SEMESTER: VI **HOURS: 6**
CODE: U15CA6:1 **CREDITS: 5**

Elective – II A: COMPUTER NETWORKS

Objectives:

To know about the physical structure of networks.
To know about various network communications.

UNIT-I: **12 hrs**

Introduction: Data Communication Networks - Protocols and Standards - Basic Concepts – Line Configuration – Topology - Transmission Mode - Categories Of Networks - The OSI Model – Functions of the Layers.

UNIT-II: **12 hrs**

Physical Layer Signals: Analog and Digital - Periodic and Aperiodic Signals - Analog Signals, Composite Signals - Digital Signals - Transmission Media – Unguided Media & Guided Media.

UNIT-III: **12 hrs**

Data Link Layer: Error Detection and Correction – Types of Errors – Error Detection - Various Redundancy Checks – Checksum - Error Correction - Data Link Control – Line Discipline - Flow Control - Error Control - Data Link Protocols – Character Oriented Protocols and Bit Oriented Protocols.

UNIT-IV: **12 hrs**

Network Layer: Switching – Circuit Switching, Packet Switching and Message Switching - Networking and Internetworking Devices – Repeaters – Bridges – Routers – Gateways - Routing Algorithm – Distance Vector Routing and Link State Routing - **Transport Layer:** Functions of Transport Layer.

UNIT-V: **12 hrs**

Session Layer: Session and Transport interaction - Synchronization points - Session Protocol Data Unit - **Presentation Layer:** Translation - Encryption and Decryption - Authentication and Data compression – **Application Layer:** Message Handling System - File transfer - Access and Management - Virtual Terminal - Directory Services - Common Management Information Protocol.

Book for study:

Behrouz A. Forouzan, ***"Data Communication and Networking"***, TATA McGraw-Hill Publications, 2nd Edition, 2012.

Introduction

- **Data Communication**
- **Networks**
- **Protocols and Standards**
- **Standard Organizations**

DATA COMMUNICATIONS

- When we communicate, we are sharing information.
- This sharing can be local or remote.
- Between individuals, local communication usually occurs face to face, while remote communication takes place over distance.
- The term *telecommunication*, *which* includes telephony, telegraphy, and television, means communication at a distance *(tele* is Greek for "far").
- Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable.
- For data communications to occur, the communicating devices must be part of a communication system made up of a combination of hardware (physical equipment) and software (programs).
- The effectiveness of a data communications system depends on four fundamental characteristics:

  Delivery, Accuracy, Timeliness, and Jitter.

Characteristics of the effective data communications system:

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.

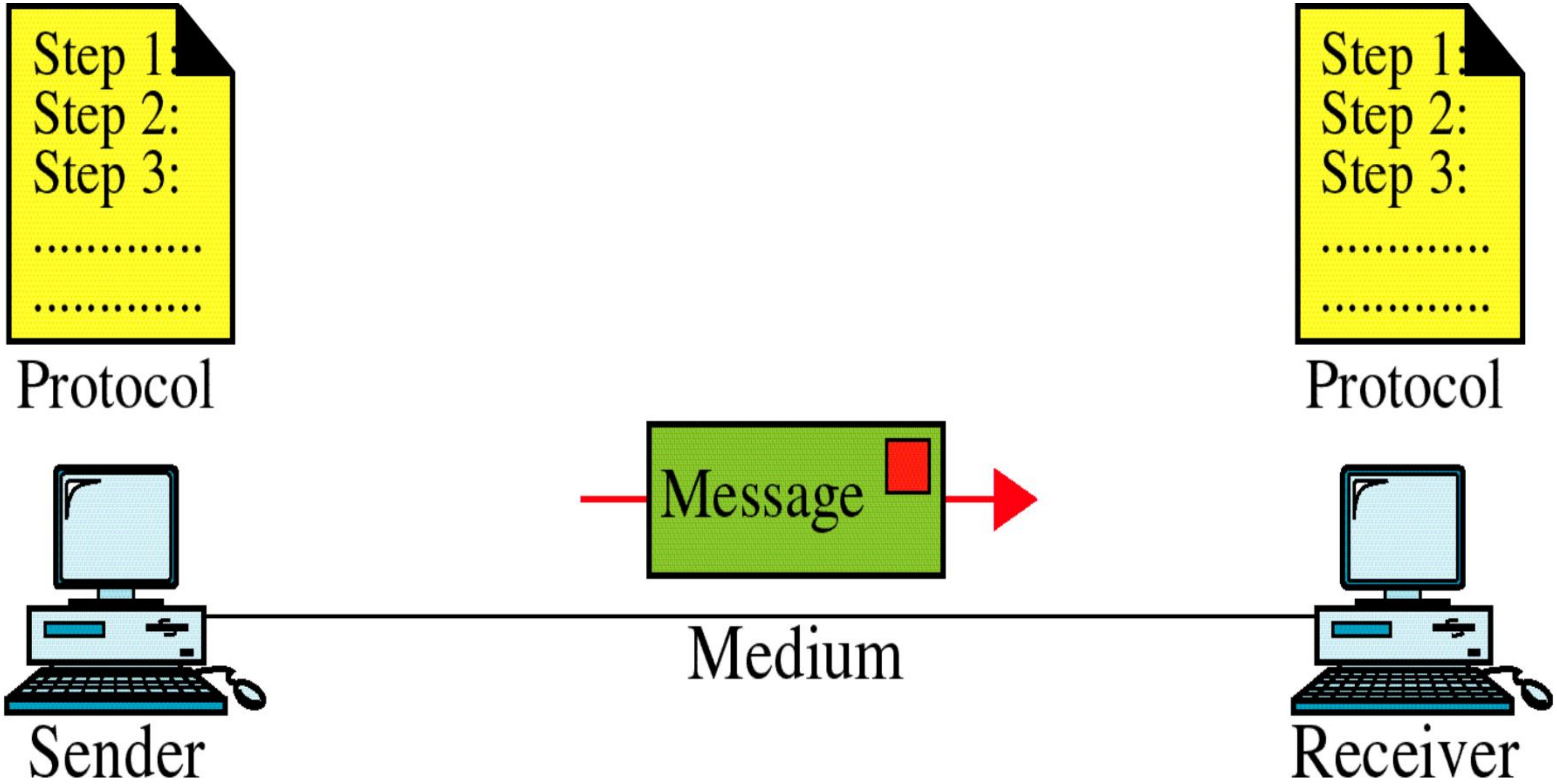
- This kind of delivery is called *real-time transmission.*

4. Jitter:

- Jitter refers to the variation in the packet arrival time.

Data Communication System Components

- A data communications system has five components



1. Message:

- The message is the information (data) to be communicated.
- Popular forms of information include text, numbers, pictures, audio, and video.

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. Transmission medium:

- The transmission medium is the physical path by which a message travels from sender to receiver.
- Some examples of transmission media include twisted-pair wire, coaxial cable, fiber-optic cable, and radio waves.(wire less)

5. Protocol:

- A protocol is a set of rules that govern data communications.
- It represents an agreement between the communicating devices.
-Without a protocol, two devices may not be connected.

Data Representation

Text

- In data communications, text is represented as a bit pattern, a sequence of bits (Os or Is).

Numbers

- Numbers are also represented by bit patterns.
- However, a code such as ASCII is not used to represent numbers; the number is directly converted to a binary number to simplify mathematical operations.

Images

- Images are also represented by bit patterns.
- In its simplest form, an image is composed of a matrix of pixels (picture elements), where each pixel is a small dot.
- The size of the pixel depends on the *resolution.*

Audio

- Audio refers to the recording or broadcasting of sound or music.
- Audio is by nature different from text, numbers, or images.
- It is continuous, not discrete.

Video

- Video refers to the recording or broadcasting of a picture or movie.
- Video can either be produced as a continuous entity (e.g., by a TV camera), or it can be a combination of images, each a discrete entity, arranged to convey the idea of motion.

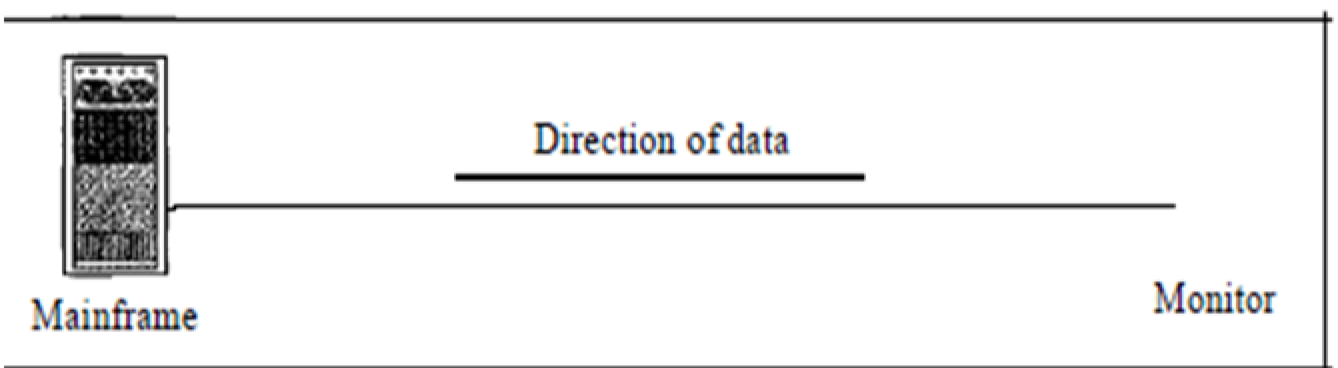
Data Flow:

- Communication between two devices can be
  - **simplex**
  - **half-duplex**
  - **full-duplex**

  as shown in Figure

(i) Simplex Transmission:

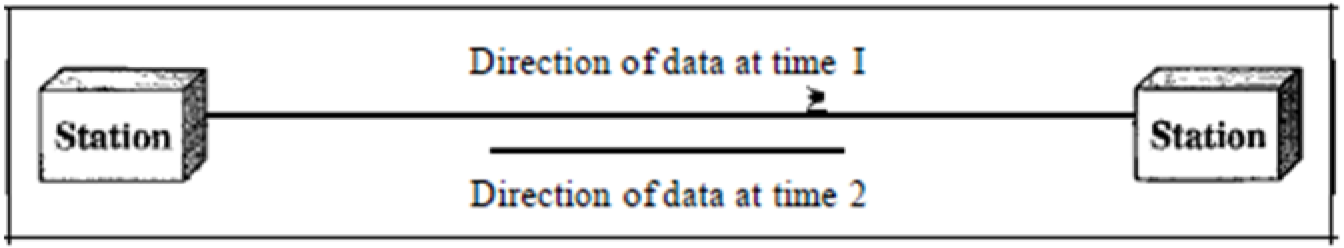
- In simplex mode, the communication is unidirectional, as on a one-way street.
- Only one of the two devices on a link can transmit; the other can only receive (see Figure a).
- Keyboards and traditional monitors are examples of simplex devices.
- The keyboard can only introduce input; the monitor can only accept output.
- The simplex mode can use the entire capacity of the channel to send data in one direction.



a. Simplex

(ii) Half – Duplex Transmission:

- 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 (see Figure b).
- The half-duplex mode is like a one-lane road with traffic allowed in both directions.
- When cars are travelling in 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.
- Walkie-talkies and CB (citizens band) radios are both half-duplex systems.



b. Half-duplex

- The half-duplex mode is used in cases where there is no need for communication in both directions at the same time; the entire capacity of the channel can be utilized for each direction.

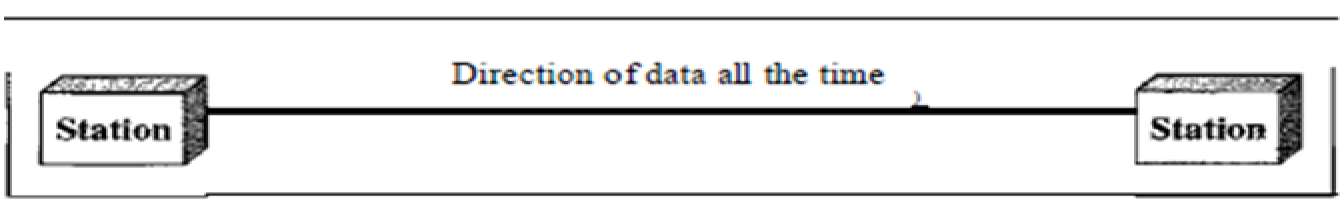
(iii) Full-Duplex Transmission:

- In full-duplex mode (also called duplex), both stations can transmit and receive simultaneously (see Figure c).

- 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 one direction share the capacity of the link: with signals going in the other direction.

- 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 travelling in both directions.



c. Full-duplex

- 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.

- The full-duplex mode is used when communication in both directions is required all the time.

- The capacity of the channel, however, must be divided between the two directions.

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.

1.2.1 Distributed Processing:

- Most networks use distributed processing, in which a task is divided among multiple computers.
- Instead of one single large achine being responsible for all aspects of a process, separate computers handle a subset.

Advantages of Distributed Processing:

(i) Security/Encapsulation
(ii) Distributed databases
(iii) Faster Problem Solving
(iv) Security through Redundancy
(v) Collaborative processing

(i)Security/Encapsulaltion:

- A system designer can limit the kinds of interactions that a given user can have with the entire system.

Eg: A bank can allow users access to their own accounts through the ATM without allowing them access to the bank's entire database.

(ii)Distributed Databases:

- No one system needs to provide storage capacity for the entire database.

Eg: WWW gives users access to information that may actually stored and manipulated anywhere on the internet.

(iii)Faster Problem Solving:

-can solve the problem faster than a single machine working alone.

(iv) Security through redundancy:

Multiple computers running the same program at the same time can provide security through redundancy.

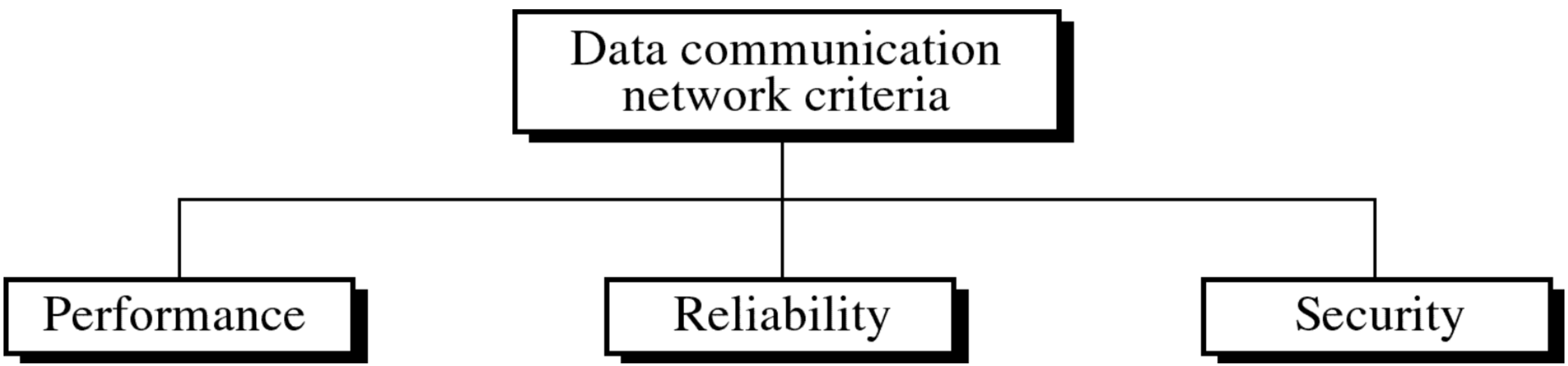
Eg. Three computers run the same program so that if one has a hardware error, the other two can override it.

(v) Collaborative Processing:

Both multiple computers and multiple users may interact on a task.

1.2.1Data Communication Network Criteria:

- A network must be able to meet a certain number of criteria.
- The most important of these are
  - ✓ Performance
  - ✓ Reliability
  - ✓ Security.



✓ *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

  * Number of Users:

  *Type of transmission medium

  * Hardware

  * Software

- ✓ *Reliability*

- Network reliability is measured by the

  * Frequency of Failure: A n/w that fails often, is of little value to a user
  * Recovery time of a network after a failure.
  * Catastrophe: N/w must be protected from catastrophic events such as fire, earthquake or theft.

- ✓ *Security*

- Network security issues include

  *unauthorized access: For a n/w to be useful, sensitive data must be protected from unauthorized access.

  Protection can be accomplished at a number of levels.

  Lowest Level: user identification codes and passwords

  Higher Level: Encryption techniques.

  * Viruses: A virus is an illicitly introduced code that damages the system.

  A good system is protected from viruses.

Applications:

- Data communication n/ws have become an indispensable part of business, industry and entertainment.
- **Some of the n/w applications in different fields are the following**

(i) Marketing and Sales:

- computer n/ws are used extensively in both marketing and sales organizations.

-Marketing professionals use them to collect,exchange,and analyze data relating to customer needs and product development cycles.

- Sales applications include teleshopping, on-line reservation for hotels, airlines and so on

(ii)Financial Services:

- Today financial services are totally dependent on computer n/ws

- Application include credit history searches, foreign exchange and investement services and electronic funds transfe(EFT), which allows the user to transfer money without going into a bank.

(iii)Manufacturing:

- Two applications that use n/w to provide essential services are Computer-Assisted Design(CAD) and Computer-Assisted Manufacturing(CAM), both of which allow multiple users to work on a project simultaneously.

(iv) Electronic Messaging:

- E-mail

(v) Directory Services:

-It allows list of files to be stored in a central location to speed world wide search operations.

(vi) Information services:

It include bulletin boards and databanks.

(vii) Electronic data interchange(EDI):

- It allows business information to be transferred without using paper.

(viii) Teleconferencing:

-It allows conferences to occur without the participants being in the same place.Application including text conferencing and video conferencing.

(ix) Cellular Telephone:

- Today's cellular networks make it possible to maintain wireless phone connections even while travelling over large distances.

(x) Cable Television:

- Future services provided by cable television n/ws may include video on request, as well as the same information, financial, and communication services currently provided by the telephone companies and computer n/ws.

Protocols and Standards

Protocols:

- In computer n/ws , communication occurs between entities in different systems.

- An entity is anything capable of sending or receiving information.

- Eg: application programs
  file transfer packages
  database management systems
  electronic mail s/w

- A system is a physical object that contains one or more entities.

  Eg: computers and terminals

- But two entities cannot just send bit streams to each other and expect to be understood.

- For communication to occur , the entities must agree on a protocol.

- **“A protocol is a set of rules that govern data communication”.**

- A protocol defines what is communicated, how it is communicated, and when it is communicated.

- **The key elements of a protocol are**
  - *** syntax** **hi how are you? I am fine**
  - *** semantics** **fine how am you? hi I are**
  - *** timing**

*Syntax: it refers to the **structure** or **format** of the data, meaning the order in which they presented.

Eg: a simple protocol might expect the first eight bit of data to be the address of the sender, the second eight bits to be the address of the receiver , and the rest of the stream to be the message itself.

*Semantics:

- It refers to the meaning of each section of bits.

  Eg: an address identify the route to be taken or the final destination of the message.

hi /how /are/ you? /I /am /fine.

1 2 3 4 5 6 7

* Timing:

- It refers to two characteristics:
  - when the data should be sent
  - how fast they can be sent.

Basic Concepts

(a) Line configuration

(b) Topology

(c) Transmission mode

(d) Categories of N/ws

(e) Internetworks

(a) Line Configuration:

- It refers to the way two or more communication devices attach to a link.

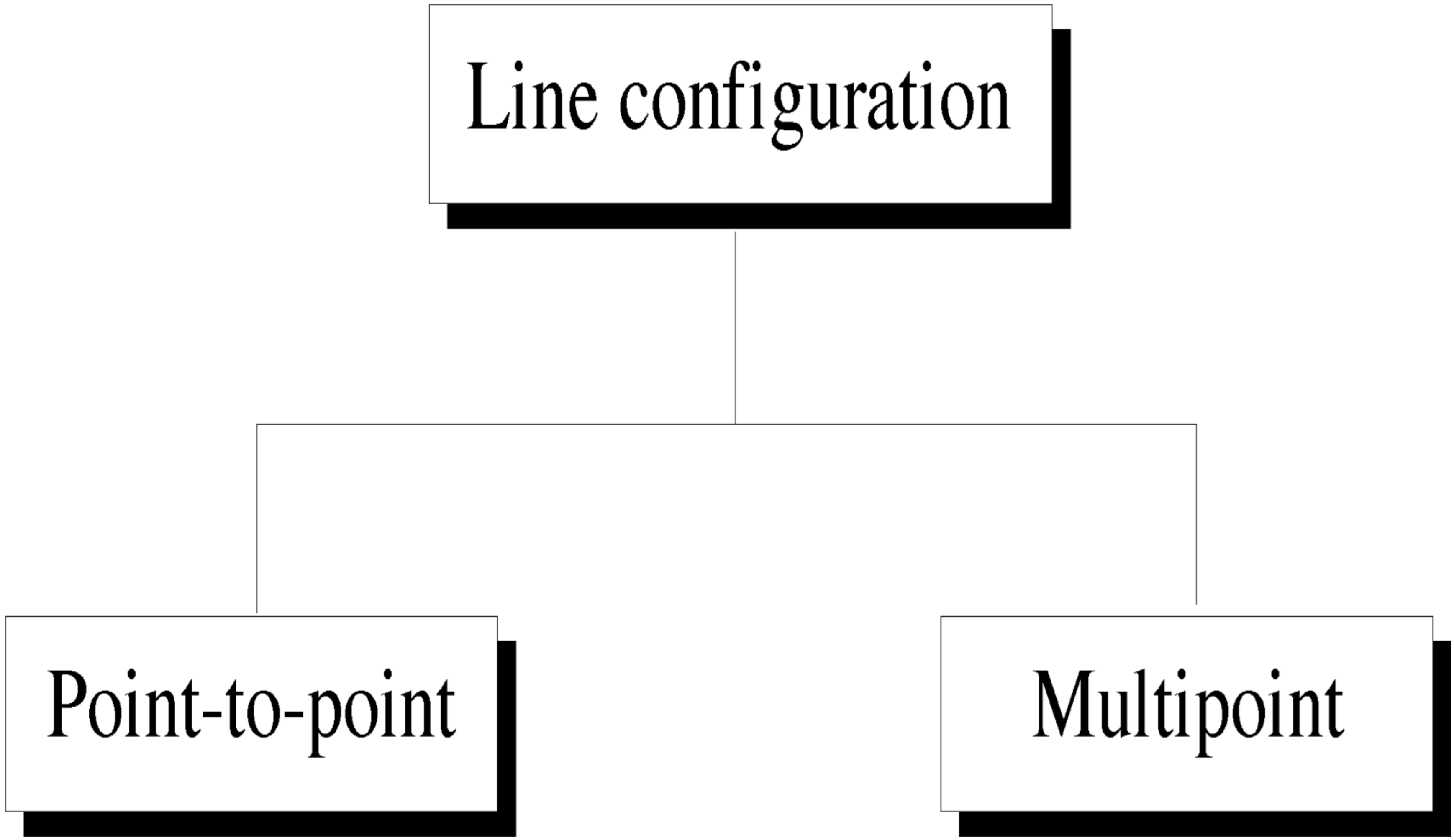
- A link is the physical communication pathway that transfers data from one device to another.

- Line configuration defines the attachment of communication devices to link.

- There are two possible line configurations

(i) Point-to-Point line configuration

(ii) Multipoint line configuration


Line configuration
Point-to-point
Multipoint

(i) Point-to-Point Connection:

- 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.

- 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.

Point-to-Point Line Configuration

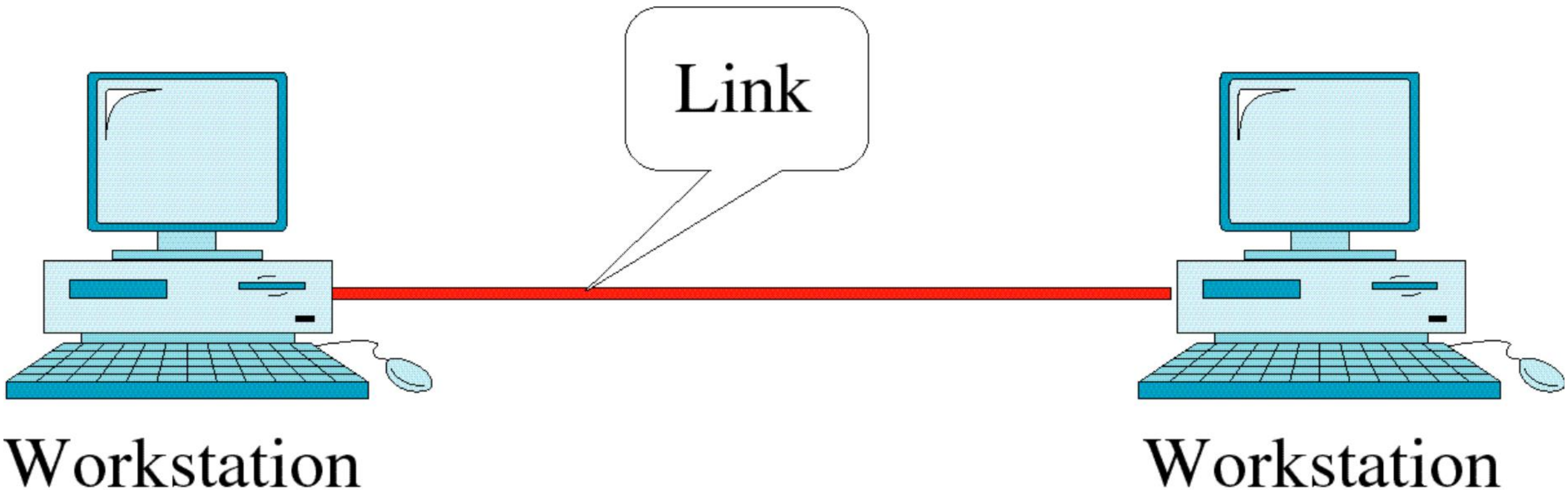


Figure 2-2-continued

Point-to-Point Line Configuration

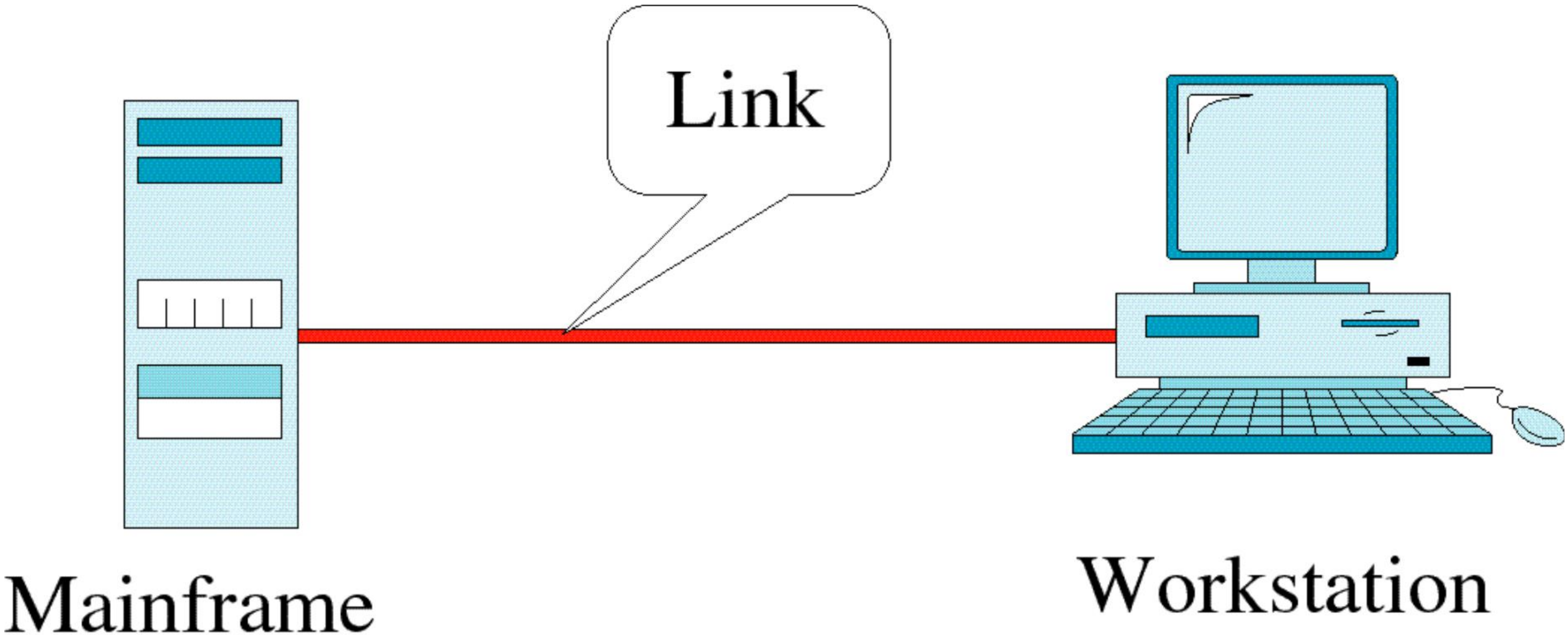


Figure 2-2-continued

Point-to-Point Line Configuration

(ii) Multipoint Connection:

- A multipoint (also called multidrop) connection is one in which more than two specific devices share a single link (see Figure 2.3b).

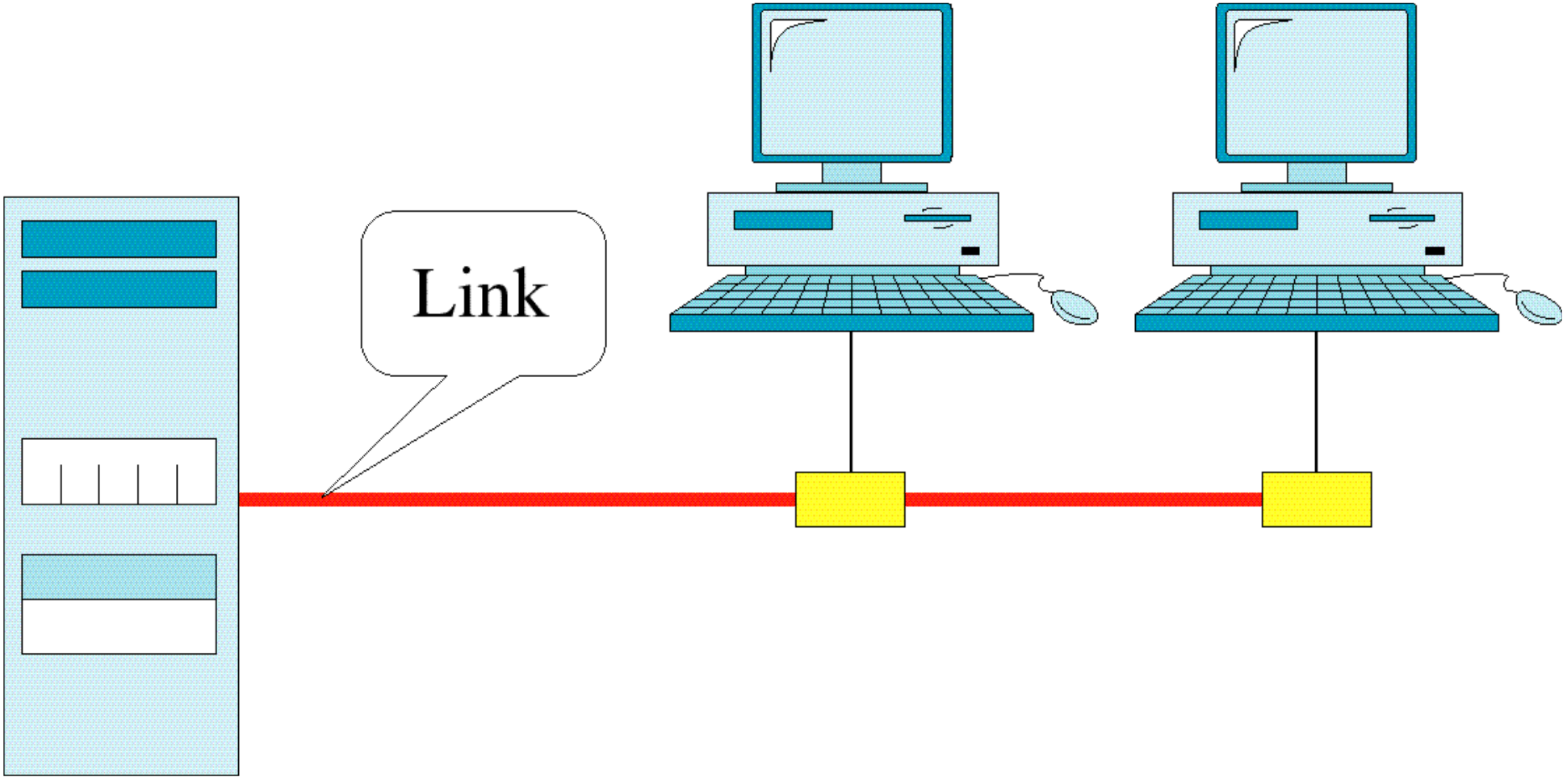
- In a multipoint environment, the capacity of the channel is shared, either spatially or temporally.

- If several devices can use the link simultaneously, it is a *spatially shared* connection.

- If users must take turns, it is a *timeshared connection.*

Figure 2-3

Multipoint Line Configuration



(b) 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.

" Topology defines the physical or logical arrangement of links in a network"

- 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 five basic topologies

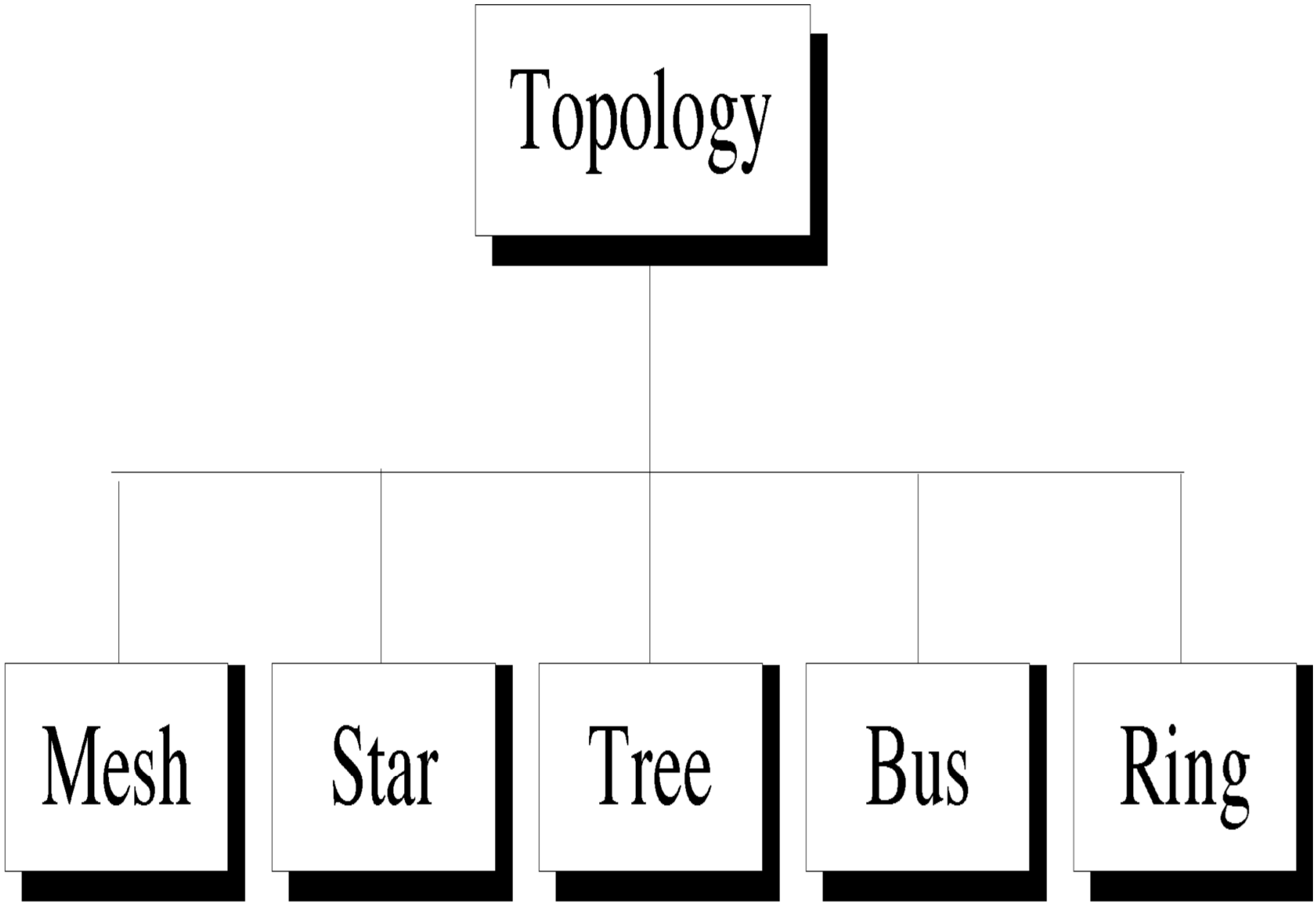
  (i) Mesh Topology

  (ii) Star Topology

  (iii) Bus Topology

  (iv) Ring Topology

  (v) Tree Topology


Topology
Mesh
Star
Tree
Bus
Ring

1.Mesh Topology:

- 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.

- To find the number of physical links in a fully connected mesh network with *n nodes, we first consider that each node must be connected to every* other node.

- Node 1 must be connected to *n - I nodes, node 2 must be connected to n – 1* nodes, and finally node *n must be connected to n - 1 nodes.*

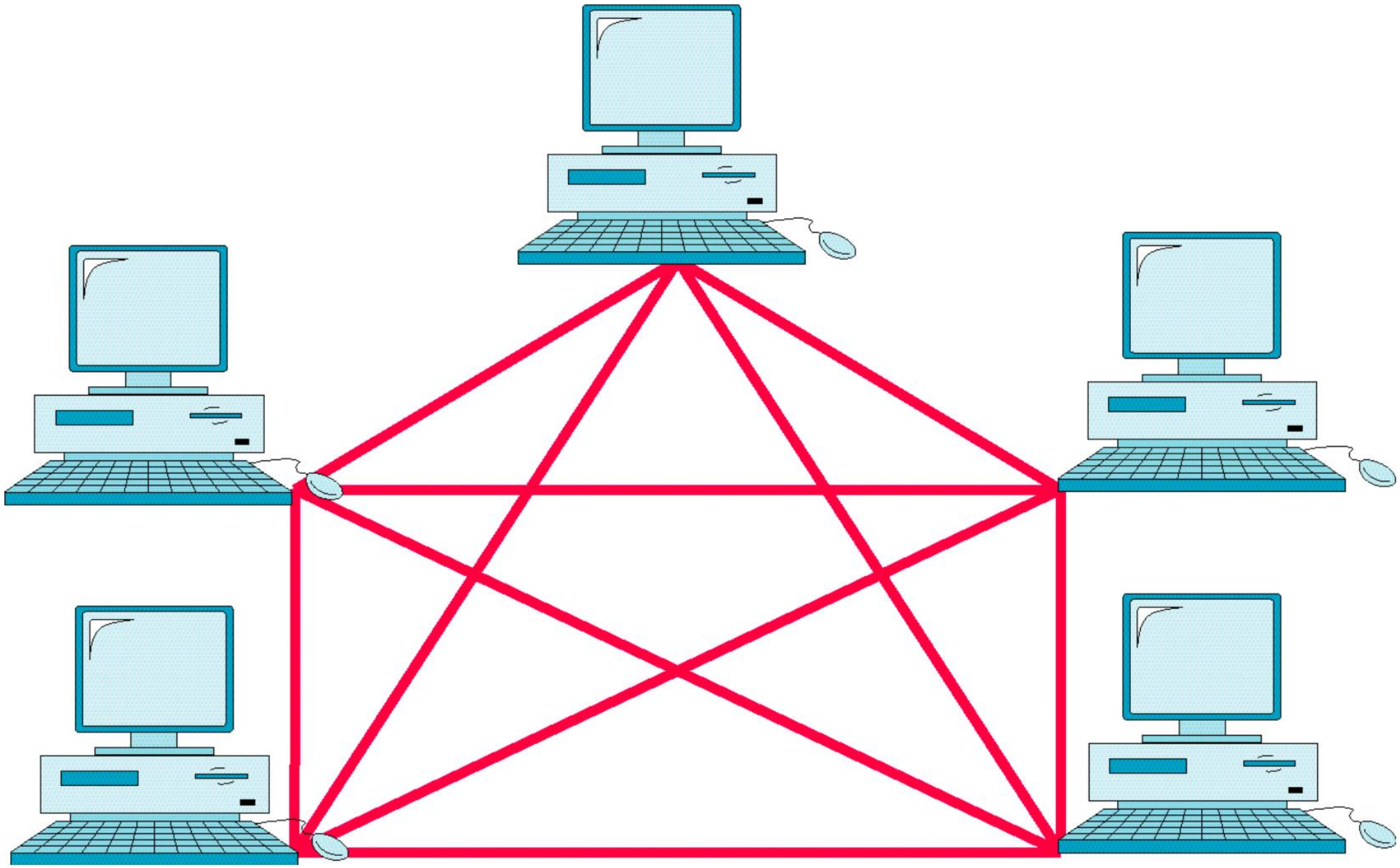
- *We need n(n - 1) physical* links.

- However, if each physical link allows communication in both directions (duplex mode), we can divide the number of links by 2.

- In other words, we can say that in a mesh topology, we need

n(n -1) /2 duplex-mode links

- every device on the network must have *n – 1* input/output *ports (see Figure 1.5) to be connected to the other n - 1 stations.*



Advantages:

(i) dedicated links guarantees that each connection can carry its own data load, thus eliminating the traffic.

(ii) a mesh topology is robust.(If one link becomes unusable, it does not incapacitate the entire system)

(iii) privacy or security

(iv) point-to-point links make fault identification and fault isolation easy.

Disadvantages:

(i) amount of cabling and the number of I/O ports required.

(ii) installation and reconnection are difficult (every device must be connected to every other device)

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

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

2.Star Topology

- In a star topology, each device has a dedicated point-to-point link only to a central controller, usually called a hub.

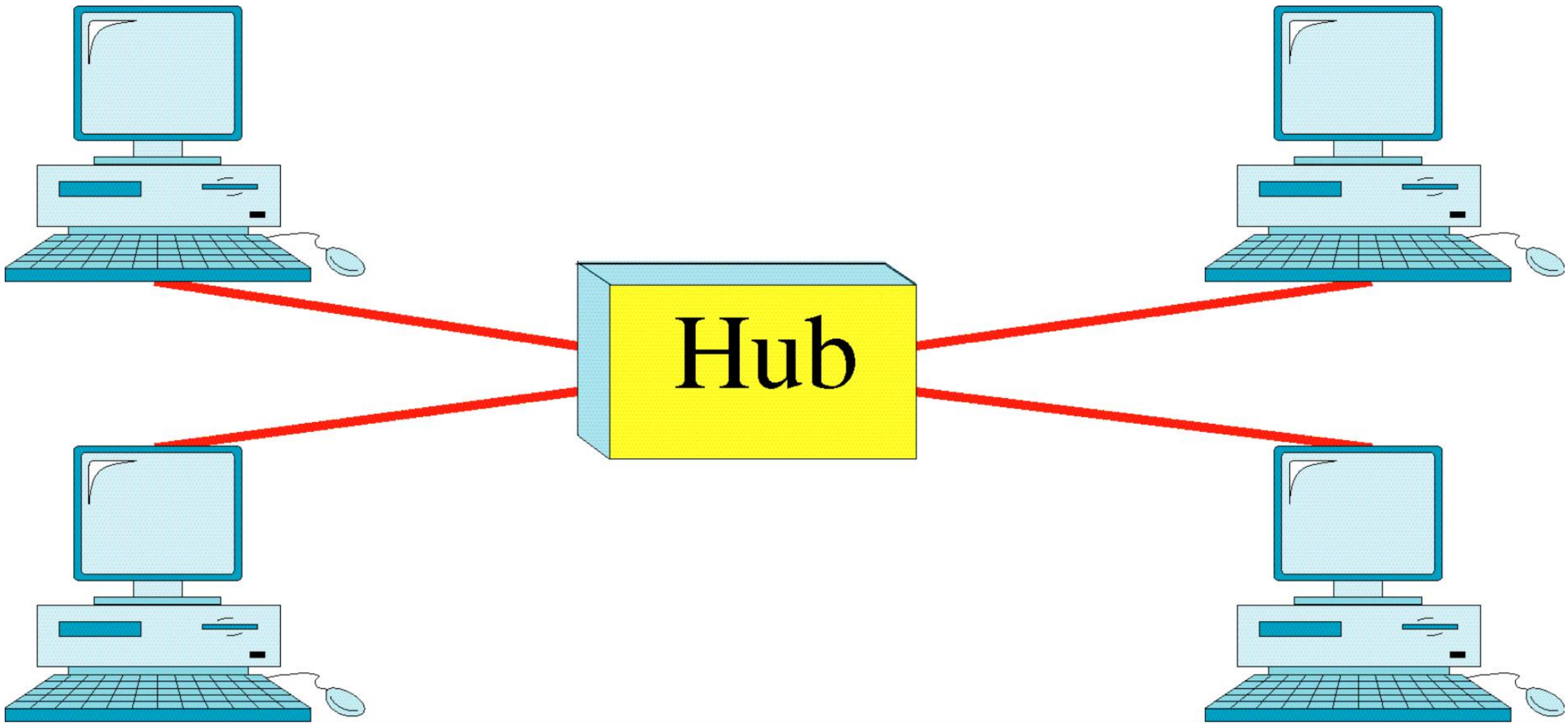
- The devices are not directly linked to one another.

- 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 (see Figure 1.6) .

Figure 2-6

Star Topology



Advantages:

(i) Less expensive than a mesh topology.

(ii) Easy to install and reconfigure(In a star, each device needs only one link and one I/O port to connect it to any number of others)

(iii) Robustness- If one link fails, only that link is affected. All other links remain active. This factor also lends itself to easy fault identification and fault isolation.

Disadvantages:

(i) Require more cabling(each node must be linked to a central hub).

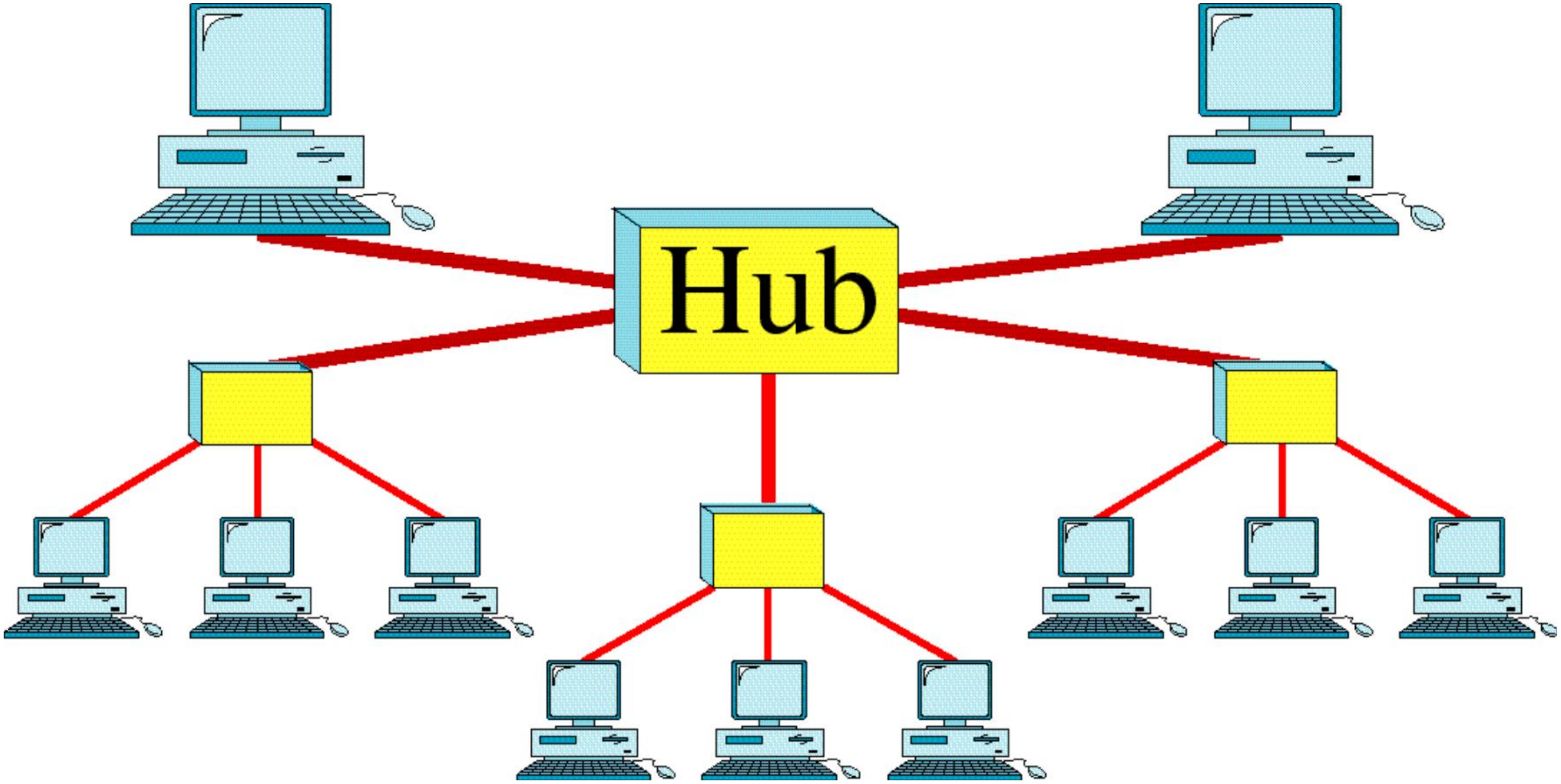
(ii) One big disadvantage of a star topology is the dependency of the whole topology on one single point, the hub. If the hub goes down, the whole system is dead.

3. Tree Topology

- Not every device plugs directly into the central hub.
- The majority of devices connect to a secondary hub that in turn in connected to the central hub.
- The central hub in the tree is an active hub.
- An active hub contains a repeater, which is a hardware device that regenerates the received bit patters before sending them out.

Figure 2-7

Tree Topology



- The secondary hubs may be active or passive hubs.
- A passive hub provides a simple physical connection between the attached devices.

Advantages:

(i) It allows more devices to attached to a single central hub and can therefore increase the distance a signal can travel between devices.

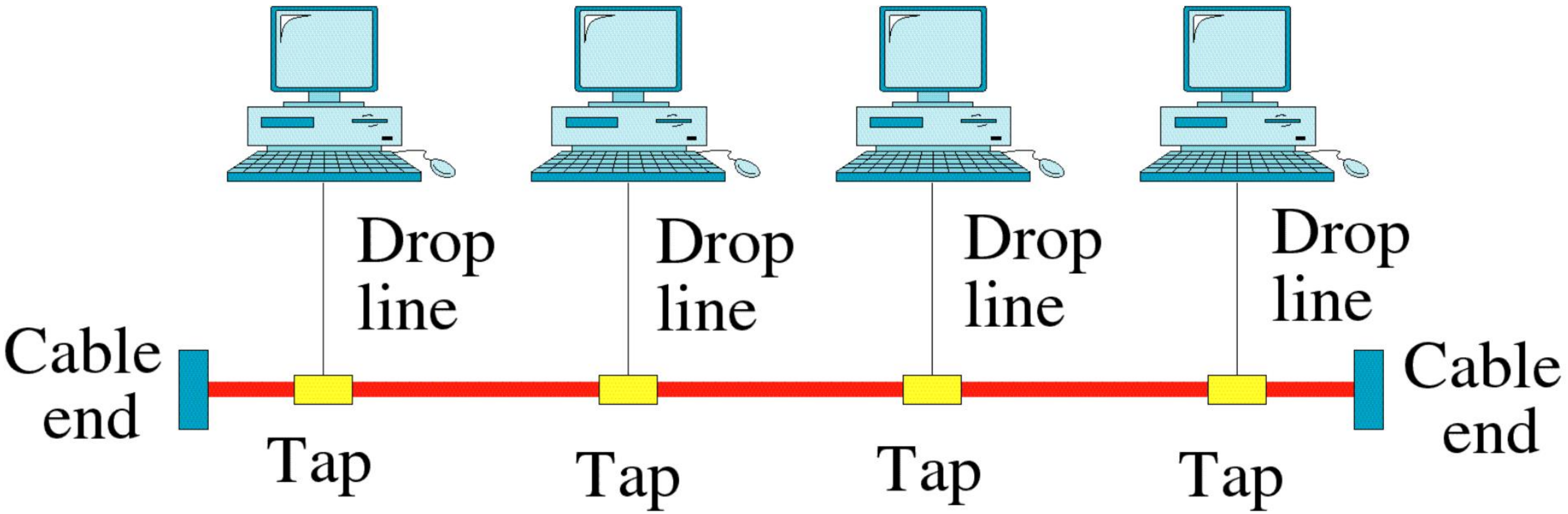
(ii) Network designers and operator can guarantee that time-sensitive data will not have to wait to access to the network.

4. Bus Topology:

- A bus topology 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.
- As a signal travels along the backbone, some of its energy is transformed into heat.
- Therefore, it becomes weaker and weaker as it travels 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 .

Figure 2-8

Bus Topology



Advantages:

(i) ease of installation

(ii) Backbone cable can be laid along the most efficient path.

(iii) less cabling

Disadvantages:

(i) difficult reconnection and fault isolation.

(ii) Signal reflection at the taps can cause degradation in quality.

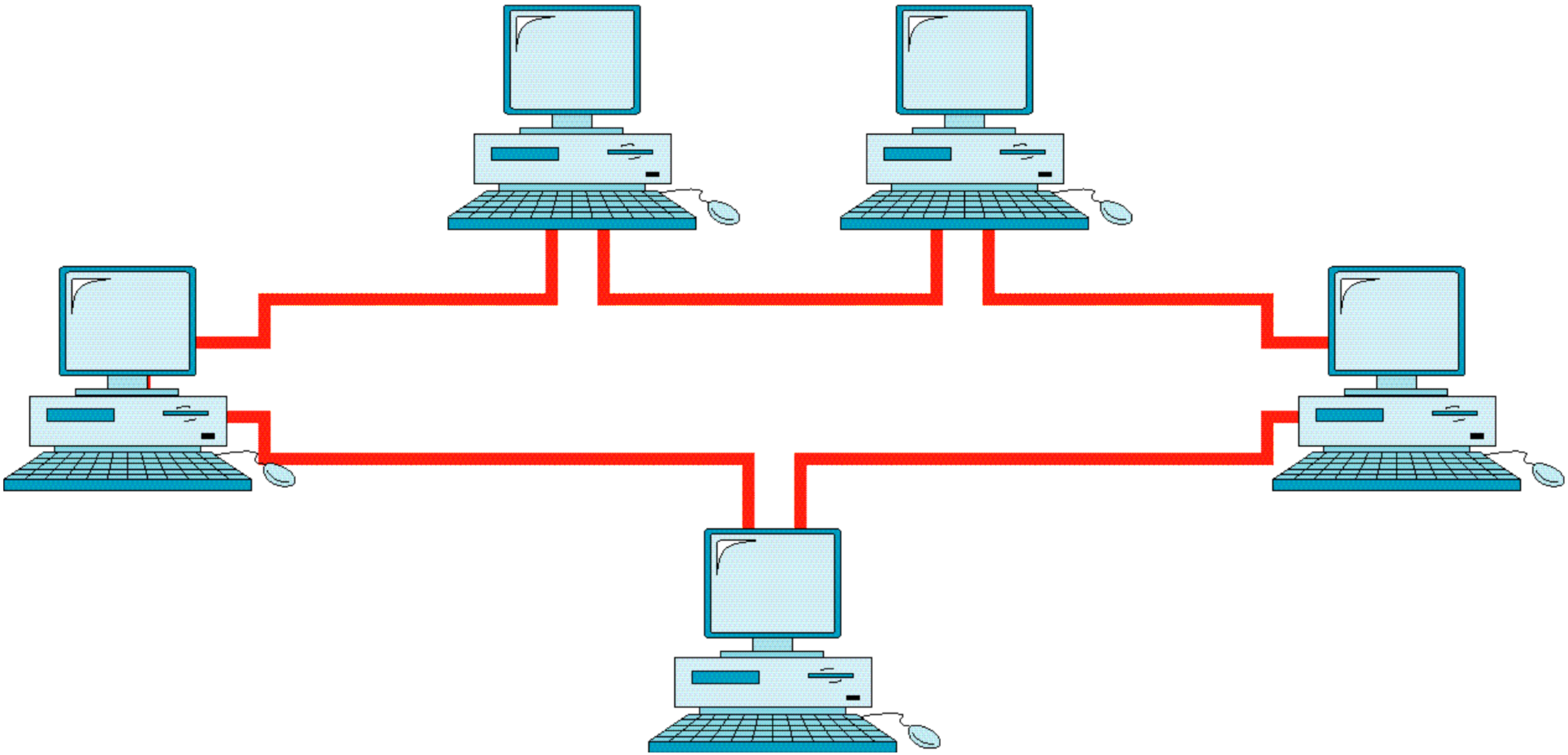
(iii) Adding new devices may therefore require modification or replacement of the backbone.

5.Ring Topology

- In a ring topology, each device has a dedicated point-to-point connection with only 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.

Figure 2-9

Ring Topology



Advantages:

- Easy to install and reconfigure(each devices is linked only to its immediate neighbors).

- Fault isolation is simplified.

- To add or delete a device requires moving only two connections.

- In a ring , a signal is circulating at all times. If one device does not receive a signal within a specified period, it can issue an alarm. This alarm alerts the n/w operator to the problem and its location.

Disadvantages:

- Unidirectional traffic.

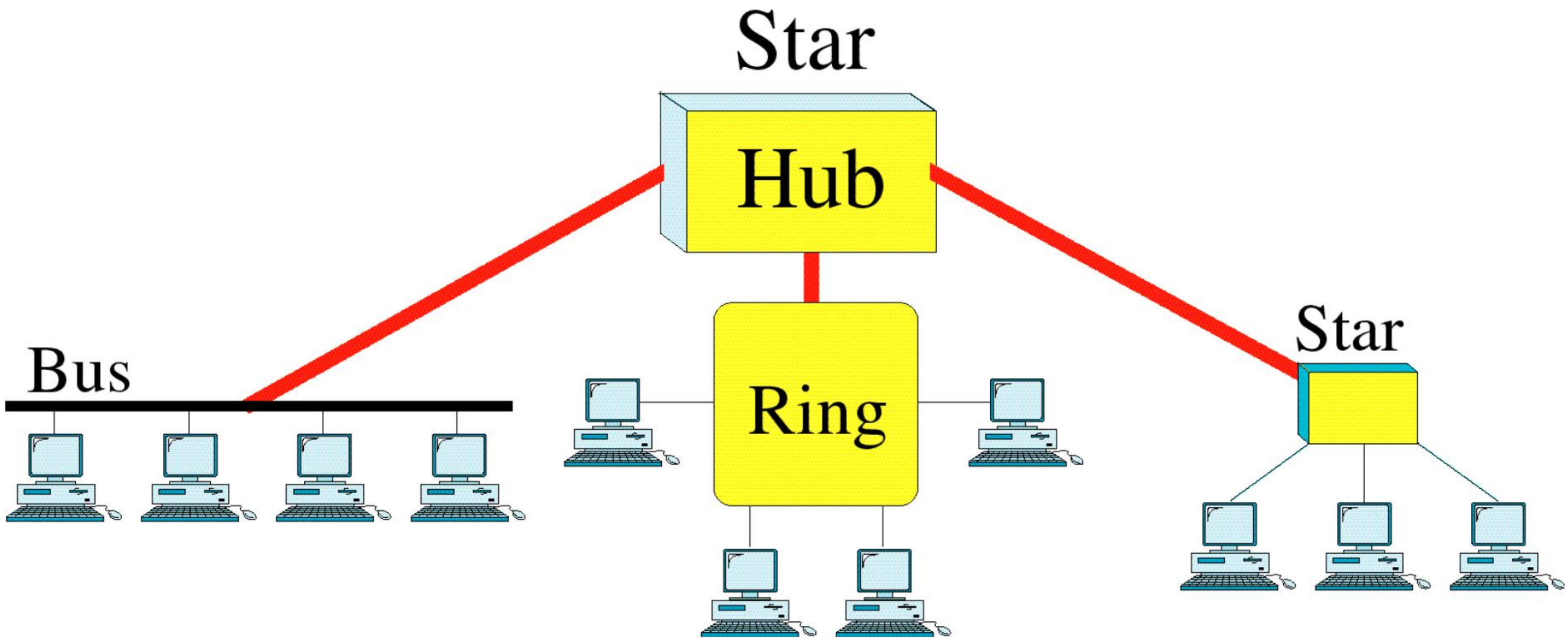
- A break in the ring can disable the entire n/w

6. Hybrid Topology

- A network can be hybrid.
- For example, we can have a main star topology with each branch connecting several stations in a bus topology as shown in Fig.

Figure 2-10

Hybrid Topology



C. Transmission Mode

- The term transmission mode refers to the direction of information flow between two devices.
- There are three types of transmission modes:

  (i) Simplex

  (ii) Half-Duplex

  (iii) Full-Duplex

(D) Categories of Networks

- Three primary categories:

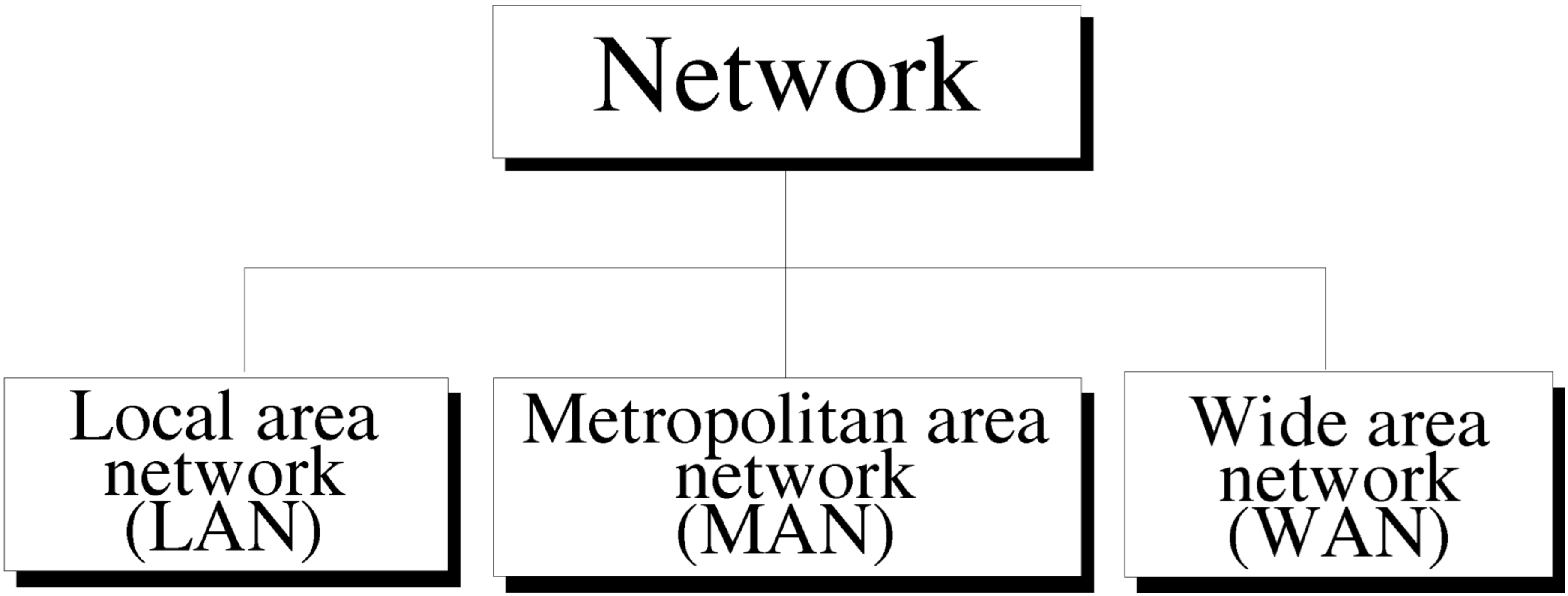
  (i) Local-area networks

  (ii)Metropolitan area networks

  (iii) Wide-area networks.

- The category into which a network falls is determined by its size.

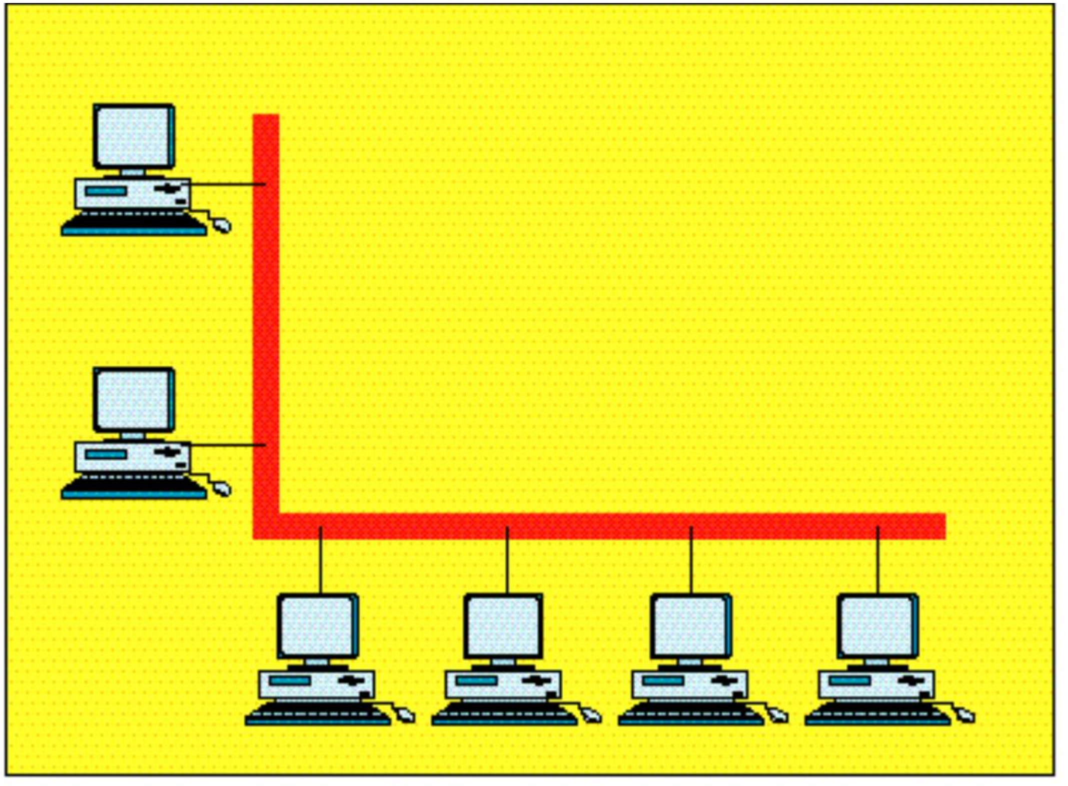
Figure 2-15


Network
Local area network (LAN)
Metropolitan area network (MAN)
Wide area network (WAN)

(i) Local Area Network(LAN)

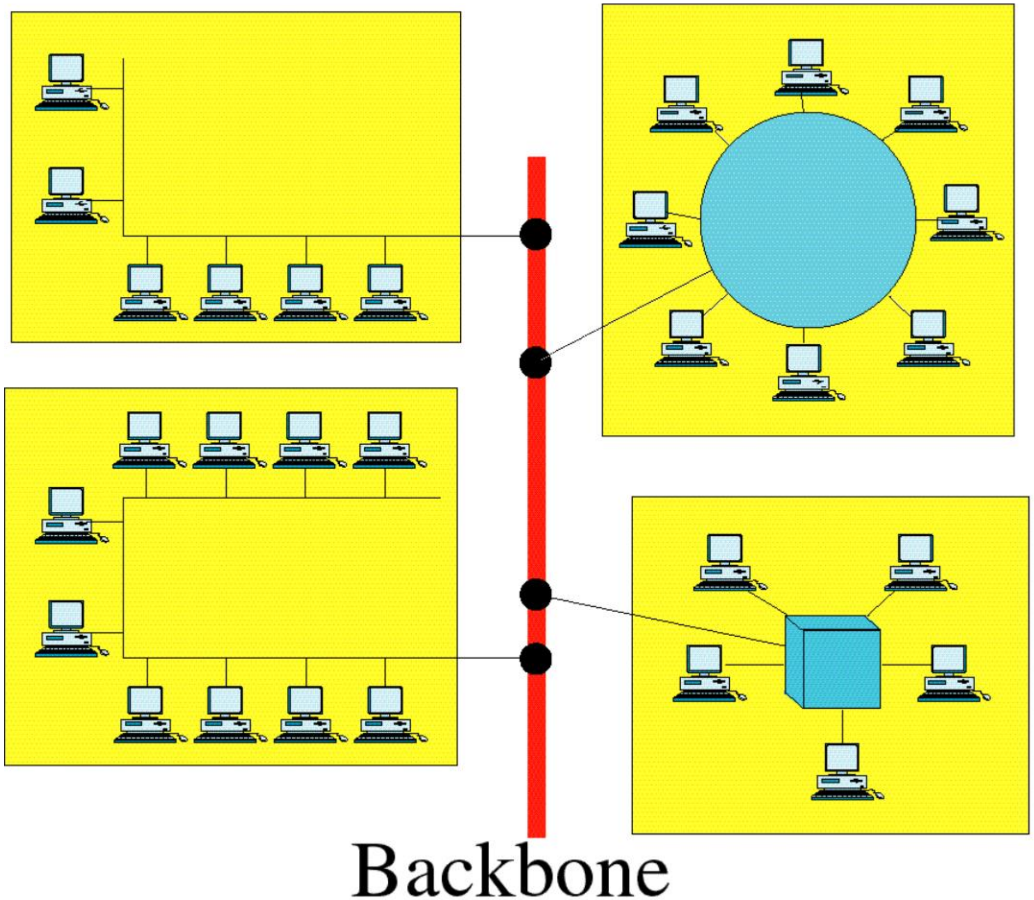
- A local area network (LAN) is usually privately owned and links the devices in a single office, building, or campus .
- Depending on the needs of an organization and the type of technology used, a LAN can be as simple as two PCs and a printer in someone's home office; or it can extend throughout a company and include audio and video peripherals.
- Currently, LAN size is limited to a few kilometers.

Local Area Network



Single building LAN

Local Area Network



Multiple building LAN

- 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.

- One of the computers may be given a large capacity disk drive and may become a server to clients.

- Software can be stored on this central server and used as needed by the whole group.

- In addition to size, LANs are distinguished from other types of networks by their transmission media and topology.

- In general, a given LAN will use only one type of transmission medium.

- The most common LAN topologies are bus, ring, and star.

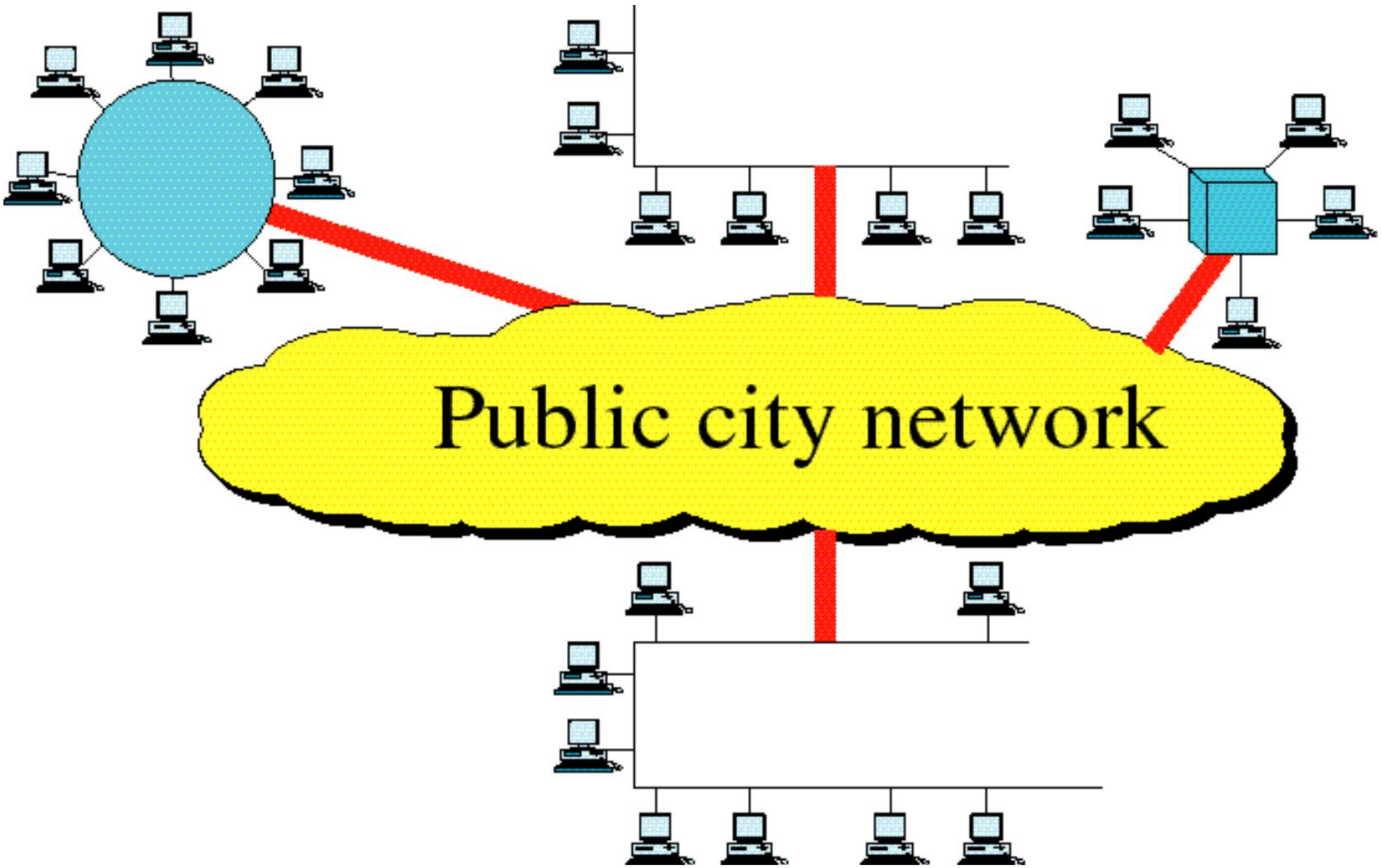
- Early LANs had data rates in the 4 to 16 megabits per second (Mbps) range.

- Today, however, speeds are normally 100 or 1000 Mbps.

(ii) Metropolitan Area Network(MAN)

- It normally covers the area inside a town or a city.
- It is designed for customers who need a high-speed connectivity.
- A good example of a MAN is the part of the telephone company network that can provide a high-speed line to the customer.
- Another example is the cable TV network that originally was designed for cable TV, but today can also be used for high-speed data connection to the Internet.

Metropolitan Area Network



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

- Many telephone companies provide a popular MAN service called Switched Multi-megabit Data Services(SMDS)

(iii) Wide Area Network(WAN)

- A wide area network (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.

- A WAN can be as complex as the backbones that connect the Internet or as simple as a dial-up line that connects a home computer to the Internet.

- WAN may utilize public,leased,or private communication devices , usually in combinations, and can therefore span an unlimited number of miles.

- It is wholly owned and used by a single company is often referred to as enterprise n/w.

Wide Area Network

WCB/McGraw-Hill

(E) Internetworks:

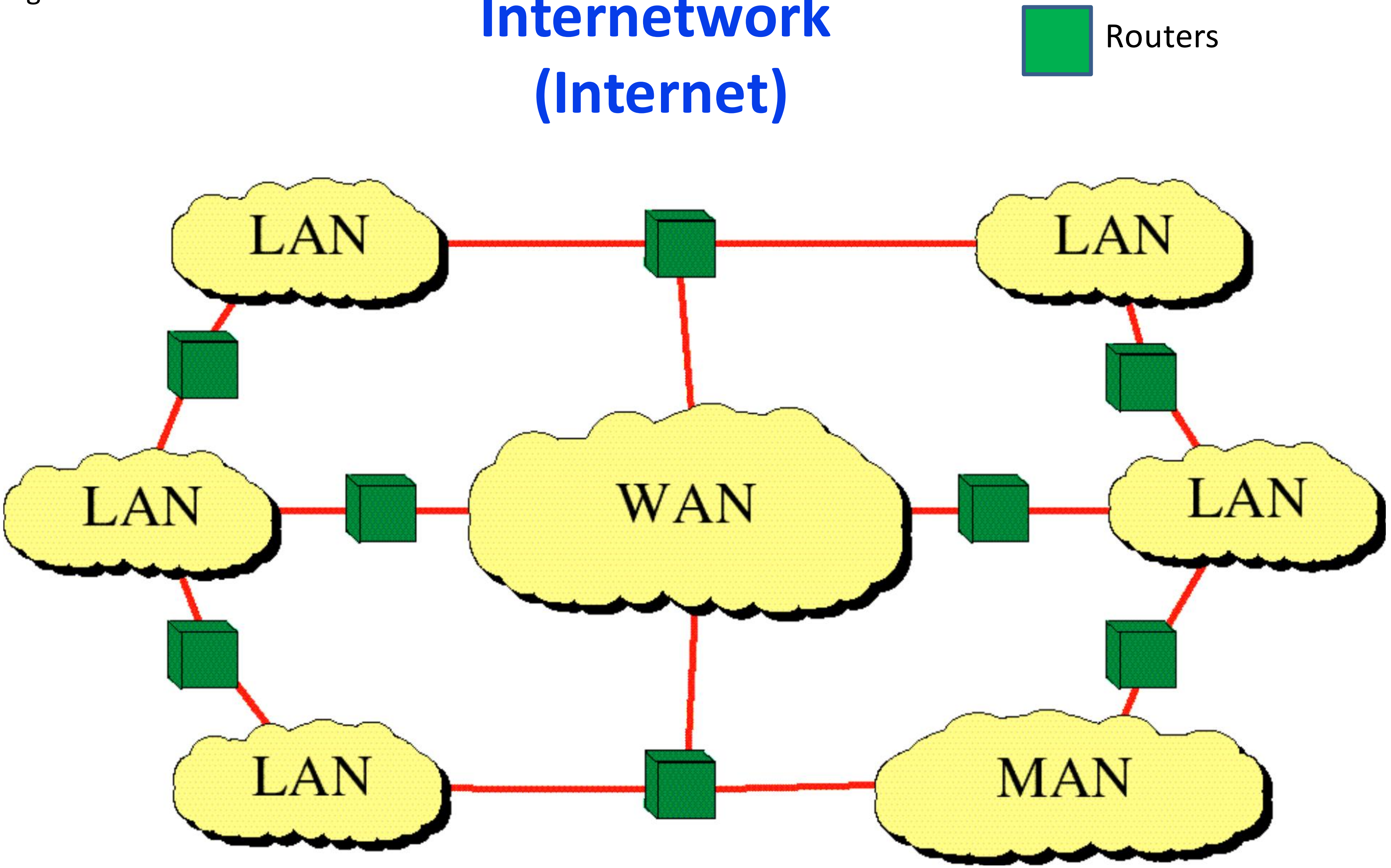
- When two or more networks are connected, they become an internetwork, or internet.

- Individual networks are joined into internetworks by the use of internetworking devices.

- These devices , which include routers and gateways.

Figure 2-19

Internetwork (Internet)



3. The OSI Model

- An **ISO** standard that covers all aspects of network communications is the **Open Systems Interconnection** model.
- **Iso =osi**
- It was first introduced in the late 1970s.
- **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.

3.1 The Model:

- The OSI model is a layered framework for the design of network systems that allows communication between all types of computer systems.

- It consists of seven separate but related layers, each of which defines a part of the process of moving information across a network .

- An understanding of the fundamentals of the OSI model provides a solid basis for exploring data communications.

OSI Model

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data link
1	Physical

Layered Architecture:

- The OSI model is composed of seven ordered layers:

  -Layer 1 : physical

  -Layer 2 : data link

  -Layer 3 : network

  -Layer 4 : transport

  -Layer 5 : session

  -Layer 6 :presentation

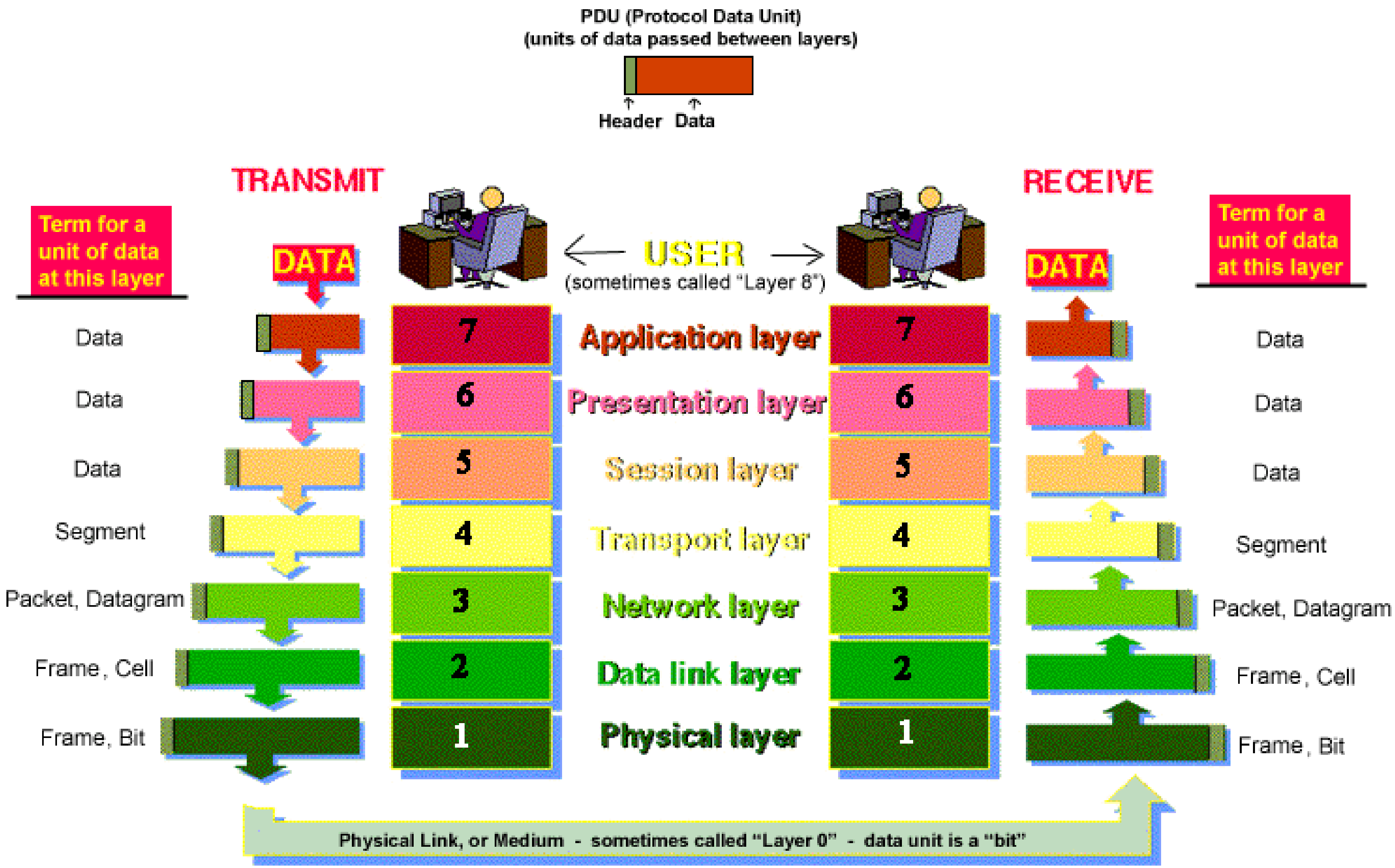
  - Layer 7: application

- The following figure shows the layers involved when a message is sent from device A to device B.

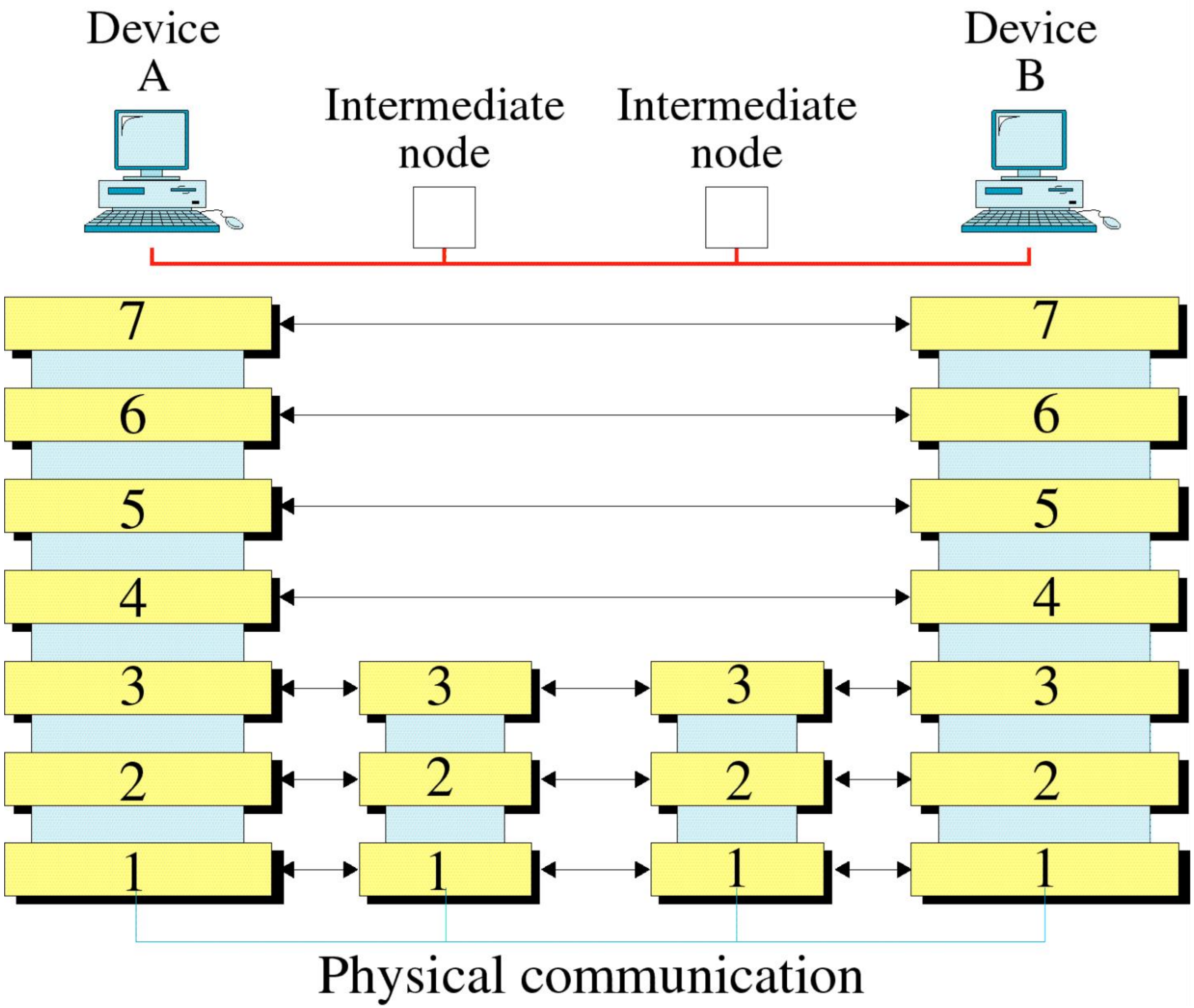
- As the message travels from A to B, it may pass through many intermediate nodes.

- These intermediate nodes usually involve only the first three layers of the OSI model.

THE 7 LAYERS OF OSI



OSI Layers


Device A
Intermediate node
Intermediate node
Device B
7
6
5
4
3
2
1
3
2
1
3
2
1
7
6
5
4
3
2
1
Physical communication

- A mnemonic for remembering the layers of the OSI model is:

" Please Do Not Touch Steve's Pet Alligator"

Peer-to-Peer Processes:

- Protocol: - set of rules and regulations.
- The processes on each machine that communicate at a given layer are called Peer-to-Peer processes.
- At the physical layer, communication is direct: device A sends a **stream of bits** to device B (through intermediate nodes).
- At the higher layers, however, communication must move down through the layers on device A, over to device B, and then back up through the layers.
- Each layer in the sending device adds its own information to the message it receives from the layer just above it and passes the whole package to the layer just below it.
- This information is added in the form of headers or trailers.
- **Headers are added to the message at layers 6,5,4,3 and 2.**
- **A trailer is added at layer 2**

- At layer 1 the entire package is converted to a form that can be transmitted to the receiving device.

- At the receiving machine, the message is unwrapped layer by layer, with each process receiving and removing the data meant for it.

- For example, layer 2 removes the data meant for it, then passes the rest to layer 3.

- Layer 3 then removes the data meant for it and passes the rest to layer 4, and so on.

Interfaces Between Layers

- The passing of the data and network information down through the layers of the sending device and back up through the layers of the receiving device is made possible by an interface between each pair of adjacent layers.

- Each interface defines the information and services a layer must provide for the layer above it.

- Well-defined interfaces and layer functions provide modularity to a network.

Organization of the Layers

- The seven layers can be thought of as belonging to three subgroups.

  <u>* Layers I, 2, and 3:</u>

  physical, data link, and network-are the network support layers; they deal with the physical aspects of moving data from one device to another.

  <u>* Layers 5, 6, and 7:</u>

  session, presentation, and application-can be thought of as the user support layers; they allow interoperability among unrelated software systems.

  <u>* Layer 4:</u>

  the transport layer, links the two subgroups and ensures that what the lower layers have transmitted is in a form that the upper layers can use.

- The upper OSI layers are almost always implemented in software; **lower layers are a combination of hardware and software,** except for the **physical layer, which is mostly hardware.**

Network layer protocols forward encapsulated Transport Layer PDUs between hosts

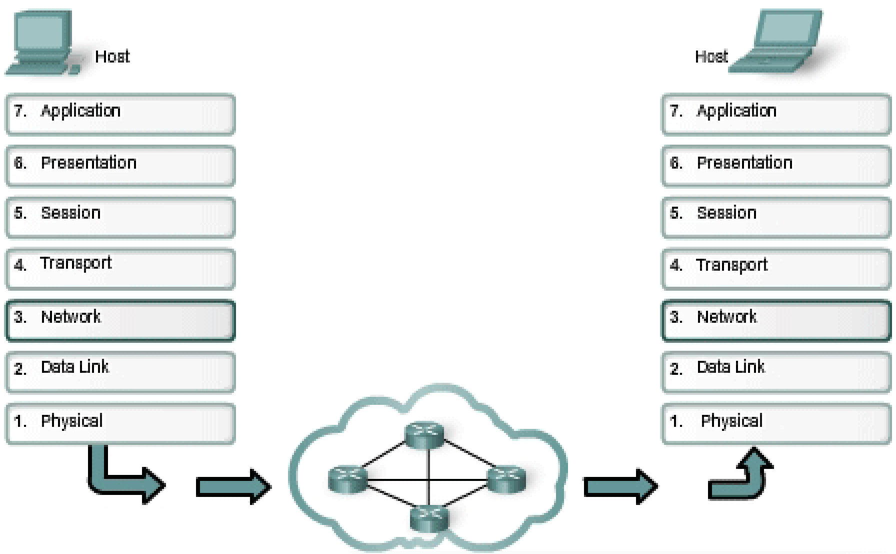
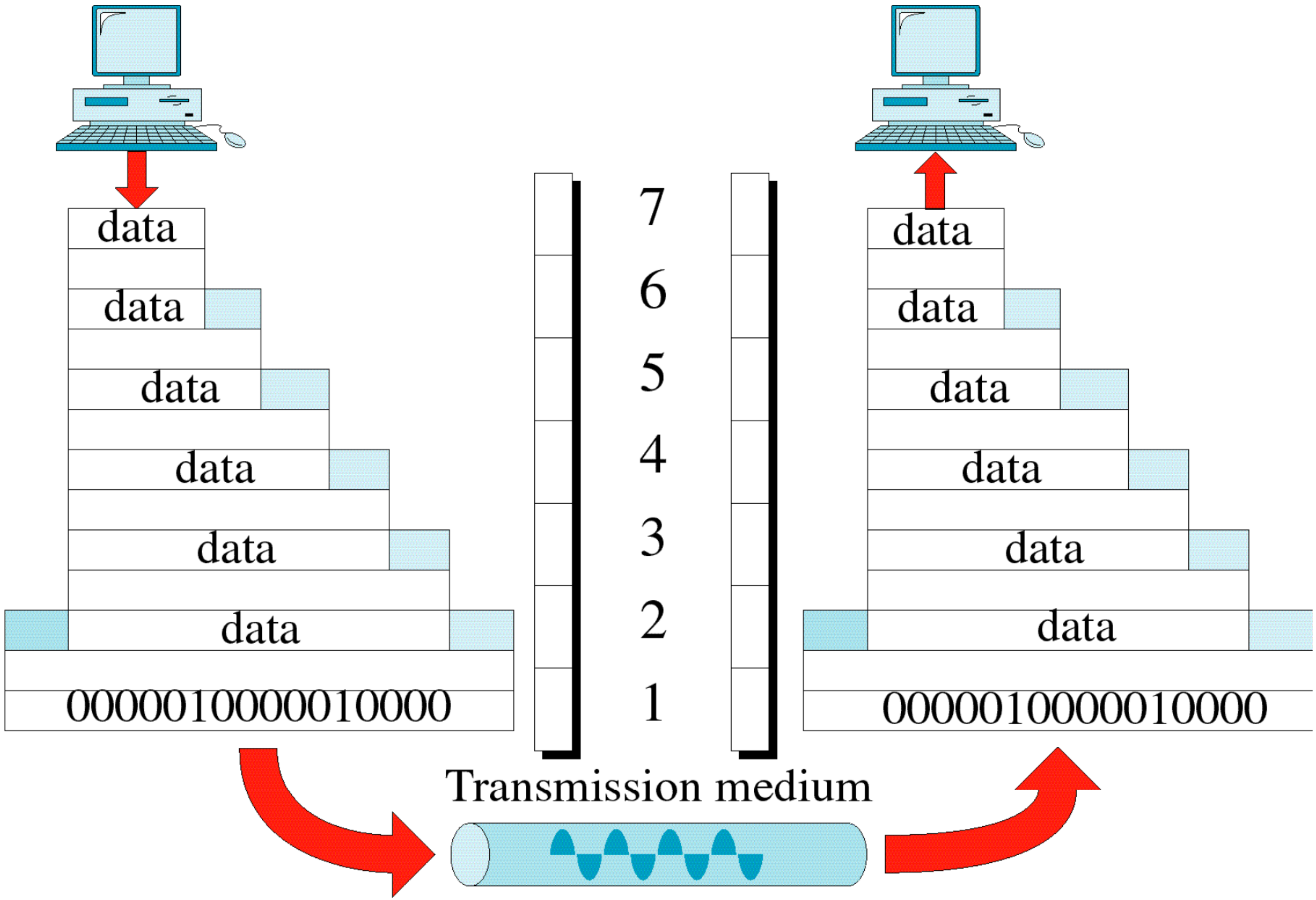


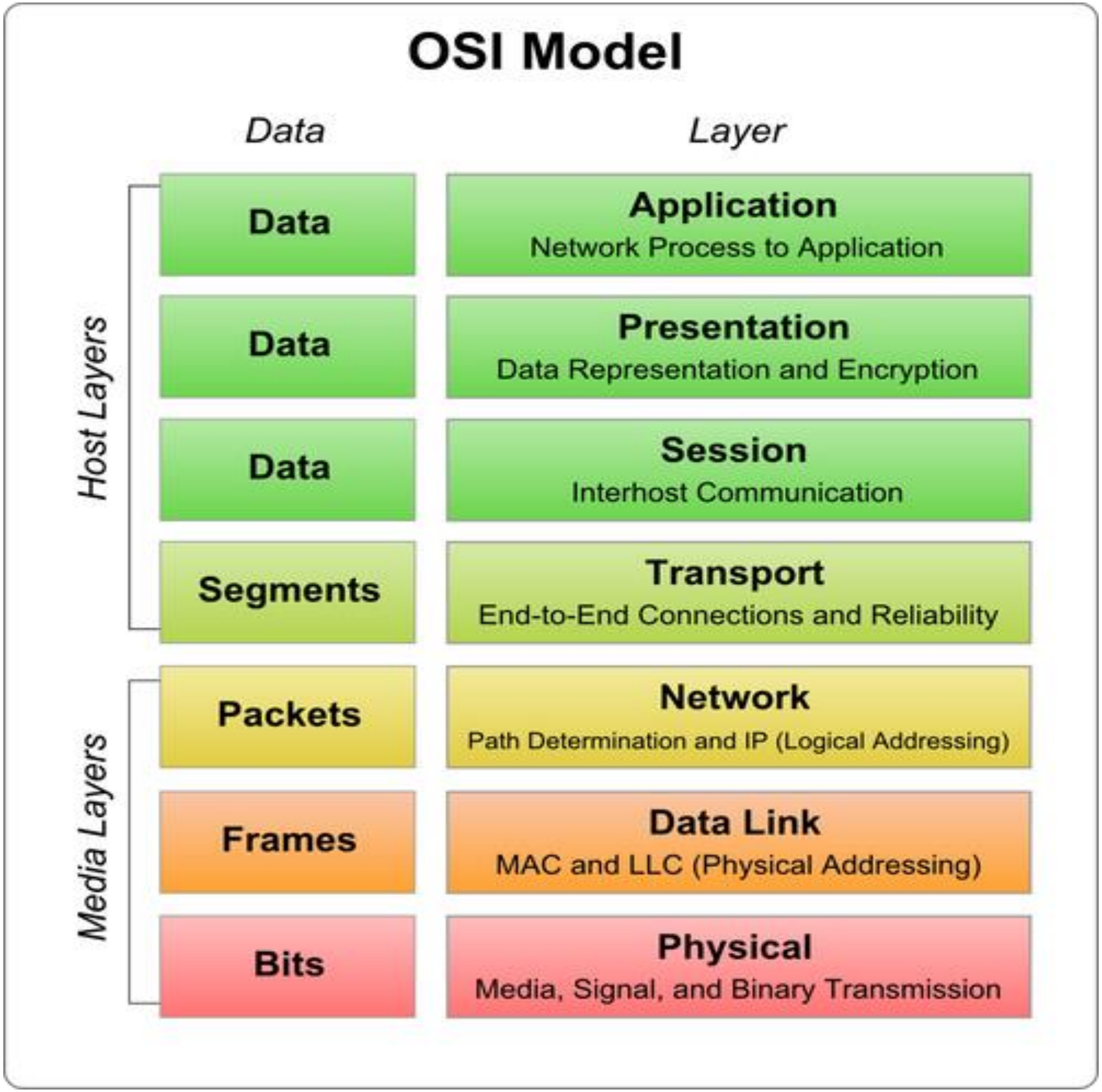
Figure 3-3

An Exchange Using the OSI Model



WCB/McGraw-Hill

- The process starts at layer 7 (the application layer), then moves from layer to layer in descending, sequential order.
- At each layer, a **header, or possibly a trailer, can be added to the data unit.**
- Commonly, the trailer is added only at layer 2.
- When the formatted data unit passes through the physical layer (layer 1), it is changed into an electromagnetic signal and transported along a physical link.
- Upon reaching its destination, the signal passes into layer 1 and is transformed back into digital form.
- The data units then move back up through the OSI layers.
- As each block of data reaches the next higher layer, the headers and trailers attached to it at the corresponding sending layer are removed, and actions appropriate to that layer are taken.
- By the time it reaches layer 7, the message is again in a form appropriate to the application and is made available to the recipient.

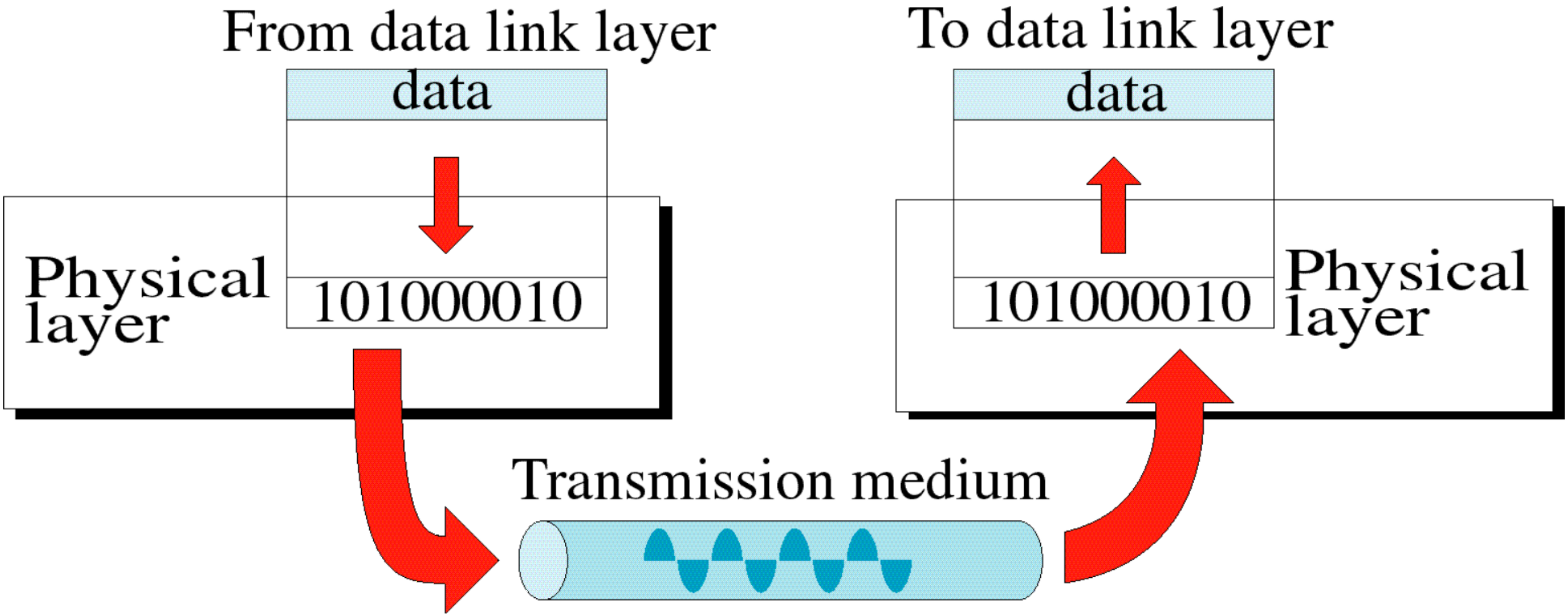

OSI Model
Data
Layer
Host Layers
Data
Application
Network Process to Application
Data
Presentation
Data Representation and Encryption
Data
Session
Interhost Communication
Segments
Transport
End-to-End Connections and Reliability
Media Layers
Packets
Network
Path Determination and IP (Logical Addressing)
Frames
Data Link
MAC and LLC (Physical Addressing)
Bits
Physical
Media, Signal, and Binary Transmission

Functions of the Layers

1. Physical Layer:

- The physical layer coordinates the functions required to carry a bit stream over a physical medium.
- It deals with the mechanical and electrical specifications of the interface and transmission medium.
- It also defines the procedures and functions that physical devices and interfaces have to perform for transmission to Occur.

Physical Layer



The physical layer is also concerned with the following:

- **Physical characteristics of interfaces and media:**

    -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 Os or 1s).

    - To be transmitted, bits must be encoded into signals electrical or optical.

- **Data rate:**

  - The transmission rate-the number of bits sent each second-is also defined by the physical layer.

- **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.

- Devices can be connected by using a mesh topology, a star ,a ring ,a bus topology, or a hybrid topology .

- **Transmission mode:**

The physical layer also defines the direction of transmission between two devices:

simplex, half-duplex, or full-duplex.

2. Data Link Layer:

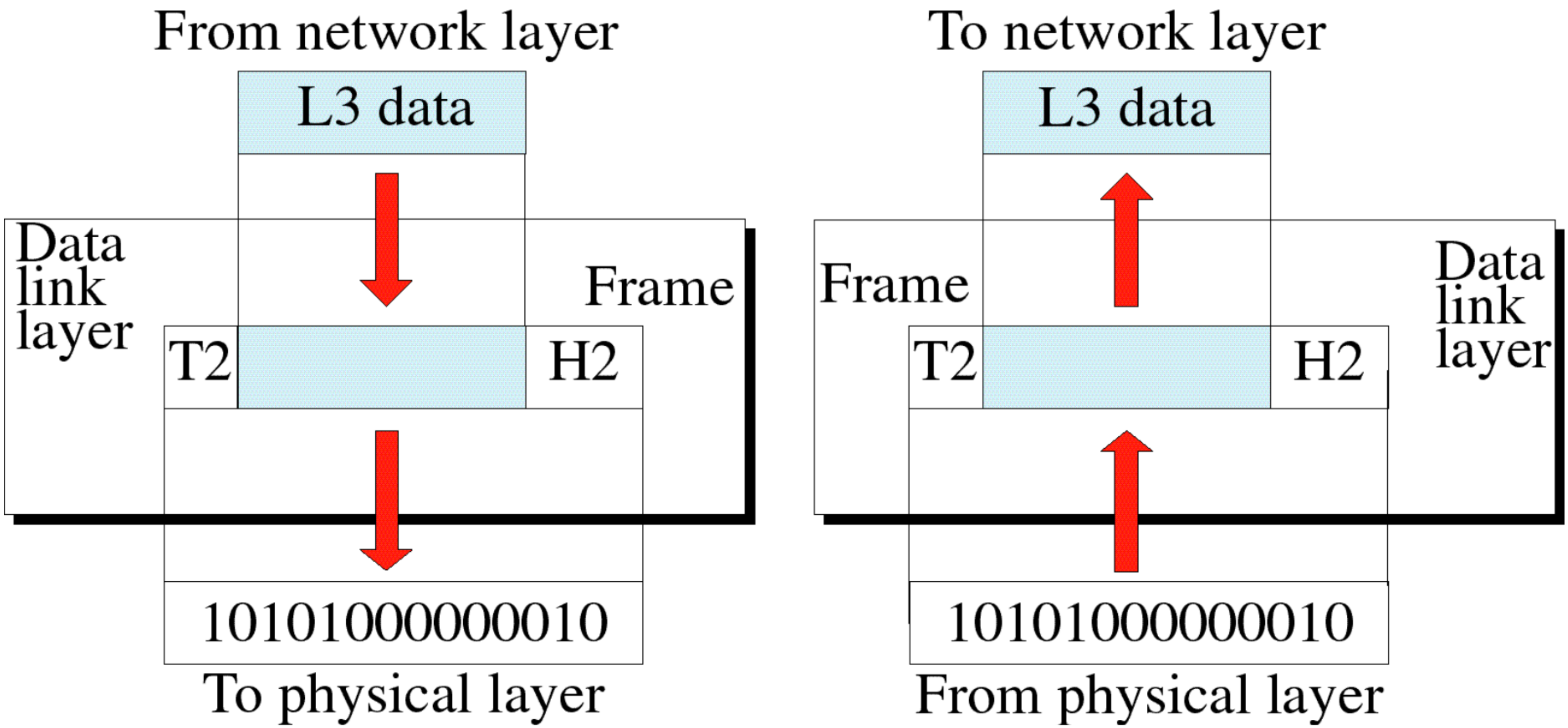
- The data link layer transforms the physical layer, a raw transmission facility, to a reliable link.

- It makes the physical layer appear error-free to the upper layer (network layer).

- Figure shows the relationship of the data link layer to the network and physical layers.

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

Data Link Layer



Responsibilities of the data link layer:

- **Framing:**

-The data link layer divides the stream of bits received from the network layer into manageable data units called f**rames**.

- **Physical addressing:**

- If frames are to be distributed to different system 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.

3. Network Layer:

- **The network layer is responsible for the source-to-destination delivery of a packet,** possibly across multiple networks (links).

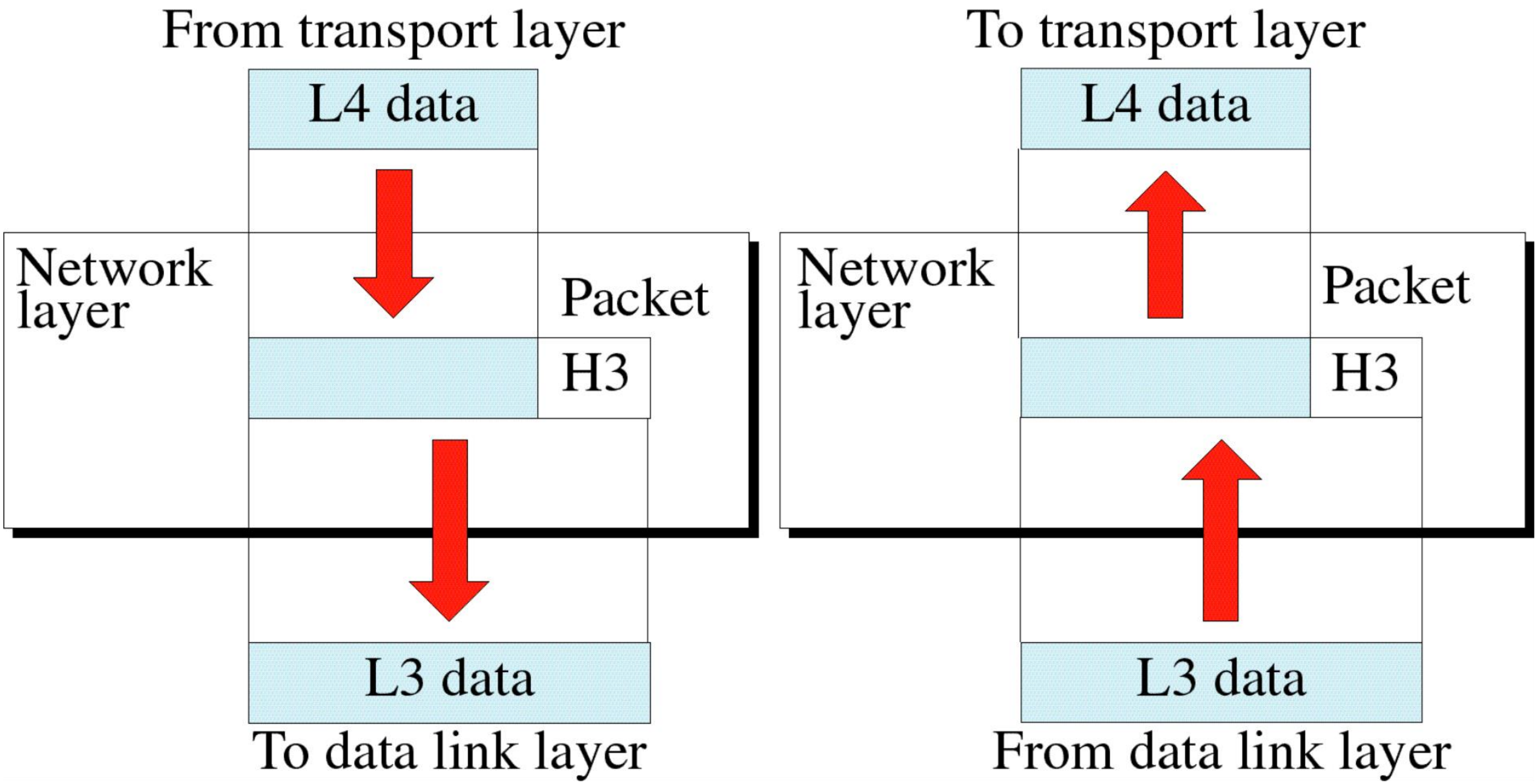
- Whereas the data link layer oversees the delivery of the packet between two systems on the same network (links), the network layer ensures that each packet gets from its point of origin to its final destination.

- If two systems are connected to the same link, there is usually no need for a network layer.

- However, if the two systems are attached to different networks (links) with connecting devices between the networks (links), there is often a need for the network layer to accomplish source-to-destination delivery.

- Figure shows the relationship of the network layer to the data link and transport layers.

Network Layer



Responsibilities of the network layer :

- **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.*

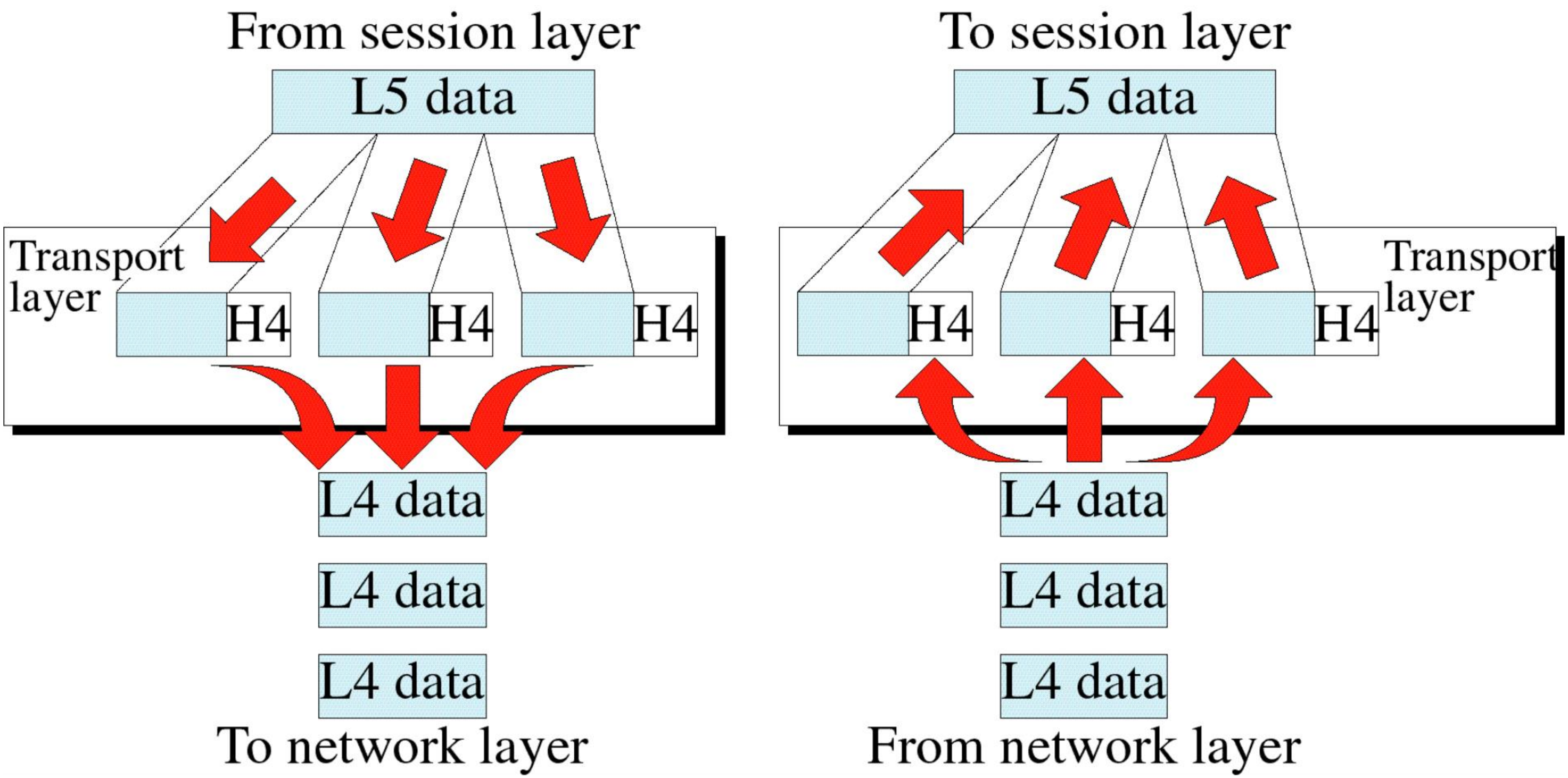
  -*One of the functions* of the network layer is to provide this mechanism.

4. Transport Layer:

- **Purpose of this layer is to provide a reliable mechanism for the exchange of data between two processes in different computers.**
- **Ensures that the data units are delivered error free.**
- **Ensures that data units are delivered in sequence.**
- **Ensures that there is no loss or duplication of data units.**
- **Provides connectionless or connection oriented service.**
- **Provides for the connection management.**

Figure 3-9

Transport Layer



Responsibilities of the transport layer :

- ## 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:**

  -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).

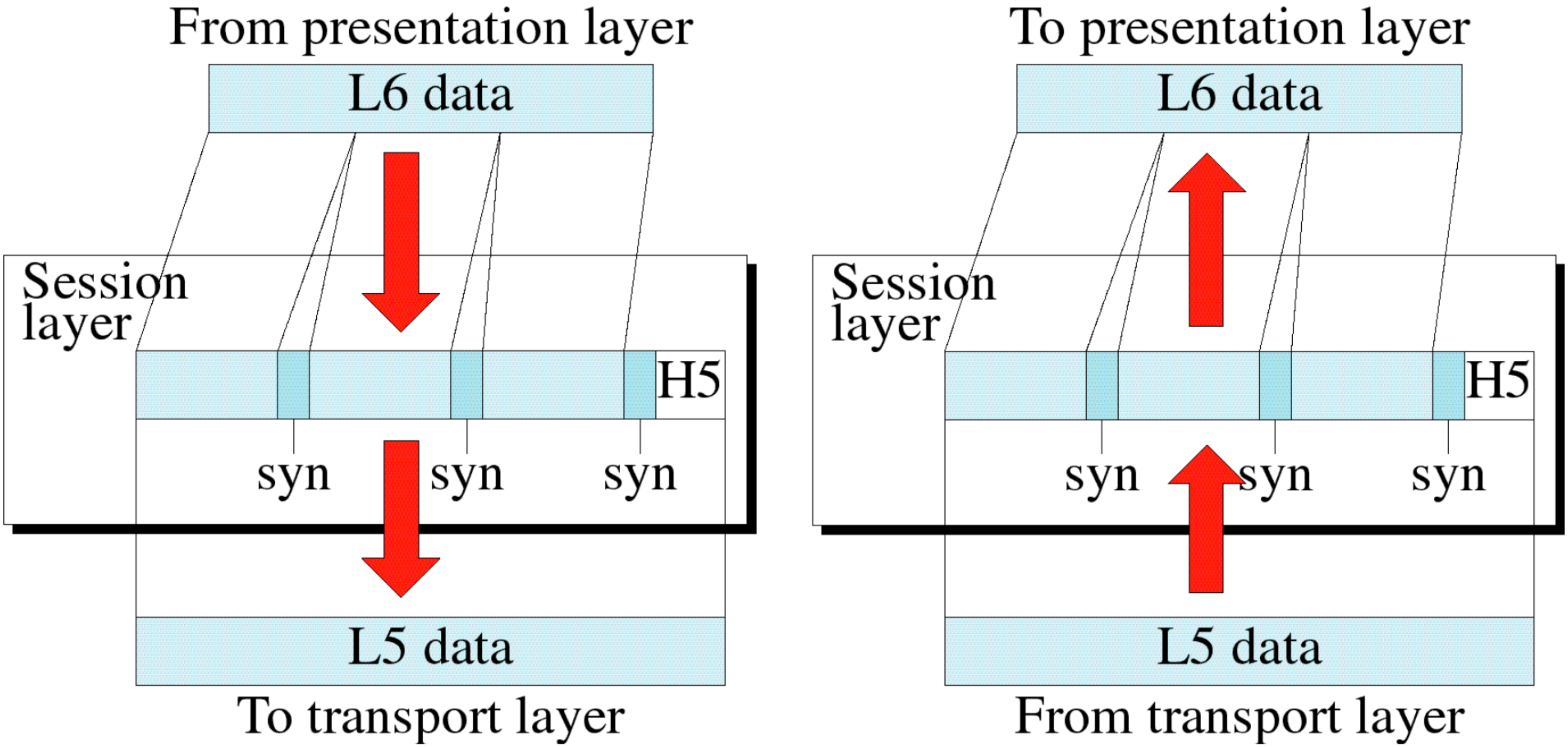
  -Error correction is usually achieved through retransmission.

5.Session Layer

- The session layer is the network ***dialog controller***.
- **Session layer provides mechanism for controlling the dialogue between the two end systems.**
- **It defines how to start, control and end conversations (called sessions) between applications.**
- **This layer requests for a logical connection to be established on an end-user's request.**
- **Any necessary log-on or password validation is also handled by this layer.**
- **Session layer is also responsible for terminating the connection.**

Figure 3-11

Session Layer



Responsibilities of the session layer:

- **Dialog control:**

- **This layer provides services like dialogue discipline which can be full duplex or half duplex.**

- **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.

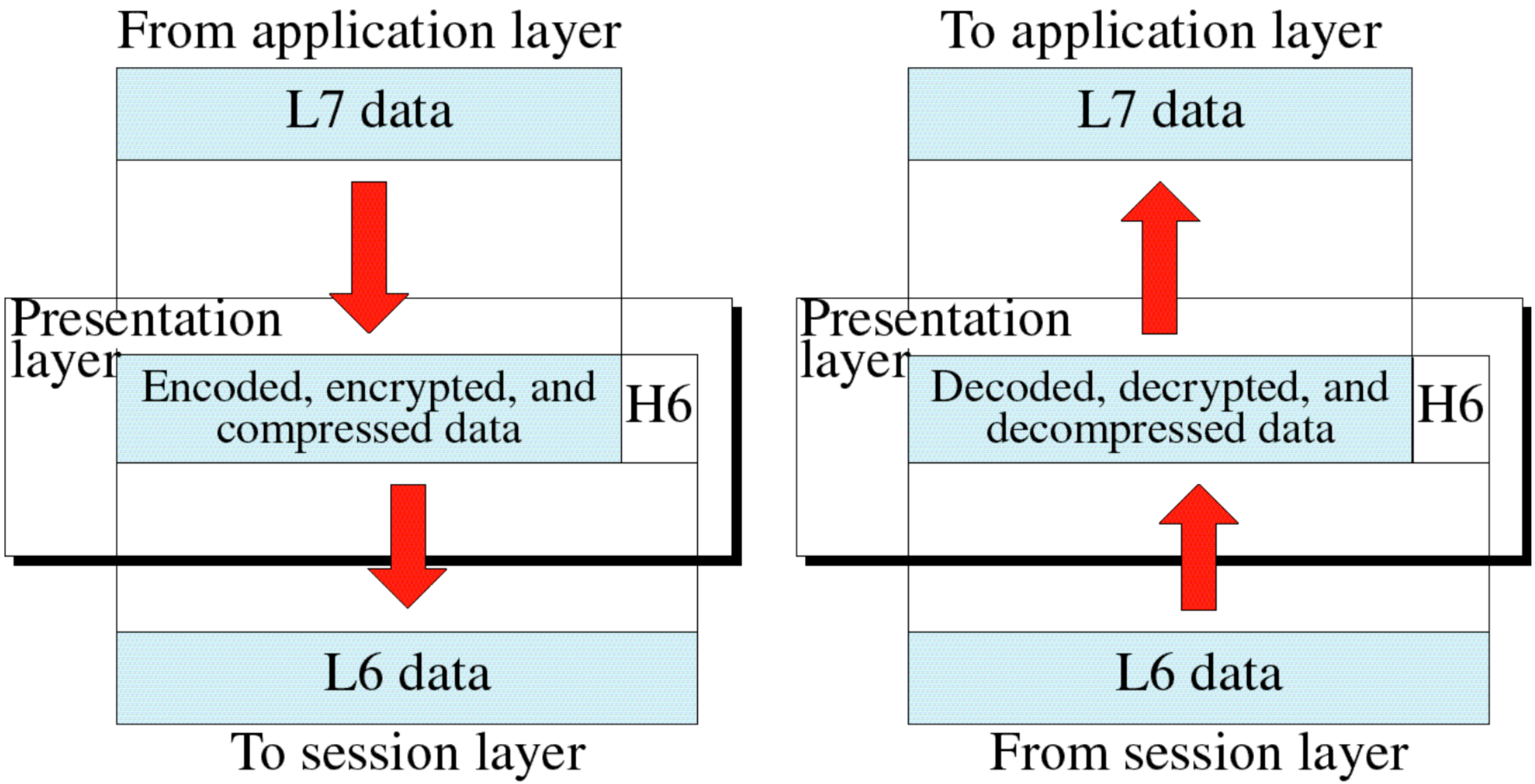
6.Presentation Layer

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

- The presentation layer is responsible for defining how information is presented to the user in the interface (application layer) that they are using.

- Examples of presentation layer protocols and standards include ASCII, BMP, GIF, JPEG, WAV, AVI, and MPEG.

Presentation Layer



Responsibilities of the presentation layer:

- **Translation:**

Different computers use different encoding systems, the presentation layer is responsible for interoperability between these different encoding methods.

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 to 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.**

7.Application Layer

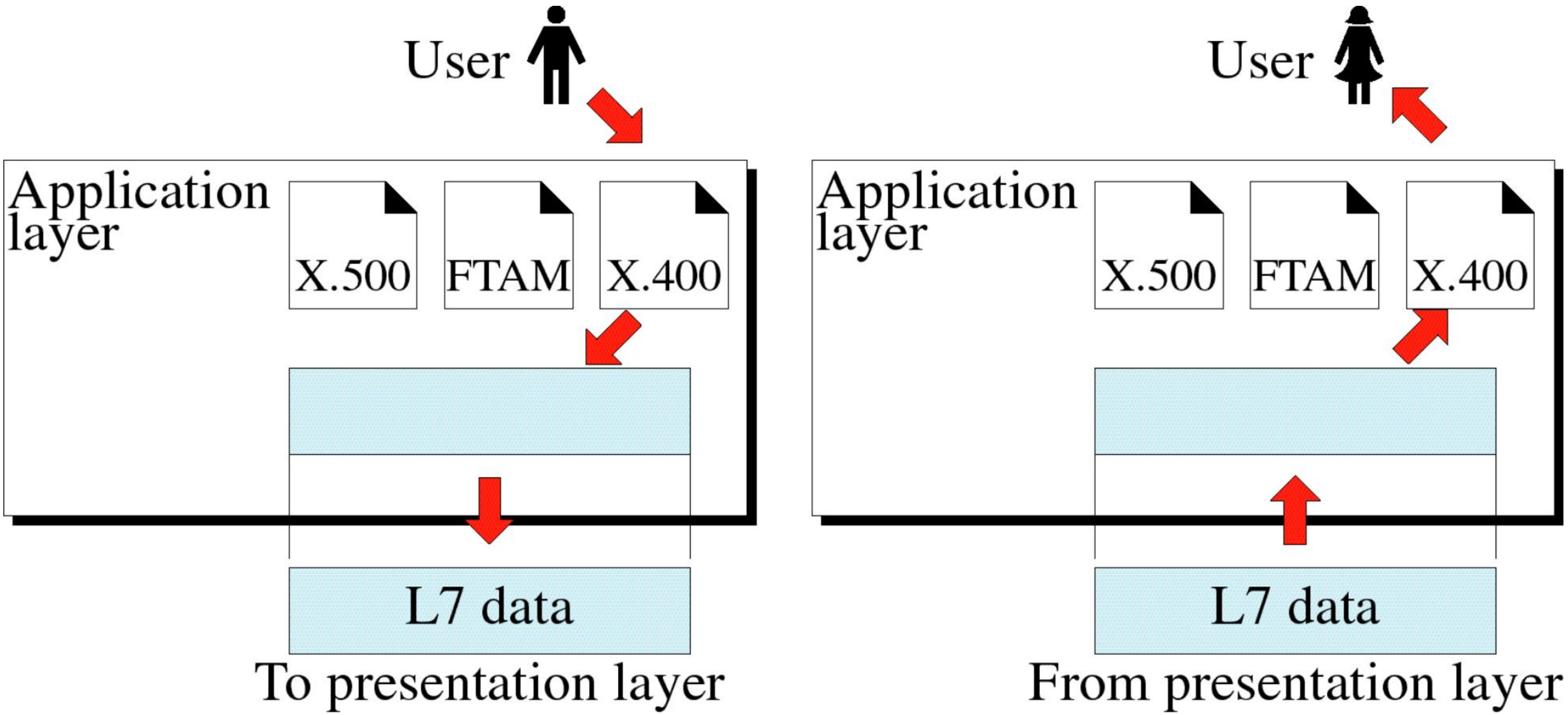
- The application layer enables the user, whether human or software, to access the network.

- 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.

- the figure shows only three:

  - *XAOO (message-handling services),*
  - *X.500 (directory services),*
  - *and file transfer,*

Application Layer



Services provided by the application layer:

- **Network virtual terminal.**

  A network virtual terminal is a software version of a physical terminal, and it allows a user to log on to a remote host.

- **File transfer, access, and management**.

  This application allows a user to access files in a remote host

- **Mail services**.

  This application provides the basis for e-mail forwarding and storage.

- **Directory services**.

  This application provides distributed database sources and access for global information about various objects and services.

Summary of Layer Functions

Layer	Function
Application	To allow access to network resources
Presentation	To translate, encrypt, and compress data
Session	To establish, manage, and terminate sessions
Transport	To provide end-to-end message delivery and error recovery
Network	To move packets from source to destination; to provide internetworking
Data link	To organize bits into frames; to provide node-to-node delivery
Physical	To transmit bits; to provide mechanical and electrical specifications

UNIT – II

Physical Layer -Signals: Analog and Digital - Periodic and Aperiodic Signals - Analog Signals, Composite Signals - Digital Signals – **Transmission Media** – Unguided Media & Guided Media.

Physical Layer Signals

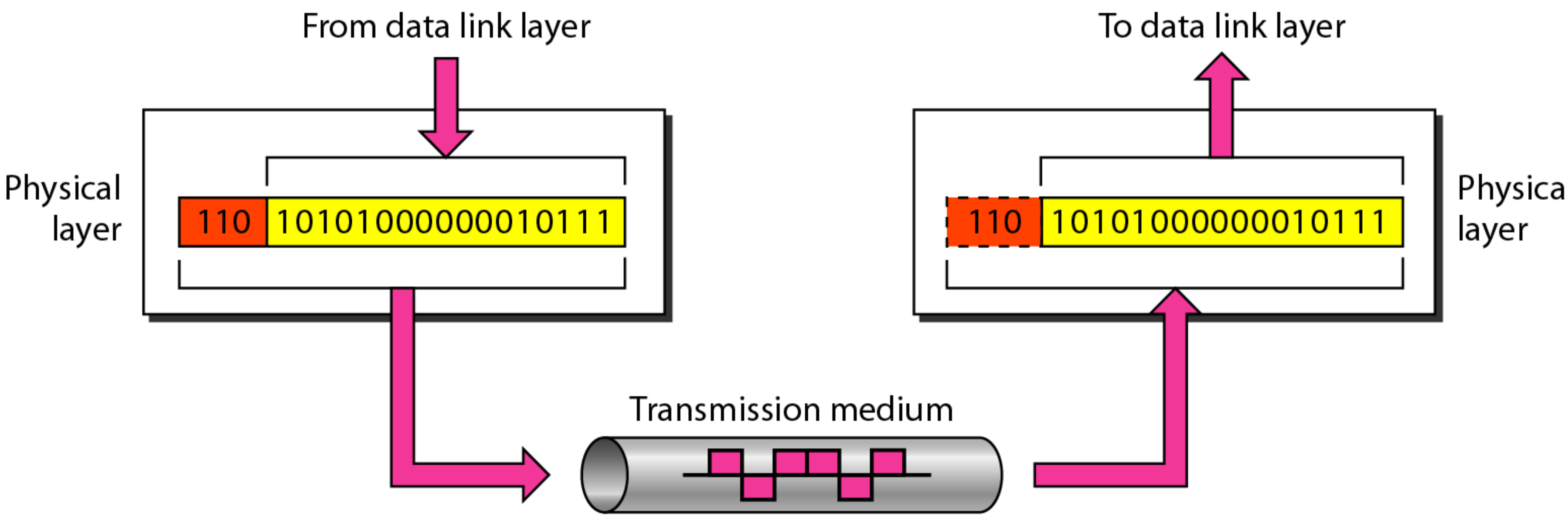
- Analog and digital
- Aperiodic and periodic signals
- Analog signals
- Composite Signals
- Digital Signals

Signals

- The major functions of the physical layer is to move data in the form of electromagnetic signals across a transmission medium.

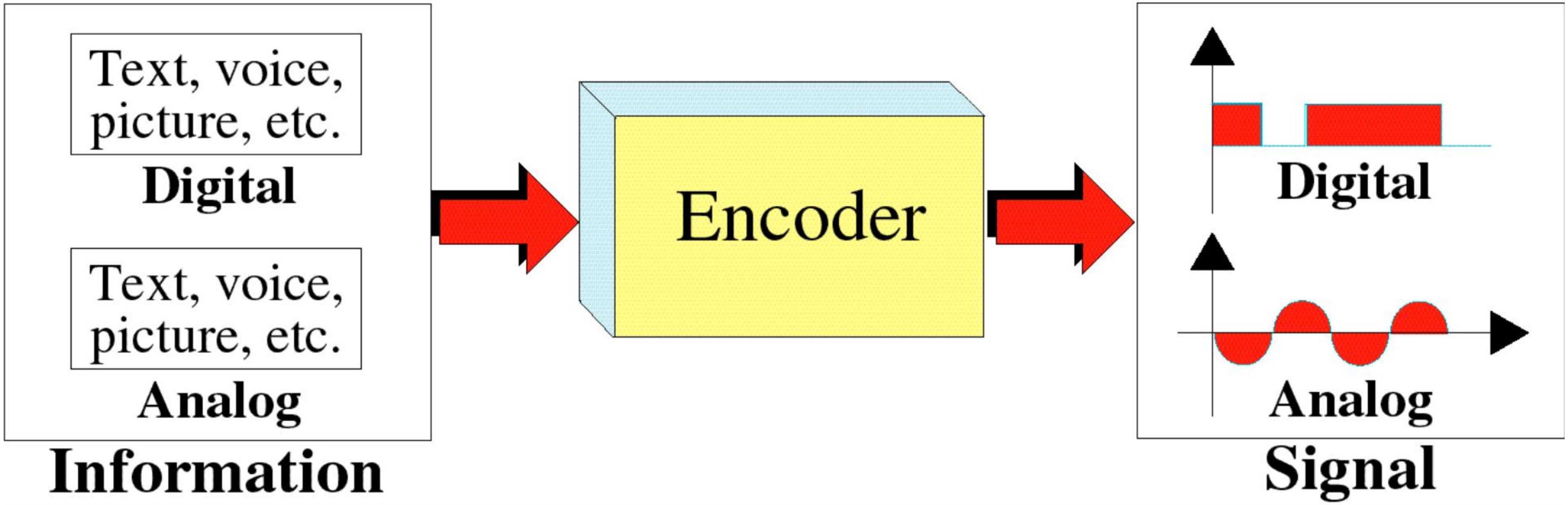
- **To be transmitted, data must be transformed to electromagnetic signals.**

Physical layer



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

Transformation of Information to Signals



2.1 ANALOG AND DIGITAL

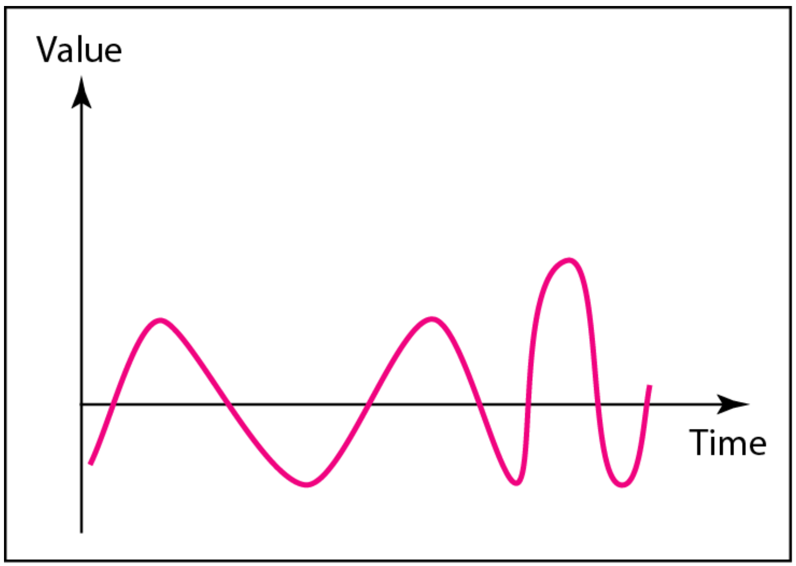
Data can be analog or digital

- Analog data refers to information that is continuous
- Analog data take on continuous values
- Analog signals can have an infinite number of values in a range

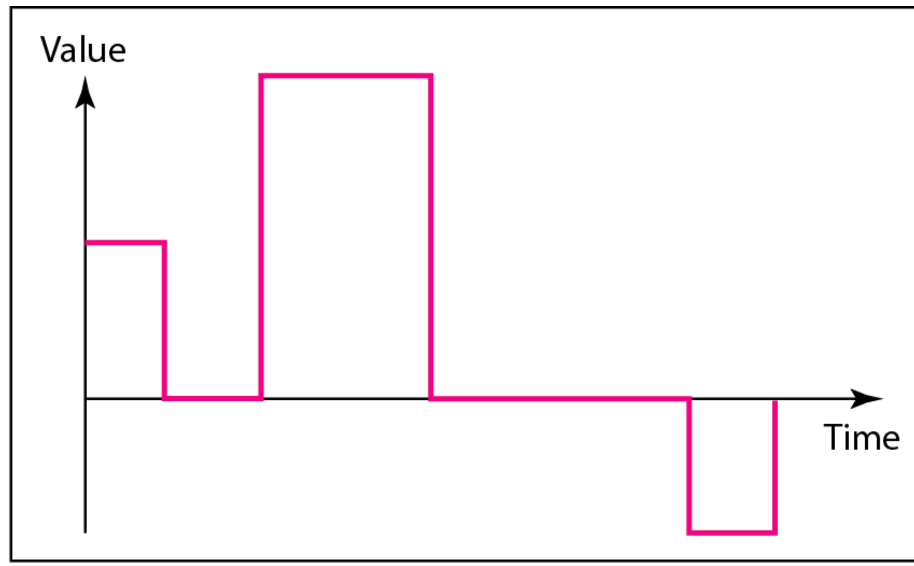
- Digital data refers to information that has discrete states
- Digital data take on discrete values
- Digital signals can have only a limited number of values

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

Comparison of analog and digital signals

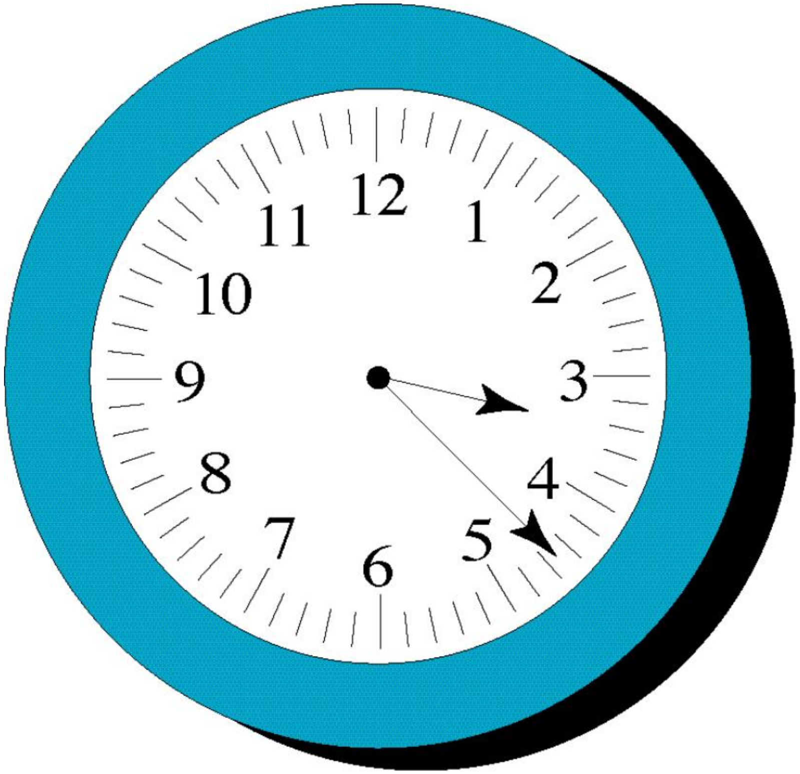


a. Analog signal



b. Digital signal

Analog and Digital Clocks



a. Analog

b. Digital

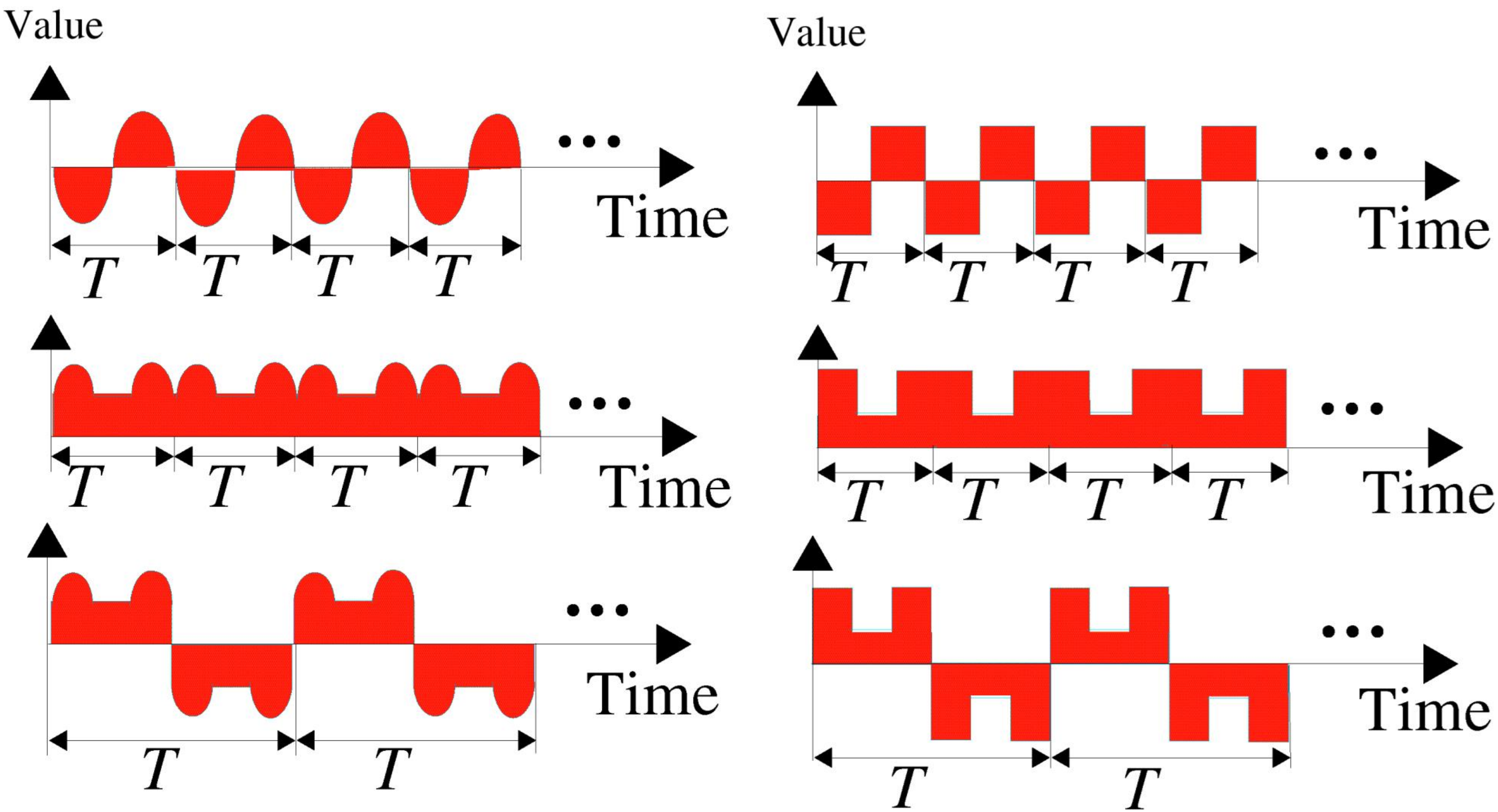
2.2 Periodic and Aperiodic signals

- Both analog and digital signals can take one of two forms:
  periodic or nonperiodic (sometimes refer to as *aperiodic)*

Periodic Signals:

- A periodic signal completes a pattern within a measurable time frame, called a period, and repeats that pattern over subsequent identical periods.
- The completion of one full pattern is called a **cycle**.
- *A period is defined as the amount of time(expressed in seconds) required to complete one full cycle.*
- *The duration of period represented by T*

Periodic Signals



a. Analog

b. Digital

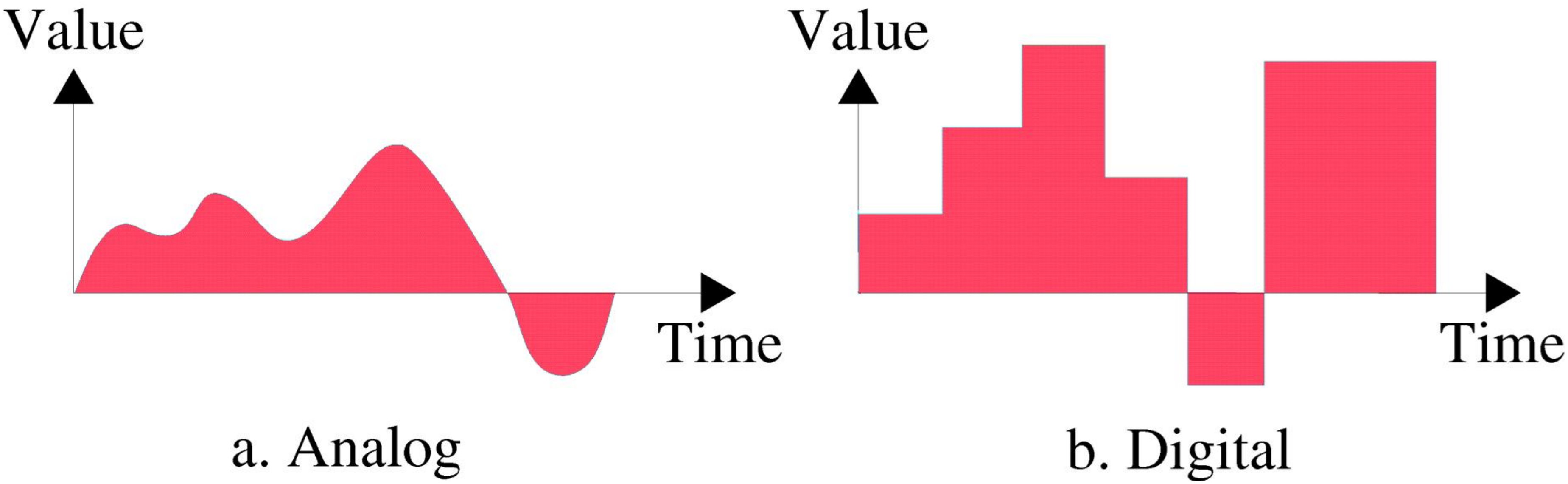
Aperiodic Signals:

- A nonperiodic signal changes without exhibiting a pattern or cycle that repeats over time.

- An aperiodic signal can be decomposed into an infinite number of periodic signals.

- A sine wave is the simplest periodic signal.

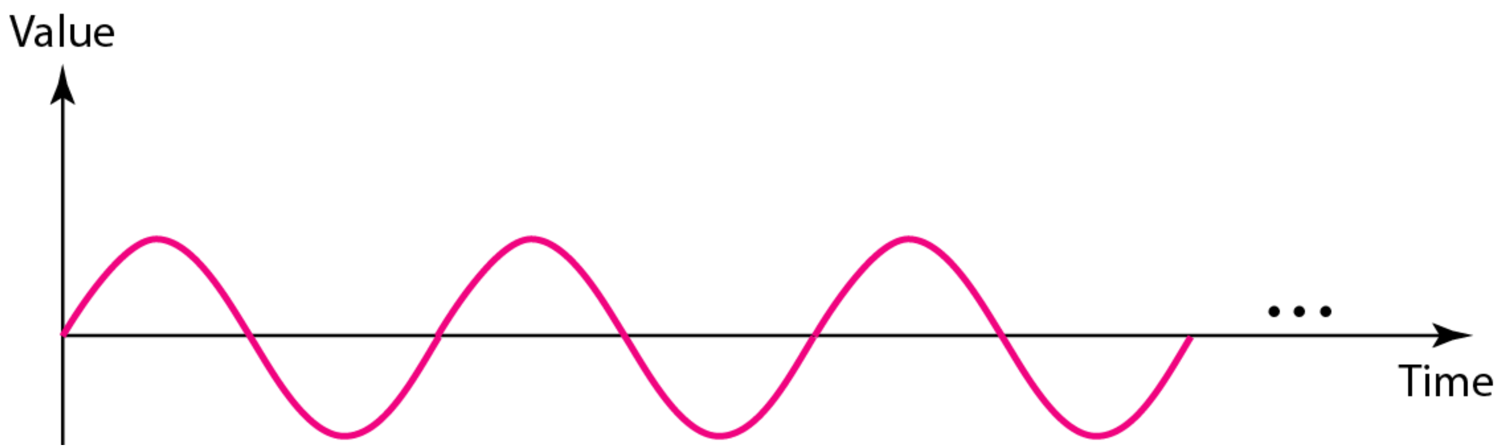
Aperiodic Signals



2.3 ANALOG SIGNALS

Aanalog signals can be classified as simple or composite.

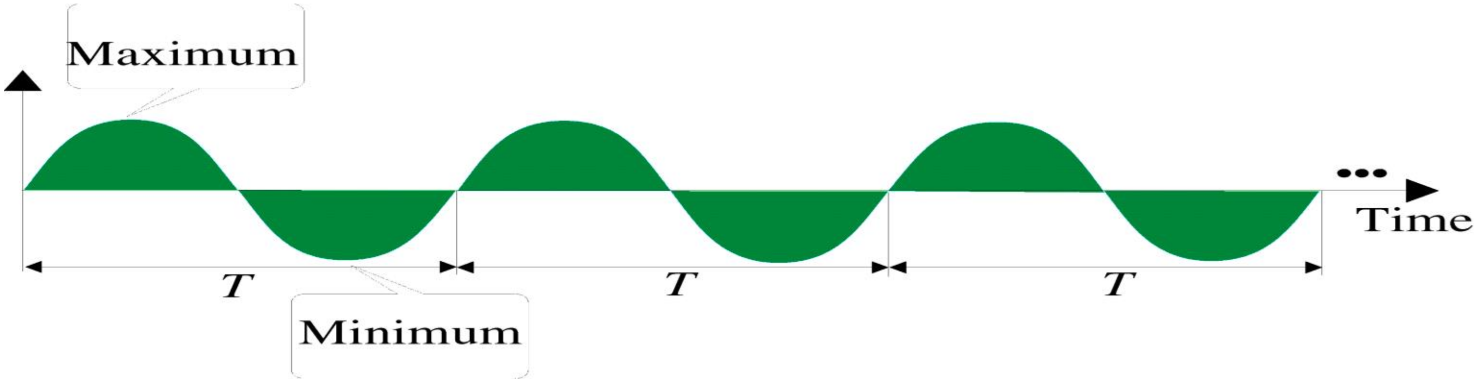
- A simple analog signal, a sine wave, cannot be decomposed into simpler signals.
- A composite analog signal is composed of multiple sine waves.



Simple Analog Signals

- The sine wave is the most fundamental form of a periodic analog signal.

- When we visualize it as a simple oscillating curve, its change over the course of a cycle is smooth and consistent, a continuous, rolling flow. Figure shows a sine wave.



- Each cycle consists of a single arc above the time axis followed by a single arc below it.

- A sine wave can be represented by three parameters:

  (i) *Amplitude*

  (ii) Frequency and Period,

  (iii)*Phase.*

- *These three parameters fully describe a sine wave.*

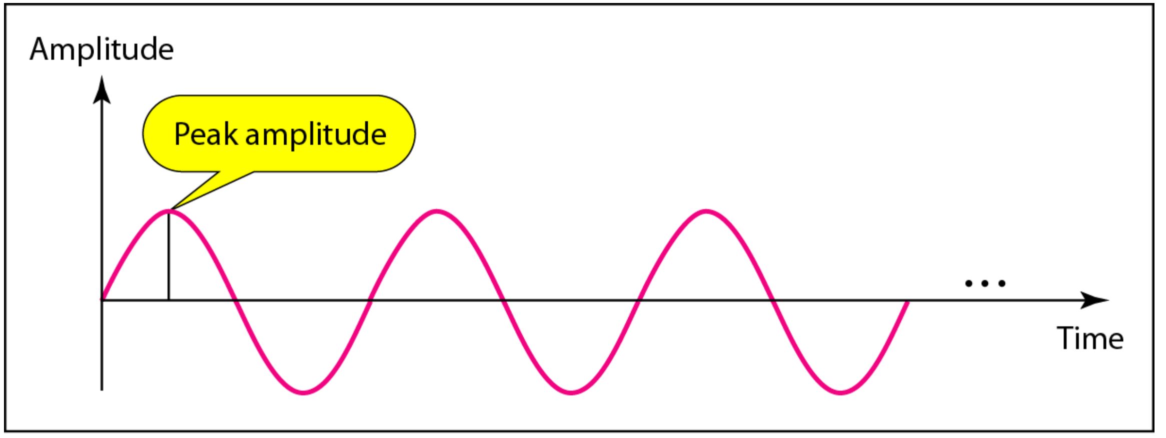
(i) Amplitude:

- It refers to the height of the signal.

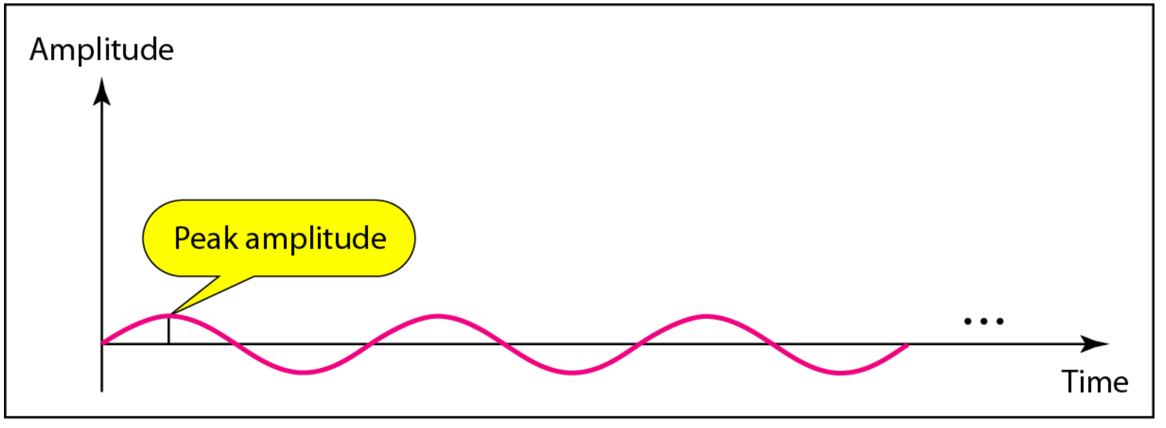
- The unit for amplitude depends on the type of the signal.

- For electrical signals, the unit is normally volts, amperes or walts.

Signal amplitude



a. A signal with high peak amplitude



b. A signal with low peak amplitude

(ii) Period and Frequency:

- Period refers to the amount of time, in seconds, a signal needs to complete 1 cycle.

- Frequency refers to the number of periods in one second.

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.

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

Frequency and Period

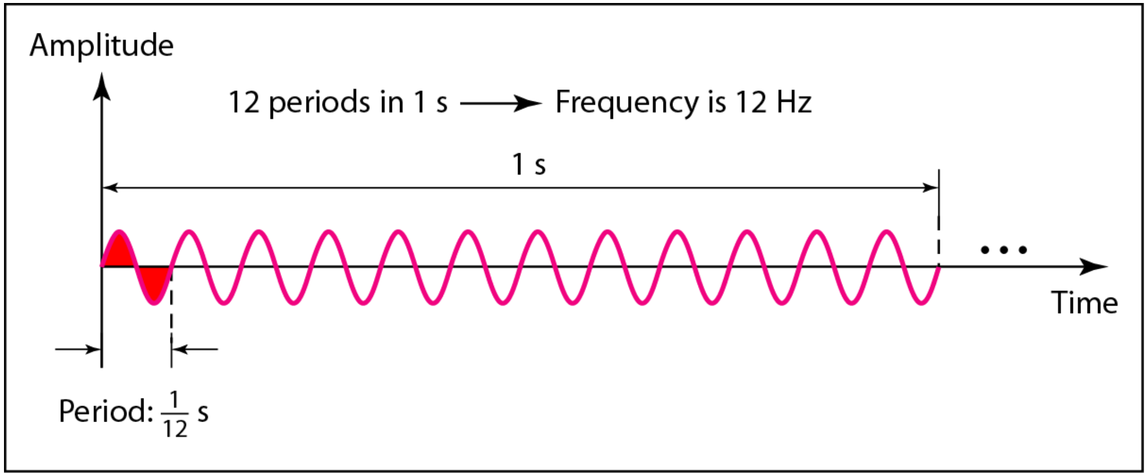
Frequency and period are the inverse of each other.

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

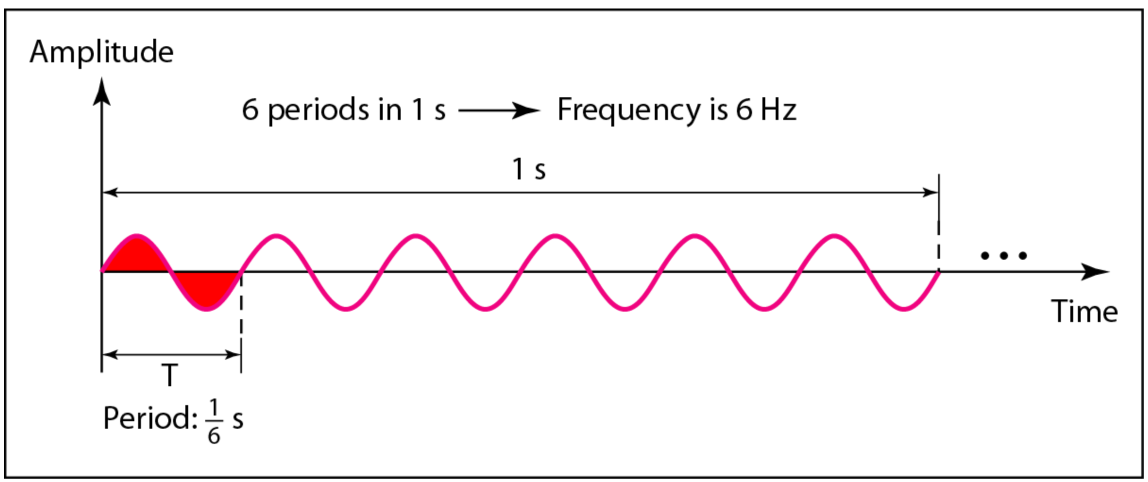
Units of period and frequency

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

Two signals with the same amplitude, but different frequencies



a. A signal with a frequency of 12 Hz

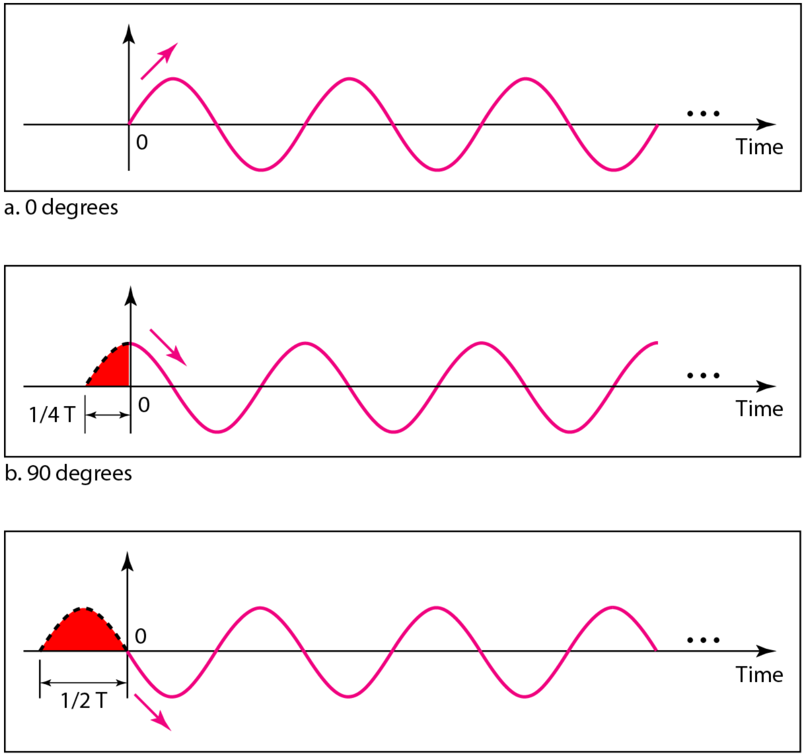


b. A signal with a frequency of 6 Hz

Phase

Phase describes the position of the waveform relative to time 0

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



a. 0 degrees

b. 90 degrees

c. 180 degrees

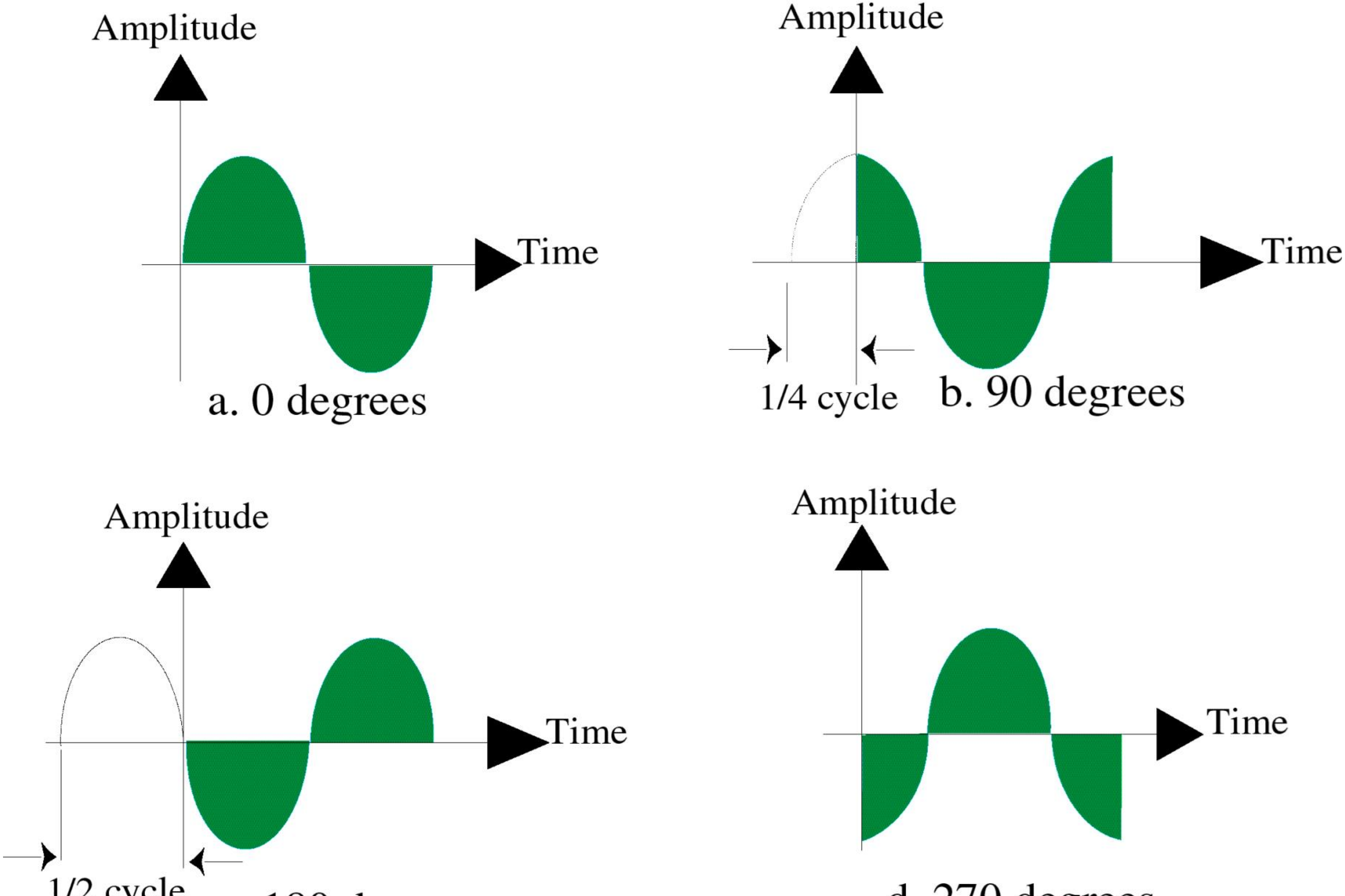
- Phase is measured in **degrees or radians**.

- *A phase shift of 360° corresponds to a shift of a complete period;*

- *A phase* shift of 180° corresponds to a shift of one-half of a period;

- A phase shift of 90° corresponds to a shift of one-quarter of a period

Phases



a. 0 degrees
b. 90 degrees
c. 180 degrees
d. 270 degrees

Figure 4-8

Amplitude Change

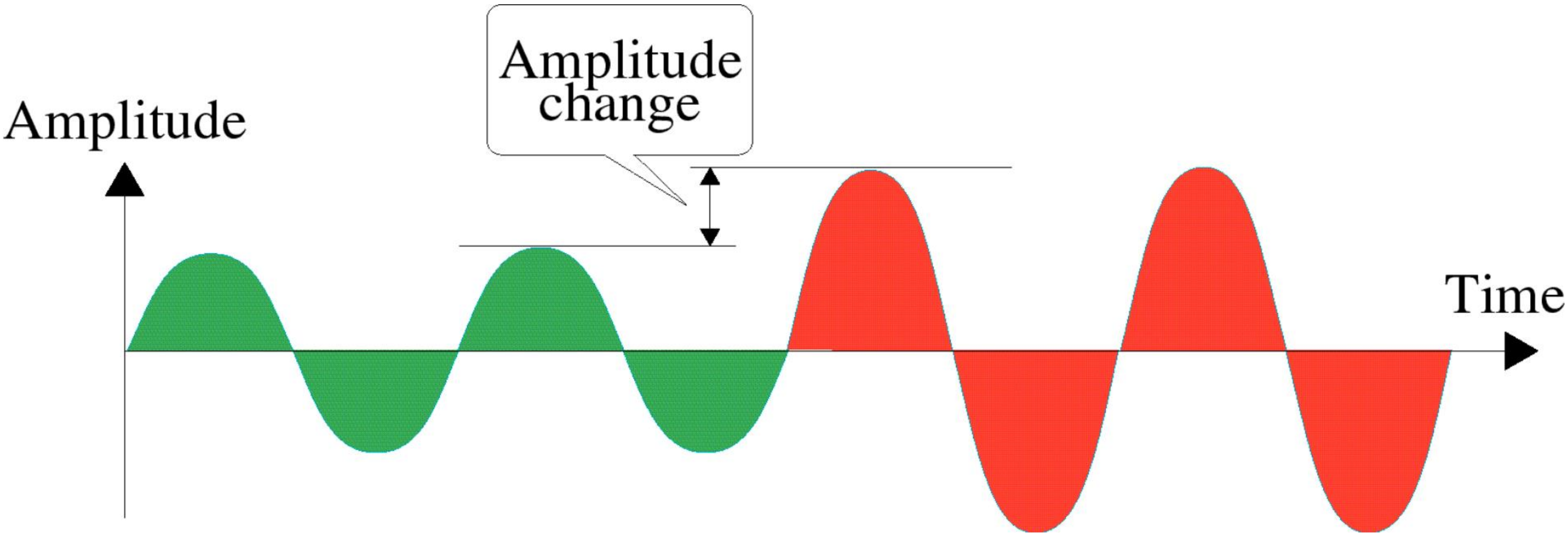
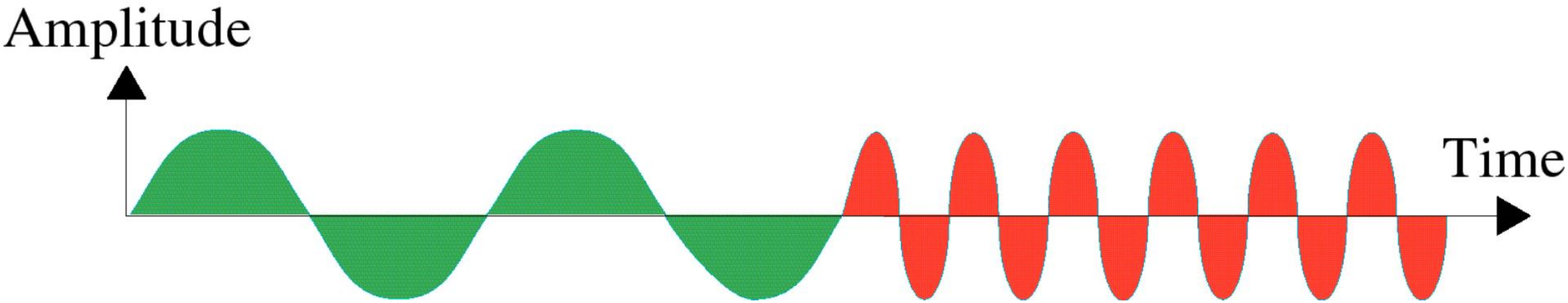


Figure 4-9

Frequency Change



2.4 Time and Frequency Domains

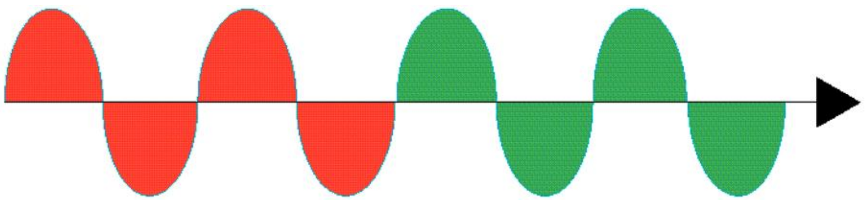
- A sine wave is comprehensively defined by its amplitude, frequency, and phase.

- We have been showing a sine wave by using what is called a time-domain plot.

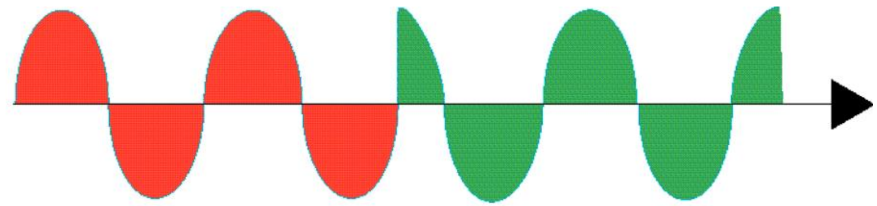
- The time-domain plot shows changes in signal amplitude with respect to time (it is an amplitude-versus-time plot).

- Phase is not explicitly shown on a time-domain plot.

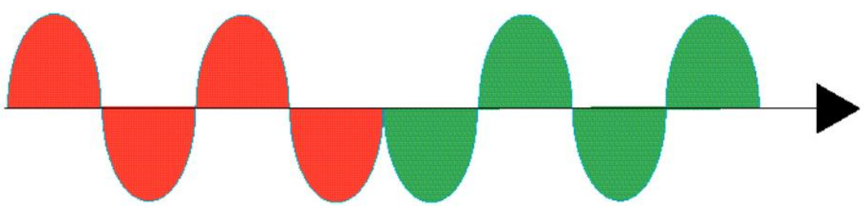
Phase Change



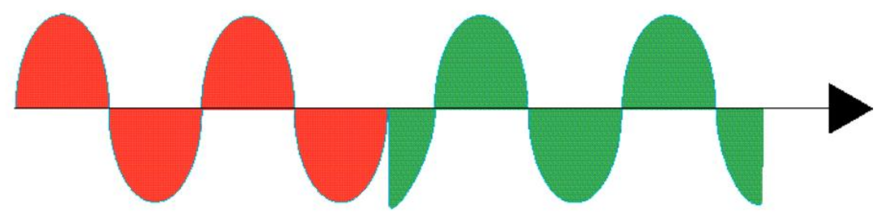
a. No phase change



b. 90 degree phase change



c. 180 degree phase change

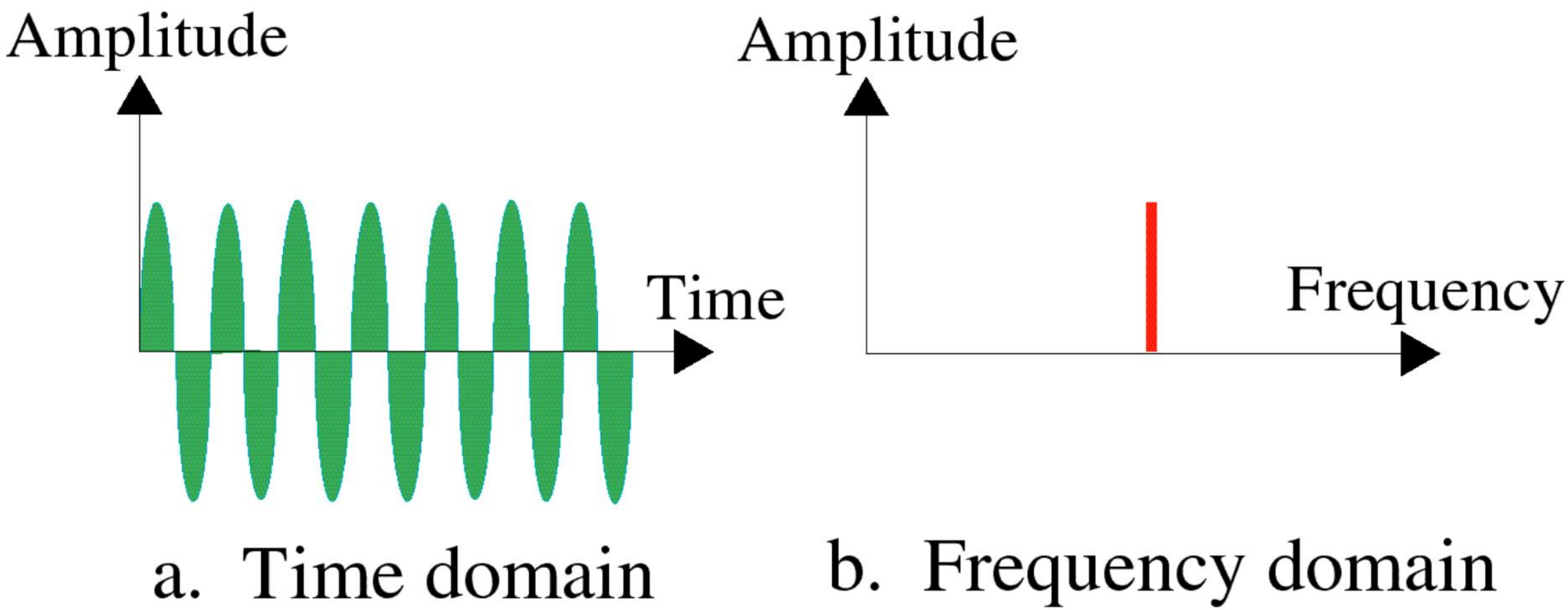


d. 270 degree phase change

- To show the relationship between amplitude and frequency, we can use a **frequency-domain plot**.

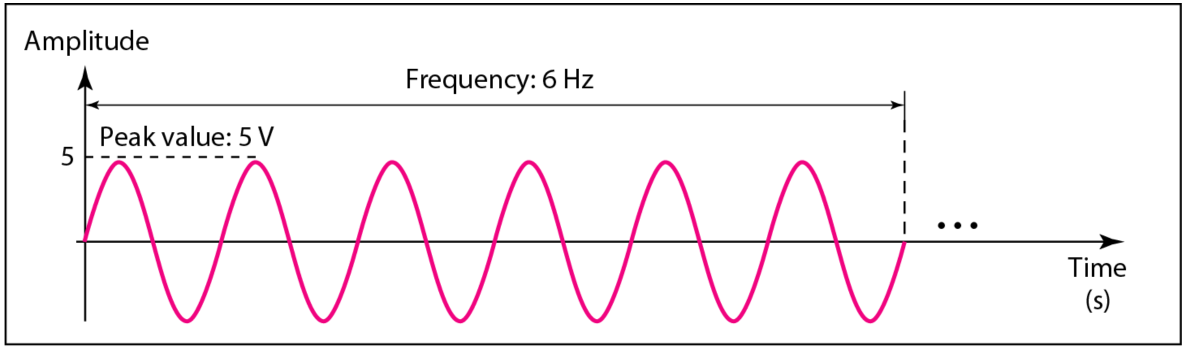
- A frequency-domain plot is concerned with only the peak value and the frequency.

Time and Frequency Domain

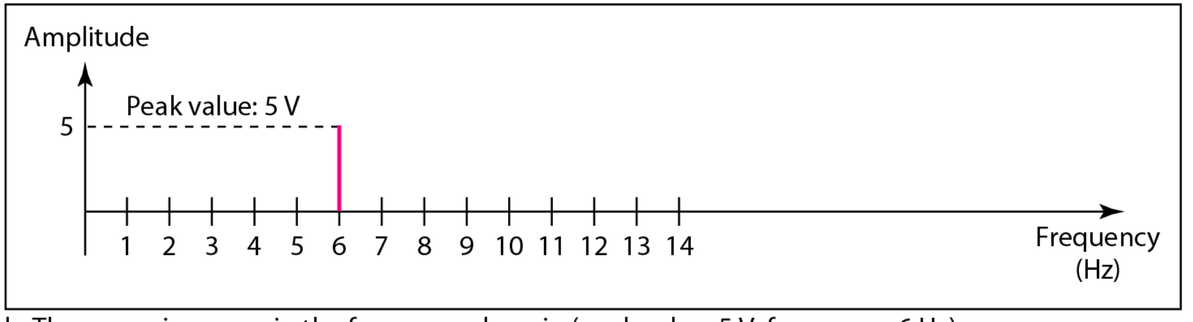


Time-domain and frequency-domain plots of a sine wave

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

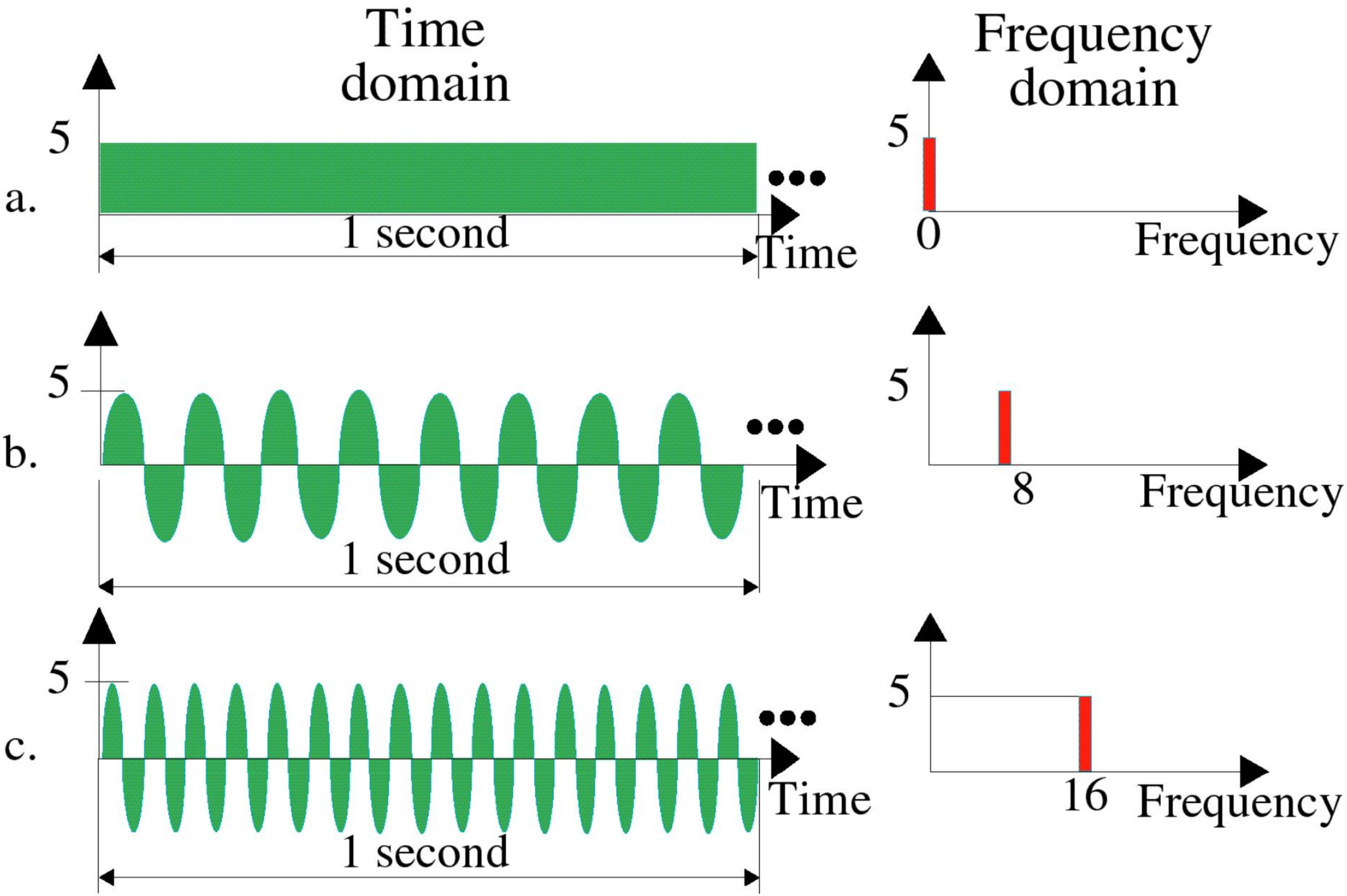


a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)



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

Examples


Time
domain
Frequency
domain
5
a.
1 second
Time
5
0
Frequency
5
b.
1 second
Time
5
8
Frequency
5
c.
1 second
Time
5
16
Frequency

2.5 Composite Signals

- 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.

- A composite signal can be periodic or nonperiodic.

- A periodic composite signal can be decomposed into a series of simple sine waves with discrete frequencies- frequencies that have integer values (1, 2, 3, and so on).

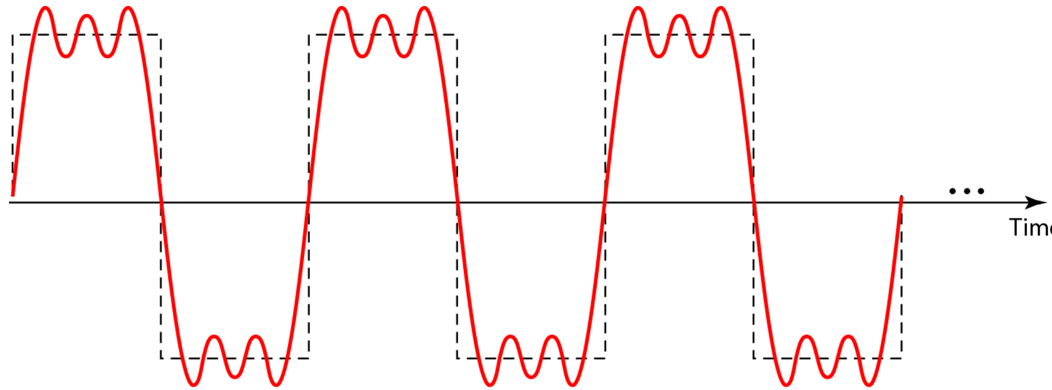
- A nonperiodic composite signal can be decomposed into a combination of an infinite number of simple sine waves with continuous frequencies, frequencies that have real values.

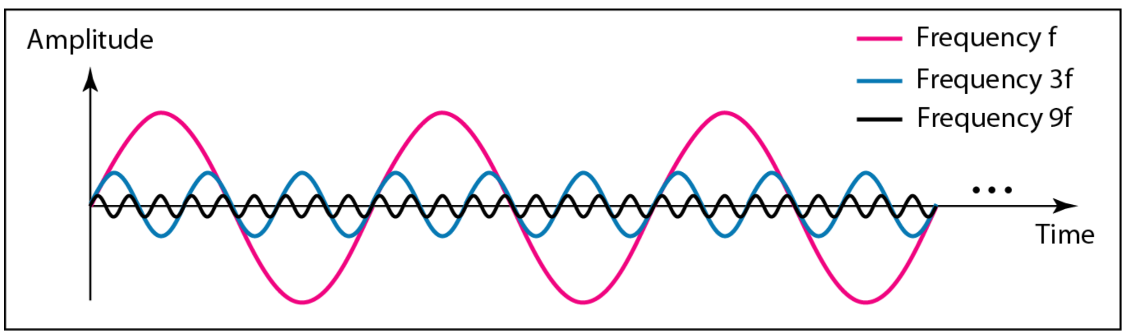
Fourier Analysis

According to Fourier analysis,
any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

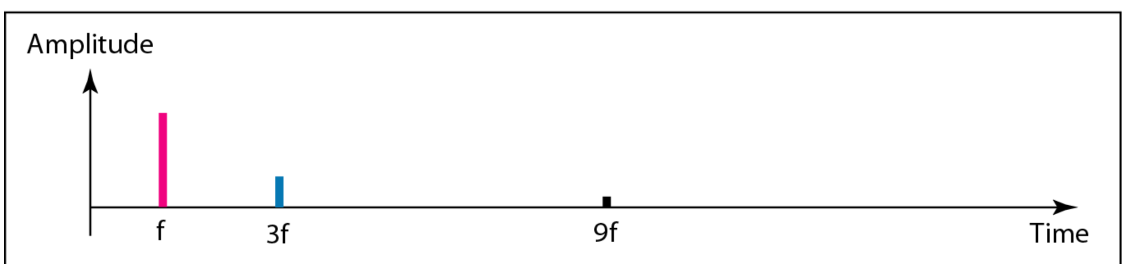
- If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies;
- If the composite signal is nonperiodic, the decomposition gives a combination of sine waves with continuous frequencies.

A composite periodic signal





a. Time-domain decomposition of a composite signal



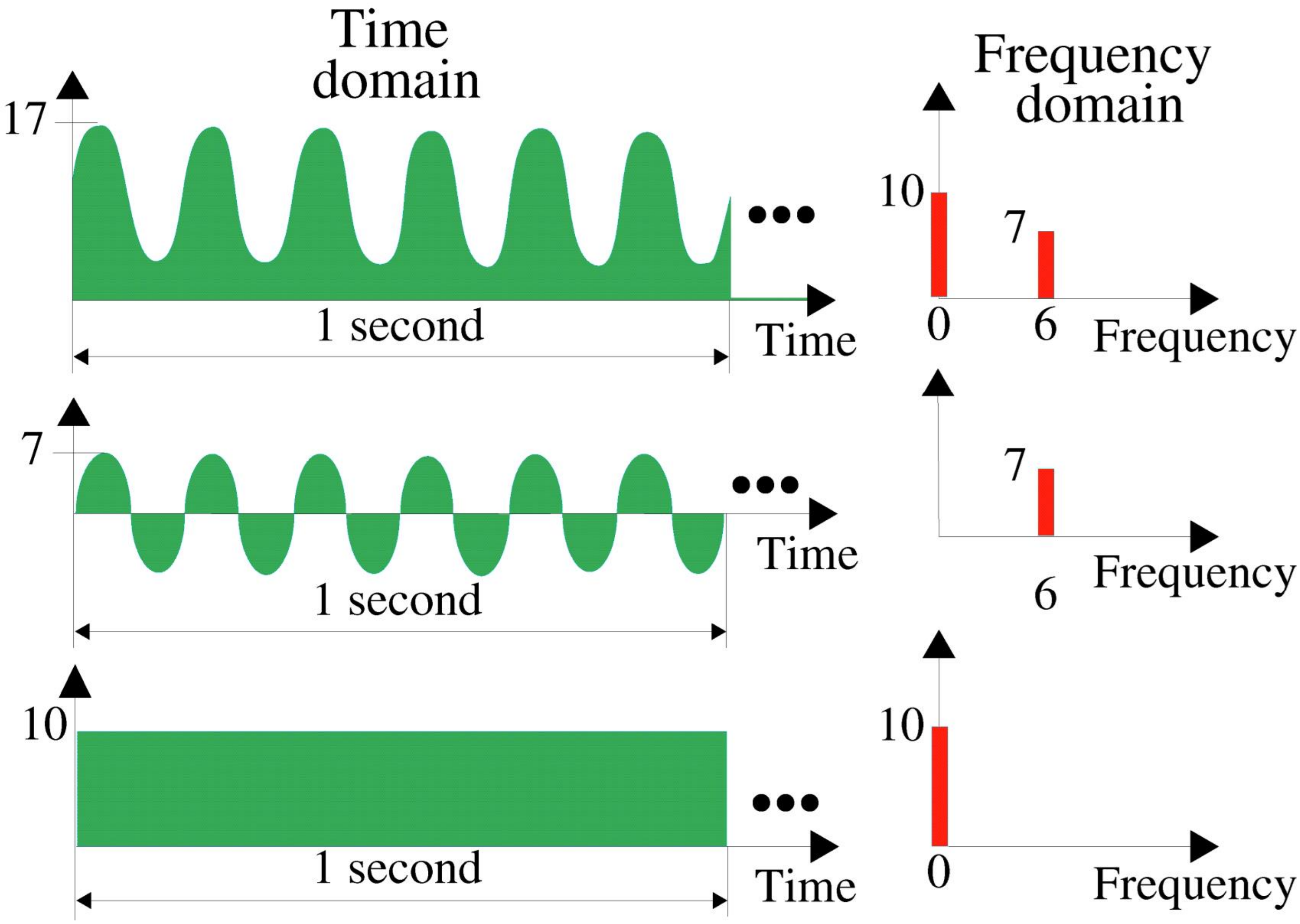
b. Frequency-domain decomposition of the composite signal

Decomposition of the composite periodic signal in the time and frequency domains

- The following figure shows a periodic signal decomposed into two sine waves.
- The first sine wave(middle plot) has a frequency of 6 while the second sine wave has a frequency of 0.

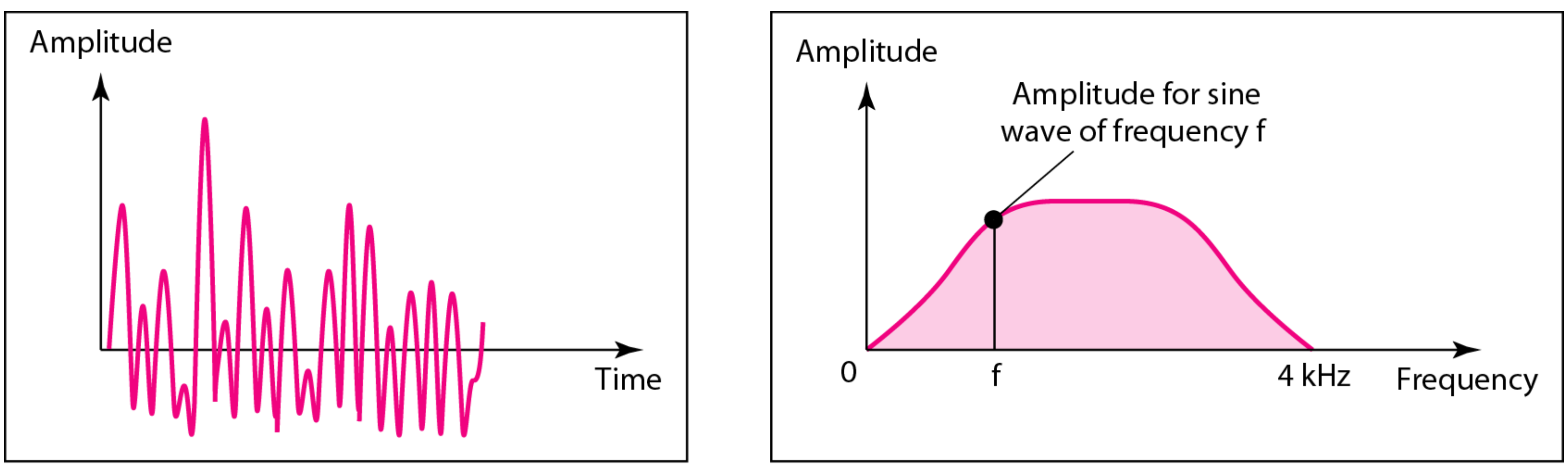
Figure 4-13

Signal with DC Component



Time and frequency domains of a nonperiodic composite signal

- A nonperiodic composite signal
  - It can be a 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.

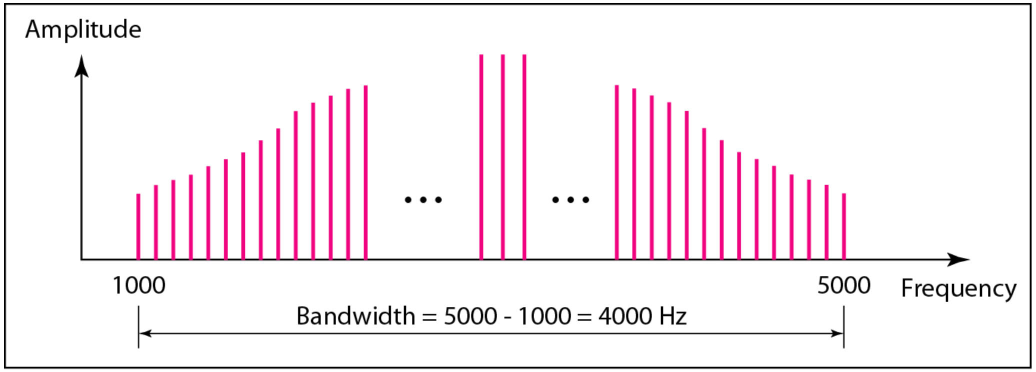


a. Time domain

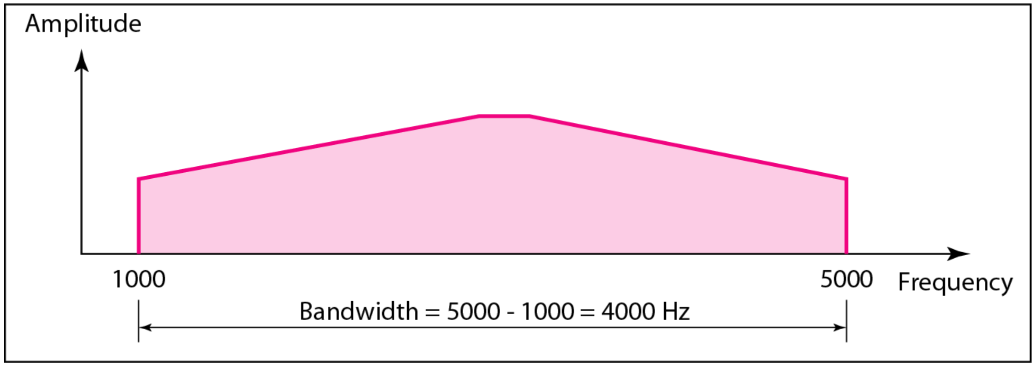
b. Frequency domain

Bandwidth

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



a. Bandwidth of a periodic signal

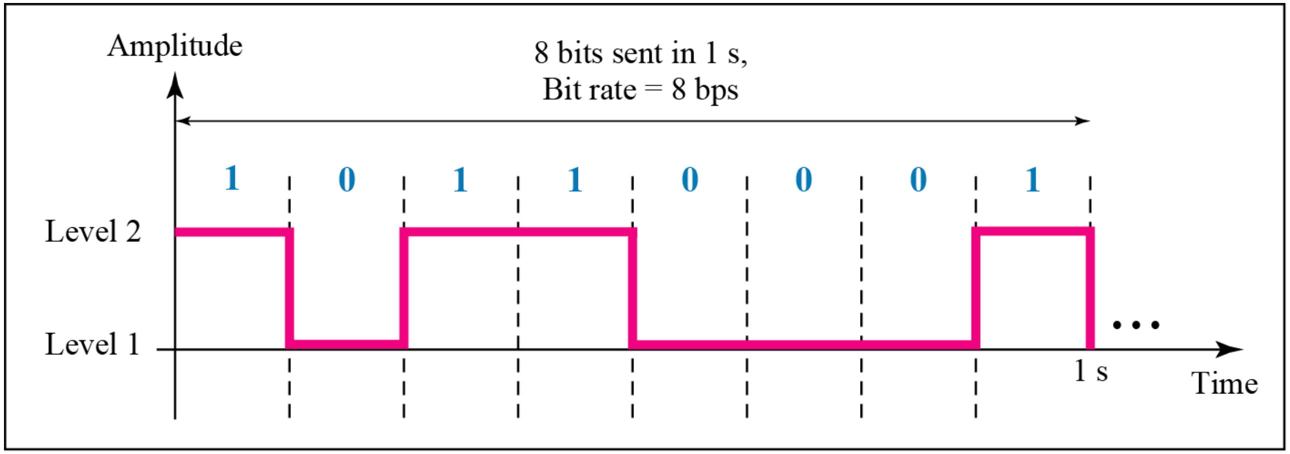


b. Bandwidth of a nonperiodic signal

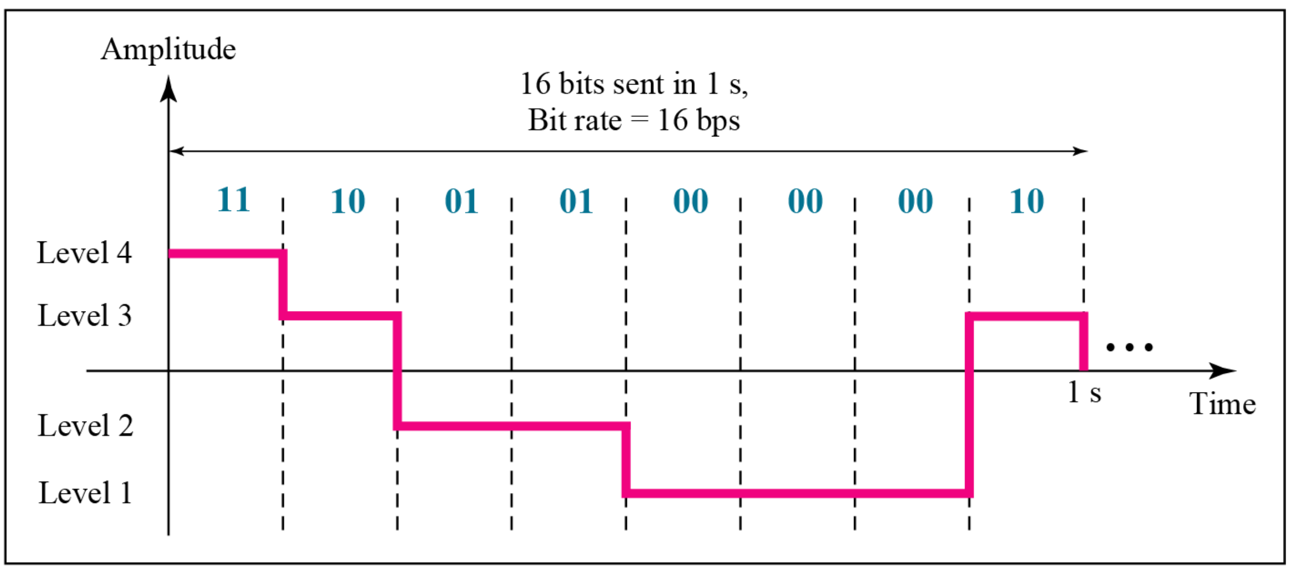
2.6 DIGITAL SIGNALS

- In addition to being represented by an analog signal, information can also be represented by a digital signal.
- For example, a 1 can be encoded as a positive voltage and a 0 as zero voltage.
- A digital signal can have more than two levels.
- In this case, we can send more than 1 bit for each level.

Two digital signals: one with two signal levels and the other with four signal levels



a. A digital signal with two levels



b. A digital signal with four levels

Bit Interval and Bit Rate:

- Most digital signals are nonperiodic, and thus period and frequency are not appropriate characteristics.

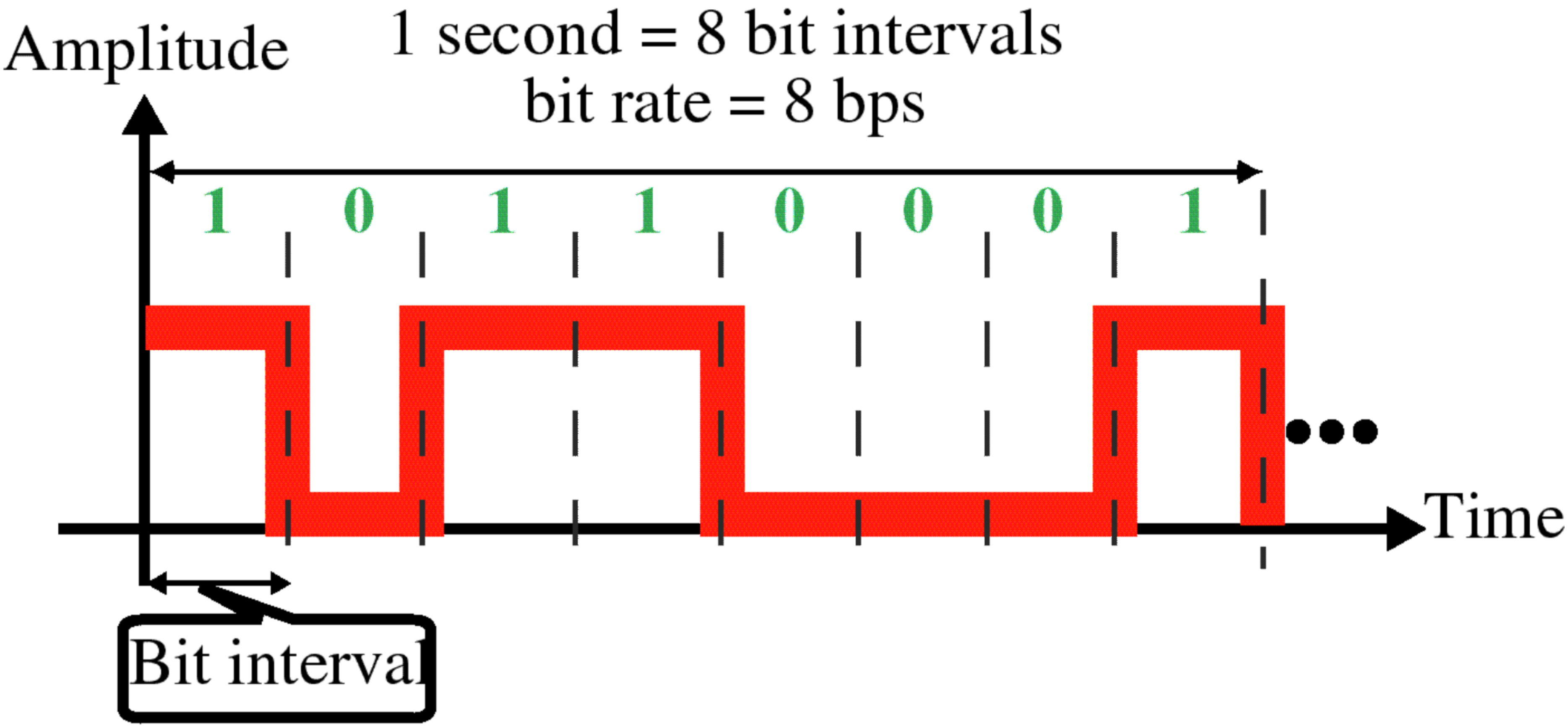
- The two terms , bit interval (instead of period).

- Another *term-bit rate (instead of frequency) is used to describe* digital signals.

- The bit rate is the number of bits sent in one second, expressed in bits per second (bps). Figure shows the bit rate for two signals.

Figure 4-18

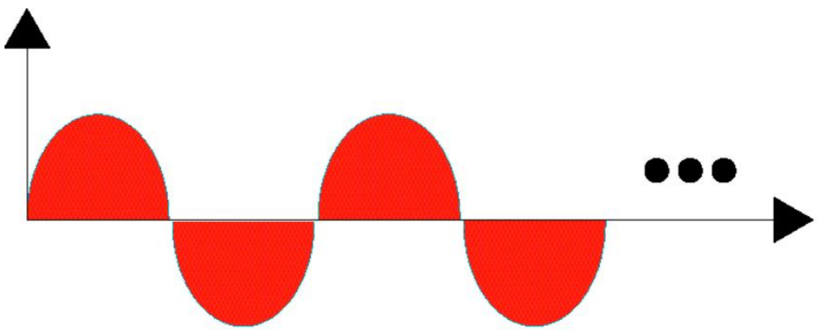
Bit Rate and Bit Interval



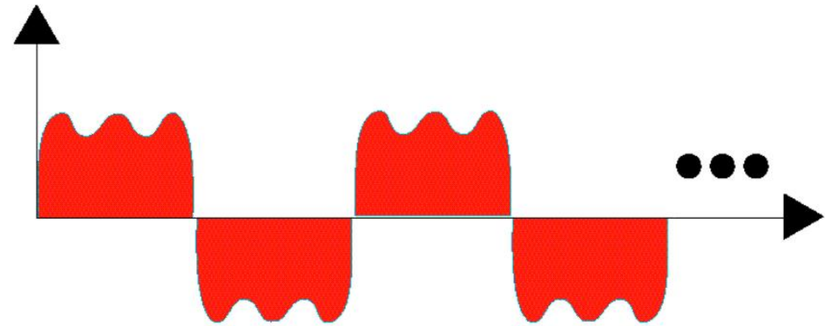
Decomposition of Digital Signal

- A digital signal can be decomposed into an infinite number of simple sine waves called harmonics.

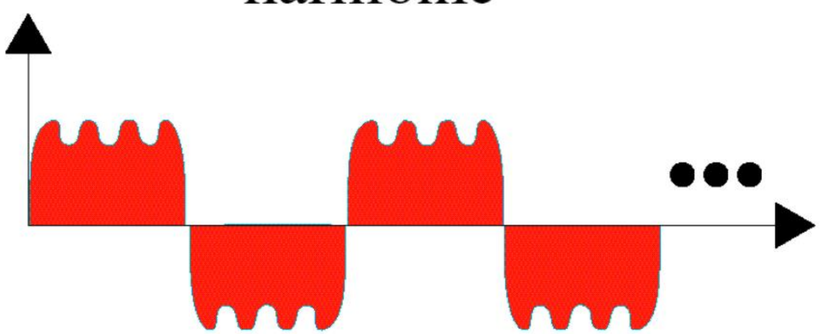
Harmonics of a Digital Signal



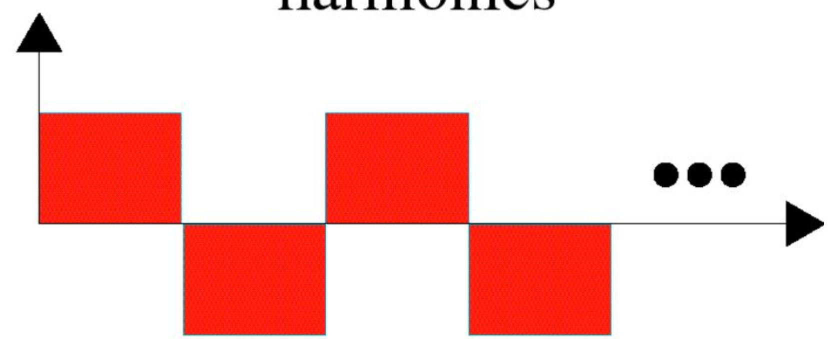
a. Only first harmonic



b. First, third, and fifth harmonics



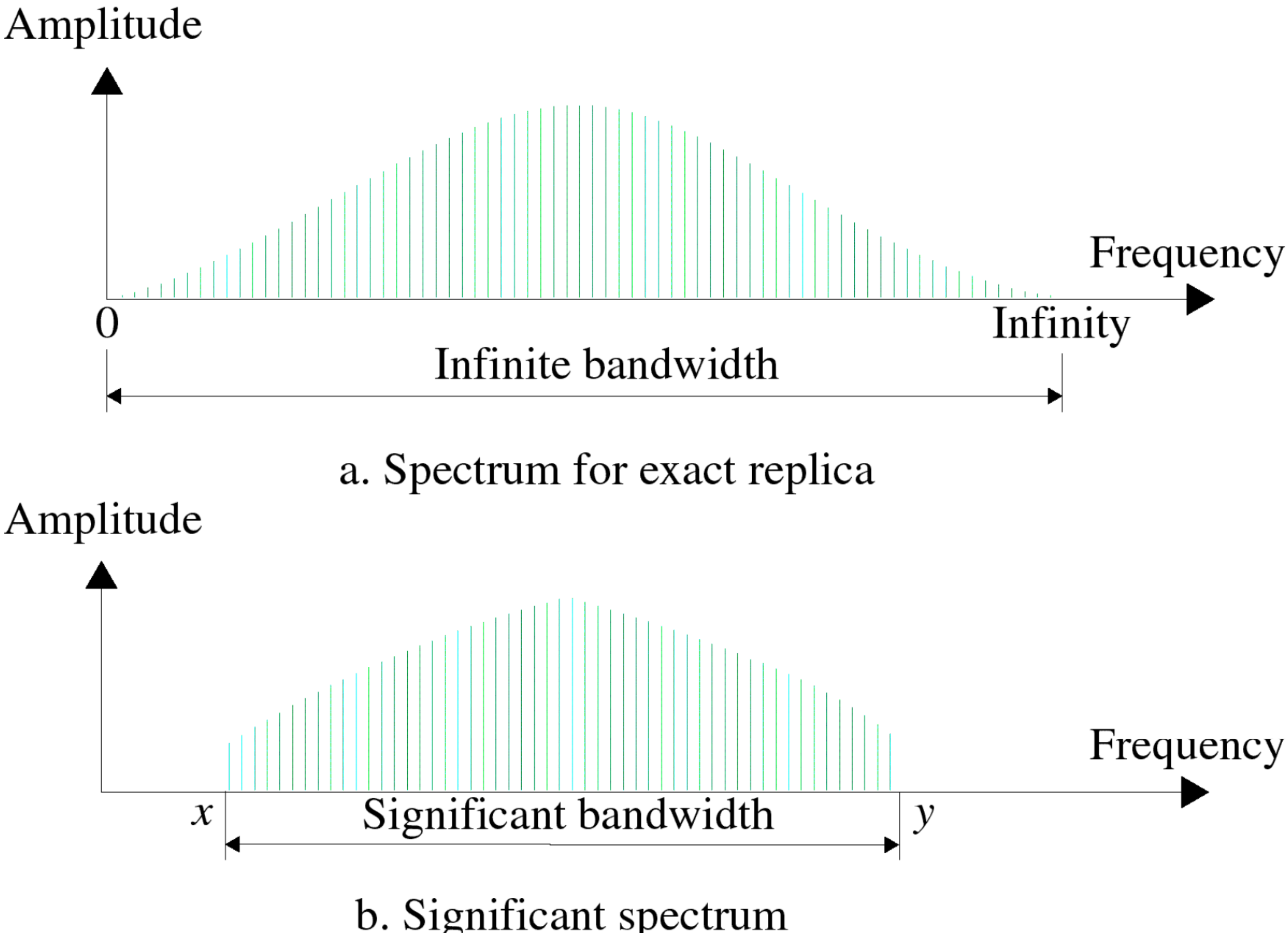
c. First, third, fifth, and seventh harmonics



d. Infinite number of harmonics

- Although the frequency spectrum of a signal contains an infinite number of frequencies with different amplitudes.

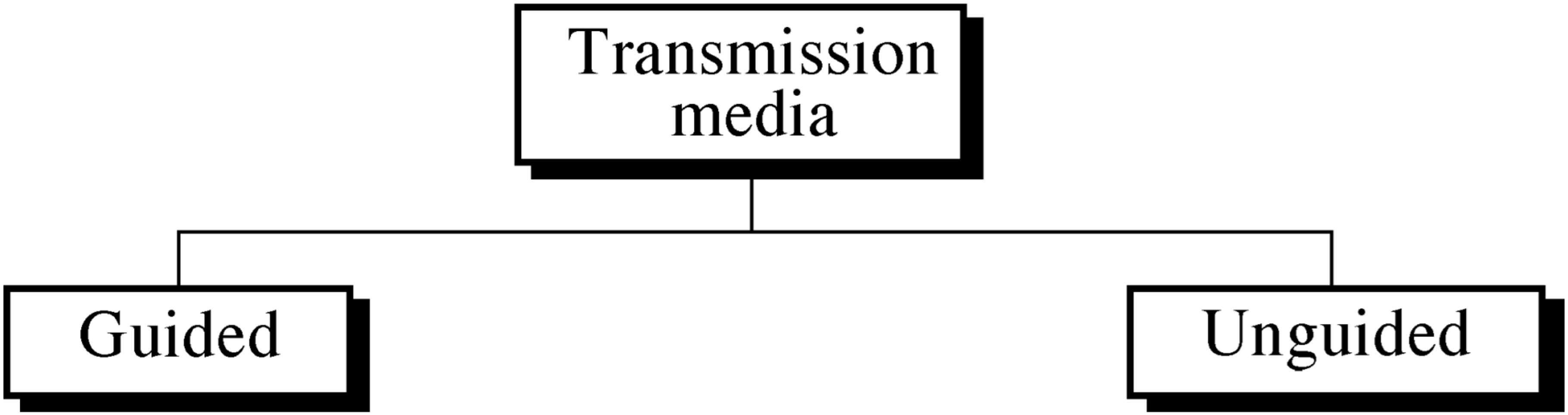
Exact and Significant Spectrums



Transmission Media

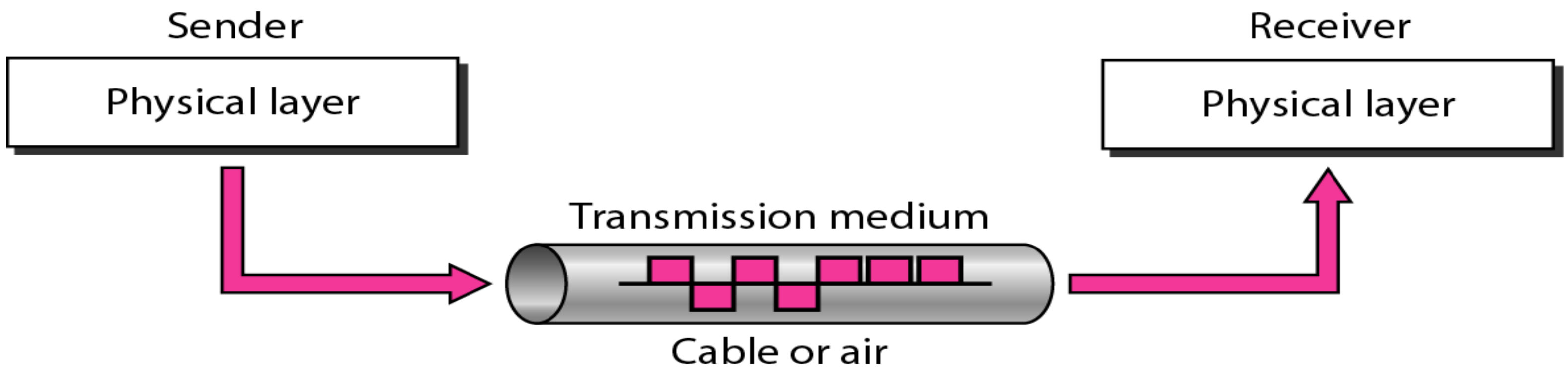
Transmission Media

- Guided Media – wired transmission
- Unguided Media - - wireless transmission

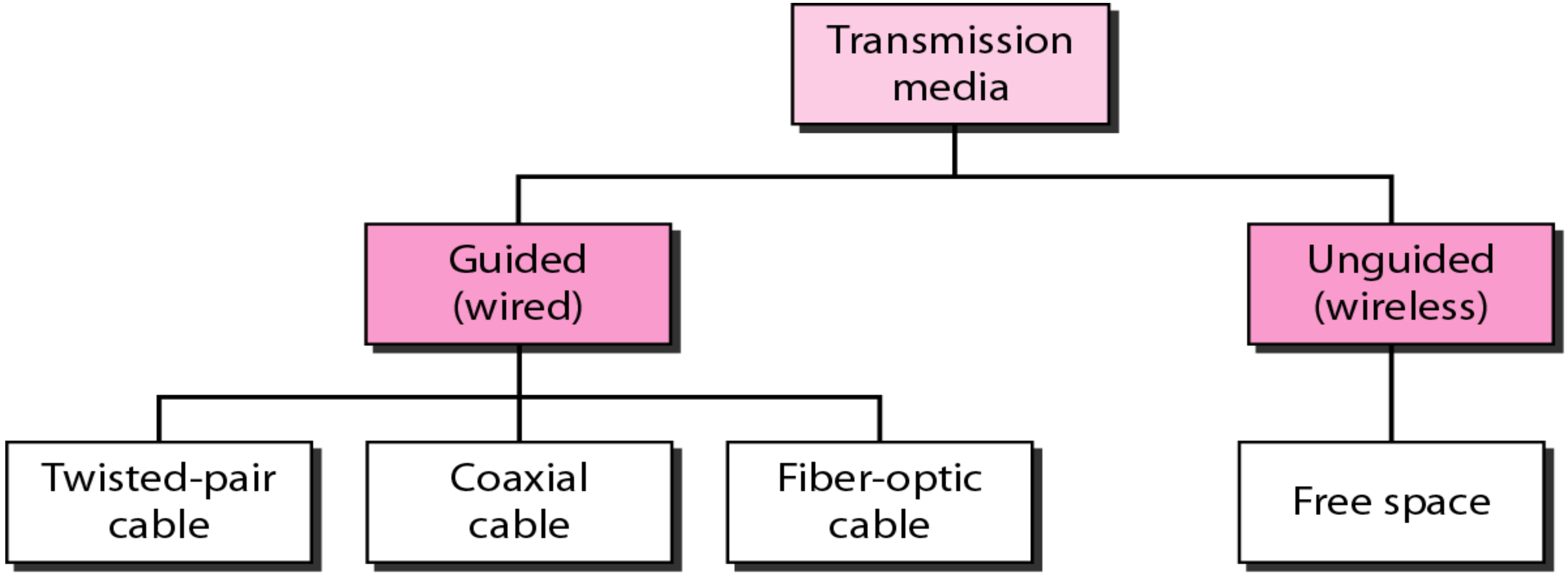

Transmission media
Guided
Unguided

A transmission media define as anything that can carry information from a source to a destination.

Transmission medium and physical layer

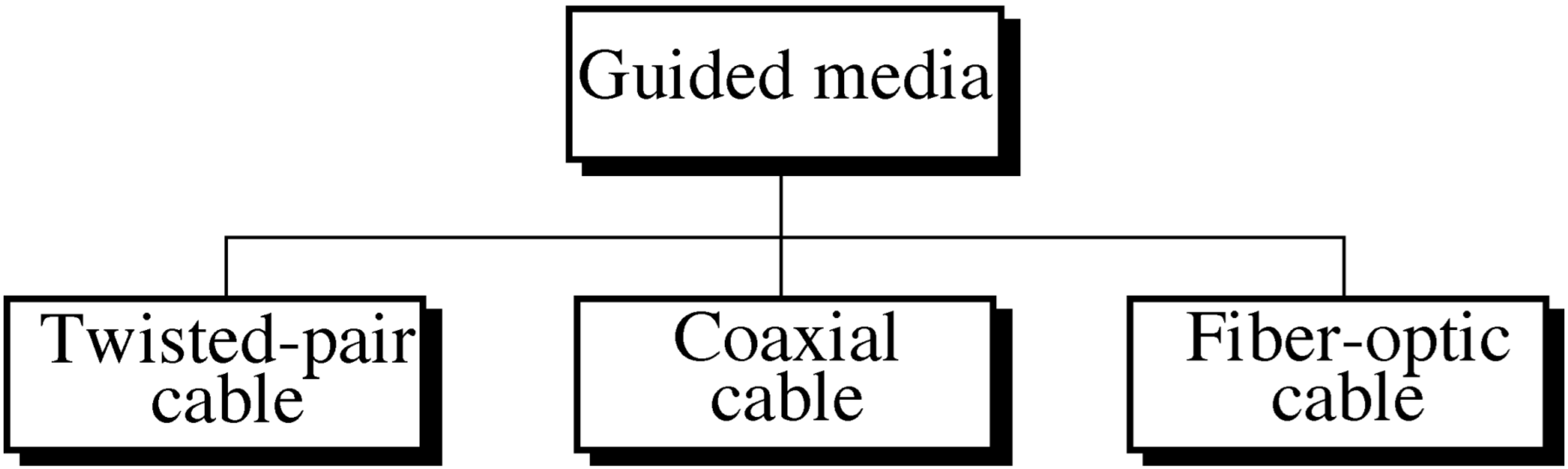


Classes of transmission media



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.


Guided media
Twisted-pair cable
Coaxial cable
Fiber-optic cable

- A signal traveling along any of these media is directed and contained by the physical limits of the medium.

- **Twisted-pair and coaxial cable** use metallic (copper) conductors that accept and transport signals in the form of electric current.

- **Optical fiber** is a cable that accepts and transports signals in the form of light.

1. Twisted-Pair Cable

- Twisted-pair cable comes in two forms:

  *** unshielded**

  *** shielded**

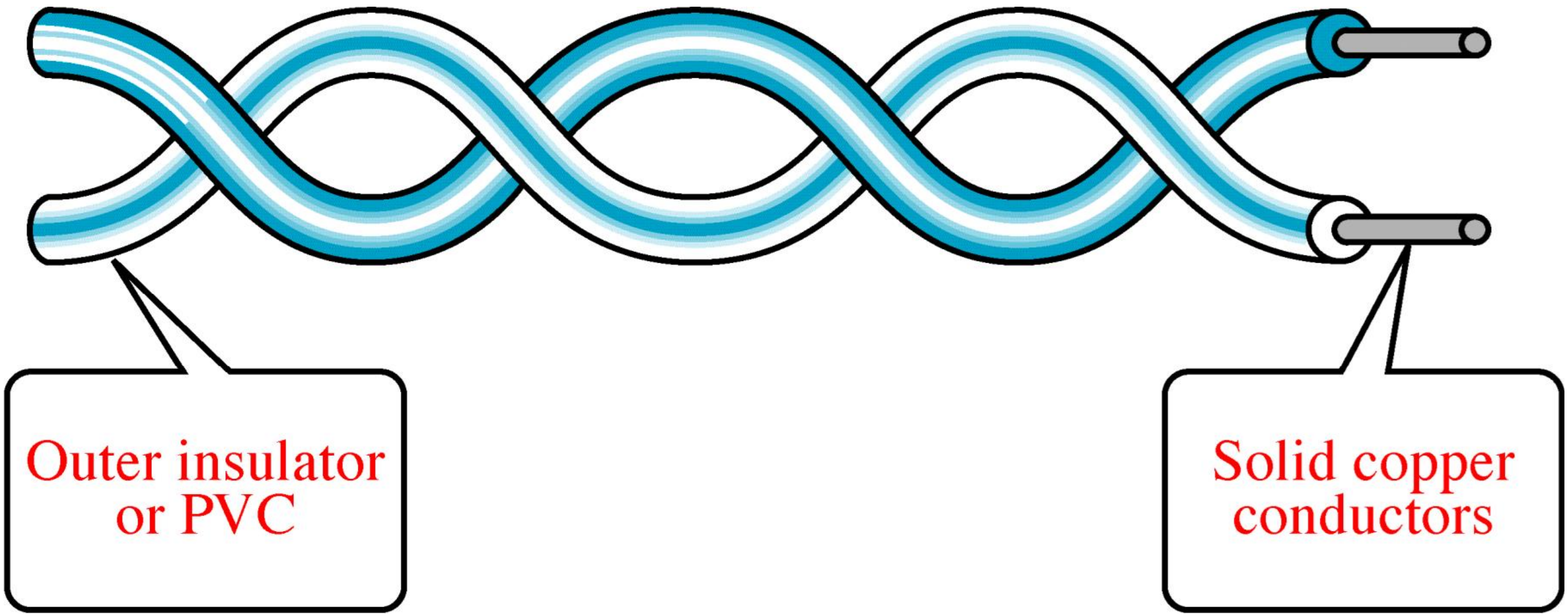
- A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in Figure .

- The plastic insulation is color-banded for identification.

- Colors are used to both to identify the specific conductors in a cable and to indicate which wires belong in pair.

Twisted-Pair Cable

Frequency Range for Twisted-pair cable



- One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference.

- The receiver uses the difference between the two.

- 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.

- If the two wires are parallel, the effect of these unwanted signals is not the same in both wires because they are at different locations relative to the noise or crosstalk sources .

- This results in a difference at the receiver. By twisting the pairs, a balance is maintained.

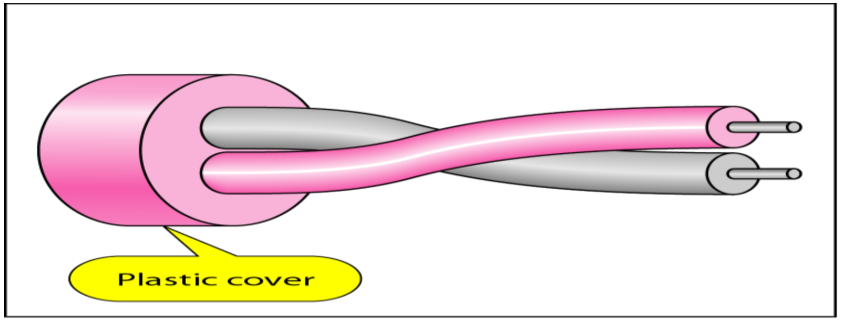
- For example, suppose in one twist, one wire is closer to the noise source and the other is farther; in the next twist, the reverse is true.

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

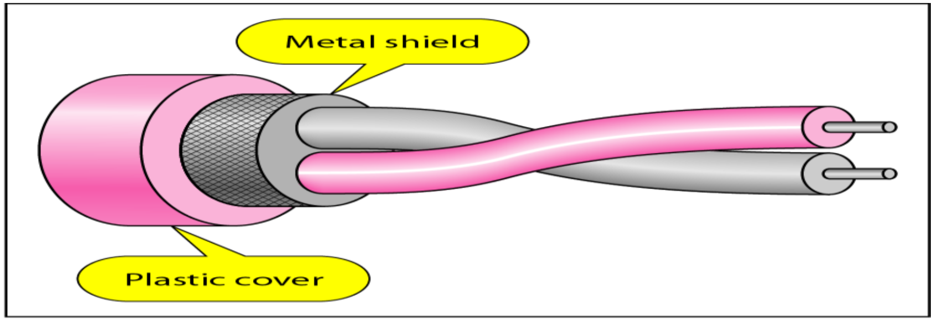
- IBM has also produced a version of twisted-pair cable for its use called shielded twisted-pair (STP).

- 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.

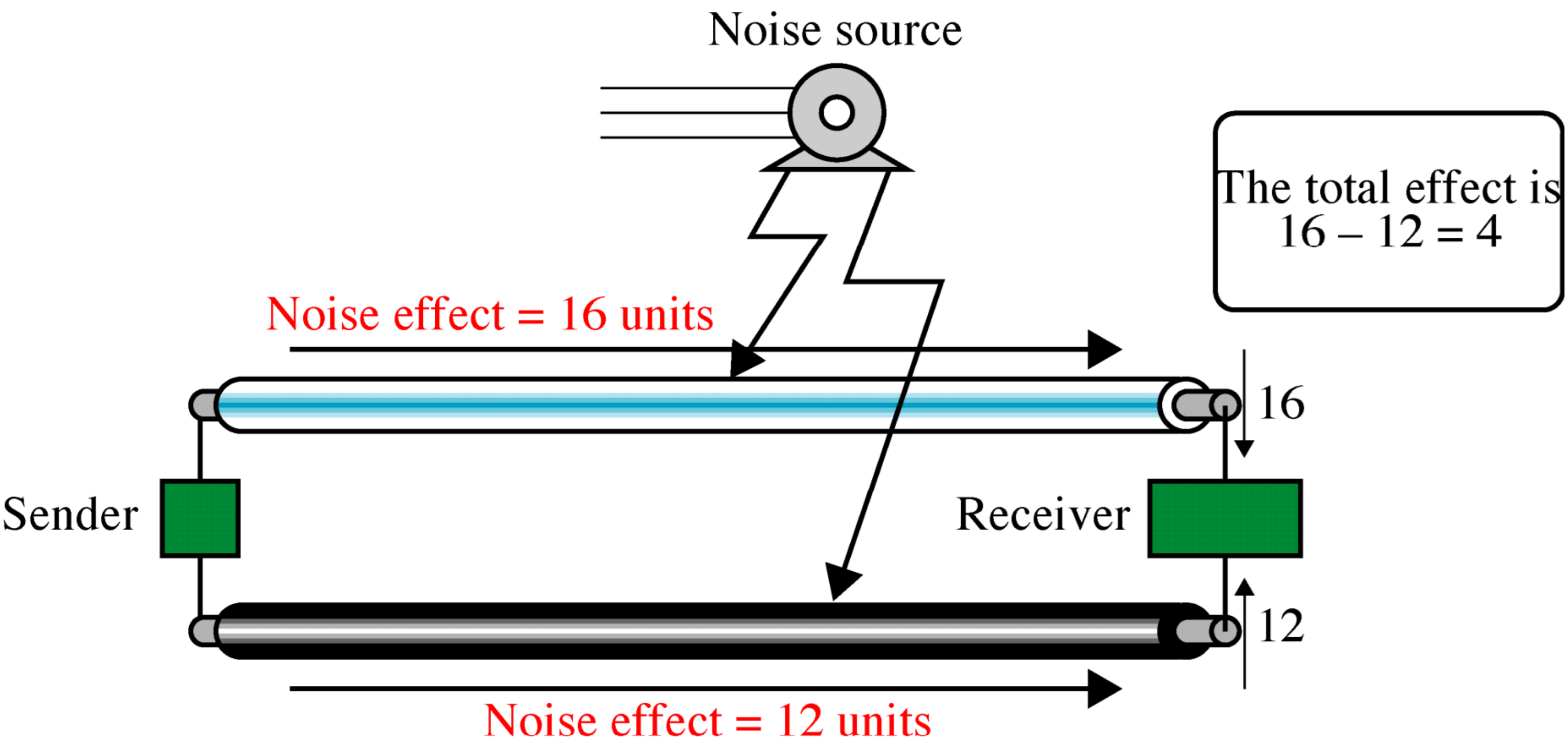


a. UTP

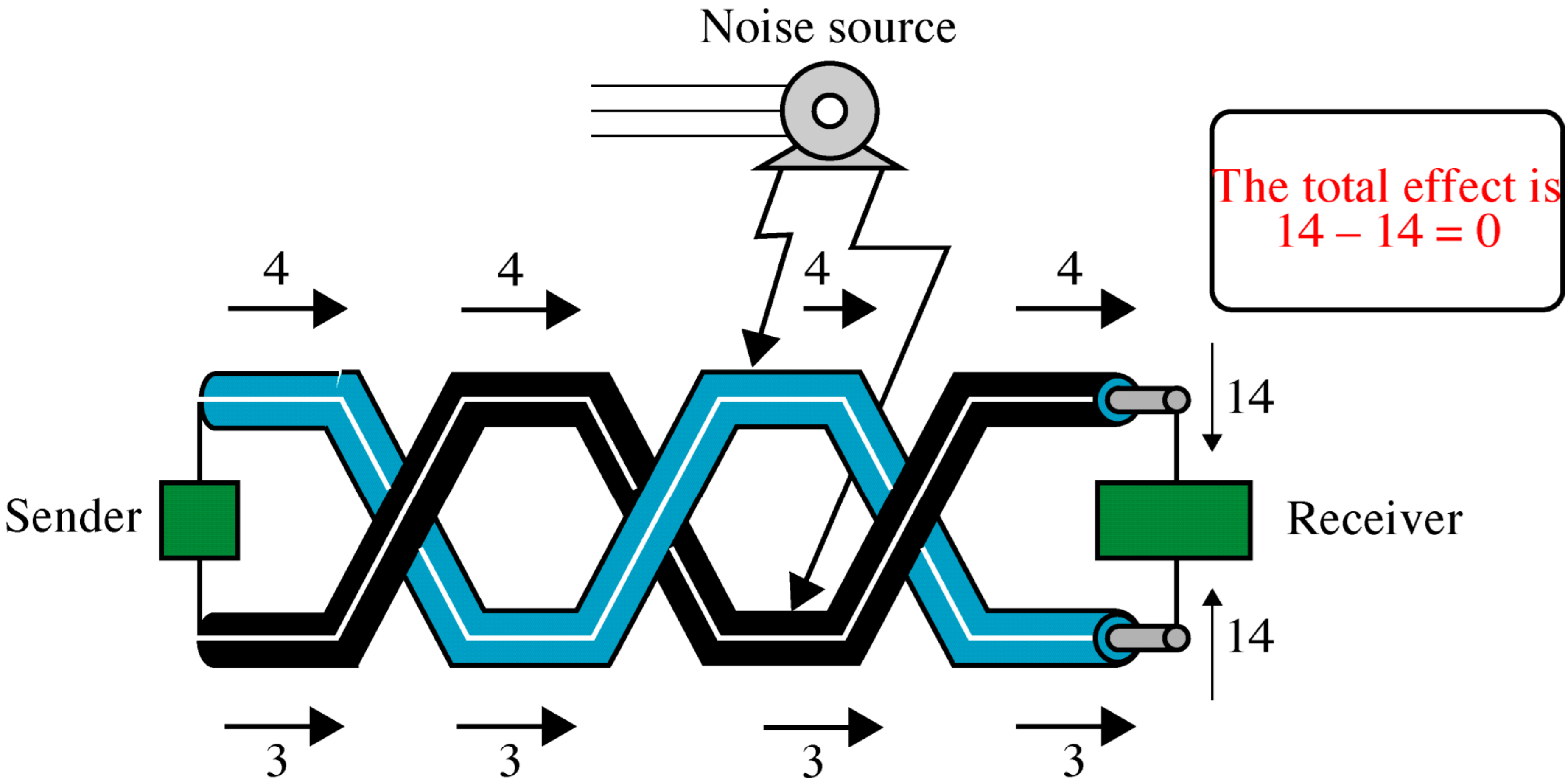


b. STP

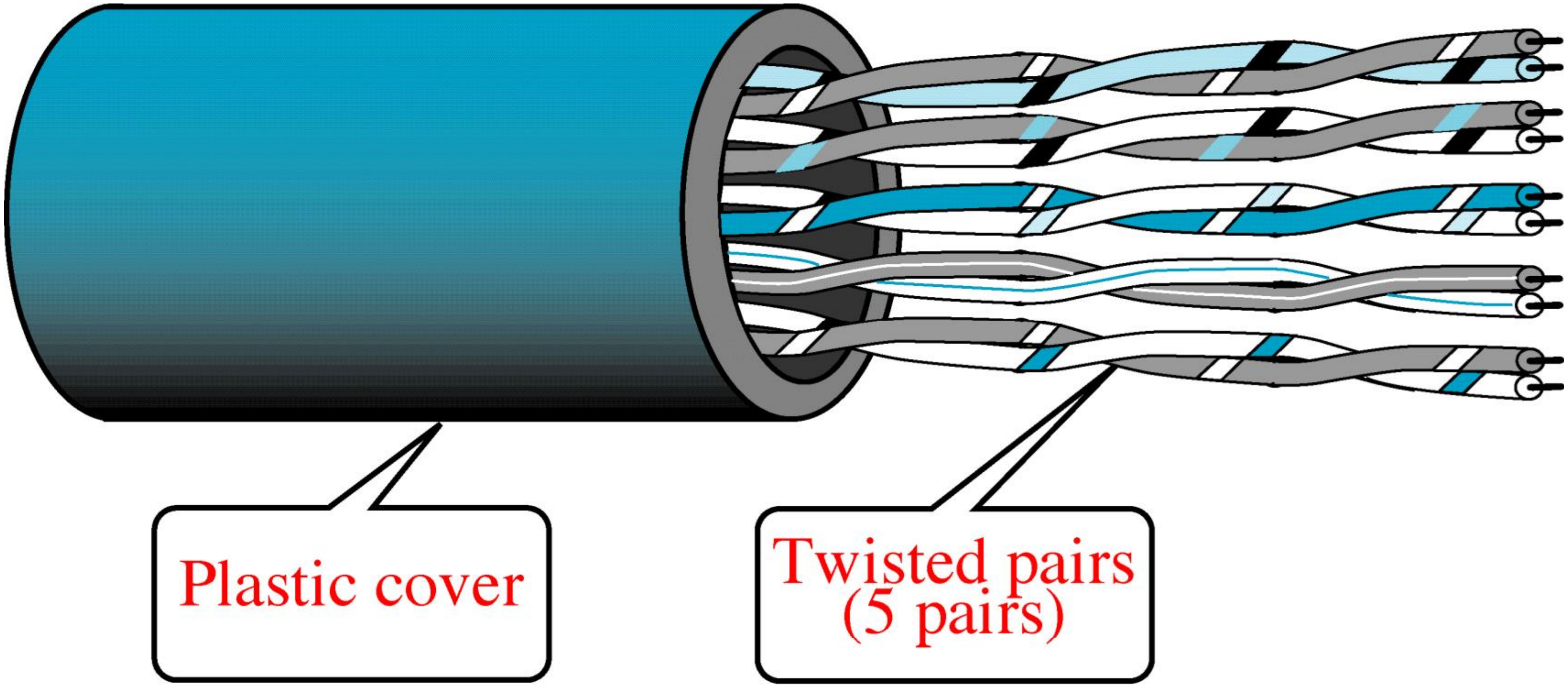
Effect of Noise on Parallel Lines



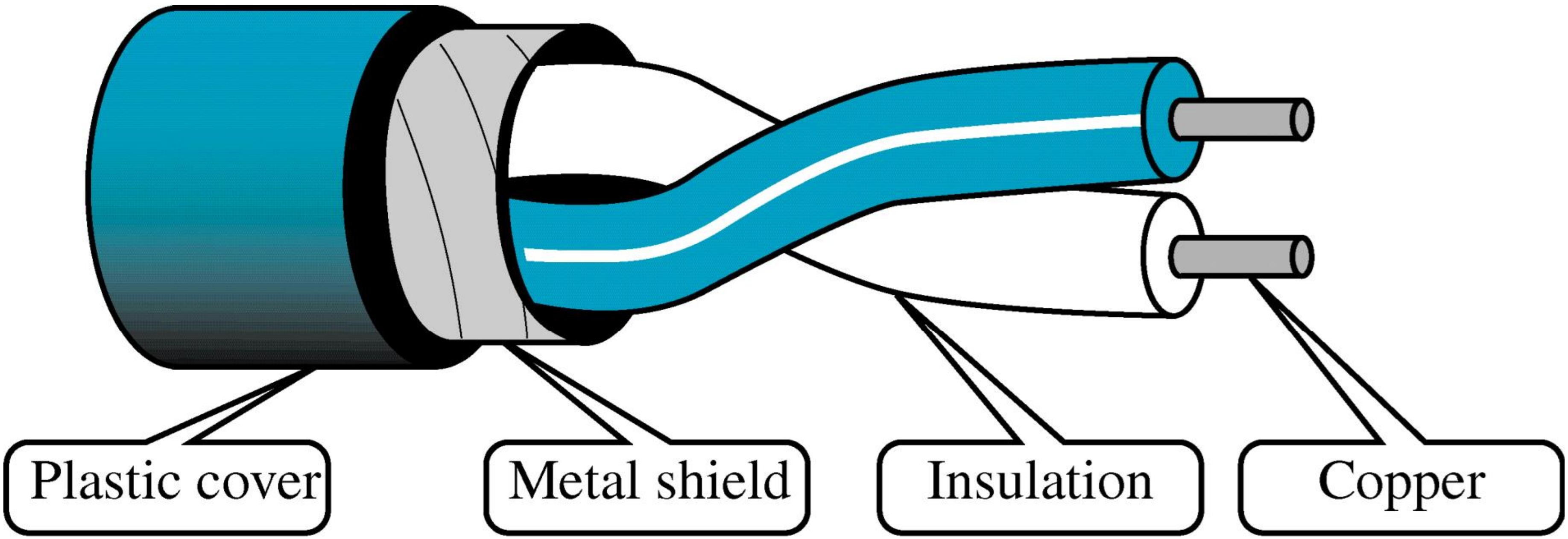
Noise on Twisted-Pair Lines



Unshielded Twisted-Pair Cable



Shielded Twisted-Pair Cable



Applications

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

- The local loop--the line that connects subscribers to the central telephone office---commonly consists of unshielded twisted-pair cables.

- 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.

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-1lines
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
SE	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

2. *Coaxial Cable*

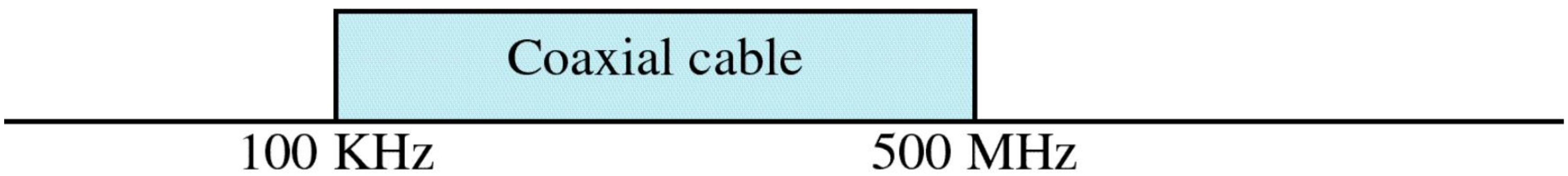
- Coaxial cable (or coax) carries signals of higher frequency ranges than those in twisted- pair cable.

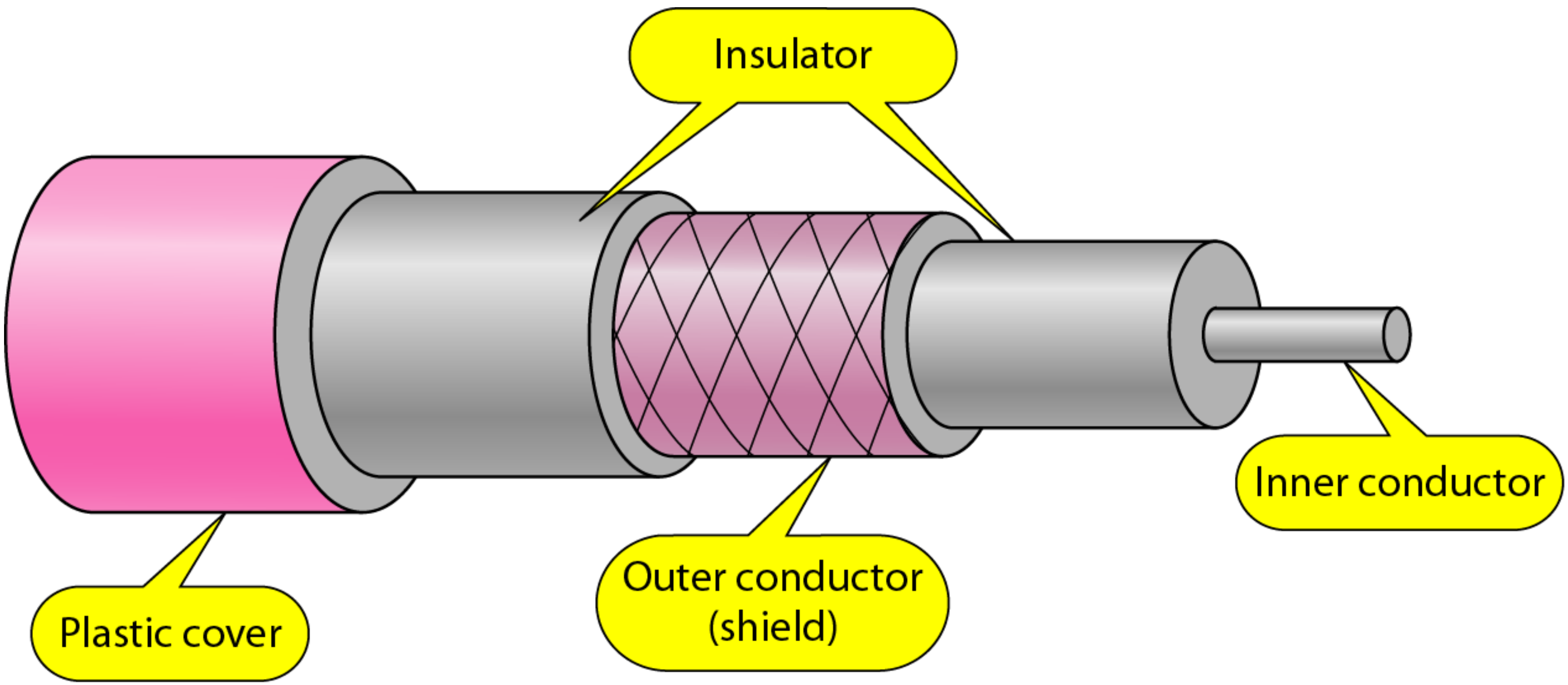
- Instead of having two wires, coax has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil, braid, or a combination of the two.

- The outer metallic wrapping serves both as a shield against noise and as the second conductor, which completes the circuit.

- This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover

Frequency Range of Coaxial Cable





Coaxial Cable standards:

- Coaxial cables are categorized by their **radio government (RG)** ratings.

- Each cable defined by RG ratings is adapted for a specialized functions.

Categories of co axial cable

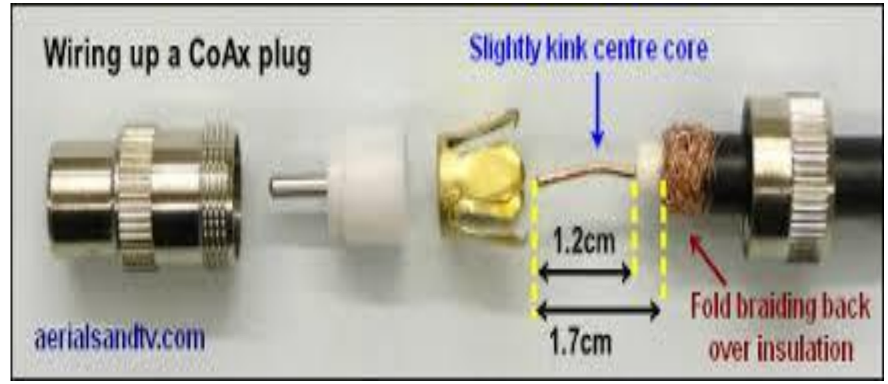
RG-8 : used in thick Ethernet

RG-9: Used in thick Ethernet

RG-11: Used in thick Ethernet

RG-58: Used in thin Ethernet

RG-59: Used for TV

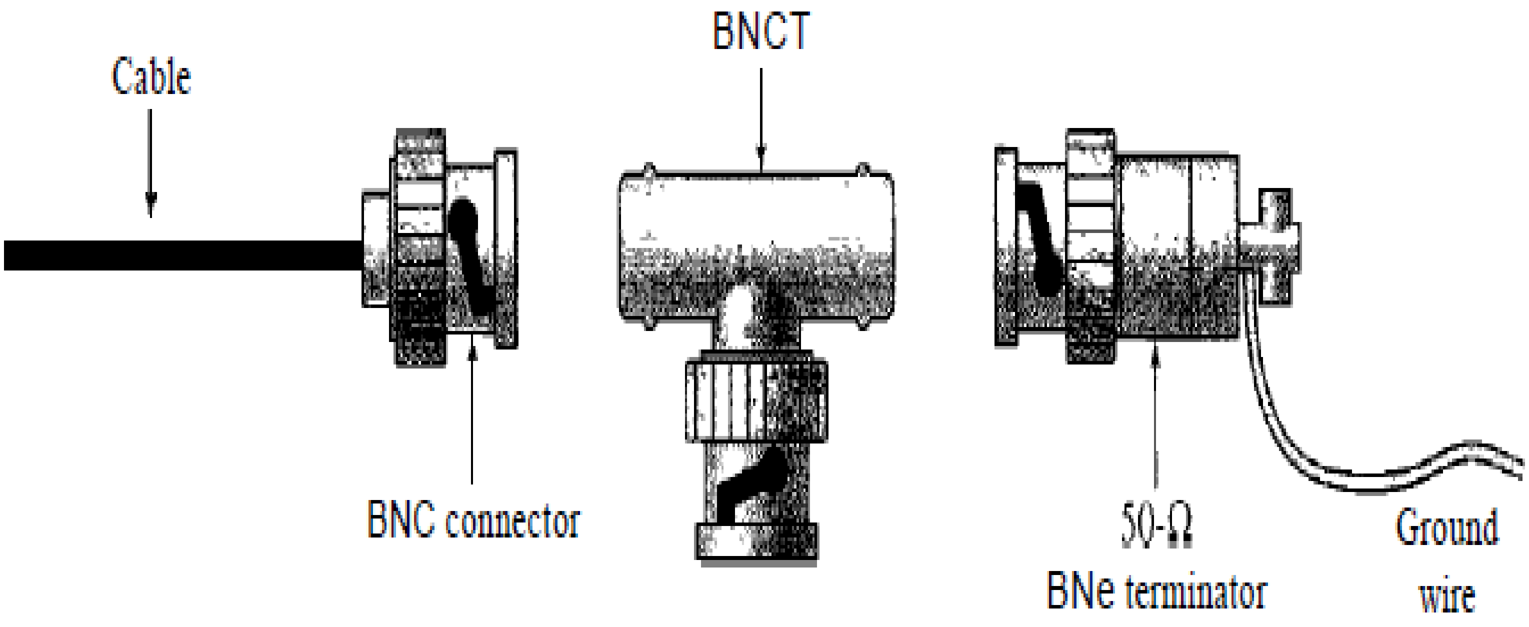


Wiring up a CoAx plug
Slightly kink centre core
1.2cm
1.7cm
Fold braiding back
over insulation
aerialsandtv.com

COAXIAL CABLE
braided shield
foil shield
center conductor
outer jacket
dielectric

Coaxial Cable Connectors:

- To connect coaxial cable to devices, we need coaxial connectors.
- The most common type of connector used today is the **Bayone-Neill-Concelman (BNe), / BNC connector.**
- The following figure shows three popular types of these connectors: the BNC connector, the BNC T connector, and the BNC terminator.
- The BNC connector is used to connect the end of the cable to a device, such as a TV set.
- The BNC T connector is used in Ethernet networks to branch out to a connection to a computer or other device. The BNC terminator is used at the end of the cable to prevent the reflection of the signal.



Cable
BNCT
BNC connector
50-Ω
BNe terminator
Ground
wire

Applications

- Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals.

- Later it was used in digital telephone networks where a single coaxial cable could carry digital data up to **600 Mbps.**

- However, **coaxial cable in telephone networks** has largely been replaced today with fiber-optic cable.

- **Cable TV networks also use coaxial cables.**

- In the traditional cable TV network, the entire network used coaxial cable.

3. Fiber-Optic Cable

- A fiber-optic cable is made of **glass or plastic** and transmits signals in the **form of light.**

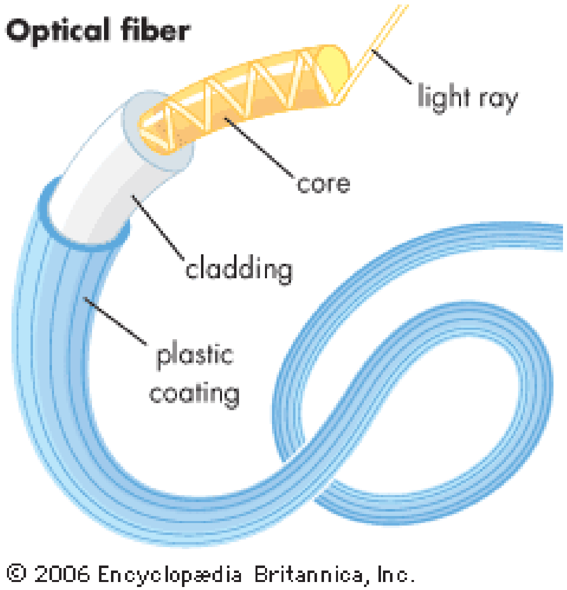
- To understand optical fiber, we first need to explore several aspects of the nature of light.

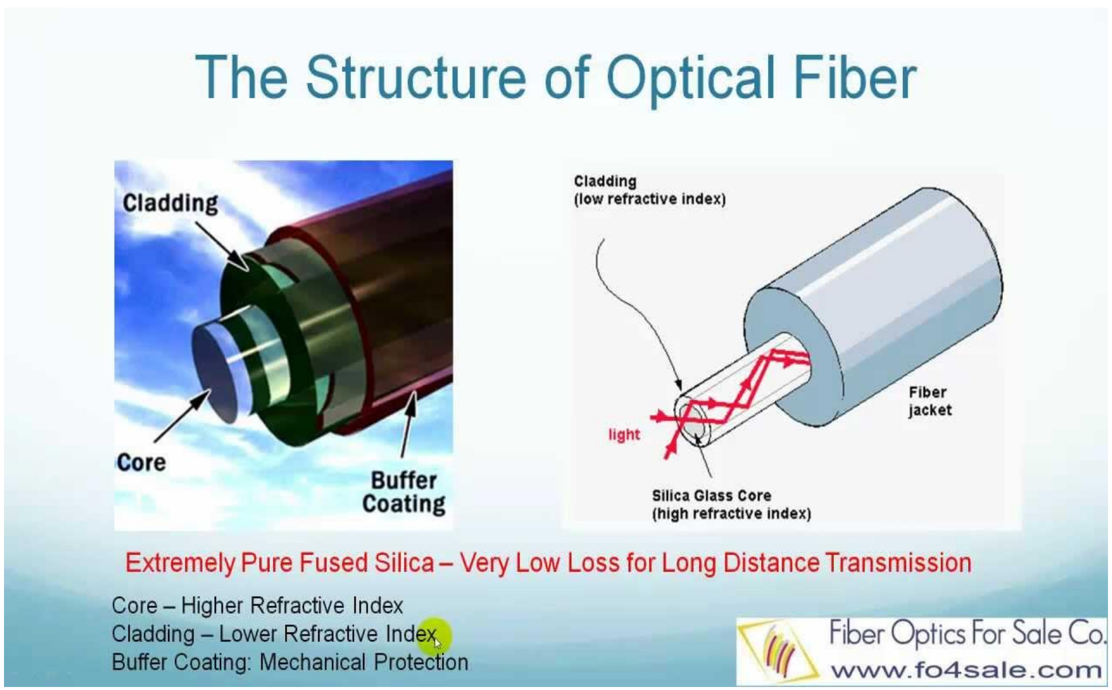
Nature of Light:

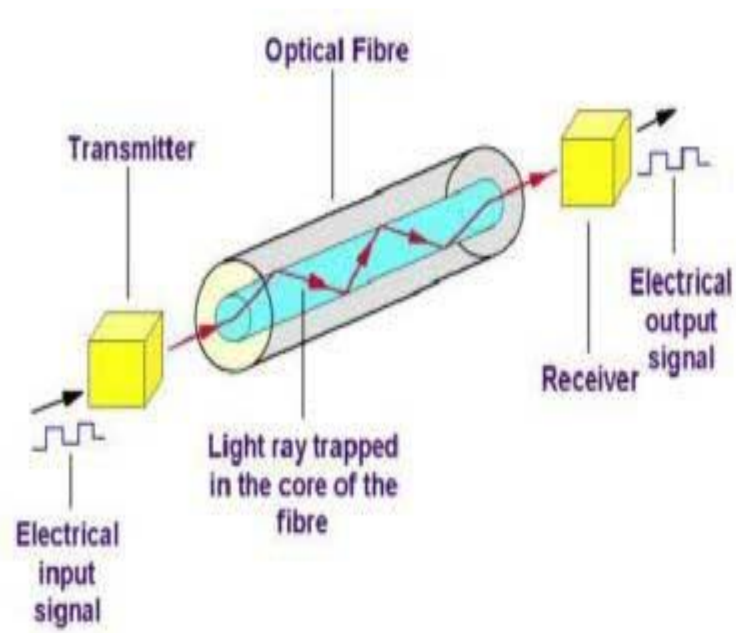
- Light is a form of electromagnetic energy.

- It travels at its fastest in a vacuum:300,000 km/s

- The speed of the light depends on the density of the medium through which it is travelling.


Optical fiber
light ray
core
cladding
plastic coating
© 2006 Encyclopædia Britannica, Inc.


The Structure of Optical Fiber
Cladding
Core
Buffer Coating
Cladding (low refractive index)
light
Fiber jacket
Silica Glass Core (high refractive index)
Extremely Pure Fused Silica – Very Low Loss for Long Distance Transmission
Core – Higher Refractive Index
Cladding – Lower Refractive Index
Buffer Coating: Mechanical Protection
Fiber Optics For Sale Co.
www.fo4sale.com


Optical Fibre
Transmitter
Electrical output signal
Receiver
Light ray trapped in the core of the fibre
Electrical input signal

Refraction:

- Light travels in a straight line as long as it is moving through a single uniform substances.

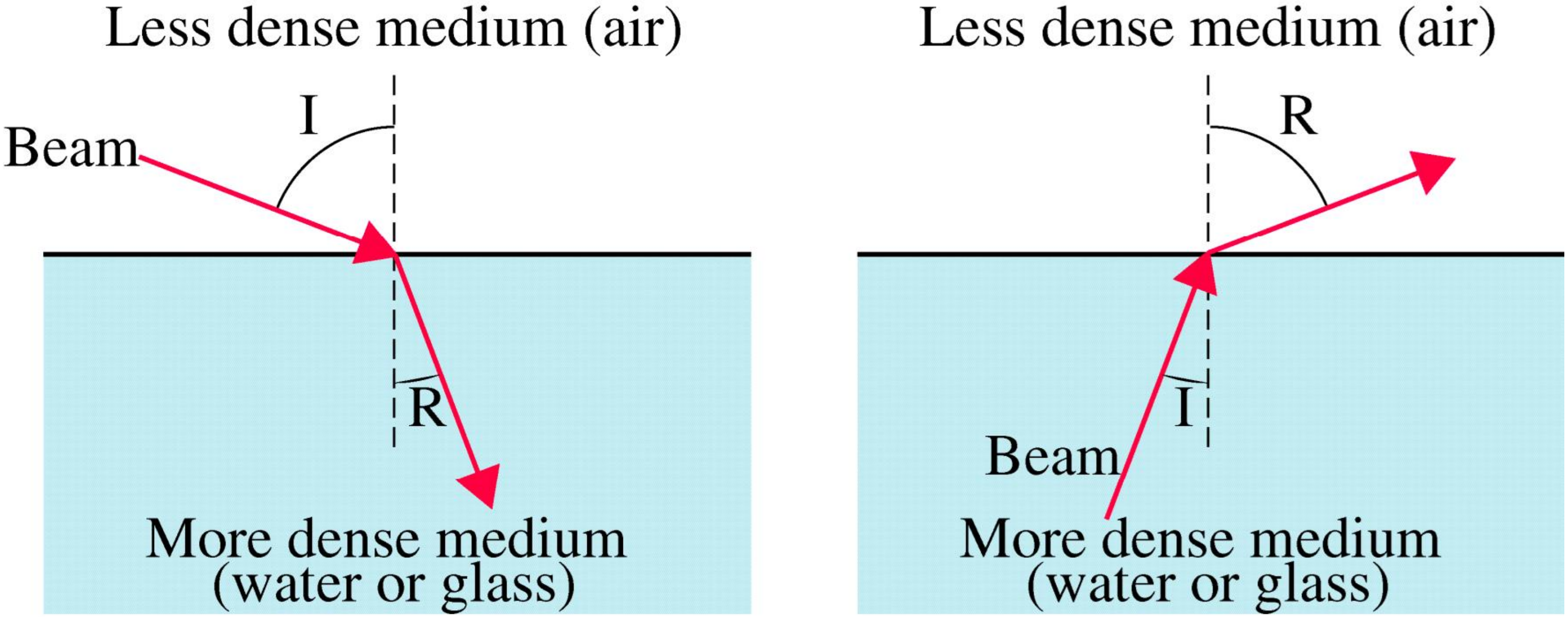
- If a ray of light travelling through one substance suddenly enters another substance (of a different density), the ray changes direction.

- This change is called refraction.

- The direction in which a light ray is refracted depends on the change in density encountered.

Figure 7-13

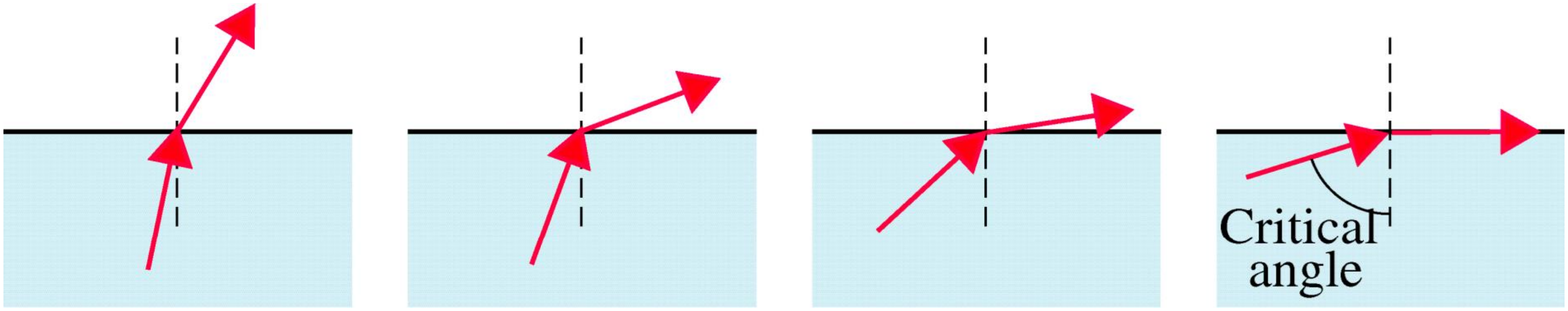
Refraction



a. From less dense to more dense medium

b. From more dense to less dense medium

Critical Angle



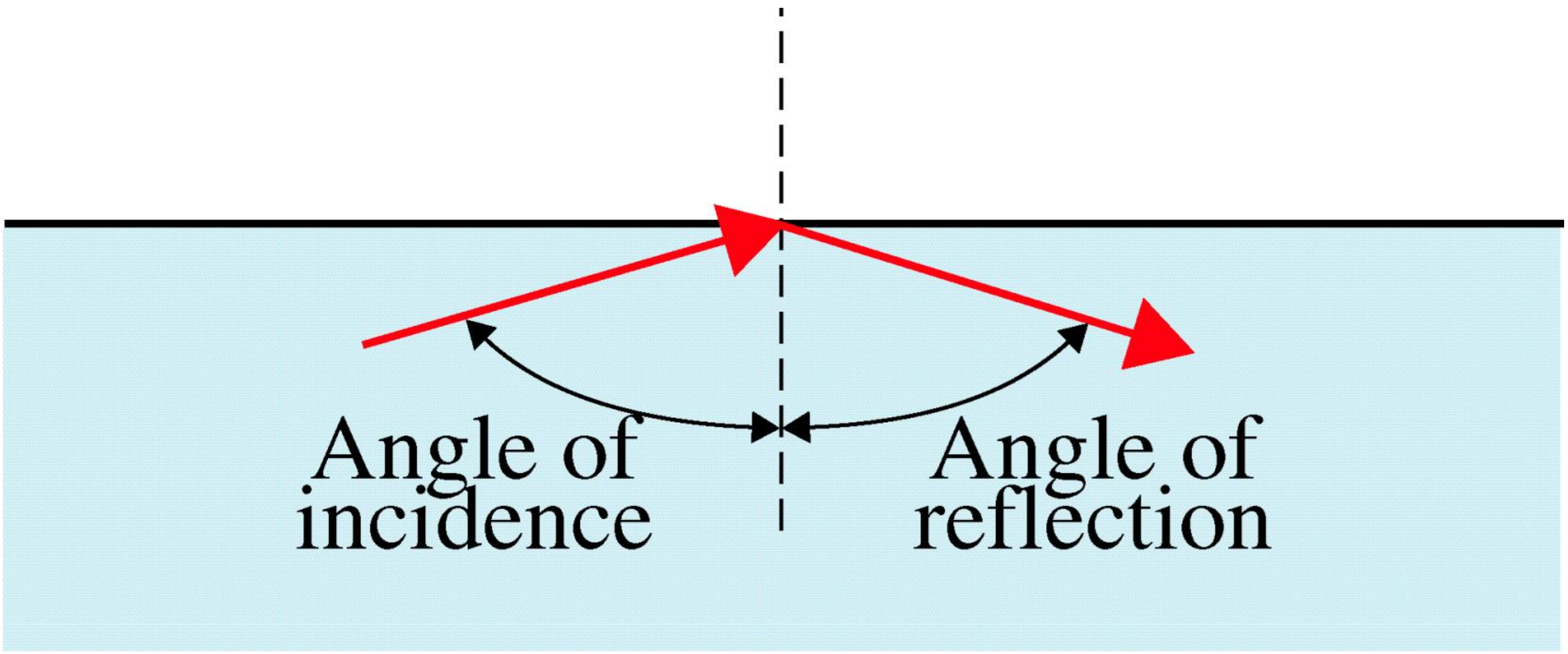
Reflection:

- When the angle of incidence becomes greater than the critical angle , a new phenomenon occurs called Reflection.

- Light no longer passes into the less dense medium at all.

- In this case , the angle of incidence is always equal to the angle of reflection.

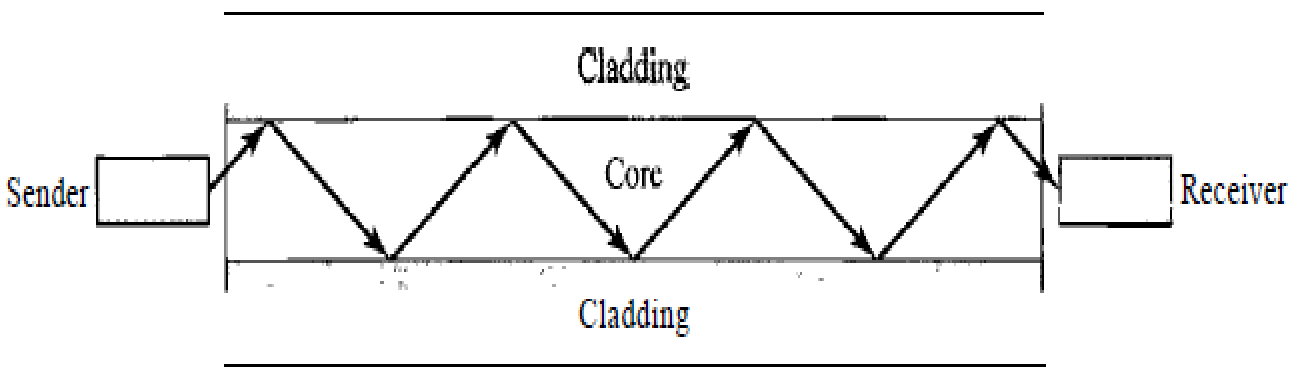
Reflection



- Optical fibers use reflection to guide light through a channel.

- A glass or plastic core is surrounded by a cladding of less dense glass or plastic.

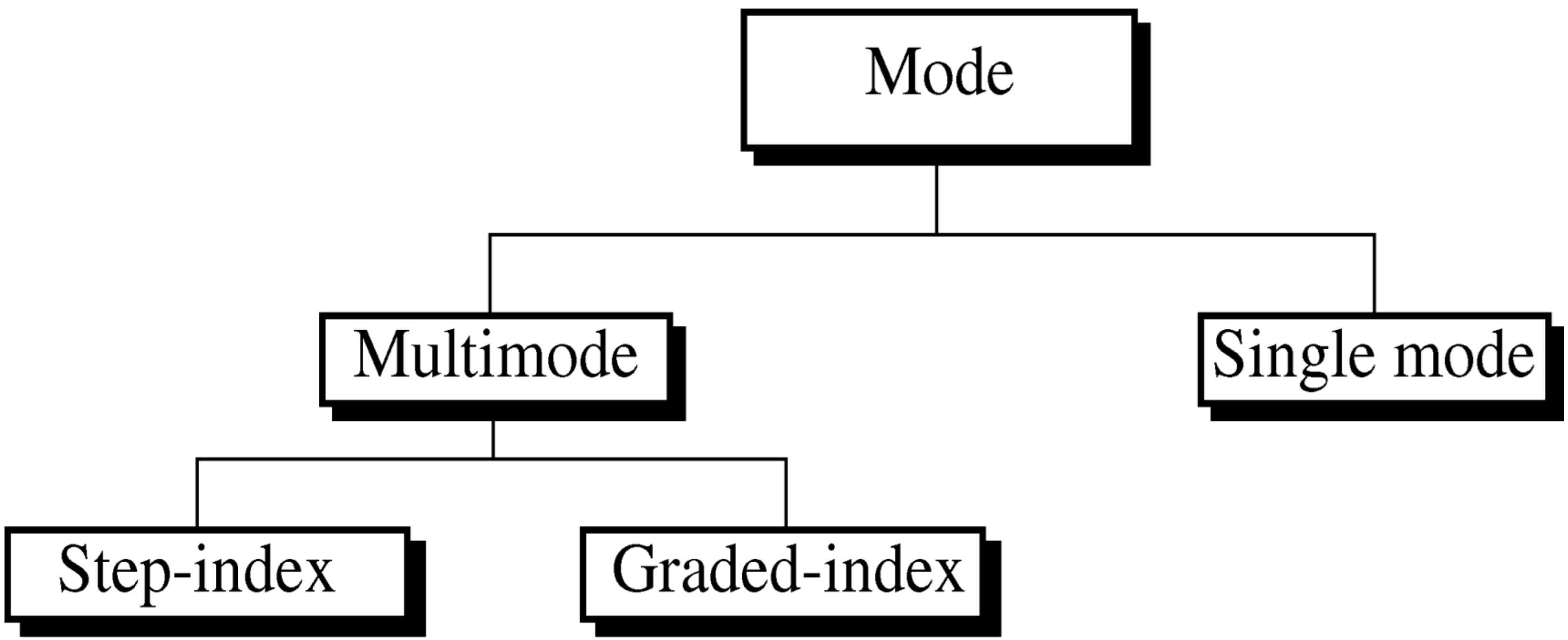
- The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it. See Figure.



Propagation Modes:

- Current technology supports two modes (multimode and single mode) for propagating light along optical channels, each requiring fiber with different physical characteristics.

- Multimode can be implemented in two forms: step-index or graded-index



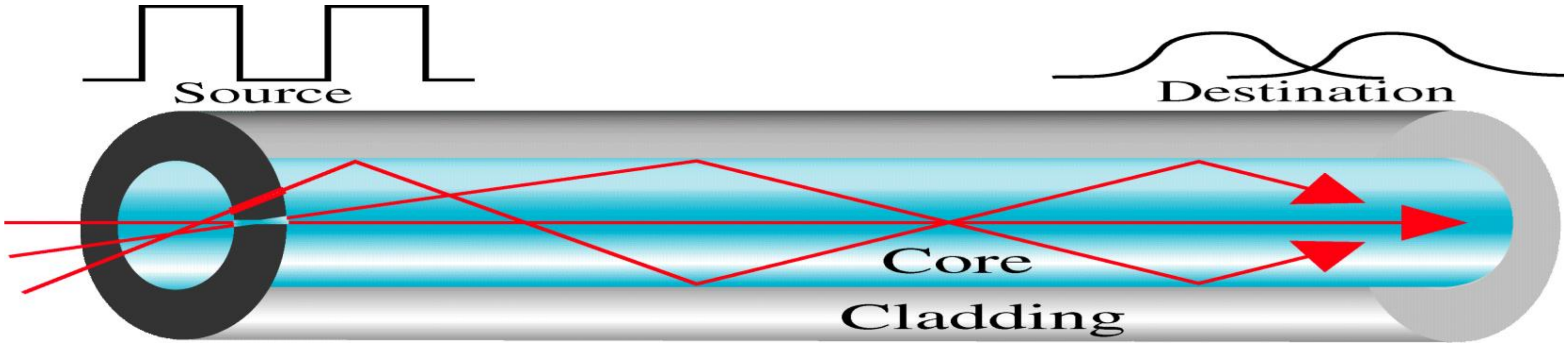
Multimode:

- Multimode is so named because multiple beams from a light source move through the core in different paths.

Multimode step-index fiber:

- the density of the core remains constant from the center to the edges.
- A beam of light moves through this constant density in a straight line until it reaches the interface of the core and the cladding.
- At the interface, there is an abrupt change due to a lower density; this alters the angle of the beam's motion.

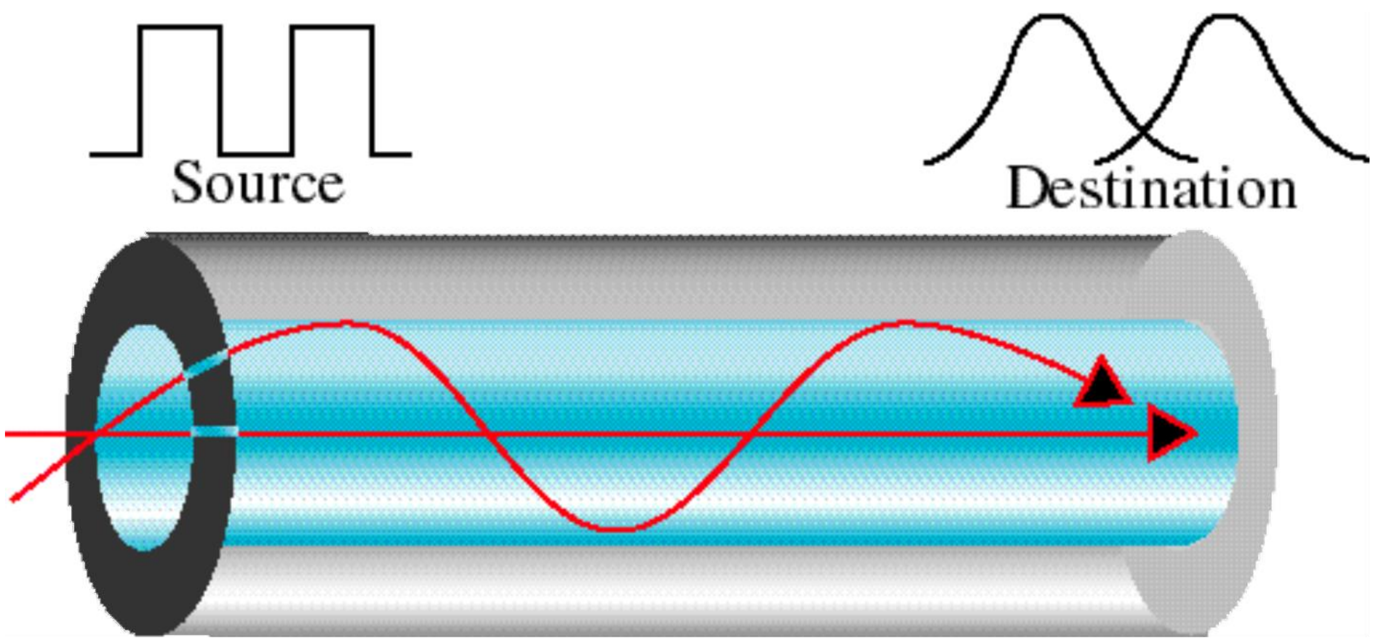
Multimode Step-Index



Multimode graded-index fiber:

- decreases this distortion of the signal through the cable.
- The word *index here refers to the index of refraction.*

Multimode Graded-Index



Single-Mode

- Single-mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal.

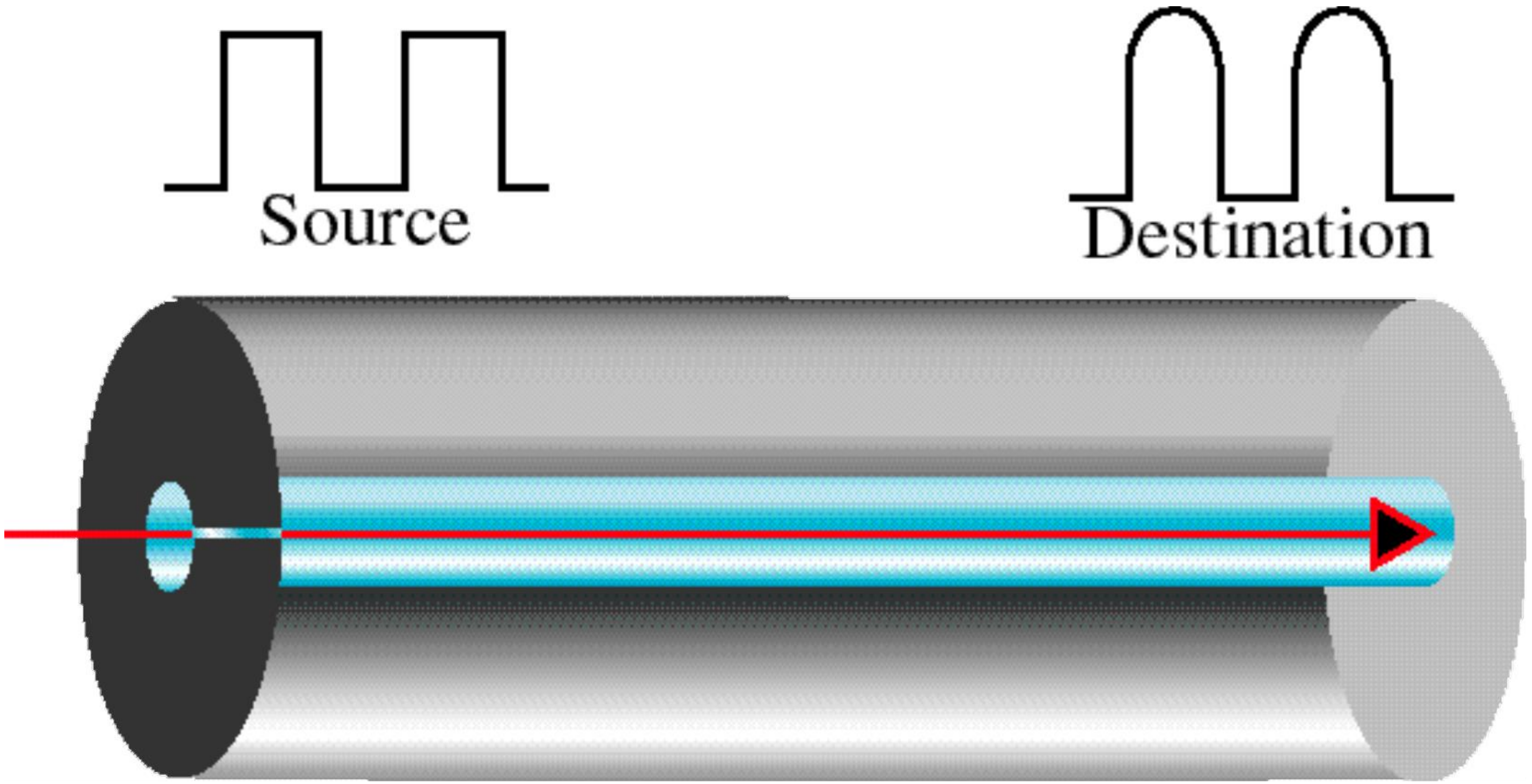
- The single mode fiber itself is manufactured with a much smaller diameter than that of multimode fiber

- The decrease in density results in a critical angle that is close enough to 90° to make the propagation of beams almost horizontal.

- In this case, propagation of different beams is almost identical, and delays are negligible.

- All the beams arrive at the destination "together" and can be recombined with little distortion to the signal.

Single Mode



Fiber Sizes:

- Optical fibers are defined by the ratio of the diameter of their core to the diameter of their cladding, both expressed in micrometers.

- The common sizes are shown in Table

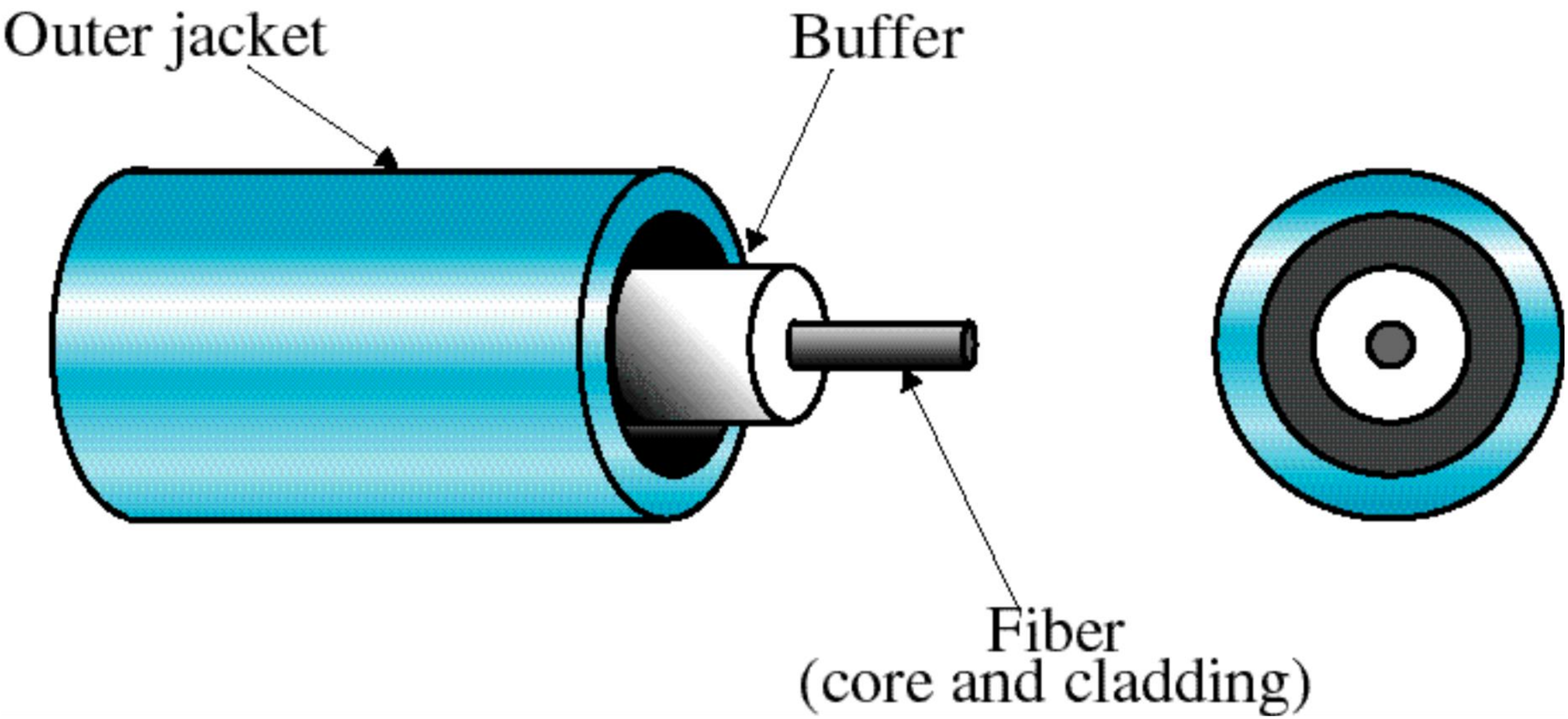
Fiber types

Type	*Core (μm)*	*Cladding (μm)*	*Mode*
501125	50.0	125	Multimode, graded index
62.51125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

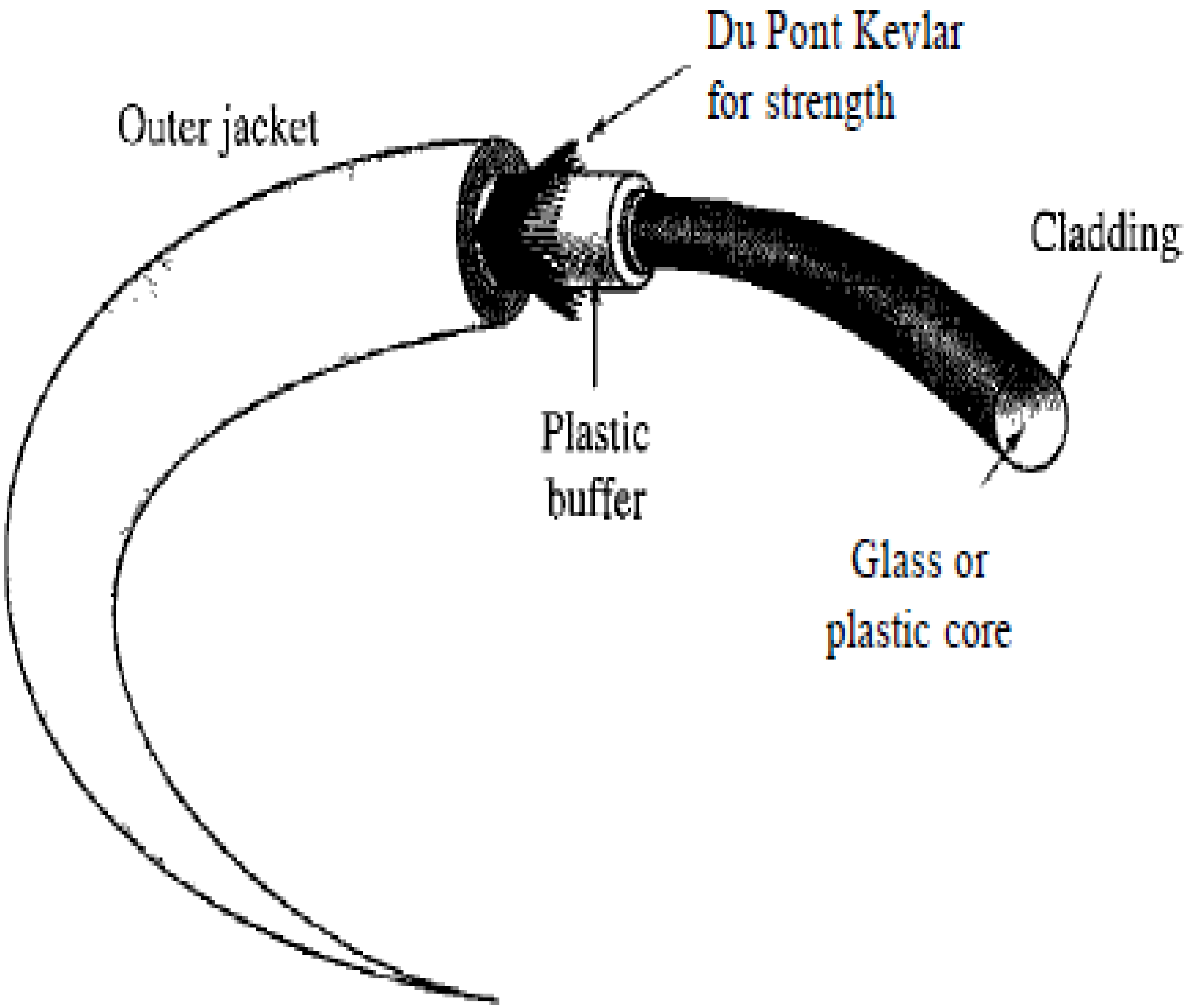
Cable Composition

- Figure shows the composition of a typical fiber-optic cable.

Fiber Construction



Fiber construction



- The outer jacket is made of either PVC or Teflon.
- Inside the jacket are Kevlar strands to strengthen the cable.
- Kevlar is a strong material used in the fabrication of bulletproof vests.
- The fiber is at the center of the cable, and it consists of cladding and core.
- Both core and cladding can be made of either glass or plastic but must be of different densities.

Light Sources for Optical Cable:

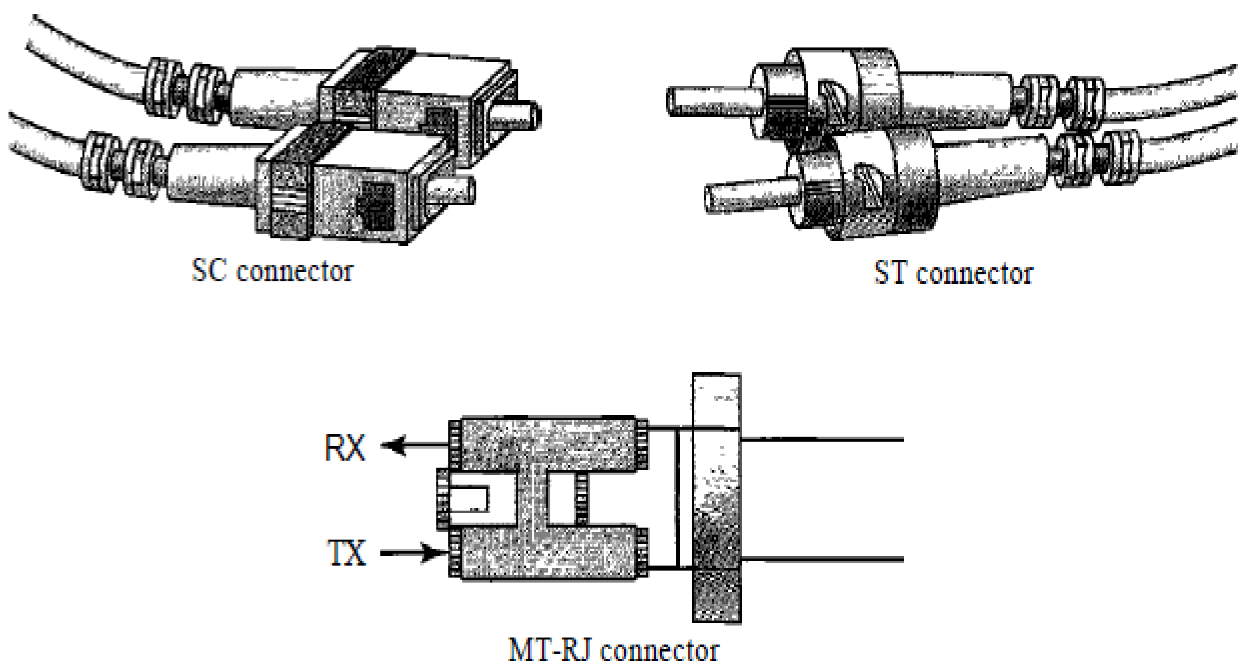
- The purpose of fiber-optic cable is to contain and direct a beam of light from source to target.
- For transmission to occur, the sending device must be equipped with a light source and the receiving device with a photosensitive cell(called a photodiode) capable of translating the received light into current usable by a computer.

- The light source can be either a light-emitting diode(LED).
- LED are the cheaper source.
- LEDs are limited to short-distance use.
- Lasers, on the other hand, can be focused to a very narrow range.
- Laser signals preserve the character of the signal over considerable distances.

Fiber-Optic Cable Connectors

- There are three types of connectors for fiber-optic cables,

Fiber-optic cable connectors



Subscriber Channel (SC) connector :

- **It is used for cable TV. It uses a push/pull** locking system.

Straight-Tip (ST) connector :

- **It is used for connecting cable to** networking devices. It is more reliable than SC.

MT-RJ connector:

- **It is a connector that is the same size as RJ45.**

Advantages and Disadvantages of Optical Fiber

- Advantages Fiber-optic cable has several advantages over metallic cable (twisted pair or coaxial).

Higher bandwidth:

- Fiber-optic cable can support dramatically higher bandwidths than either twisted-pair or coaxial cable.

Less signal attenuation:

- Fiber-optic transmission distance is significantly greater than that of other guided media.
- A signal can run for 50 km without requiring regeneration.
- We need repeaters every 5 km for coaxial or twisted-pair cable.

- Immunity to electromagnetic interference. Electromagnetic noise cannot affect fiber-optic cables.

- Resistance to corrosive materials. Glass is more resistant to corrosive materials than copper.

- Light weight. Fiber-optic cables are much lighter than copper cables.

- Greater immunity to tapping. Fiber-optic cables are more immune to tapping than copper cables

Disadvantages :

There are some disadvantages in the use of optical fiber.

- Installation and maintenance:

  - Fiber-optic cable is a relatively w technology.

  -Its installation and maintenance require expertise that is not yet available everywhere.

- Unidirectional light propagation:

  - Propagation of light is unidirectional.

  - If we need bidirectional communication, two fibers are needed.

- Cost:

  - The cable and the interfaces are relatively more expensive than those of other guided media.

- Fragility:

  - Glass fiber is more easily broken than wire.

UNGUIDED MEDIA: WIRELESS

- Unguided media transport electromagnetic waves without using a physical conductor.
- This type of communication is often referred to as wireless communication.
- **Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them.**
- **Radio, satellite microwave,, Bluetooth, and infrared light are all different forms of electromagnetic waves that are used to transmit data.**

Radio Frequency Allocation:

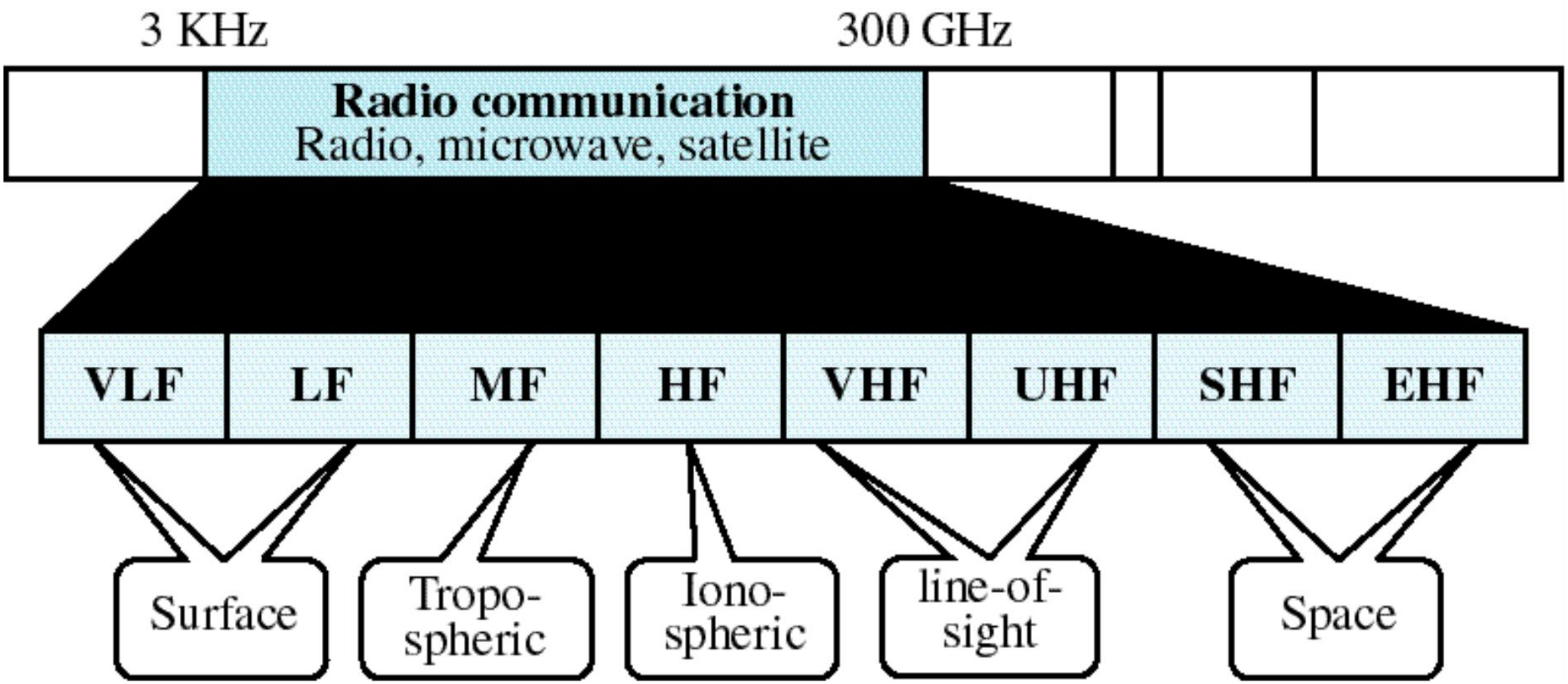
- The section of the electromagnetic spectrum defined as radio communication is divided into eight ranges, **called bands.**

- These bands are related from very low frequency(VLF) to extremely high frequency(EHF)

Figure 7-21

Radio Communication Band

VLF	Very low frequency	VHF	Very high frequency
LF	Low frequency	UHF	Ultra high frequency
MF	Middle frequency	SHF	Super high frequency
HF	High frequency	EHF	Extremely high frequency



Propagation of Radio Waves:

Types of Propagation:

- Radio wave transmission utilizes five different types of propagation:

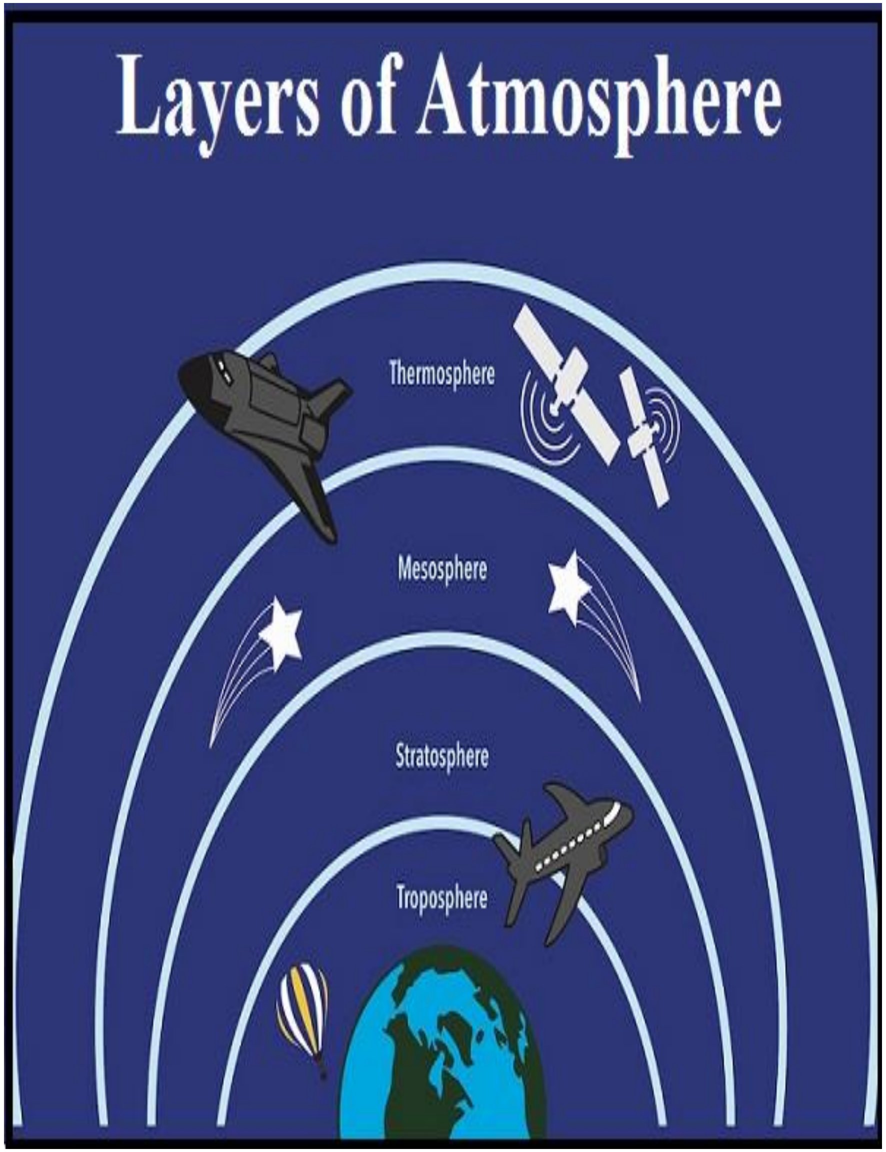
  (i) surface propagation

  (ii) tropospheric propagation

  (iii) Ionospheric propagation

  (iv) Line-of-sight propagation

  (v) space propagation


Layers of Atmosphere
Thermosphere
Mesosphere
Stratosphere
Troposphere

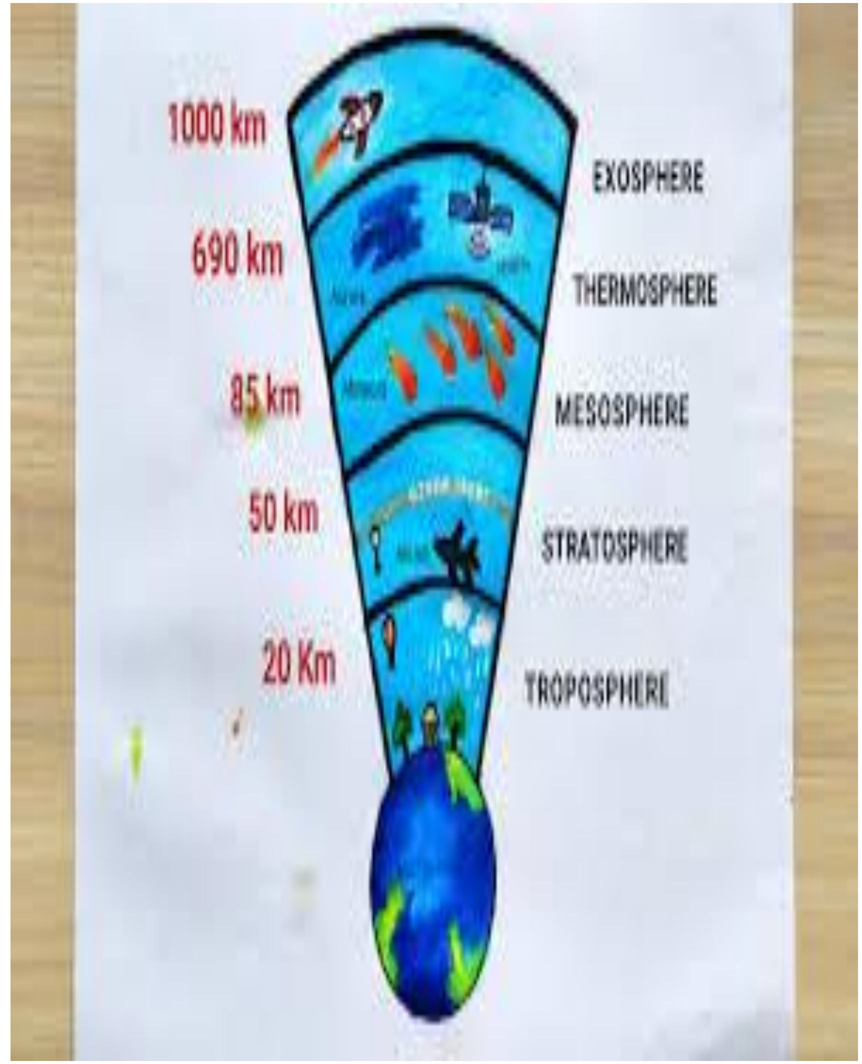
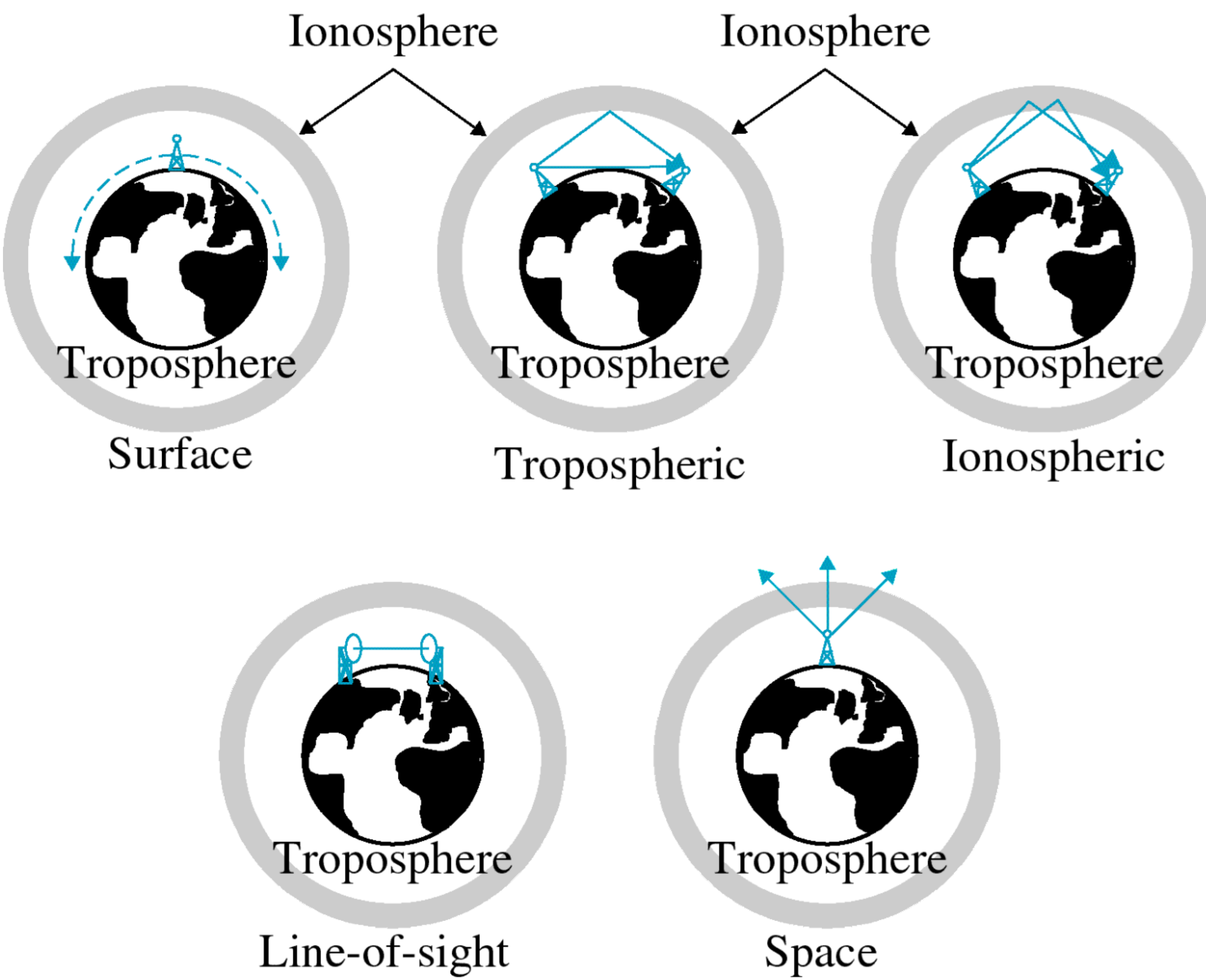

1000 km
690 km
85 km
50 km
20 Km
EXOSPHERE
THERMOSPHERE
MESOSPHERE
STRATOSPHERE
TROPOSPHERE

Figure 7-22

Propagation Types



- Radio technology considers the earth as surrounded by two layers of atmosphere:

  (a) Troposphere

  (b) Ionosphere

(a) Troposphere:

- is the portion of the atmosphere .
- approximately 30 miles from the earth's surface

(b) Ionosphere:

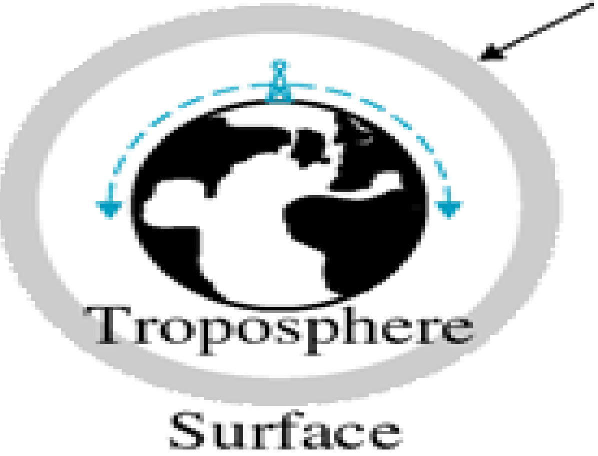
- is the layer of atmosphere above the troposphere but below the space.

(i) Surface Propagation:

- Radio waves travel through the lowest portion of the atmosphere, hugging the earth.

- At the lowest frequencies, signals emanate in all directions form the transmitting antenna and follow the curvature of the planet.

- Surface propagation can also take place in seawater.



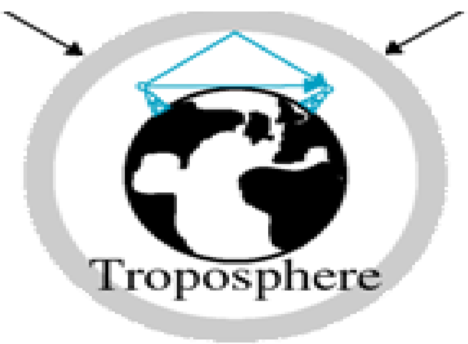
(ii) Tropospheric Propagation:

- It can work two ways.

-Either a signal can be directed in a straight line from antenna to antenna or it can be broadcast at an angle into the upper layer of the troposphere where it is reflected back down to the earth surface.

- The first method requires placement of receiver and transmitter.

-The second method allows greater distances to be covered.

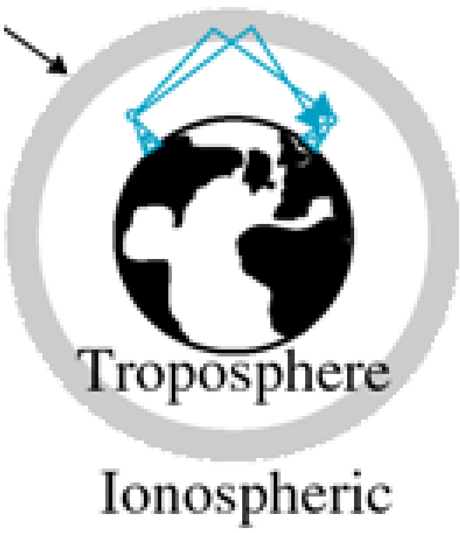


Tropospheric

(iii)Ionospheric Propagation:

- Higher-frequency radio waves radiate upward into the ionosphere where they are reflected back to the earth.

- This type of transmission allows for greater distances to be covered with lower power output.



(iv) Line-of-Sight Propagation:

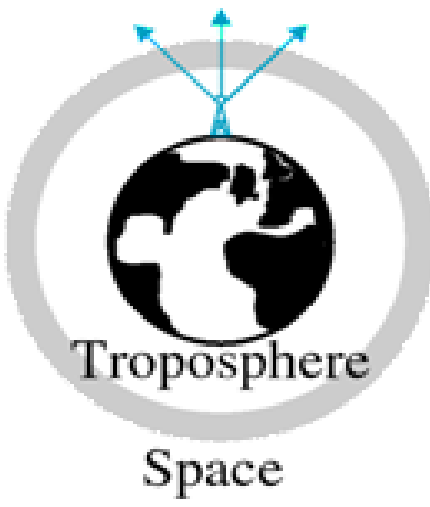
- Very high frequency signals are transmitted in straight lines directly from antenna to antenna.

- Antennas must be directional, facing each other, and either all enough or close enough together not to be affected by the curvature of the earth.

(v) Space Propagation:

- It utilizes satellite relays in place of atmospheric refraction.

-A broadcast signal is received by an orbiting satellite, which rebroadcasts the signal to the intended receiver back on the earth.



Propagation of Specific Signals

- The type of propagation used in radio transmission depends on the frequency (speed) of signal.

- Each frequency is suited for a specific layer of the atmosphere .

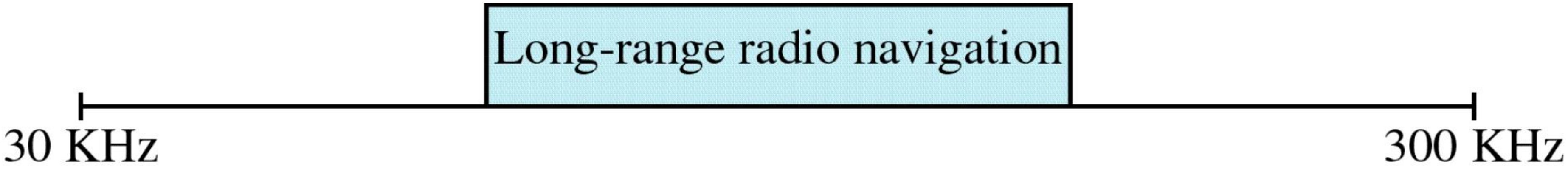
VLF(Very Low Frequency):

- Propagated as surface waves, usually through air sometimes through seawater.
- VLF waves do not much attenuation in transmission.
- VLF waves are used mostly for long-range radio navigation and for submarine communication.

LF (Low Frequency):

- Similar to VLF, LF waves are also propagated as surface waves.
- LF waves are used for long-range radio navigation.
- Attenuation is greater during the day time.

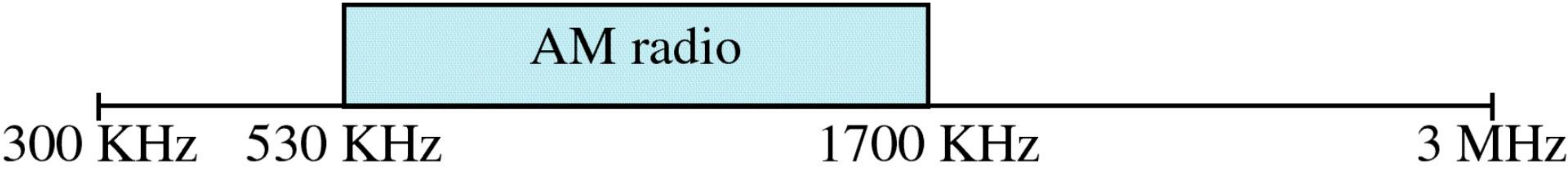
LF



MF(Middle Frequency):

- Signals are propagated in the troposphere.
- These frequencies are absorbed by the ionosphere.
- Absorption increases during the daytime.
- Uses for MF transmissions include AM radio,maritime radio, radio direction finding(RFD), and emergency frequencies.

MF



HF(High Frequency):

- Signals use ionospheric propagation.

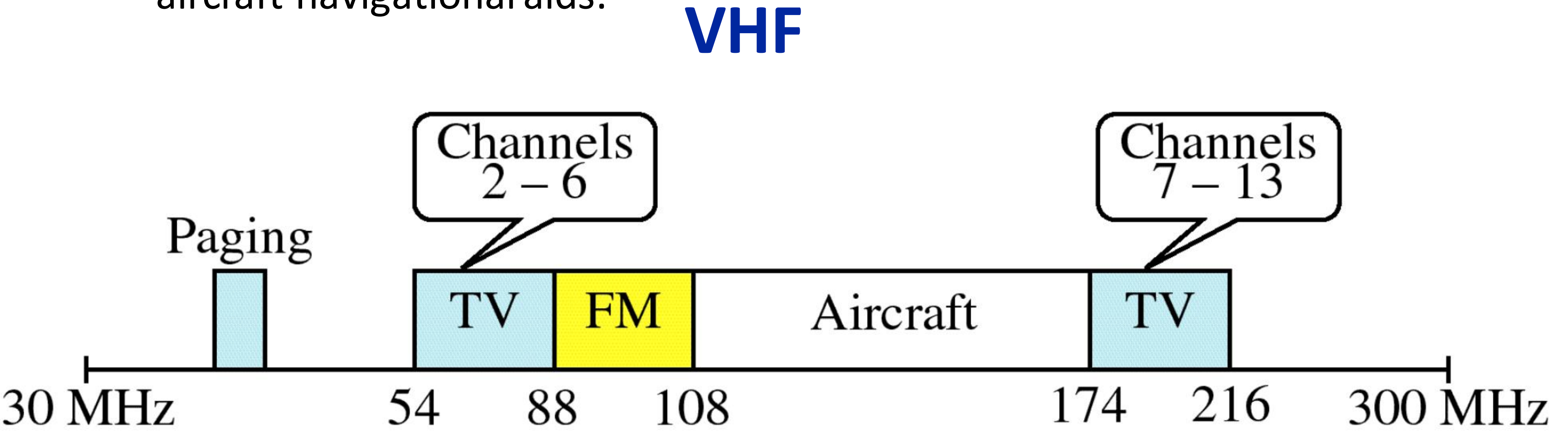
- These frequencies move into the ionosphere.

- Uses for HF signals include amateur radio(ham radio), citizens band(CB) radio, international broadcasting, military communication, long-distance aircraft and ship communication, telephone, telegraph.

VHF(Very High Frequency):

- Most VHF waves use the line-of-sight propagation.

- Uses for VHF include VHF television,FM radio, aircraft AM radio, and aircraft navigational aids.

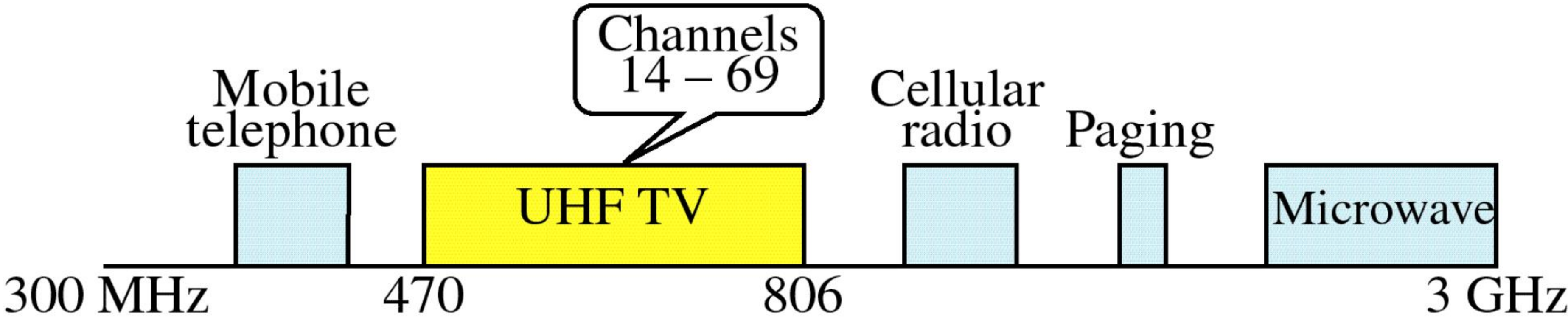


UHF(Ultra High Frequency):

- UHF waves always use line-of-sight propagation.

- Uses for UHF include UHF television, mobile telephone, cellular radio, paging, and microwave links.

UHF

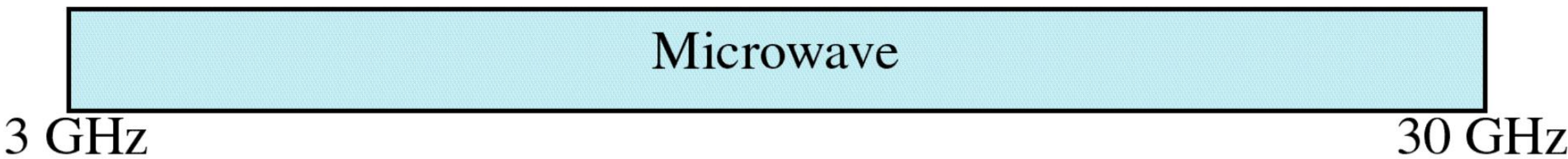


SHF(Super High Frequency):

- SHF waves are transmitted using mostly line-of-sight and some space propagation.

- Uses for SHF include terrestrial and satellite microwave and radar communication.

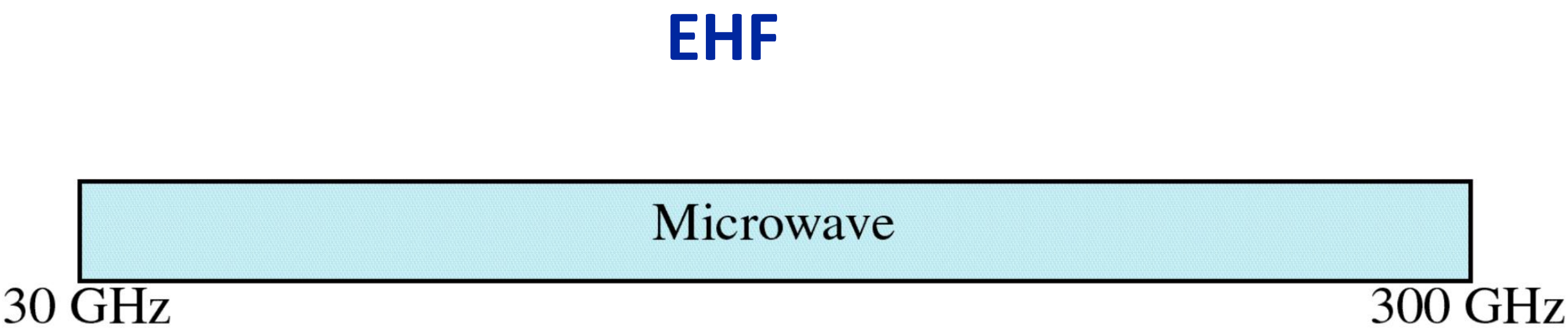
SHF



EHF(Extremely High Frequency):

- EHF waves use space propagation .

- Uses for EHF are predominantly scientific and include radar, satellite,and experimental communications.



Terrestrial Microwave:

- Microwaves do not follow the curvature of the earth and therefore require line-of-sight transmission and reception equipment.

- The distance coverable by a line-of-sight signal depends to a large extent on the height of the antenna: the taller the antennas, the longer the sight distance.

- Height allows the signal to travel farther without being stopped by the curvature of the planet and raises the signal above many surface obstacles , such as low hills and tall buildings .

- Typically antennas are mounted on towers that are in turn often mounted on hills or mountains.

- Microwave signals propagate in one direction at a time, which means that two frequencies are necessary for two-way communication such as a telephone conversation.

- One frequency is reserved for microwave transmission in one direction and the other for transmission in the other.

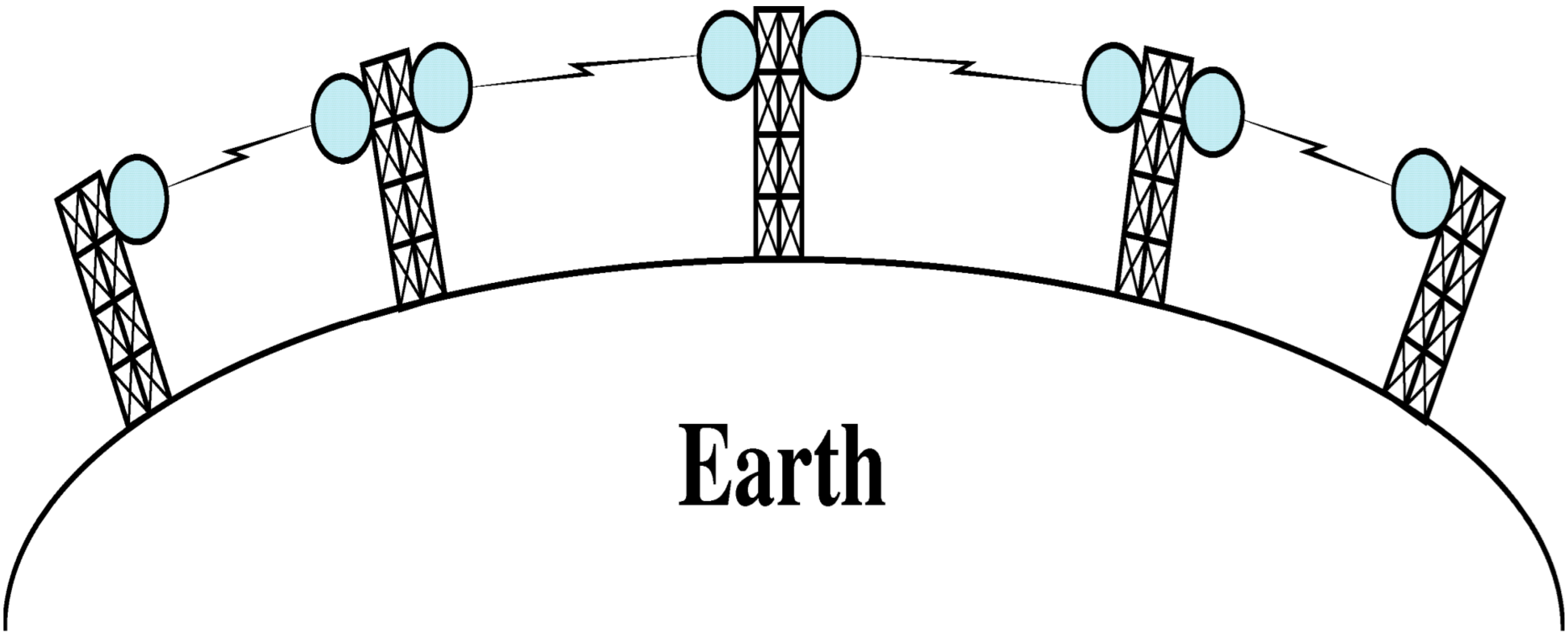
- Each frequency requires its own transmitter and receiver.

Repeaters:

- To increase the distance served by terrestrial microwave, a system of repeaters can be installed with each antenna.

- A signal received by one antenna can be converted back into transmittable form and relayed to the next antenna.

Terrestrial Microwave



- The distance required between repeaters varies with the frequency of the signal and the environment in which the antennas are found.

- A repeater may broadcast the regenerated signal either at the original frequency or at a new frequency, depending on the system.

Antennas:

- Two types of antennas are used for terrestrial communications:

(i) Parabolic Dish Antenna

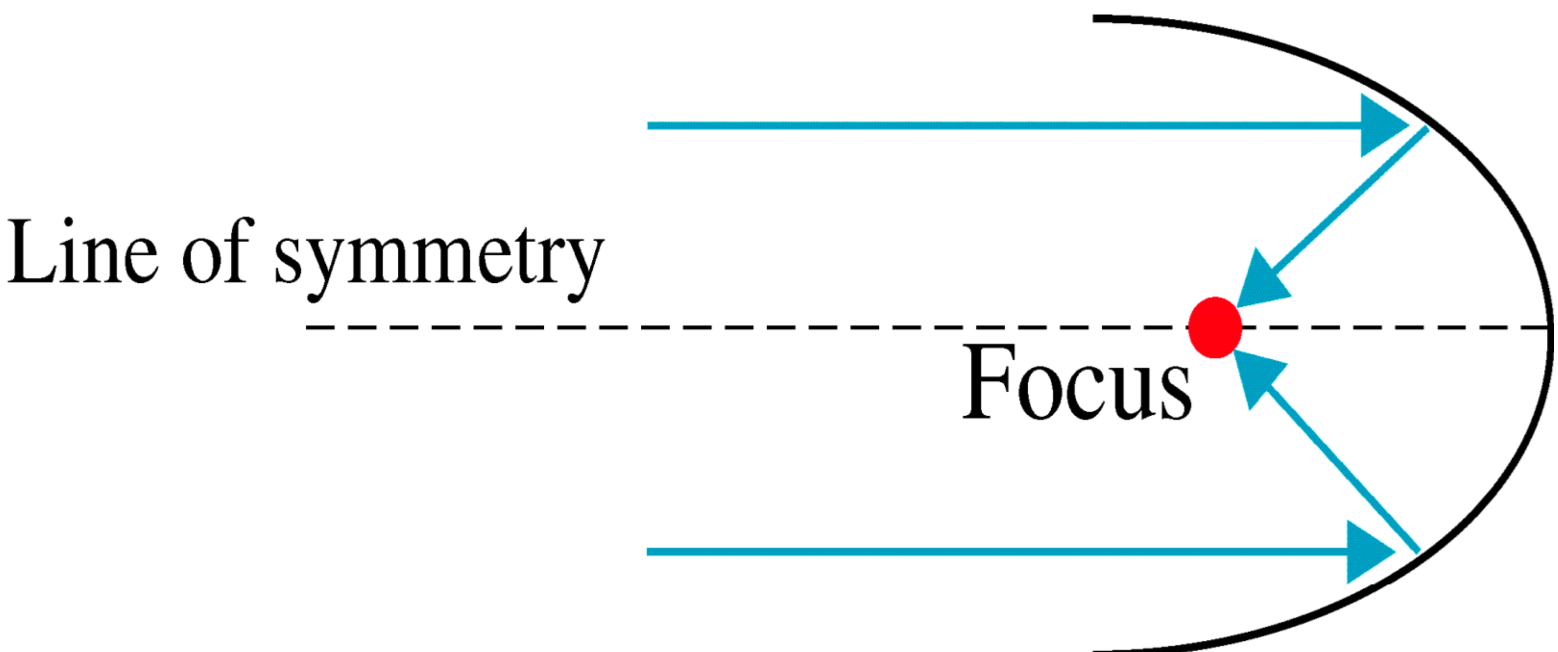
(ii) Horn Antenna

(i) Parabolic dish antenna:

- It is based on the geometry of a parabola:

  every line parallel to the line of symmetry(line of sight) reflects off the curve at angles such that they intersect in a common point called the focus.

Parabolic Dish Antenna



- The parabolic dish works like a funnel, catching a wide range of waves and directing them to a common point.

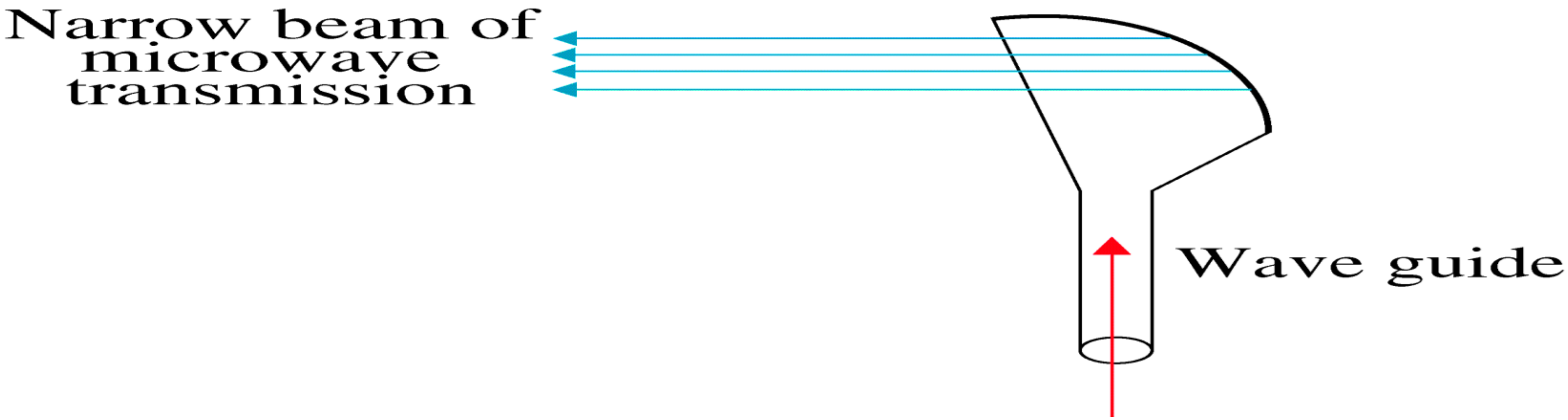
- Outgoing transmissions are broadcast through a horn aimed at the dish.

- The microwaves hit the dish and are deflected outward in a reversal of the receipt path.

(ii)Horn Antenna:

- outgoing transmissions are broadcast up a stem and deflected outward in a series of narrow parallel beams by the curved head.

Horn Antenna



- The received transmissions are collected by the scooped shape of the horn, and are deflected down into the stem.

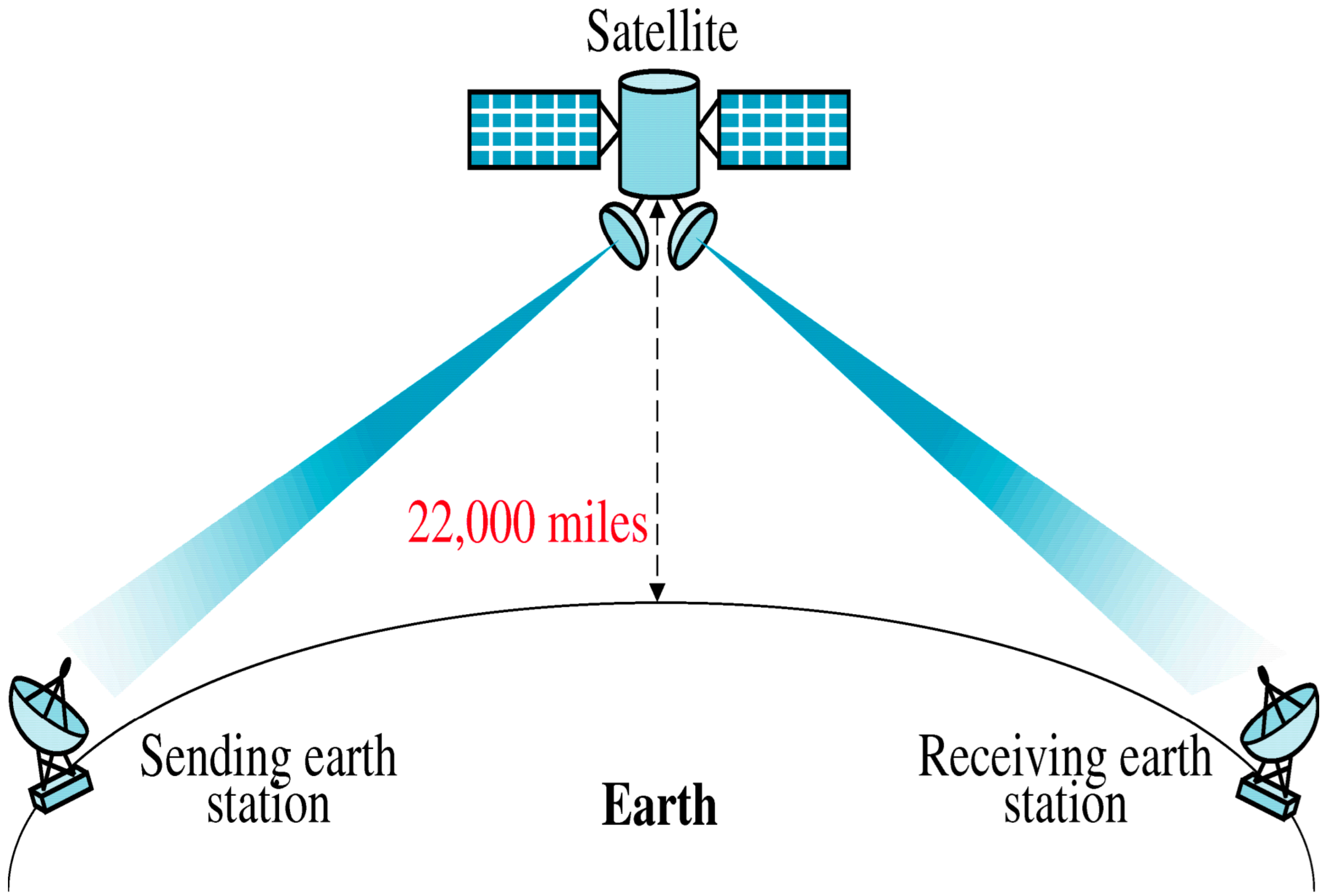
Satellite Communication:

-It is much like line-of-sight microwave transmission in which one of the stations is a satellite orbiting the earth.

- The principle is the same as terrestrial microwave, with a satellite acting as a super tall antenna and repeater.

- It can provide transmission capability to and from any location on earth , no matter how remote.

- This advantage makes high-quality communication available to undeveloped parts of the world without requiring a huge investment in ground-based infrastructure.


Satellite
22,000 miles
Sending earth station
Earth
Receiving earth station

Geosynchronous Satellites:

- Line-of-sight propagation requires that the sending and receiving antennas be locked onto each others location all time.

- For this reason, a satellite that moves faster or slower than the earth's rotation is useful only for short periods of time same.

- To ensure constant communication, the satellite must move at the same speed as the earth so that it seems to remain fixed above a certain spot.

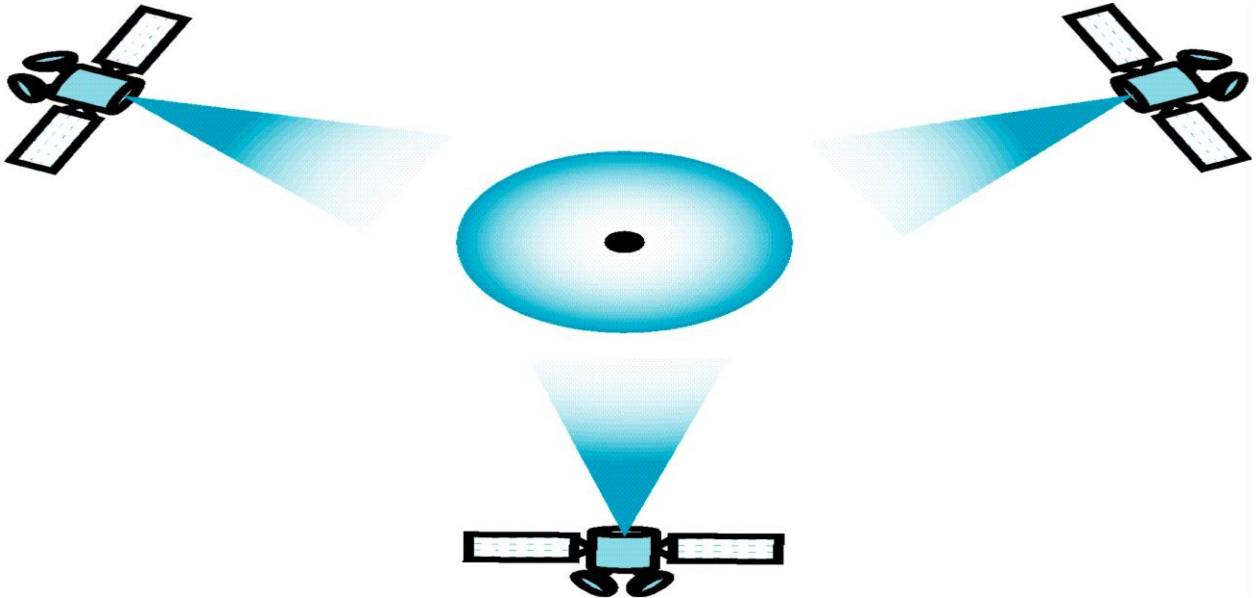
- Such satellites are called geosynchronous.

- This orbit occurs at the equatorial plane and is approximately 22,000 miles from the surface of the earth.

- But one geosynchronous satellite cannot cover the whole earth.

- Minimum of three satellites are used to provide full global transmission .

Geosynchronous Orbit



Frequency Bands for Satellite Communication:

- The frequencies reserved for satellite microwave communication are in the gigahertz(GHz).

- Each satellite sends and receives over the two different bands.

- Transmission from the earth to the satellite is called uplink.

- Transmission from the satellite to the earth is called downlink.

Satellite Frequency bands

Band	Downlink	Uplink
C	3.7 to 4.2 GHz	5.925 to 6.425 GHZ
Ku	11.7 to 12.2 GHz	14 to 14.5 GHZ
Ka	17.7 to 21 GHz	27.5 to 31 GHZ

Cellular Telephony:

- It is designed to provide stable communications connections between two moving devices or between one mobile unit and one stationary unit(land).

- A service provider must be able to locate and track a caller, assign a channel to the call , and transfer the signal from the channel to channel moves out of the range of one channel and into range of another.

- To make this tracking, each cellular service area is divided into small regions called cells.

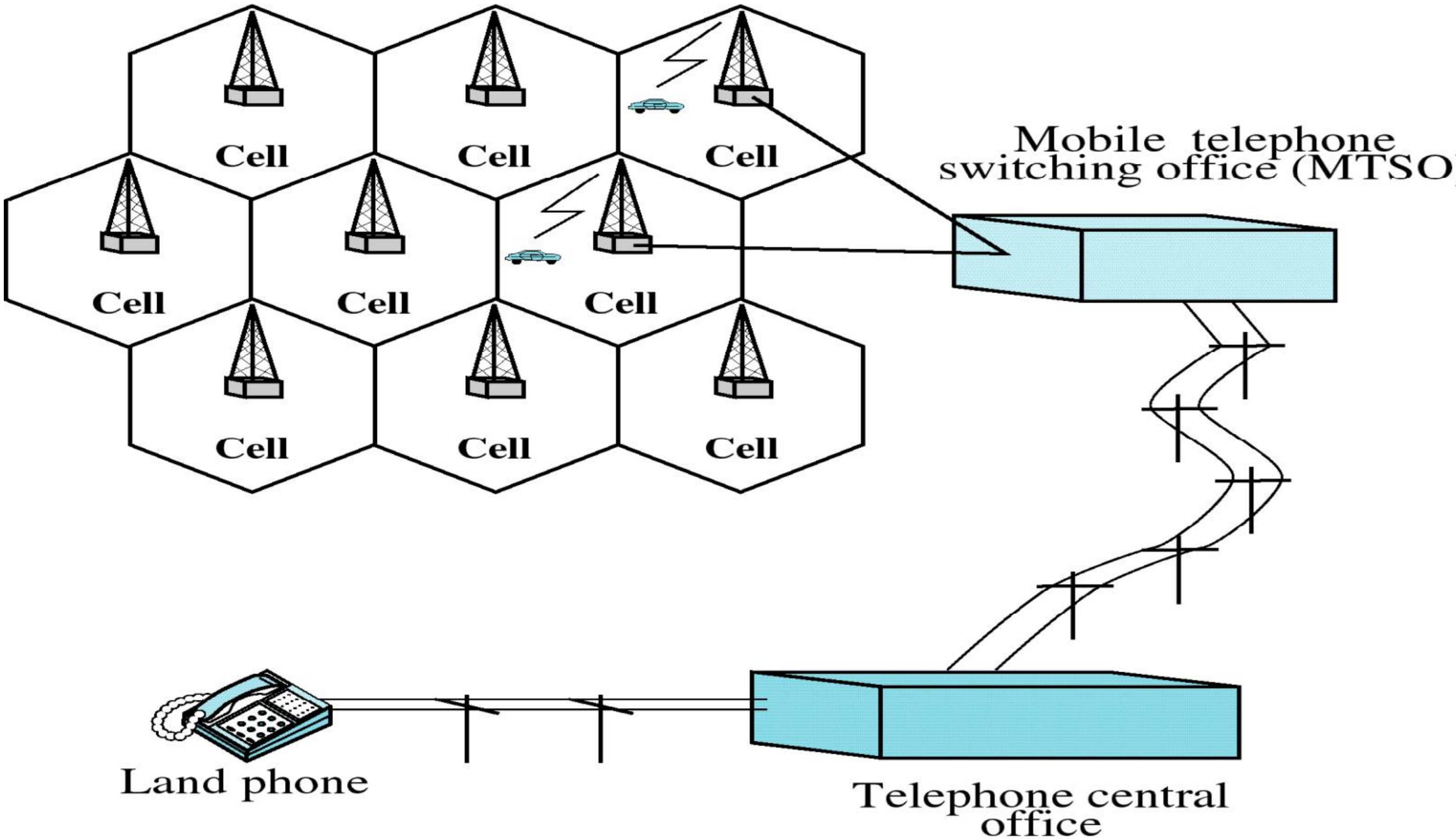
- Each cell contains an antenna and is controlled by a small office called the cell office.

- Each cell office is controlled by a switching office called a mobile telephone switching office(MTSO)

- The MTSO coordinates communication between all of the cell offices and the telephone central office.

- It is a computerized center that is responsible for connecting calls as well as recording call information and billing.

Cellular System



- Cell size is not fixed and can be increased or decreased depending on the population of the area.

- The typical radius of a cell is 1 to 12 miles.

Cellular Bands:

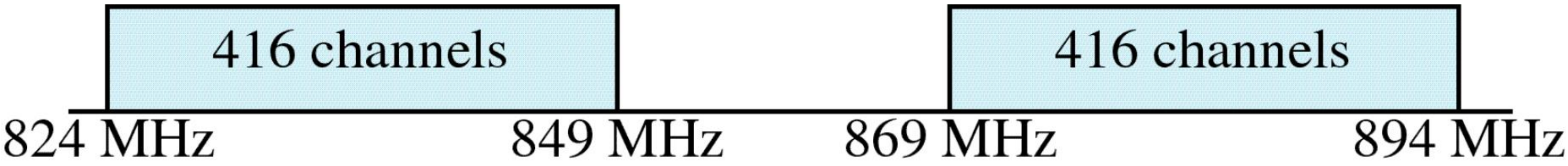
- Traditional cellular transmission is analog.

- To minimize noise, frequency modulation is used for communication between the mobile telephone and the cell office.

- The band between 824 and 849 MHz carries communications that initiate from mobile phones.

- The band between 869 and 894 MHz carries those communications that initiate from land phone.

Cellular Bands



- Carrier frequencies are spaced every 30 KHz , allowing each band to support up to 833 carriers.

- Two carriers are required for full-duplex communication which doubles the required width of each channel to 60 KHz .

- To prevent interference, channels are distributed among the cells , adjacent cells do not use the same channels.

- This restriction means that each cell normally has access to only 40 channels.

Transmitting:

- To place a call from a mobile phone, the caller enters a code of 7 or 10 digits(a phone number) and presses the send button.
- The mobile phone then scans the band, seeking a setup channel with a strong signal, and sends the data (Phone number) to the closest cell office using that channel.
- The cell office relays the data to the MTSO .
- The MTSO sends the data onto the telephone central office.
- If the party is available, a connection is made and the result is relayed back to the MTSO.
- At this point, the MTSO assign voice channel to the call and a connection is established.

- The mobile phone automatically adjusts its tuning to the new channel and voice communication can begin.

Receiving:

- When a land phone places a call to a mobile phone,the telephone central office sends a number to the MTSO.

- The MTSO searches for the location of the mobile phone by sending query signals to each cell in a process called paging.

- Once a mobile phone is found, the MTSO transmits a ringing signal and, when the mobile phone is answered, assigns a voice channel to the call, allowing voice communication to begin.

Handoff:

- It happen, during a conversation, the mobile phone moves from one cell to another.
- When it does , the signal may become weak.
- To solve this problem, the MTSO monitors the level of the signal every few seconds.
- If the strength of the signal diminishes, the MTSO seeks a new cell that can accommodate the communication better.
- The MTSO then changes the channel carrying the call.

Digital:

- Analog cellular services are based on a standard called analog circuit switched cellular(ACSC).

- To transmit digital data using an ACSC service requires a modem with a maximum speed of 9600 to 19,200 bps.

- Cellular Digital Packet Data(CDPD) provides low-speed digital service over the existing cellular network.

- It is based on the OSI Model.

- CDPD uses Trisector. A trisector is a combination of three cells each using 19.2 kbps.

- United states is divided into 12,000 trisectors. For every 60 trisectors, there is one router.