DATA COMMUNICATION AND NETWORKS (18UCSE1)

III B.Sc Computer Science

(Semester - V)

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DATA Communication and Network - Author Behrouz A. Forouzan

Definition: Data Communication refers to the transmission of digital data between 2 or more computers and a computer Network or data Network. It is a Telecom n/w that allows computers to exchange data.

Data Communication:

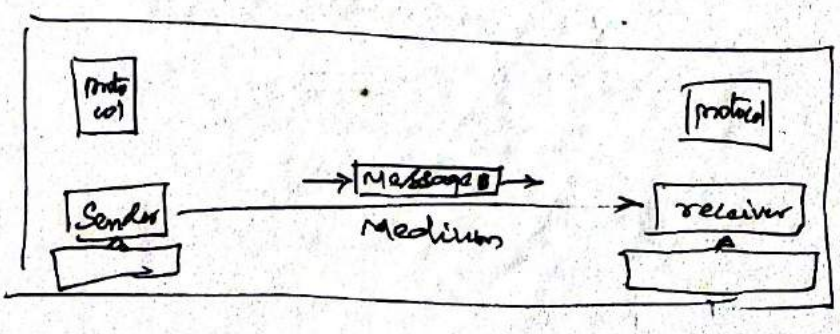
* It is a exchange of data between two devices via some transmission medium.
* It is local (DC) when if one communication devices are in the same building or or area
* (DC) It is remote if the devices are farther apart.

Effectiveness of DC system depends on the following:

1. Delivery – system must deliver data to the correct destination. (ie) data must be received by intended device or user.
2. Accuracy – Data must be delivered accurately. (What every sent should be received)
3. Timeliness – Data to be delivered on time. should not be delivered late. (ie) data to be transferred in real-time.

Components:

DC system made up of 5 components.



1. Message: Information to be communicated.
Consists of Text, DOCs, pictures, video or Sound.
(or) combination of these.

2. Sender: The device which sends the message.
* It can be computer, Workstation, telephone, TV etc..

3. Receiver: The devices which receives the message.
* as above.

4. Medium: It's a physical path by which a message travels from sender to receiver. It can be twisted pair wire, co-axial cable, fiber optics, laser or radio waves.

5. Protocol: It's a set of rules and regulations that govern dc.

—x—

Networks:
It's a set of devices or node connected by media links.
Node can be a computer, printer, or any other device.
Link connecting the devices are called Comm channels.

Distributed processing
- Network uses Distributed processing.

Advantages
* Security
* Distributed database
* Faster problem solving
* Security through redundancy (eg 3 systems usage) if one failed can use others
* Collaborative processing

Network criteria:
(a) Performance
(b) Reliability
(c) Security
- Based on the above three can measure the effectiveness & efficiency of the N/W.

(a) Performance

It depends on, Number of users, type of transmission medium, H/W & S/W.

(b) Reliability:

Measured by frequency of failure, Recovery of D/D after failure & catastrophe (protected from catastrophe event like fire, earthquake, or theft)

(c) Security:

protecting data from un-authorised access & Viruses

Nowdays DCN become indispensable part of business, industry & entertainment. (Eg). Marketing, sales, manufacturing, cable TV, cellular telephone, EDI etc.

protocols and standards

protocol

Entity → is anything capable of sending and receiving information.

protocol is the set of rules that govern data communication.

Syntax - refers the structure or format of data

Semantics - refers to the meaning of each section of bits

Timing - how fast the data can be sent.

Standards (1) Defacto (by fact)

Proprietary (or) closed
- invented by commercial agencies as the basis of for the operation of its product (Eg)

Non-proprietary or open
- developed by groups or committees that have passed them to public domain

(2) De jure (by law)
- legislated by an officially recognised body.

Line Configuration

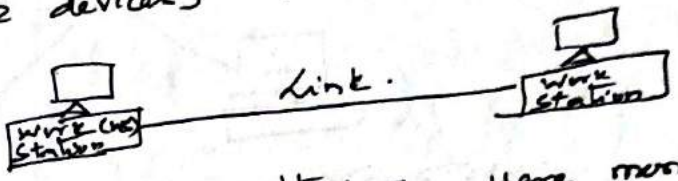
- It refers to the way 2 or more comm devices attach to a link.

Link - physical comm pathway that transfers data from one device to another.

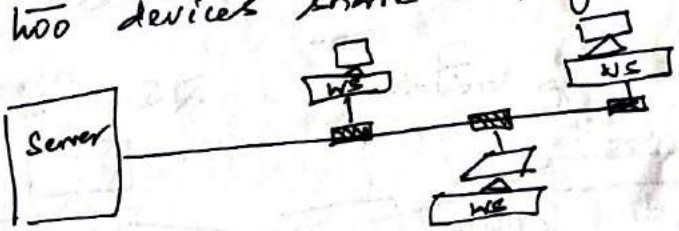
Two line Configurations

1. point-to-point :- provides dedicated link between two devices. [entire capacity of the channel reserved for these 2 devices]

line configuration →



2. Multipoint :- or Multidrop, there more than two devices share a single line.



Topology

* It refers to the way a nlw is laid out, either physically or logically. Two or more links form a topology.

5 Basic topologies:

1. Mesh 2. Star 3. Tree 4. Bus 5. Ring.

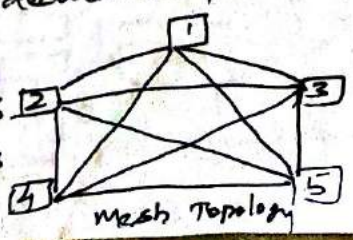
2 relationships are:

ⓐ. peer-to-peer - devices share link equally.

ⓑ. primary-to-secondary - one device controls traffic and others must transmit through it.

1. Mesh : every device has a dedicated point-to-point link to every other device

Advantage - use of dedicated links
- its robust (if one link failures others will work)



Mesh Topology

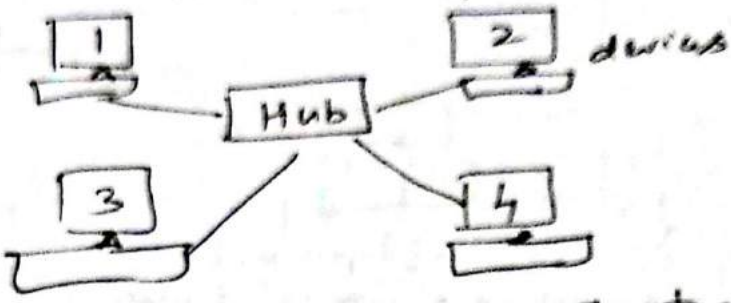
Advan * privacy or security

* Fault identification and isolation is easy.

Disadvantage: management of cabling & I/O port required.

2. Star: each device has a dedicated point-to-point link only to a central controller (i.e.) hub.

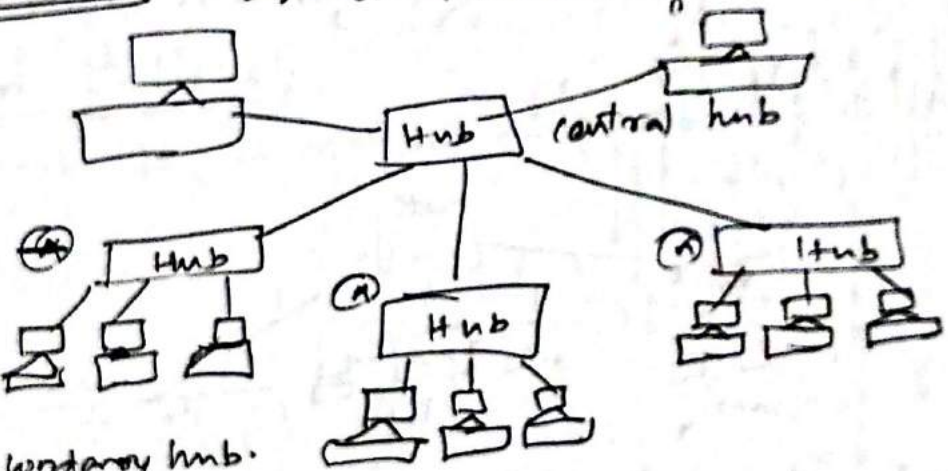
- It does not allow direct traffic between devices
- hub acts as a exchange.



Adv: * less expensive * robustness

* needs less cable (than mesh)

3. Tree: It's a variation of star.



(X) - secondary hub.

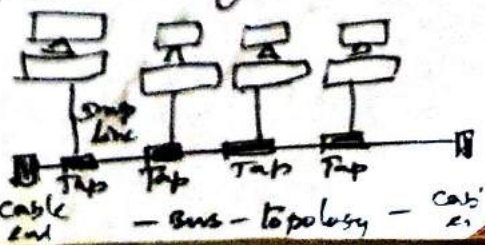
* central hub in the tree is active hub. It contain repeater (h/w devices which regenerate received bits).

(A) cable TV.

4. Bus: It is multipoint. one cable acts as a backbone to link all devices.

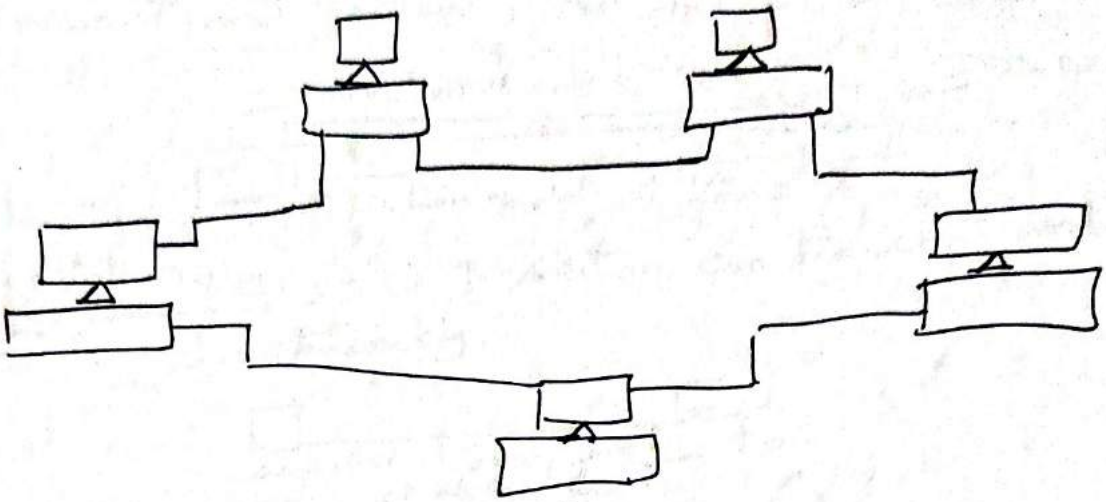
Advantage: ease of installation, less cabling than mesh, star or tree

Disadvantage: difficult reconfiguration and fault isolation. (If there is a fault cable stops all transmission.



- Bus - topology - cable

5. Ring: each device has dedicated point-to-point line configuration, only with the 2 devices on either side of it.



— Ring Topology —

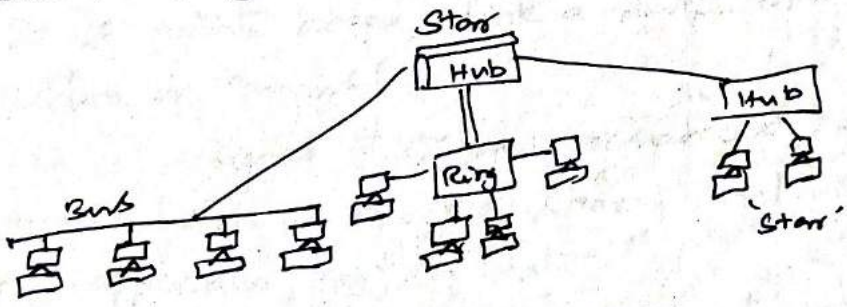
Advantage: * easy to install & configure (add or delete devices requires only 2 connections)

Disadvantage: * Undirectional traffic.

* break in a ring can disable entire network.

Hybrid topologies:

= Several topologies as subnetwork combined together.



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Transmission Mode

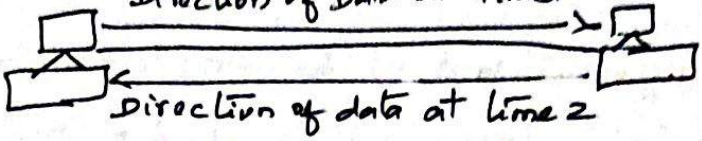
Def: It is used to define the direction of signal flow between two linked devices.

* 3 types of transmission modes are:

1. Simplex
2. Half-duplex
3. Full-duplex.

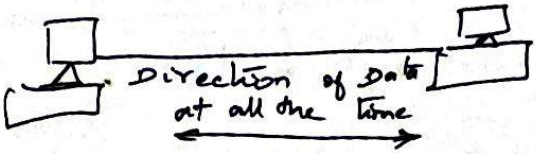
1. Simplex: only one device on a link can transmit.
(eg) Key board & Traditional monitors

2. Half Duplex: Each station or device can both transmit and receive, but not at a same time.



(eg) Walkie-talkie

3. Full Duplex - both station can transmit and receive simultaneously.



(eg) Telephone.

Catagories of Network

3 primary catagories are:
1. LAN 2. MAN & 3. WAN.

1. Local Area Network (LAN)

* It is private owned, link a device in a single office, building, or campus.
* It is designed to share resources between PCs or workstations. Resource shared includes h/w (printer), s/w (application prog.) or data.
* One computer is given large capacity HDD and become server. S/w needed is stored on central server
* No of users in LAN depends on the OS of LAN or License of OS.
* LAN uses only one type of transmission medium:
  * Common LAN topologies are bus, ring & star.
* Data rate of LAN 4 to 16 Mbps, but today 100 Mbps.

2. Metropolitan Area Network:

- Designed to extend over an entire city.
- It is like Cable TV N/w. (ex) It may connect no of LANs into larger N/w.
- (eg) A company can connect all their LANs through MAN.
- * It is owned & operated by private company or public

SMDS – Switched Multi-megabit Data Services → Popular MAN service provided by Telecom Companies

3. Wide Area Network

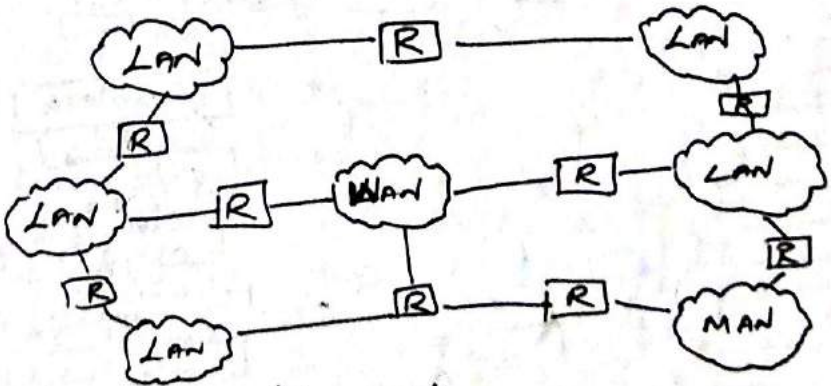
- * provides long distance transmission of data, voice image & video over larrage geographical area. (country, continent or whole world).
- * It may utilize public, leased or private comm devices.

Enterprise Network :→ WAN wholly owned and used by a single company.

— * —

Internetworks

When 2 or more n/w are connected, they become internetwork or internet. shown below:



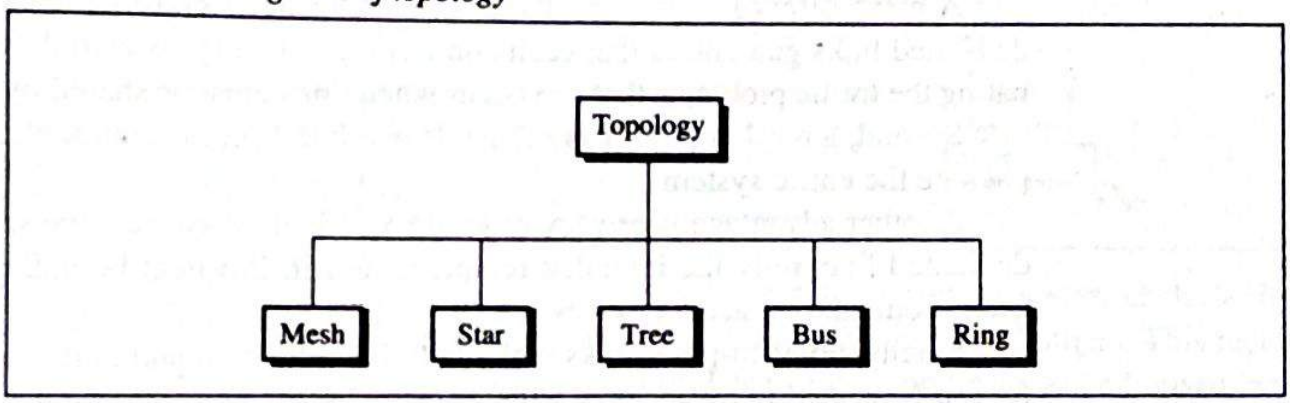
R → Represents Router.

- * Individual n/w are joined into internetwork or internet by the use of internetworking devices. These includes Routers, gateways.

internet – used to mean interconnection of n/w

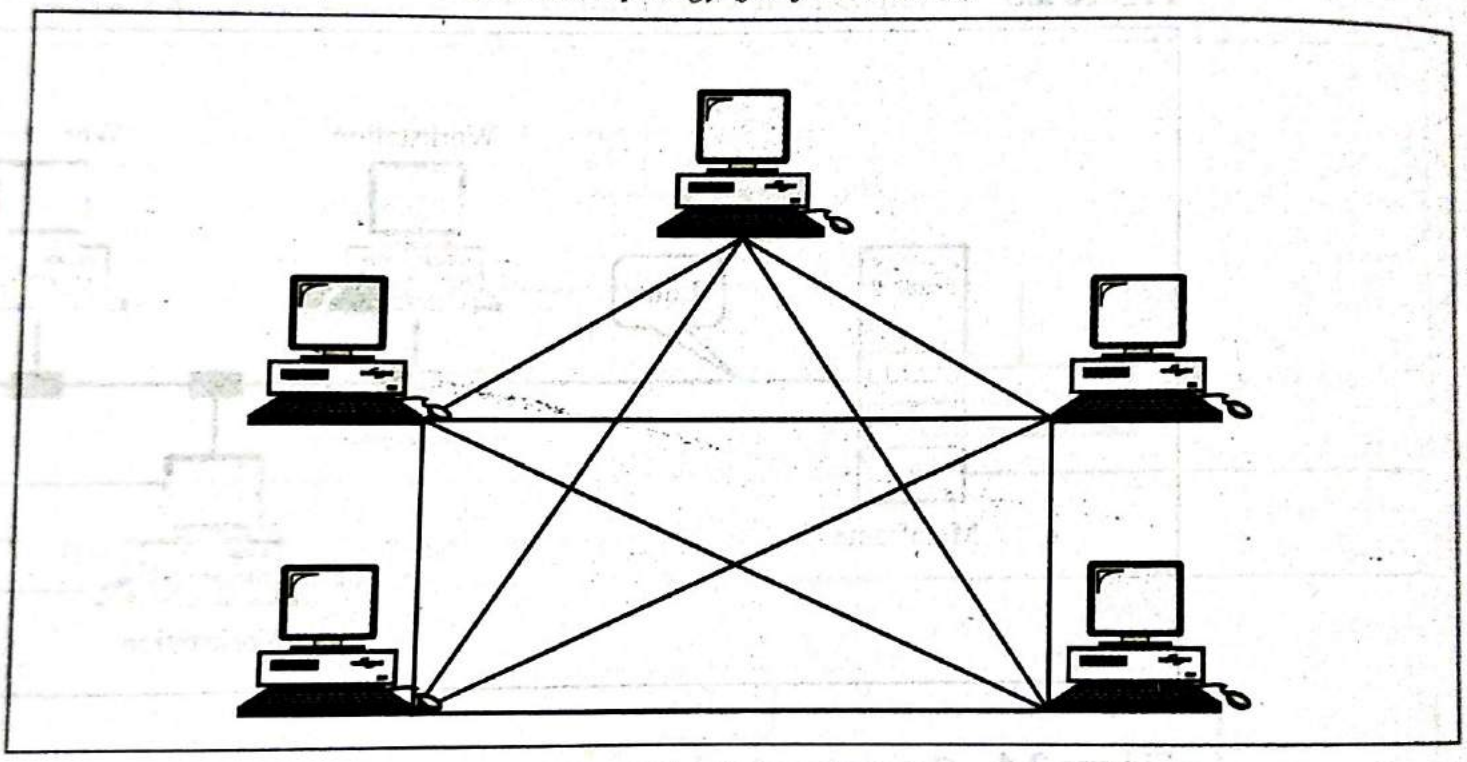
Internet – name of specific worldwide n/w.

Figure 2.4 *Categories of topology*



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

Figure 2.5 *Fully connected mesh topology (for five devices)*



A mesh offers several advantages over other network topologies. First, the use of

Figure 2.6 *Star topology*

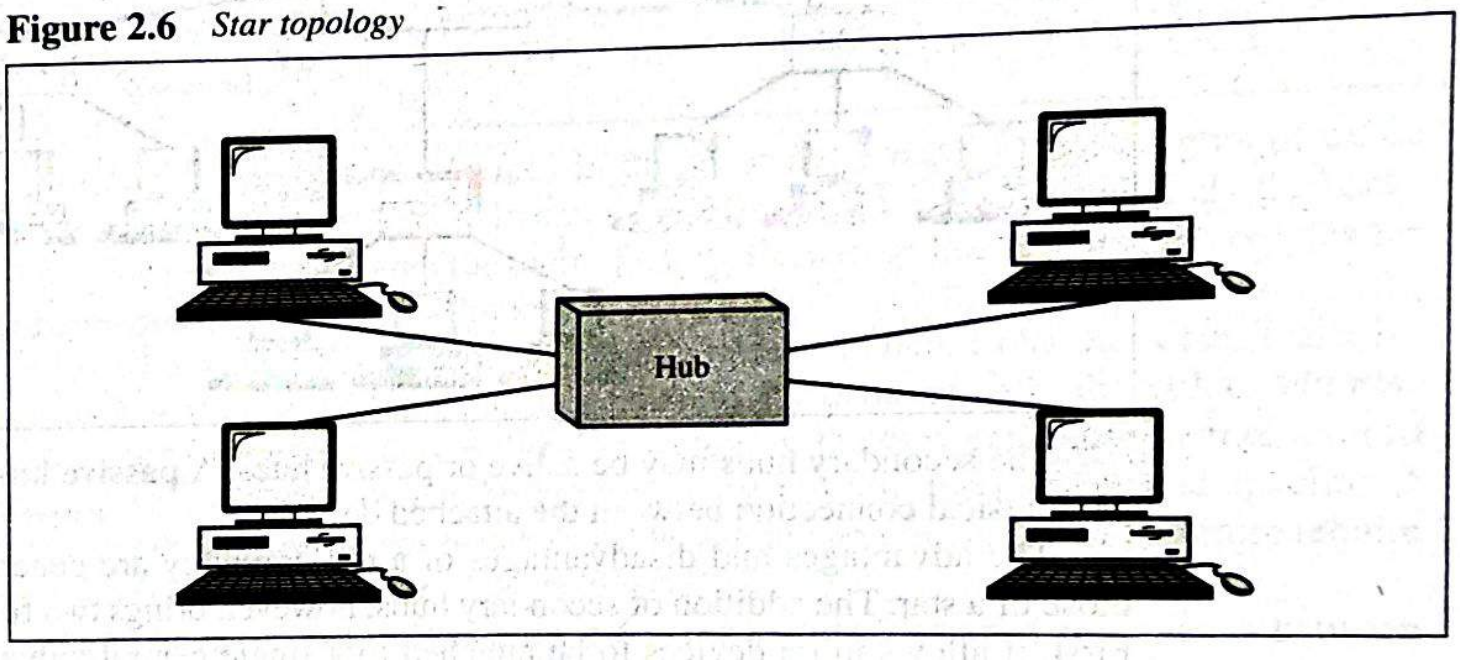


Figure 2.7 *Tree topology*

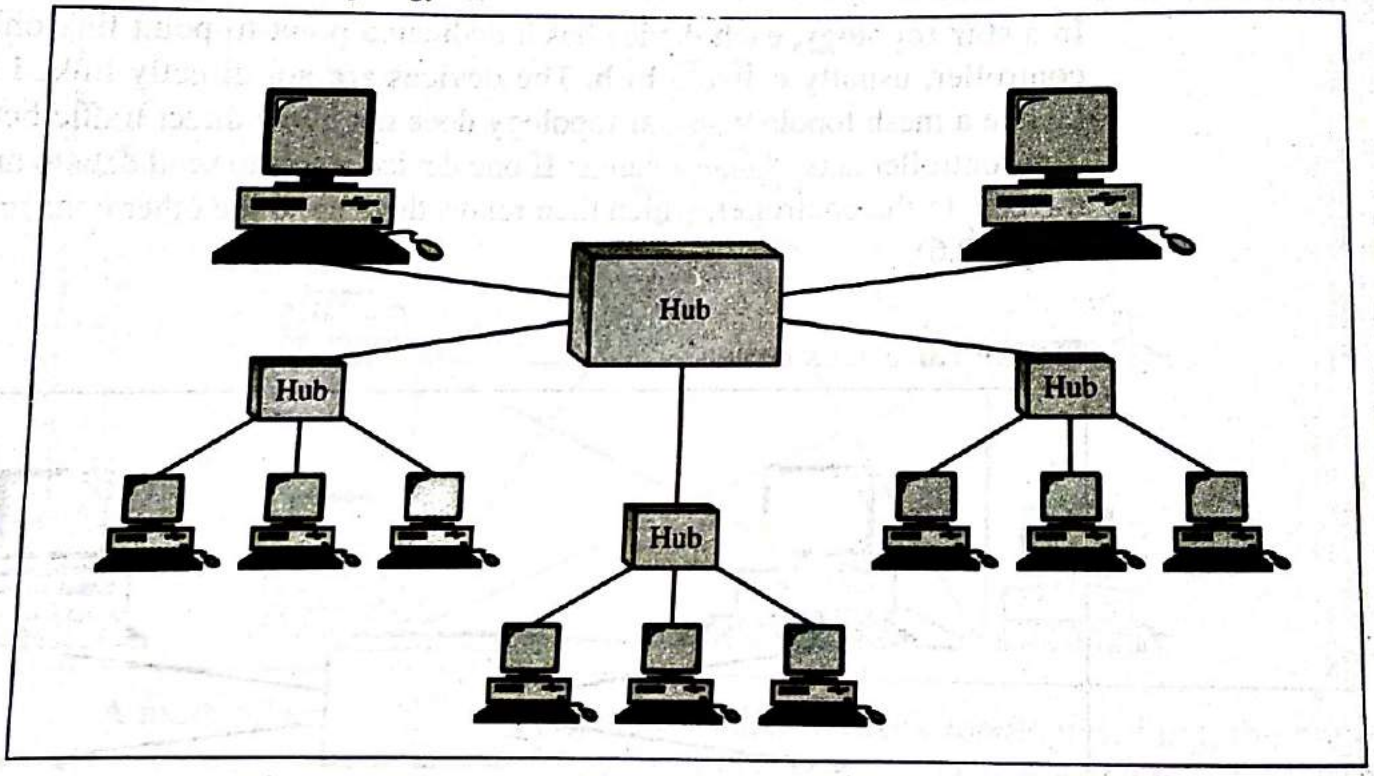


Figure 2.8 *Bus topology*

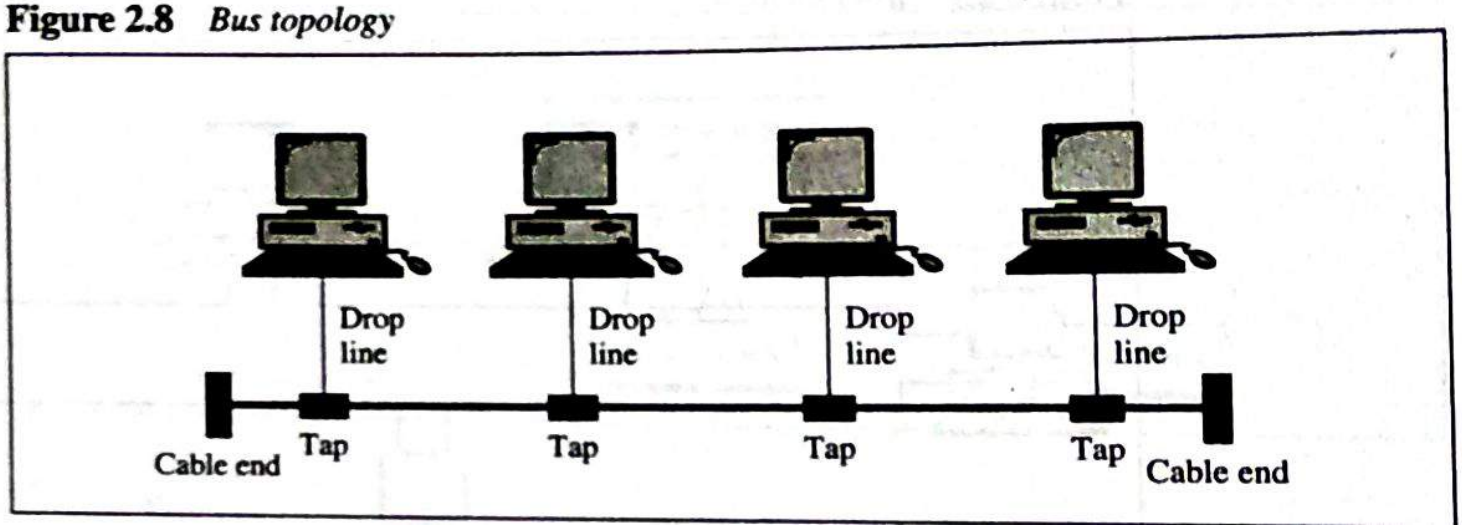
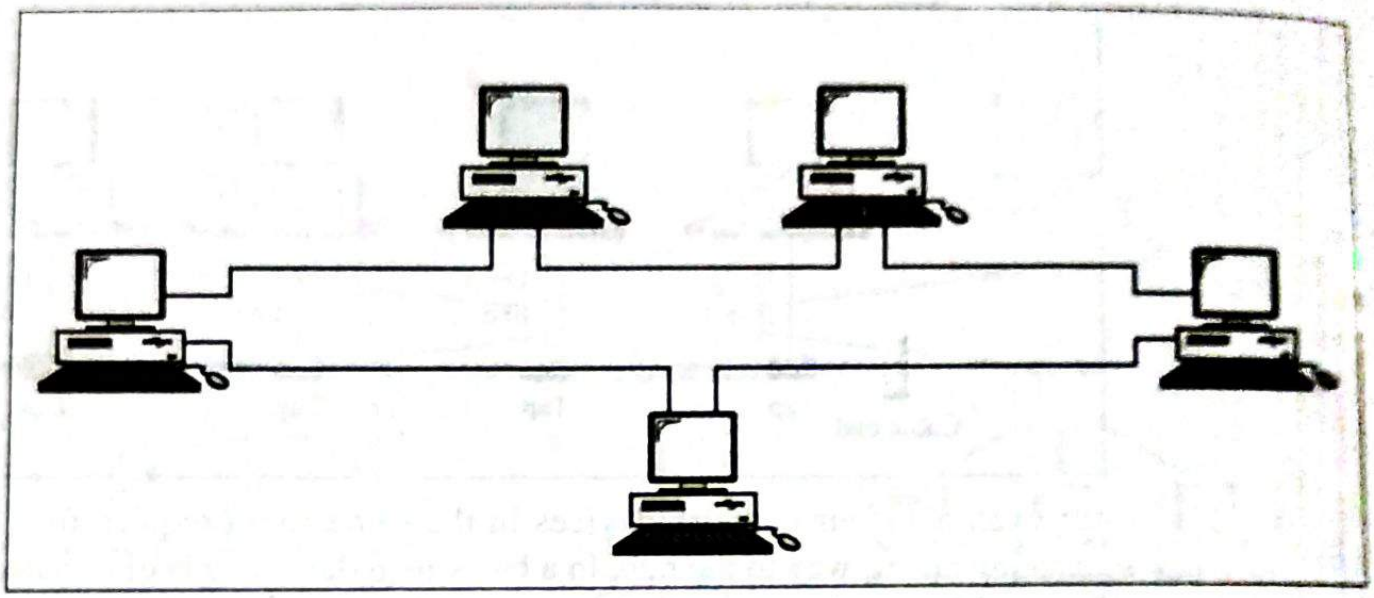


Figure 2.9 *Ring topology*



Solution

To connect *n* devices in a ring topology, we need *n* cable links. An eight-device ring needs eight cable links.

Hybrid Topologies

Often a network combines several topologies as subnetworks linked together in a larger topology. For instance, one department of a business may have decided to use a bus topology while another department has a ring. The two can be connected to each other via a central controller in a star topology (see Figure 2.10).

Figure 2.10 *Hybrid topology*

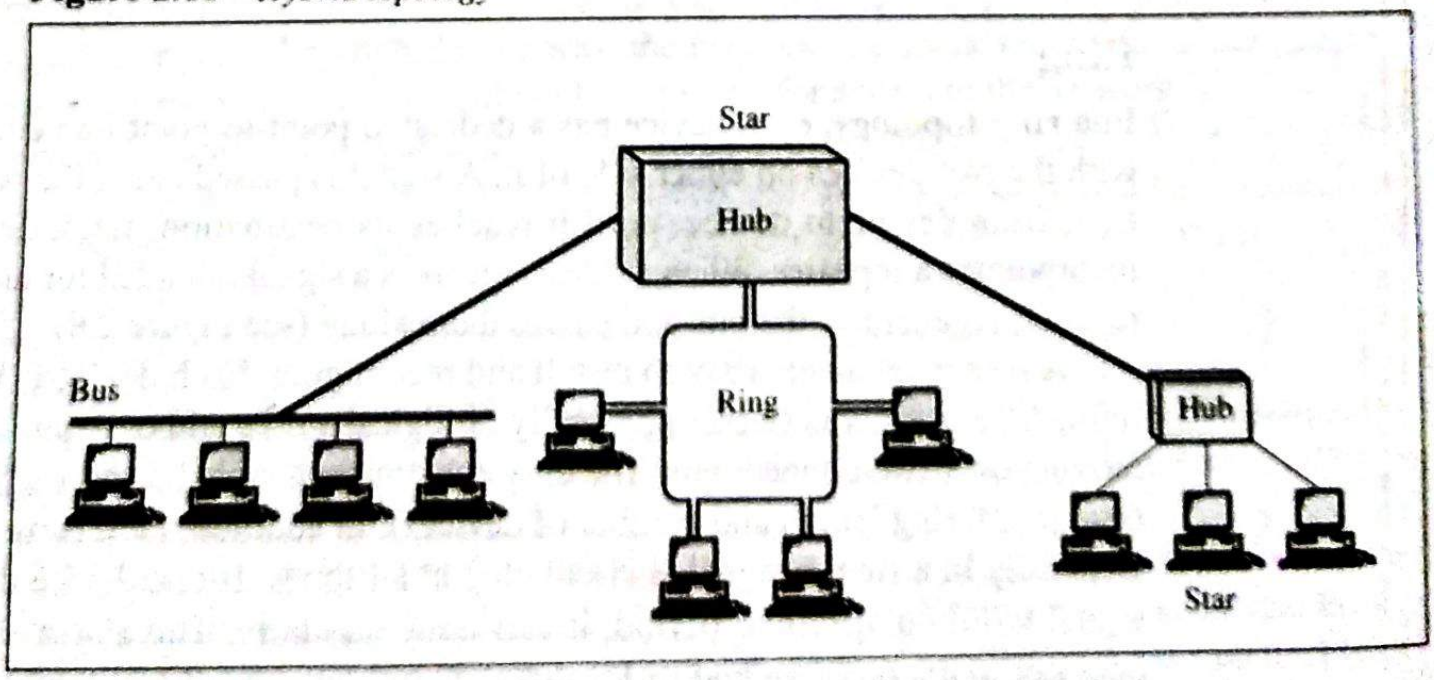


Figure 3.1 *The OSI model*

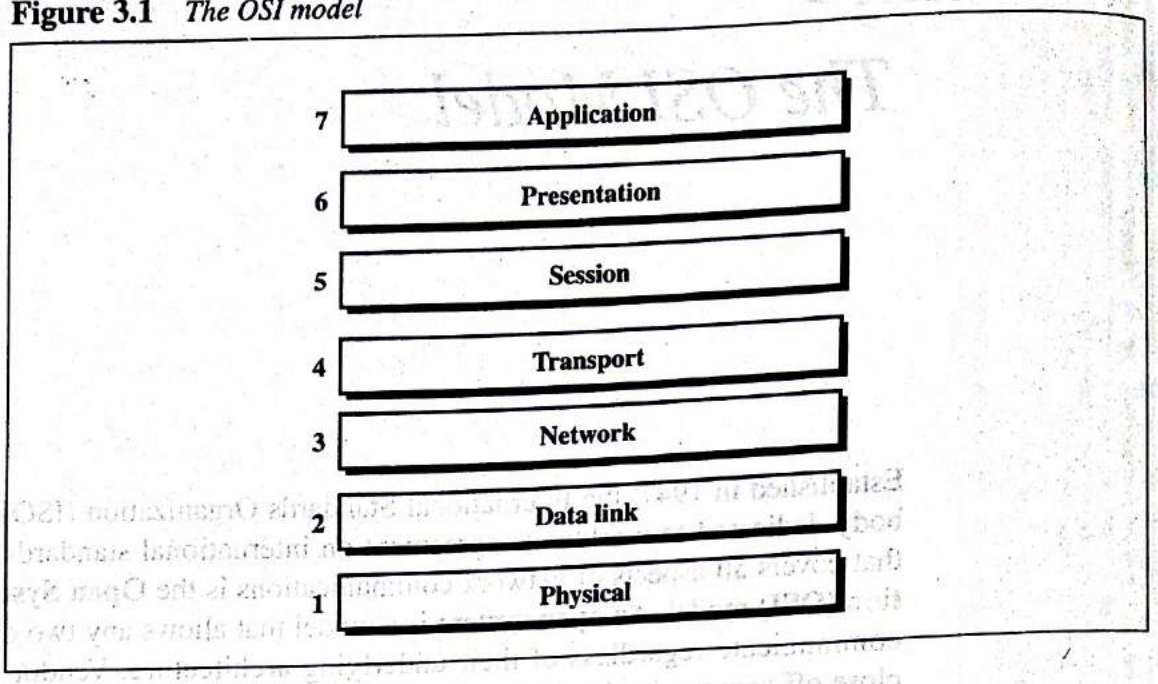
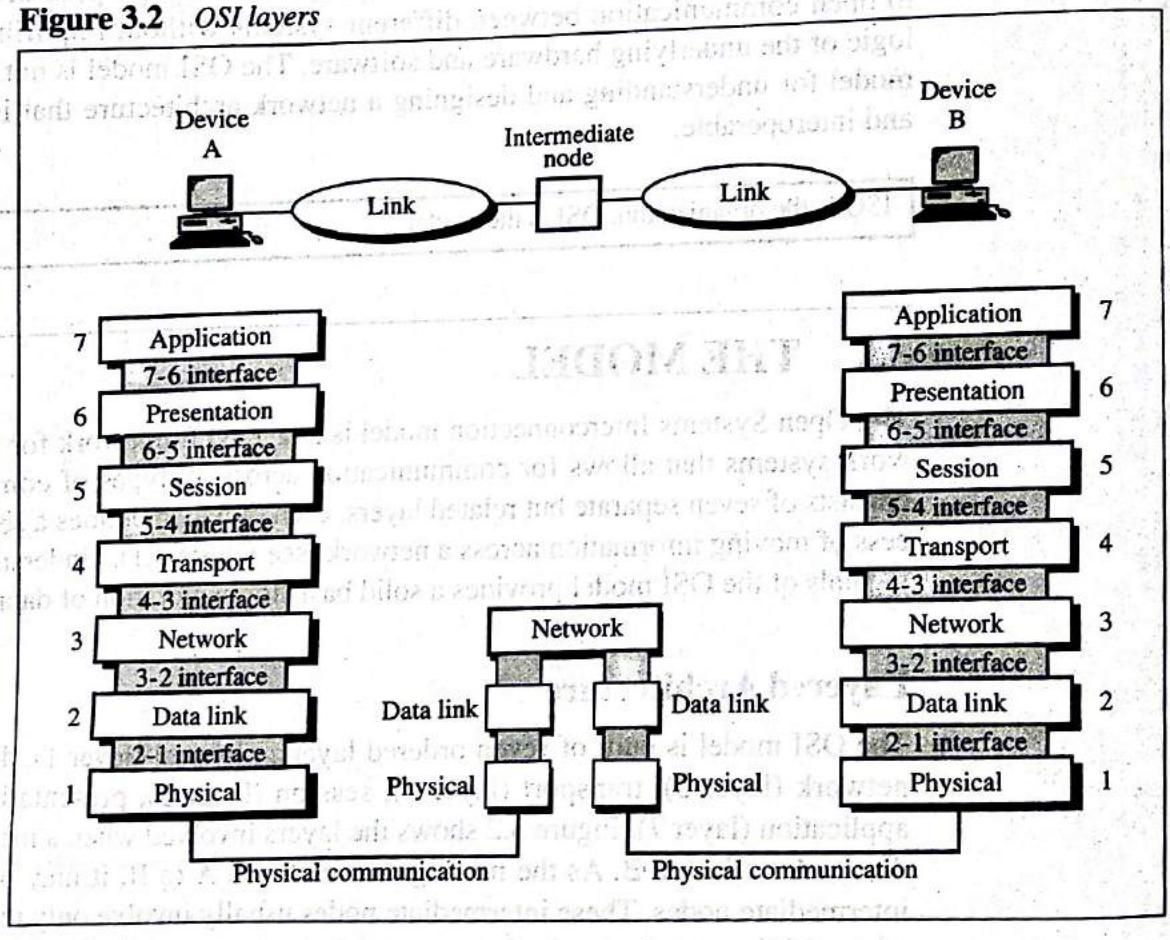


Figure 3.2 *OSI layers*



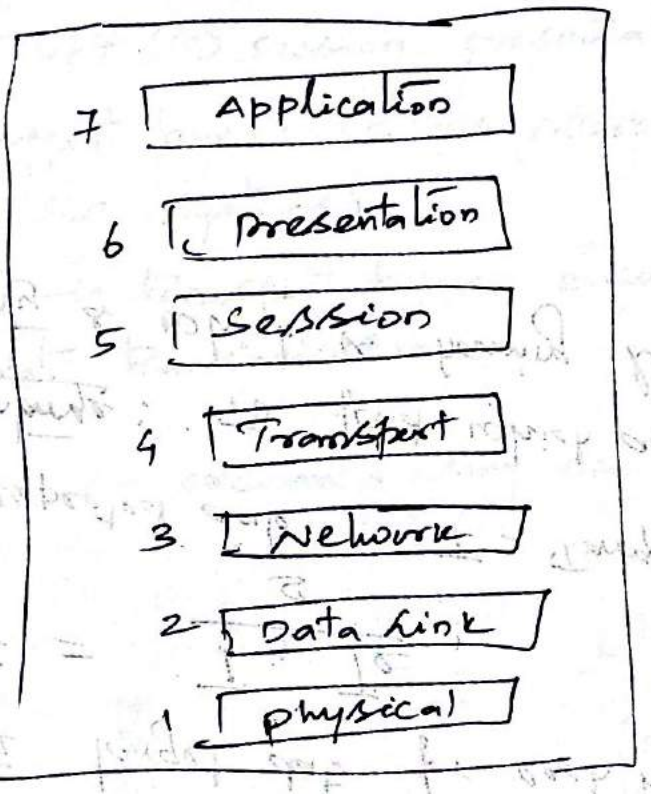
functions had related uses and collected those functions into discrete groups that became the layers. Each layer defines a family of functions distinct from those of the other layers. By defining and localizing functionality in this fashion, the designers

OSI Model UNIT-II

OSI - open System Interconnection is a layered framework for the design of n/w systems, that allows communication across all types of computer system.

* Consists 7 layers.

OSI model



* Seven ordered layers starts from physical to application.

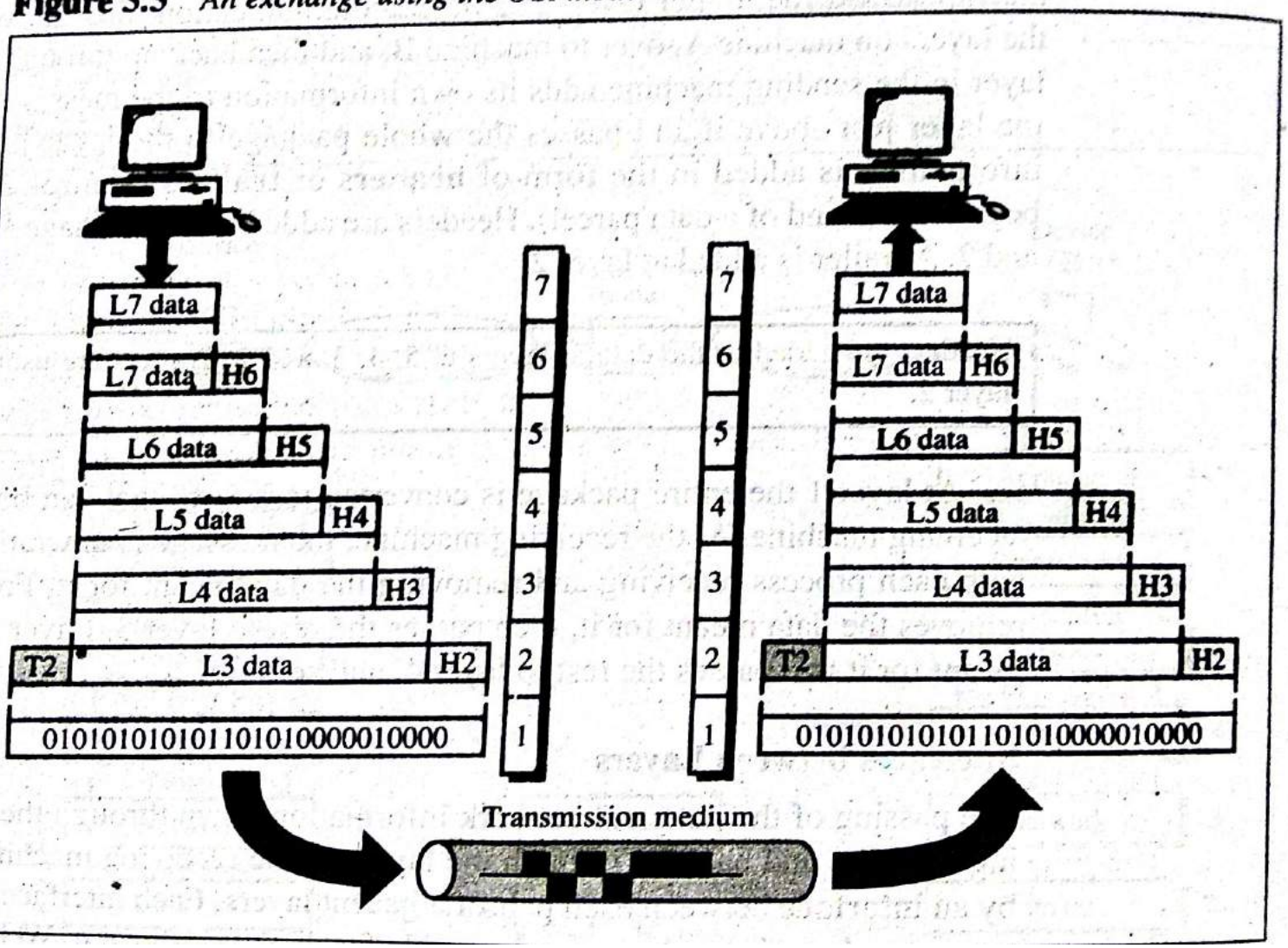
Interface between layers :→ passing data and n/w info down through layers of the sending machine and back up through the layers of the receiving machine is made possible by an interface between each pair of adjacent layers.

* Layer 1, 2, 3 (ie) physical, Data link and Network
  - are n/w support layers. (deal with physical aspect of moving data from one device to another)

* Layers 5, 6, 7 (ie) session, presentation & application
  - user support layers. (allows interoperability among unrelated s/w systems)

* Layer 4 → transport layer - ensures end-to-end reliable data transmission.

Figure 3.3 *An exchange using the OSI model*



In sending side: (Transmitting Medium)

- L6, L7 etc... means data unit at layer 6 or 7. Process starts at layer 7 & goes in descending order.
- At each layer a header is added to the data unit. H2, H3 etc (except 1 & 7)
- At layer 2 a trailer is added. "T2".
* When data passes through physical layer (layer 1) it is changed into electromagnetic signal.

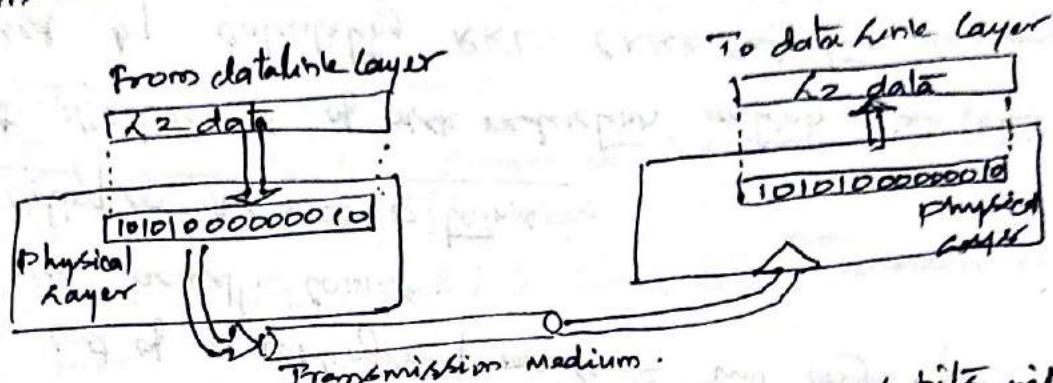
In Receiving side:

* When data passes through the corresponding layers, the header or trailer is removed, actions appropriate are taken.
* When it reaches at layer 7, the message becomes the proprietary form, and is visible to recipient.

FUNCTIONS OF THE LAYERS

① Physical layer :

- Co-ordinate the function to transmit data over a physical medium.
- It also defines procedures and functions that physical devices & interfaces have to perform for transmission to occur.



- Physical layer data consists of stream of bits without any interpretation. (bits encoded into signals electrical or optical) - defines type of encoding.
- Data rate ⇒ Transmission rate - no of bits sent each second.
- Synchronization of bits - sender & receiver must be synced.
- Line configuration - point-to-point or multipoint.
- physical topology - how devices are connected to make a n/w.
- Transmission mode - duration of transmission between two devices : (ie) simplex, half-duplex or full-duplex.

② Data-link Layer:

It transforms the physical layer to a reliable link and is responsible for node to node delivery.

Responsibilities :

- Framing → divides stream of bits received from n/w layer into manageable data units called frames.
- physical addressing → Adds a header to the frame to define physical address of sender or receiver.
- Flow control - rate at which data observed by receiver is less than rate produce by sender, DLL imposes flow control mechanism to prevent overwhelming the receiver.

* Error control: Achieved by adding a trailer at the end of the frame. [used to detect & transmit damaged or lost frames. Mechanism to prevent duplication of frames].
* Access control: When 2 or more devices connected to the same link, DLL protocols are in determines which device has control over the link at the given time.

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(3) Network layer.

It is responsible for source to destination delivery of packets. across multiple n/ws.

* If 2 systems are connected to same link, then no need for n/w layer.
* If 2 systems attached to different n/w, n/w layer is needed to accomplish S-to-D delivery.

Responsibilities:

* Logical addressing: (physical address implemented by DLL) Here, it adds a header to the packet coming from upper layers, (ie) includes a logical addresses of Sender & Receiver
* Routing: - connecting devices which routes the packet to their destination.

(4) Transport layer.

It is responsible for delivery of entire message from Source to Destination.

* This layer creates a "connection" between 2 end ports

Connection - It's a single logical path from S to D

Here 3 steps: (1) Connection establishment (2) data transfer (3) Connection release.

Responsibilities

* Service point addressing: Computers often runs several pgms at same time. Source to destination delivery is not only from one computer to another but also from one process to another.
  -: Transport layer header includes service point address.

* Segmentation and re-assembly: message is divided into segments and each segment contains a sequence number. (these nos used for reassemble of message while arrival)

* Connection control: TL is either ⓐ Connection less or ⓑ Connection-oriented.

ⓐ Treats each segment as independent packet & delivers it to TL of destination machine

ⓑ - First makes first connection with TL of destination machine and deliver packets.

If data transfered, connection terminated.

* Flow control: responsible for end-to-end flow control.

* Error control: " " error ".

error correction is achieved through retransmission.

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⑤ Session Layer:

It is the network dialog controller. (ie) It establishes, maintains and synchronise the interaction between comm systems.

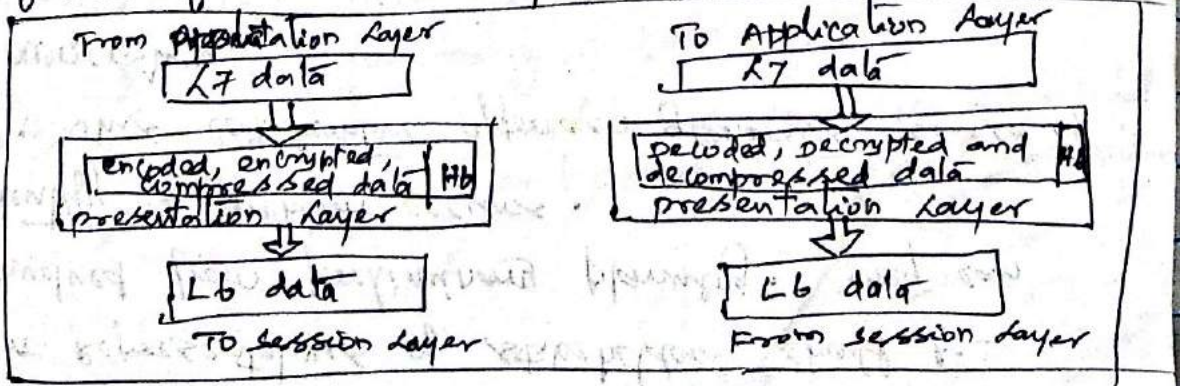
Responsibilities:

* Dialog control – allows two systems to enter into a dialog.
* Sync – allows process to add checkpoints into stream of data.

For eg. if 2000 pages of data transfered, inserting checkpoint after 100 pages, a acknowledgement is received for every 100 pages transfered. Assume a crash happen during transmission of 525th page, pages 1 to 500 need not be retransmitted, but begin from 501 page.

⑥ presentation Layer:

* It concerned with the syntax and semantics of the information exchanged between 2 systems.



Responsibilities: Translation, Encryption and compression.

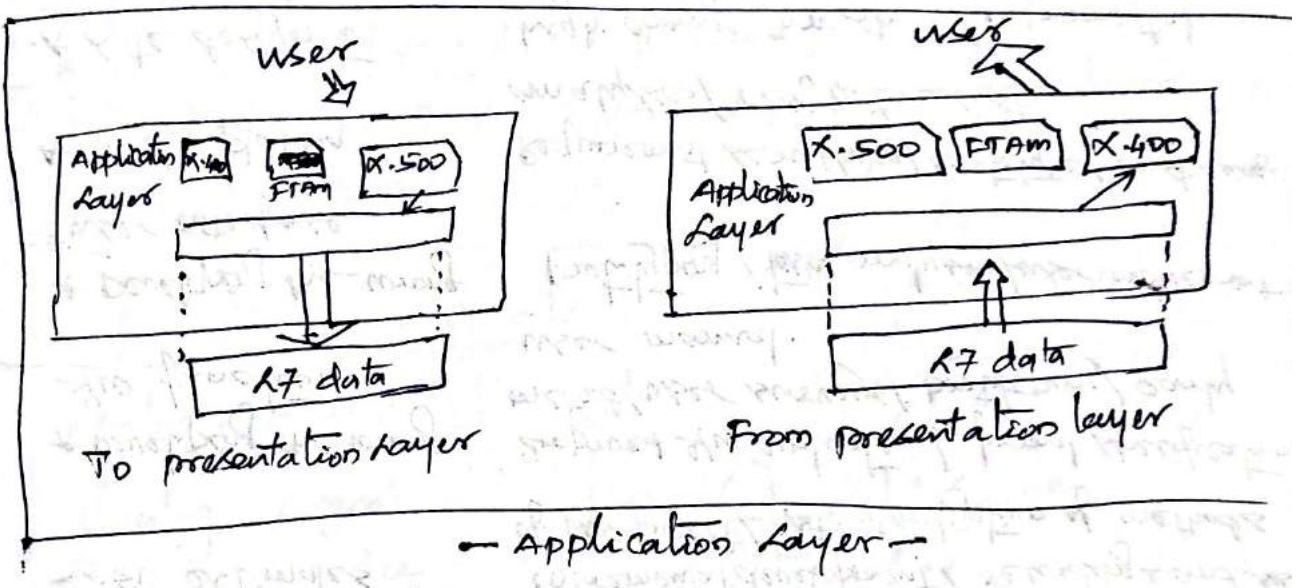
Characters to bit stream, for sensitive info, Reduces no of bits.

(7) Application Layer:

* Enables user to access the network.
* provides user interface and support for services. (such as email, remote file access & transfer, database sharing and other types of distributed information services).

Following diagram shows relationship of application layer to the user and the presentation layer. [Among many application services available diagram shows three

X.400 – Message handling services
X.500 – Directory services
FTAM – File Transfer Access and Management



Services provided:

* Network virtual terminal – Bi directional version of a physical terminal, allows user to log on to remote host.
* FTAM – Application which allows a user to access files in a remote computer, to retrieve, to manage or control files in a remote computer.
* Mail services – This application provides the basis for email forwarding and storage.
* Directory services – Application provides distributed database sources and access for global information

TCP/IP protocol suite

* It is used in Internet. * Developed prior to OSI model
* Transmission Control protocol / Internet protocol do not match with OSI
* TCP/IP made up of 5 layers

Physical, data link, network, Transport & Application

First 4 provides, physical standards, n/w interface, internetworking, & transport function.

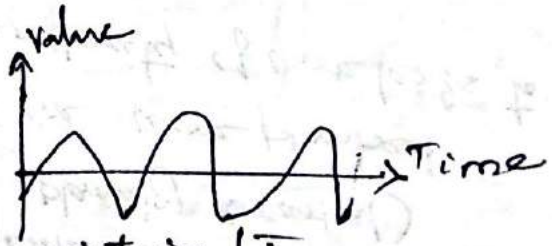
* First 3 layers in OSI model is represented in TCP/IP by a single layer called application.
* TCP/IP is a hierarchical protocol, means that, each upper level protocol is supported by one or more lower level protocols.

Signals

Analog and Digital

Analog signal

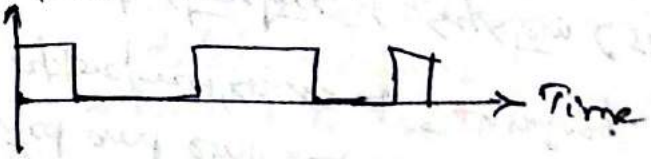
(Eg) human voice



Signal can be analysed at any point in time.

Digital signal

(Eg) data stored on computer memory.

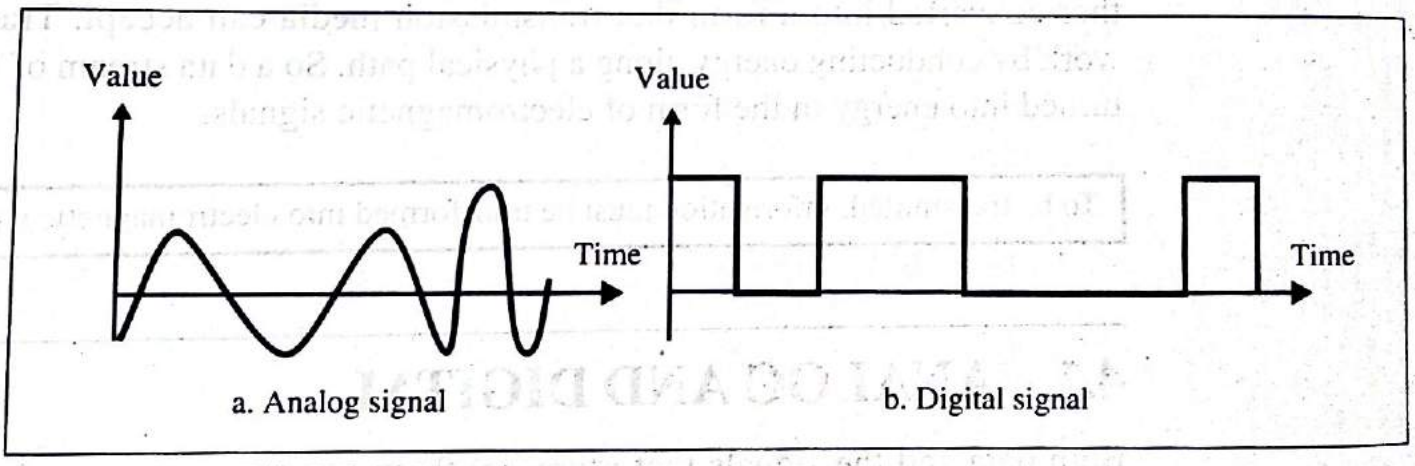


* Signal can be analysed only at particular point on time.

Signals: Analog signals - continuous wave form smoothly over time.

Digital signals - It is discrete. often it is 1 or 0.

Figure 4.1 *Comparison of analog and digital signals*

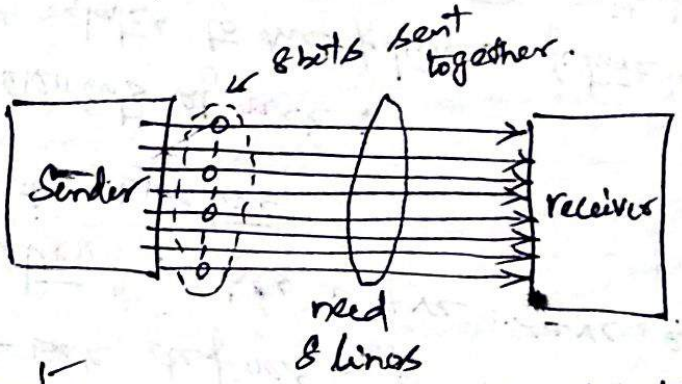


Digital Data Transmission

* Transmission of data from one device to another. done in two ways:
  1. Parallel Transmission
  2. Serial Transmission
     - (a) Synchronous
     - (b) Asynchronous.

(1) Parallel Transmission:

organising the binary data into group of 'n' bits. We can send 'n' bits at a time instead of one bit. The mechanism is, use 'n' wires to send 'n' bits as shown below.



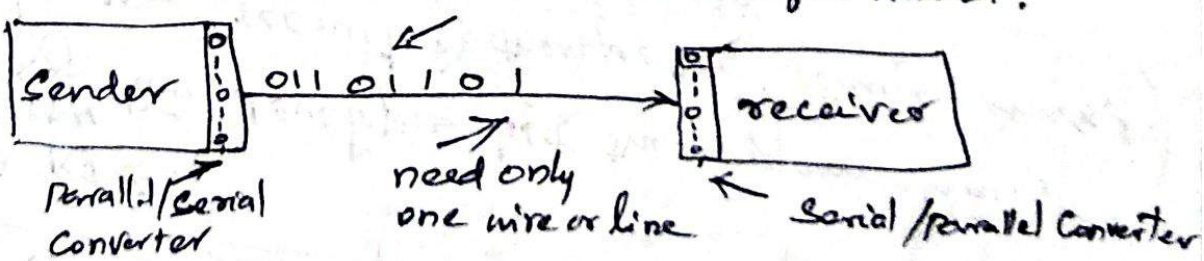
- Advantage → speed.

Disadvantage → cost. (need 'n' comm lines to transmit the data stream).

* limited to short distance.

(2) Serial Transmission:

one bit follows another, so only one comm channel is needed.

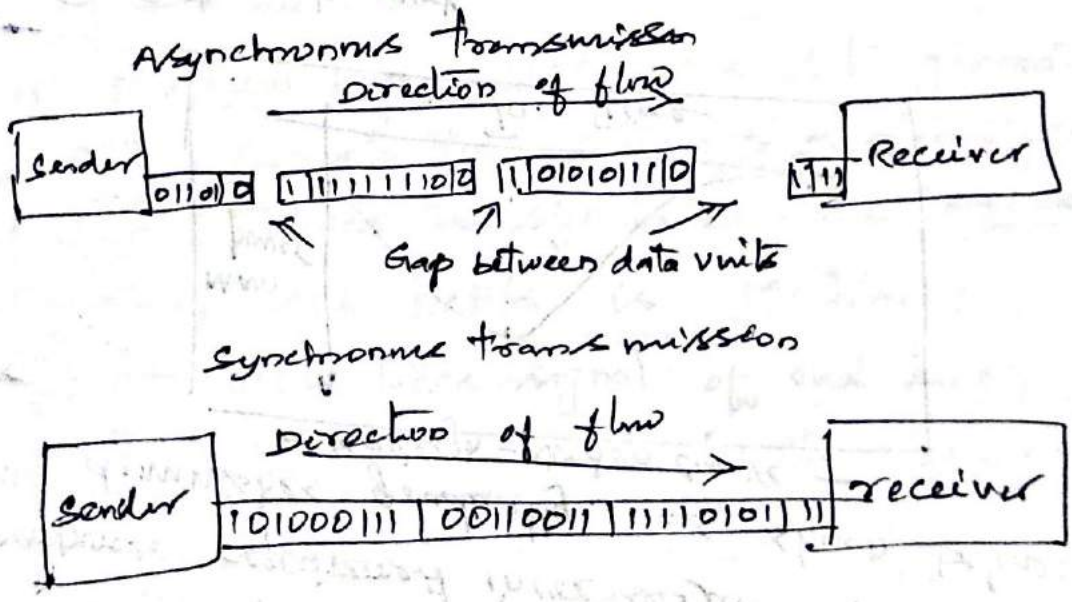


Adv: only one Comm channel., reduced cost.

* Communication within the device is parallel, conversion devices are required at the interface between S & R.

In Asynchronous transmission, timing of signal is unimportant. Information is received and translated by agreed-upon patterns. (Patterns are based on grouping the bit stream into bytes)
To alert the receiver for an arrival of new group, an extra bit is added to the beginning of each byte, called ~~stop bit~~. start bit, usually '0'. At the end of each byte, a stop bit is added, which is usually '1'. So, each byte size is increased to 10 bits.

In synchronous transmission, contains multiple bytes. Each byte is introduced into transmission line without a gap between it and the next one.



— a —

DTE-DCE Interface

[Data Terminal Equipment & Data circuit-Terminating Equipment]

Data Terminal Equipment (DTE)

- It includes any unit that functions either as a source of or a destination for binary digital data

* At the physical layer, it can be a terminal, microcomputer, computer, printer, fare machines or another device that generates or consumes digital data.
* DTE, donot comm directly with one another, need a intermediatry to communicate.

(eg) Person to person communication.

our mind & friends mind are DTE

Vocal chords and mouth are DCE.

ear is also ⟶

DCE - Data Circuit - Terminating Equipment

DCE - It is any device that transmits or receives data in the form of an analog or digital signal through a n/w.

* At physical layer DCE takes data generated by DTE, converts them into appropriate signal, and then introduces the signals onto the Telecom link.
* Commonly used DCE's is Modem.
* Second DCE takes signal off the line, converts it to a form usable by its DTE, and delivers it.

Standards:

Most active standards:

1. EIA standard (Electronic Industries Association)
2. ITU-T standard (International Telecom Union - Telecomm Standard)

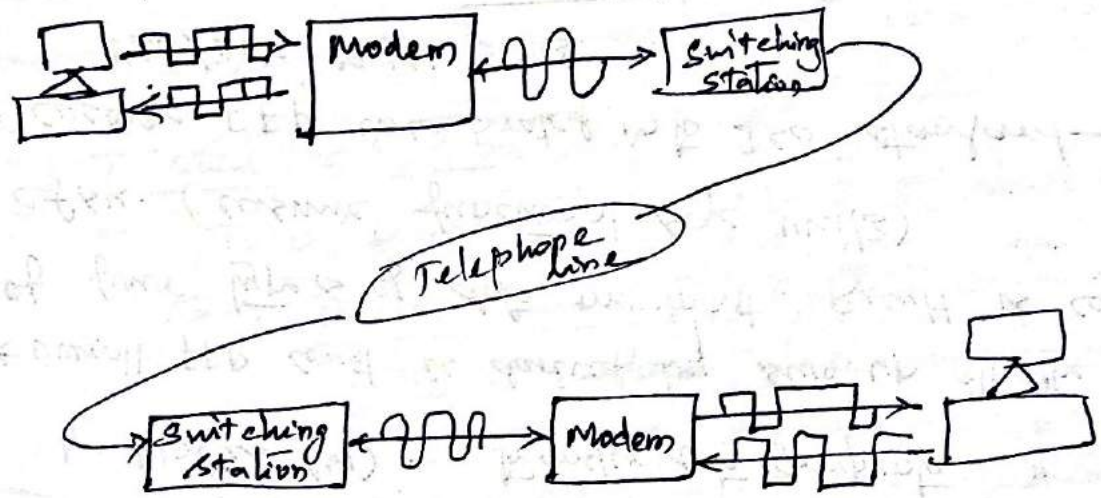
→ EIA-232, EIA 442, EIA 449

→ called V-Series and X-series.

Modems

- Most familiar DCE.
  Rt.s called Modulator / Demodulator

Modulator – Converts digital signal into analog signal
Demodulator – " Analog " " digital "



— Modem Concept —

Transmission rate : How many bits per second a specific device is capable of transmitting or receiving

Bandwidth : Every line has a upper or lower limit on the frequencies of the signals it can carry. [This limited range is called bandwidth]

Two modem standards are:

① Bell modems
② ITU-T modems.

→ First Commercial modem – Introduced early 1970's by Bell Telephone Company.

UNIT - III

Transmission Media:

Two types ① Guided Media
② un-guided media.

① Guided Media

→ provides a conduit from one device to another.

① Twisted pair cable ② co-axial cable ③ fiber optics etc.

① Twisted pair cable

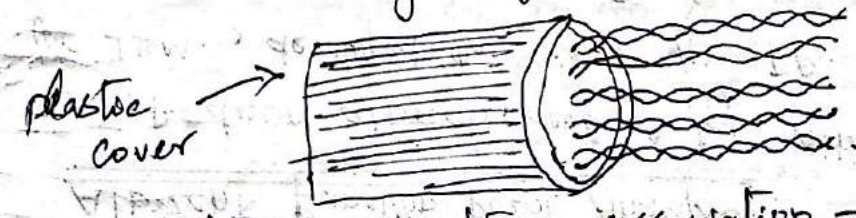
Two forms ⓐ unshielded ⓑ shielded.

ⓐ Unshielded Twisted Pair (UTP) cable

- used in todays telecommunication.
- It consists of 2 conductors (usually copper) each with its own plastic insulation. Plastic insulation is color-banded for identification.
- Twisted pair significantly reduces noise, compared with parallel lines.

Advantage: cost and ease of use. (cheap, flexible & easy to install)

Higher grade UTP as shown below.



EIA - Electronic Industries Association - developed standards to upgrade UTP cable by quality.

1 denotes lowest and 5 denotes highest.

Category 1: basic twisted pair used in telecomm

Category 2: suitable for voice & data transmission of upto 4 Mbps.

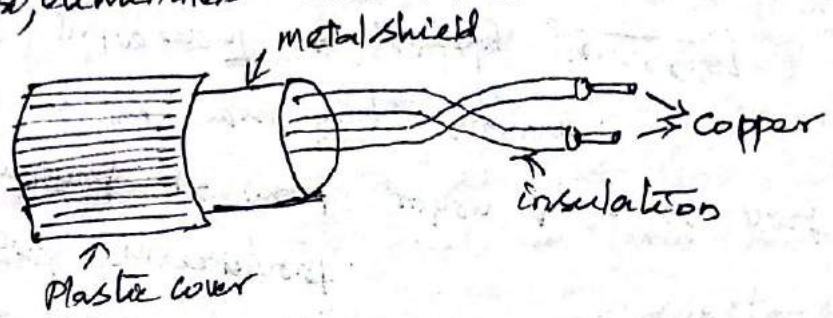
Category 3: used for data transmission of upto 10 Mbps. (3 at least twisted pairs per foot)

Category 4: Transmission of 16 Mbps.

Category 5: used for data transmission upto 100 Mbps

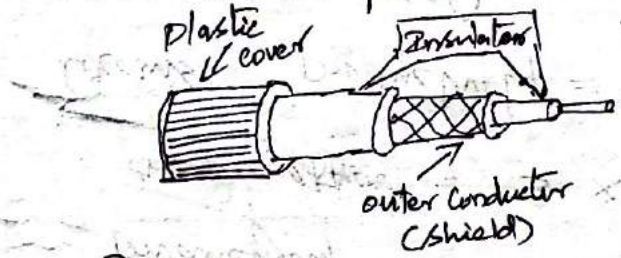
(b) Shielded Twisted pair (STP) cable

* It has a metal foil or mesh covering that encases of each pair of insulated conductors.
* Metal casing prevents penetration of electromagnetic noise, also, eliminates crosstalk.



(2) Co-axial Cable:

- Carries signals of higher frequency ranges than twisted pair.



- Frequency range from 100 KHz to 500 MHz.

Co-ax has: a central core conductor (usually copper) enclosed in an insulating sheath, encased in an outer conductor of metal foil.
outer metallic wrapping serves both as shield against noise and as second conductor, enclosed in a sheath. Whole cable is protected by a plastic cover.

Co-ax Standardards:

RG 8, 9 & 11 — used in thick ethernet.
RG 58 — " " thin "
RG 59 — used for Tv.

No of connector have been designed. Among most popular is BNC. (Bayonet Network Connector) Terminator is also needed.

(3) Optical Fiber,

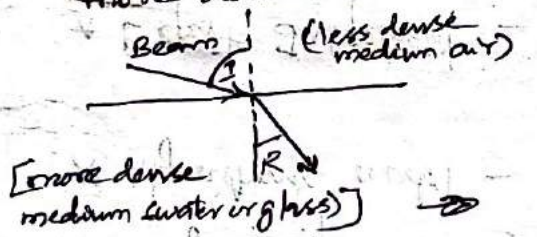
- It is made up of Glass or plastic and transmits the signals in the form of light.

Light - A form of electromagnetic energy.
Travels 300,000 km/per second. or 186,000 miles in a vacuum. (speed decreases, as the medium through which the light travels become denser

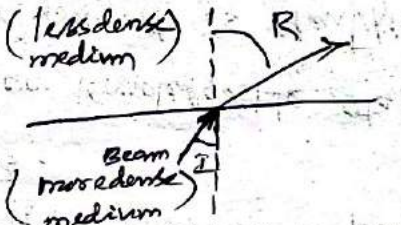
* Light Travels in a straight line, as it moving through a single uniform substance.
* When it moves from one substance to another, causing the rays to change direction, is called refraction.

Refraction

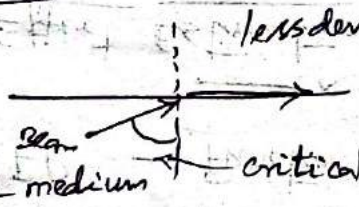
From less dense to more dense medium



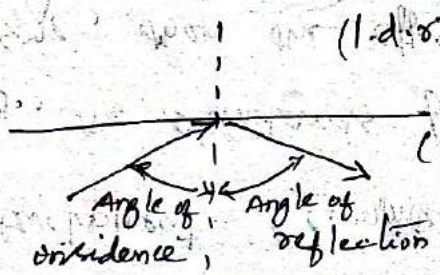
From more dense to less dense medium



Critical angle:



Reflection: Angle of incidense becomes greater than than the critical angle, called reflection



- optical fiber uses reflection to guide light through the channel. Information encoded on the beam of light as a series of on-off flashes (which represents 1 and 0 bits)

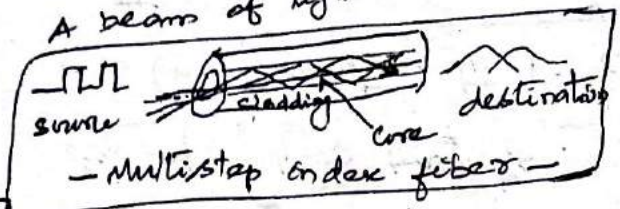
Propagation modes:

Multimode

* Multiple beams from a light source move through the core to different paths. (movement of beam in cable depends on structure of core)

@ Multimode step-index fiber

the density of core remains constant from center to edge. A beam of light moves through



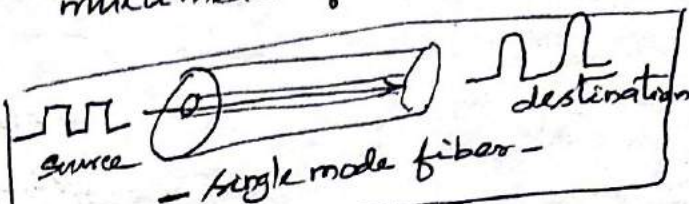
this constant density in a straight line until reach the interface of the core and the cladding.

In above diagram various beams travelling through a step-index fiber.

single mode.

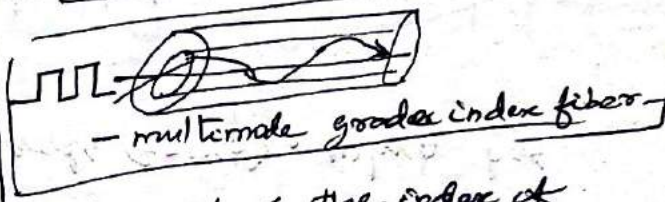
– It uses step index fiber.

It is smaller in size than multimode fiber.



multimode

⑤ Multimode grade-index fiber

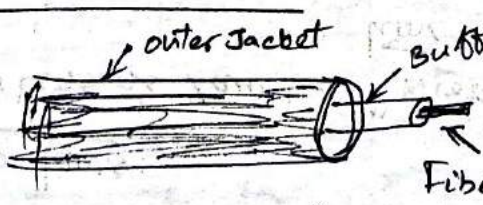


* Index refers the index of refraction
* Graded index fiber is one with varying densities
* density is highest at the center of the core and decreases gradually to the lowest at the edge

Fiber sizes

Fiber Type	Core (microns)	cladding (microns)
62.5/125	62.5	125
50/125	50.0	125
100/140	100.0	140
8.3/125	8.3	125.

Fiber Construction



Advantage: * Noise resistance.
* less signal attenuation (go for long distance without regeneration)
* Higher bandwidth.

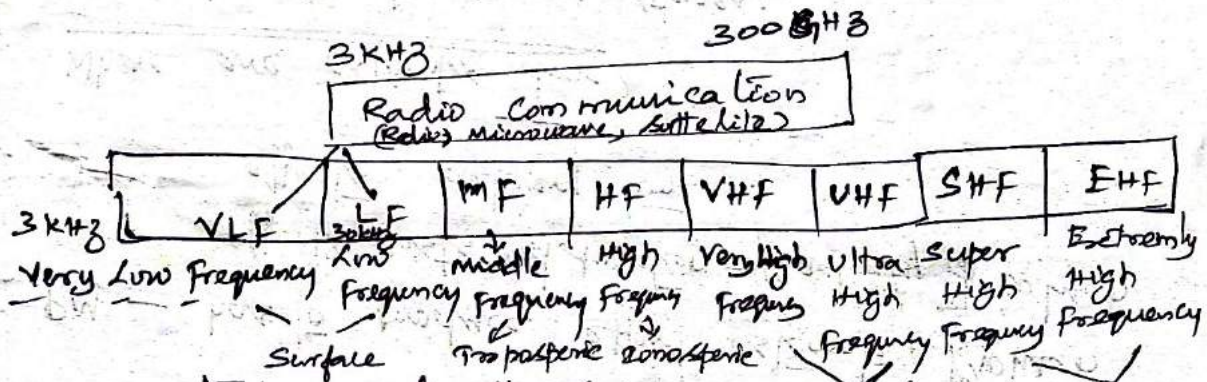
Disadvantage:
* Cost * Installation/Maintenance * Fragility (easily broken)

Unguided media

- Also called wireless communication, transmits electromagnetic waves without using physical conductor. (ie) signals broadcast through air.

Radio frequency allocation

* radio comm is divided into 8 ranges, called bands



Propagation of Radio Waves:

Types of propagation:

* Radio wave transmission utilises 5 different types of propagation.

① Surface propagation:
* radio waves travels through the lowest portion of atmosphere, hugging the earth. This propagation can take place in sea water.

② Tropospheric propagation:

Can work in 2 ways: ~~Eight~~ ~~Eight~~ Either a signal can be directed in a straight line (Antena to antena) or it can broadcast into an angle into upper layers, where it is reflected back down to earth's surface. No1 requires a receiver and transmitter within a line of sight distance.
In 2nd method greater distance is covered.

③ Ionospheric propagation:

* upper frequency radio waves radiate upward into ionosphere where they are reflected back to the earth.
* Covers greater distance with lower output.

④ Line-of-sight propagation:

very high frequency signals are transmitted in straight line from antenna to antenna.

⑤ space propagation.

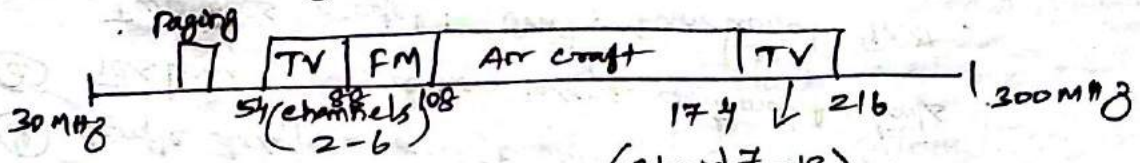
* utilises satellite relays. A broadcast signal received by an orbiting satellite, which rebroadcast the signals to the intended receiver back on the earth.

Frequency Range

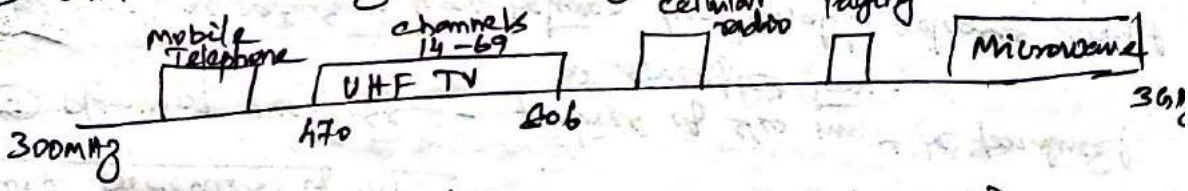
① VLF → 3KHz to 30 kHz ② LF → 30KHz to 300 KHz

③ MF → 300 kHz to 3 MHz (AM radio) ④ HF → 3MHz to 30MHz (CB radio)

⑤ VHF → 30 MHz to 300 MHz



⑥ UHF → 300MHz to 3 GHz



⑦ SHF → 3GHz to 30GHz (Micro wave)

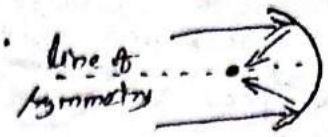
⑧ EHF → 30 GHz to 300 GHz (Micro wave)

Terrestrial Microwave.

- It requires line-of-sight transmission. distance coverage is depends on height of antenna.
- signals propagates one direction at a time. So, two frequencies are needed for 2 way comm. Each requires a transmitter & receiver. Nowaday it is combined in a single piece called Transceivers.

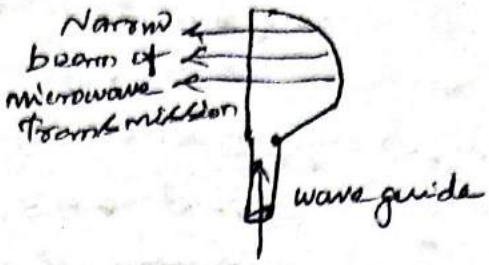
Repeaters: Installed in each antenna, to increase the distance served.

Antenna : 2 types of used in microwave comm.

(1) Parabolic dish. 

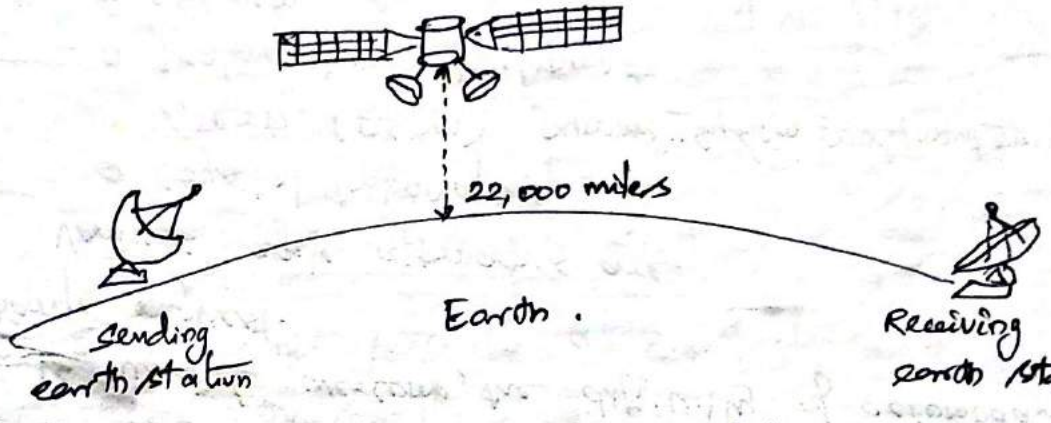
(2) Horn.

- like a giant scoop.



Satellite Comm :

- Its like line-of-sight transmission



For the constant comm, the satellite must move at the same speed as the earth. So that such satellites are called geosynchronous.

satellite frequency bands

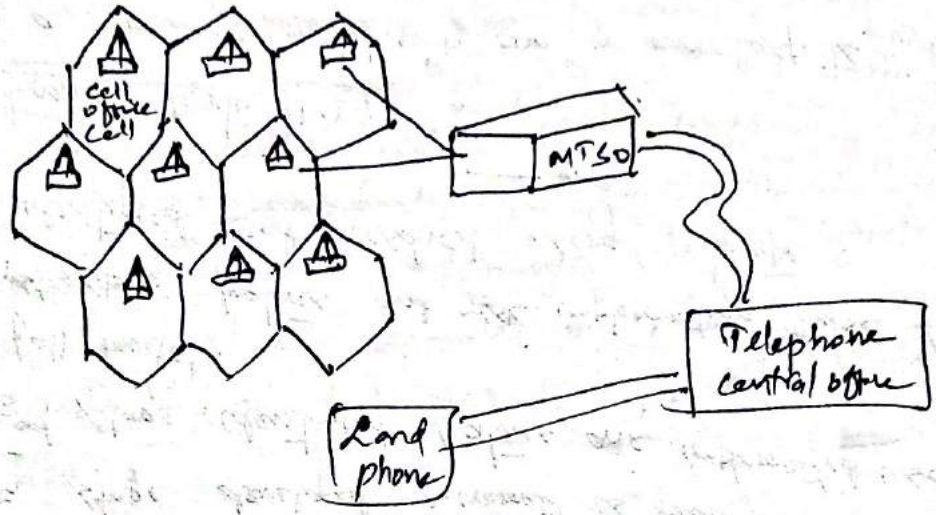
Band	Downlink	Uplink
C	3.7 to 4.2 GHz	5.925 to 6.425 GHz
Ku	11.7 to 12.2 GHz	14 to 14.5 GHz
Ka	17.7 to 21 GHz	27.5 to 31 GHz.

Cellular Telephony.

* Provide stable comm between two moving devices. or between one mobile unit and one stationary unit.
* To make tracking possible, each cellular service area is divided into small regions called cells.

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

* Each cell office is controlled by a switching office called MTSO. (Mobile Telephone Switching Office)
* MTSO Coordinates comm between all the cell offices & Telephone central office.



— cellular system —.

Transmission Impairment

* Trans media are not perfect. The imperfections cause impairment in the signal.

3 type of Impairment

Attenuation

Means loss of energy. Happens when it passes through a medium.

Distortion

Signals changes its form or shape. It occurs in Composite signals. (made of different frequencies)

Noise

Types of noise: Thermal, induced noise, crosstalk and impulse noise. It may corrupt signals. Thermal noise occurs due to random motion of electrons in wire

Induced noise comes from motor or appliance. Crosstalk is the effect of one wire on the other.

— a —

Media Comparison:

For Comparision of several media 5 factors should be kept in mind: Cost, Speed, Attenuation, Electromagnetic interference (EMI) and Security.

Cost - Costs of material + installation
Speed - Maximum no of bits per second.
Security - protection against eavesdropping.

EMI: the susceptibility of medium to external electromagnetic energy & familiar effects of EMI are Audio (static) & Snow (Visual)

Figure 8.2 *Categories of multiplexing*

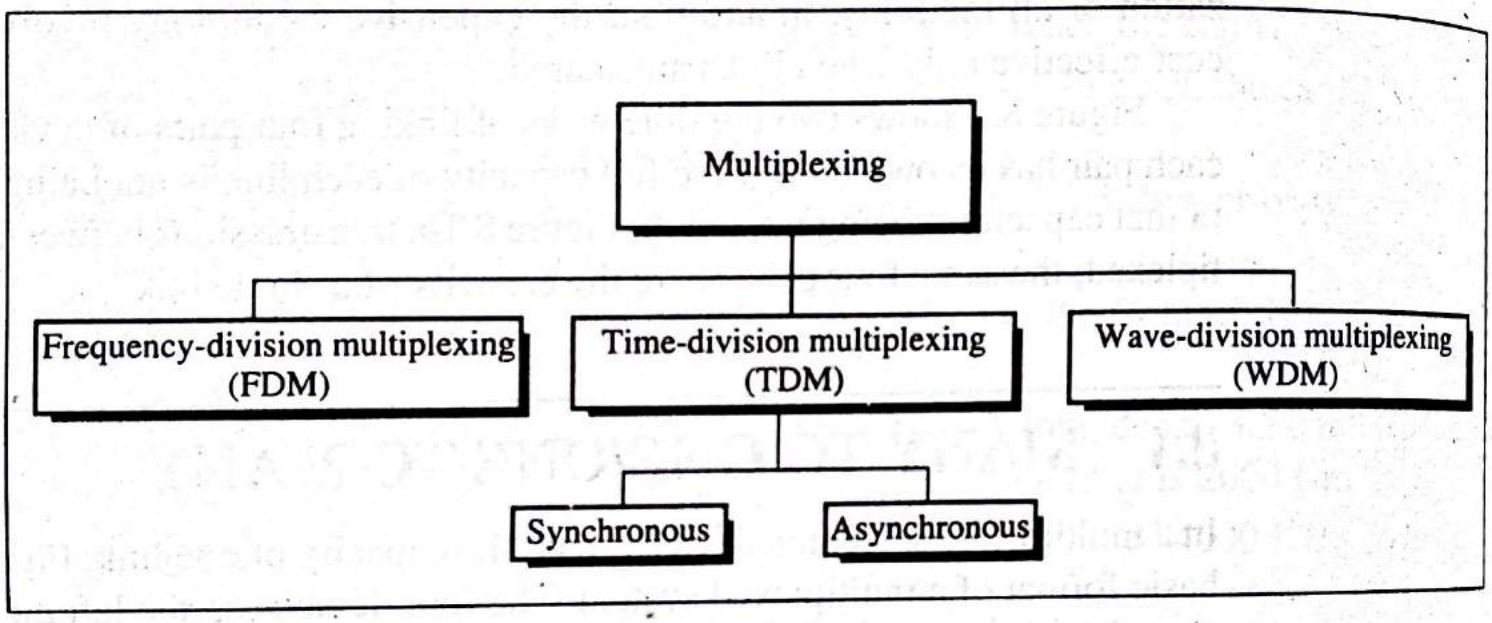
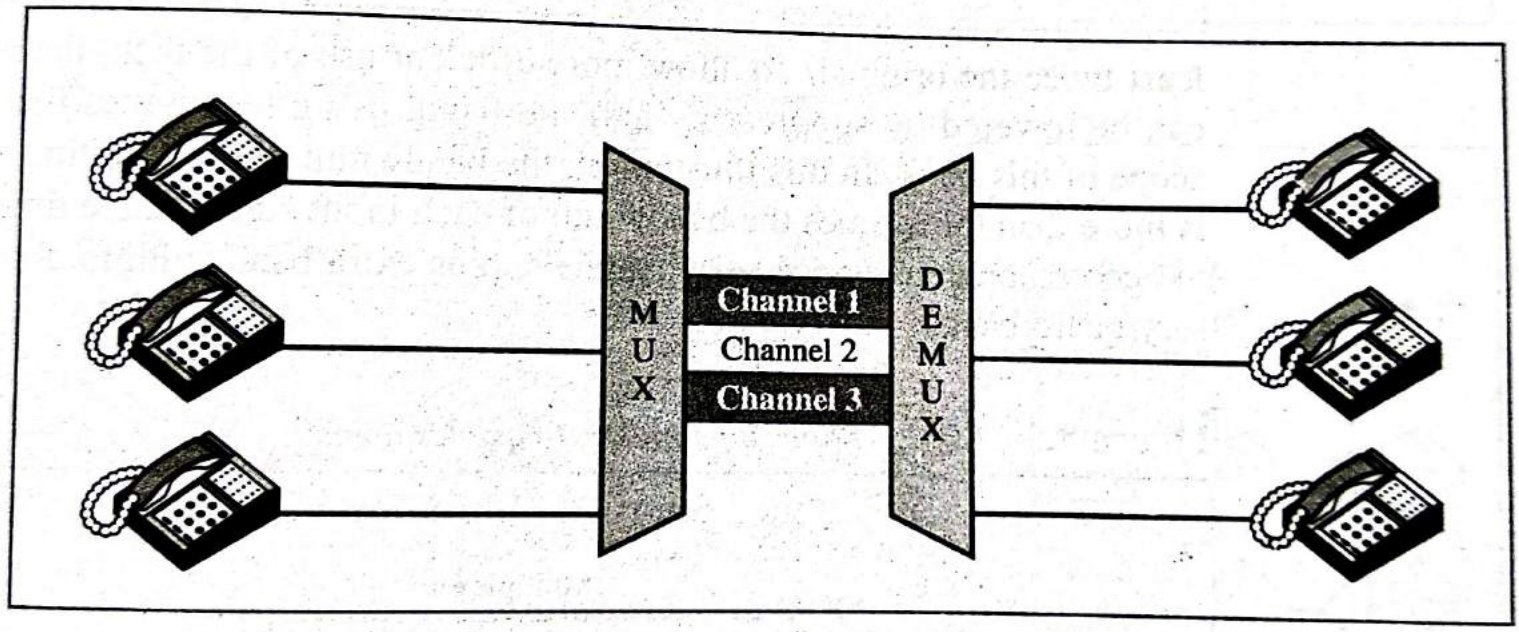


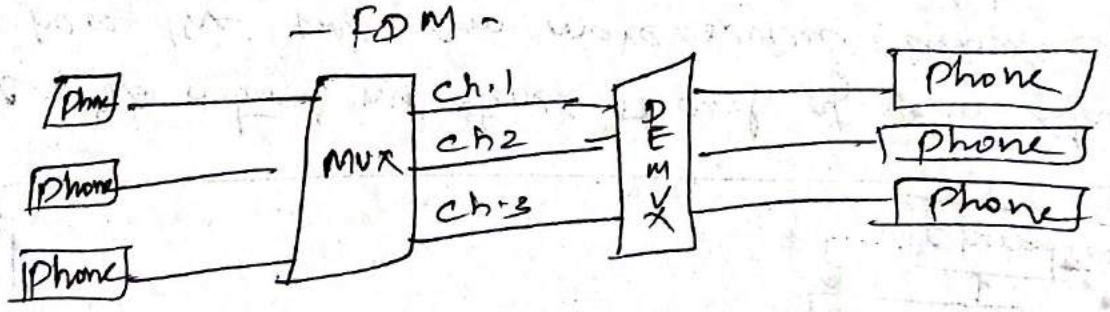
Figure 8.3 *FDM*



Frequency Division Multiplexing (FDM)

Multiplexer – Many to one.
Demultiplexer – one to many

* It is an analog technique, applied when a bandwidth of a link is greater than the combined bandwidths of the signals to be transmitted.
* In FDM, signal generated by each sending device modulate different carrier frequencies. These modulated signals then combined into a single composite signal that can be transported by the link. These bandwidth ranges are the channels. (through various signals travels)
* channels must be separated by strips of unused bandwidths (guard bands) to prevent signals from overlapping.



Time-domain Multiplexing

In Time-domain Multiplexing – each telephone generates a signal of similar frequency range. Inside Multiplexer, these signals are modulated as different carrier frequencies (f1, f2, f3). Resulting signals are combined into a single composite signal and send over the link. (the link has enough bandwidth to accomodate it)

Figure 8.4 *FDM multiplexing process, time domain*

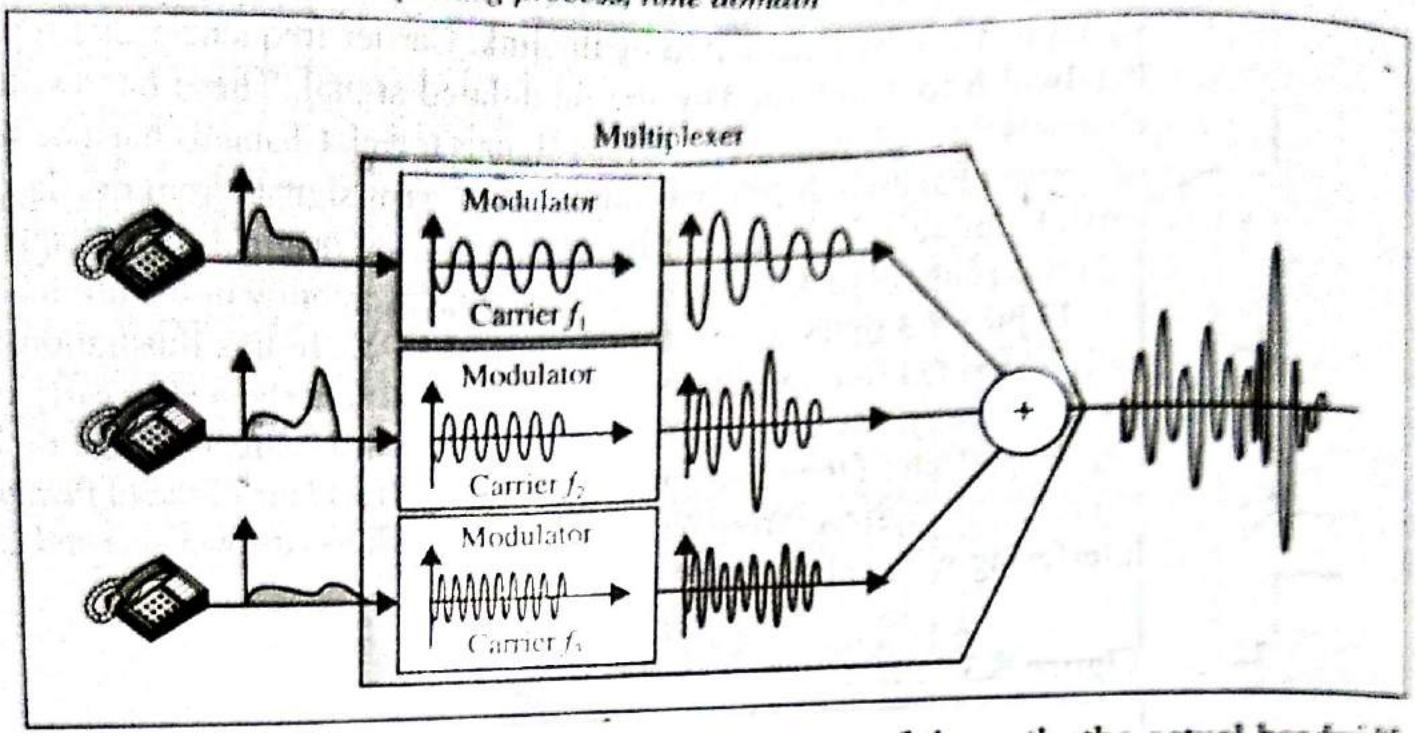


Figure 8.5 *FDM multiplexing process, frequency domain*

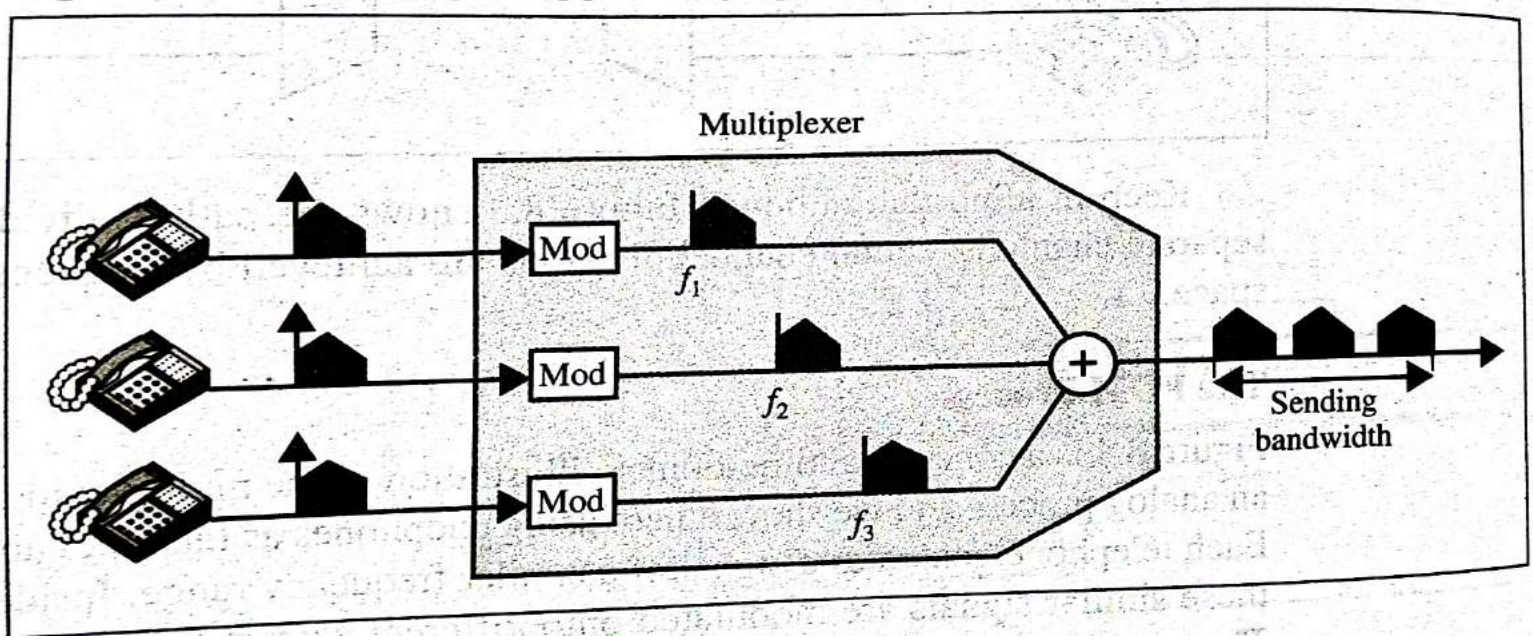


Figure 8.6 *FDM demultiplexing process, time domain*

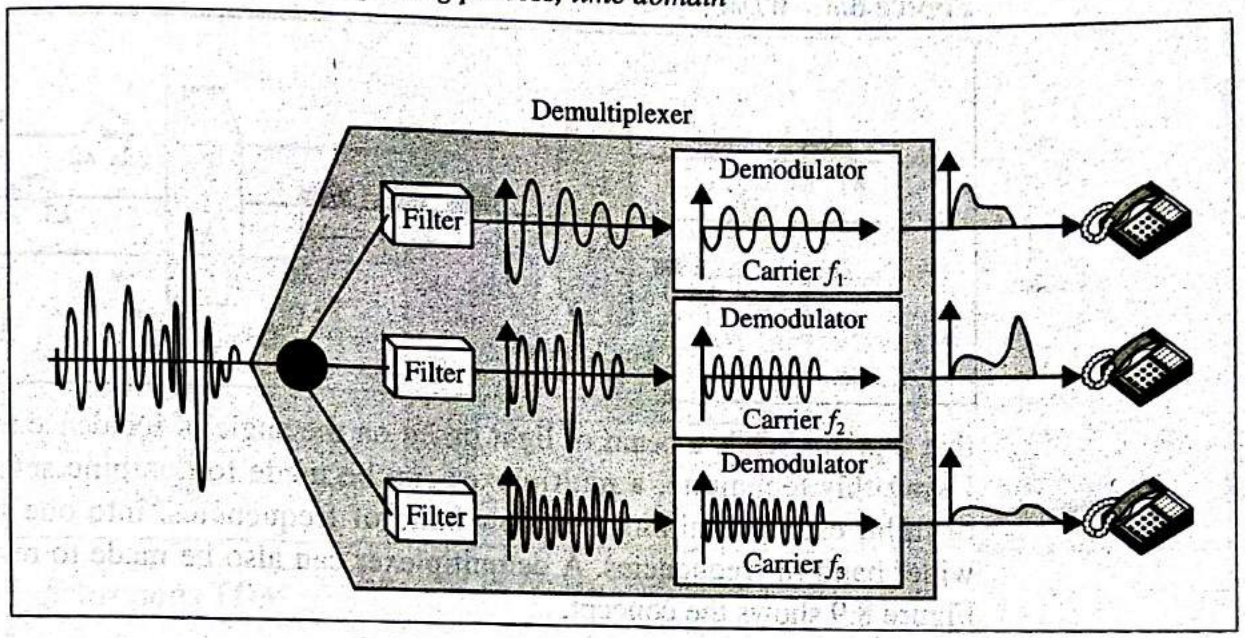
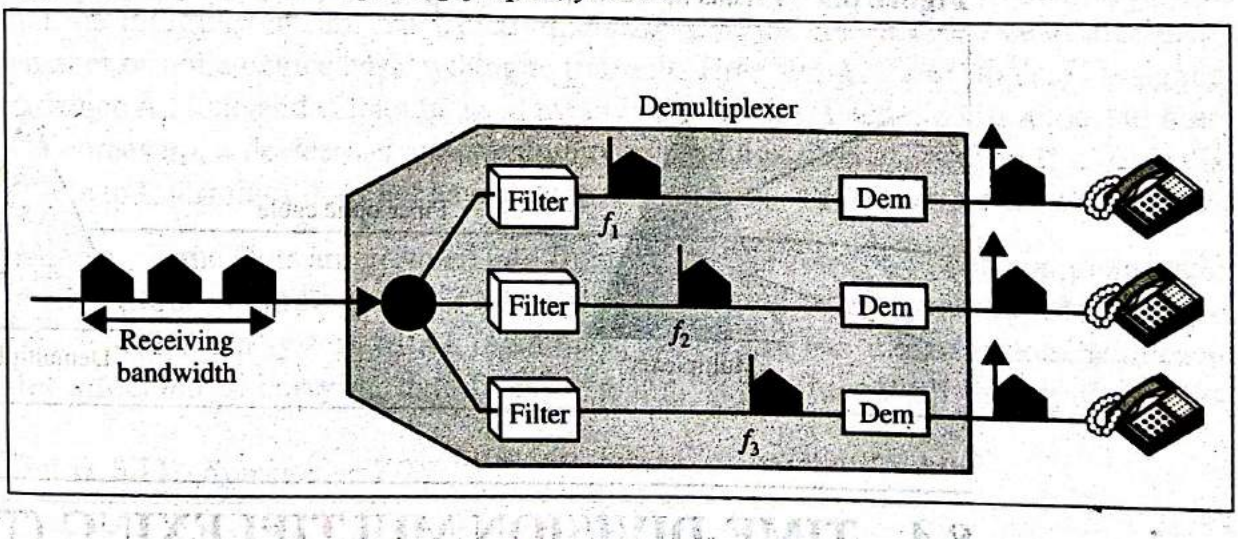


Figure 8.7 *FDM demultiplexing, frequency domain*

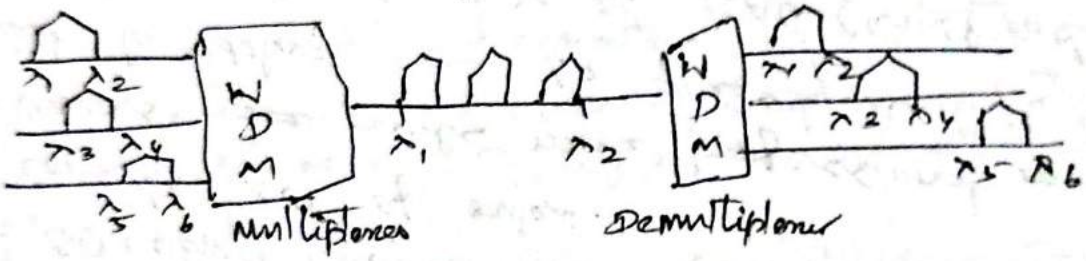


① WAVE-DIVISION MULTIPLEXING (WDM)

Its same as FDM, except multiplexing and demultiplexing involves light signals transmitted through fiber optic channels.

* Combining different signals of different frequencies. (difference is frequencies are very high).

— Conceptual view WDM Multiplexer & Demultiplexer —

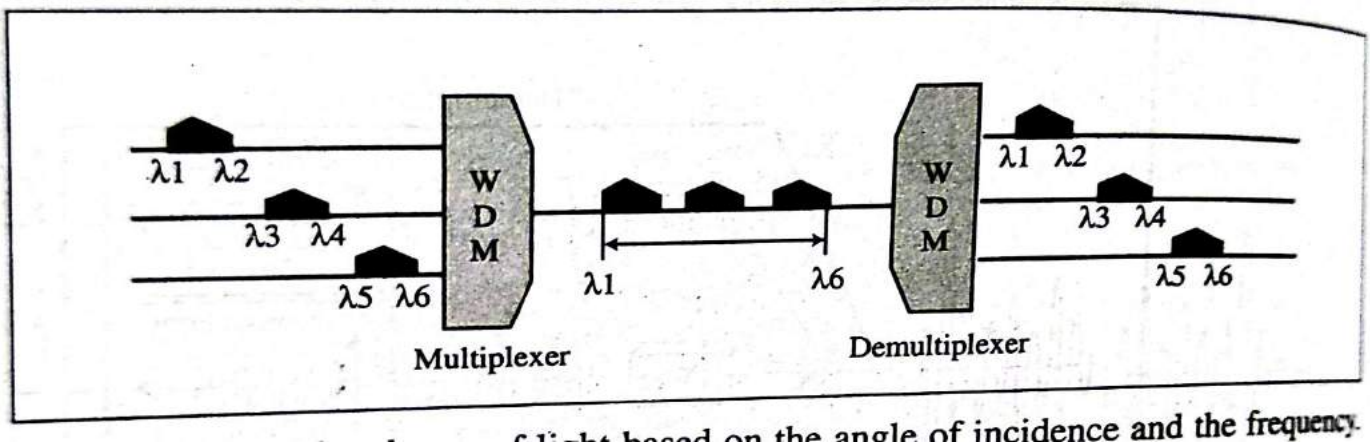


~~Technique~~

Technology is complex, the idea is very simple.

- Combining multiple light sources into single light at Multiplexer, and the reverse in demultiplexer. It is handled by a prism.

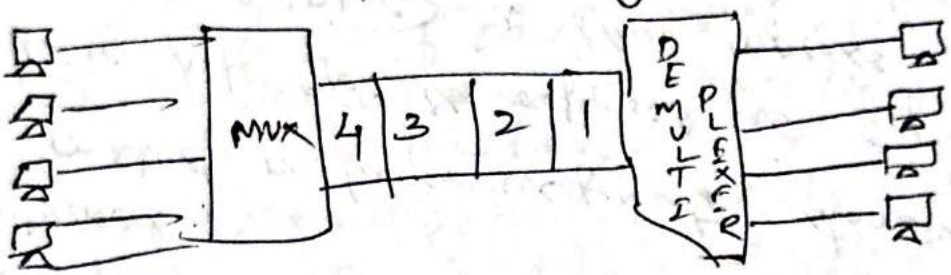
Figure 8.8 *WDM*



of light based on the angle of incidence and the frequency.

Time division multiplexing (TDM)

It can be applied when data rate capacity of the transmission medium is greater than the data rate required by the sending and receiving devices. So, multiple transmission can occupy a single link as shown below:



Two types of TDM : ① Synchronous TDM
② Asynchronous TDM.

① Synchronous TDM

Here, the multiplexer allocate same time slot to each device at all time, whether or not the device has anything to transmit. Time slot of one device can't used by other device. Time slots are grouped into frames. A frame consists of one complete cycle of time slots.

Figure 8.10 *TDM*

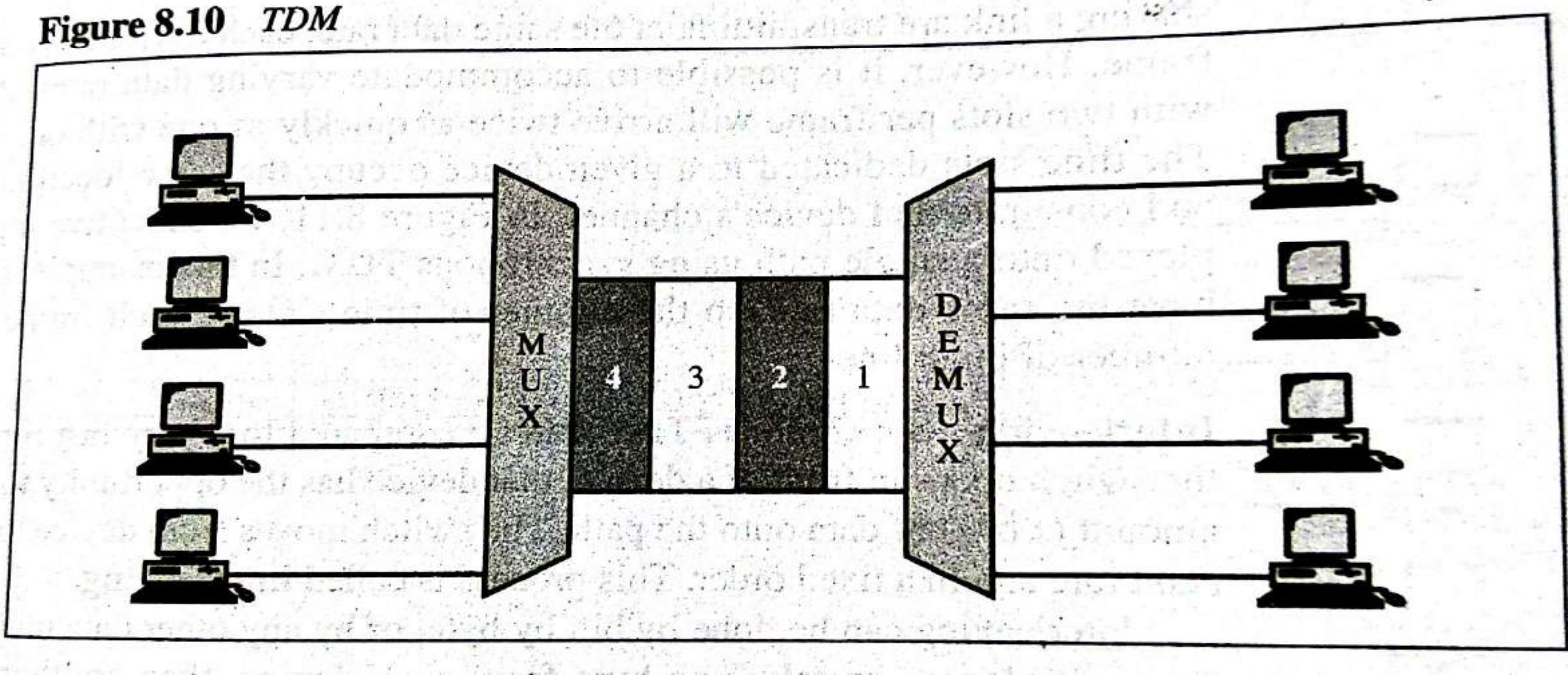
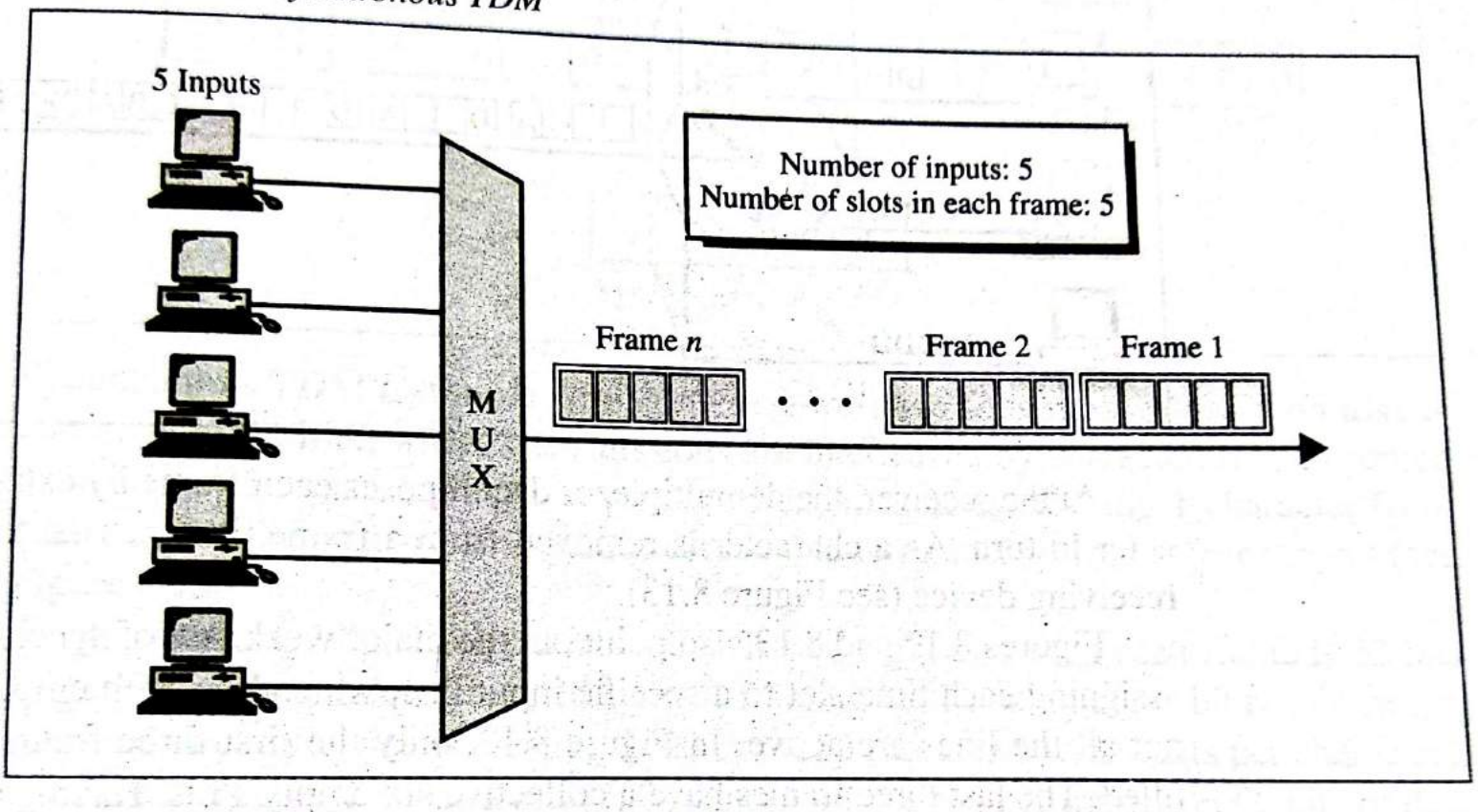


Figure 8.11 *Synchronous TDM*



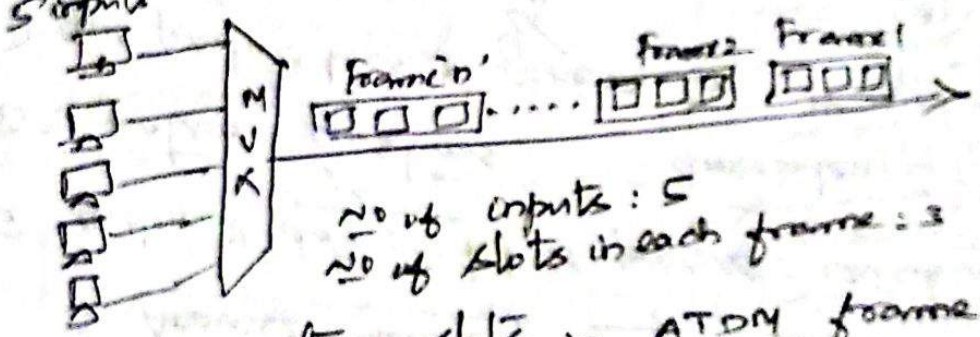
② Asynchronous TDM :

Assume, we have 20 computers, at a time only 10 of them are sending information. speed of line is 20 times the speed of each input line. Here half of the capacity of line is wasted.

So, to avoid the above Asynchronous TDM was designed. It is also called statistical TDM. Asynchronous means flexible not fixed.

Here, the total speed of the input lines can be greater than the capacity of the path. many more no of input lines can be connected. It supports more devices than sync TDM.

— Asynchronous TDM —



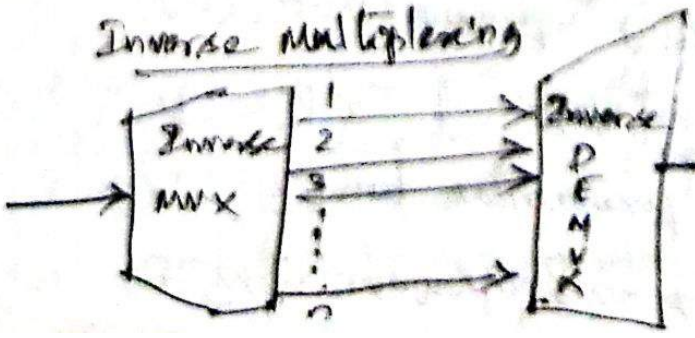
No of inputs : 5
No of slots in each frame : 3

- The no of time slots in ATDM frame (m) is based on a statistical analysis of no of input lines likely to be transmitting at a time. Multiplexer scans the input lines, and sends the frames accross the link.

Disadvantages: Addressing and overhead. If 5 devices sending info it's ok. If 4 sends info then multiplexer has to see which data send and not. Demultiplexer may not identify from which devices it comes from. So, overhead increases.

- Time slots length may vary. Faster data rate devices have been given longer slots.

Inverse Multiplexing



- It is opposite of multiplexing. It takes data stream from one high speed line and breaks it into portions and can be sent accross several lower speed lines simultaneously, without loss in collective data rate.

Figure 8.16 *Asynchronous TDM*

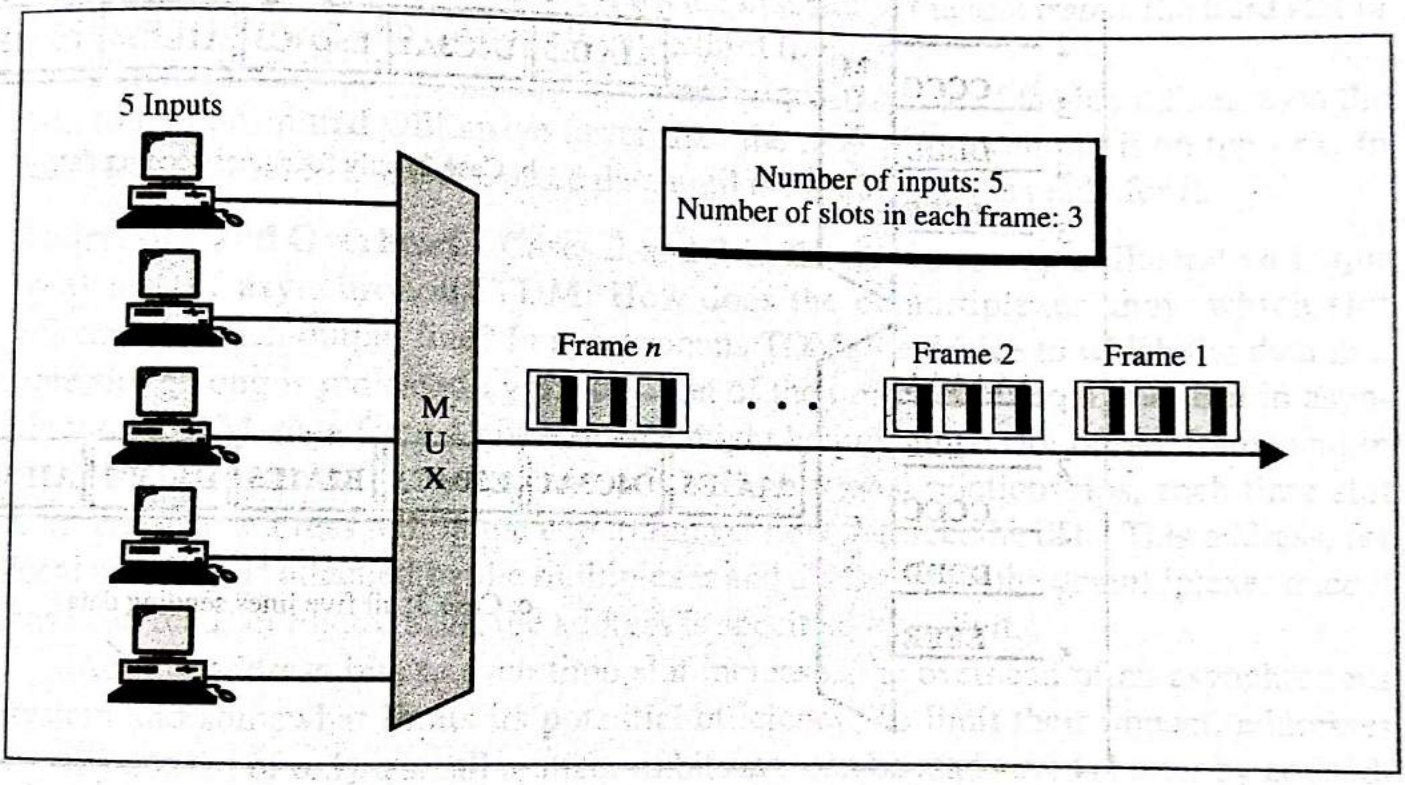
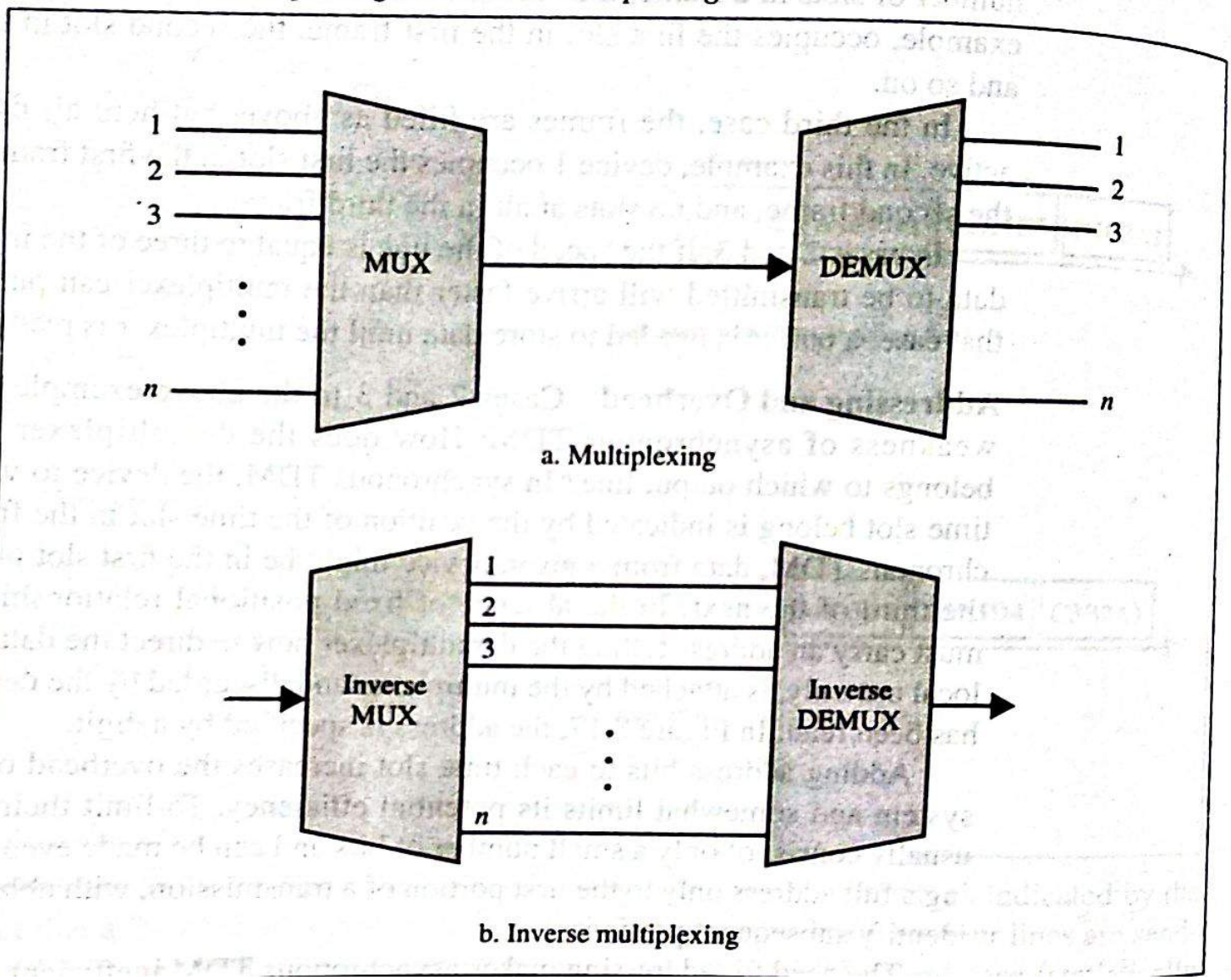


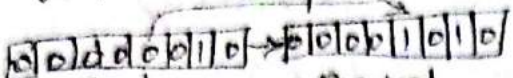
Figure 8.18 *Multiplexing and inverse multiplexing*



Types of Errors

① Single bit error
– only one bit of a given data unit is changed. [1 bit error]

② Burst error.
Two or more bits in the data unit have changed.



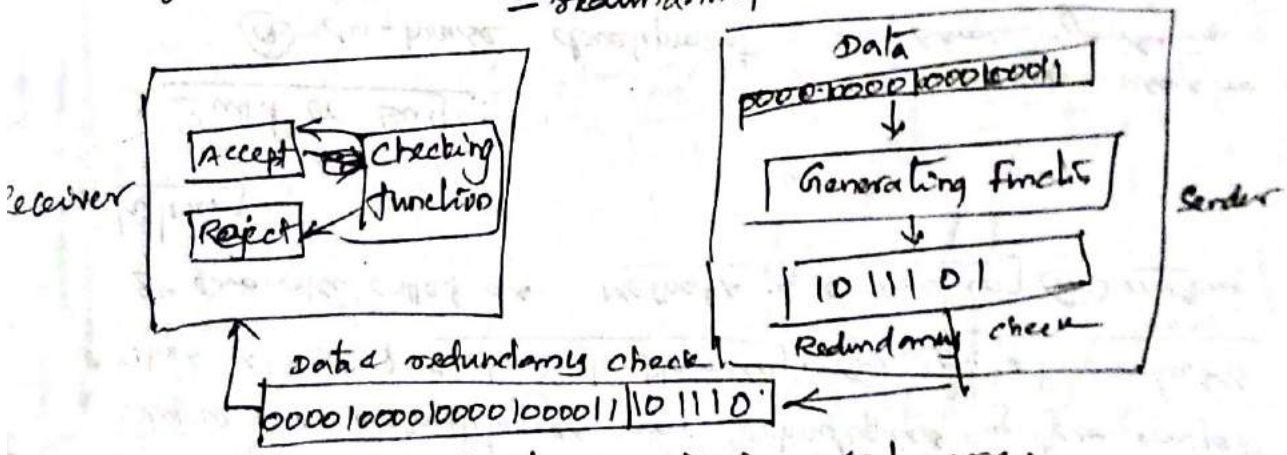
— a —

Error DETECTION

Redundancy

* Its a mechanism [For example can send data twice. While receiving can compare the data.] Instead of sending full data twice a shorter group of bits may append to the end of each unit. This technique is called redundancy. (Because extra bits are redundant to the info, it is discarded if accuracy of transmission is determined)

– redundancy –

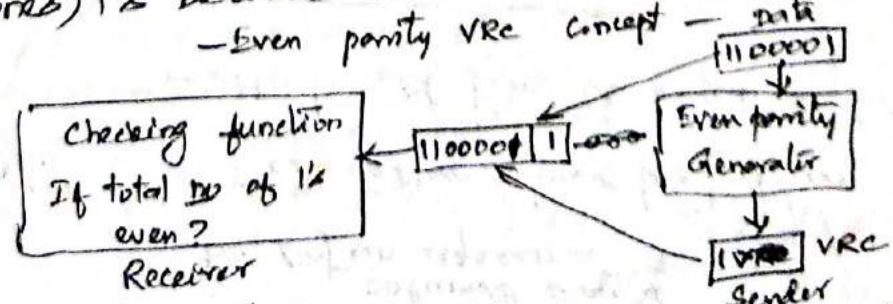


* Four types of redundancy checks used are:
① VRC - Vertical Redundancy check ② LRC - Longitudinal
③ CRC - cyclical " — " ④ checksum.

Vertical Redundancy check:

* Also called parity check. Its a least expensive mechanism In VRC A parity bit is added to every data unit so that the total no of (ones) 1's become even.

– Even parity VRC concept –



If one data sent is in odd format (or) no of 1's is odd in a odd parity VRC may used.

Figure 9.4 *Redundancy*

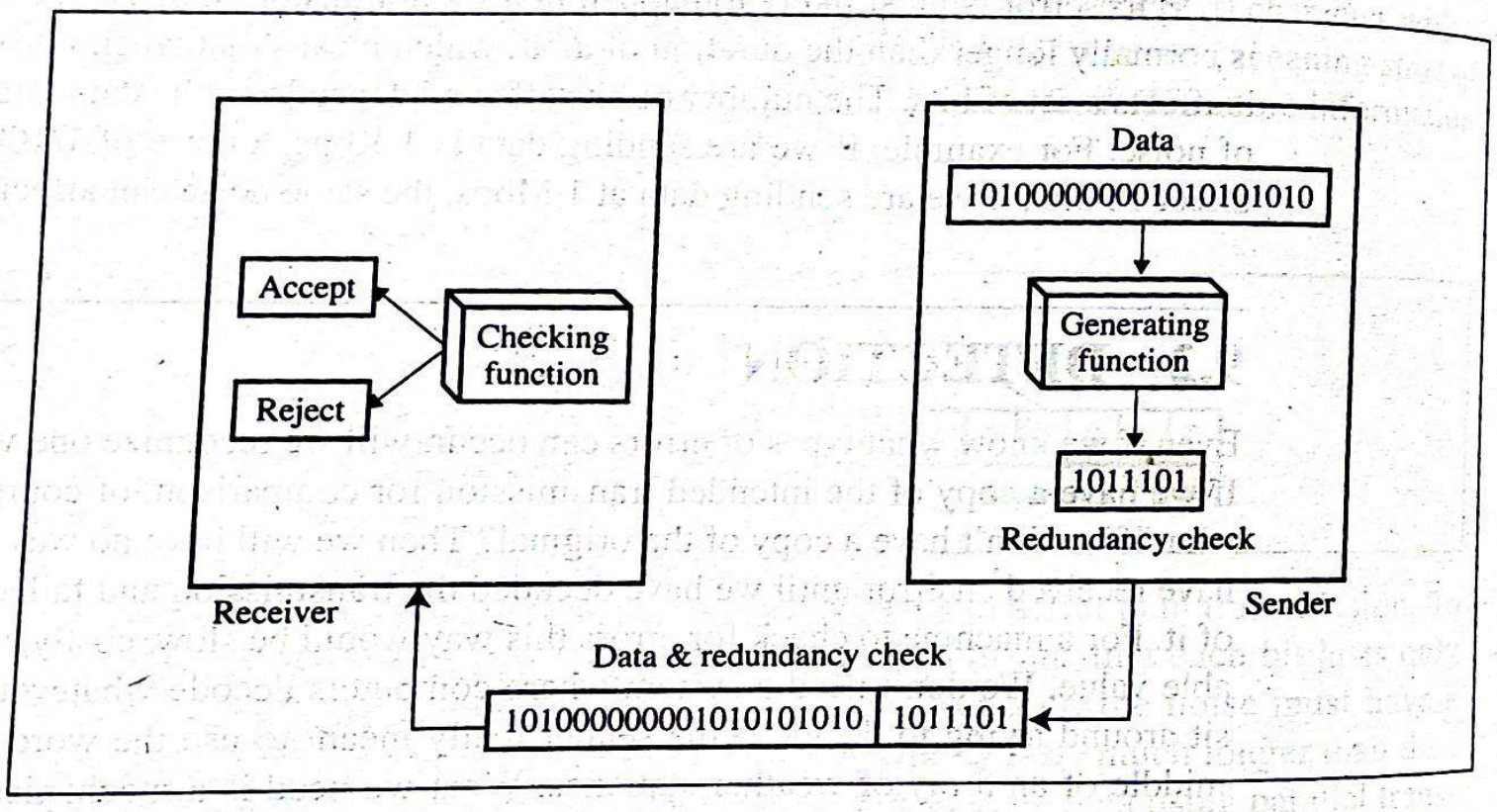
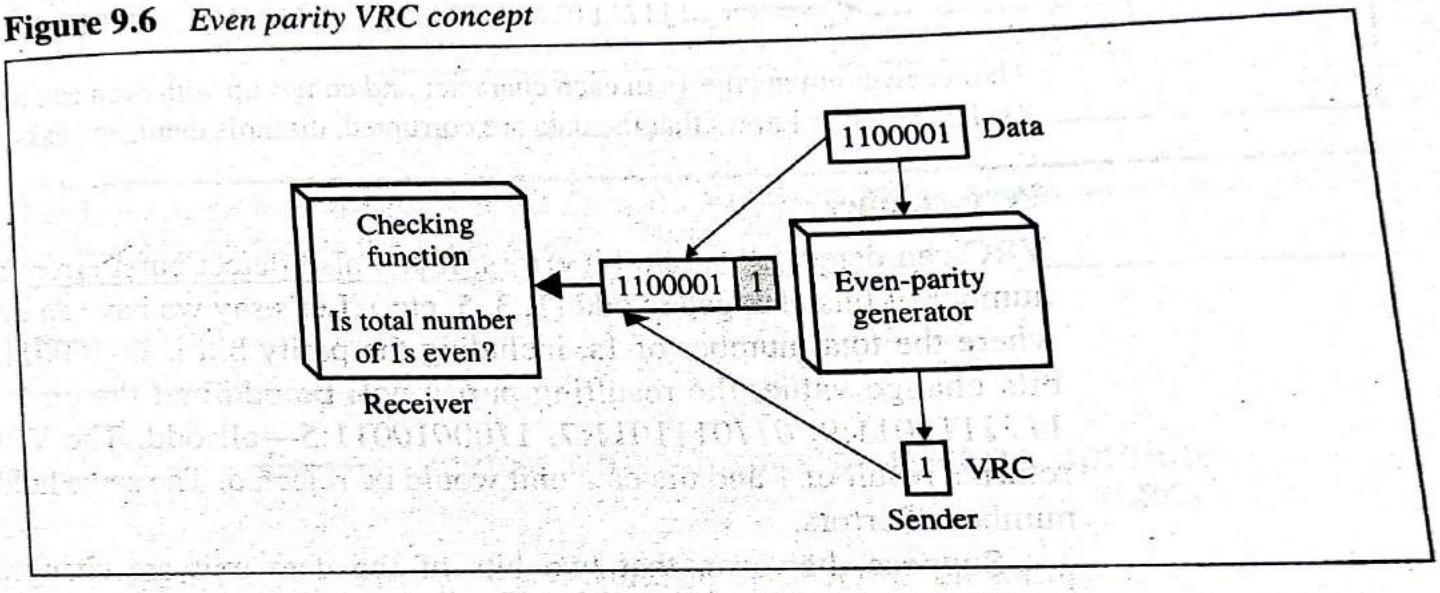
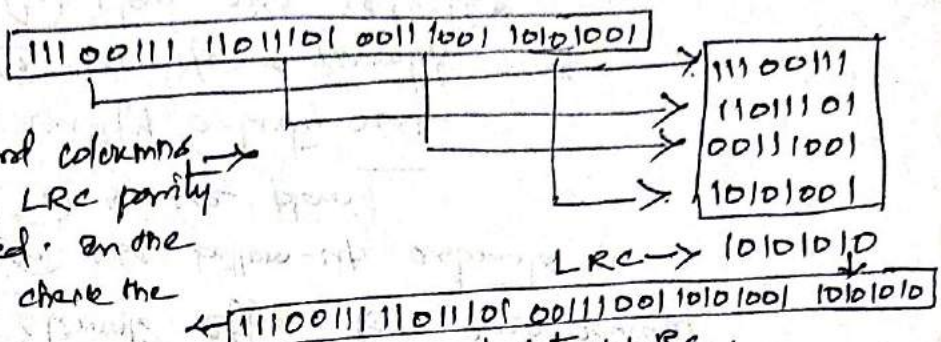


Figure 9.6 *Even parity VRC concept*



② Longitudinal Redundancy check

It is a block of bits is divided into rows and a redundant row of bits is added to a whole block.



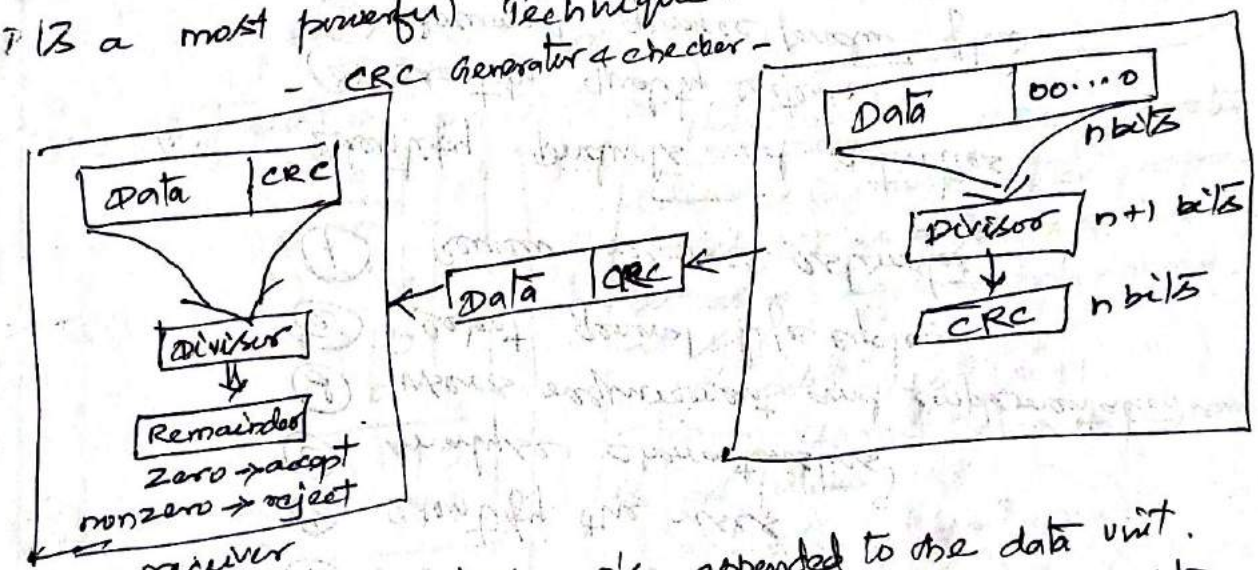
Based on the rows and columns in the block in RHS, LRC parity bits are generated. On the receiving side it's check the parity.

LRC increases the likelihood of detecting burst errors.

③ Cyclic Redundancy check (CRC)

* It is a most powerful Technique.

– CRC Generator & checker –



Sending side / receiver

Step1: A string of 'n' 0's appended to the data unit. 'n' should be one less than the bits in the predetermined divisor, which is n+1 bits.

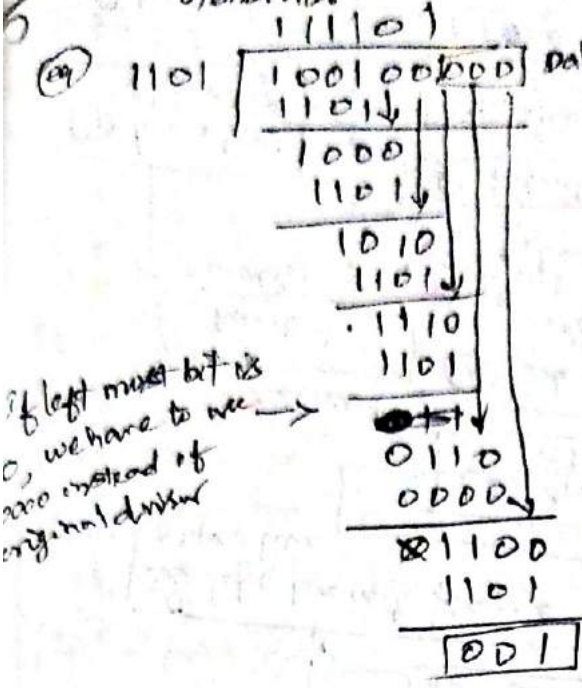
Step2: The newly elongated data unit is divided by the divisor using binary division. The remainder comes is CRC.

Step3: CRC of n' bits derived in step2 replaces the appended zero ~~at step1~~. the end of data unit. [CRC may consists all (zero's) 0's]

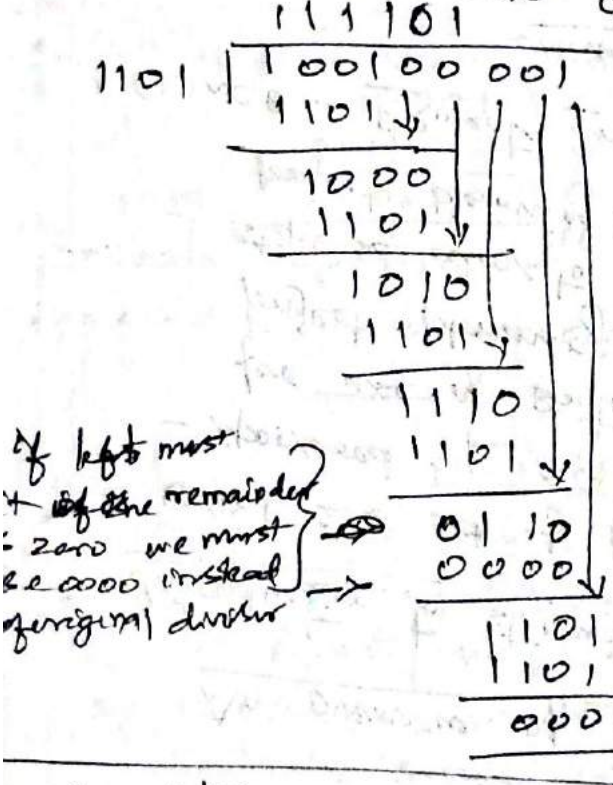
Receiving side: It is received in the receiver end. First data followed by CRC. Receiver takes these two as a unit and divides it with the same divisor. If the remainder is '0' then data unit passes (ie) no error. If the remainder non '0' then data unit does not pass. (ie) error.

→ {Binary division in a CRC Generator} ←

Binary division in CRC Generator



CRC checker —



Polynomials: CRC generator (divisor) is most often represented not as a string of 1's & 0's but as an algebric polynomial. as shown below:

$x^7 + x^6 + x^4 + x^3 + x + 1$

binary representation of polynomial is as follows:

$x^7 + x^6 + x^4 + x^3 + x + 1$

x^5 x^2

1 1 0 1 1 0 1 1

polynomial selection is as follows:

- It should be divisible by x
- " " " " " $(x+1)$

First condition guarantees all burst errors. Second, all burst errors that affects an odd no of bits are detected.

CRC is a very effective error detection method.

Standard polynomials:

CRC-ITV-T

$x^{16} + x^{12} + x^5 + 1$

CRC 12

$x^{12} + x^{11} + x^3 + x^2 + 1$

CRC 16

$x^{16} + x^{15} + x^2 + 1$

CRC 32

$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$

CHECKSUM

- This method is used by higher-layer protocols

Steps in sender side:

- All sections are added together using one's complement to get the sum.
- The sum is complemented to become a checksum.
- The checksum is sent with data.

Steps in receiver side:

- The unit is divided into k-sections, each of 'n' bits
- All sections are added together using one's complement to get sum.
- The sum is complemented
- If the result is zero, the data are accepted: Otherwise they are rejected.

(Eg) Sender side

data to be sent → 10101001 00111001

add bits using 1's complement arithmetic

```
  10101001
  00111001
  --------
  11100010   Sum
  --------
  00011101   Checksum   ← Complement
```

pattern sent is 10101001 00111001 00011101

Receiver side

Data received is:
10101001 00111001 00011101

add 3 sections

```
  10101001
  00111001
  00011101
  --------
  11111111   Sum
  --------
  00000000   Complement  ← means the pattern is ok.
```

Error Correction

Handled in one of two ways:

1) When error is discovered, receiver can ask the sender can retransmit the entire data unit.
2) Receiver can use an error-correction code, which automatically corrects certain errors.

Single bit error correction:

* Secret of error correction is to locate the invalid bit or bits

(Eg) To correct single bit error in an ASCII character, the error correction code must determine which of the 7 bits are changed. ∴ we have eight states to error, error in position 1, ..., error in position 7. So, enough redundancy bits requires to show all 8 states. ∴ 3 bit redundancy code is adequate because 3 bits can show 8 different states (000 to 111). It will identify only eight bits but we have 10 bit (i.e data + 3 redundancy bit).

8 Redundancy Bits:

No of data bits (m)	No of redundancy bits (r)	Total bit (m+r)
1	2	3
2	3	5
3	3	6
4	3	7
5	4	9
6	4	10
7	4	11

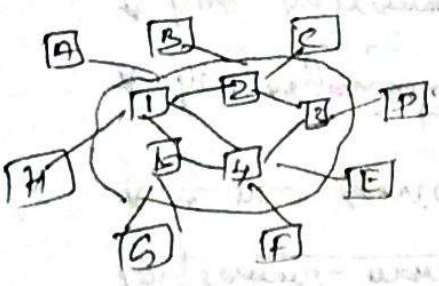
Unit - IV & V

Switching

(1) Circuit Switching

A switched n/w consists of a series of interlinked nodes called switches. It is n/w of s/w.

Switched n/w

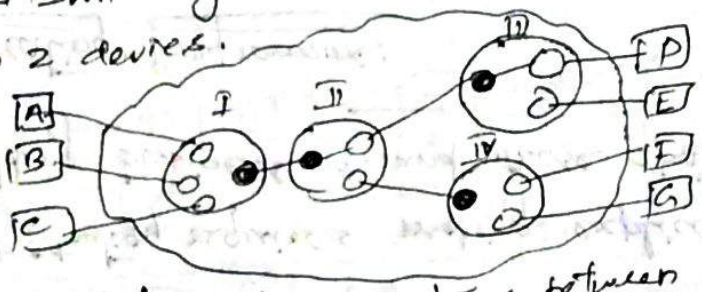


A, B, ..., H – devices or computer

1, 2 ... 5 – switches.

circuit switching:- creates direct physical connection between 2 devices.

(eg)



- Here if point-to-point connections between A, BC & DEFG requires 12 links.
- We can use 4 switches to reduce no and total length of links.
- In above example A is connected to 'D' via switches I, II & III
- A circuit switch is a device with 'n' inputs and 'm' outputs that creates a temporary connection between an input link & an output link.
- no of inputs does not have a match with no of output.

Circuit switching use one following 2 technologies:

(a) space division switches (b) Time division switches.

(a) space division switches:

- paths in the circuit are separated big from each other spatially. Designed for analog n/w, but used in both n/w's today.

Crossbar switch: connects 'n' inputs to 'm' outputs in a grid using electronic micro switches (transistors) at each cross point.

limitation: no of cross points. If 10 input & 10 output we need 150 crossbars. If 1000 input to 1000 output requires 1990,000 cross bars.

Multistage switch: used to overcome limitation of crossbar. Here, devices are linked to switches, that, in turn, are linked to a hierarchy of other switches. uses multiple

Blocking: It refers to the time when one input cannot be connected to an output because there is no path available between them.

(b) Time division switches

It uses Time division multiplexing to achieve switching.

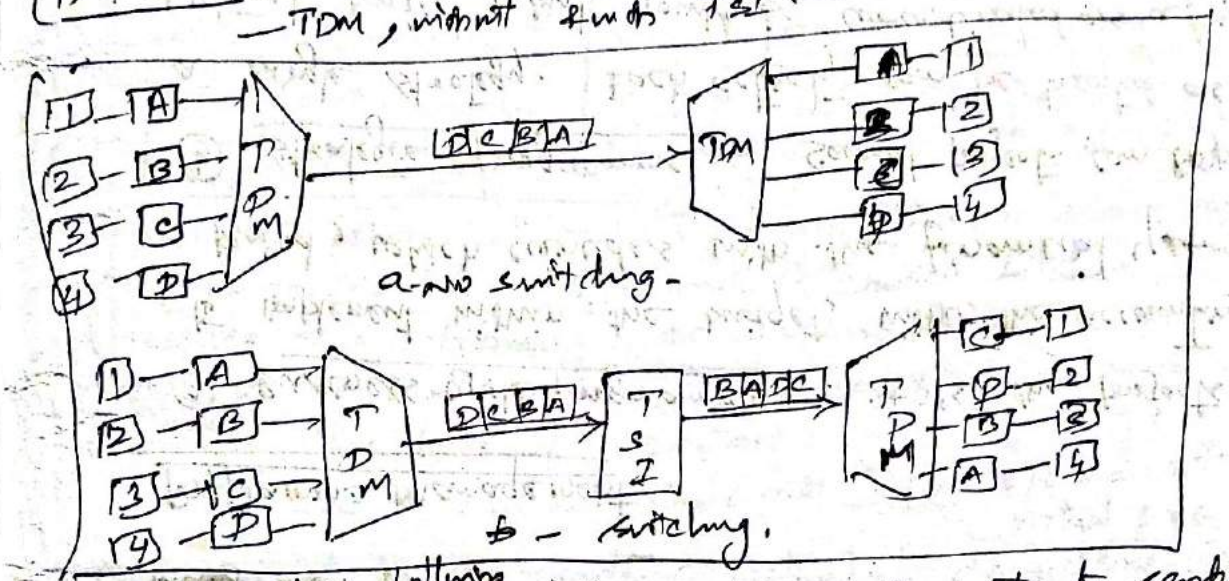
Two methods used here are:

(a) Time slot interchange (TSI)

(b) TDM bus.

(1) TSI:

— TDM, without & with TSI —



— Imagine, one following pattern, each input wants to send data to output line.

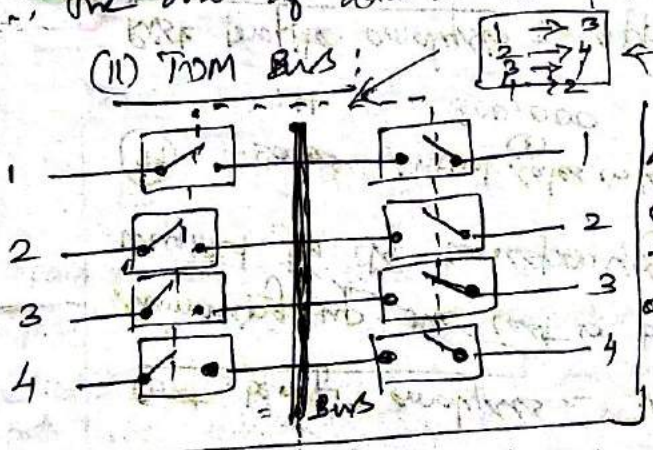
1 → 3 2 → 4 3 → 1 4 → 2

The above diagram 'a' shows without switching.

In diagram 'b', a device called TSI is inserted in the link

∴ the order of data is changed from A, B, C, D to C, D, A, B.

(11) TDM Bus:



— Here, the input/output lines are connected to a high speed bus through I/O gates (micro switches)

Each input gate is closed during one of the 4 time slots, during the same time only one output gate is closed.

PSTN - Public Switched Telephone Network — eg. for Circuit switching in North America; circuit switching designed for voice communication.

Packet Switching: Here, data are transmitted in discrete units of variable length blocks called, Packets.

Each packet contains: data and header with control informations

Two popular approaches are:

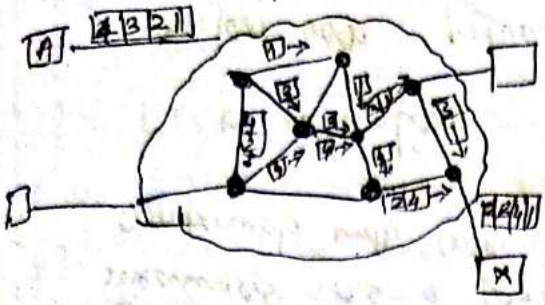
(1) Data gram Approach (2) Virtual circuit approach.

(a) SVC (b) PVC.

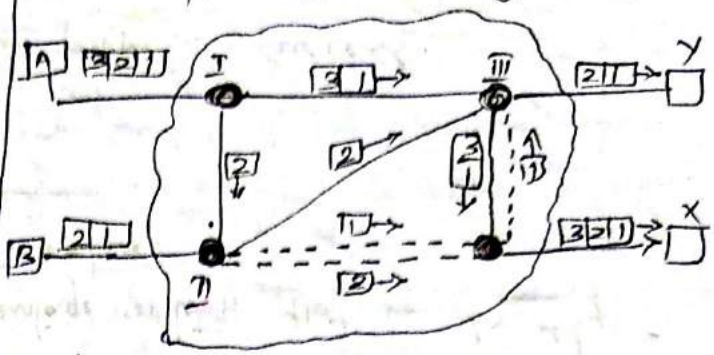
① Datagram approach:

Each packet is treated independently from all others.

- datagram approach -



- Multiple channels in datagram approach.



A to x and B to y.

② Virtual Circuit approach.

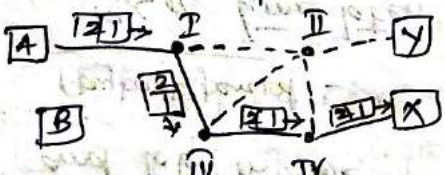
- Relationship between all packets belonging to a message or session is preserved. Single route is chosen between sender and receiver at the beginning of the session. When data are sent all packets of the transmissions travel one after another along that route. Two types of V.C.A. are:

ⓐ SVC - Switched virtual circuit ⓑ PVC - Permanent virtual circuit.

ⓐ SVC: Format is comparable conceptually to dial-up lines in circuit switching.

(i) Connection establishment (ii) Data Transfer (iii) Connection release

ⓑ PVC: Are comparable to leased line in circuit switching



Path vs route: A circuit switched connection creates a path between 2 point. A virtual-circuit connection creates a route between two points.

Dedicated vs sharing: In a circuit switched connection, the links that make a path are dedicated. They cannot be used by other connections.

Message Switching:

In this mechanism, a node receives a message, store it until the appropriate route is free, then sends it along.

[store and forward is considered as switching technique.
There is no direct link between the sender and receiver]

In this switching, messages are stored and relayed from secondary storage. (disk etc). (X) But in packet switching the packets are stored and forwarded from primary storage (RAM)

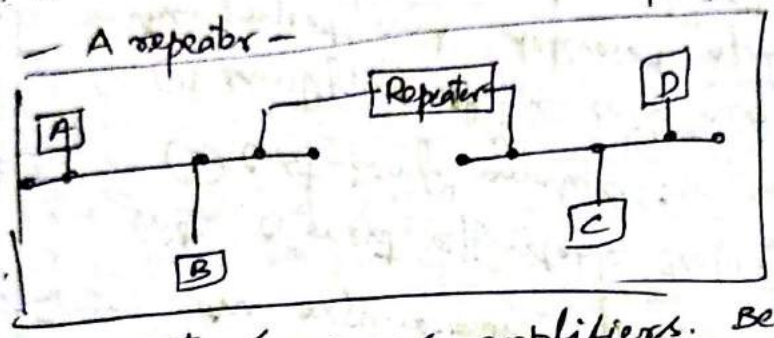
Networking and Internetworking devices

Networking devices : Repeaters and Bridges.
Internetworking devices : Routers and Gateways.

Repeaters :

- It is a physical device operates on only in physical layer.
- It is installed on link, before a signal becomes too weak; (ie) regenerates the original bit pattern.
- It allows us to extend the physical length of the n/w.

— A repeater —

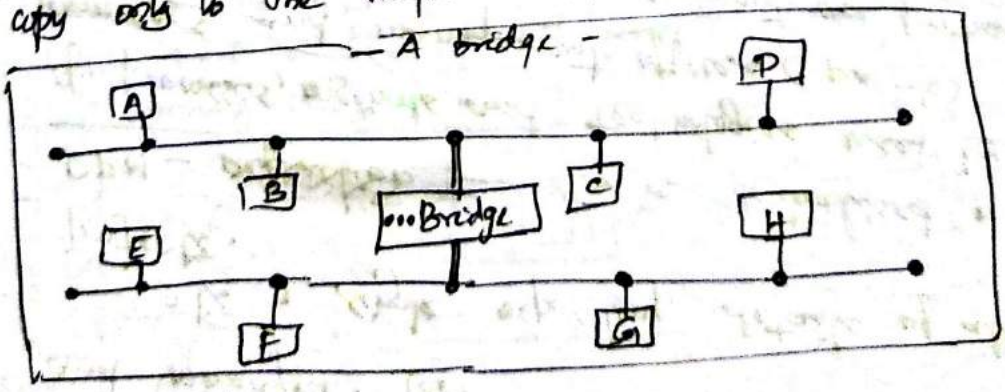


- It's not same as amplifiers. Because, it is not amplify the signal but regenerates it.

Bridges :

- It operates on both physical and data link layers.
- It divides large n/w into smaller segments.
- It contains logic that allows to keep the traffic for each segment separate.
- It provides security through partitioning of traffic.
- Bridge operates on data link layer, giving it access to the physical address of all stations connected to it. When a frame enters a bridge, it not only regenerates the signal but also checks the address of the destination and forwards the new copy only to the segments which the address belongs.

— A bridge —



Types of bridges

① Simple bridge : Most primitive and least expensive. It links 2 segments and contains a table that list the addresses of all stations included in each of them.

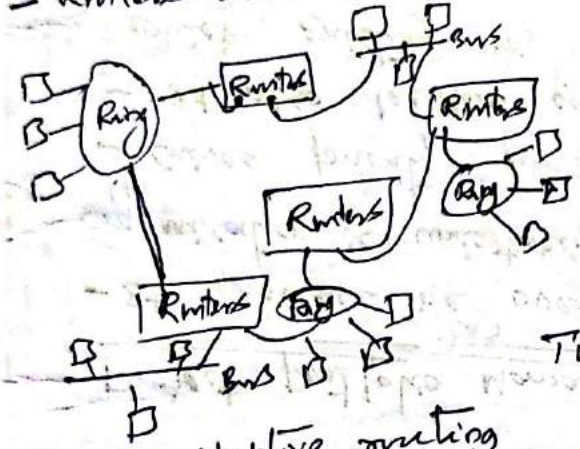
② Multiport bridge: used to connect more than 2 LANs. It has a table for each of the 3 LANs, each one listing the physical addresses of stations reachable through corresponding port.

③ Transparent bridge:
It is also called learning, builds its table of station addresses on its own as it perform its bridge function. When it is installed, its table is empty.

—^—

Routers: It's a networking device that forwards data packets between computer networks. Relay packets among multiple interconnected n/w's.

— Routers in Internet —



Routing Concept: Routers forward packets through set of n/w's.

Eg If we want to move packet from N/W 'A' to 'C' via 'B'.
Least cost routing: which of the available pathway is cheapest or n/w terminology shortest?

Two types of Routing:

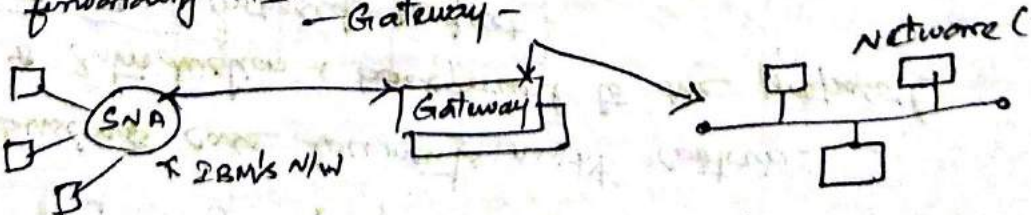
1) Non Adaptive routing
Routing decisions are not made based on the condition or topology of the n/w. (If a pathway is selected then data sent through it)

2) Adaptive routing
Router may select a new route for each packet in response to changes in condition and topology of n/w's

—a—

Gateways: It operates on all 7 layers of the OSI model.
A gateway is a protocol Converter. [A router by itself transfers, accepts, and relays packets only across n/w's using similar protocols. A Gateway, can accept packet formated for one protocol and convert it to a packet formated for another protocol before forwarding it]

— Gateway —



—a—

Routing Algorithms:

Most popular routing algorithms:
1) Distance vector routing
2) Link state routing.

① Distance Vector Routing :

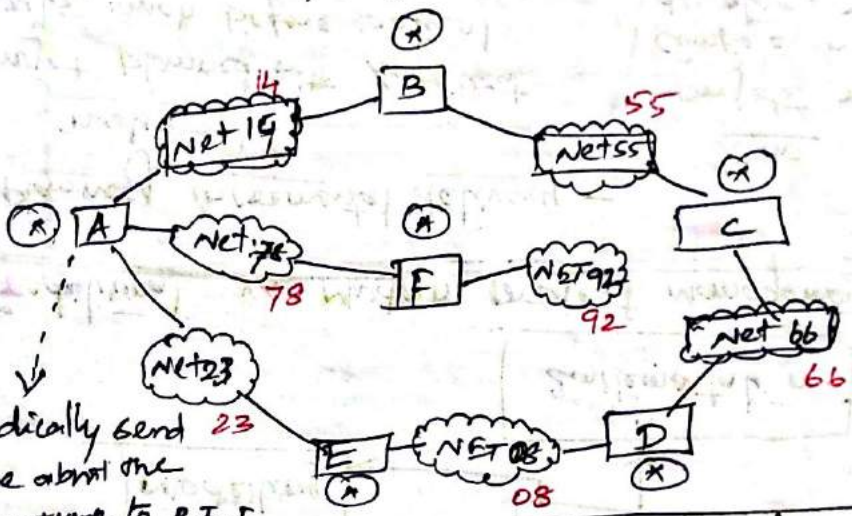
Here, each router periodically shares its knowledges about the entire n/w with its neighbours. Three keys of this algorithm:

① Knowledge about the whole n/w. : Each router shares its knowledge about entire n/w.

② Routing only to neighbours : Each router periodically sends its knowledge about the n/w only to those routers to which it has direct links.

③ Information sharing at regular intervals : Each router sends its information about the whole n/w to its neighbours at regular time intervals. (Eg every 30 sec).

— Concept of distance vector routing —



(A) R periodically send my knowledge about the whole internetwork to B, E, F:

Distance vector routing table :->

Network id	cost	Next Hop

creating a table :

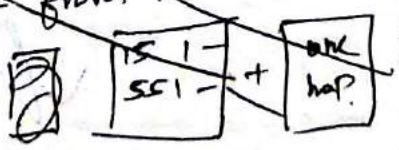
For example as per above diagram A's table is

A's old Table

14	1	—
23	1	—
78	1	—

cost - refers to hop count

When it receive from 'B'



Received from 'B'

14	1	—
55	1	

+ onehop =

14	2	B
55	2	B

→

14	1	—
14	2	B
23	1	—
55	2	B
93	1	—

After adjustment

→

14	1	—
23	1	—
55	2	B
78	1	—

A's new table.

— α — α —

② Link-State routing :

Here, each routers shares its knowledge of its neighbourhood with every other router in the internetwork. The key steps are:

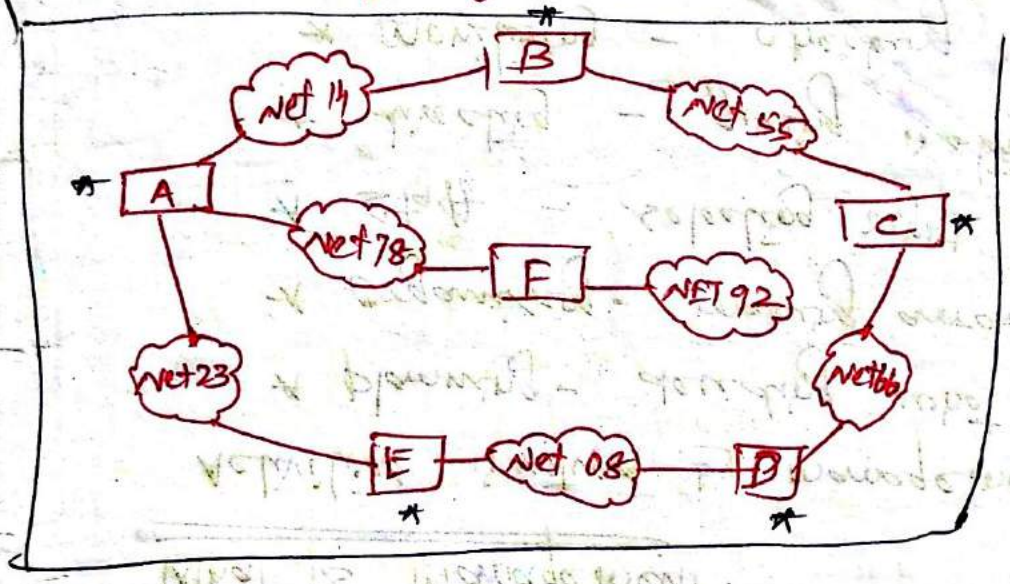
① Knowledge about the neighbourhood : Instead of sending the

routing table, a router sends information about its neighbourhood only.

② To all routers: Each router sends its information about neighbourhood to every other router. This process is called flooding.

③ Information sharing when there is a change: Each router sends out information about the neighbours when there is a change.

– Concept of link state routing –



* – I send information about my neighbours to every router.