V SEMESTER

COMPUTER NETWORKS
21CST502

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UNIT 1

INTRODUCTION TO NETWORKS

UNIT 1

CHAPTER 1
INTRODUCTION

Introduction

- **When we communicate, we share information**
- **Information sharing can be**
  - **Local Communication**
    - Communication between individuals occur face to face
  - **Remote Communication**
    - Communication between individuals occur over distance
- **Telecommunication**
  - Communication at a distance
  - In Greek **Tele** means **Far**
  - **Example** Telephony, Telegraphy, Television

1.1 Data Communications

- **Data :**
  - Data refers to the information presented in whatever form is agreed upon by the parties creating and using data.

- **Data Communications :**
  - Exchange of data between two devices via some form of transmission medium such as a wire cable.
  - For Data communication to occur, the communicating devices must be a part of a **Communication System.**
  - **Communication System** consists of
    - **Hardware** – Physical equipment
    - **Software** - Programs

Fundamental Characteristics of Data Communications

- **Delivery :**
  - The system must deliver data to the Correct Destination
- **Accuracy :**
  - The system must deliver the Data accurately.
- **Timeliness :**
  - The system must deliver data in a Timely manner.
  - Real Time Transmission – for audio & videos
- **Jitter :**
  - It is the variation in the packet arrival time.

Components of Data Communications System

- **Message :**
  - It is the information to be communicated.
  - Text, numbers, pictures, audio, video
- **Sender :**
  - It is the device that sends data message.
  - Computers, telephone handset, video camera
- **Transmission medium :**
  - It is the physical path by which a message travels from sender to receiver
  - Twisted pair wire, coaxial cable, fiber optics cable, radio waves

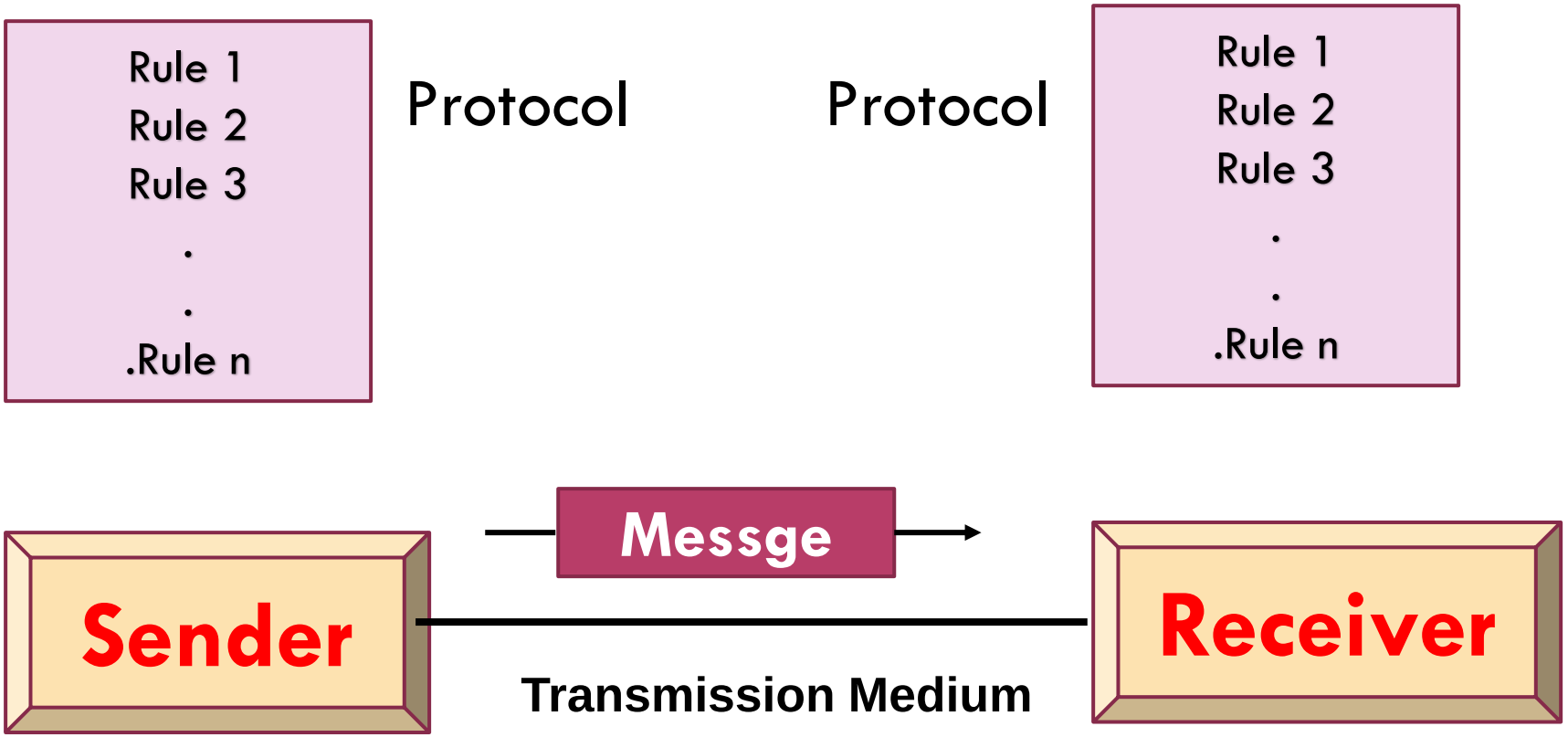
Components of Data Communications System

Contd..

- **Receiver :**
  - It is the device that receives the data message.
  - Computers, telephone handset, television, workstation
- **Protocol :**
  - It is a set of rules that govern data communications.
  - It represents the agreement between the communicating devices.
  - Without a protocol, two devices may be connected but not communicating.

Components of Data Communications System

Contd..



Data Representation

- **Text :**
  - Bit pattern
  - Code
  - **Unicode** – 32 bits - any language
  - **ASCII** American Standard Code for Information Interchange
- **Numbers :**
  - Bit patterns
  - ASCII is not used
  - **Decimal** - Base 10
  - **Binary** – Base 2
  - **Hexadecimal** – Base 16

Data Representation

- **Images :**
  - Bit patterns
  - Matrix of pixels (picture elements)
  - **Black and White image**
    - 0 – Black
    - 1 - White
  - **Grey Scale image**
    - 00 Pure black
    - 01 Dark Grey
    - 10 Light Grey
    - 11 Pure white
  - **Color image**
    - RGB method – Red, Green, Blue
    - YCM Method – Yellow, Cyan, Magenta
- **Audio**
- **Video**

AGENDA

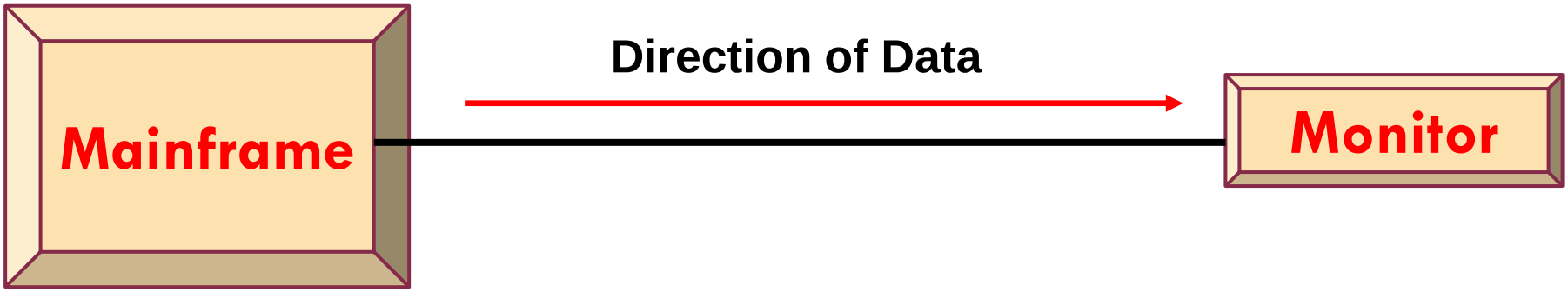
1. DATA COMMUNICATIONS
2. NETWORKS

Data Flow

- **Communication (Data flow) between two devices can be**
  - Simplex
  - Half-duplex
  - Full-duplex

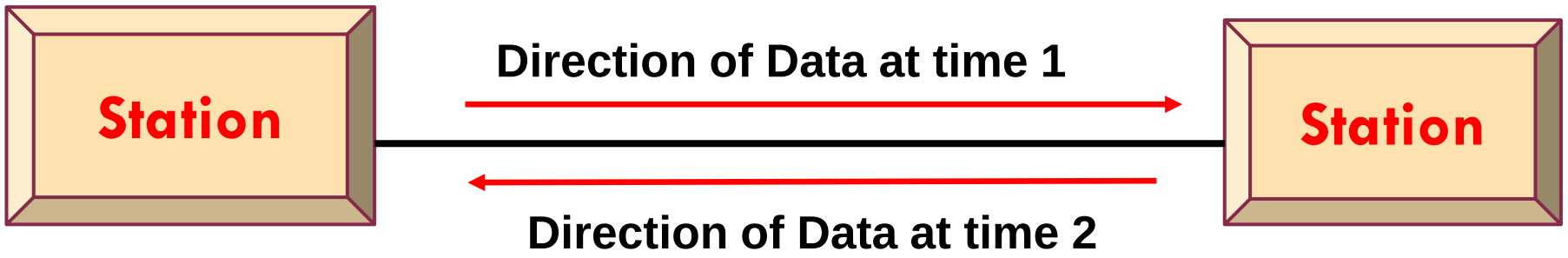
Simplex Communication (Data flow)

- **Communication :** Unidirectional
- **Transmission :** Only one device on a link can transmit and the other device can only receive.
- **Channel capacity :** used to send data in one direction
- **Example :** Keyboard, Traditional monitor



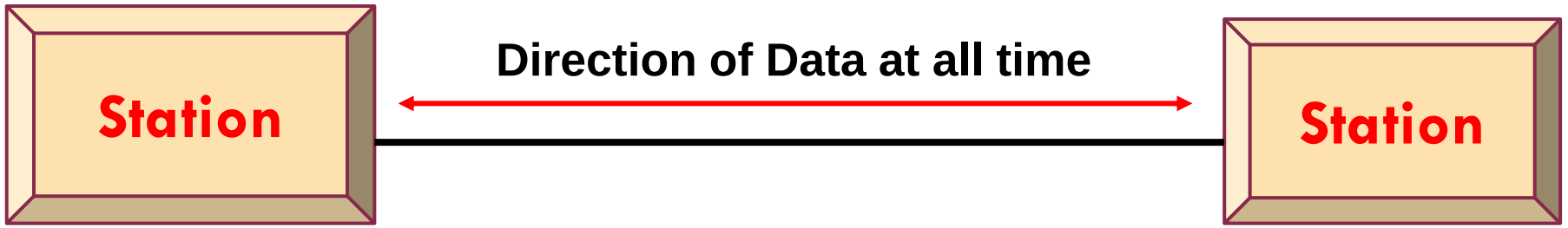
Half-Duplex Communication (Data flow)

- **Communication :** Each station can both transmit and receive, but not at the same time.
- **Transmission :** When one device is sending the other device can only receive and vice versa.
- **Channel capacity :** Entire capacity of the channel is taken over by the device which is transmitting at that time.
- **Example :** Walkie–Talkies, CB (Citizen Band) radios



Full-Duplex Communication (Data flow) or Duplex

- **Communication :** Bi-directional
- **Transmission :** Both stations can transmit and receive, simultaneously
- **Channel capacity :** Entire capacity of the channel is divided between the two devices. The sharing can occur in 2 ways:
  - The link must contain 2 physically separate transmission paths. One for sending and other for receiving.
  - The capacity of the channel is divided between signals travelling in both directions.
- **Example :** Telephone network



1.2 Networks

- **Network** is the interconnection of a set of devices capable of communication.
- **A Device can be**
  - Host (or End System)
  - Connecting device

- **Host - Example:** Large computer, Desktop, laptop, workstation, cellular phone, security system, etc.
- **Connecting device**
  - **Router :** Connects the network to other networks
  - **Switch :** Connects devices together
  - **Modem :** Changes the form of data

Networks

- **Transmission media** used for connecting the devices in a network are
  - **Wired : Example** Cable
  - **Wireless : Example** Air

- In **Distributed Processing** a task is divided among multiple computers.
  - Most networks use distributed processing instead of one single large machine being responsible

Network Criteria

- **A network must meet a certain criteria such as**
  - **Performance :**

    refers to the measures of service quality of a network as perceived by the user
  - **Reliability :**

    refers to the working of the network without disruption for a specified period of time
  - **Security :**

    refers to protecting the usability and integrity of the network and data.

Network Criteria - Performance

- **Networking metrics used to evaluate Performance**
  - **Throughput :**

    is the amount of data that can be transmitted through a network within a given period of time.
  - **Delay :**

    is the amount of time required for one packet to go from its source to a destination.
- Performance increases if throughput is more and delay is less.
- **Performance can be measured based on**
  - **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 response

Network Criteria – Performance (Contd..)

- **Performance of a network depends on**
  - Number of users
  - Type of transmission medium
  - Capabilities of the connected hardware
  - Efficiency of the software

Network Criteria - Reliability

- **Network reliability is measured by**
  - Frequency of failure
  - Time it takes to link to recover from a failure
  - Network's robustness in a Catastrophe

Network Criteria - Security

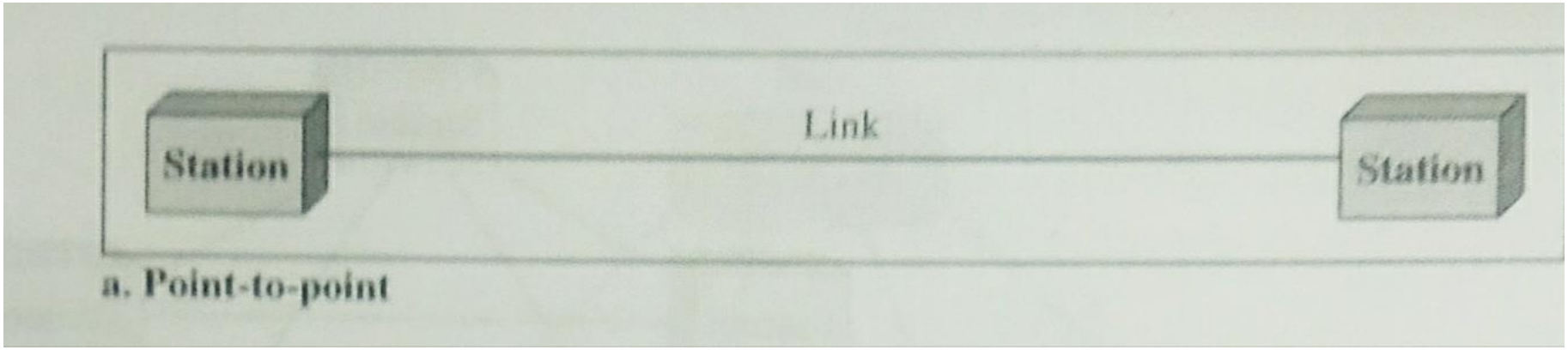
- **Network security issues include**
  - Protecting data from unauthorized access
  - Protecting data from damage & development
  - Implementing policies & procedures for recovery from breaches & data losses

Physical Structures

- **Network attributes are**
  - **Types of connection**
    - Point-to-Point connection
    - Multipoint connection (Multidrop connection)
  - **Physical Topology**
    - Mesh topology
    - Star topology
    - Bus topology
    - Ring Topology
  - **Network Models**
    - LAN – Local Area Network
    - WAN –Wide Area Network
    - MAN – Metropolitan Area Network

Types of Connection – Point-to-Point connection

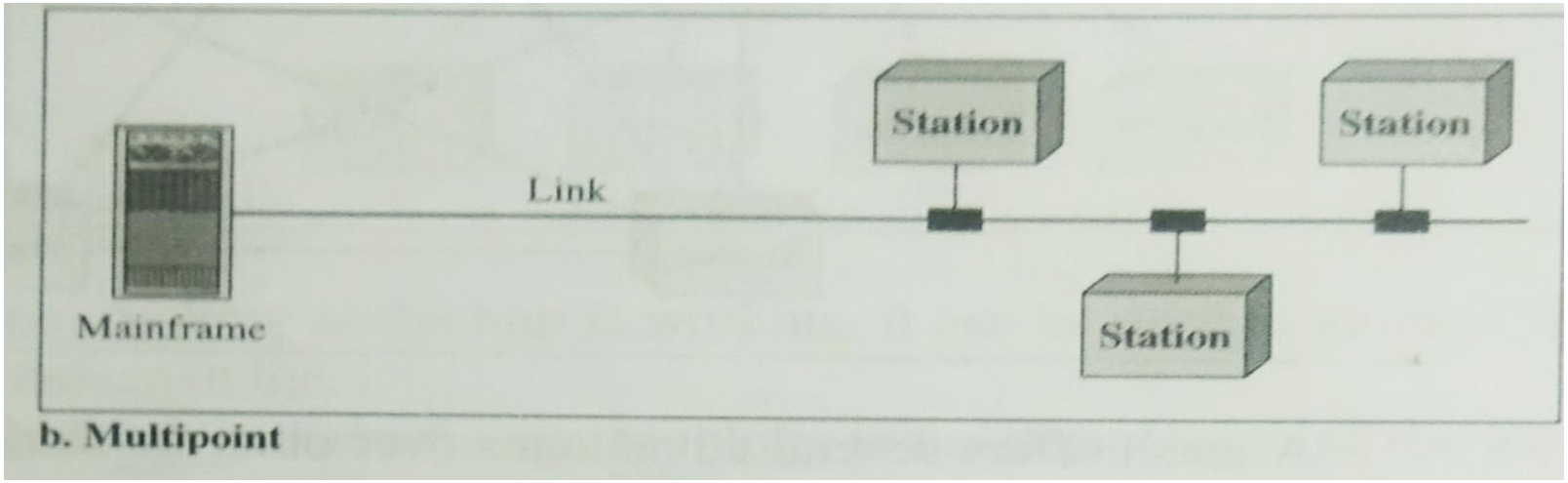
- Provides dedicated link between 2 devices
- Entire capacity of the link is for transmission between these 2 devices
- Connections use
  - Actual length of wire or cable to connect the 2 ends
  - Microwave or satellite links
- **Example :** connection between Television's control system and infrared remote control



a. Point-to-point

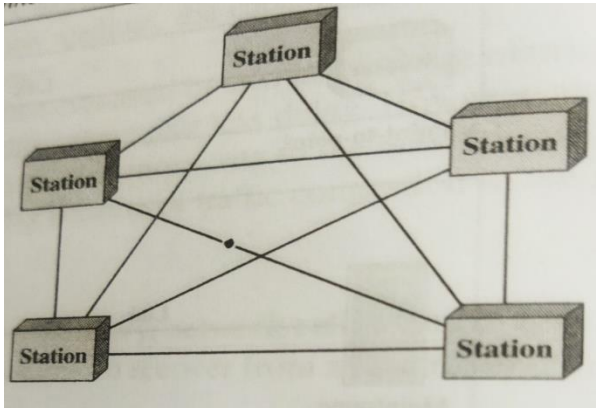
Types of Connection – Multipoint connection (Multidrop connection)

- More than 2 specific devices share a single link
- The capacity of the channel is shared in one of the ways
  - Spatially
  - Temporally
- **Spatially :** Several devices can use the link simultaneously
- **Temporally :** Users (devices) must take turns to use the link
- **Example :** Radio and Television broadcasting



Physical Topology – Mesh Topology

- A mesh topology is a type of computer network in which each node (computer or other device) is connected to every other node in the network.
- Used in large organizations or companies because it can handle a large amount of data traffic and can be easily expanded.
- All the devices are connected to each other .
- There exists a dedicated point-to-point link between all devices.
- There are n(n-1) physical channels to link n devices.
- Every device not only sends its own data but also relays data from other nodes.
- For 'n' nodes,
  - there are n(n-1) physical-links
  - there are n(n-1)/2 duplex-mode links
- Every device must have (n–1) I/O ports to be connected to the other (n-1) devices.



Physical Topology – Mesh Topology (Contd..)

Advantages:

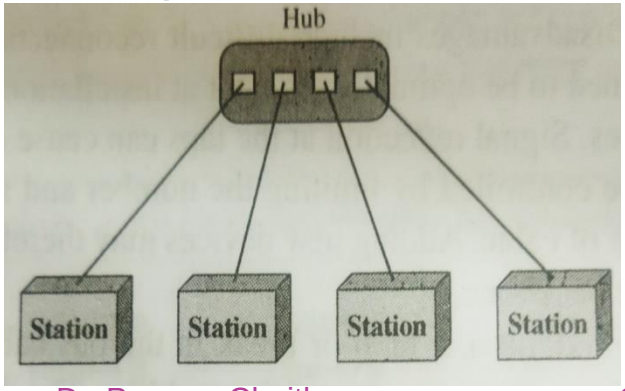
- Congestion reduced: Each connection can carry its own data load.
- Robustness: If one link fails, it does not affect the entire system.
- Security: When a data travels on a dedicated-line, only intended-receiver can see the data.
- Easy fault identification & fault isolation: Traffic can be re-routed to avoid problematic links.

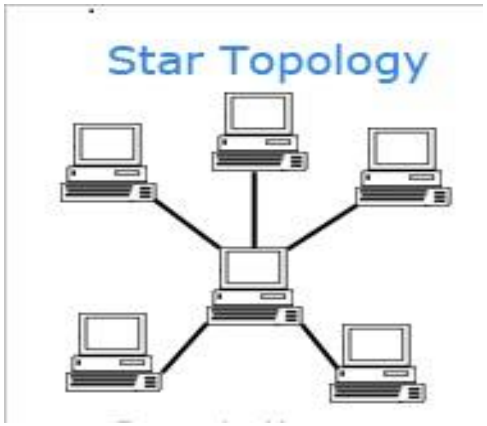
Disadvantages:

- Difficult installation and reconfiguration.
- Bulk of wiring occupies more space than available space.
- Very expensive: as there are many redundant connections.
- Not mostly used in computer networks. It is commonly used in wireless networks.
- High redundancy of the network-connections.

Physical Topology – Star Topology

- Every node connects to a central network device in this configuration, like a hub, switch, or computer.
- The central network device acts as a server, and the peripheral devices act as clients.
- Entire capacity of the link is for transmission between these 2 devices
- There exists a dedicated point-to-point link between a device & a hub.
- The devices are not directly linked to one another. Thus, there is no direct traffic between devices. The hub acts as a junction:
- If device-1 wants to send data to device-2, the device-1 sends the data to the hub, then the hub relays the data to the device-2.





Physical Topology – Star Topology (Contd..)

Advantages:

- Less expensive: Each device needs only one link & one I/O port to connect it to any devices.
- Easy installation & reconfiguration: Nodes can be added/removed without affecting the network.
- Robustness: If one link fails, it does not affect the entire system.
- Easy to detect and troubleshoot fault.
- Centralized management: The hub manages and controls the whole network.

Disadvantages:

- Single point of failure: If the hub goes down, the whole network is dead.
- Cable length required is the more compared to bus/ring topologies.
- Number of nodes in network depends on capacity of hub.

Physical Topology – Bus Topology

- Bus topology is a type of network topology in which all devices are connected to a single cable called a "bus."
- This cable serves as a shared communication medium, allowing all devices on the network to receive the same signal simultaneously.
- Every device communicates with the other device through this bus.
- A data from the source is broadcasted to all devices connected to the bus.
- Only the intended-receiver, whose physical-address matches, accepts the data.
- Devices are connected to the bus by drop-lines and taps.
- A drop-line is a connection running between the device and the bus.
- A tap is a connector that links to the bus

Figure 1.4 *A bus topology connecting three stations*

Physical Topology – Bus Topology (Contd..)

- **Advantages:**
  - Easy installation.
  - Cable required is the least compared to mesh/star topologies.
  - Redundancy is eliminated.
  - Costs less (Compared to mesh/star topologies).
  - Mostly used in small networks. Good for LAN.
- **Disadvantages:**
  - Difficult to detect and troubleshoot fault.
  - Signal reflection at the taps can cause degradation in quality.
  - A fault/break in the cable stops all transmission.
  - There is a limit on
  - Cable length
  - Number of nodes that can be connected.
  - Security is very low because all the devices receive the data sent from the source.
  -

Physical Topology – Ring Topology

- Ring topology is a type of network configuration where devices are connected in a circular manner, forming a closed loop.
- Each device is connected to exactly two other devices, creating a continuous pathway for data transmission.
- Each device is connected to the next, forming a ring.
- There are only two neighbors for each device.
- Data travels around the network in one direction till the destination is reached.
- Sending and receiving of data takes place by the help of token.
- Each device has a repeater.
- A repeater
  - receives a signal on transmission-medium
  - regenerates & passes the signal to next device.

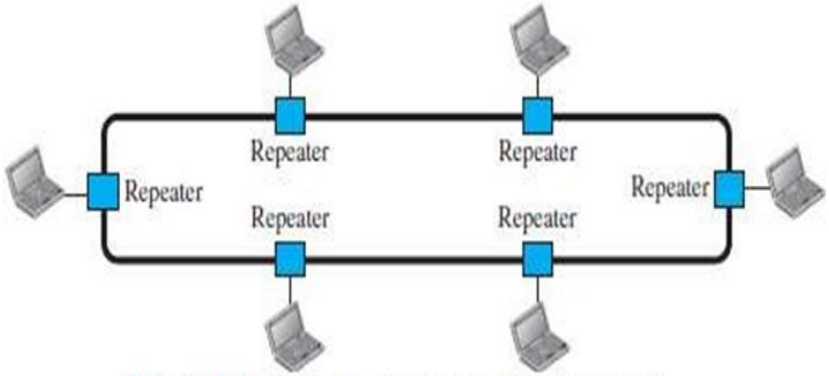


Figure 1.6 *A ring topology connecting six stations*

Physical Topology – Ring Topology (Contd..)

Advantages :

- Easy installation and reconfiguration.
  - To add/delete a device, requires changing only 2 connections.
- Fault isolation is simplified.
  - If one device does not receive a signal within a specified period, it can issue an alarm. The alarm alerts the network-operator to the problem and its location.
- Congestion is reduced because all the traffic flows in only one direction.

Disadvantages :

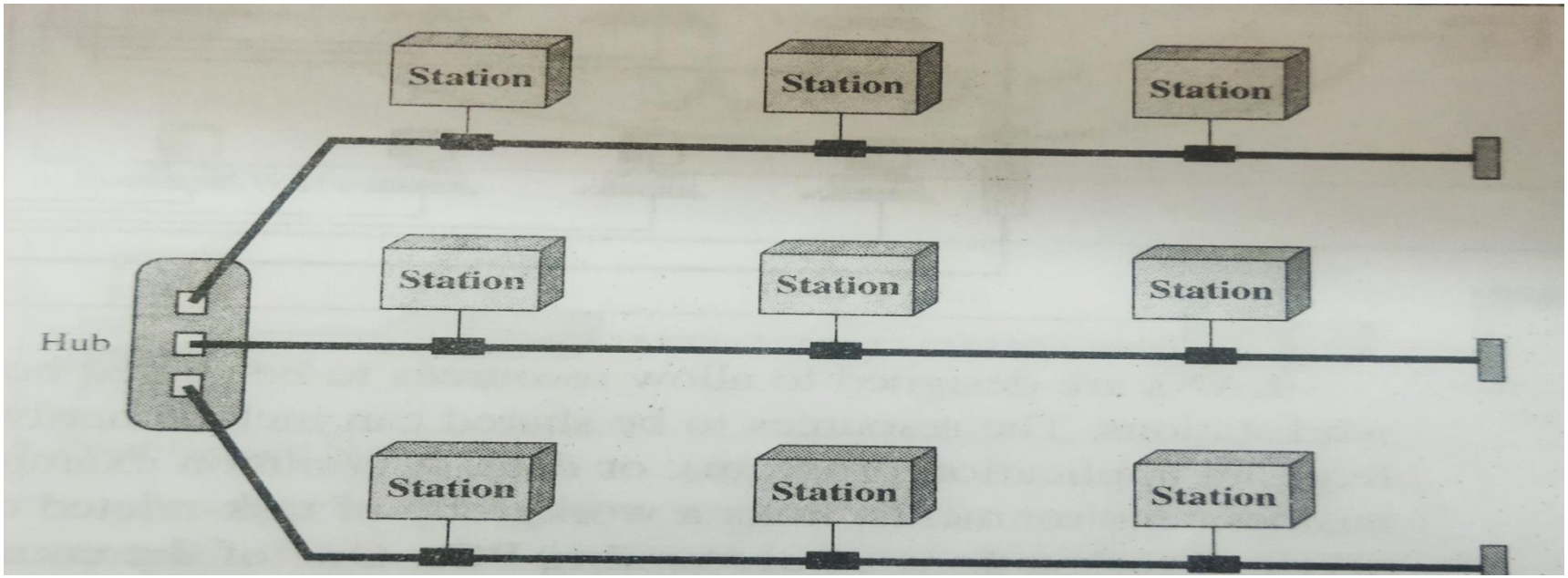
- Unidirectional traffic.
- A fault in the ring/device stops all transmission.

The above 2 drawbacks can be overcome by using dual ring.

1. There is a limit on
   i) Cable length
   ii) Number of nodes that can be connected.
2. Slower: Each data must pass through all the devices between source and destination.

Physical Topology – Hybrid Topology

- Hybrid topology is an interconnection of two or more basic network topologies, each of which contains its own nodes.
- The resulting interconnection allows the nodes in a given basic topology to communicate with other nodes in the same basic topology as well as those in other basic topologies within the hybrid topology.



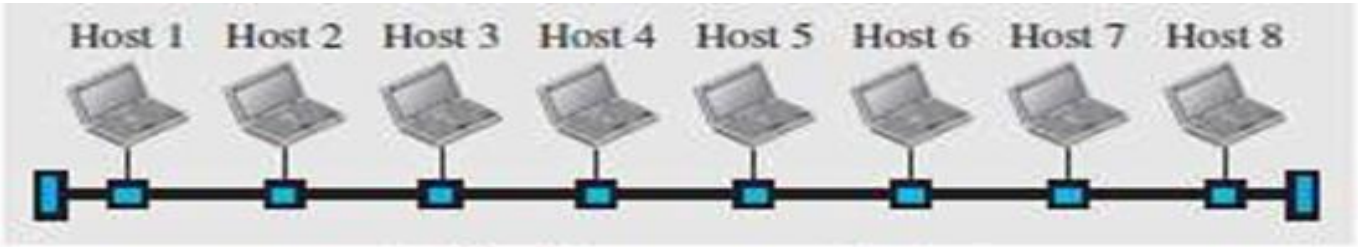
Network Models – LAN – Local Area Network

- A local area network (LAN) is a computer network that interconnects computers within a limited area such as a residence, school, laboratory, university campus or office building.
- **Example :** Accounting PCs
  - LAN is used to connect computers in a single office, building or campus.
  - LAN is usually privately owned network.
  - A LAN can be simple or complex.
    - Simple: LAN may contain 2 PCs and a printer.
    - Complex: LAN can extend throughout a company.
  - Each host in a LAN has an address that uniquely defines the host in the LAN.
  - A packet sent by a host to another host carries both source host's and destination host's addresses.
  - LANs use a smart connecting switch.

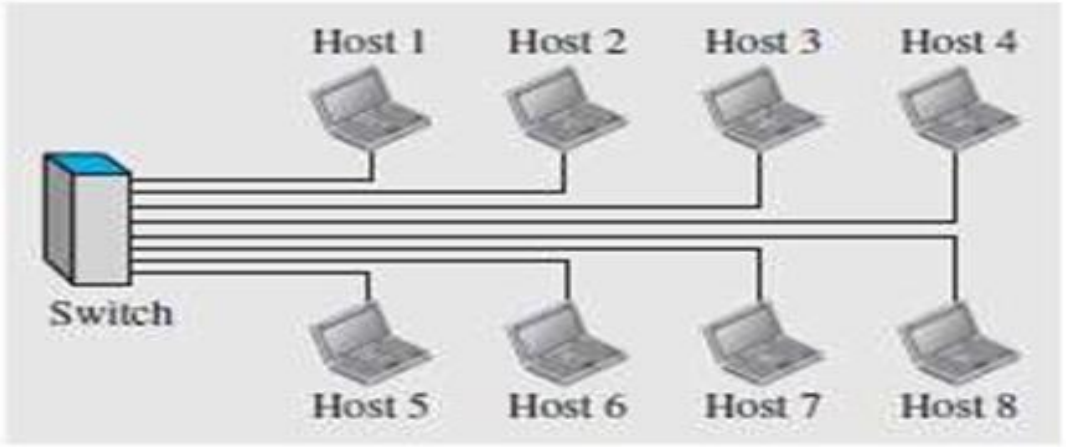
Network Models – LAN – Local Area Network (Contd..)

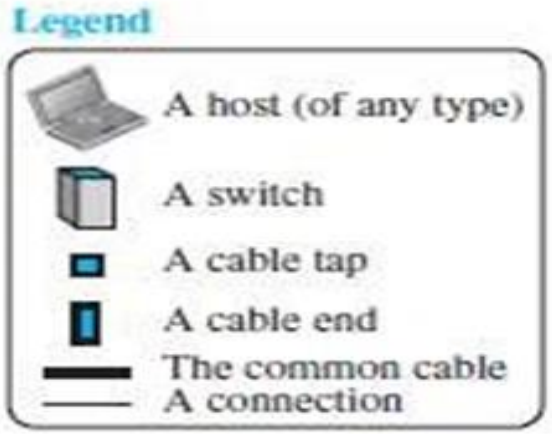
- The switch is able to
  - recognize the destination address of the packet &
  - guide the packet to its destination.
- The switch
  - reduces the traffic in the LAN &
  - allows more than one pair to communicate with each other at the same time.
- Advantages:
  - Resource Sharing
    - Computer resources like printers and hard disks can be shared by all devices on the network.
  - Expansion
    - Nowadays, LANs are connected to WANs to create communication at a wider level.

Network Models – LAN – Local Area Network (Contd..)



a. LAN with a common cable (past)





b. LAN with a switch (today)

Figure 1.8 *An isolated LAN in the past and today*

Network Models – WAN – Wide Area Network

- A **Wide-area Network (WAN)** is a Computer Network that connects your offices, data centers, cloud applications, and cloud storage together.
- It spans beyond a single building or large campus to include multiple locations spread across a specific geographic area, or even the world.
- It is used to connect computers anywhere in the world.
- It can cover larger geographical area. It can cover cities, countries and even continents.
- It interconnects connecting devices such as switches, routers, or modems.
- Normally, WAN is
- created & run by communication companies (Ex: BSNL, Airtel)
- leased by an organization that uses it.

WAN – Wide Area Network
Point-to-Point WAN

- **Point-to-Point WAN** A point-to-point WAN is a network that connects 2 communicating devices through a transmission media
- Consists of a leased line that connects a computer or a small LAN to an ISP
- Generally used to provide internet access
- **Example :** Point to Point WAN – leased line from a Telephone

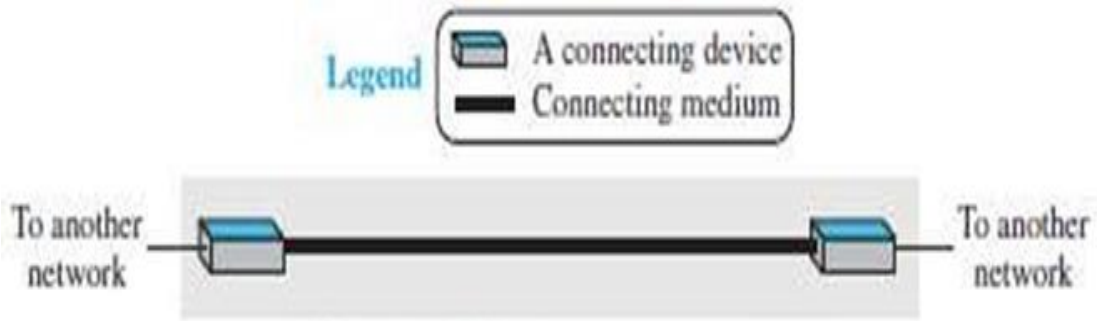


Figure 1.9 *A point-to-point WAN*

WAN – Wide Area Network
Switched WAN

- **Switched WAN** Connects the end systems which generally consists of a router that connects to another LAN or WAN.
  - It is a network with more than two ends.
  - It can be the backbones that connect the Internet.
  - A switched WAN is a combination of several point-to-point WANs that are connected by switches
- **Example :** Switched WAN - Asynchronous Transfer Mode network

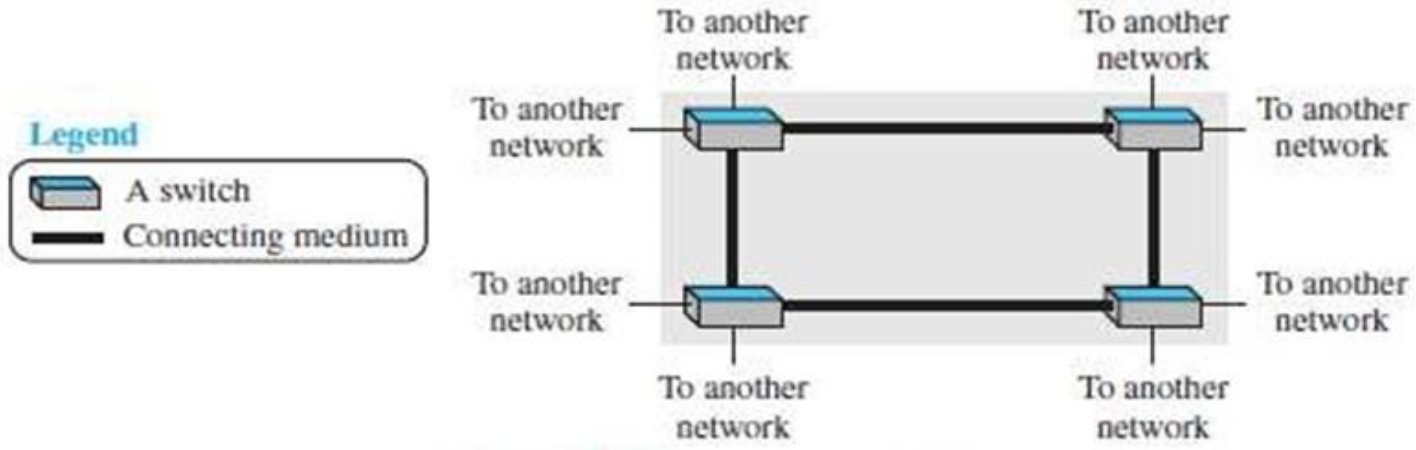
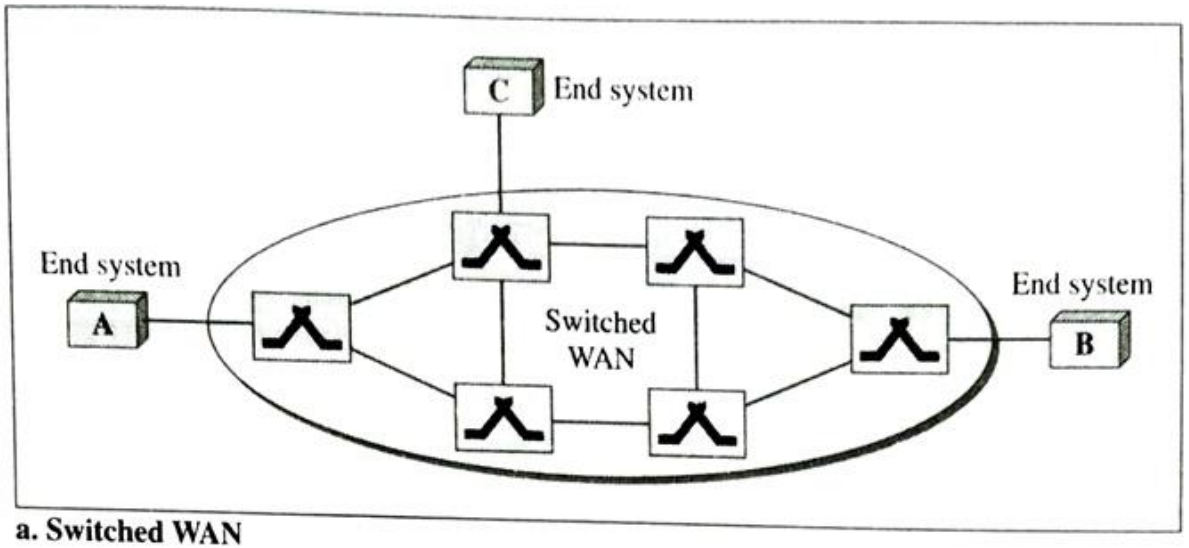


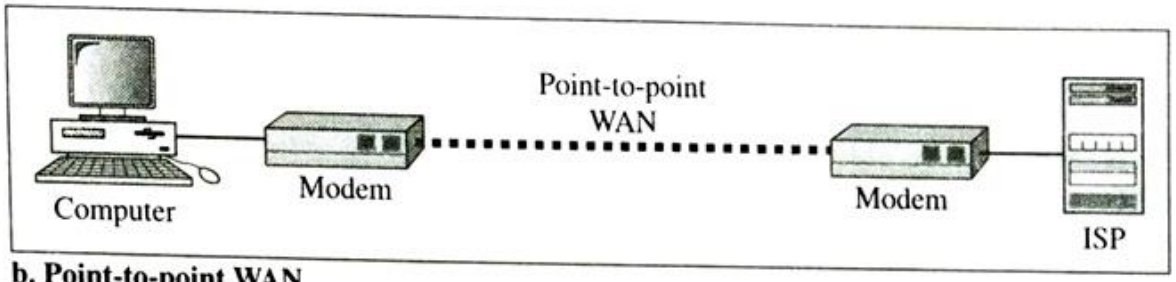
Figure 1.10 *A switched WAN*

Network Models – WAN – Wide Area Network

- **Internetwork** Connection of two or more networks



a. Switched WAN



b. Point-to-point WAN

Network Models – MAN – Metropolitan Area Network

- A metropolitan area network (MAN) is a computer network that connects computers within a metropolitan area, which could be a single large city, multiple cities and towns, or any given large area with multiple buildings.
- Network size is between that of a LAN and WAN.
- **Example :** Cable TV network

1.3 The Internet

- **internet** is two or more networks that can communicate with each other.
  - Most notable internet is **Internet**

- **Internet** is a collaboration of more than hundreds of thousands of interconnected networks.
  - Internet came to existence in 1960s.
  - In 1969 ARPANET came into existence

The Internet Today

- The **Internet** today is made up of many WANs and LANs joined by connecting devices and switching stations
- **Internet Service Provider - ISP-** provides Internet to the end users
- **Different types of ISPSs**
  - **International Internet Service Providers**

    Connects nations together
  - **National Internet Service Providers**

    Connects within the nation
  - **Regional Internet Service Providers**

    are smaller ISPs connected to one or more national ISPs
  - **Local Internet Service Providers**

    provide direct service to the end users

The Internet Today (Contd..)

International Internet Service Providers

- They connect nations together
- They are at the top of the hierarchy

National Internet Service Providers

- They are backbone networks created and maintained by specialized companies
- There are connected by complex switching stations called **Network Access Points** (NAPs)
- Some national ISP networks are also connected to one another by Private Switching stations called **Peering Points**
- They operate at High data rate.

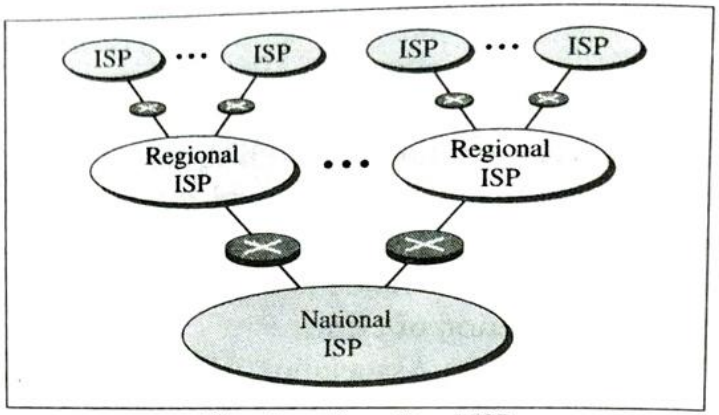
The Internet Today (Contd..)

- **Regional Internet Service Providers**
  - They are smaller ISPs connected to one or more national ISPs
  - They operate at smaller data rate.

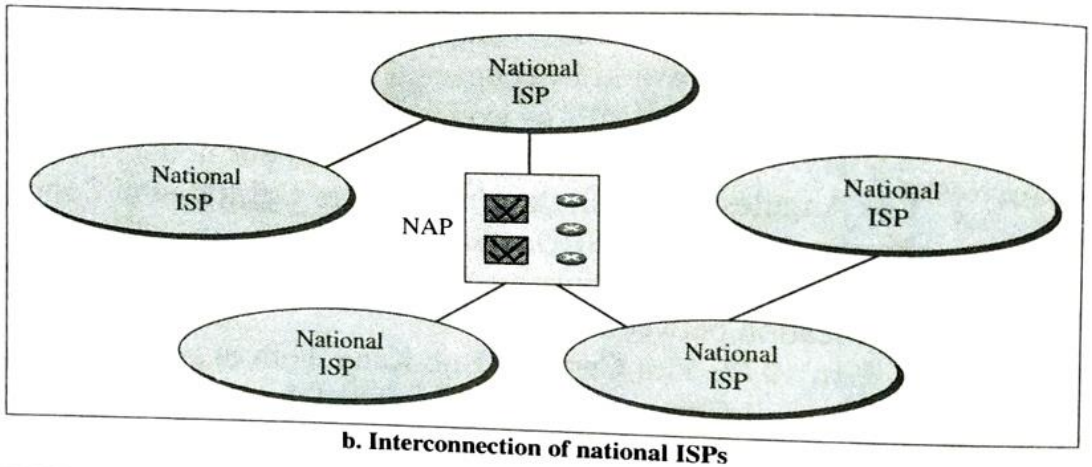
- **Local Internet Service Providers**
  - They provide direct service to the end users
  - They are connected to regional ISPs or directly to the national ISPs
  - Most end users are connected to the local ISPs

Internet Service Providers

e 1.13 *Hierarchical organization of the Internet*



a. Structure of a national ISP



b. Interconnection of national ISPs

1.4 Protocols and Standards
Protocols

- A **Protocol** is a set of rules that govern data communications.
  - It defines
    - What is communicated
    - How it is communicated
    - When it is communicated
- **Key Elements of a Protocol**
  - **Syntax :** Structure or format of the data

Example: 1st 8 bits sender address, 2nd 8 bits receiver address remaining bits Message

  - **Semantics :** Meaning of each section of bits

Example : Address is route to be taken or final destination

  - **Timing :** When data should be send and fast they can be sent

Example : Sender sends data at 100 Mbps, Receiver can receive at 10 Mbps, Data will be lost due to overload

1.4 Protocols and Standards
Standards

- **Standards**

  They provides guidelines to manufacturers, vendors, government agencies and other service providers to ensure the kind of interconnectivity necessary in today's market place and in international communications.

- **2 categories of Data Communications Standards**
  - **De facto standards**
  - **De facto : (by fact or by convention)**
  - Structure or format of the data
  - **De jure standards**
  - **De jure : (by law or by regulation)**
  - are standards that have been legislated by an officially recognized body.

Standards Organizations

- **Standards** are developed through the cooperation of
  - **Standards Creation Committee**
    - ISO : International Organization for Standardization
    - ITU-T : International Telecommunication Union – Telecommunication Standards Sector
    - CCITT : Consultative Community for International Telegraphy and Telephony
    - ANSI : American National Standards Institute
    - IEEE : Institute of Electrical and Electronics Engineers
    - EIA : Electronic Industries Association
  - **Forums**
  - **Regulatory Agencies**

Internet Standards

- **Internet Standard** is a formalized regulation that must be followed by those who work with the internet.
- A specification begins as an internet draft.
- **Internet Draft** is a working document with o official status and a 6 month lifetime.
- **Request for Comment (RPC)** upon recommendation from the internet authorities a draft may be published as a Request for Comment (RPC)
- Each RPC is edited, assigned a number and made available to all the interested parties.

UNIT 1

CHAPTER 2
NETWORK LAYERS

Layered Tasks

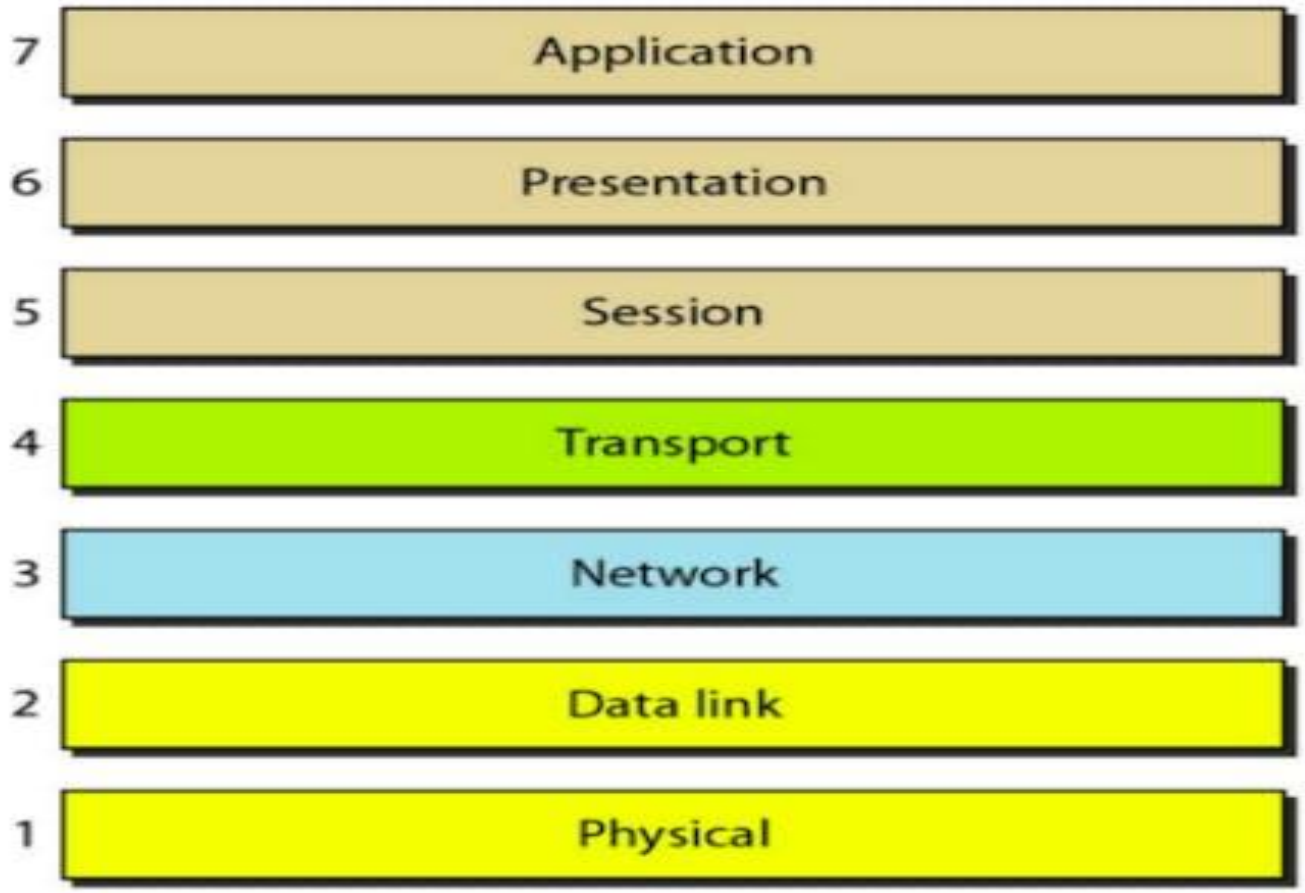
- Each layer uses the services of the layer immediately below it.
- **Layered model for Data communication and networking are**
  - **OSI Model - Open Systems Interconnection Model**
    - Standard for Data Communication
    - It was not fully implemented
  - **TCP/IP Protocol Suite (Transmission Control Protocol/Internetworking Protocol)**
    - Dominant commercial architecture as it was used and tested extensively in the Internet

OSI Model
Open Systems Interconnection Model

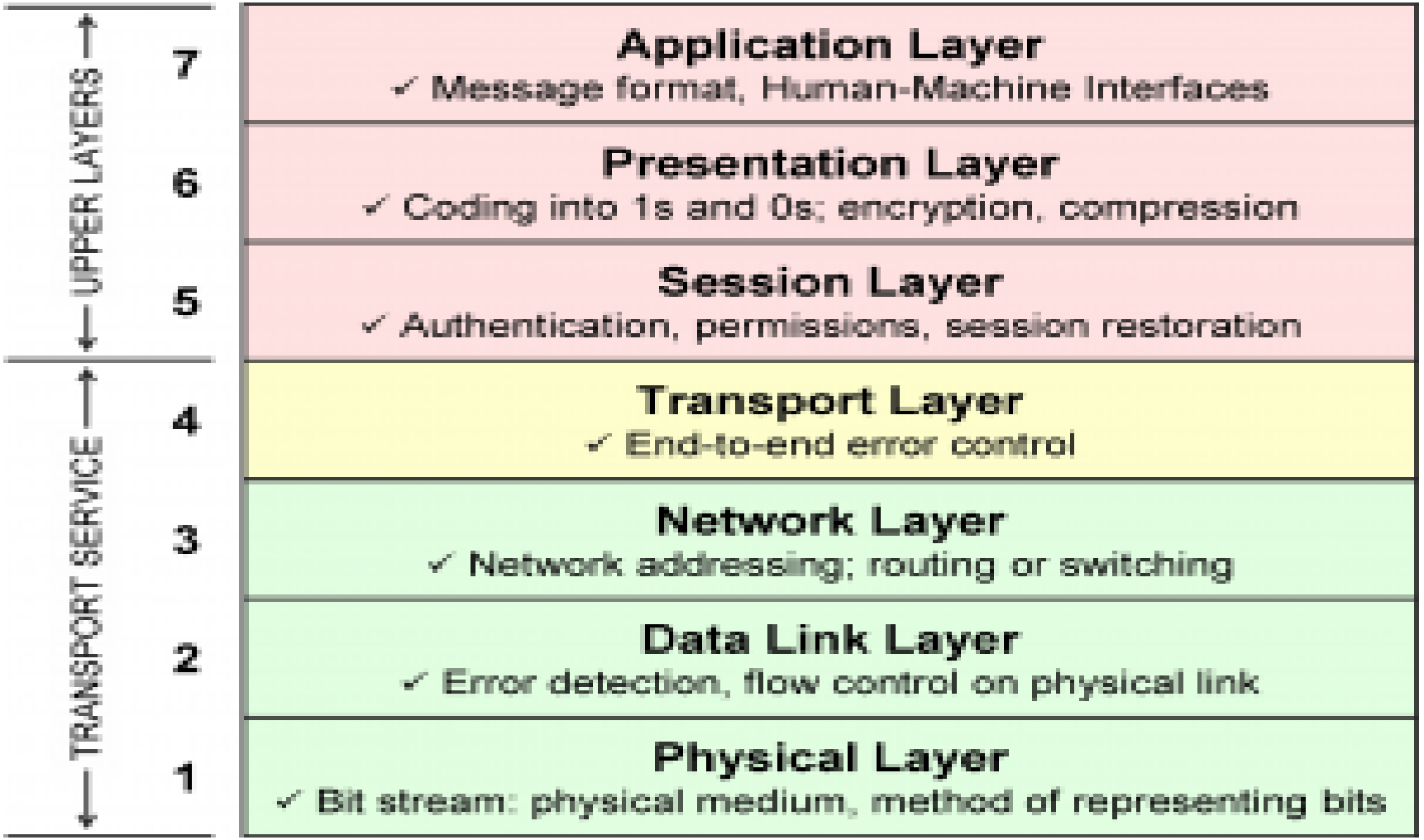
- **OSI** is an ISO Standard that covers all aspects of network communications.
  - **Introduction :** in late 1970s
  - **Model:** OSI is a model and not a protocol.
  - **Purpose :** to show how to facilitate communication between different systems without requiring changes to the logic of the underlying hardware and software
- **Open System** is a set of protocols that allows any two different systems to communicate regardless of their underlying architecture.

OSI Model Layers

Layers in the OSI Model



An exchange using the OSI model



TCP/IP Protocol Suite

- The TCP/IP protocol suite is made of five layers:
  1. Physical Layer
  2. Data link Layer
  3. Network Layer
  4. Transport Layer
  5. Application Layer
- The first four layers provide physical standards, network interfaces, internetworking, and transport functions that correspond to the first four layers of the OSI model.
- The three topmost layers in the OSI model, however, are represented in TCP/IP by a single layer called the application layer

TCP/IP Protocol Suite
Physical Layer & Data link Layer

- At the physical and data link layers, TCPI/IP does not define any specific protocol.
- It supports all the standard and proprietary protocols.
- A network in a TCP/IP internetwork can be a local-area network or a wide-area network.

TCP/IP Protocol Suite
Network Layer

- At the network layer (or, more accurately, the internetwork layer), TCP/IP supports the Internetworking Protocol (IP)
- IP uses four supporting protocols:
  - ARP - Address Resolution Protocol
    - is used to associate a logical address with a physical address
  - RARP - Reverse Address Resolution Protocol
    - allows a host to discover its Internet address when it knows only its physical address
  - ICMP - Internet Control Message Protocol
    - ICMP sends query and error reporting messages
  - IGMP - Internet Group Message Protocol
    - is used to facilitate the simultaneous transmission of a message to a group of recipients

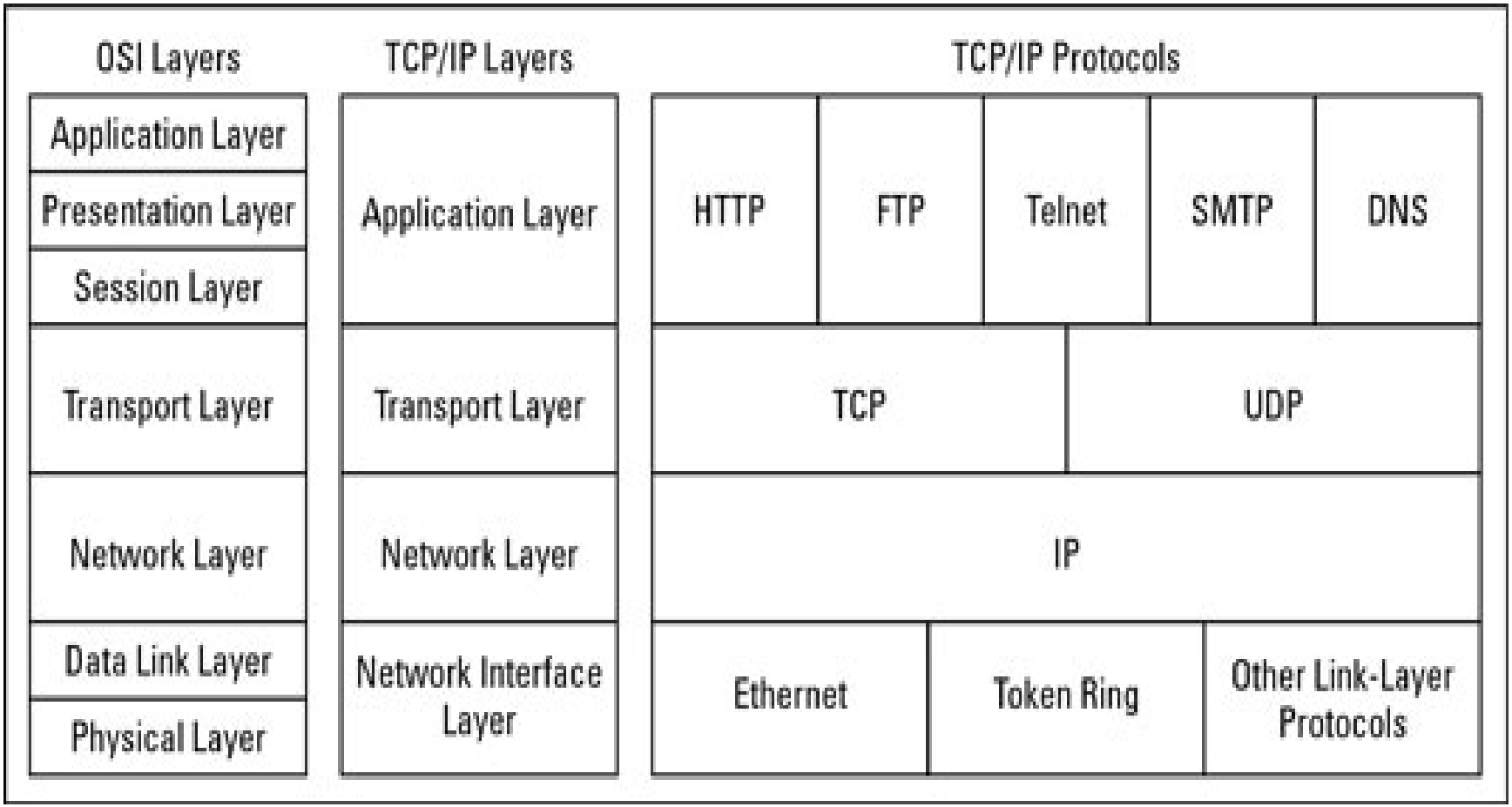
TCP/IP Protocol Suite
Transport Layer

- Transport layer has UDP and TCP protocols responsible for delivery of a message from a process (running program) to another process.
  - UDP - User Datagram Protocol
    - It is a process-to-process protocol
    - It adds only port addresses, checksum error control, and length information to the data from the upper layer.
  - TCP - Transmission Control Protocol
    - provides full transport-layer services to applications.
  - SCTP - Stream Control Transmission Protocol
    - allows a host to discover its Internet address when it knows only its physical address

TCP/IP Protocol Suite
Application Layer

- The application layer is equivalent to the combined session, presentation, and application layers in the OSI model.
- Many protocols are defined at this layer.
  - HTTP - Hyper Text Transfer Protocol
    - It is the underlying protocol for world wide web. It defines how hypermedia messages are formatted and transmitted.
  - FTP - File Transfer Protocol
    - It is a client-server based protocol for transfer of files between client and server over the network.
  - Telnet - Terminal Network
    - provides bi-directional text-oriented services for remote login to the hosts over the network
  - SMTP - Simple Network Management Protocol
    - It is for managing, monitoring the network and for organizing information about the networked devices.
  - DNS - Domain Name System
    - It maps the IP addresses into domain names (human readable names).

TCP/IP Protocol Suite



UNIT 2

THE DATA LINK LAYER

Introduction

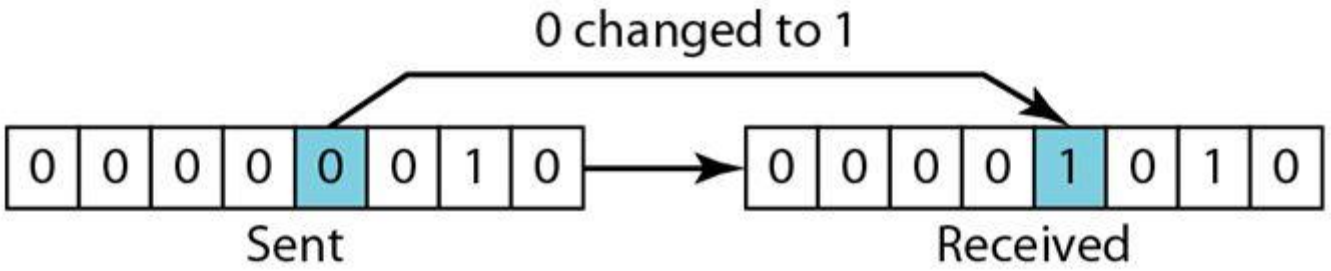
- Whenever bits flow from one point to another, they are subjected to unpredictable changes because of **Interference.**

- **Types of Errors**
  - **Single-Bit Error**
    - Only 1 bit in the data unit has changed
  - **Burst Error**
    - 2 or more bits in the data unit have changed

- **Redundancy**
  - To detect or correct errors, we need to send extra (redundant) bits with data.

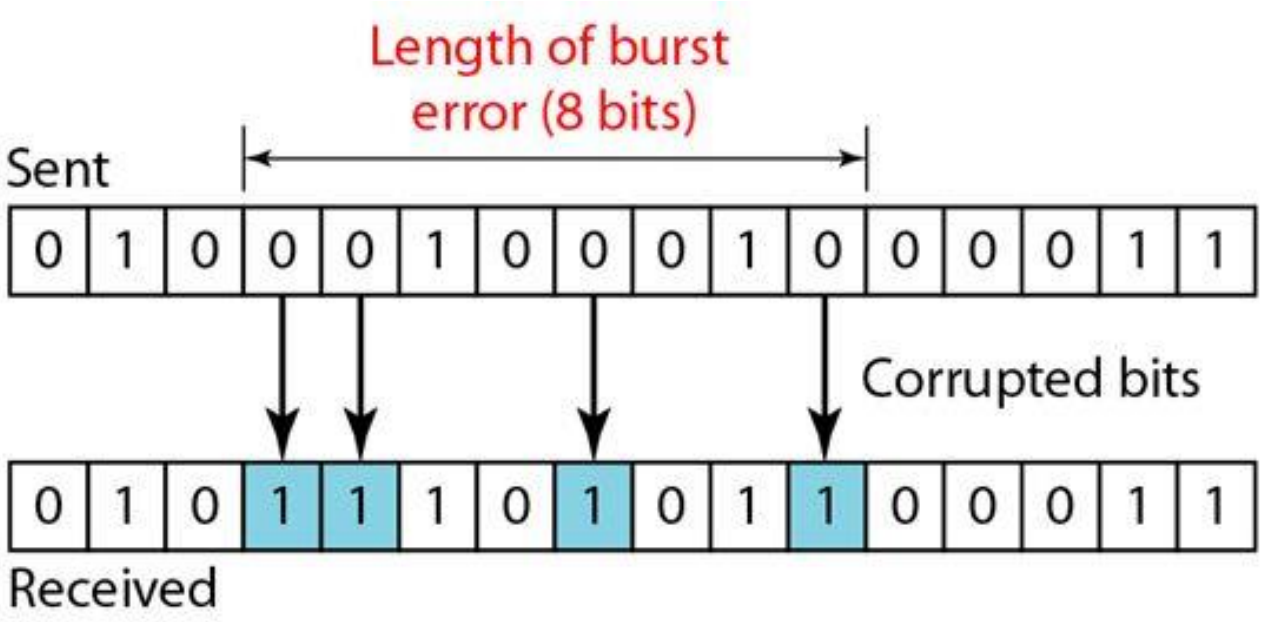
Single-Bit Error

- **Single-bit error** means that only 1 bit of a given data unit (such as a byte, character, or packet) is changed from 1 to 0 or from 0 to 1.
- Least likely to occur



Burst Error

- **Burst error** means that 2 or more bits in the data unit have changed from 1 to 0 or from 0 to 1.
- A burst error is more likely to occur than a single-bit error



Redundancy

- To detect or correct errors, we need to send extra (redundant) bits with data.
- These redundant bits are added by the sender and removed by the receiver.
- Their presence allows the receiver to detect or correct corrupted bits.

Detection Versus Correction

Detection

- **Error Detection** we are looking only to see if any error has occurred.
- The answer is a simple yes or no.

Detection Versus Correction
Correction

- **Error Correction** we need to know the exact number of bits that are corrupted and their location in the message.
- The correction of errors is more difficult than the detection.

THANK YOU