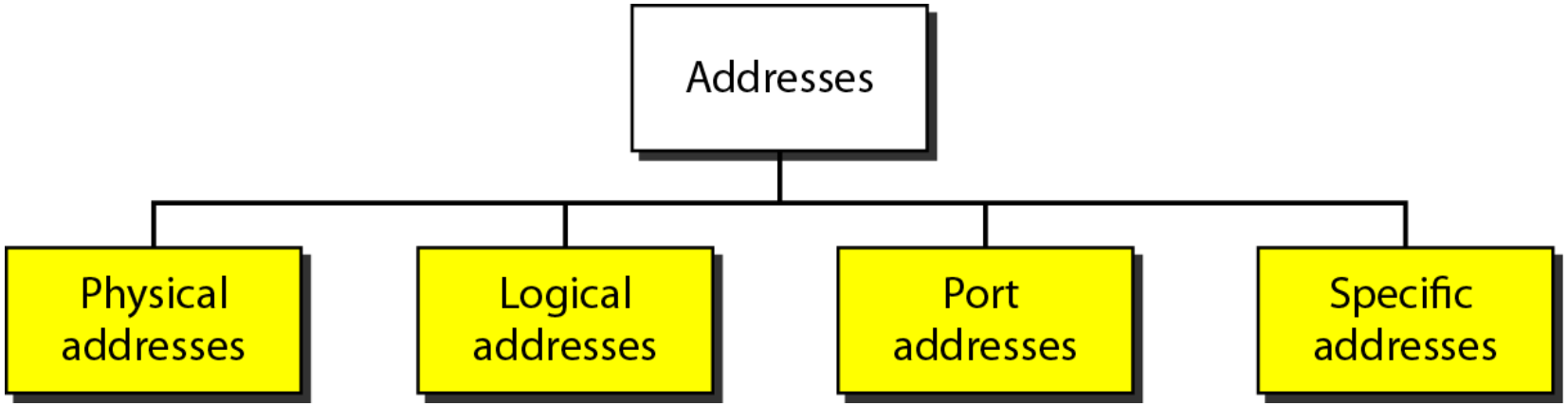
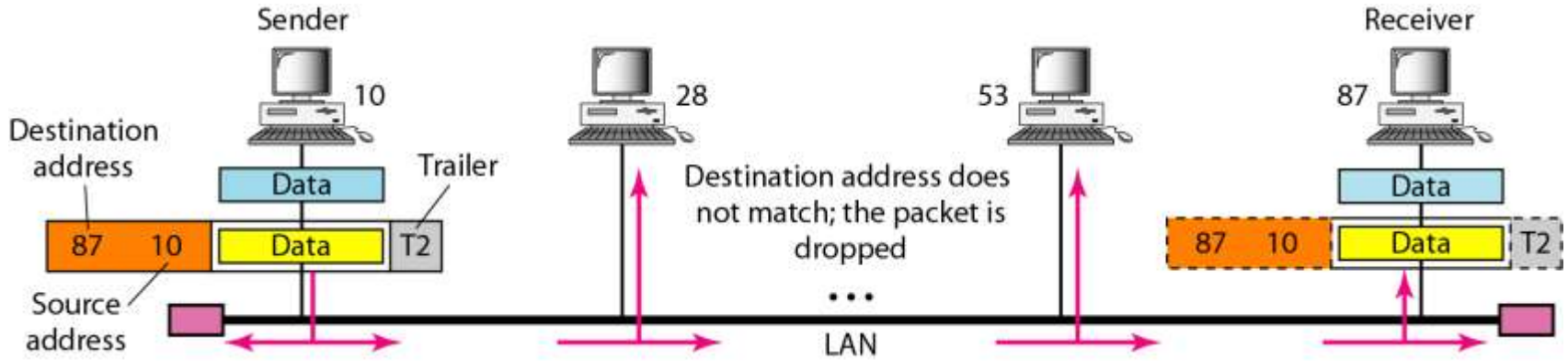


Figure *Physical addresses*



Example 2.1

In Figure 2.19 a node with physical address 10 sends a frame to a node with physical address 87. The two nodes are connected by a link (bus topology LAN). As the figure shows, the computer with physical address 10 is the sender, and the computer with physical address 87 is the receiver.

Example 2.2

Most local-area networks use a 48-bit (6-byte) physical address written as 12 hexadecimal digits; every byte (2 hexadecimal digits) is separated by a colon, as shown below:

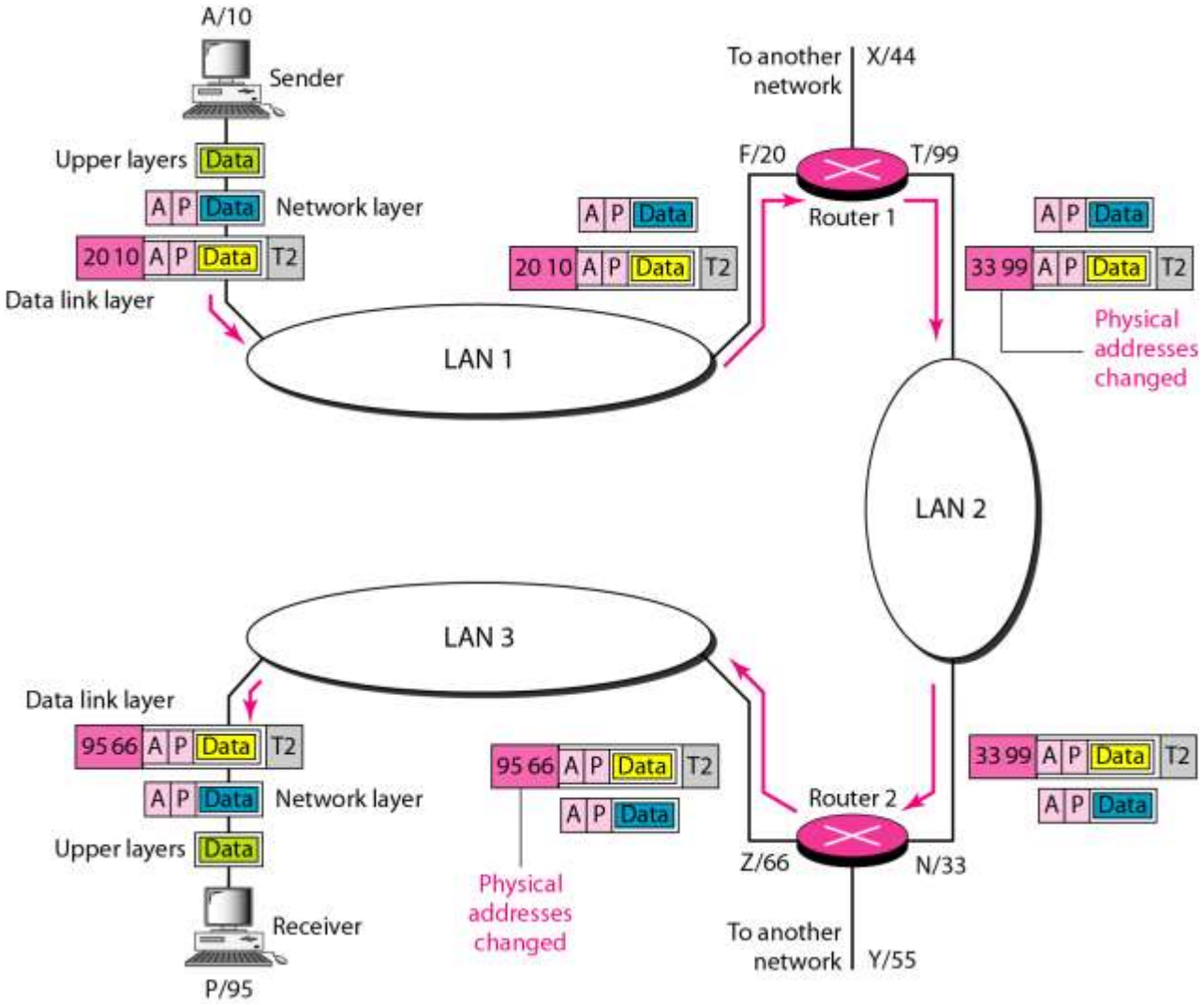
07:01:02:01:2C:4B

A 6-byte (12 hexadecimal digits) physical address.

Example 2.3

Figure 2.20 shows a part of an internet with two routers connecting three LANs. Each device (computer or router) has a pair of addresses (logical and physical) for each connection. In this case, each computer is connected to only one link and therefore has only one pair of addresses. Each router, however, is connected to three networks (only two are shown in the figure). So each router has three pairs of addresses, one for each connection.

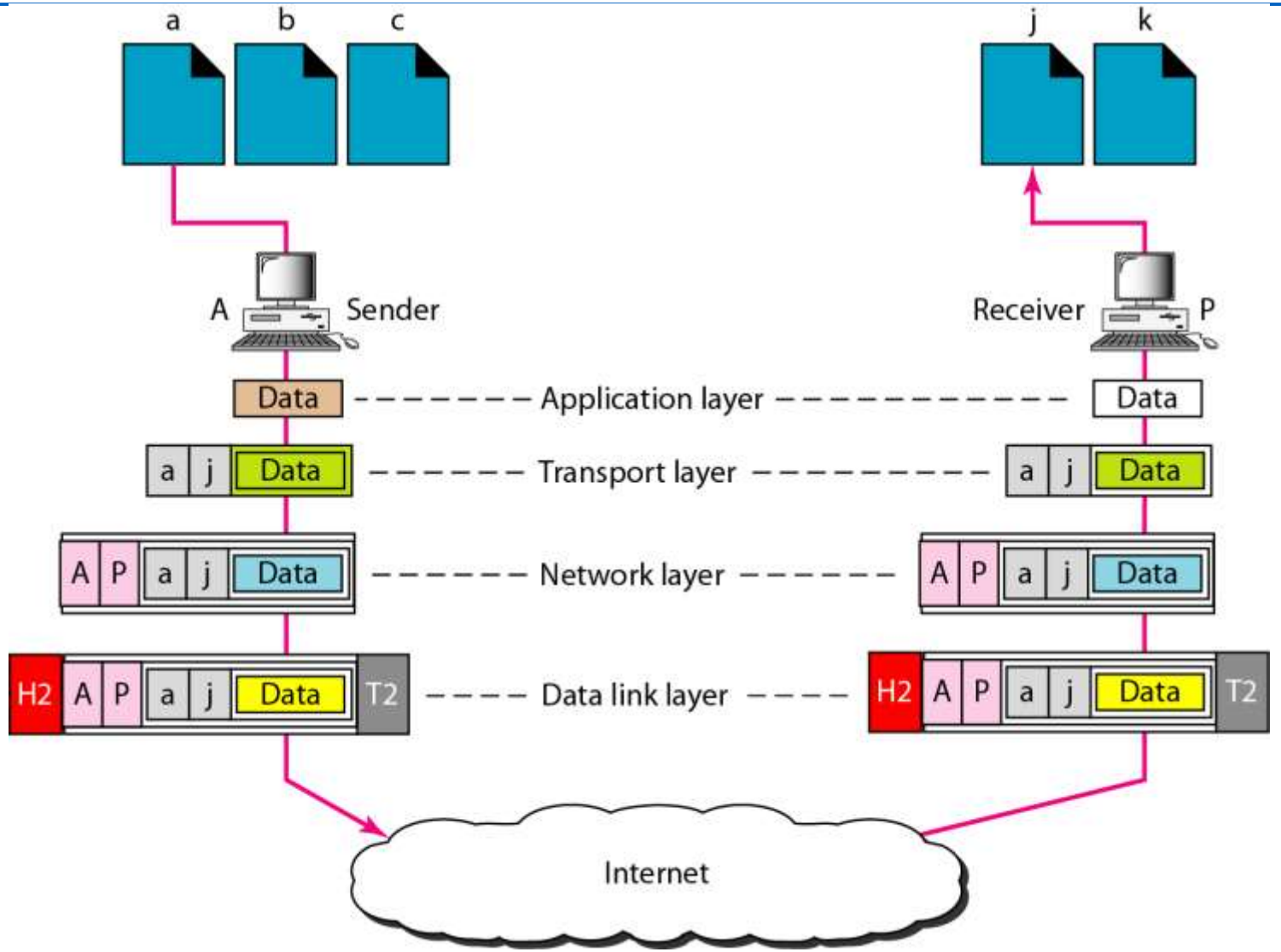
Figure 2.20 *IP addresses*



Example

Figure 2.21 shows two computers communicating via the Internet. The sending computer is running three processes at this time with port addresses a, b, and c. The receiving computer is running two processes at this time with port addresses j and k. Process a in the sending computer needs to communicate with process j in the receiving computer. Note that although physical addresses change from hop to hop, logical and port addresses remain the same from the source to destination.

Figure 2.21 *Port addresses*



Note

The physical addresses will change from hop to hop, but the logical addresses usually remain the same.

Example 2.5

A port address is a 16-bit address represented by one decimal number as shown.

753

A 16-bit port address represented as one single number.

Data and Signals

Note

To be transmitted, data must be transformed to electromagnetic signals.

3-1 ANALOG AND DIGITAL

Data can be analog or digital. The term analog data refers to information that is continuous; digital data refers to information that has discrete states. Analog data take on continuous values. Digital data take on discrete values.

Topics discussed in this section:

- Analog and Digital Data
- Analog and Digital Signals
- Periodic and Nonperiodic Signals

Analog and Digital Data

- Data can be analog or digital.
- Analog data are continuous and take continuous values.
- Digital data have discrete states and take discrete values.

Analog and Digital DATA

- Ex. of Analog Data

  analog clock contains hour, minute and seconds.

  Human voice.

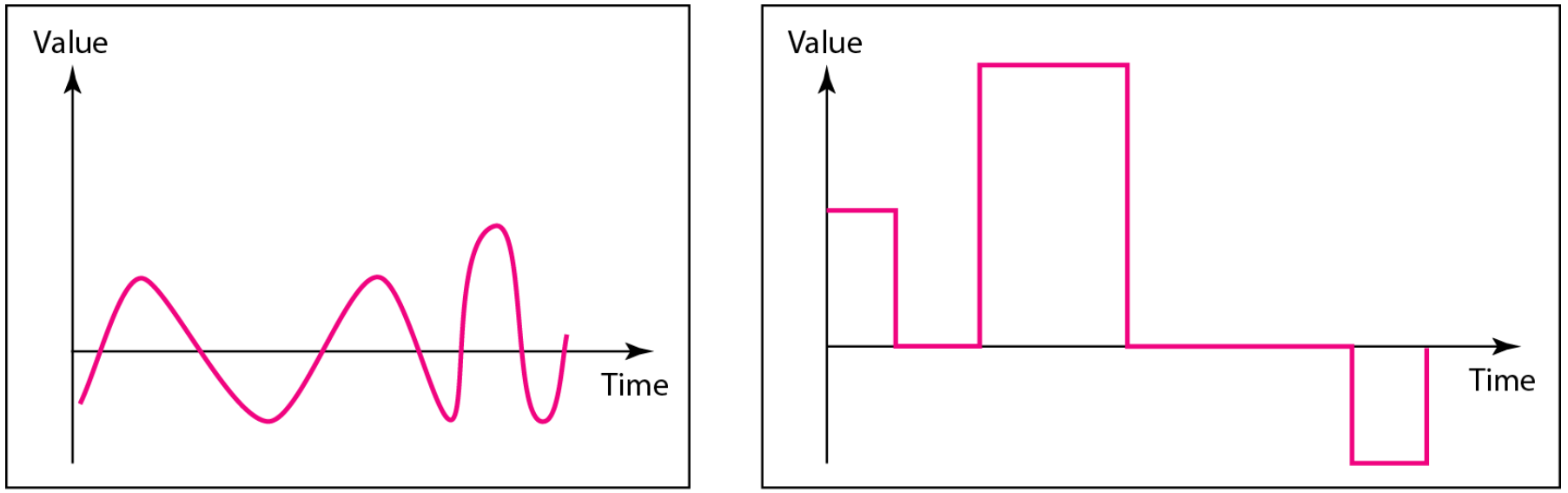
- Ex. of Digital Data

  Digital clock – which changes suddenly from 8:00 to 8:01

Analog and Digital Signals

- Signals can be analog or digital.
- Analog signals can have an infinite number of values in a range.
- Digital signals can have only a limited number of values.

Figure 3.1 Comparison of analog and digital signals



a. Analog signal

b. Digital signal

3-2 PERIODIC ANALOG SIGNALS

In data communications, we commonly use periodic analog signals and nonperiodic digital signals.

Periodic analog signals can be classified as simple or composite. A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals. A composite periodic analog signal is composed of multiple sine waves.

Topics discussed in this section:

- Sine Wave
- Wavelength
- Time and Frequency Domain
- Composite Signals
- Bandwidth

Figure 3.2 A sine wave

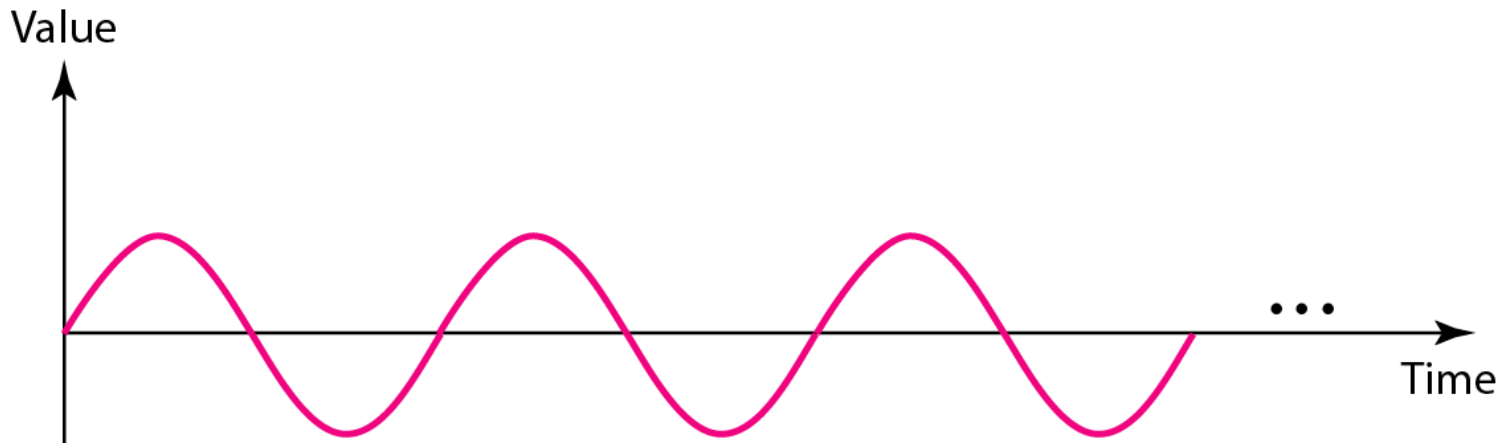
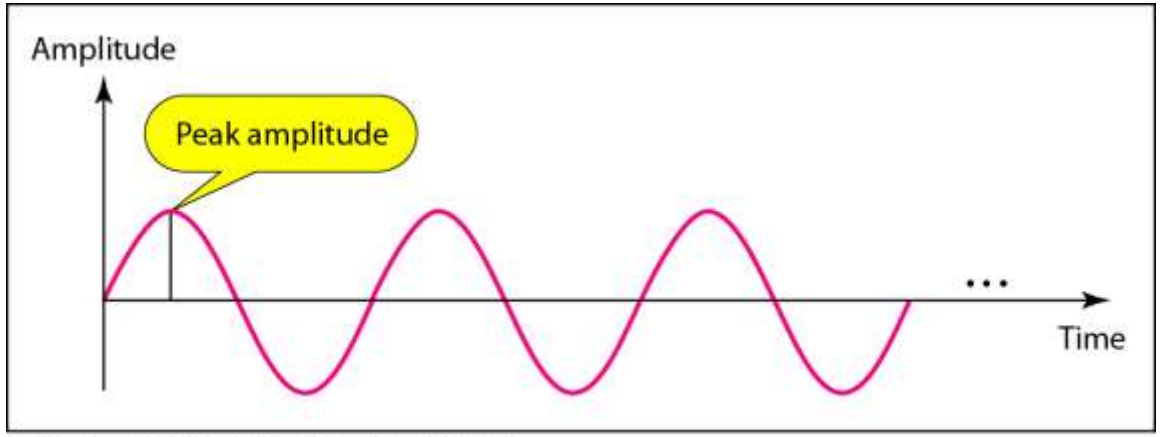
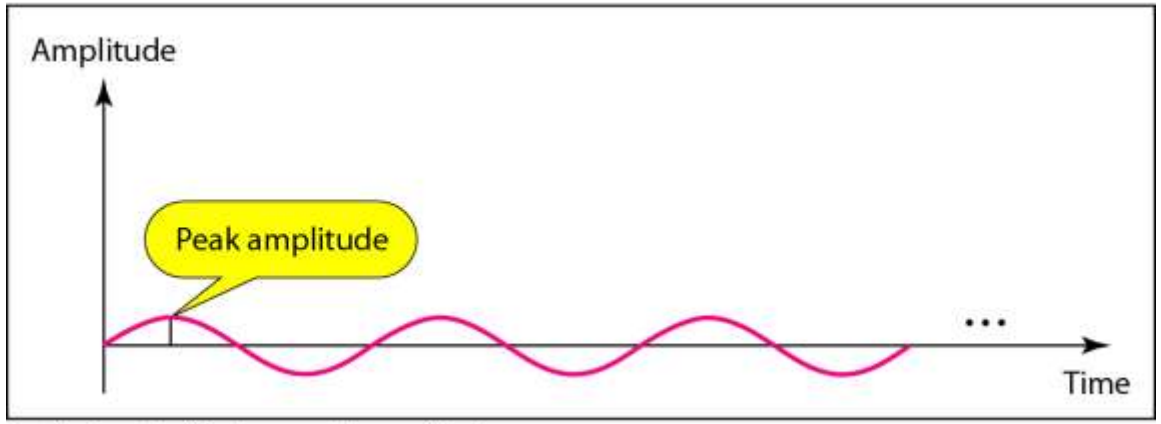


Figure 3.3 Two signals with the same phase and frequency, but different amplitudes



a. A signal with high peak amplitude



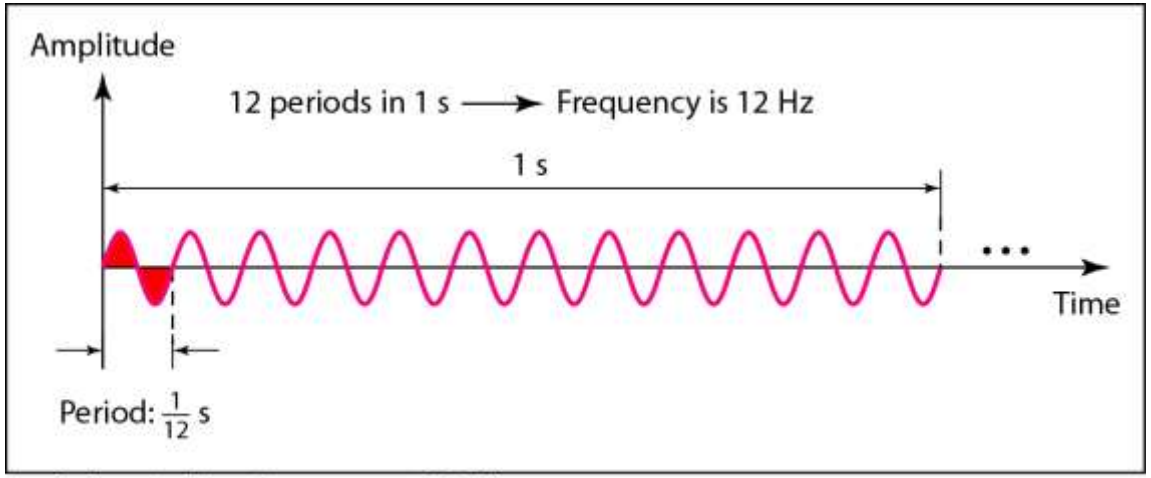
b. A signal with low peak amplitude

Note

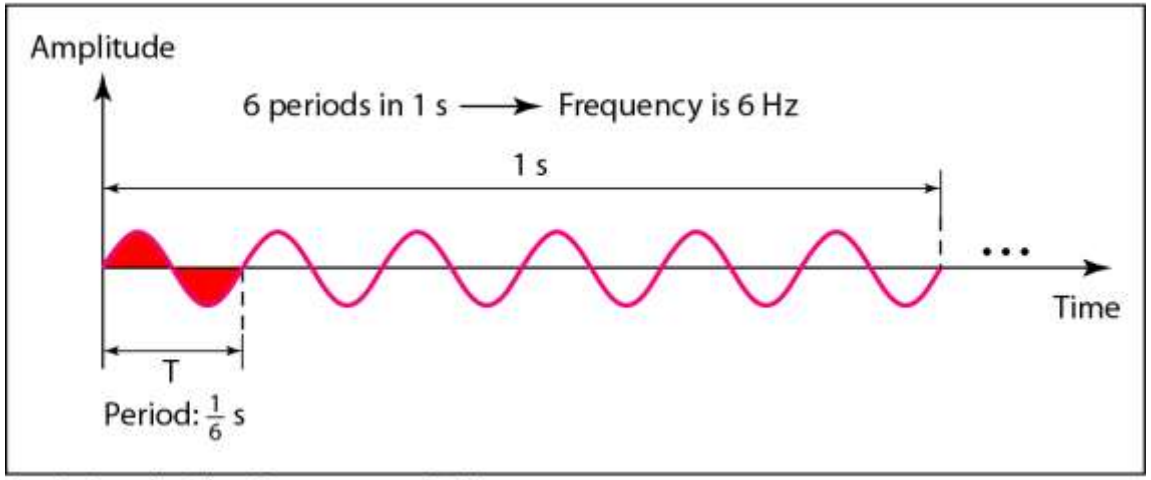
Frequency and period are the inverse of each other.

$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$

Figure 3.4 Two signals with the same amplitude and phase, but different frequencies



a. A signal with a frequency of 12 Hz



b. A signal with a frequency of 6 Hz

Table 3.1 Units of period and frequency

Unit	*Equivalent*	*Unit*	*Equivalent*
Seconds (s)	1 s	Hertz (Hz)	1 Hz
Milliseconds (ms)	10^{-3} s	Kilohertz (kHz)	10^{3} Hz
Microseconds (μs)	10^{-6} s	Megahertz (MHz)	10^{6} Hz
Nanoseconds (ns)	10^{-9} s	Gigahertz (GHz)	10^{9} Hz
Picoseconds (ps)	10^{-12} s	Terahertz (THz)	10^{12} Hz

Example 1

The power we use at home has a frequency of 50 Hz. The period of this sine wave can be determined as follows:

$$T = 1/f = 1/50 = 0.02s \quad \text{or } 2.0 \text{ ms}$$

If the frequency is 60 Hz

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166 \text{ s} = 0.0166 \times 10^3 \text{ ms} = 16.6 \text{ ms}$$

Example.2

The period of a signal is 100 ms. What is its frequency in kilohertz?

Solution

First we change 100 ms to seconds, and then we calculate the frequency from the period (1 Hz = 10^{-3} kHz).

$$100 \text{ ms} = 100 \times 10^{-3} \text{ s} = 10^{-1} \text{ s}$$

$$f = \frac{1}{T} = \frac{1}{10^{-1}} \text{ Hz} = 10 \text{ Hz} = 10 \times 10^{-3} \text{ kHz} = 10^{-2} \text{ kHz}$$

Frequency

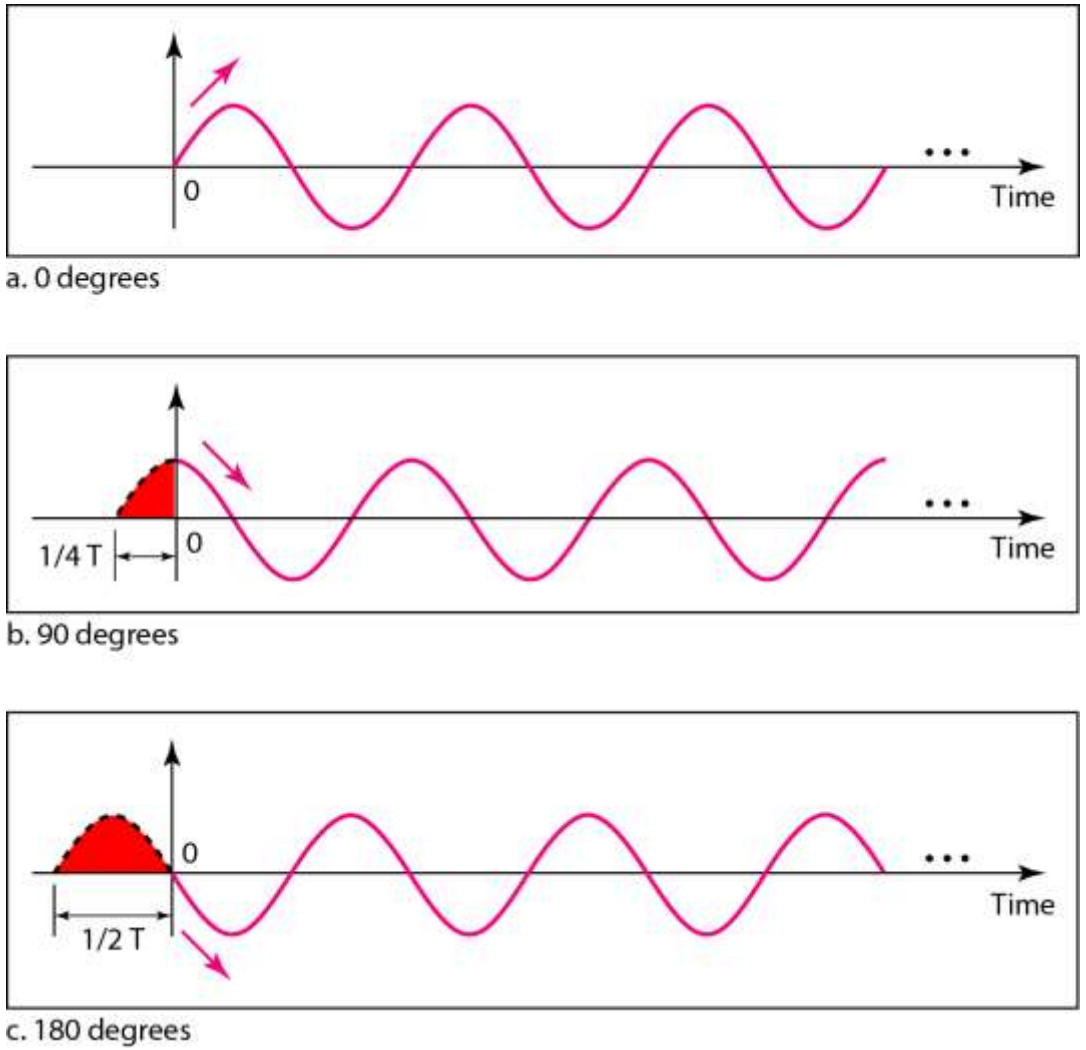
- Frequency is the rate of change with respect to time.
- Change in a short span of time means high frequency.
- Change over a long span of time means low frequency.

Note

If a signal does not change at all, its frequency is zero.
If a signal changes instantaneously, its frequency is infinite.

Phase describes the position of the waveform relative to time 0.

Figure 3.5 Three sine waves with the same amplitude and frequency, but different phases



Example 3

A sine wave is offset 1/6 cycle with respect to time 0. What is its phase in degrees and radians?

Solution

We know that 1 complete cycle is 360°. Therefore, 1/6 cycle is

$$\frac{1}{6} \times 360 = 60° = 60 \times \frac{2\pi}{360} \text{ rad} = \frac{\pi}{3} \text{ rad} = 1.046 \text{ rad}$$

Difference between Analog & Digital Signal

Analog

- An analog signal is a continuous wave that changes over a time period.
- An analog signal is represented by a sine wave
- An analog signal is described by the amplitude, period or frequency, and phase.

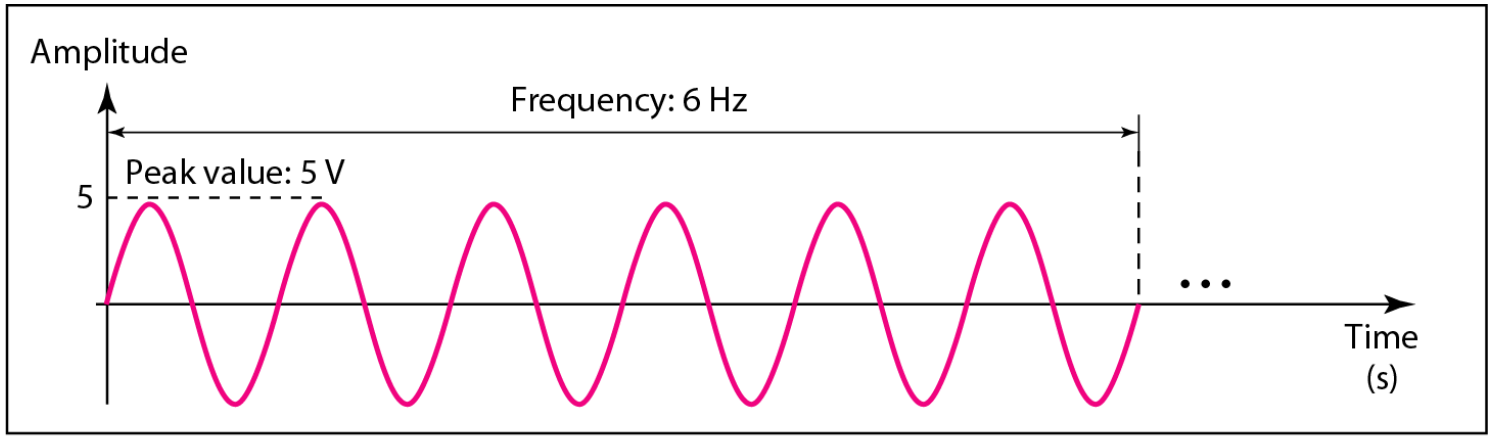
Digital

- A digital signal is a discrete wave that carries information in binary form.
- A digital signal is represented by square waves.
- A digital signal is described by bit rate and bit intervals.

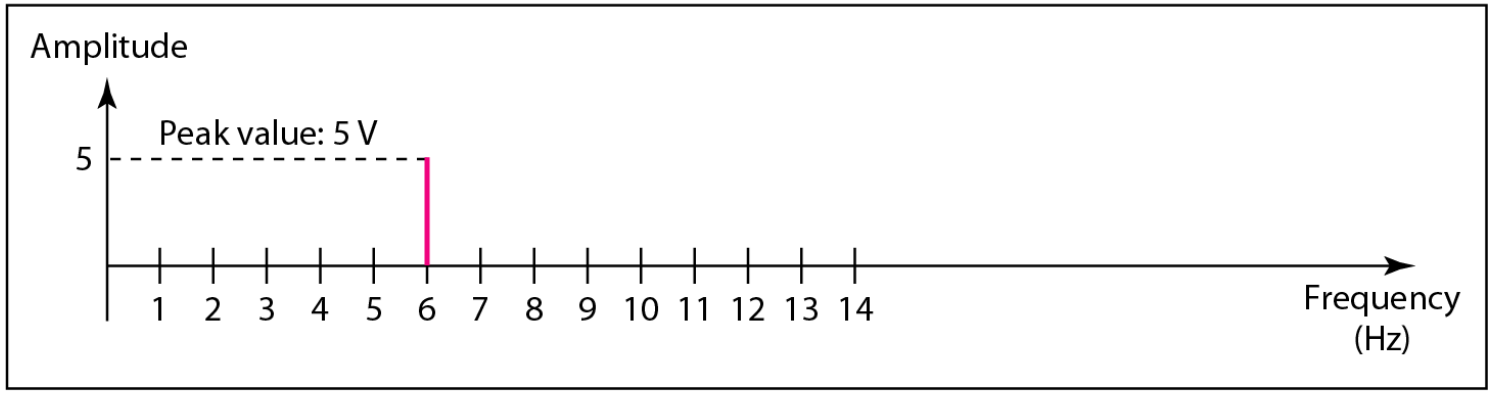
- An analog signal is more prone to distortion.
- An analog signal transmit data in the form of a wave.
- The human voice is the best example of an analog signal.

- A digital signal is less prone to distortion.
- A digital signal carries data in the binary form i.e. 0 and 1.

Figure 3.7 The time-domain and frequency-domain plots of a sine wave



a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)



b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

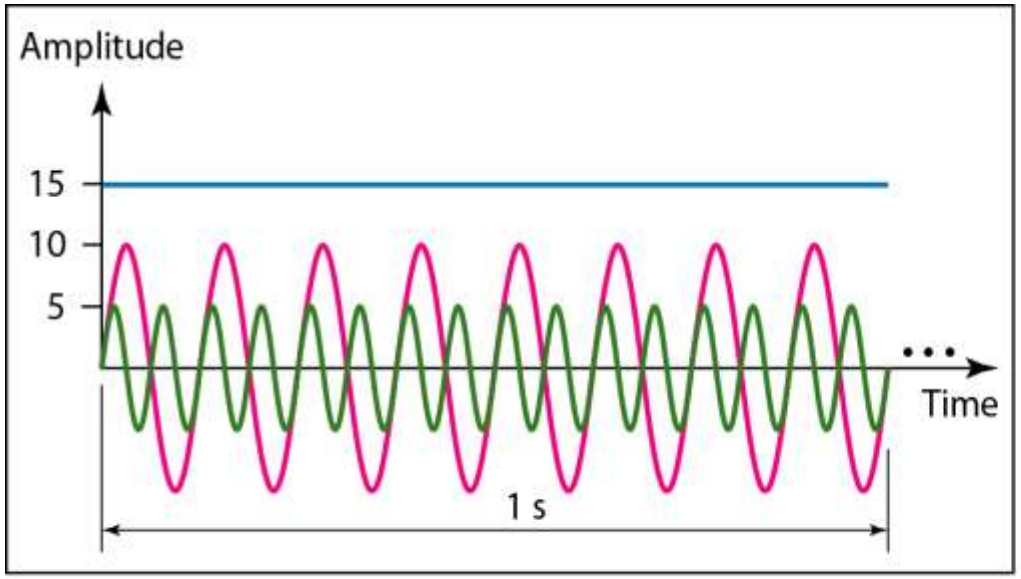
Note

A complete sine wave in the time domain can be represented by one single spike in the frequency domain.

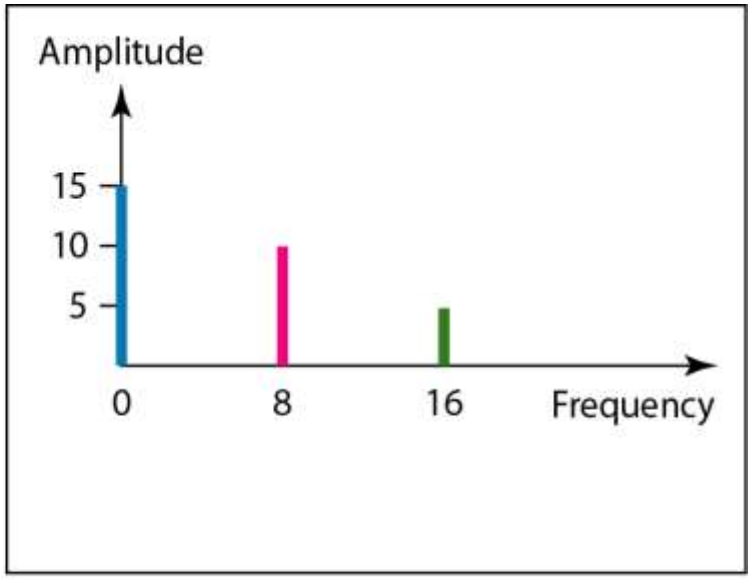
Example 3.7

The frequency domain is more compact and useful when we are dealing with more than one sine wave. For example, Figure 3.8 shows three sine waves, each with different amplitude and frequency. All can be represented by three spikes in the frequency domain.

Figure 3.8 The time domain and frequency domain of three sine waves



a. Time-domain representation of three sine waves with frequencies 0, 8, and 16



b. Frequency-domain representation of the same three signals

Signals and Communication

- A single-frequency sine wave is not useful in data communications
- We need to send a composite signal, a signal made of many simple sine waves.
- According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

Composite Signals and Periodicity

- If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies.
- If the composite signal is nonperiodic, the decomposition gives a combination of sine waves with continuous frequencies.

Example

Figure 3.9 shows a periodic composite signal with frequency f. This type of signal is not typical of those found in data communications. We can consider it to be three alarm systems, each with a different frequency. The analysis of this signal can give us a good understanding of how to decompose signals.

Figure 3.9 A composite periodic signal

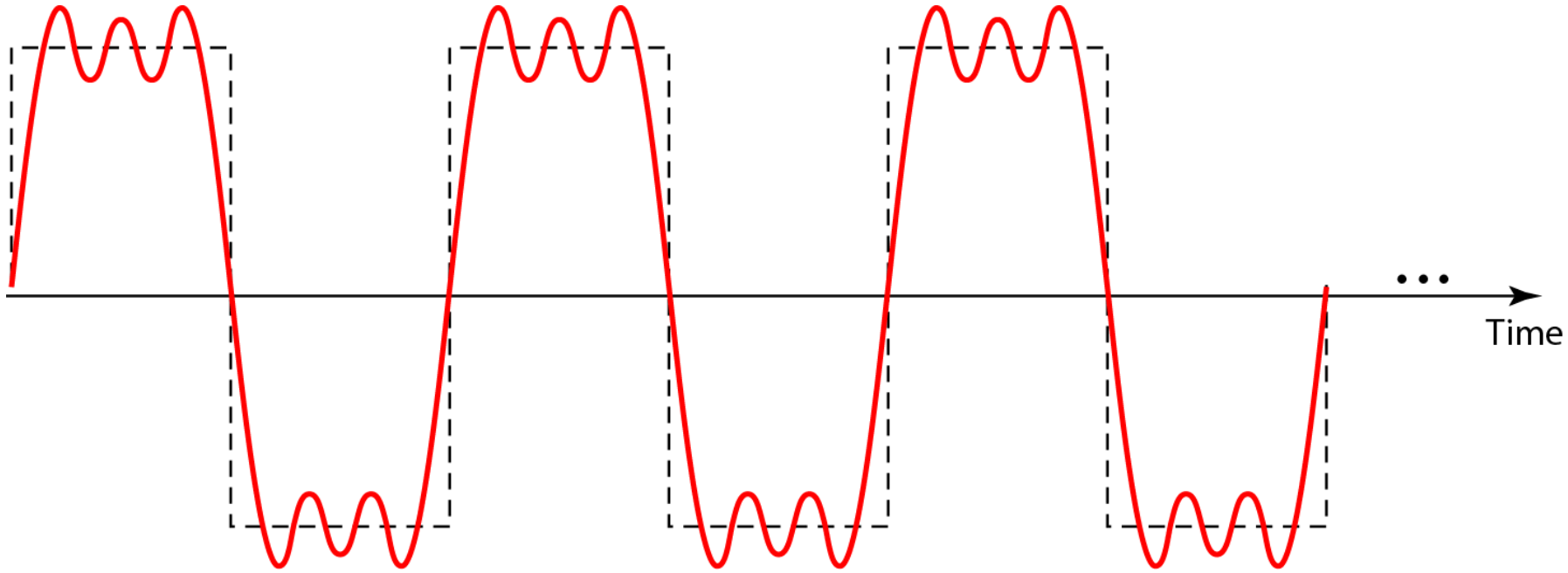
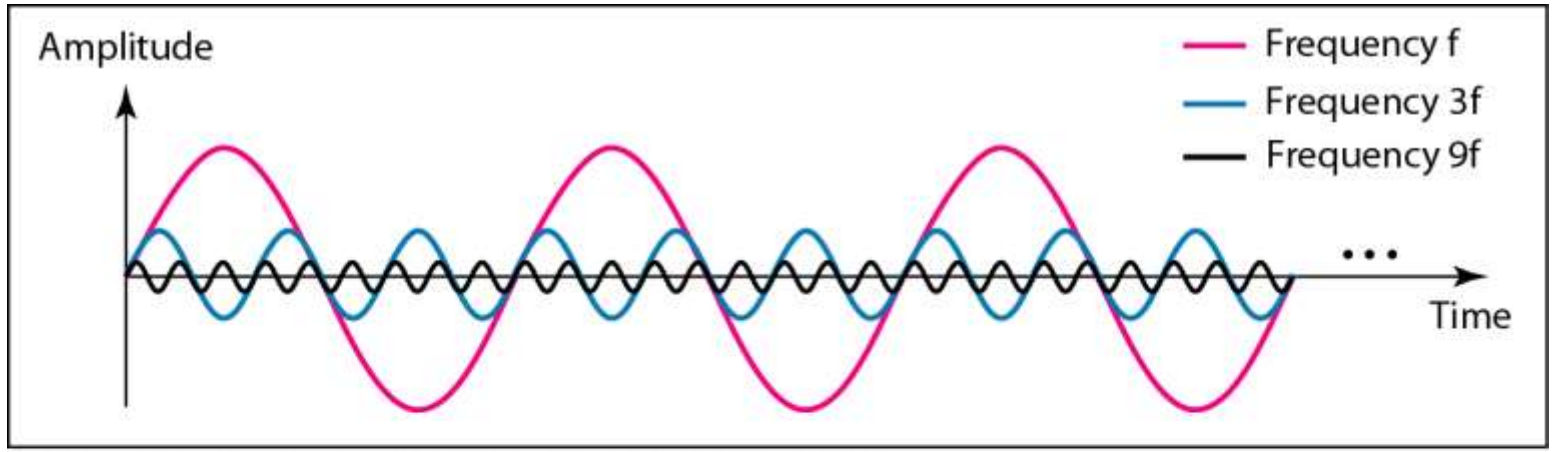
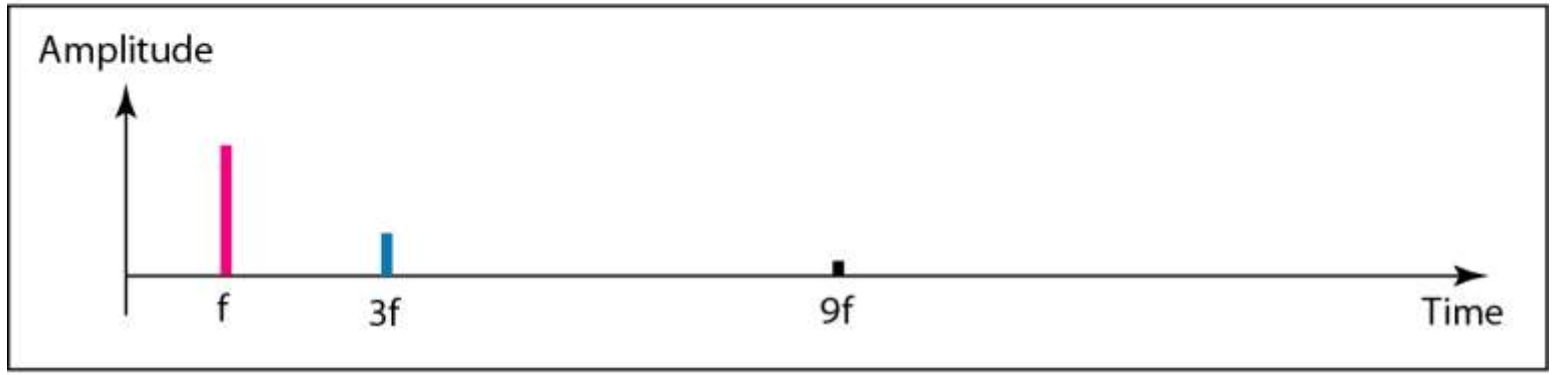


Figure 3.10 Decomposition of a composite periodic signal in the time and frequency domains



a. Time-domain decomposition of a composite signal

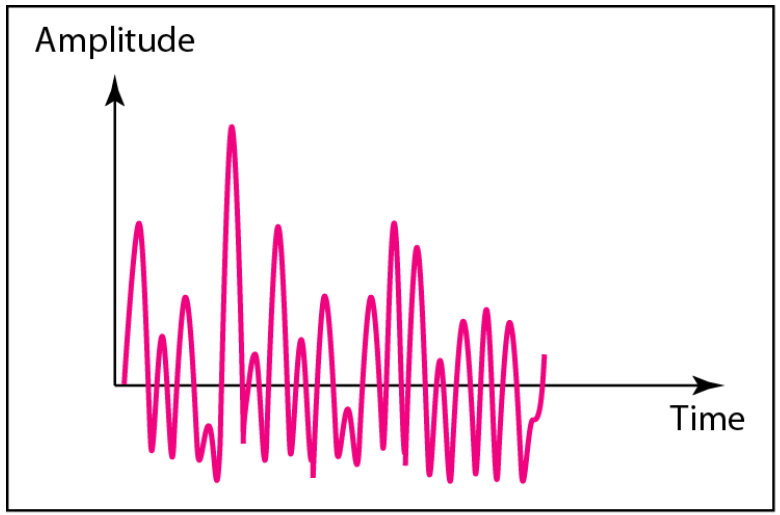


b. Frequency-domain decomposition of the composite signal

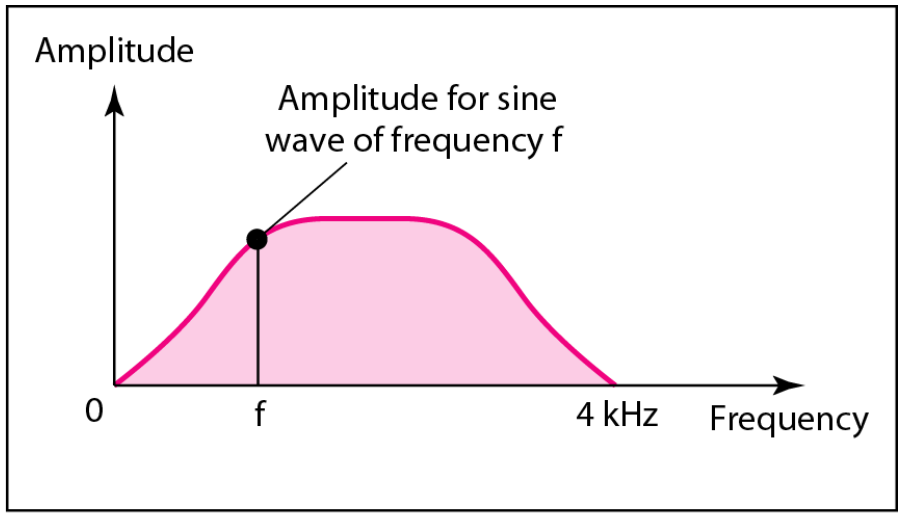
Example

Figure 3.11 shows a nonperiodic composite signal. It can be the signal created by a microphone or a telephone set when a word or two is pronounced. In this case, the composite signal cannot be periodic, because that implies that we are repeating the same word or words with exactly the same tone.

Figure 3.11 The time and frequency domains of a nonperiodic signal



a. Time domain

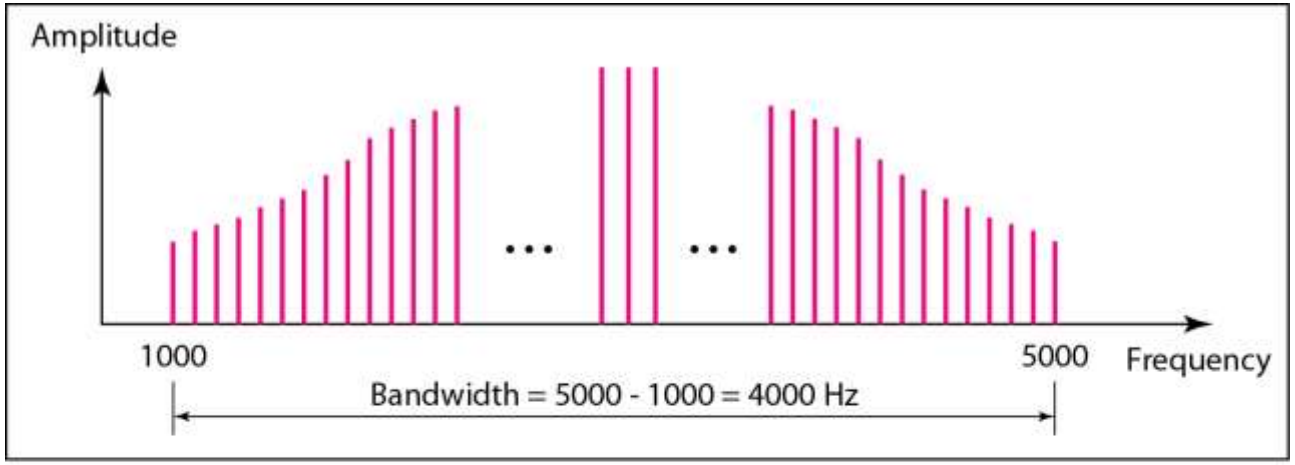


b. Frequency domain

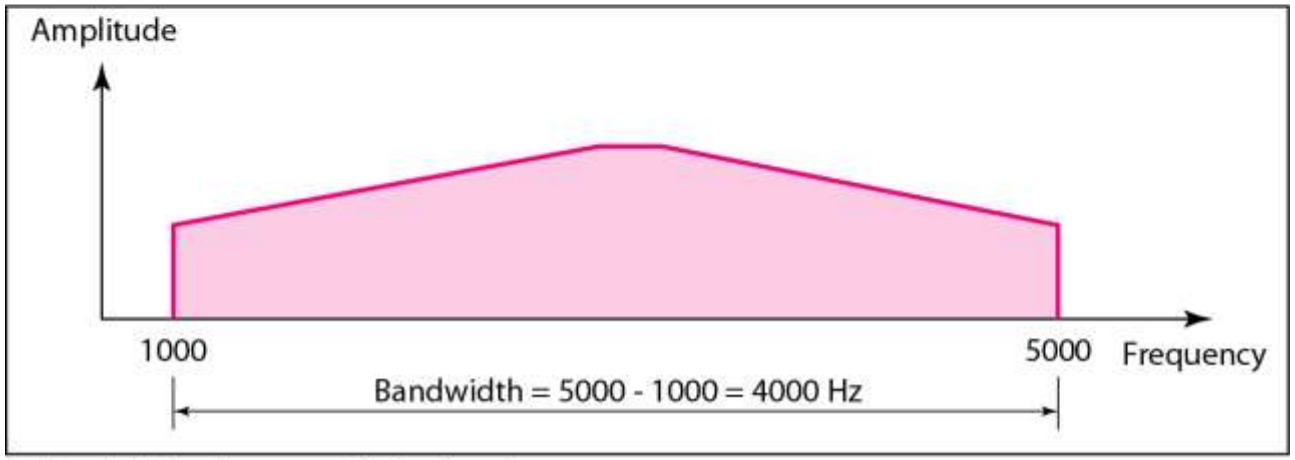
Bandwidth and Signal Frequency

- The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.

Figure 3.12 The bandwidth of periodic and nonperiodic composite signals



a. Bandwidth of a periodic signal



b. Bandwidth of a nonperiodic signal

Example

If a periodic signal is decomposed into five sine waves with frequencies of 100, 300, 500, 700, and 900 Hz, what is its bandwidth? Draw the spectrum, assuming all components have a maximum amplitude of 10 V.

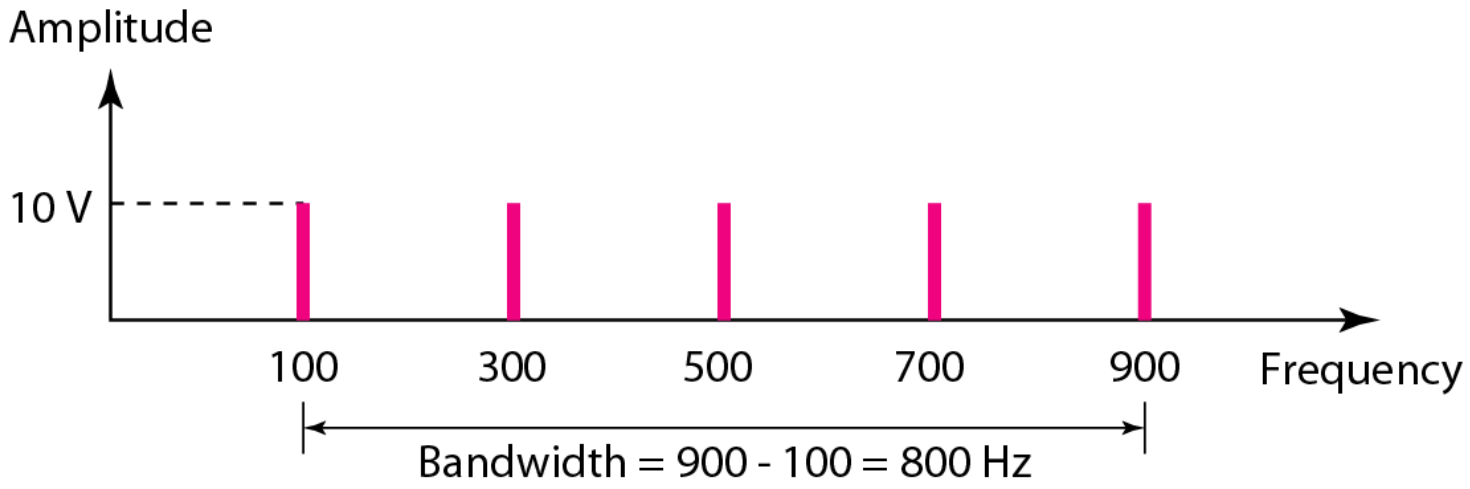
Solution

Let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth. Then

$$B = f_h - f_l = 900 - 100 = 800 \text{ Hz}$$

The spectrum has only five spikes, at 100, 300, 500, 700, and 900 Hz.

Figure 3.13 The bandwidth for Example 3.6



Example

A periodic signal has a bandwidth of 20 Hz. The highest frequency is 60 Hz. What is the lowest frequency? Draw the spectrum if the signal contains all frequencies of the same amplitude.

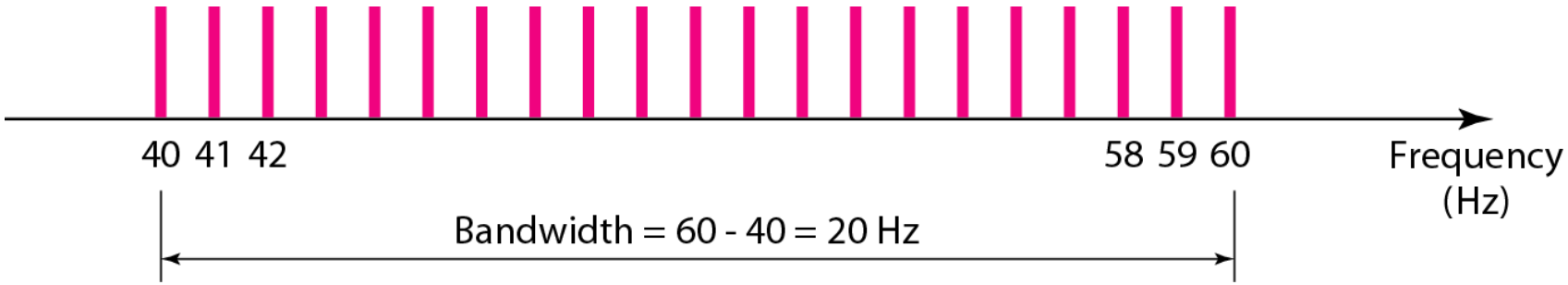
Solution

Let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth. Then

$$B = f_h - f_l \Rightarrow 20 = 60 - f_l \Rightarrow f_l = 60 - 20 = 40 \text{ Hz}$$

The spectrum contains all integer frequencies. We show this by a series of spikes (see Figure).

Figure 3.14 The bandwidth for Example



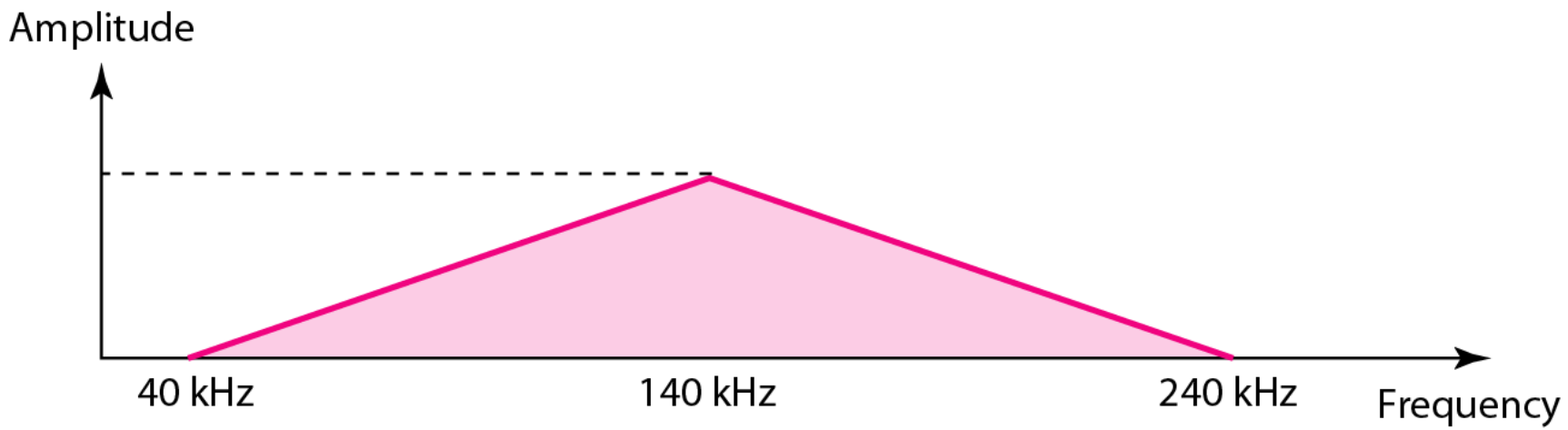
Example

A nonperiodic composite signal has a bandwidth of 200 kHz, with a middle frequency of 140 kHz and peak amplitude of 20 V. The two extreme frequencies have an amplitude of 0. Draw the frequency domain of the signal.

Solution

The lowest frequency must be at 40 kHz and the highest at 240 kHz. Figure shows the frequency domain and the bandwidth.

The bandwidth diagram



BIT RATE & BAUD RATE

- **Bit rate** and **Baud rate**, these two terms are often used in data communication.
- Bit rate is simply the **number of bits** (i.e., 0's and 1's) transmitted in per unit time.
- Baud rate is the **number of signal units** transmitted per unit time that is needed to represent those bits.

- The crucial difference between bit rate and baud rate that one change of state can transfer one bit, or slightly more or less than one bit that relies on the modulation technique used.

- **Bit rate = baud rate x the number of bit per baud**

- An analogy can illustrate the concept of bauds and bits. In transportation, a baud is comparable to a bus, a bit analogous to a passenger. A bus can carry multiple passengers. If 1000 buses go from one point to another carrying only one passenger (the driver), then 1000 passengers are transported. However, if each bus carries twenty passengers (suppose), then 20000 passengers are transported. In this case, busses determine traffic not the number of passengers consequently broader highways are needed. Likewise, the number of bauds determines the required bandwidth, not the number of bits.

Key Differences Between Bit Rate and Baud Rate

1.Bit rate is the number bits (0’s and 1’s) transmitted per second.

2.On the other hand Baud rate is the number of times a signal is traveling comprised of bits.

3.Baud rate can determine the **bandwidth** of the channel or its required amount to send the signal while through Bit rate it is not possible.

4.Bit Rate can be expressed by the given equation:

.**Bit rate = baud rate x the number of bits per signal unit**

5. In contrary Baud rate is expressed in the given equation:

Baud rate = bit rate / the number of bits per signal unit

Bit rate = baud rate x the number of bits per signal unit

Ex: 1. An analog signal has a baud rate of 200. Find out bit rate if each signal is carrying 04 bits.

baud = 200, number of signals each signal is carrying = 4

bit rate = 200 x 4 = 800 bits.

Ex 2 : The channel capacity is 5000 bps. Each signal is carrying 8 bits. Find out the baud rate.

bit rate = 5000 bps, number of bits each signal carrying = 8.

baud rate = 5000/8 = 625

- Key Differences Between Bit Rate and Baud Rate
- Bit rate is the number bits (0's and 1's) transmitted per second. On the other hand Baud rate is the number of times a signal is traveling comprised of bits.
- Baud rate can determine the **bandwidth** of the channel or its required amount to send the signal while through Bit rate it is not possible.
- Bit Rate can be expressed by the given equation:
  Bit rate = baud rate x the number of bits per signal unit
  In contrary Baud rate is expressed in the given equation:
  Baud rate = bit rate / the number of bits per signal unit

SWITCHING

CIRCUIT,

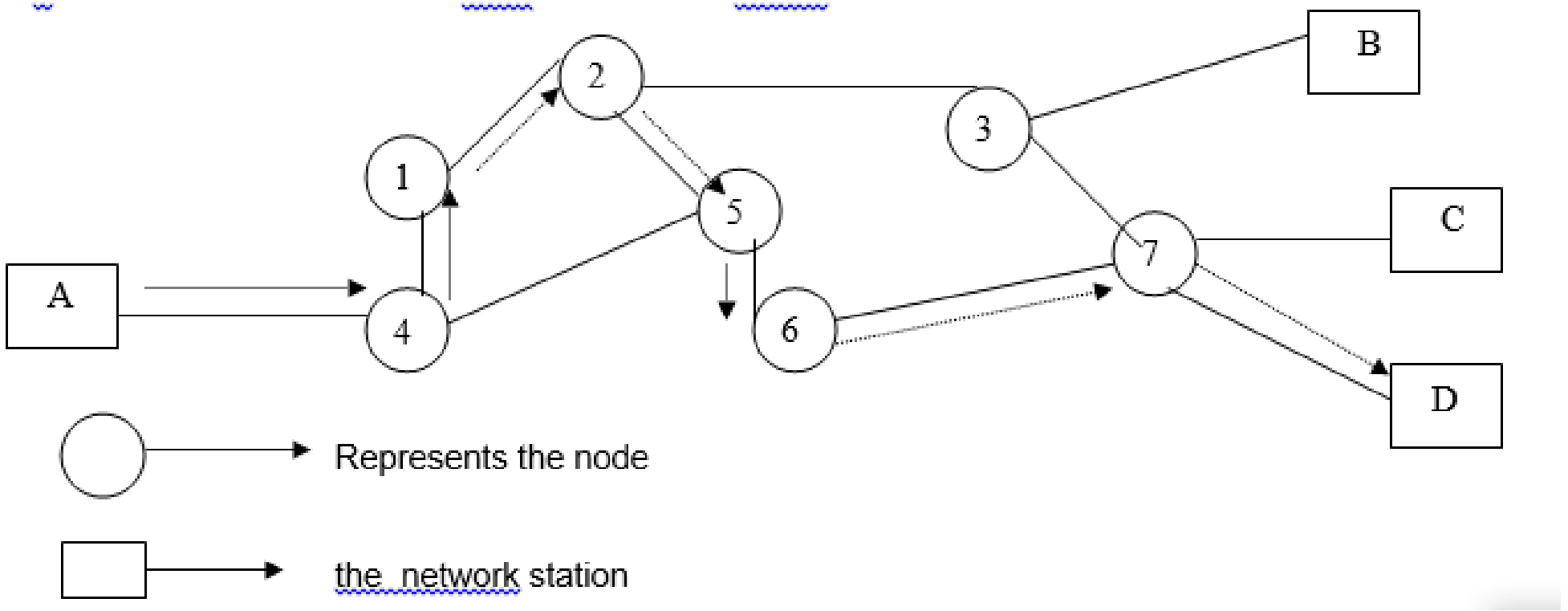
PACKET,

VIRTUAL PACKET

Switching Methods

- Two different types of switching methods are used :
  - Circuit switching and
  -- Packet switching.

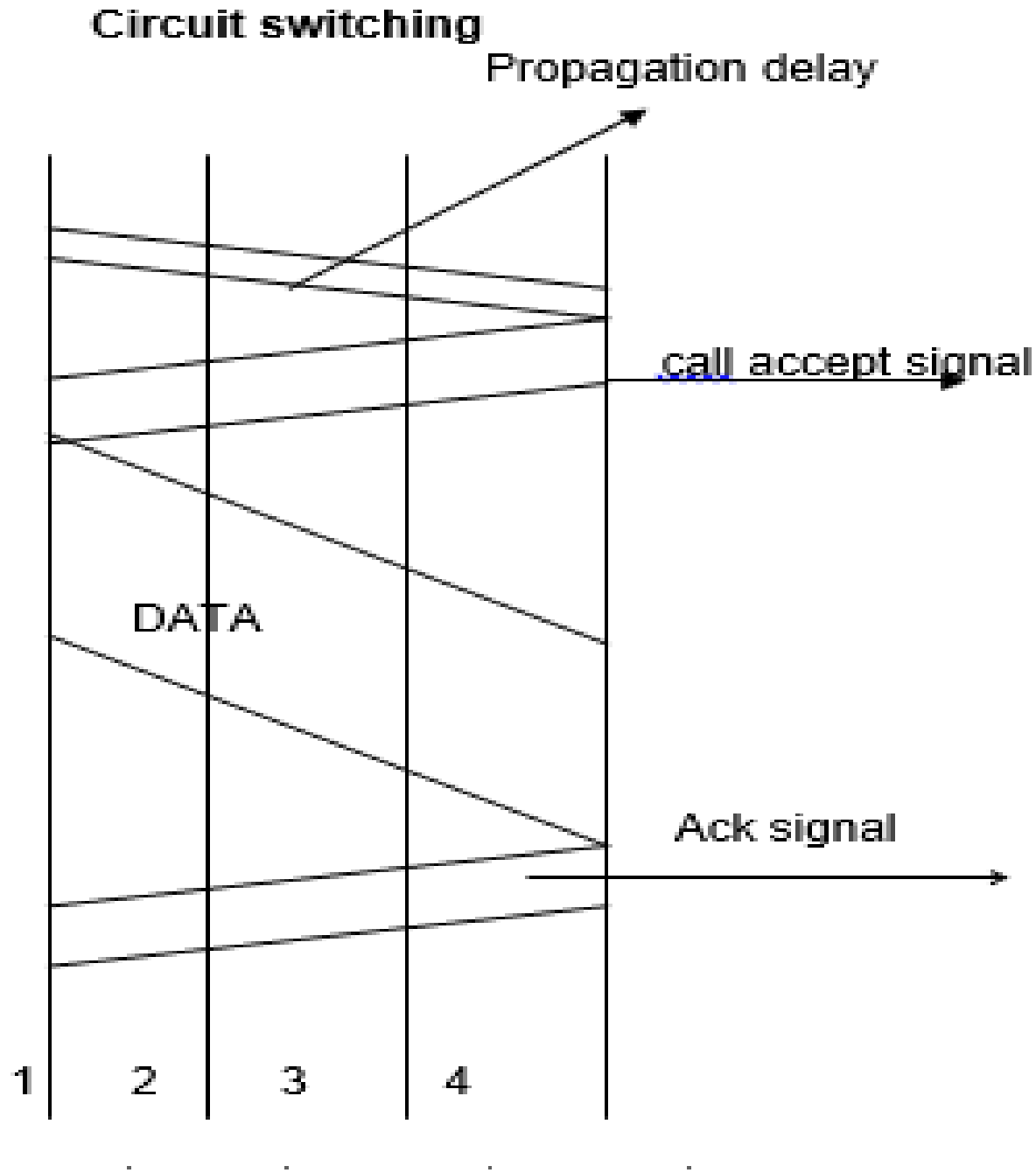
Circuit Switching



In this switching there are three phases

a. circuit establishment
b. data transfer
c. Circuit disconnection

- Suppose if we want to send the data, say, from A to D, before sending the data a circuit will be established between A to D as shown in fig . All the data will follow the same path. After data is transferred the circuit will be disconnected.

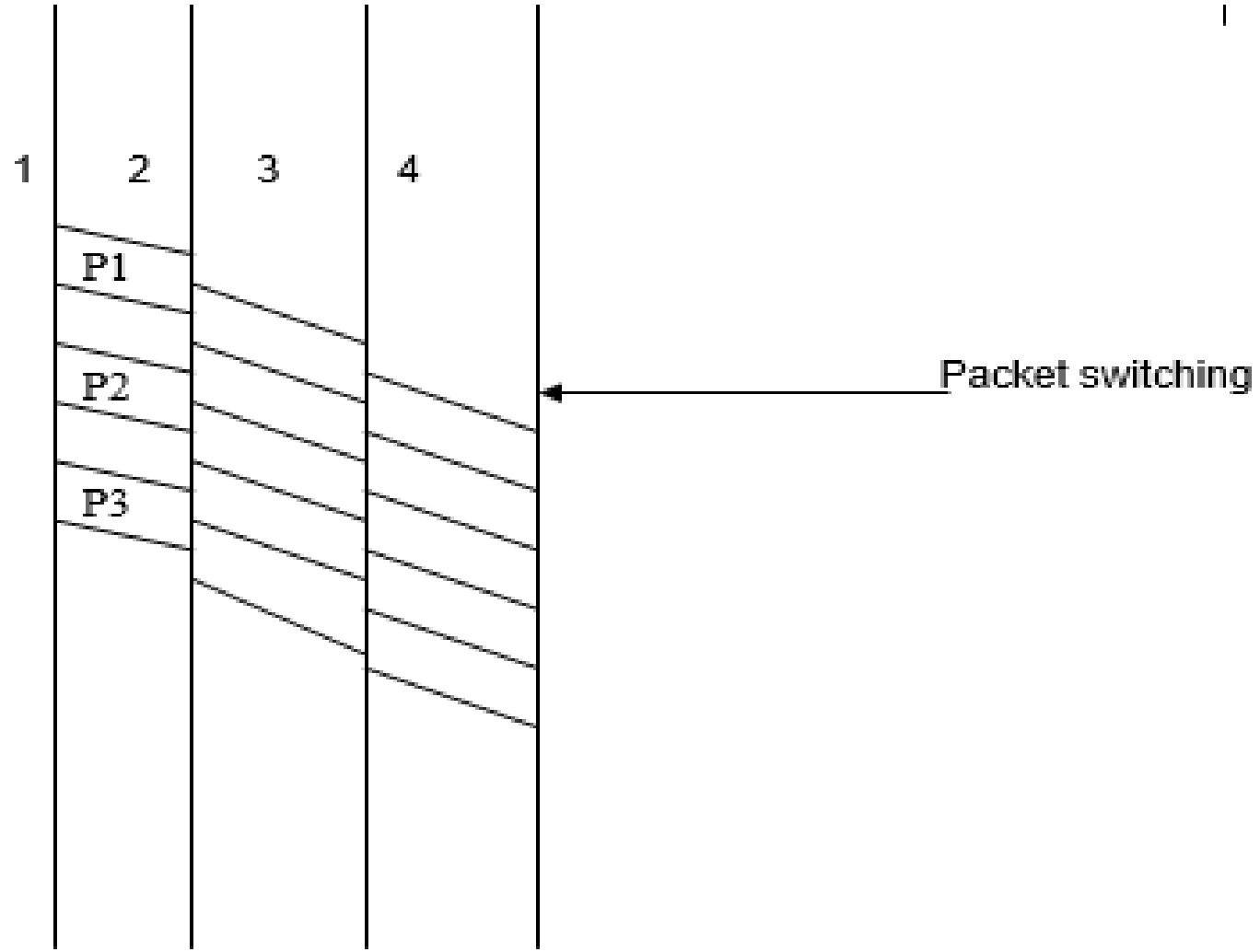

Circuit switching
Propagation delay
call accept signal
DATA
Ack signal
1
2
3
4

Packet switching will be done in two ways.

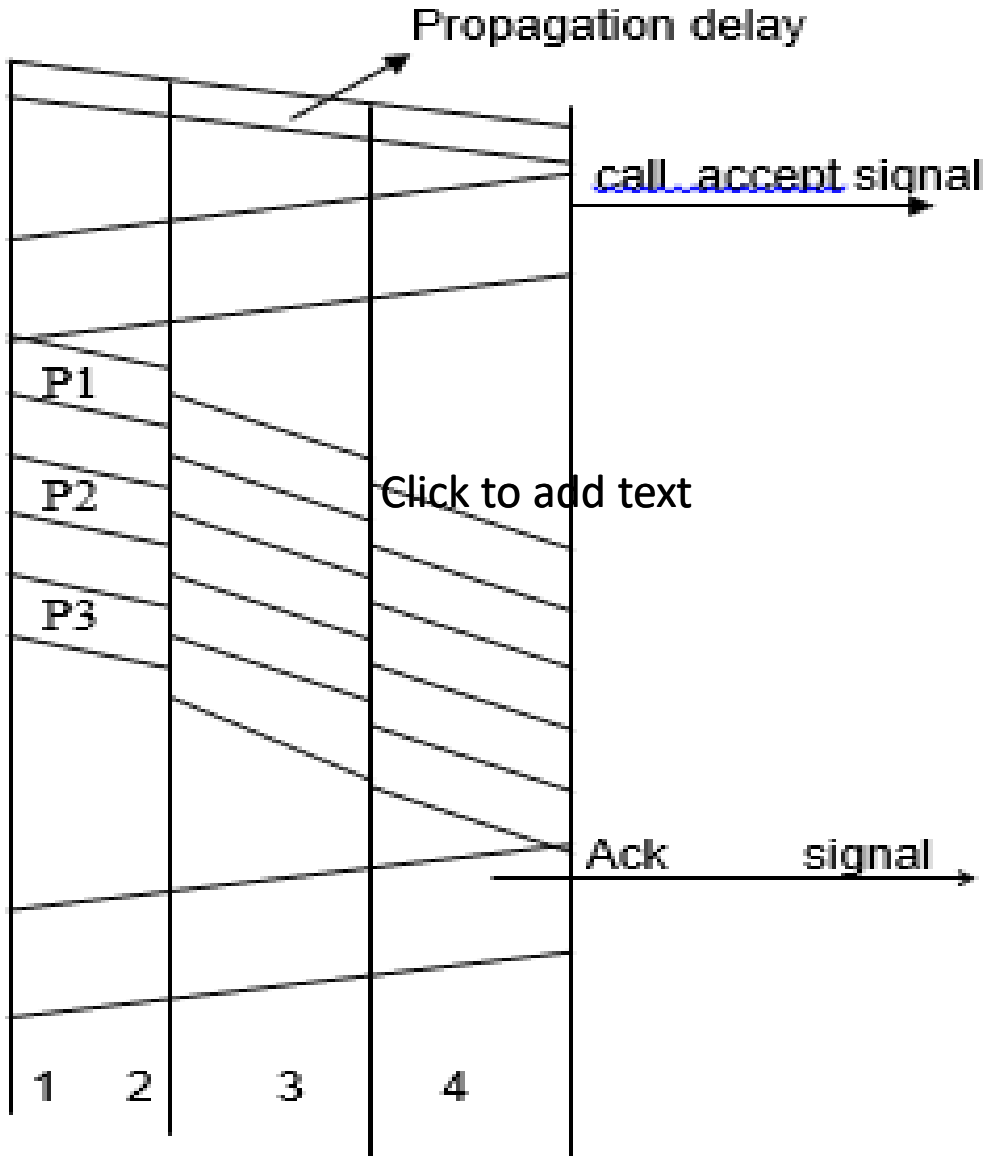
1. Data gram Packet switching

2. Virtual Packet switching

PACKET SWITCHING



Virtual packet switching



Circuit switching	Data gram packet	Virtual packet
Dedicated transmission	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Messages are not stored	Packets are stored	Packets are stored until delivered
Path will be established for entire conversation	Route will be established for each packet.	Route will be established for entire conversation
Fixed bandwidth transmission	Dynamic use of bandwidth	Dynamic use of bandwidth

TRANSMISSION MEDIA

TWISTED,COAXIAL,FIBER OPTIC &SPACE

Figure 7.1 *Transmission medium and physical layer*

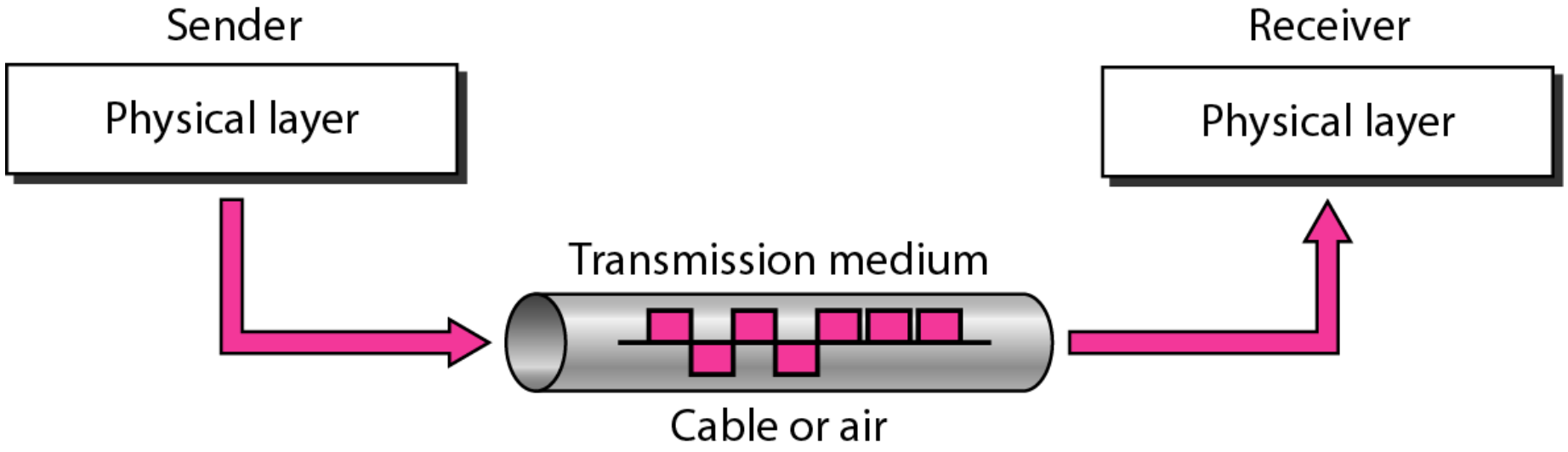
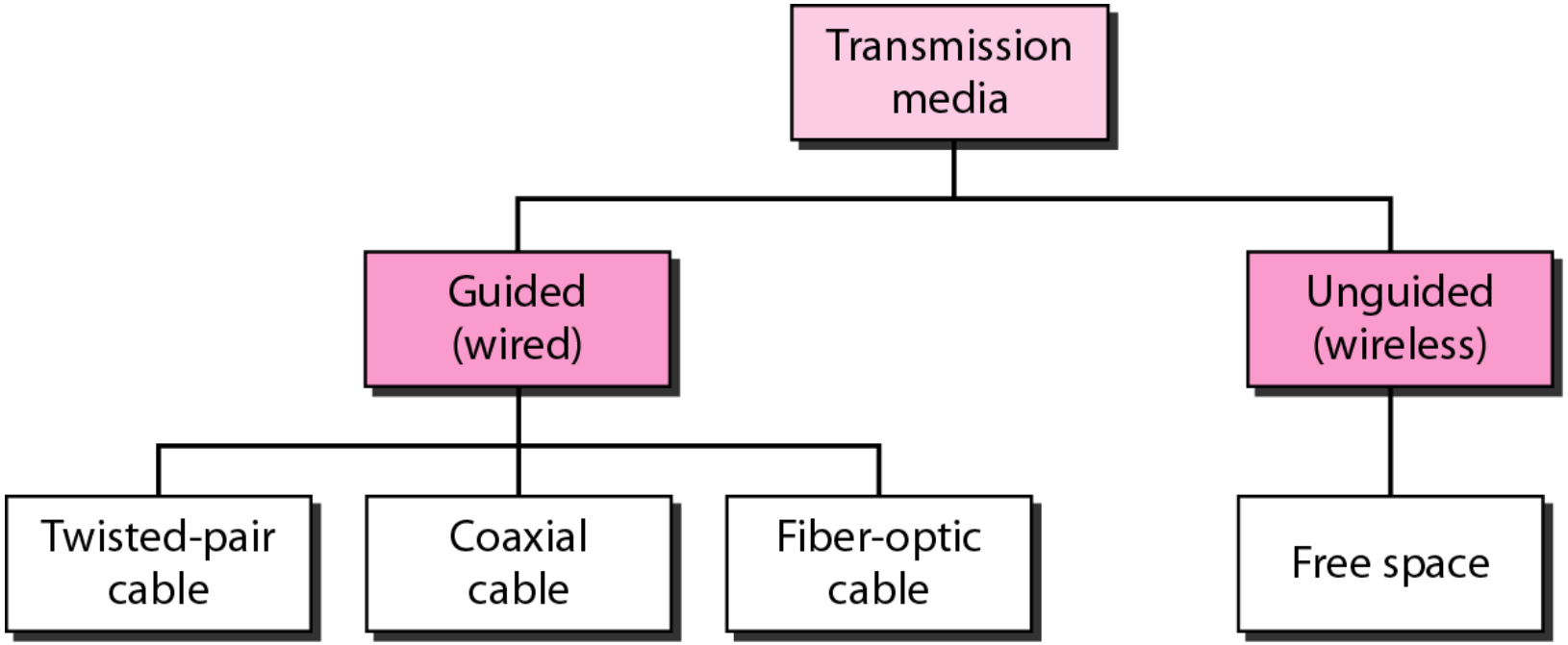


Figure 7.2 *Classes of transmission media*



Transmission medium

- **Characteristics and Quality of Data Transmission are determined by medium and signal Characteristics.**
- **For Guided Media, the medium is more important in determining the limitations of transmission.**
- **For Unguided media, the Band width of the signal produced by the transmitting antenna is more important than the medium.**

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.

Topics discussed in this section:

Twisted-Pair Cable
Coaxial Cable
Fiber-Optic Cable

Figure 7.3 *Twisted-pair cable*

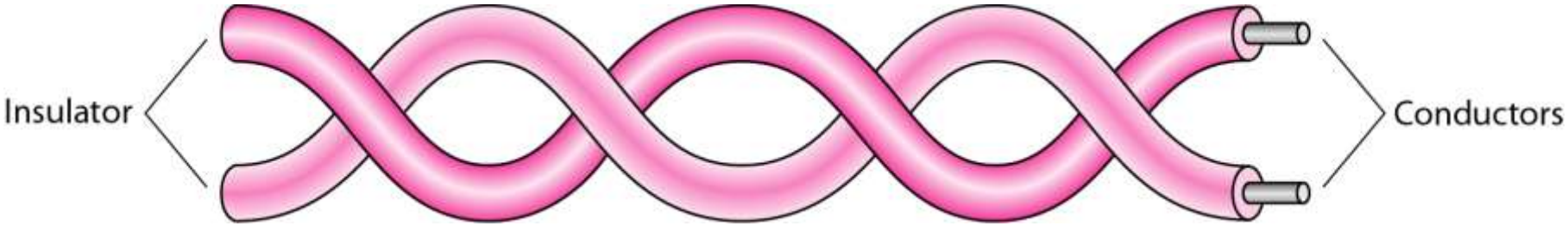
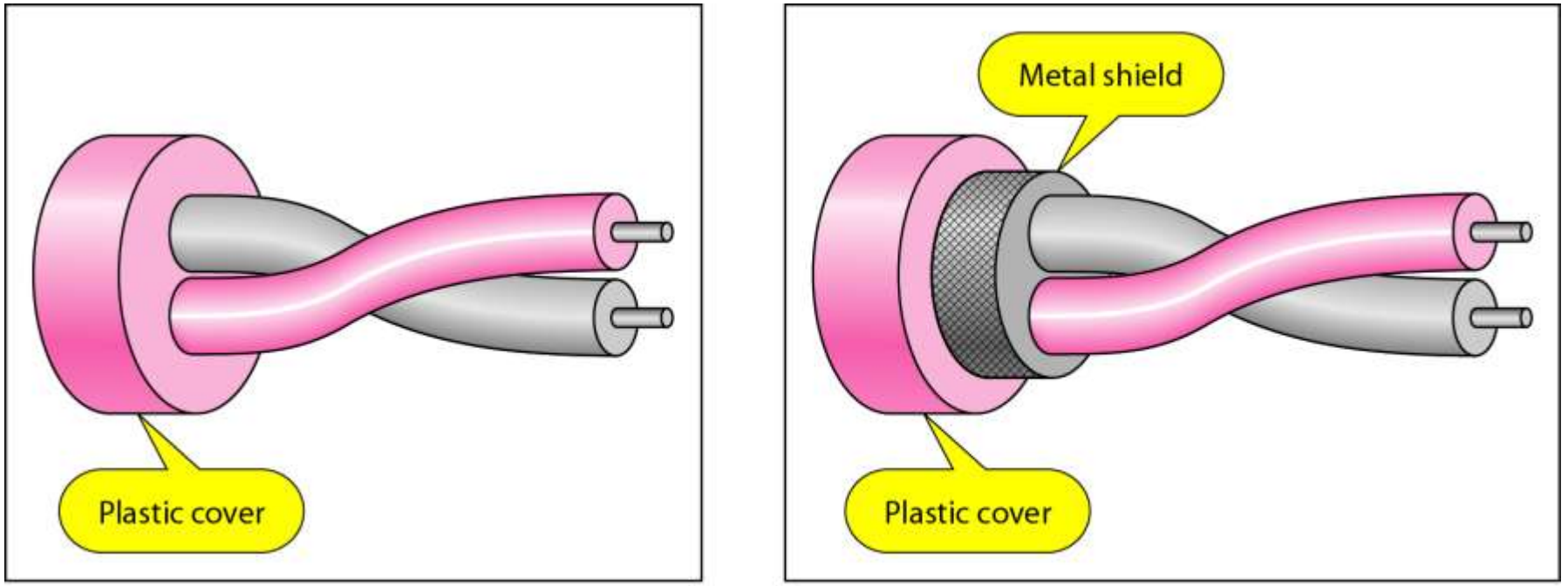


Figure 7.4 *UTP and STP cables*



a. UTP

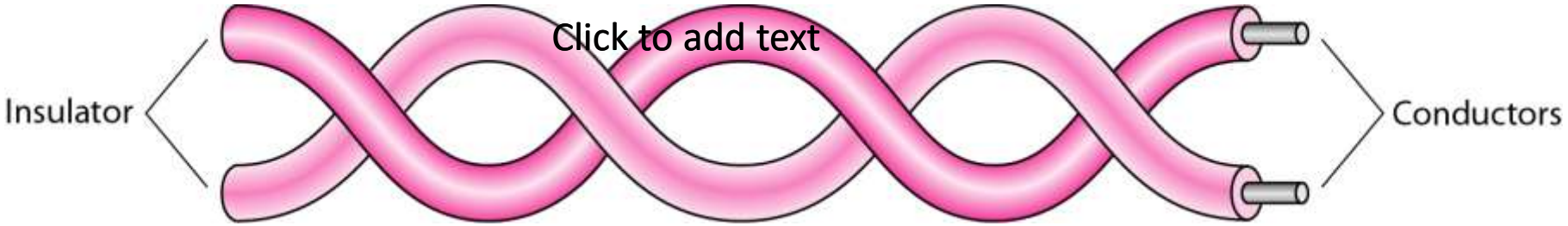
b. STP

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

Twisted-Pair Cable

- Consists of Two insulated copper wires arranged in a Regular spiral Pattern.
- A number of pairs are bundled together into a cable by wrapping them in a tough protective sheath.



Why Twisting?

- Twisting of cable is cancelling out the interferences between adjacent cables.

Twisted-Pair Cable

- Decreases the cross talk interference between adjacent pairs in a cable.
- Minimizes the Cross Talk.
- Tighter twisting provides much better performance, but increases cost.

APPLICATIONS

- Local loop in telephone lines (UTP)
- Digital Subscriber line (DSL)
- LAN
- Connectors (RJ 45)

Figure 7.5 *UTP connector*

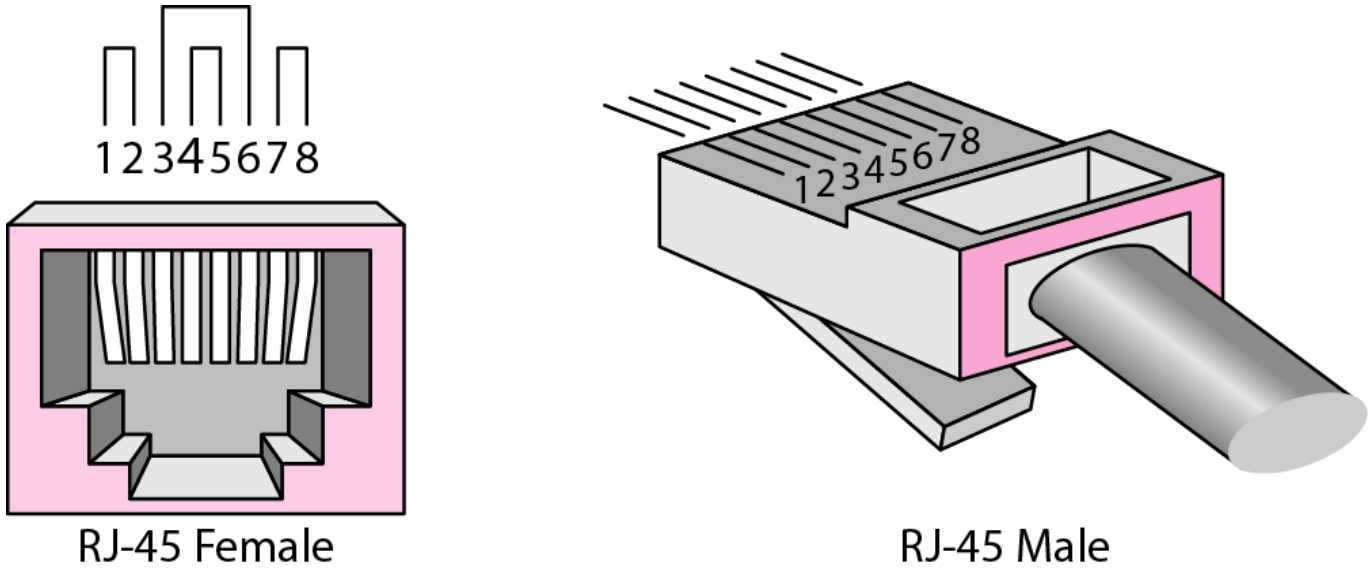
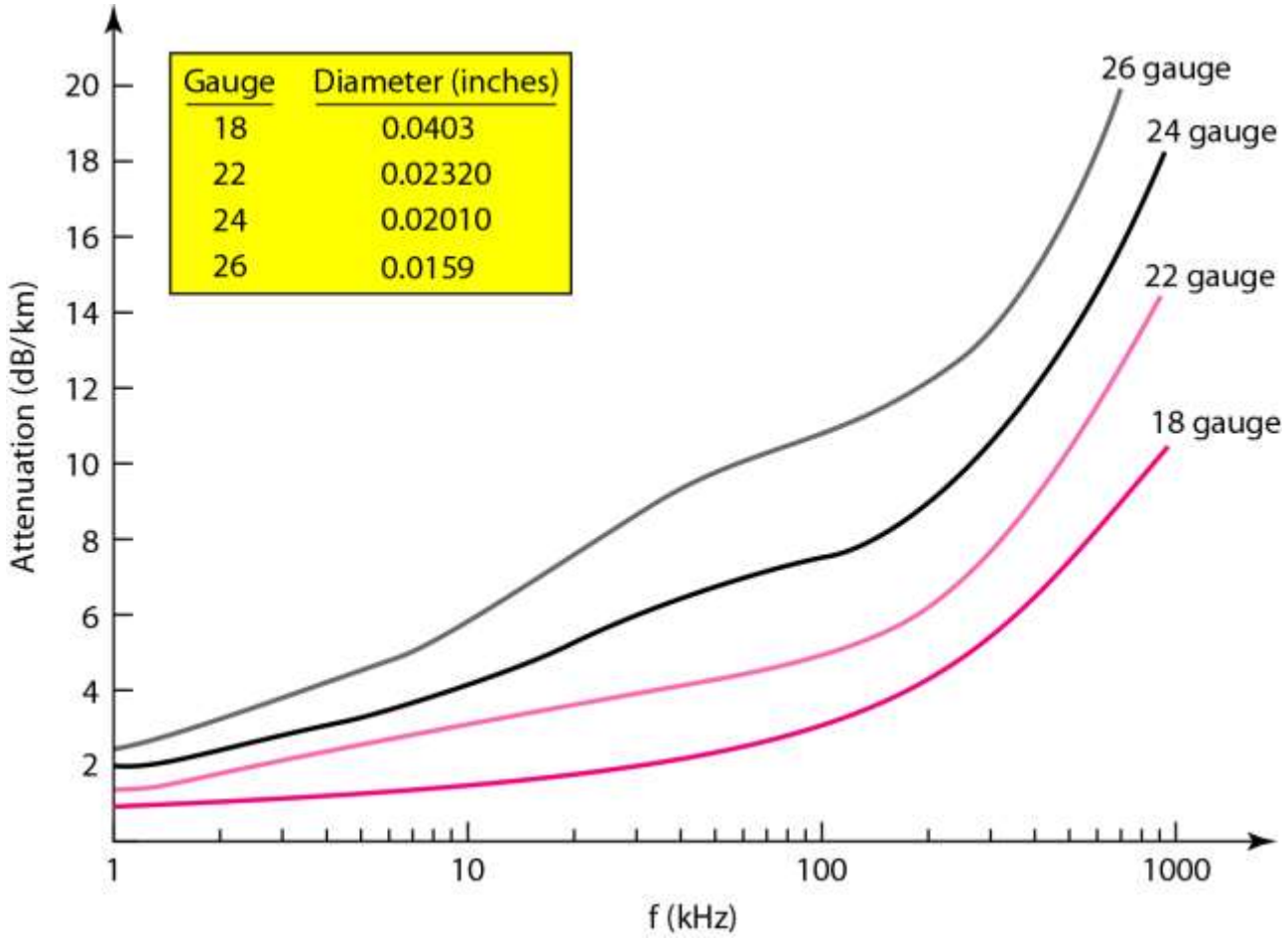


Figure 7.6 *UTP performance*



Coaxial cable

- Coaxial cables are the most common, basic transmission lines.
- They are used to transmit electrical energy, or signals, from one location to another: to connect a source to a load, such as a transmitter to an antenna.
- A coax cable consists of two conductors separated by a dielectric material.
- The center conductor and the outer conductor, are configured in such a way that they form concentric cylinders with a common axis. Hence the term and name co-axial.

Figure 7.7 *Coaxial cable*

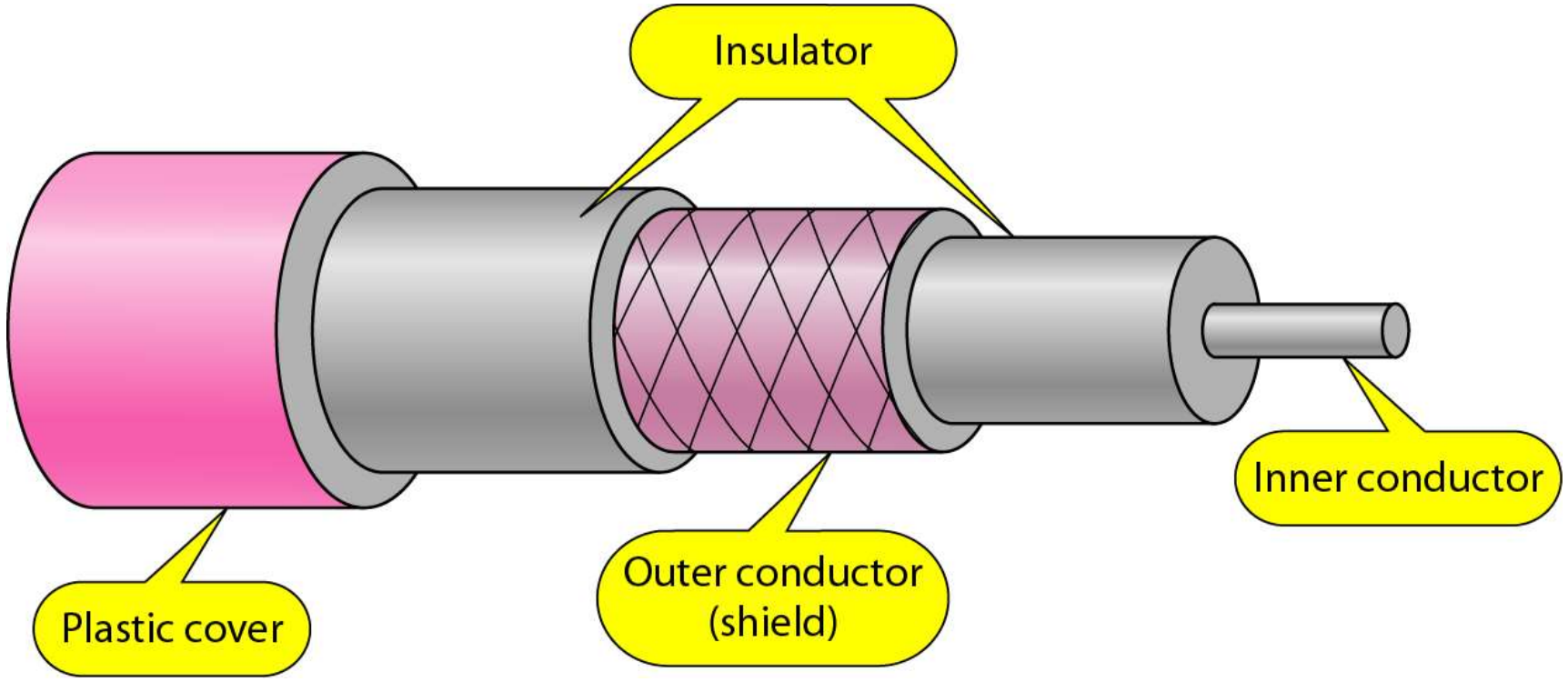


Table 7.2 *Categories of coaxial cables*

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

Construction

- The center conductor may be made of various materials and constructions.
- Most common constructions are solid or seven-strand conductors.
- Solid conductors are used in permanent and infrequently handled applications.
- stranded conductors are used in flexible cable applications.

Coaxial cable

- Common materials include copper, tinned or silver plated copper, copper clad steel and copper clad aluminum.
- Plated copper is used to aid in solder ability of connectors or to minimize corrosion effects.
- Data is transmitted through the center wire.
- The outer braided layer serves as a line to ground.
- Both of these conductors are parallel and share the same axis. That’s is why the wire is called coaxial.
- Because of a phenomena known as skin-effect, copper clad materials may be used in higher frequency applications (> 50 MHz) to improve tensile strength and reduce weight and cost. Skin-effect is the result of higher frequency signals propagating along the outermost surface, or skin, of the conductor.

- **The insulation, or dielectric material, is used to provide separation between the conductors.**
- **It is desirable that the material has stable electrical characteristics across a broad frequency range.**
- **Temperature range of the cable is often limited by the choice of jacket material.**
- **The jacket material serves as a protective covering from the environment.**

COAXIAL CABLE TRANSMISSION:

Working of Coaxial Cable

Defining that inner core is connected to positive terminal and use as conductor and outer metallic foil connected to ground also use as second conductor and shield for noise.

Types Of Coaxial Cable

T here are tow types of coaxial cable:

- Thinnet cable
- Thicknet cable

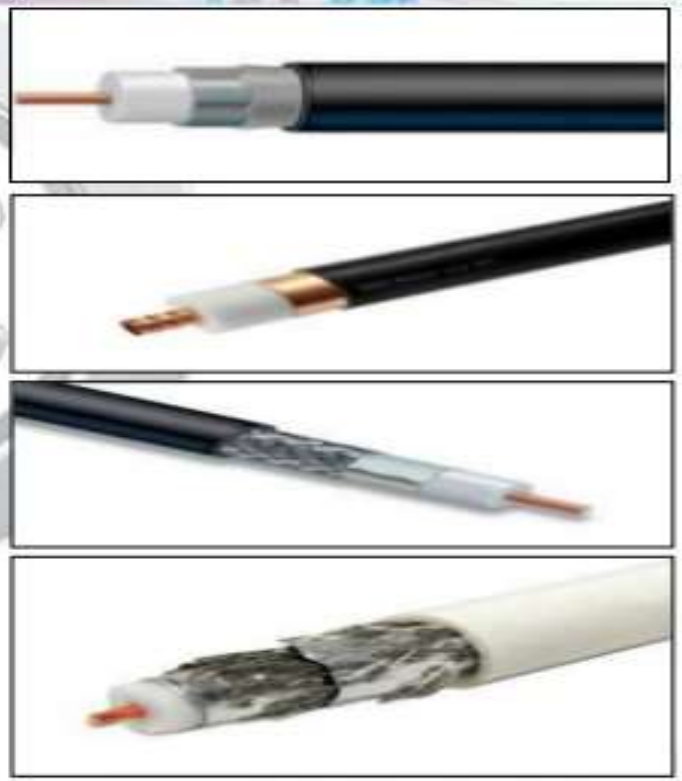
- **THINNET CABLE (10BASE2 ETHERNET):**
- 10 refer to the rate of data transfer.
- 2 refer to distance allowed between computers it should be no more than 2 meters.
- Total segment length is 185 Meters (Distance between the farthest computers).
- Total number of nodes (devices) connected - 30 nodes per trunk.
- Thinnet cable is a flexible coaxial cable about 0.64 centimeters (0.25 inches) thick.

- **THICKNET CABLE (10BASE5 ETHERNET):**
- 10 refer to the rate of data transfer. It transfers data at the rate of 10Mbps (Megabits per second)
- 5 refer to distance between computers it should be no more than 5 meters.
- A maximum of 100 workstations is allowed per trunk and the distance between should be a maximum of 5 meters.
- Segment length is 500 metres.
- Thicknet cable is a relatively rigid coaxial cable about 1.27 centimeters (0.5 inches) in diameter

Types of Coaxial Cable:

Types of Coaxial Cable

- **Hard line:**
  - Used in broadcasting and many other forms of radio communication.
  - Using round copper, silver or gold tubing or a combination of such metals as a shield.
- **Radiating:**
  - A similar fashion to hard line.
  - It is constructed with tuned slots cut into the shield.
- **RG-6**
  - **RG-6** is available in four different types designed for various applications.
  - In addition, the core may be copper clad steel (CCS) or bare solid copper (BC).
- **Triaxial cable:**
  - coaxial cable with a third layer of shielding, insulation and sheathing.
  - The outer shield, which is earthed (grounded), protects the inner shield from electromagnetic interference from outside sources.



Types of Coaxial Cable

- **Twin-axial cable:**
  - twisted pair within a cylindrical shield.
  - It allows a nearly perfect differential signal which is *both* shielded *and* balanced to pass through.
- **Biaxial cable:**
  - **biax** is a configuration of two 50 Ω coaxial cables.
  - Biax is used in some proprietary computer networks.
  - Others may be familiar with 75Ω biax which at one time was popular on many cable TV services.
- **Semi-rigid:**
  - a coaxial form using a solid copper outer sheath.
  - offers superior screening compared to cables with a braided outer conductor, especially at higher frequencies.
- **Rigid line:**
  - a coaxial line formed by two copper tubes maintained concentric every other meter using PTFE-supports.
  - Rigid lines can not be bent, so they often need elbows.

Semi Rigid Coaxial cable:

- Semi rigid cable is using a solid copper outer sheath.
- This type of coax offers superior transmission, especially at higher frequencies.
- The major disadvantage of this type is that the cable, as its name implies, is not very flexible.

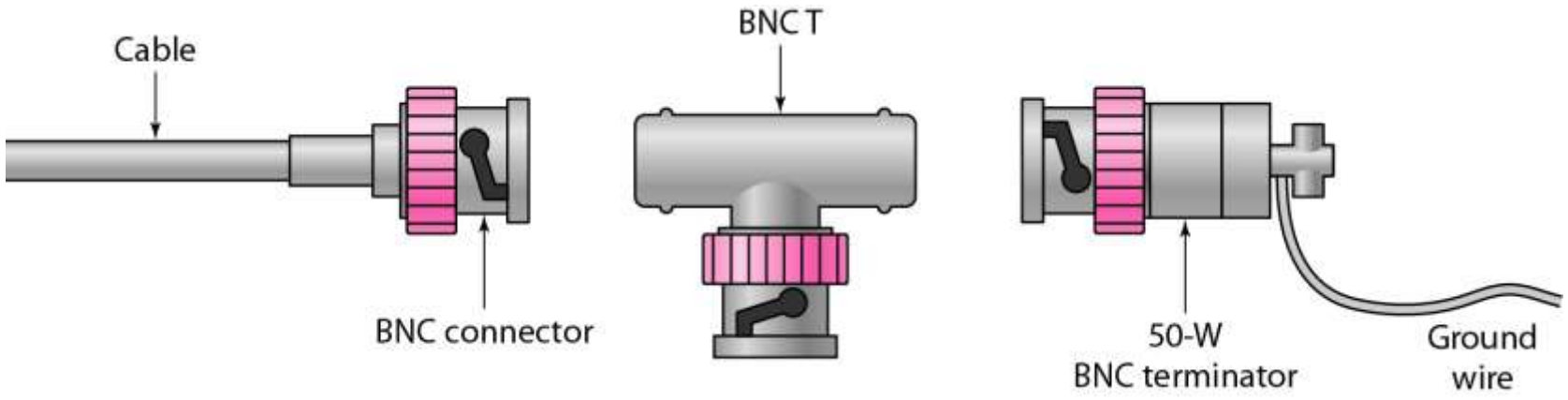
Hand Formable Coaxial Cable:

- These cables are between flexible and semi rigid cables.
- These cables are good choices when forming at a point of installation is required.

Triaxial cable:

- Triaxial cable is a coaxial cable with a third layer of shielding, insulation and sheathing. The outer shield is grounded and protects the inner shield from interference from outside sources.

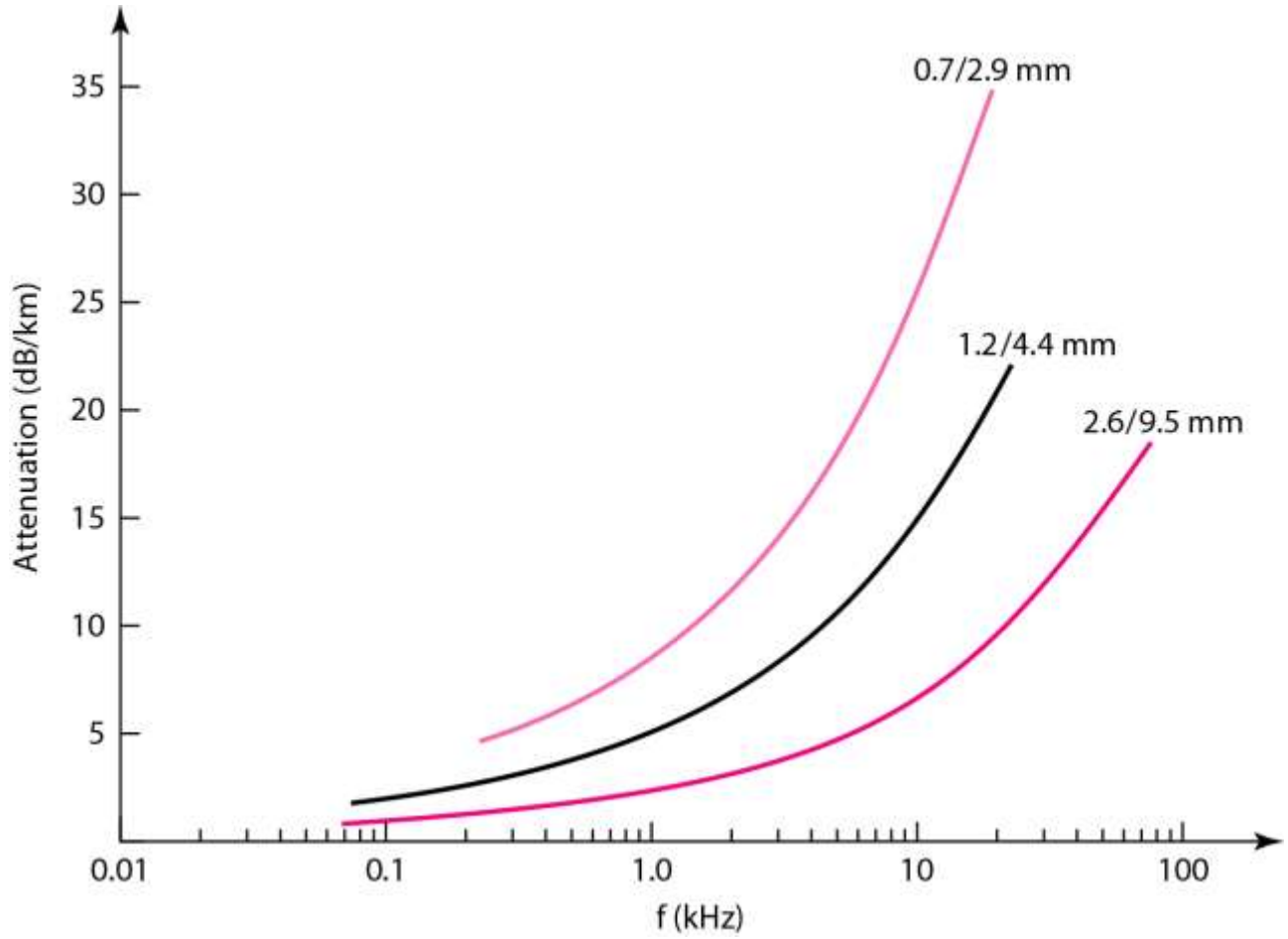
Figure 7.8 *BNC connectors*



Attenuation:

- Reduction of signal strength during transmission.
- It is dependent upon the cable design and is both frequency and length dependent. It increases with the increase in frequency.
- Attenuation is measured in decibels.

Figure 7.9 *Coaxial cable performance*



Uses of Coaxial Cable

- Short coaxial cables are commonly used to connect
  - home video equipment
  - in ham radio setups
  - in measurement electronics.
  - cable television
- They used to be common for implementing computer networks, in particular Ethernet
- Long distance coaxial cable was used in the 20th century to connect
  - radio networks
  - television networks
  - Long Distance telephone
- Micro coaxial cables are used in
  - a range of consumer devices,
  - military equipment,
  - ultra-sound scanning equipment.
- The most common impedances that are widely used are 50 or 52 ohms, and 75 ohms, although other impedances are available for specific applications.

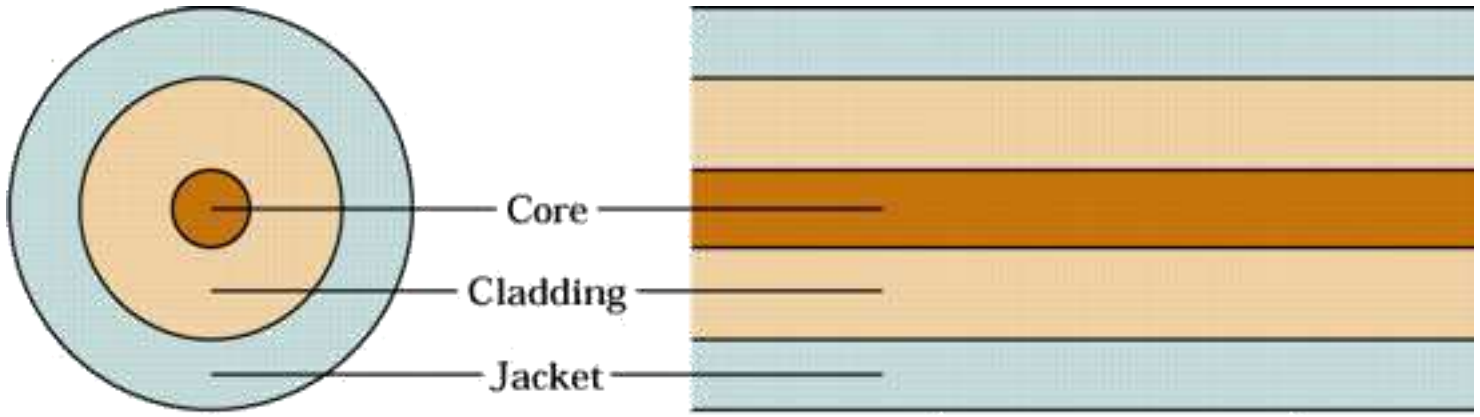
Disadvantages of Coaxial Cable

- Signals entering the cable can cause unwanted noise and picture ghosting. making it useless.
- A continuous current flow, even if small, along the imperfect shield of a coaxial cable can cause visible or audible interference.
- More expensive than twisted pairs and is not supported for some network standards.
- Its also has high attenuation, have the need to implement repeaters

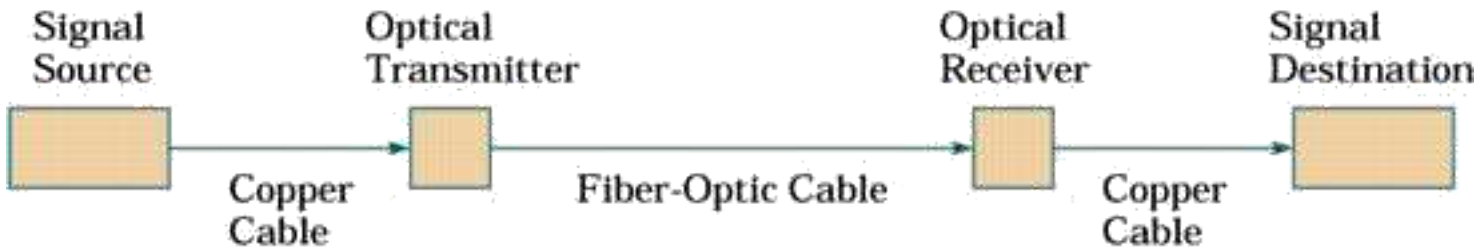
Optical Fiber & Communications System

- An optical fiber is essentially a waveguide for light
- It consists of a **core** and **cladding** that surrounds the core
- The **index of refraction** of the cladding is less than that of the core, causing rays of light leaving the core to be refracted back into the core
- A light-emitting diode (LED) or **laser diode** (LD) can be used for the source
- Advantages of optical fiber include:
  - Greater bandwidth than copper
  - Lower loss
  - Immunity to **crosstalk**
  - No electrical hazard

Optical Fiber & Communications System



(a) Fiber cross section



(b) System

Optical Fiber & Communications System

- Optical fiber is made from thin strands of either glass or plastic
- It has little mechanical strength, so it must be enclosed in a protective jacket
- Often, two or more fibers are enclosed in the same cable for increased bandwidth and redundancy in case one of the fibers breaks
- It is also easier to build a full-duplex system using two fibers, one for transmission in each direction

Figure 7.10 Fiber optics: *Bending of light ray*

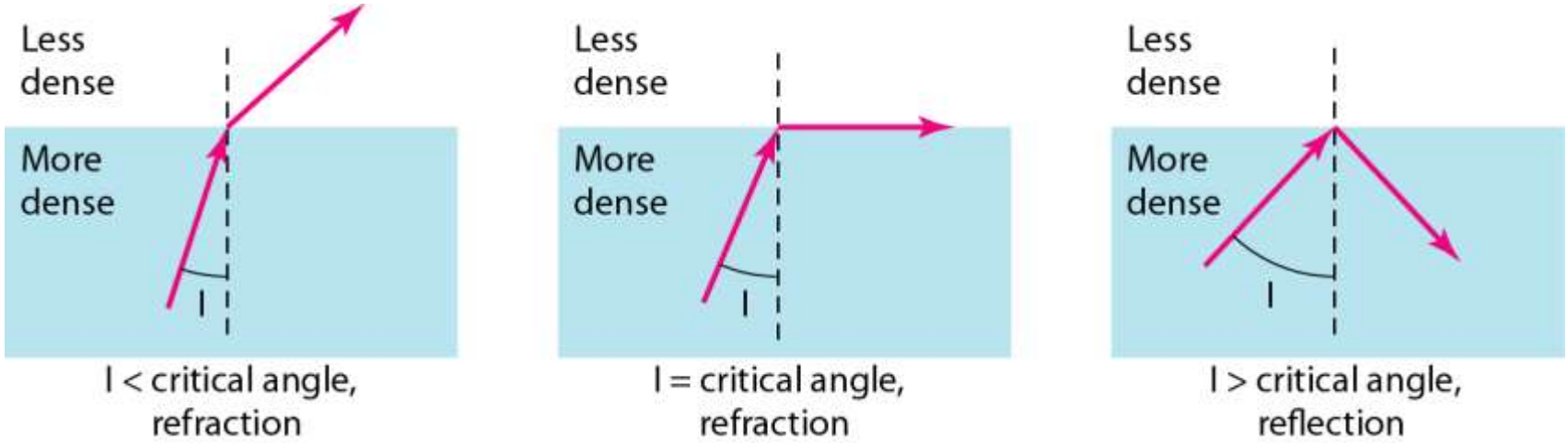


Figure 7.11 *Optical fiber*

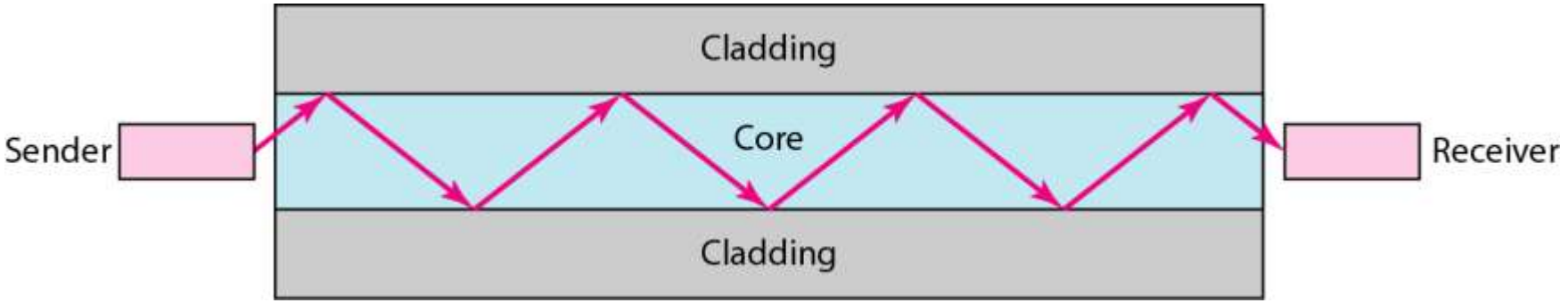


Figure 7.12 *Propagation modes*

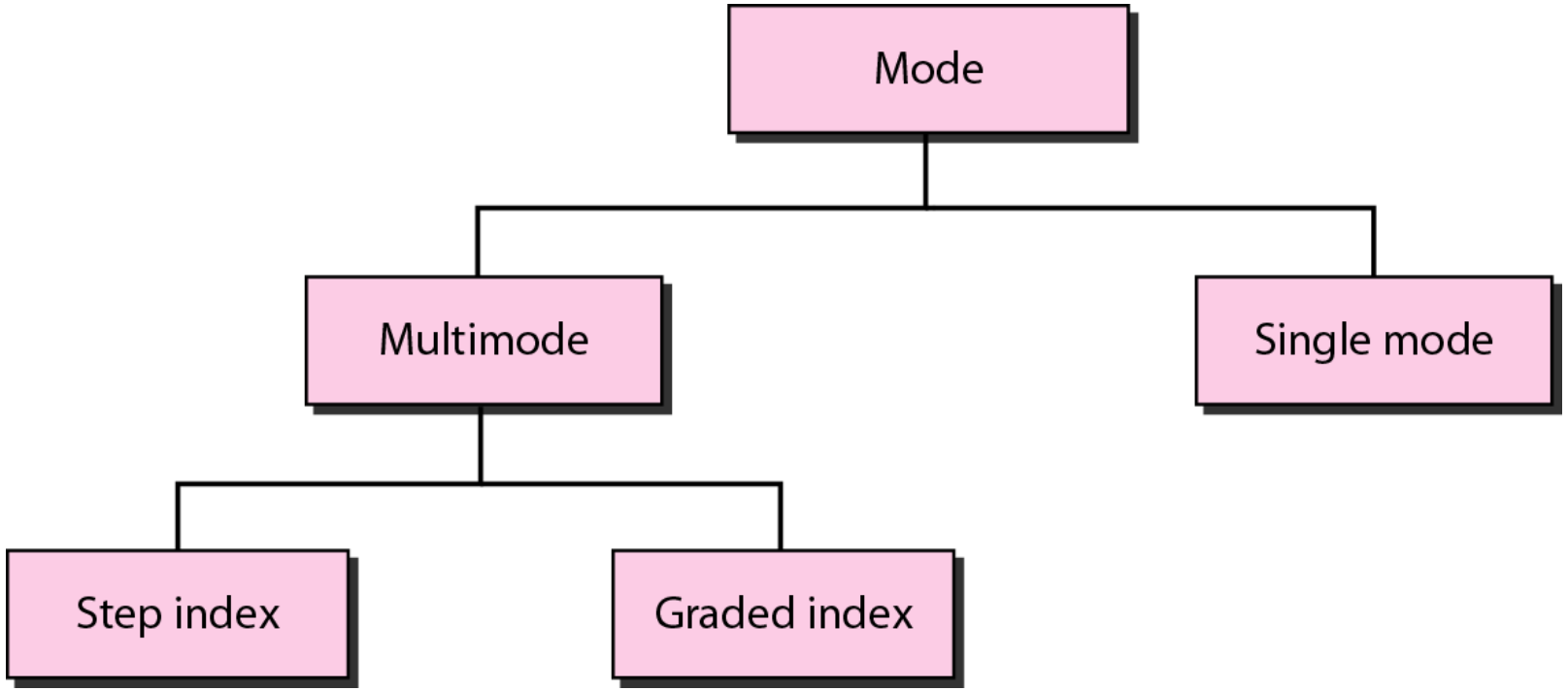
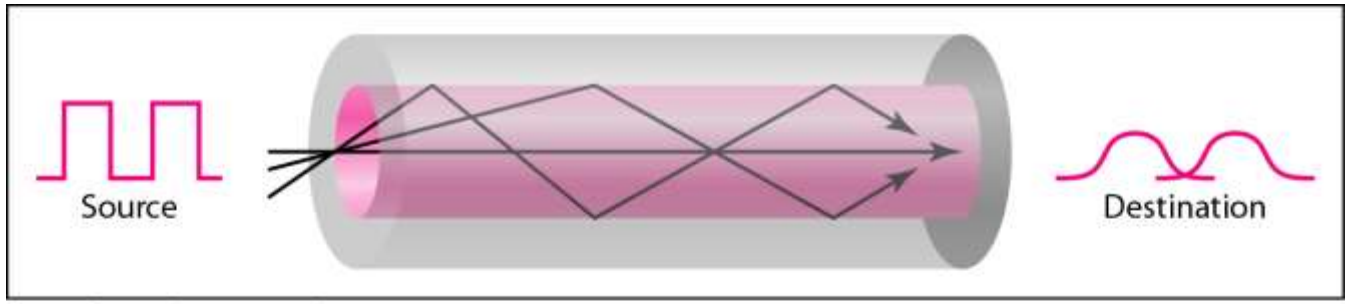
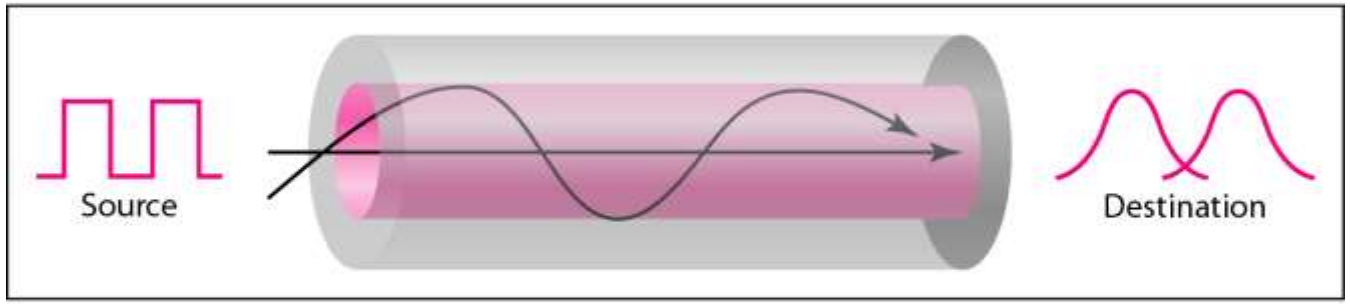


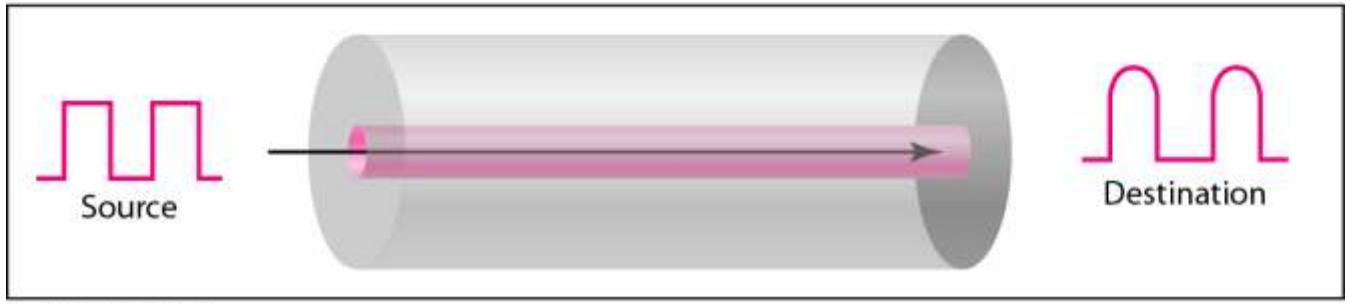
Figure 7.13 *Modes*



a. Multimode, step index



b. Multimode, graded index



c. Single mode

Table 7.3 *Fiber types*

Type	*Core (μm)*	*Cladding (μm)*	*Mode*
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

Figure 7.14 *Fiber construction*

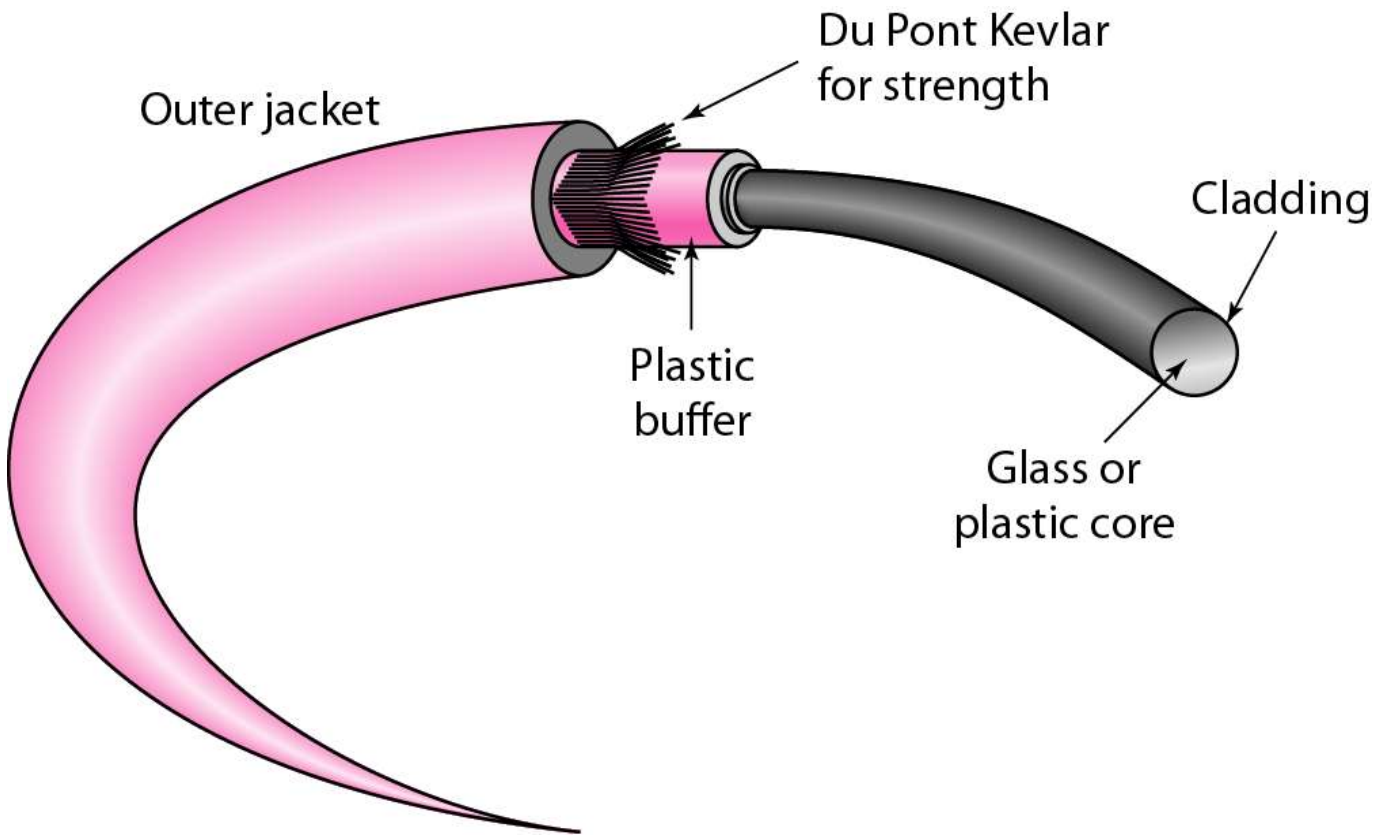


Figure 7.15 *Fiber-optic cable connectors*

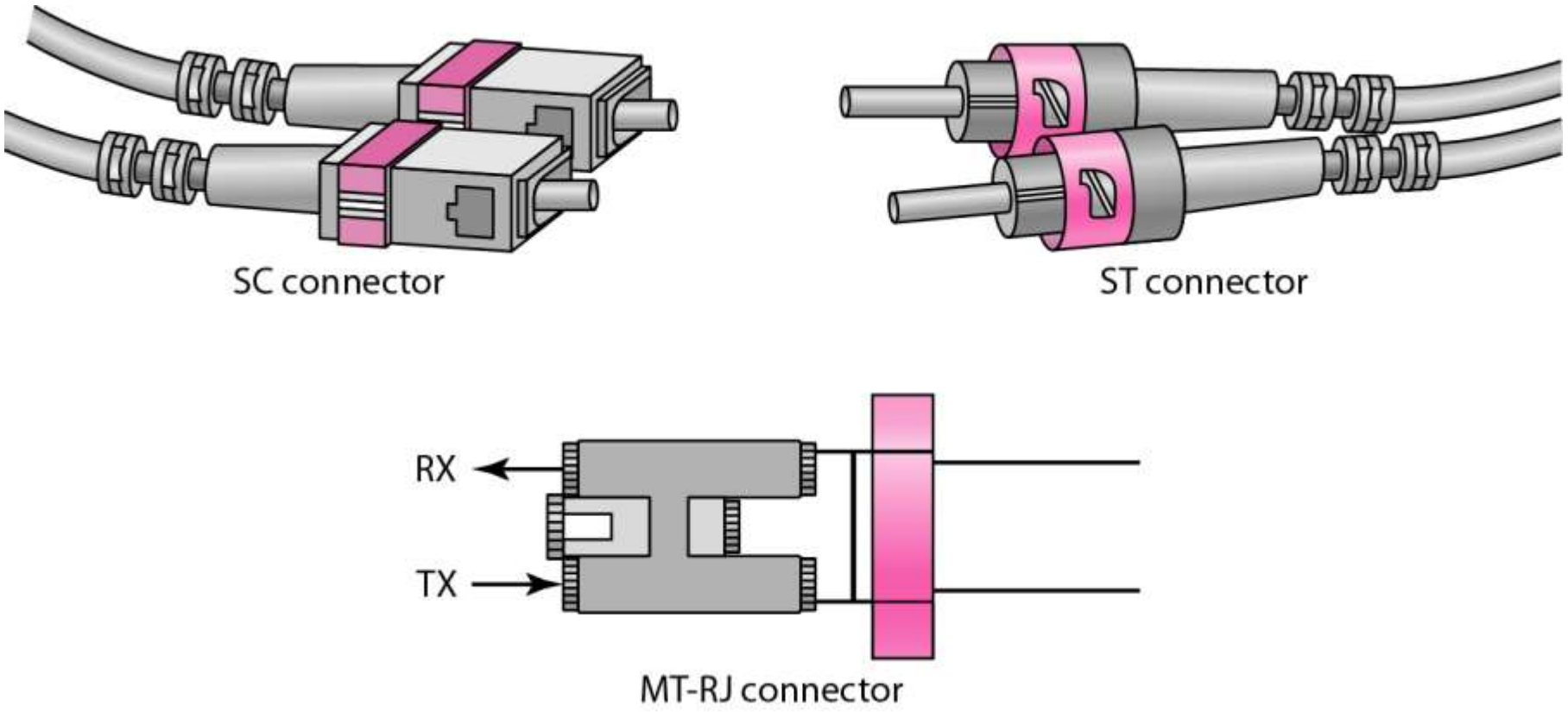
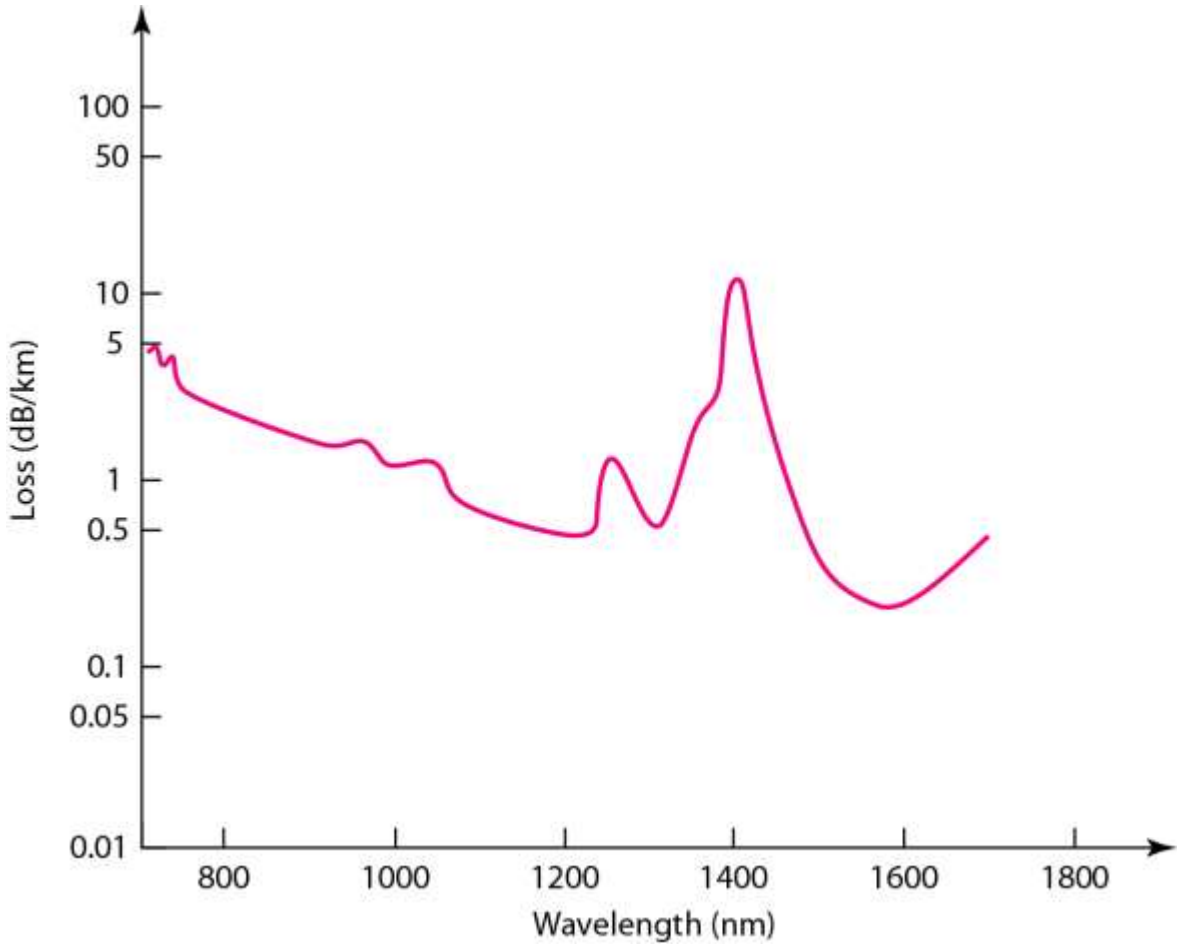


Figure 7.16 *Optical fiber performance*



Difference between UTP STP Coaxial and Fiber Optic Cable

Characteristics	UTP	STP	Coaxial Cables	Fiber Optic Cables
Bandwidth	10 Mbps – 100 Mbps	10 Mbps – 100 Mbps	10 Mbps	100 Mbps -1 Gbps
Maximum cable segment	100 meters	100 meters	200 – 500 meters	2 k.m. – 100 k.m.
Interference rating	Poor	Better than UTP	Better than Twisted Pair Cable	Very good as compared to any other cable
Installation cost	Cheap	Costly than UTP	Costlier than twisted pair wires	Costliest to install
Bend radius	360 degrees / feet	360 degrees / feet	360 degrees / feet or 30 degrees / feet	30 degrees / feet
Security	Low	Low	Low	High

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.

Topics discussed in this section:

Radio Waves
Microwaves
Infrared

Figure 7.17 *Electromagnetic spectrum for wireless communication*

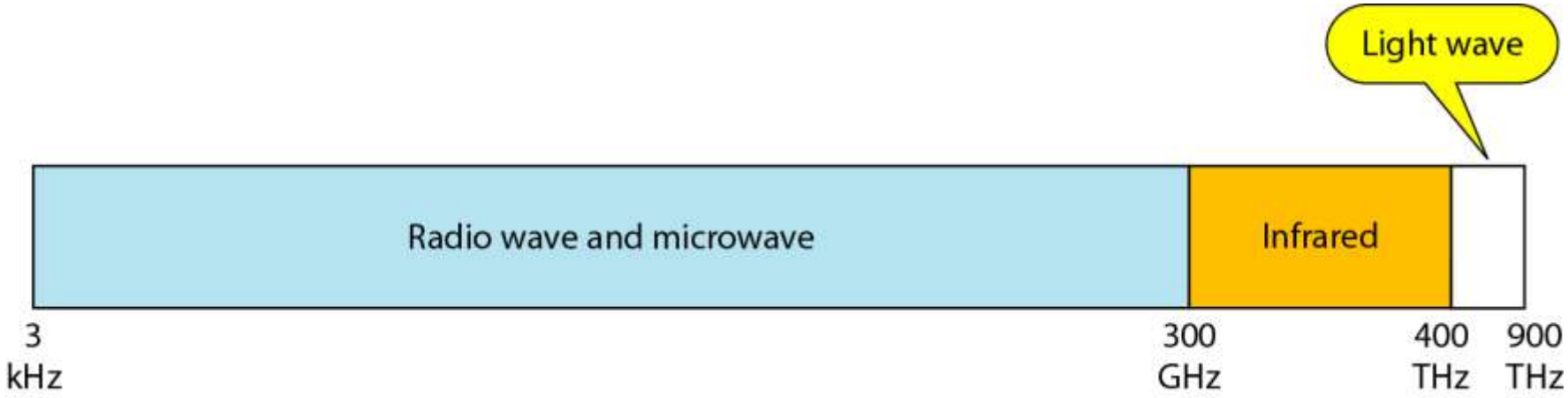


Figure 7.18 *Propagation methods*

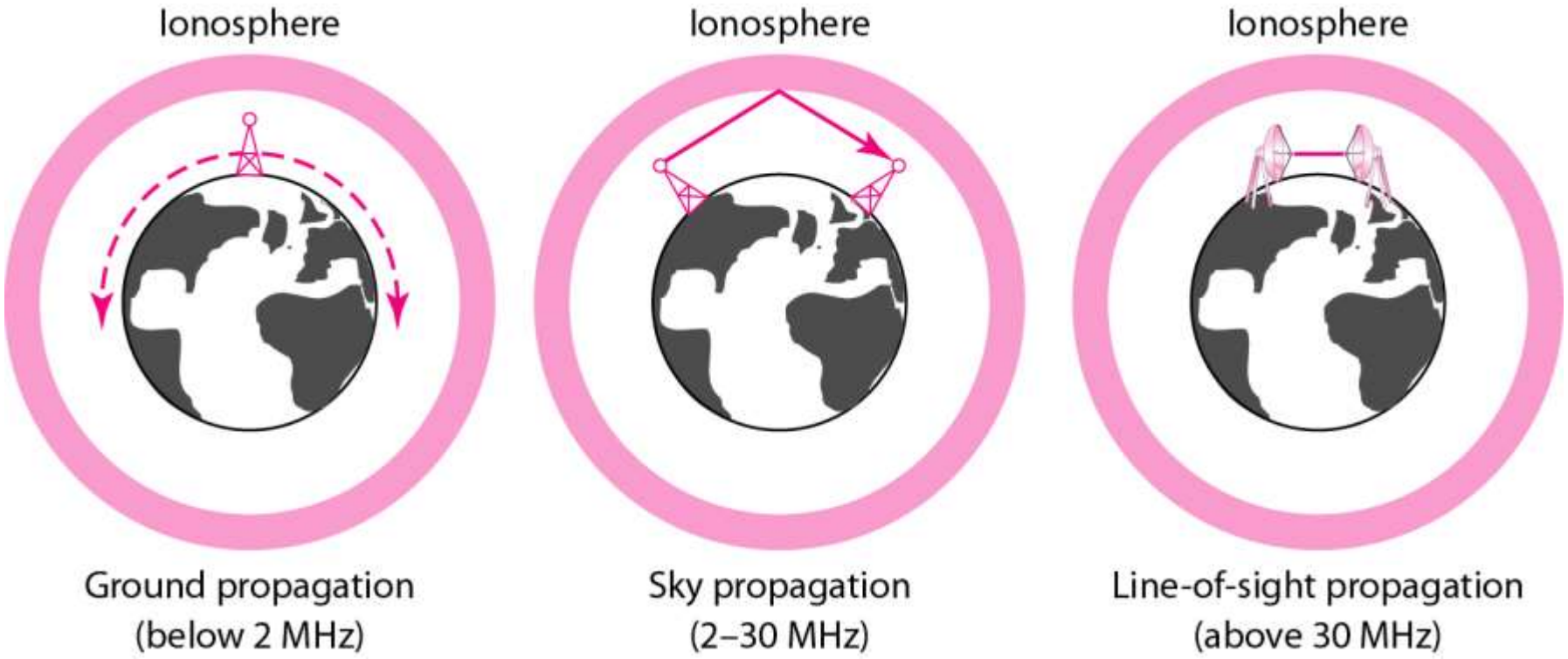
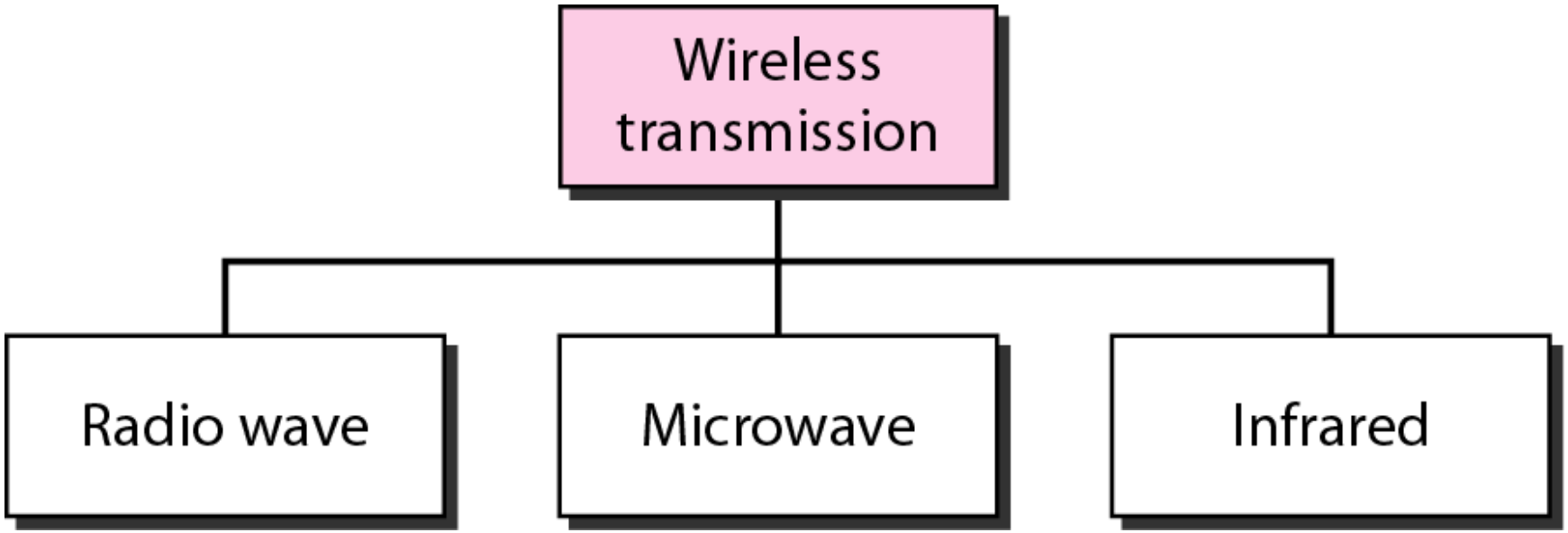


Table 7.4 *Bands*

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

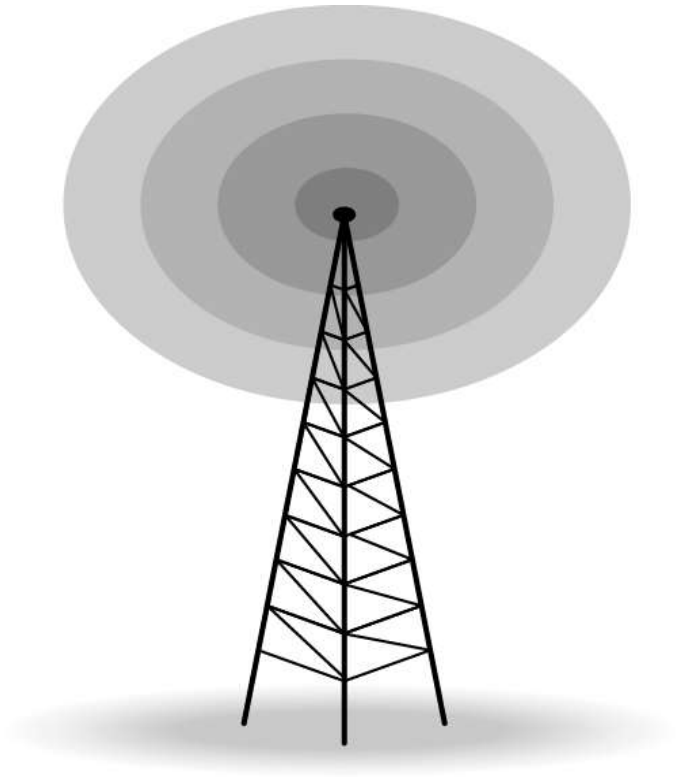
Figure 7.19 *Wireless transmission waves*



Note

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

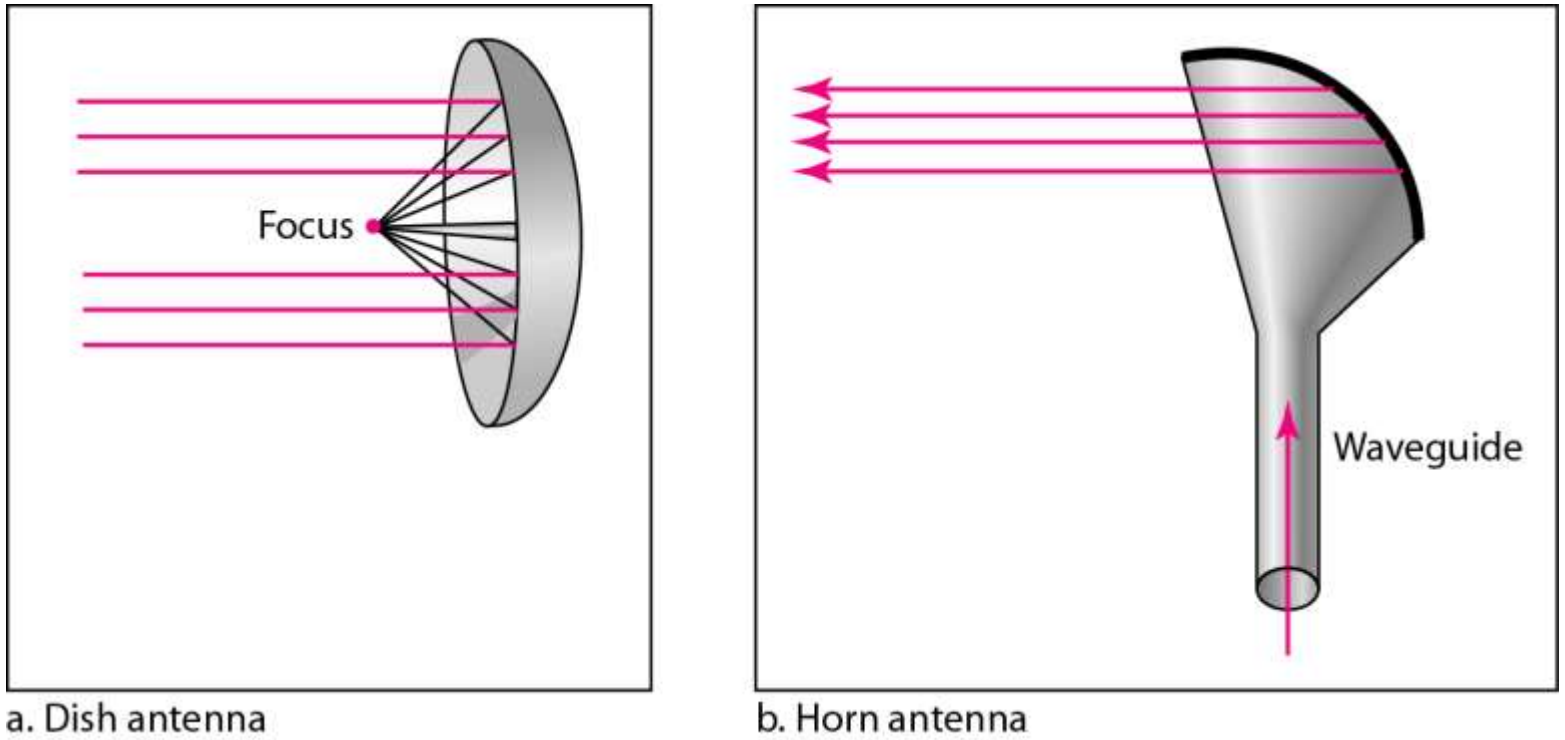
Figure 7.20 *Omnidirectional antenna*



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

Note

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

Wireless Channels

- Are subject to a lot more errors than guided media channels.
- Interference is one cause for errors, can be circumvented with high SNR.
- The higher the SNR the less capacity is available for transmission due to the broadcast nature of the channel.
- Channel also subject to fading and no coverage holes.