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EC8551 - COMMUNICATION NETWORKS

UNIT-I FUNDAMENTALS AND LINK LAYER.

COMMUNICATION:

It's a process of Exchanging information (or) Establish connection (or) link between point to point (or) Device-to-Device for Exchanging information.

DATA COMMUNICATION:

Exchange of data between two devices via some form of transmission medium such as a wire cable.

Four fundamental characteristics:

1. Delivery 2. Accuracy 3. Timeliness 4. Jitter

Delivery: S/m of Data must deliver to the correct destination.

Accuracy: The S/m must deliver the data accurately.

Timeliness: S/m must deliver data in a timely manner.

Jitter: It refers to the variation in the packet arrival time.

COMPONENTS: Five components,

1. message: originate from information source, message contains, word, symbols, code, picture, etc data (or) Information to be communicated.
2. Sender: It's device that sends the data message. It can be computer, workstation, telephone handset, television, ..
3. Receiver: Device that receives the message.
4. Transmission medium: Physical path by which a message Travels from Sender to Receiver.
   ex: Twisted-pair cable, OFC and Radio waves

5. protocol : Set of rules that govern data Communication. It represents an agreement b/w Communicating devices.

DATA REPRESENTATION:

1. TEXT : It's represented as a bit pattern, a sequence of bits (0's (or) 1's)
   - Different set of bit patterns designed to represent Text symbols.
   - Each set is called a code. & process of representing symbols is called coding.
   - prevalent Coding S/m is called Unicode.

   ASCII (American Standard Code for Information Interchange)

2. NUMBERS: Represented by bit patterns.
   ASCII is not used to represent numbers.

3. IMAGES : Image is Composed of a matrix of pixels (picture Elements)
   - Each pixel is a small dot.

   Size of the pixel depends on resolution.
   RGB & YCMagenta (Yellow, Cyan)

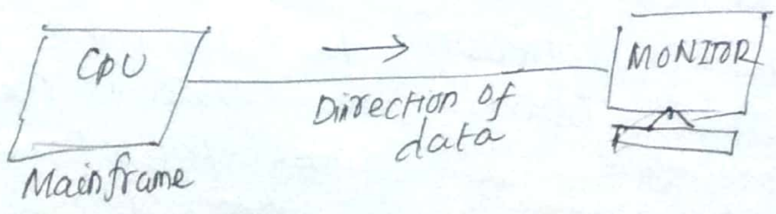
4. AUDIO : Refers to the recording (or) broadcasting of sound (or) music.
   Audio by nature different from text, number (or) images.

5. VIDEO : Refers to the recording (or) broadcasting of a picture (or) movie.
   Eg: TV camera.

DATA FLOW:

Communication b/w two devices can be Simplex, half-duplex and Full-duplex.

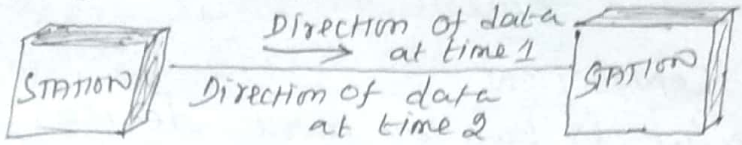
Simplex: Communication is unidirectional. data can flow in one direction only. eg. Keyboards and traditional Monitors



HALF-DUPLEX:

Each Station Can both Transmit & Receive but not at the same time.

- when one device is sending, the other can only receive and vice versa. eg. walkie-Talkies
- No need for Communication in both directions at the same time.

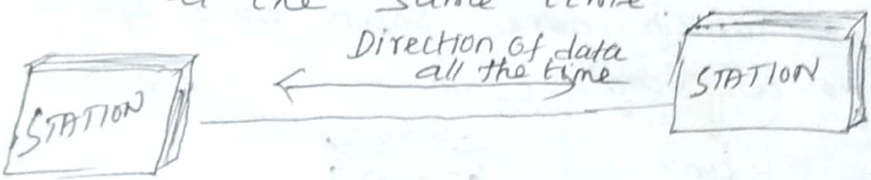


Full-DUPLEX (OR) DUPLEX:

Both Stations Can be transmit and Receive Simultaneously.

It's used when Communication in both directions is required all the time.

eg. Telephone N/w, both can talk and listen at the same time.



NETWORKS:

It is a Set of devices (referred to nodes) Connected by Communication links.

A node Can be a Computer, printer (or any other device capable of sending/(or Receiving data.

NETWORK CRITERIA:

1. PERFORMANCE: measured in transit time and response time.

Transit time: amount of time required for a message to travel from one device to another

Evaluated by two metrics: Throughput and delay

2. Response time: Elapsed time between an inquiry and a response.

Performance depends on no. of users type of Transmission medium, capabilities of connected H/w and efficiency of S/w.

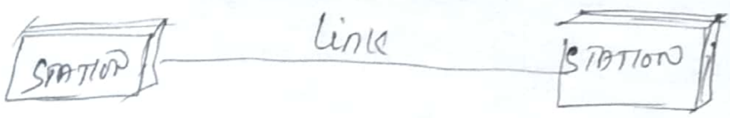
2. RELIABILITY:
To accuracy of delivery, It's measured by frequency of failure time it takes a link to recover from a failure.

3. SECURITY:
To protecting data from unauthorized access, protecting data from damage and development.

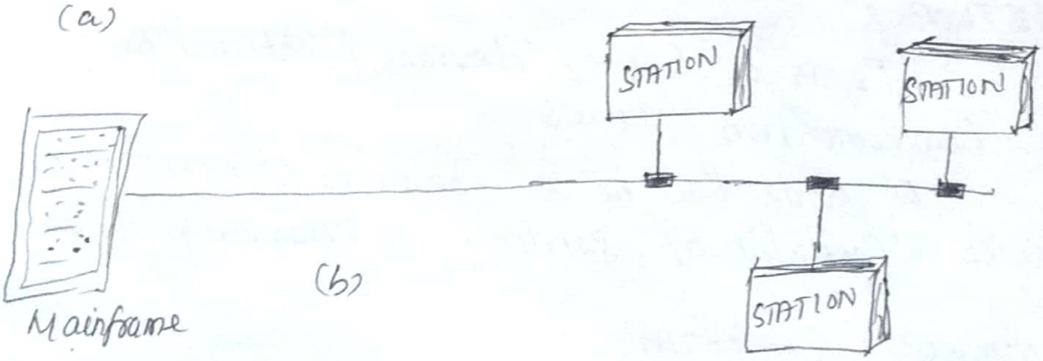
TYPES OF CONNECTION:
A N/w is two (or) more devices connected through links.
A link is a Communications pathway that transfer data from one device to another.

Two possible types of Connections:
1. point-to-point 2. multi-point (or multi-drop)

1. provides a dedicated link b/w two devices.
2. one in which more than two Specific devices Share a single link.



(a)



(b)

PHYSICAL Topology:
It refers to the way in which a N/w is laid out physically.
Two (or) More devices Connect to a link.
Two (or) More links from a topology.

Topology : N/w is the geometric representation of the relationship of all the links and linking devices (nodes) to one another.

Topology:

- → Mesh
- → Star
- → Bus
- → Ring

1. MESH: Every device has a dedicated point-to-point link to Every other device.

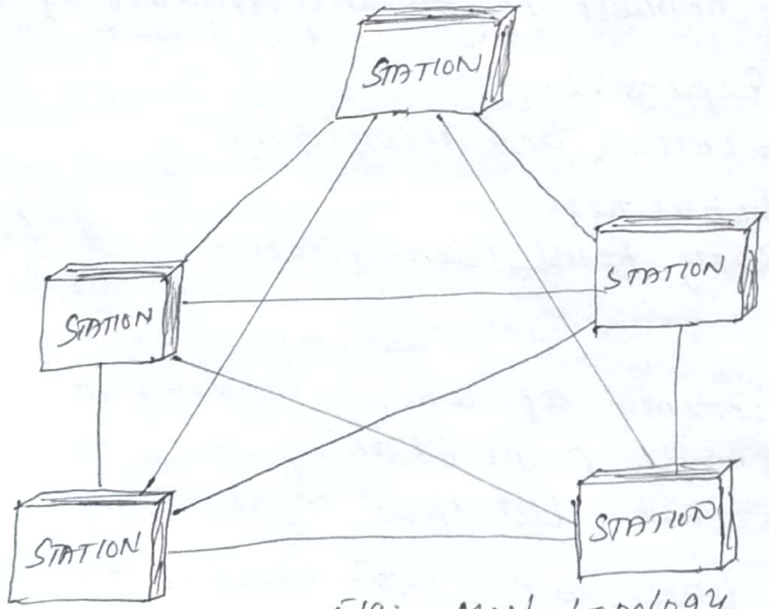


Fig: Mesh topology

link Carries traffic only b/w the two devices it connects.

To find the no of Physical links in a fully Connected mesh N/w with 'n' nodes.

$n(n-1)/2$

$n(n-1) \rightarrow$ Physical link.

Adv: • dedicated links guarantees that each Connection can carry its own data load

• It is robust.

• privacy (or) Security

Disadv: amount of cabling & no of I/o ports required.
Installation & reconnection are difficult.
H/w required to Expensive.

STAR Topology: Each device has a dedicated point-to-point link only to a Central Controller, called HUB.

- The devices are not directly linked to another.
- Does not allow direct traffic b/w devices.
- The controller acts as an Exchange.

Each device needs only one link and one I/O port to connect it to any number of others

Adv: Less Expensive
Easy to Install and reconfigure
Robustness.
To easy fault identification and fault isolation.

DisAdv: . dependency of whole topology on one single point (hub)
. far cable less than mess.

Applications: LANs and High-speed LANs with a central hub.

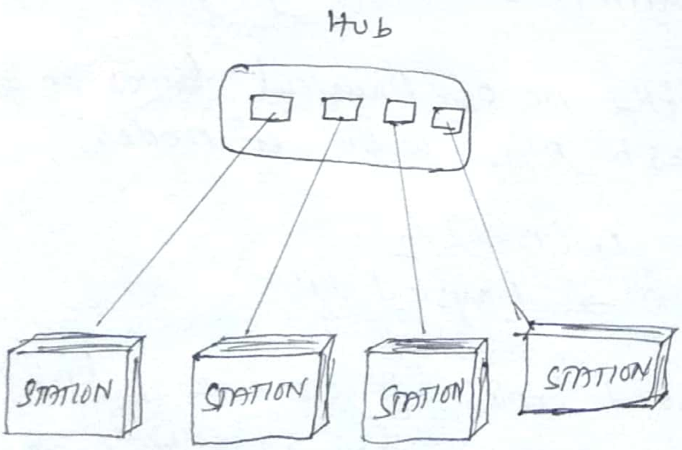


Fig: Star topology

BUS TOPOLOGY: Examples of all describe point-to-point connections:

Otherwise act as multipoint.

One long cable acts as a backbone to link all the devices in a N/w.

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

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

A Tap is a connector either splices into main cable (or) punctures the sheathing of a cable to create a connect with the metallic core.

Signal Travels along backbone, Some of its energy is transformed into heat.

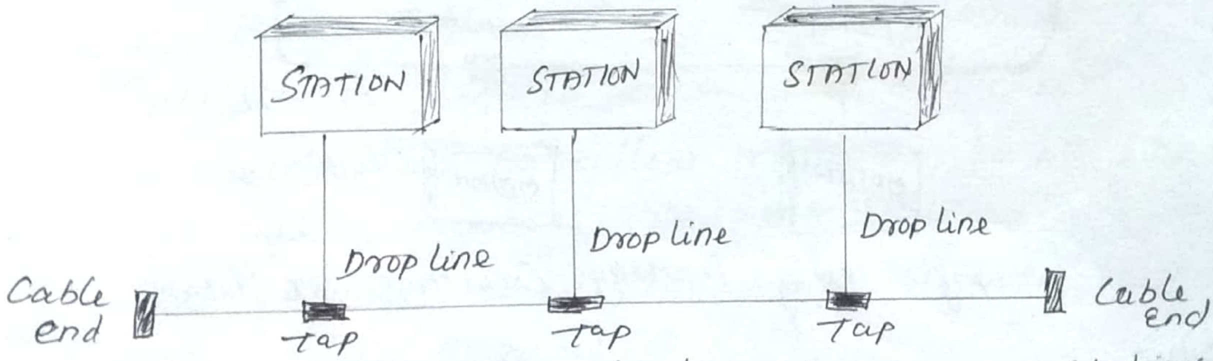


Fig: Bus topology connecting 3 stations

Adv:
- Ease of Installation.
- Backbone cable can be laid along the most efficient path.
- Less cabling than mesh (or) star.

DisAdv:

difficult reconnection and fault isolation

Signal reflection at taps can cause degradation in quality.

A fault (or) Break in bus cable stops all Transmission.

Eg: Ethernet LANs

RING Topology: Each device has dedicated point-to-point connection with only two devices on either side of it.

A S/g is passed along the ring in one direction from device to device, untill it reaches its destination

Each device in the ring incorporates a Repeater.

when a device receives a S/g intended for another device, its Repeater regenerates the bits and passes them along.

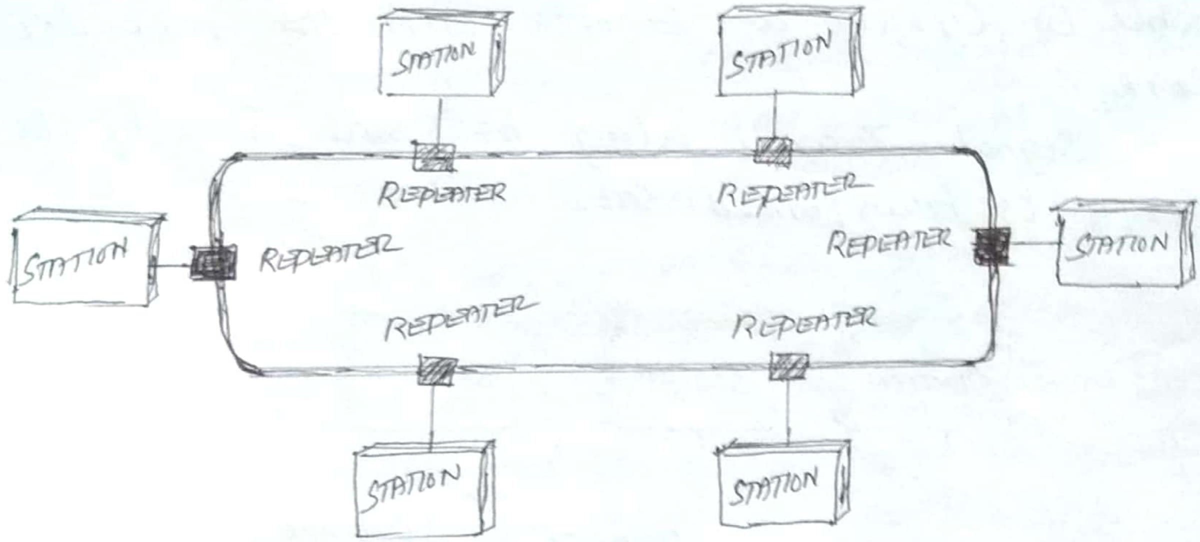


Fig: Ring topology Connecting six stations.

Adv:
- Easy to install and Reconfigure.
- Each device is linked to only its immediate neighbors. (either physically (or logically)
- To add (or) delete a device requires changing only two connections.

DisAdv:
- unidirectional traffic.
- Simple ring, a break in the ring can disable the entire N/w.
- To solve by using dual ring (or) Switch capable of closing off the break.

Eg: IBM introduced its LAN token Ring High-Speed LAN

NETWORK MODELS:

Computer N/w are Created by different entities. Standards are needed that heterogeneous N/w's Can Communicate with one another.

Best Standards are OSI model & Internet model

OSI (Open Systems Interconnection) → Seven-layer network

Internet model → Five layer Network

Categories of Networks:

LAN and WAN, MAN

The category into which a N/w falls is determined by its size.

LAN covers an area less than 2 miles.

WAN worldwide.

N/w of size in b/w are normally referred to as MAN. (Metropolitan Area N/w) and Span tens of miles.

LAN: [Local Area Network]

It's usually privately owned and links the devices in a single office, building (or) campus.

LAN size is limited to a few kilometers.

LANs are designed to allow resources to be shared b/w personal Computers (or) work stations.

The resources to be Shared Can include Hardware (Printer), S/w (program) (or) data.

Past LANs data rates in 4 to 16 megabits/sec (Mbps) Nowdays, Speeds are normally 100 (or) 1000 Mbps.

WAN: (Wide Area Network)

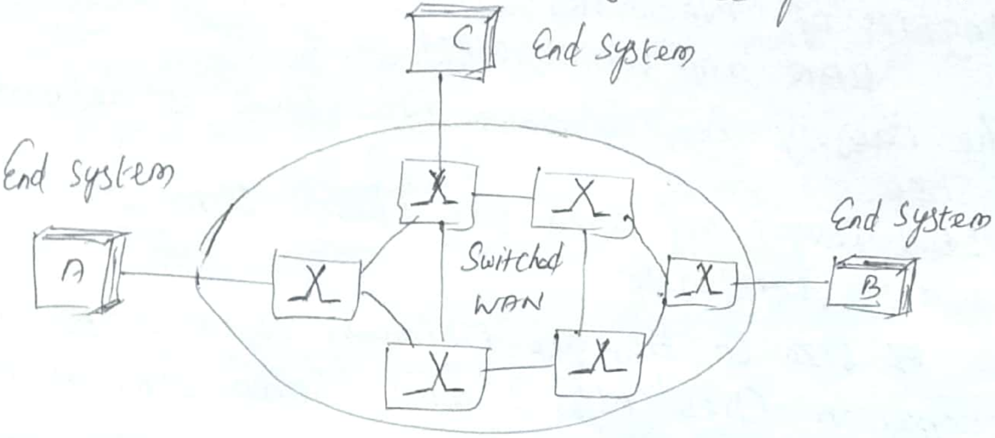
It provides long-distance transmission of data, image, audio and video information over large geographic areas (or) whole world.

WAN as complex as the backbones that connect the internet (or) simple as a dial-up line that Connects a home Computer to the internet.

WAN Refer to 1) Switched WAN 2) point-to-point WAN

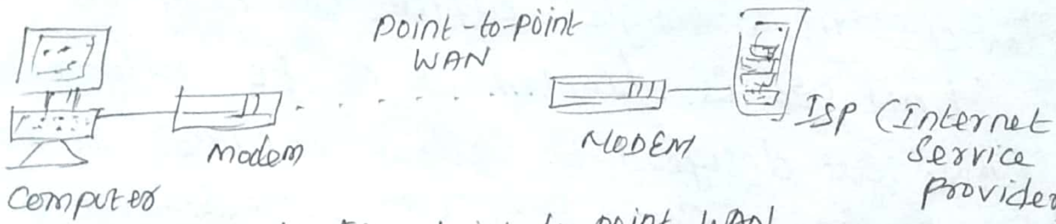
Switched WAN → Connects the end s/m's usually Comprise a router (internet working Connecting device) that connects to another LAN (or) WAN

Point-to-point WAN → a line leased from a telephone (or) Cable TV provider Connects a home Computer (or) small LAN to internet Service provider (ISP).



(a) Fig. Switched WAN

Eg: X.25 & ATM [Asynchronous transfer Mode]



b) Fig. point-to-point WAN.

MAN [Metropolitan Area Networks]

N/w with a size b/w LAN & WAN

It normally Covers the area inside a town (or) City.

Designed for Customers who need a high-speed Connectivity, normally to internet & end points Spread over a city (or) part of City.

Eg. MAN is part of the telephone company N/w that can provide a high-speed DSL line to Customer.

Eg. Cable TV N/w, used for high-speed data Connection to the Internet.

INTERNETWORK (or) INTERNET.

when two (or) more networks are connected, become an internetwork (or) Internet.

A N/w is a group of connected Communicating devices such as Computers and printers.

An 'internet' is two (or) more networks that Communicate with each other.

'Internet' a collaboration of more than hundreds of thousands of interconnected networks.

private individuals as well as various organizations such as government agencies, Schools, research facilities, Corporations and libraries in more than 100 Countries use the internet (1969)

Internet Connection use the services of Internet Service providers (ISPs).

(upto 600 Mbps) There are International service providers, National service providers, Regional service providers and local service providers.

PROTOCOLS AND STANDARDS:

Protocols, In computer N/w's, Communication occurs b/w entities in different S/m's.

An entity is anything capable of sending (or) receiving information.

A protocol defines what is Communicated, how it is Communicated and when it is Communicated

key elements of a protocol are syntax, Semantics and timing.

Syntax: Refers to the structure (or) format of the data, meaning order in which they are presented.

Semantics: Refers to the meaning of each section of bits.

Timing: Refers to two Characteristics.

when data should be sent and how fast they can be sent.

STANDARDS:

Essential in creating and maintaining an open and competitive market for equipment manufacturers and in guaranteeing national and international interoperability of data and telecommunications technology and processes.

Eg. manufacturers, vendors, government agencies and other service providers to ensure the kind of interconnectivity.

Two categories: 1. de facto ("by fact" (or) by convention)
2. de jure ("by law (or) by regulation")

STANDARDS ORGANIZATIONS:

Standards are developed through the cooperation of standards creation committees, forums and government regulatory agencies.

1. ISO (International Organization for Standardization)
2. (ITU-T) [International Telecommunication union - Telecommunication)
3. a committee CCITT [Consultative Committee for International telegruphy and Telephony]
3. ANSI [American National Standards Institute]
4. IEEE [Institute of Electrical and Electronics Engineers]
5. EIA [Electronic Industries Association]

LAYERED PROTOCOL:

NETWORK MODELS: N/w is a Combination of H/w and S/w that sends data from one location to another.

H/w consists of the physical Equipment that Carries S/g's from one point of the N/w to another.

S/w consists of instruction set that make possible the services expect from a N/w.

LAYERED ARCHITECTURE:

Computer N/w is designed around the Concept of Layered protocols (or functions.

Eg. Exchange of data b/w Computers.

FACTORS:

1. Source S/m must either activate the direct data Communication path (or inform the Communication N/w to identify the desired destination S/m.
2. To provide for standard interface b/w network functions.
3. To provide for Symmetry in function performed at each node in the N/w.

N/w S/w is now highly structured.

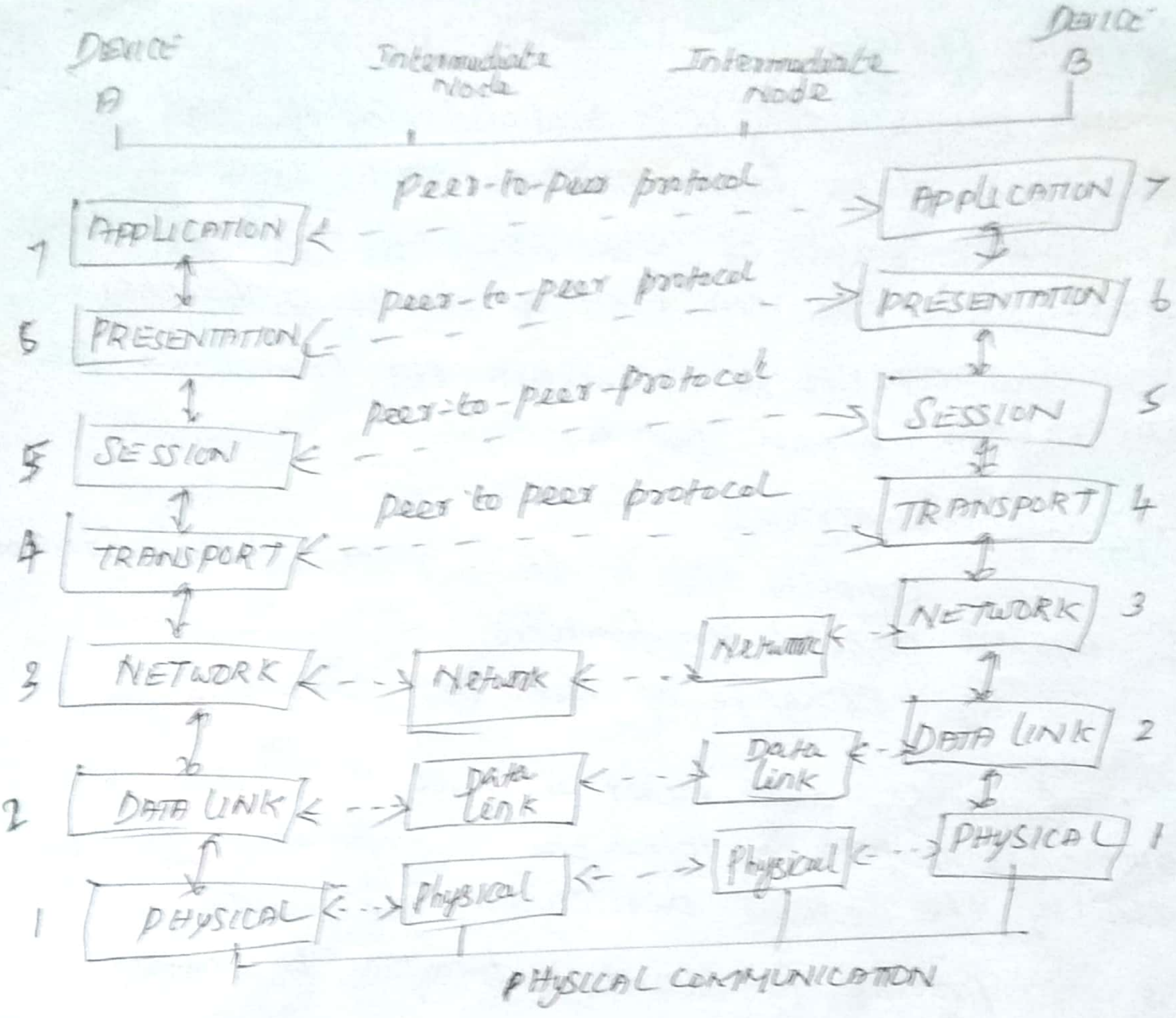
~~Device~~ layer 'n' on one node Carries on a Conversation with layer 'n' on other node.

The entities comprising the Corresponding layers on different machine are called peers.

The actual data flow from upper layer to below layer & from physical medium to destination layer.

B/w each pair of adjacent layers is called 'interface'. Interface defines which primitive operations and services the lower layer to upper layer.

A set of layers & protocols is Called a N/w Architecture.



OSI MODEL: First organizations to formally define a common way to connect Computers. Their architecture called OSI (open system Interconnection)

is the ISO (International organization for Standardization)

ISO organization, OSI is the model.

OSI model is a seven layer Standard

OSI model does not Specify the communication Standard (or) protocols to be used to perform N/w'ing tasks.

OSI model provides Services are,

1. To provides peer-to-peer logical services with layer physical implementation.
2. To provides Standards for Communication b/w system.
3. Interconnection for Exchange of information b/w S/m.
4. Each layer Should perform a well defined function.

LAYERS IN THE OSI MODEL:

1. PHYSICAL LAYER: It coordinates the functions required to carry a bit stream over a physical medium.

It deals with mechanical and electrical specifications of the interface & transmission medium.

It defines the procedure and functions that physical devices and interfaces to perform for transmission to occur.

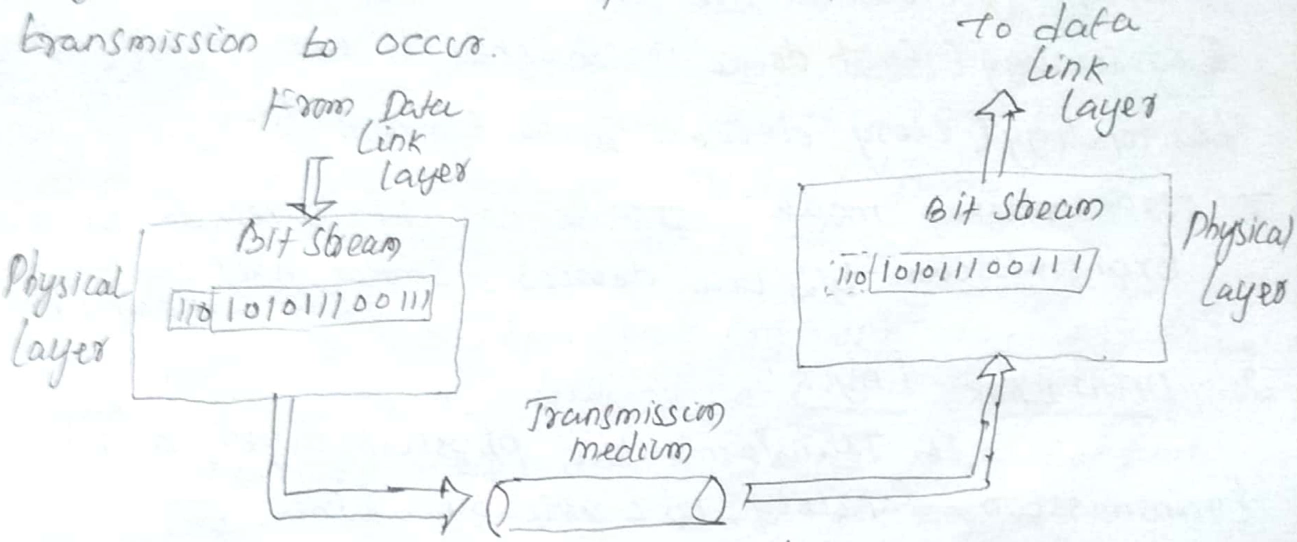


Fig. Physical layer

Def:

"Physical layer is responsible for movements of individual bits from one hop (node) to the next"

FUNCTIONS OF PHYSICAL LAYER:

1. Physical characteristics of interfaces and medium.
   Interface b/w the devices and transmission medium.
2. Representation of bits:
   data consists of a stream of bits (0's or 1's) with no interpretation.
   Encoded into signals of bit stream into electrical (or) optical.
3. Data Rate: Transmission rate, no of bits sent each defined by physical layer.
   Physical layer defines the duration of bit which is how long it lasts.
4. Synchronization of bits: Sender and R_x^r not only must use the same bit rate also must be synchronized at the bit level.

5. Line Configuration: Physical layer is concerned with the connection of devices to media. (pt-to-pt commn)

6. Physical Topology: It defines how devices are connected to make a N/w.

Devices can be connected by using a mesh topology (Every device is connected to every other device)
Star topology (devices are connected through a central device)
Ring topology (Each device is connected to next, forming a Ring)
bus topology (every device is on a common link)

7. Transmission mode: It defines the direction of transmission b/w two devices, simplex, half-duplex, full duplex.

2. DATA LINK LAYER:

It Transforms the physical layer, a raw transmission facility, to a reliable link.

It makes to appear error-free to the upper layer (N/w layer).

"Data link layer is responsible for moving frames from one hop (node) to the next"

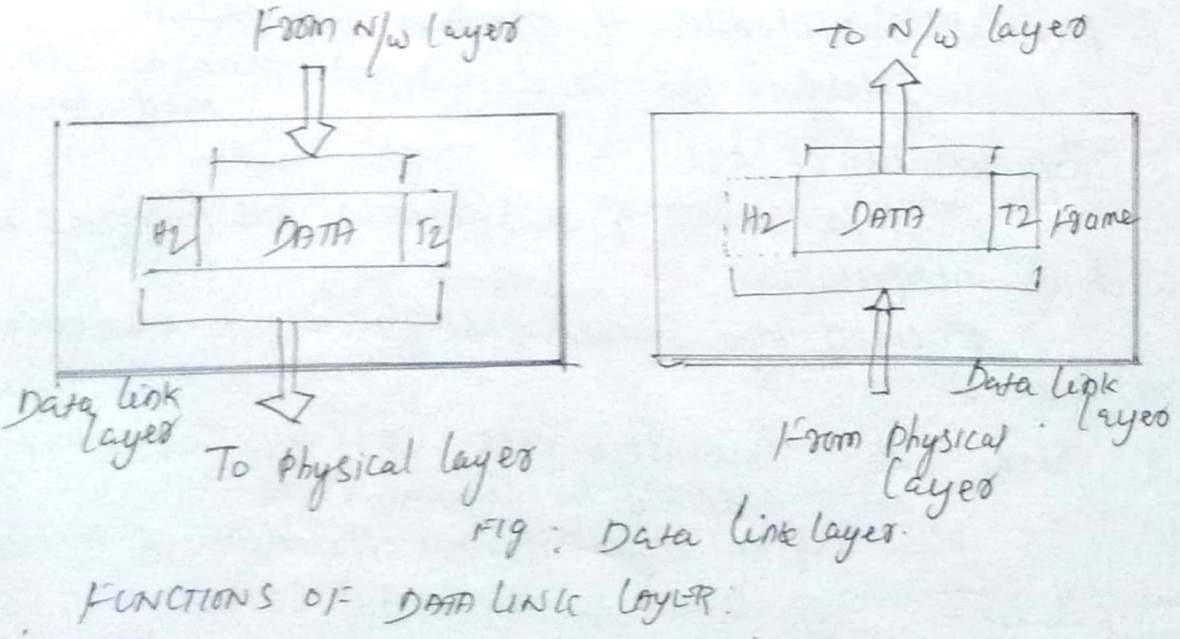


Fig: Data link layer.

FUNCTIONS OF DATA LINK LAYER:

(i) Framming: data link layer divides the stream of bits received from the N/w layer into managable data units called FRAMES

(ii) Physical Addressing: If frames are to be distributed to different S/m's on the N/w, data link layer adds a header to frame to define the sender (or R_x^r of the frame.

(iii) Flow Control: If the rate at which the data are absorbed by R_x^r is less than the rate at which data are produced in the sender.

(iv) Error Control: data link layer adds reliability to physical layer by adding mechanisms to detect and retransmit damaged (or) lost frames.

To recognize duplicate frames.

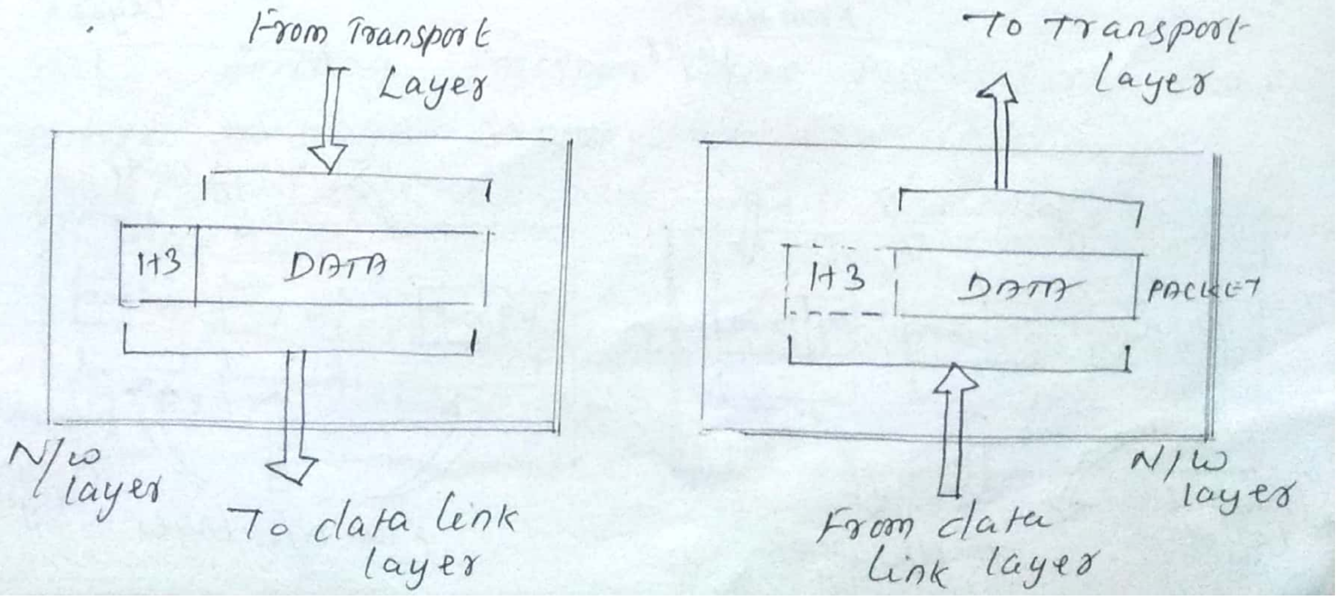
(v) Access control: when two (or) more devices are connected to same link.

To determine which device has control over the link at any given time.

3. NETWORK LAYER: It's responsible for source-to destination delivery of packet, possibly across multiple N/w's (links).

Datalink layer to delivery of the packet b/w two systems on the same N/w (links),

N/w layer ensures that each packet gets from its point of origin to final destination.



"The N/w layer is responsible for delivery of individual packets from the source host to the destination host".

FUNCTIONS (or) RESPONSIBILITIES OF N/w LAYER:

1) Logical addressing: The physical addressing implemented by data link layer handles the addressing problem locally.

If a packet passes the N/w boundary to help distinguish the source and destination systems.

(ii) Routing: when independent N/w's (or) links are connected to create internetworks (N/w of N/w's) (or) large N/w (called Routers (or) switches) route (or) switch the packets to final destination.

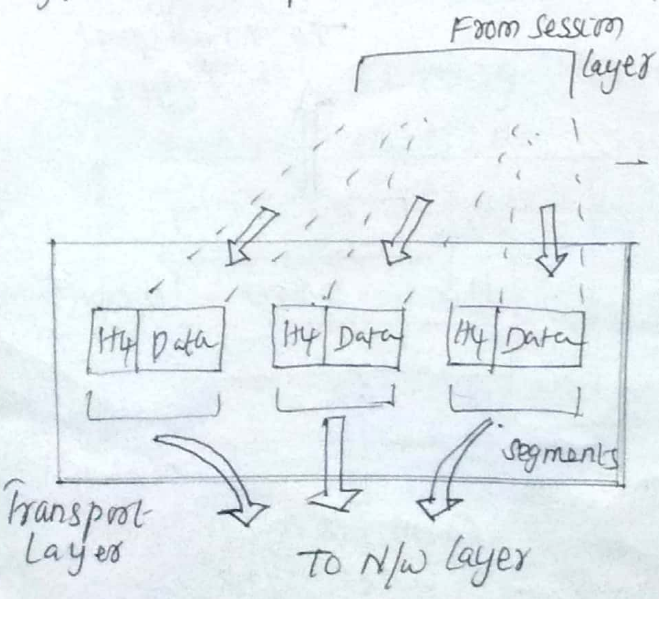
4. TRANSPORT LAYER:

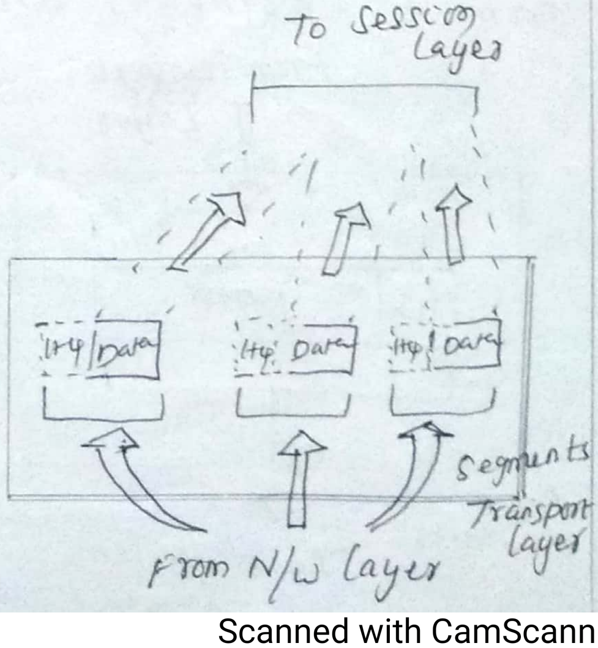
It's responsible for process-to-process delivery of the entire message.

A process is an application program running on a host.

N/w layer oversees source-to-destination delivery of individual packets, does not recognize any relationship b/w those packets.

"Transport layer is responsible for delivery of message from one process to another"





Responsibilities of Transport layer:

i) Service-point addressing: Computers often run several programs at the same time.

The transport layer header must be include a type of address called a Service-point address (or) port address.

(ii) Segmentation and Reassembly:

A message is divided into transmittable segments, with each segment containing a sequence number.

(iii) Connection Control: Transport layer can be either Connectionless (or) Connection Oriented.

A Connectionless Transport layer treats each segment as independent packet & deliver to destination Machine.

A connection oriented Transport layer makes a Connection at destination machine first before delivering the packets.

(iv) Flow Control: data & Transport layer responsible for flow Control.

Flow control at this layer is performed end-to-end rather than across a single link.

(v) Error Control: It's performed process-to-process rather than across a single link.

Sending Transport layer makes sure that entire message arrives at the receiving Transport Layer without Error [damage, Loss (or) duplication]

Error Correction is usually achieved through Retransmission.

5. SESSION LAYER

Services provided by first three layers (Physical, data link and N/w) are not sufficient for some processes.

Session layer is N/w dialog Controller.

It Establishes, Maintains, and synchronizes the interaction among Communicating S/m's.

" It is Responsible for dialog control and synchronization

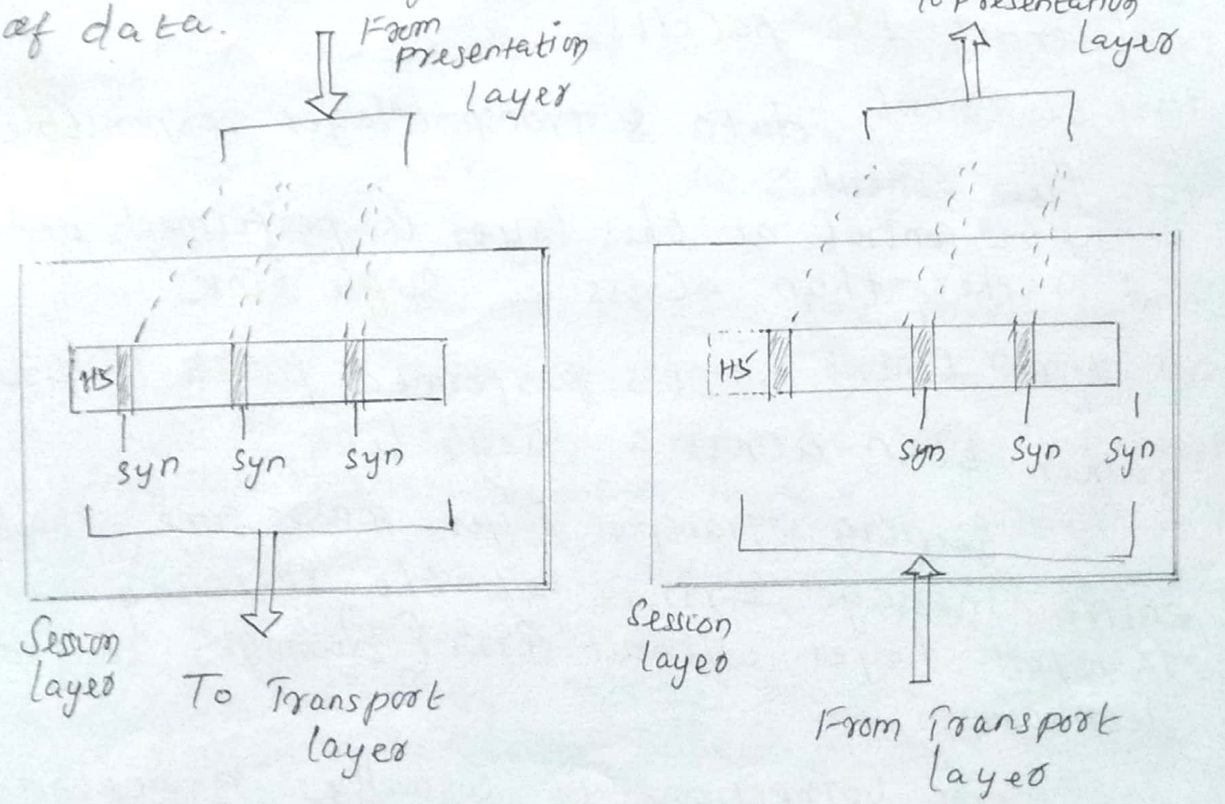
Responsibility of session layer:

(i) Dialog control: Session layer allows two S/m's to enter into a dialog.

It allows the commn b/w two processes to take place in either half-duplex (or full-duplex.

(ii) synchronization

The session layer allows a process to add checkpoints (or synchronization points to a stream of data.

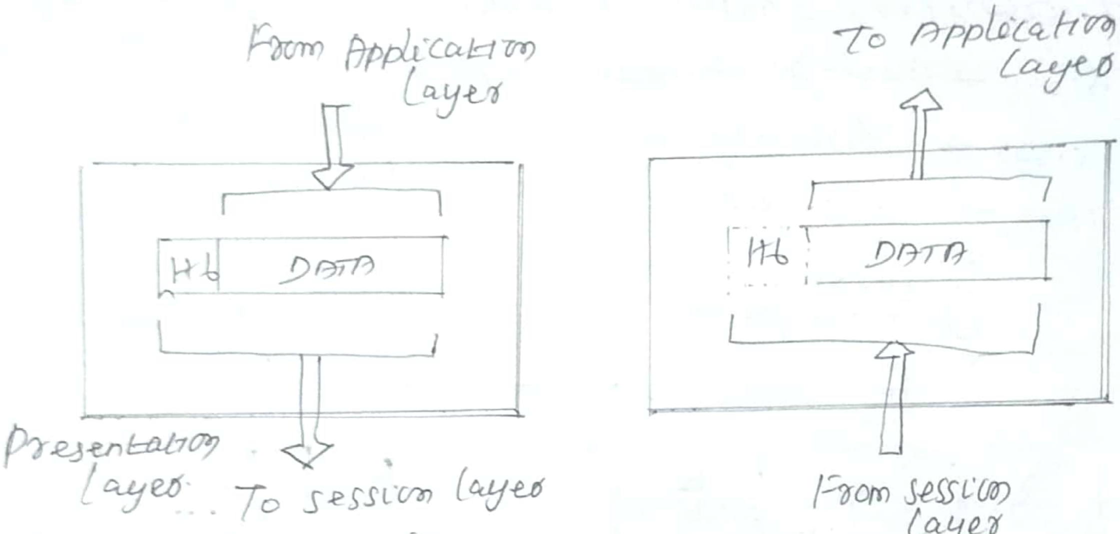


(a) Session layer.

6. PRESENTATION LAYER:

It is concerned with the syntax and semantics of the information exchanged b/w two S/m's.

"presentation layer is responsible for translation, compression and encryption"



(b) presentation layer

FUNCTIONS OF PRESENTATION LAYER:

(i) Translation: The processes (running programs) in two systems are usually exchanging information in form of character strings, numbers...

The information must be changed to bit streams before being Txd.

At the sender changes the information from its sender-dependent format into a common format.

At the receiving machine changes the common format into its receiver-dependent format.

(ii) Encryption: To carry sensitive information, a S/m must be able to ensure privacy.

It means that sender transforms the original information to another form & sends the resulting message out over the N/w.

(iii) Compression: Data compression reduces the no of bits contained in the information.

Transmission of multimedia such as text, audio and video.

7. APPLICATION LAYER:

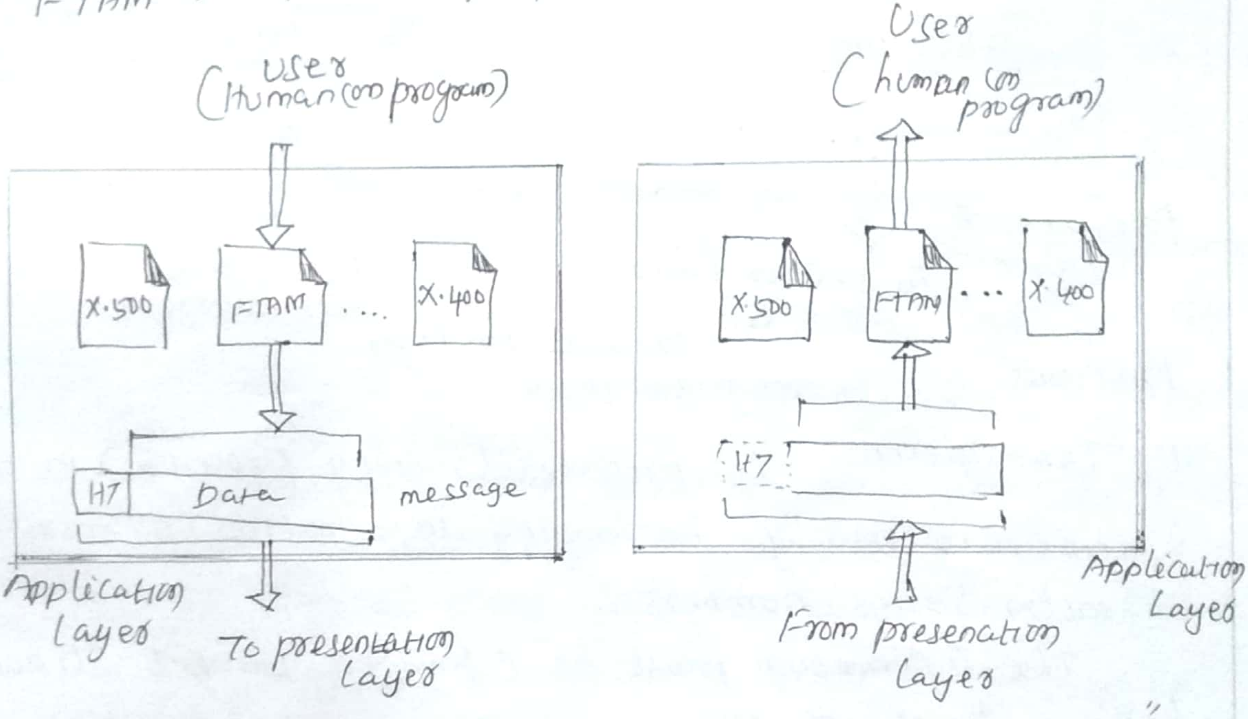
It Enables the user, whether human (or) S/w, to access the N/w.

It provides user interfaces and support for services such as Electronic mail, Remote file access and transfer, Shared database Management.

X.400 → message - handling services

X.500 → directory services

FTAM → File Transfer, Access and Management



" It's Responsible for providing services to user "

SERVICES FOR APPLICATION LAYER:

1. N/w virtual Terminal: It is a S/w version of a physical terminal and it allows a user to log on to a remote host.

2. File transfer, Access & Management:

It allows a user to access files in a remote host (to make changes (or) read data), to retrieve files from a remote computer for local computer.

3. Mail Services: To provides the basis for e-mail forwarding & storage.

4. Directory Services: It provides distributed database sources and access for global information about various objects and services.

Scanned with CamScanner

OVERVIEW OF DATA AND SIGNALS:

Physical layer to move data in form of electromagnetic signals across a transmission medium.

The data usable to a person (or) application are not in a form that transmitted over a N/w.

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

ANALOG AND DIGITAL:

Both data and signals that represent can be either analog (or) digital in form.

Data can be Analog (or) Digital

Analog data refers to information that is continuous.

Digital data refers to information that discrete states.

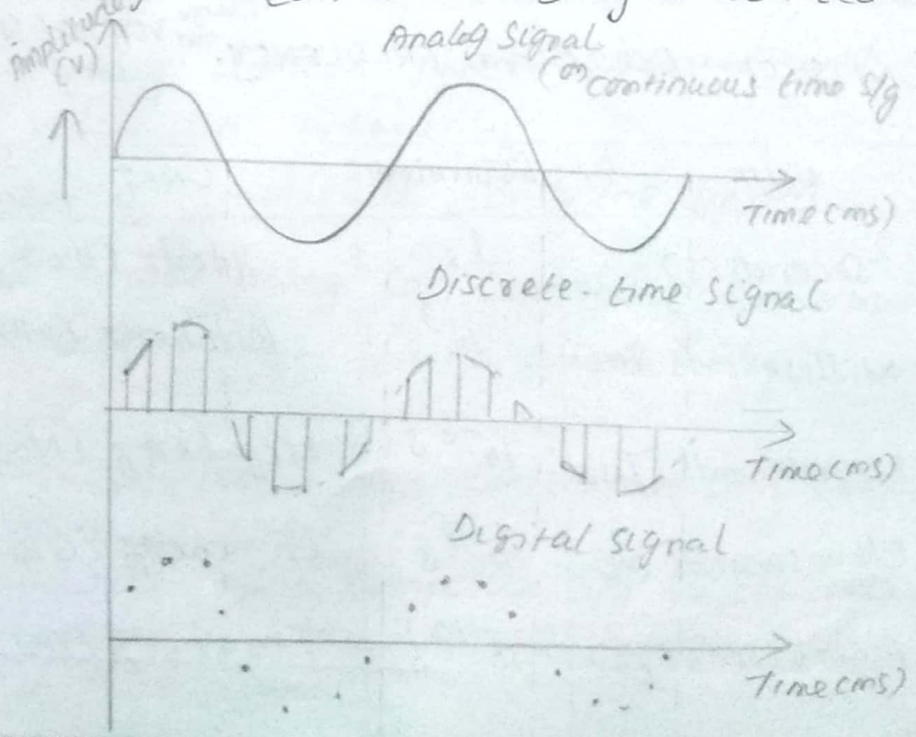
Analog data, Sounds made by a human voice on continuous values

Microphone and converted to an analog S/g (or) sampled and converted to a digital S/g.

Digital data take on discrete values. (0's & 1's)

Analog S/g's can have an infinite number of values in a range.

Digital signals can have only a limited number of values.



PERIODIC AND NON-PERIODIC SIGNALS:

PERIODIC SIGNAL: It completes a pattern within a measurable time frame called period and repeats that pattern over subsequent identical periods.

The completion of one full pattern (or) cycle is called cycle.

periodic analog signals are less Bandwidth.

Periodic analog signals can be classified as Simple (or) Composite.

A simple periodic analog s/g, a sine wave, cannot be decomposed into simpler signals.

A composite periodic analog s/g is composed of multiple sine waves.

PERIOD AND FREQUENCY:

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

Frequency refers to the number of periods in 1 s.

$$f = \frac{1}{T} \text{ (Hz) and } T = \frac{1}{f} \text{ (sec)}$$

"Frequency and period are the inverse of each other"

Frequeny is rate of change with respect to time.

Change over very short span of time → f ↑ high frequency

" Long " " → frequency ↓ low

UNITS OF PERIOD AND FREQUENCY:

S.NO	UNIT	EQUIVALENT	UNIT	EQUIVALENT
1.	Seconds (s)	1 s	Hertz (Hz)	1 Hz
2.	Milliseconds (ms)	10^{-3} s	kilohertz (kHz)	10^3 Hz
3.	Microseconds (μs)	10^{-6} s	Megahertz (MHz)	10^6 Hz
4.	Nanoseconds (ns)	10^{-9} s	Gigahertz (GHz)	10^9 Hz
5.	picoseconds (ps)	10^{-12} s	Terahertz (THz)	10^{12} Hz

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

PHASE describes the position of the waveform relative.

WAVELENGTH: Another characteristic of a S/g Traveling through a transmission medium.

Wavelength binds the period (or) frequency of a simple sine wave to propagation speed of the medium.

$$\text{wavelength} = \text{propagation speed} \times \text{period}$$

$$= \frac{\text{propagation speed}}{\text{frequency}}$$

$\lambda = c/f$, $c = 3\times10^{8}$ m/s

f in red light $= 4\times10^{14}$ in air

$$\lambda = \frac{3\times10^{8}}{4\times10^{14}} = 0.75\times10^{-6}\,m = 0.75\,\mu m.$$

TIME AND FREQUENCY DOMAIN:

Time domain plot shows changes in signal amplitude with respect to time.

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

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

Changes of amplitude during one period are not shown

A Normal human being can create a continuous range of frequencies b/w 0 and 4 KHZ.

BANDWIDTH:

Range of frequencies contained in a composite signal is its Bandwidth.

The bandwidth of a composite S/g is the difference b/w the highest and the lowest frequencies contained in that signal.

BIT RATE: (instead of frequency) is used to describe digital S/g's.
→ Number of bits sent in 1s. Expressed in bits per second (bps)

BIT LENGTH: It's distance one bit occupies on the transmission medium.

Problems: Bit length = propagation Speed x bit duration.

1. Ex: To download text documents at rate of 100 pages per minute. what is required bit rate of channel?

Solution:

A page is an average of 24 lines with 80 character in each line. assume that one character requires 8 bits,

The bit rate is,

$100 \times 24 \times 80 \times 8 = 1,536,00$ bps $= 1.536$ Mbps.

2. what is the bit rate for High-definition TV? (HDTV)

HDTV uses digital signals to broadcast high Quality video S/g's.

HDTV Screen is normally a ratio of 16:9 (Contrast to 4:3 for Regular TV)

Screen is wider.

1920 by 1080 pixels per screen. and Screen is renewed 30 times per second.

24 bits represents one color pixel.

$1920 \times 1080 \times 30 \times 24 = 1,492,992,000$ (or) 1.5 Gbps

TV stations reduce this rate to 20 to 40 Mbps through Compression.

BIT LENGTH: The distance one bit occupies on the transmission medium.

Bit length = propagation speed x bit duration

Baseband transmission means Sending a digital signal over a Channel without changing the D/A S/g.

A digital S/g is composite analog signal with an infinite Bandwidth.

In baseband transmission, the required bandwidth is proportional to the bit rate,

need to send bits faster, need more bandwidth.

Broadband Transmission (using Modulation).

It means changing the D/A signal for transmission.

Modulation allows to bandpass Channel - Channel with a bandwidth does not Start from Zero.

Bandpass Channel, cannot send the digital S/g directly to Channel. To convert before Transmission D/A S/g.

Modulation: The process in which some of Characteristic (Amplitude, Frequency and phase) in higher frequency of Carrier S/g in varies accordance with instantaneous of modulating signal (or) message signal (or) information S/g (or) input S/g.

ATTENUATION: Means a loss of energy. when a S/g simple (or) composite, travels through a medium, it loses some of its energy is overcoming the resistance of the medium.

DECIBEL: (dB).

It measures the relative Strengths of two S/g's (or) one S/g at two different points.

Decibel is -ve if a signal is attenuated

" " +ve " " " Amplified

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$ → Power of S/g's

decibel in terms of voltage instead of power.

power is proportional to square of voltage. $dB = 20 \log_{10}(V_2/V_1)$

DISTORTION: It means that the S/g changes its form (or) shape.

Distortion can occur in a composite S/g made of different frequencies.

SNR (Signal-to-Noise Ratio)

$$SNR = \frac{\text{Average Signal power}}{\text{Average Noise power}}$$

$$SNR_{dB} = 10 \log_{10} SNR$$

DATA RATE LIMITS:

data communications is how fast can send data, in bits per second, over a channel.

Data Rate depends on,

1. Bandwidth Available
2. Level of the S/g's
3. Quality of the channel (level of noise)

Two Theoretical formulas developed to calculate the data rate.

1. Nyquist for a noiseless channel
2. Shannon for a noisy channel – To determine theoretical highest data rate for noisy channel.

1. $BitRate = 2 \times bandwidth \times \log_2 L$ (↑ channel length)

2. $Capacity = bandwidth \times \log_2 (1 + SNR)$

THROUGHPUT: It is a measure of how fast can actually send data through a N/w.

B.W in bits/sec and throughput seem the same, they are different.

LATENCY (DELAY): It defines how long it takes for an entire message to completely arrive at destination from time the first bit is sent out from the source.

Latency = Propagation time + Transmission time + queuing time + Processing delay.

$$\text{Propagation time} = \frac{\text{Distance}}{\text{propagation speed}}$$

$$\text{Transmission time} = \frac{\text{message size}}{\text{Bandwidth}}$$

ERROR DETECTION AND CORRECTION

Data can be corrupted during transmission. Some application require that errors be detected and corrected

TYPES OF ERRORS:

whenever bits flow from one point to another, to unpredictable changes because of interference.

Interference can change the shape of the S/g.

1. single-Bit Error 2. Burst Error

1. single-bit Error means that only 1 bit of given data unit (byte, character (or) packet) is changed from 1 to 0 (or) from 0 to 1.

* only 1 bit in the data unit has changed

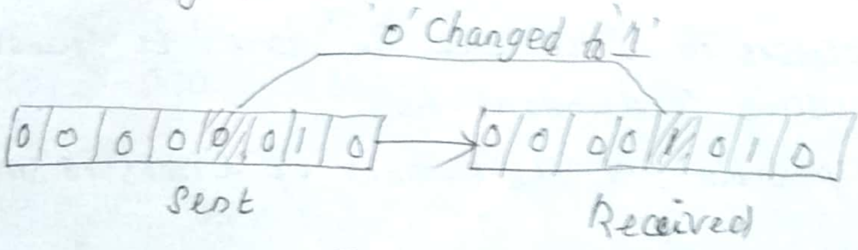
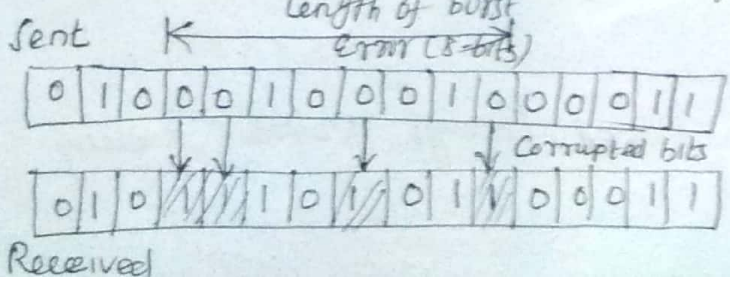


Fig: single-bit Error.

It's type of Error in Serial data Transmission

2. Burst Error means that 2 (or) more bits in the data unit have changed from 1 to 0 (or) from 0 to 1



The number of bits affected depends on data rate and duration of noise.

REDUNDANCY: The central concept in detecting (or) correcting errors is Redundancy.

To detect (or) correct errors, we need to send extra (redundant) bits with data. Redundant bit added by sender & Removed by R_x^r.

DETECTION VERSUS CORRECTION:

To detect when a transmission has changed is known Error Detection.

When an Error is detected it actually fixed without a second transmission is known Error Correction.

The correction of errors is more difficult than the detection.

Error detection, users are looking only to see if any Error has occured. A single bit Error is the same as a burst error.

Error Correction, user need to know the exact number of bits that are corrupted and their location in the message.

FORWARD ERROR CORRECTION VERSUS RETRANSMISSION:
(F.E.C)

The processes in which the R_x^r tries to guess the message by using redundant bits.

This is possible, if the number of errors is small

RETRASMISSION: Technique in which the R_x^r detects the occurance of an error and asks the sender to resend the msg.

Resending is repeated until a message arrives that R_x^r believes is error-free.

CODING:

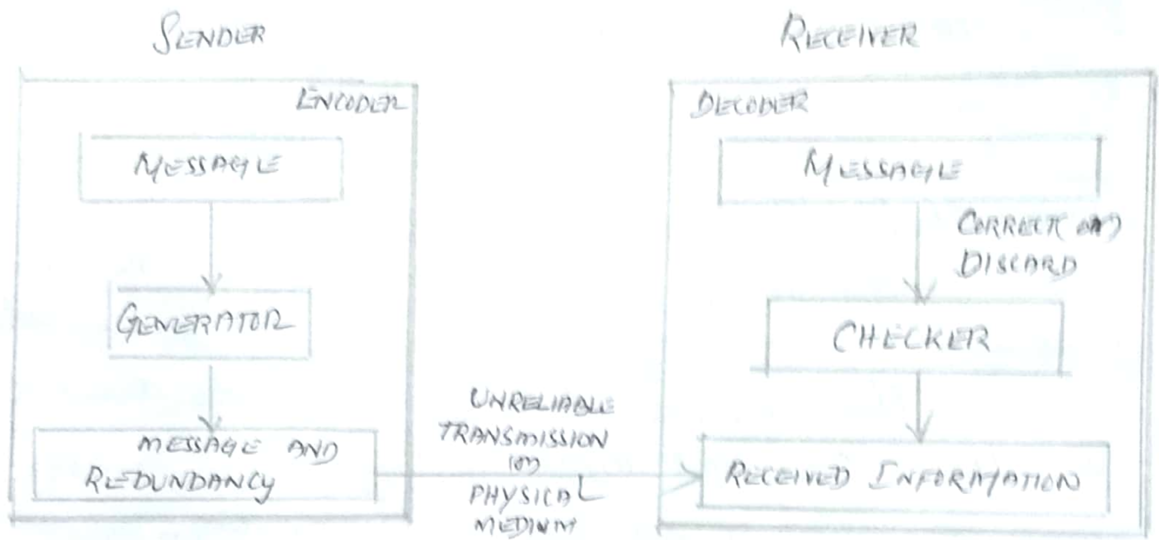
Redundancy is achieved through various coding schemes.

The sender adds redundant bits through a process that creates a relationship b/w redundant bits and actual data bits.

Coding schemes into two broad categories.

1. block coding 2. Convolution coding.

STRUCTURE OF ENCODER AND DECODER.



MODULAR ARITHMETIC: only limited range of integers. define upper limit, called a modulus 'N'.

Use only the integers 0 to N-1, inclusive.

Modulo-2 Arithmetic:

The modulus N is 2, use only 0 & 1

add (or) subtract 2 bits.

Adding: 0+0=0, 0+1=1, 1+0=1, 1+1=0

Subtracting: 0-0=0 0-1=1 1-0=1 1-1=0

"XOR" of two single bits (or) two words:

(a) $0 \oplus 0 = 0$

$1 \oplus 1 = 0$

(b) $0 \oplus 1 = 1$

$1 \oplus 0 = 1$

```
   1 0 1 1 0
⊕  1 1 1 0 0
-----------
   0 1 0 1 0
```

ii) BLOCK CODING:

We divide our message into blocks, each of 'k' bits called datawords.

Add 'r' redundant bits to each block to make the length $n = k + r$. The resulting n-bit blocks are called <u>codewords</u>.

Set of datawords, each of size 'k' and set of codewords each of size of 'n', within 'k' bits.

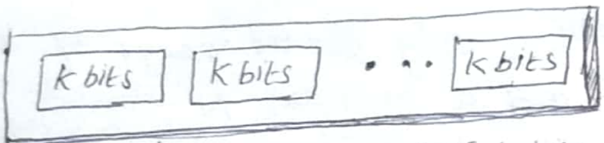
To create a combination of 2^k datawords, with 'n' bits, create a combination of 2^n codewords.

$n > k$, no of possible codewords is larger than the number of possible data words.

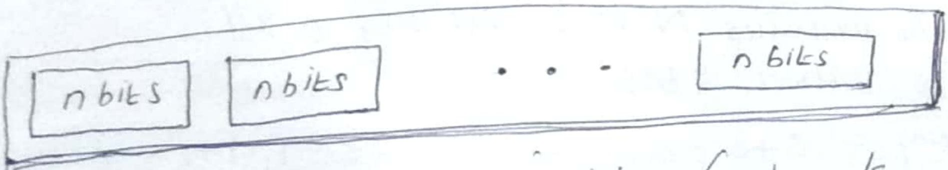
block coding process is one-to-one, the same dataword is always encoded as the same codeword.

This means $2^n - 2^k$ codewords are not used. Call these codewords <u>invalid (or) illegal</u>.

<u>Datawords and Codewords in block coding:</u>



2^k Datawords, each of k bits



2^n Codewords, each of 'n' bits (only 2^k of them are valid)

Error Detection in Block Coding.

The Receiver can detect a change in the original codeword.

1. The Receiver has (or) can find) a list of valid codewords
2. The original codeword has changed to an invalid one.

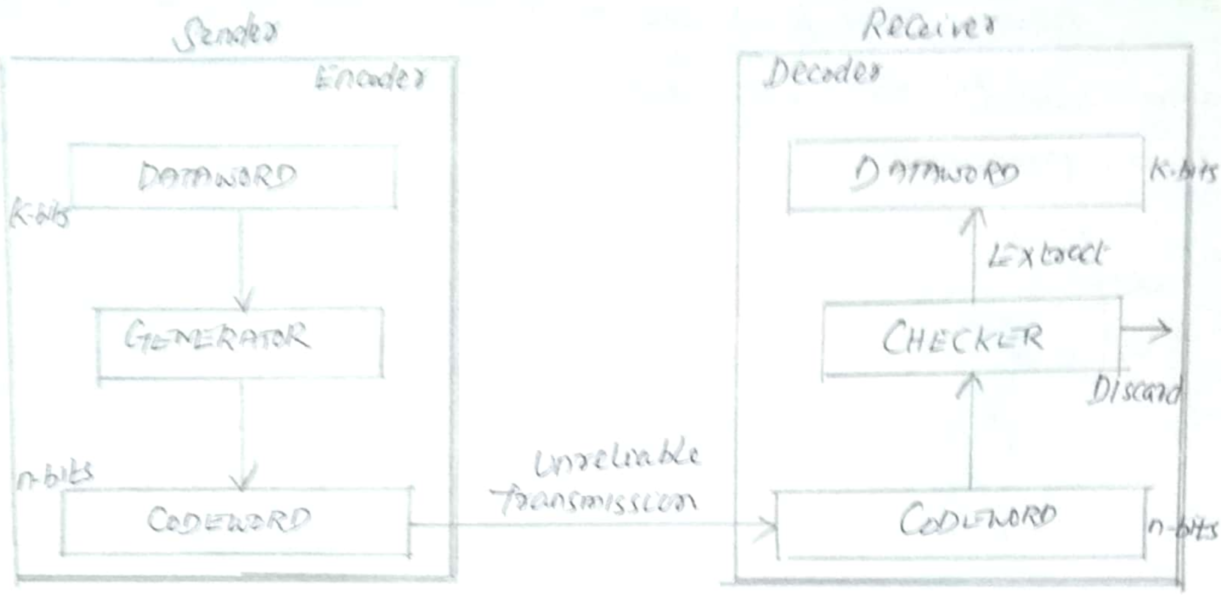


Fig. process of Error detection in block coding

An Error-detecting code can detect only the types of errors for which it is designed, other types of errors may remain undetected.

ERROR CORRECTION IN BLOCK CODING:

In Error detⁿ, the Rx needs to know only that received codeword is invalid.

In Error Correction the Rx needs to find (or) guess the original codeword sent.

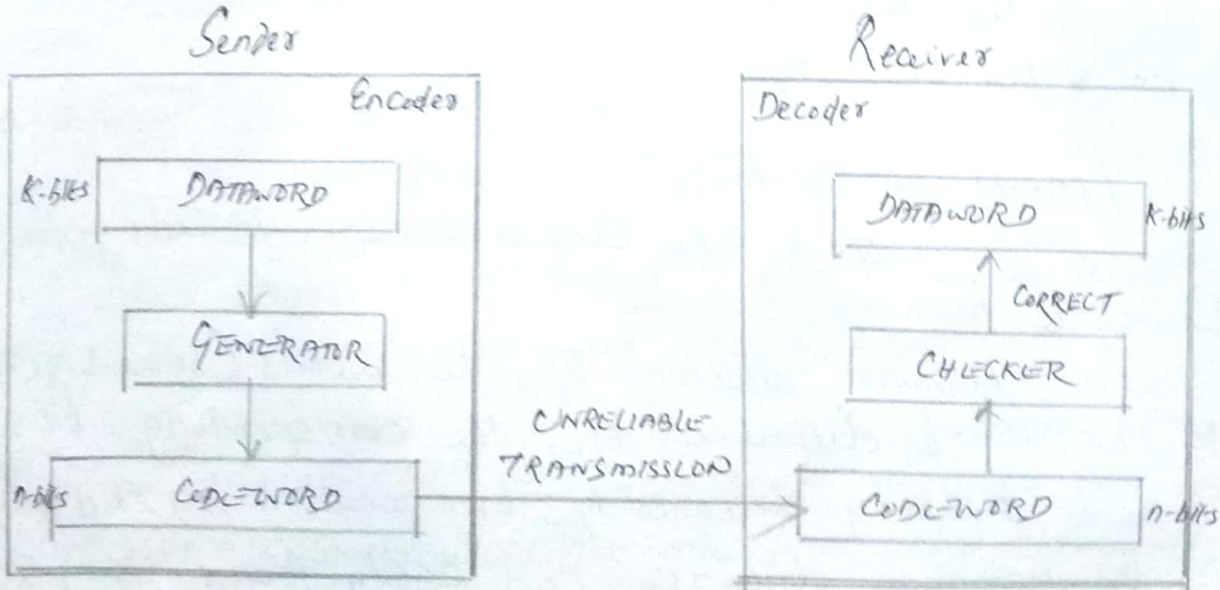


Fig. Structure of Encoder and Decoder in Error Correction.

Ex: Assume $K=2$ & $n=3$

Ex: Assume that k = 2 and n = 3.

A code for Error detection

DATAWORDS	CODEWORDS
0 0	000
0 1	011
1 0	101
1 1	110

A code for Error Correction

DATAWORDS	PREVIOUS CODEWORDS	CODEWORDS
0 0	00000	
0 1	01011	
1 0	10101	
1 1	11110	

let, we add 3 redundant bits to 2 bit dataword to 5 bit Codewords.

HAMMING DISTANCE:

one of the Central Concepts in Coding for Error Control is hamming distance.

Hamming distance b/w two words (same size) is the no of differences b/w the corresponding bits.

Hamming distance b/w two words x & y as d(x, y)

The Hamming distance Can easily found using XOR operation ($\oplus$)

Hamming distance is a value greater than Zero.

Ex: Find the Hamming distance b/w two pairs of words

1. Hamming distance d(000, 011) is 2 because 000 $\oplus$ 011 is 011 (two 1's)
2. d(10101, 11110) is 3, ∵ 10101 $\oplus$ 11110 is 01011 (3 1's)

MINIMUM HAMMING DISTANCE:

Hamming distance is the Central point in dealing with Error detection and Correction Codes, the measurement is used for designing a code is minimum Hamming distance.

The minimum Hamming distance is the smallest Hamming distance b/w all possible pairs in a set of words.

THREE PARAMETERS:

1) The codeword size 'n'
2) dataword size 'k'
3) The minimum Hamming distance d_{min}

Hamming Distance and Error

When a codeword is corrupted during transmission the Hamming distance b/w the sent & received codewords is the no of bits affected by error

(or)

The Hamming distance b/w the received codeword and sent codeword is the number of bits that are corrupted during transmission.

Minimum Distance for Error Detection

To find the minimum hamming distance in a code if able to detect upto 's' errors.

If 's' errors occur during transmission, the Hamming distance b/w the sent codeword and R_x^d codeword 's'

If our code is to detect upto 's' errors, the minimum distance b/w the valid codes must be s+1, so the received codeword does not match a valid codeword.

"To guarantee the detection of up to 's' errors in all cases, the minimum hamming distance in a block code must be $d_{min} = s+1$

Minimum Distance for Error Correction:

When a received Codeword is not a valid Code word, the R_x^r needs to decide which valid Codeword was actually sent.

" To guarantee Correction of up to 't' errors in all cases, the minimum Hamming distance in a block code must be $d_{min} = 2t+1$

LINEAR Block CODES:

Non-linear block codes for Error detection and Correction is not as widespread because theoretical analysis and implementation is difficult.

Linear block codes requires the knowledge of abstract algebra.

•• Linear block code, the exclusive OR (XOR) of any two valid Codewords Creates another valid Codeword.

Minimum distance for Linear Block Codes:

The minimum hamming distance is the no of 1's in the non zero valid Codeword with the Smallest number of 1's.

Ex:

Data words	Codewords
00	000
01	011
10	101
11	110

The number of 1s in the above non-Zero Codewords are 2, 2 and 2 (i.e, 011, 101, 110), minimum hamming distance $d_{min} = 2$

let Consider, the dataword and codeword

Data word	Code word
00	00000
01	01011
10	10101
11	11110

The numbers of 1s in the non Zero Codewords are (01011) = 3, (10101) = 3 and (11110) = 4, d_{min} = (3).

CYCLIC CODES:

In a Cyclic Code, if a codeword is Cyclically shifted (rotated), the result is another Codeword.

Ex:

1011000 is a codeword and cyclically

Left-Shift,

0110001

$b_1 = a_0$ $b_2 = a_1$ $b_3 = a_2$ $b_4 = a_3$ $b_5 = a_4$ $b_6 = a_5$ $b_0 = a_6$

CRC [Cyclic Redundancy Check]

A category of cyclic codes called CRC, It is used in Networks such as LANs and WANs.

CRC Code with C (7,4)

NO	Dataword	Codeword	NO	Dataword	Codeword
0	0000	0000000	8	1000	1000101
1	0001	0001011	9	1001	1001110
2	0010	0010110	10	1010	1010011
3	0011	0011101	11	1011	1011000
4	0100	0100111	12	1100	1100010
5	0101	0101100	13	1101	1101001
6	0110	0110001	14	1110	1110100
7	0111	0111010	15	1111	1111111

Encoder (Division in CRC Encoder)

Dataword [1001]

Division

```
                 Quotient
   Divisor        1 0 1 0
           ________________
     1011 ) 1 0 0 1 [0 0 0]  <-- Dividend: augmented dataword
            1 0 1 1
            -------
Leftmost bit 0) --> 0 1 0 0
use 0000 divisor    0 0 0 0
                    -------
                    1 0 0 0
                    1 0 1 1
                    -------
leftmost bit 0        0 1 1 0
use 0000 divisor -->  0 0 0 0
                      -------
                      [1 1 0]  Remainder
```

Codeword [1001 | 110]
Dataword | Remainder

Decoder (Division in CRC decoder) two cases

```
Codeword : [1001|110]                  Codeword [1000|110]
Division                                Division

         1 0 1 0                                 1 0 1 0
      ____________                            ____________
1011 ) 1 0 0 1 1 1 0  <- code word      1011 ) 1 0 0 0 1 1 0
       1 0 1 1                                 1 0 1 1
       -------                                 -------
       0 1 0 1                                 0 1 1 1
       0 0 0 0                                 0 0 0 0
       -------                                 -------
         1 0 1 1                                 1 1 1 1
         1 0 1 1                                 1 0 1 1
         -------                                 -------
         0 0 0 0                                   1 0 0 0
         0 0 0 0                                   1 0 1 1
         -------                                   -------
         [0 0 0] Syndrome                          [0 1 1] Syndrome

Dataword Accepted                       Dataword discarded
[1001]
```

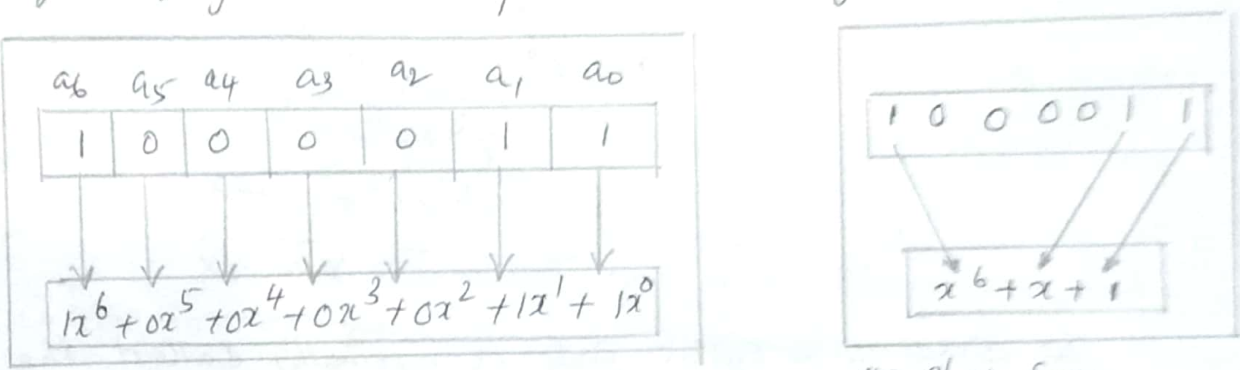
POLYNOMIALS:

To better understand Cyclic Codes & analyzed to represent as polynomials.

A pattern of 0s and 1s represented as polynomial with Co-efficients of 0 and 1.

The power of each term position of bit, The coefficient shows the value of bit.

Fig. A polynomial to represent a binary word



(a) Binary pattern and polynomial   (b) Short form

Multiplying Two polynomials.

$(x^5+x^3+x^2+x)(x^2+x+1)$

$= x^7+x^6+x^5+x^5+x^4+x^3+x^4+x^3+x^2+x^3+x^2+x$

$= x^7+x^6+x^3+x$

Shifting.

Shifting left 3 bits : 10011 becomes 10011000

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

Shifting Right 3 bits : 10011 becomes 10

x^4+x+1 becomes x

CRC Division using polynomials.

Data word x^3+1

Divisor x^3+x+1

Quotient: x^3+x

Dividend ← augmented dataword: $x^6 + x^3$

$$
\begin{array}{r}
x^6 + x^3 \\
x^6 + x^4 + x^3 \\
\hline
x^4 \\
x^4 + x^2 + x \\
\hline
x^2 + x
\end{array}
$$

x^2+x Remainder.

Codeword x^6+x^3 x^2+x

Data word Remainder

Degree of polynomials.

highest power in the polynomial. Ex x^5+x+1 is (5)

$t(x)/g(x)$ = $t(x) = x^{10}+x^9+x^7+x^5+x^4$

$g(x) = x^4+x^3+1$

$$
\begin{array}{r|l}
 & x^6 \quad +x^3 \quad +x \\
x^4+x^3+1 & x^{10}+x^9+x^7+x^5+x^4 \\
 & x^{10}+x^9 \quad +x^6 \\
 \hline
 & x^7+x^6+x^5+x^4 \\
 & x^7+x^6 \quad +x^3 \\
 \hline
 & x^5+x^4+x^3 \\
 & x^5+x^4+ \quad +x \\
 \hline
 & x^3 \quad +x
\end{array}
$$

" The divisor in a cyclic code is normally called the generator polynomial (or) simply the generator."

Cyclic Code Analysis:

To find its capabilities by using polynomials.

$f(x) \to$ polynomial with binary coefficients.

$d(x) \to$ Data word

$c(x) \to$ Code word

$g(x) \to$ Generator

$s(x) \to$ syndrome

$e(x) \to$ Error.

If $s(x)$ is not zero, then one (or) more bits is corrupted. if $s(x)$ is zero, either no bit is corrupted (or) decoder failed to detect any errors.

In a cyclic codes,

1. If $s(x) \neq 0$, one (or) more bits is corrupted.
2. If $s(x) = 0$, either
   a) No bit is corrupted (or)
   b) Some bits are corrupted, but decoder failed to detect them

Scanned with CamScanner

Generator [g(x)] to detect the type of error want to be detected.

Received Codeword = $c(x) + e(x)$

The Received Codeword is sum of the sent codeword and error.

The Receiver divides the received codeword by g(x) to get syndrome.

$$\frac{\text{Received Codeword}}{g(x)} = \frac{c(x)}{g(x)} + \frac{e(x)}{g(x)}$$

In cyclic code, Those e(x) errors that divisible by g(x) are not caught.

Single-Bit Error:

If the generator has more than one term and coefficient of x^0 is 1, all single errors can be caught.

The Structure of g(x) to guarantee the detection of a single-bit Error?

A single-bit error is $e(x) = x^i$,

$i \rightarrow$ position of the bit.

If a single-bit error is caught, then x^i is not divisible by g(x).

If g(x) has at least two terms and coefficient of x^0 is not zero (the rightmost bit is 1), then e(x) cannot be divided by g(x).