Data Communication

Final: 2020-21

① (a) What do you mean by data communication? Write shortly about the main components of a data communication system.

⇒ Data communication means the exchange of data between two devices through some form of trasmission medium.
Its goal is to send data accurately, efficiently and securely.

Main components of Data communication System:

1. sender:
the device that sends the data.

2. Receiver:
The device that receives the data.

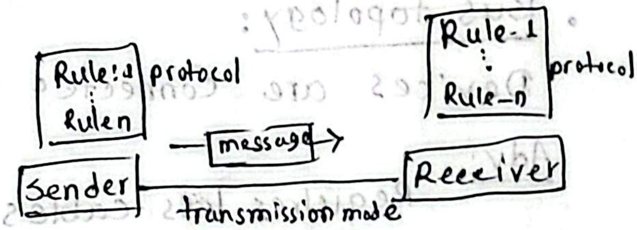


fig: components of data communication

3. Message:
The actual data/information being transmitted.

4. Medium: (transmission channel)
the path through which data travels (cables, fiber optics, radio waves)

5. protocol:
A set of rules that controls how data is send and received (TCP/IP)

(b) When two or more devices connected through links, there is a term called "physical topology". So, what do you mean by this term? Write the advantages and the disadvantages of those topologies.
For n devices in a network, what is the number of cable links required for each of those topologies?

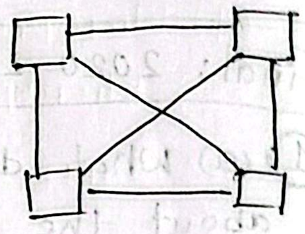
⇒ Physical topology refers to the actual layout of devices and cables in a network. It shows how devices (called nodes), cables, switches, router and others are connected in a network physically.

There are five basic topologies possible such as Mesh, Bus, Ring, star and tree topology.

Description of those topologies are given below:

- **Mesh topology:**

Every device connects to every device directly



Adv:
- very reliable and secure
- Data can take multiple paths.

Disadv:
- High cost of cabling
- complex installation

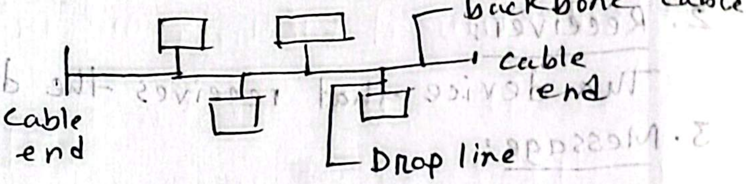
node = 4
links: $\frac{4(4-1)}{2}$
$= 4\times3/2$
$= 6$

Cable links required: $n(n-1)/2$

- **Bus topology:**

Devices are connected to a single bacbone cable.

Adv:
- Requeires less cables
- Easy to setup.



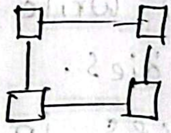
disadv:
- backbone cable faults, breaks the whole network.
- Difficult to troubleshoot.

node = 4
links = 4+1 = 5

Cable links required: n+1.

- **Ring topology:** Each device connects to exactly two other devices in a circle.

Adv:
- No collision due to - one way data flow
- Equal access for all devices.



node = 4
links = 4

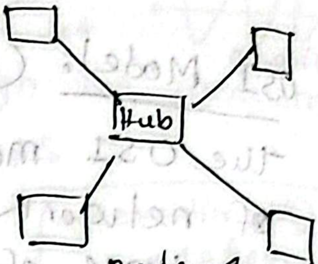
Disadv:
- faults in one device, can break the whole network
- slow, if many device are connected.

Cable links are required: N

- **Star topology:** All device are connected with central hub or switch.

Adv:

- Easy to add new device
- Failure in one device don't affect others.



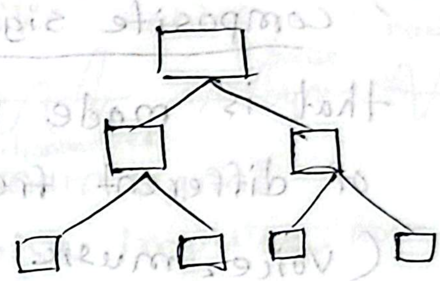
node = 4
links = 4

Disadv:

- Hub failure crash the whole network
- performance depends on central hub.

Cable links required: N

- **Tree topology**: It is a hierarchical network where devices are arranged in parent child structure.



node = 7
links = 7 - 1 = 6

Adv:

- Scalable and easy to expand.
- good for large network.

Disadv:

- If parent device fail, effects all its child devices.
- difficult to maintain.

Cable links required: N - 1.

(c). What is OSI Model? Differentiate between OSI and TCP/IP model.

⇒

OSI	TCP/IP
- Full form is open system interconnection.	- full form transmission control protocol / Internet protocol.
- Developed by international Standards organization (ISO)	- It is developed by ARPANET (Advanced Research project Agency network)
- 7 layers	- 4 layers
- Application, presentation, Session, transport, network, data link, physical.	- Application, transport, Internet, network access.
- ~~theoritical~~ theoretical model.	- practical model.
- layer functions are seperated.	- functions are combined.

OSI Model: (Open System Interconnection)

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

(2)(a) What is composite signal? How can we decompose it into its components? explain it briefly.

⇒ [combination of many sine wave]

composite signal: composite signal is a signal that is made up of multiple simple sine waves of different frequencies, amplitudes or phases. (voice, music or any data signal)

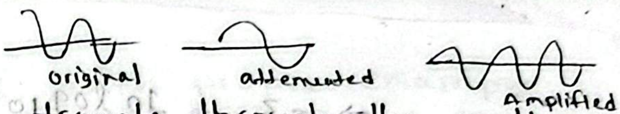
* We can break a composite signal into its individual sine waves using fourier analysis (fourier analysis tells us: Any complex signal can be represented as the sum of many sine waves.

* A composite signal consists of multiple sine waves with different frequencies, amplitudes and phases. Using Fourier analysis we can decompose the composite signal into its basic sine-wave components. This helps us understand the bandwidth and frequency content of the signal.

(b). What are the main causes of transmission impairments? Explain it briefly.

⇒ Transmission impairments means the received signal is not the same as the transmitted signal.

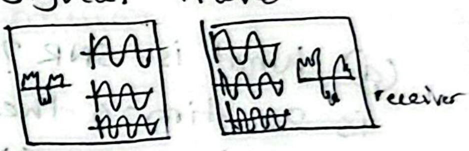
The main causes are:

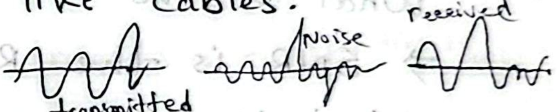
- Attenuation (signal loss): 

- signal becomes weaker as it travels through the medium
- Example: Long Cable - signal strength drops.
- Solution: use amplifier or Reapeater.

Attenuation(dB) $= 10\log_{10}(P_2/P_1)$

- Distortion (chang in shape):
- Different frequency components of a signal travel at different speeds.
- Result: shape of the signal changes.
- Mostly occurs in guided media like cables.



- Noise (Unwanted Random signal): 

SNR(dB) = 10log10 SNR

- Extra signal that mix with the main signal.
- Types of noise, include thermal noise, impulse noise, crosstalk etc.
- Noise makes the signal harder to interpret.

(c) What is the way to measure attenuation? The loss in a cable is usually defined in decibels per Kilometer (dB/Km). If the signal at the beginning of the cable with -0.3 dB/Km has a power of 2 mw, what is the power of the signal at 10 Km?

⇒ Attenuation is measured in decibels (dB).

$$\text{Attenuation (dB)} = 10\log_{10}\left(P_{received}/P_{sent}\right)$$

$P_{received}$ = power of input signal

P_{sent} = power of output signal

Given that,

attenuation (loss) = -0.3 dB/Km

Distance = 10 Km

initial power P_{in} = 2mW

total attenuation over 10Km is = $-0.3 \times 10 = -3$ dB

So, final power of signal,

total attenuation = $10\log_{10}(P_{out}/P_{in})$

$$\Rightarrow -3 = 10 \log_{10} \left(\frac{P_{out}}{2} \right)$$

$$\Rightarrow \log_{10} \left(P_{out}/2 \right) = -0.3$$

$$\Rightarrow \frac{P_{out}}{2} = 10^{-0.3}$$

$$\Rightarrow P_{out} = 1.002 \text{ mW}$$

(d) What is SNR? If the peak voltage value of a signal is 20 times the peak voltage value of the noise. What is the SNR? What is the SNR_{dB}?

⇒ SNR is the Ratio of signal power to noise power. It indicates the strength of the signal w.r.t. the noise power in a system.

Formula: $SNR = \frac{\text{avg signal power}}{\text{avg noise power}}$

given that,

peak voltage of signal = 20 × peak Voltage noise

so, $\frac{V_{signal}}{V_{noise}} = 20$

$\therefore SNR = \left(V_{signal}/V_{noise} \right)^2 = 20^2 = 400$

$\therefore SNR = 400.$

And, $SNR_{dB} = 10 \log_{10} (SNR)$

$= 10 \log_{10} (400)$

$\therefore SNR_{dB} = 26.02 \text{ dB}$

(3) (a). Explain the following terms: With proper example.
bit stuffing, byte stuffing, pulse stuffing.

• **Bit Stuffing:**

- used in bit-oriented protocols (HDLC)
- if the data contains the same pattern as the flag, extra bits are inserted to avoid confusion.

Example:

flag = 01111110

if data contains 011111, sender inserts a 0 after five 1s.

Data:

011111 → 0111110 (Stuffed bit).

• **Byte Stuffing:** (character stuffing).

- used in byte-oriented protocols.
- If data contains the same bye as control characters, the sender adds an ESC (escape byte).

Example:

Flag = F1, ESC = FE

if data contains F1, it becomes:

Data: F1 → FE F1

ESC itself becomes: FE → FE FE

• **pulse stuffing:**

- used in TDM stystems.
- If different channels produce data at slightly different rates, extra dummy pulses are inserted to synchronize the rate.

Example:

If a channel produces 999 Kbps but system needs 1 Mbps, the system inserts 1 extra pulse per second.

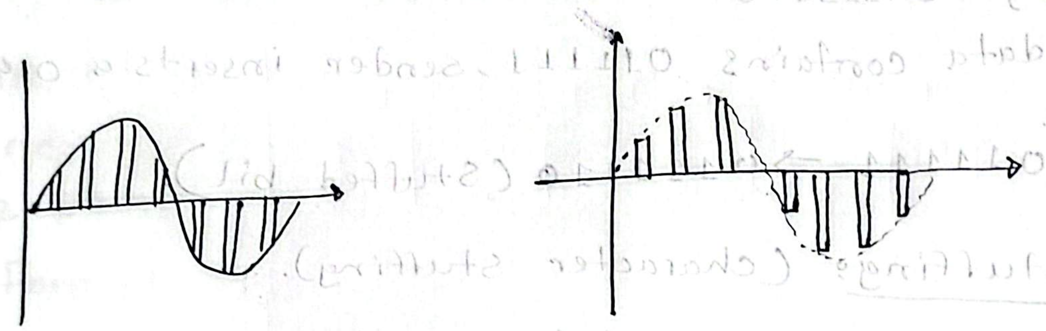
(b). How does an analog signal convert into digital signal. Briefly explain all the steps associated with it.

This process is called pulse code Modulation (PCM)

It has three main steps:

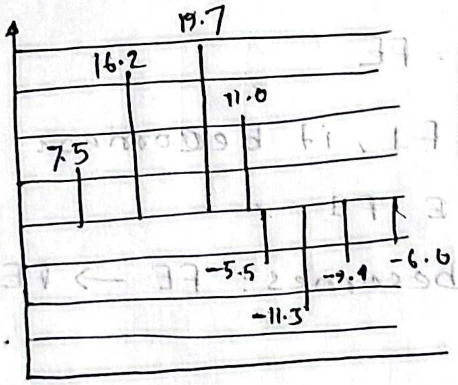
1. Sampling:

- take measurements of the analog signal at regular intervals.
- Must follow Nyquist rate: 2x highest frequency.



2. Quantization:

- convert each sample into a discreat level.
- More levels = higher accuracy



3. encoding:

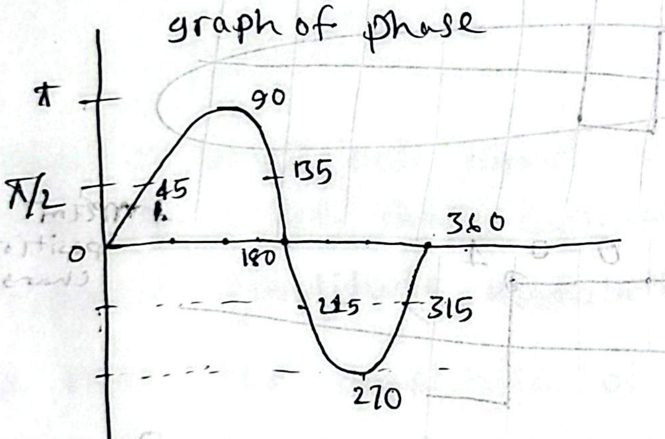
- Convert each quantized level into a binary code.

(c). What is QAM? Differentiate between 4-QAM and 8-QAM. Draw an 8QAM signal of the 000 001 111 100 101 010 001 110 011 101

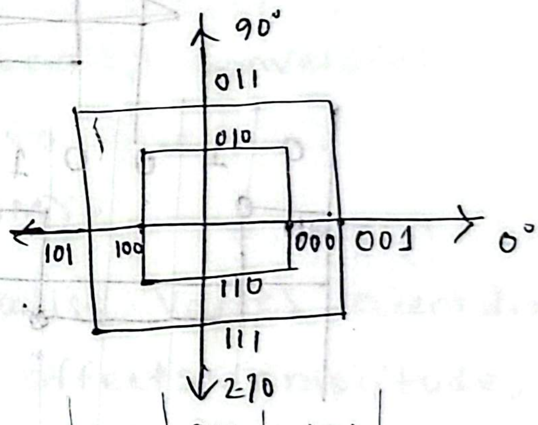
⇒ Quadrature Amplitude Modulation (QAM) is a modulation technique that can be ~~w~~ Utilized in Analog modulation concepts and digital modulation concepts. It is a combination of ASK and PSK.

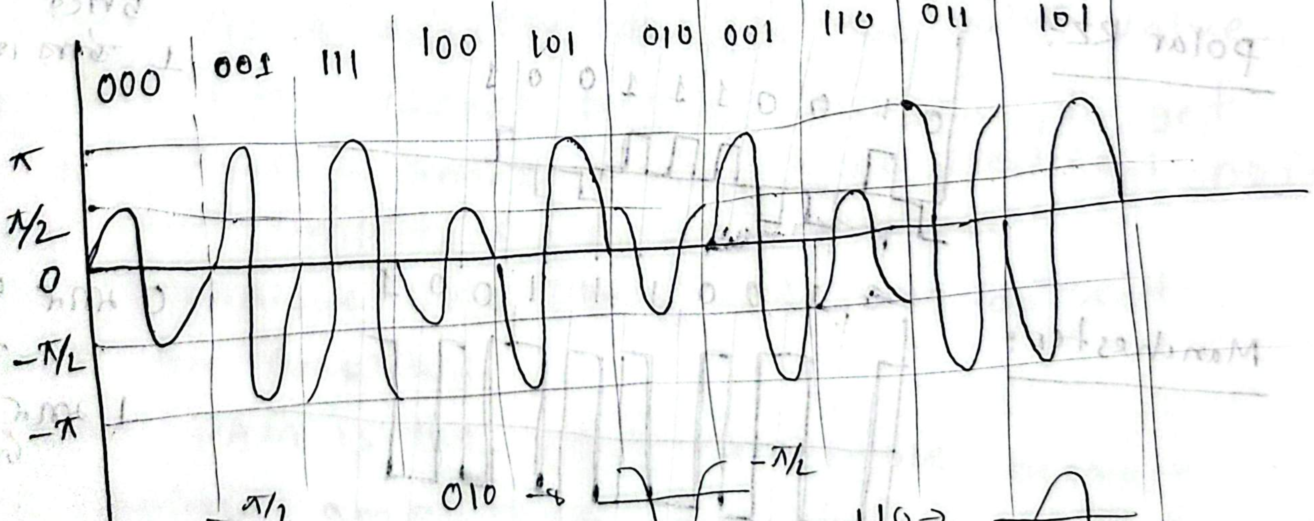
Feature	4 QAM	8 QAM
Number of points	4	8
bits per symbol	2 bits	3 bits
spectral efficiency	Lower	higher
Amplitude	Constant	Varies
Noise immunity	High	Lower
complexity	Low	higher

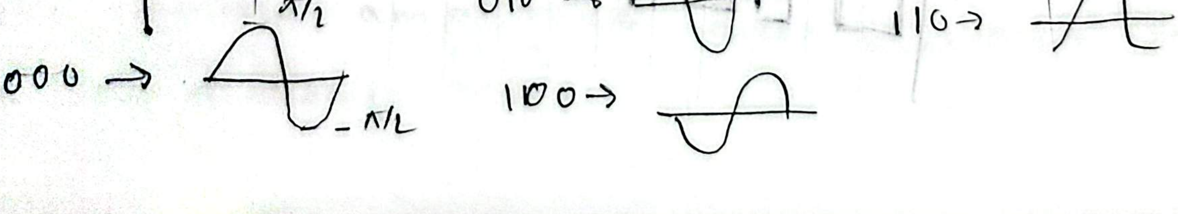
graph of phase



so, the 8 QAM constellation is 2 amplitude & 4 phases.





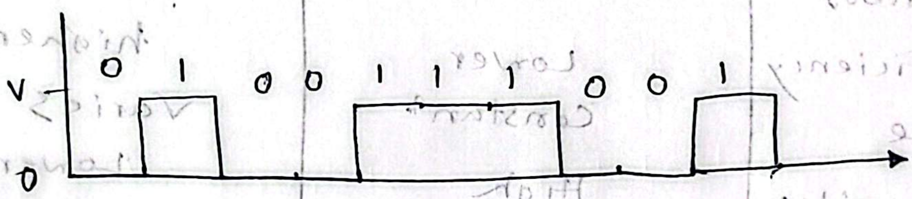


0100111001

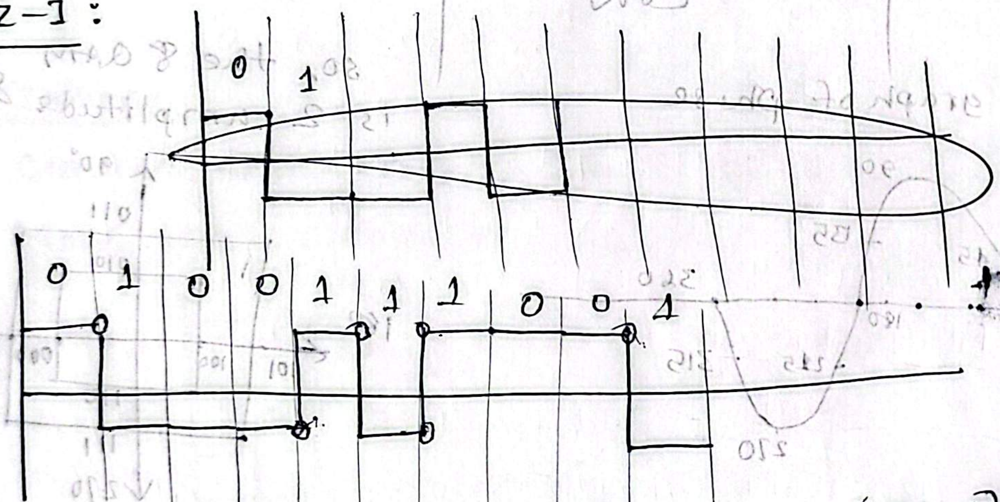
4 (a) What is line encoding scheme? Draw the digital signal of the following bit stream by the following schemes: Unipolar NRZ, polar NRZ-I, polar RZ, polar-biphase (Manchester and differential manchester), bipolar AMI and pseudo-ternary and multilevel 2B1Q.

A line encoding scheme is a specific method used to represent digital data (0s and 1s) as a digital signal for transmission over a physical medium.

Unipolar NRZ:

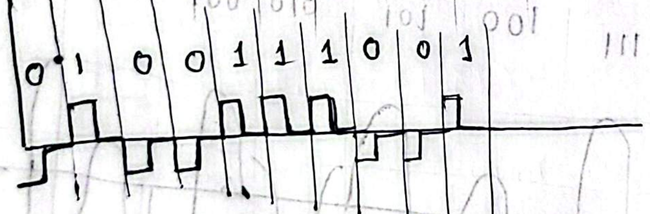


polar NRZ-I:



position change করে

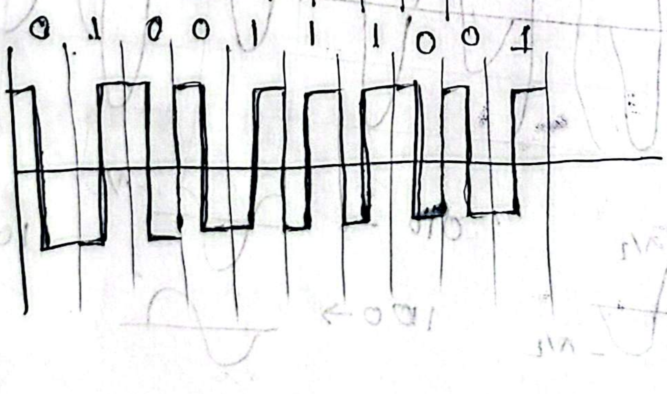
polar RZ:



Zero নীচ থেকে উপরে

1 উপর থেকে নীচে

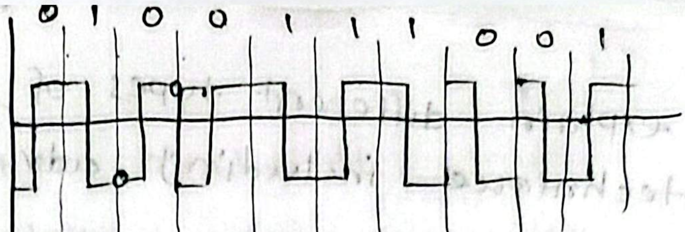
Manchester:



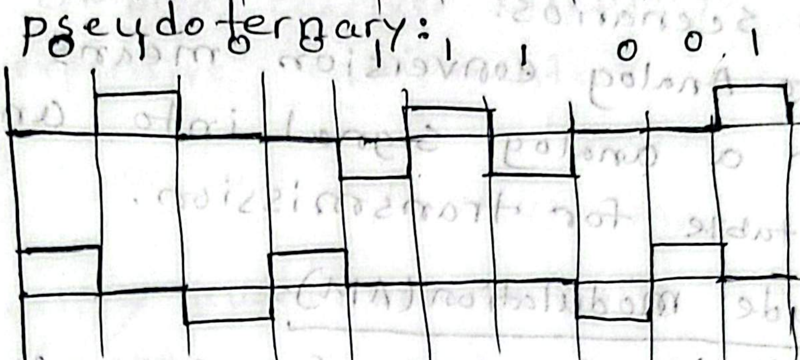
0 মানে উপরে থেকে নীচে

1 মানে নীচ থেকে উপরে

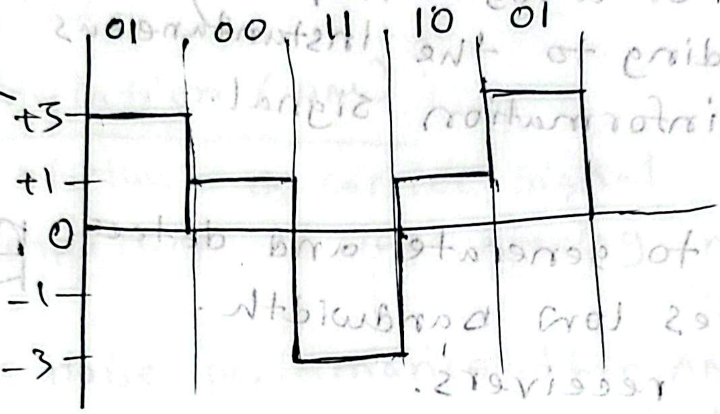
ifferential manchester:



ipolar AMI and pseudoternary:



Multilevel 2B1Q



	Previous (+)	Previous (−)
00	+1	−1
01	+3	−3
10	−1	+1
11	−3	+3

(b). Mention your logic about which analog conversion technique is the most susceptible to noise.

⇒ pulse Amplitude Modulation (PAM):

- In PAM, the amplitude of the pulse varies according to analog signal. Noise mainly affects amplitude, so any small noise directly changes the pulse value.
- Amplitude is the essiest part of a signal to get distorted. Even a small amount of electrical noise changes the amplitude, causing errors.
- Other technique like PWM and PPM do not depend on amplitude.
- Therefore, PAM is the most vulnerable because noise changes amplitude directly, which carries the information.

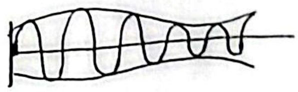
(c) Briefly explain different types of analog to analog conversion technique including adv, disadv and application scenarios.

⇒ Analog to Analog conversion means converting one form a analog signal into another analog form suitable for transmission.

- **Amplitude modulation (AM):-**

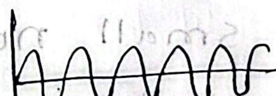
The amplitude of a high-frequency carrier wave is varied according to the instantaneous amplitude of the analog information signal.

adv:
- Simple to generate and detect.
- Requires low bandwidth.
- cheap receivers.



disadv:
- highly affected by noise
- poor audio quality.
- Less efficient in power usage.

Application:
- AM radio broadcasting.
- Aircraft communication
- citizens band radio.



- **Frequency modulation (FM):-**

The frequency of the carrier signal is varied based on the information signal while amplitude remains constant.

adv:
- very high noise immunity.
- Better sound Quality than AM.
- constant amplitude - efficient and stable

disadv:

- requires higher bandwidth.
- More complex receiver circuitry.
- More expensive equipment.

Application:

- FM radio
- High-Quality audio transmission.
- two way radio.

• **Phase Modulation (PM):**

the phase of the a carrier signal is varied according to the amplitude of the analog message signal.

Adv:

- Better noise performance than AM
- used in many digital communication systems.
- constant amplitude like FM.

disadv:

- More complex modulator / demodulator.
- Not commonly used alone for analog audio.
- Harder to implement compared to AM & FM.

Application:

- used inside digital modulation schemes such as PSK.
- Sattellite communication.
- RF ID System.

5 (a). Explain IP spoofing and packet sniffing?

IP spoofing: is a technique where an attacker fakes (forges) the source IP address of a packet to pretend it is comming from another trusted device purpose:

- to bypass security filters.
- to hide their real identity.
- to perform DoS or DDoS attacks
- to gain unauthorized access to systems.

RISK: the receiver trusts the fake ip and may allow harmful communication.

Packet sniffing: is the process of capturing and analyzing network packets traveling through a network using special software.

Who use it:

- System administrators → for troubleshooting
- Attackers → to steal sensitive data.

What attackers can capture:

- usernames and passwords
- Credit card information
- Cookies and unencrypted messages

RISK: If the data is not encrypted, sniffing exposes confidential information.

(b). Mention some error controlling protocols for a noisy channel? Explain one of them using a suitable example with illustrations.

⇒ Error controling protocol for a noisy channel:

- Stop and wait ARQ
- Go Back N ARQ
- selective Repeat ARQ
- Forward Error correction (FEC)
- Automatic Repeat request (ARQ)

Stop and Wait ARQ:

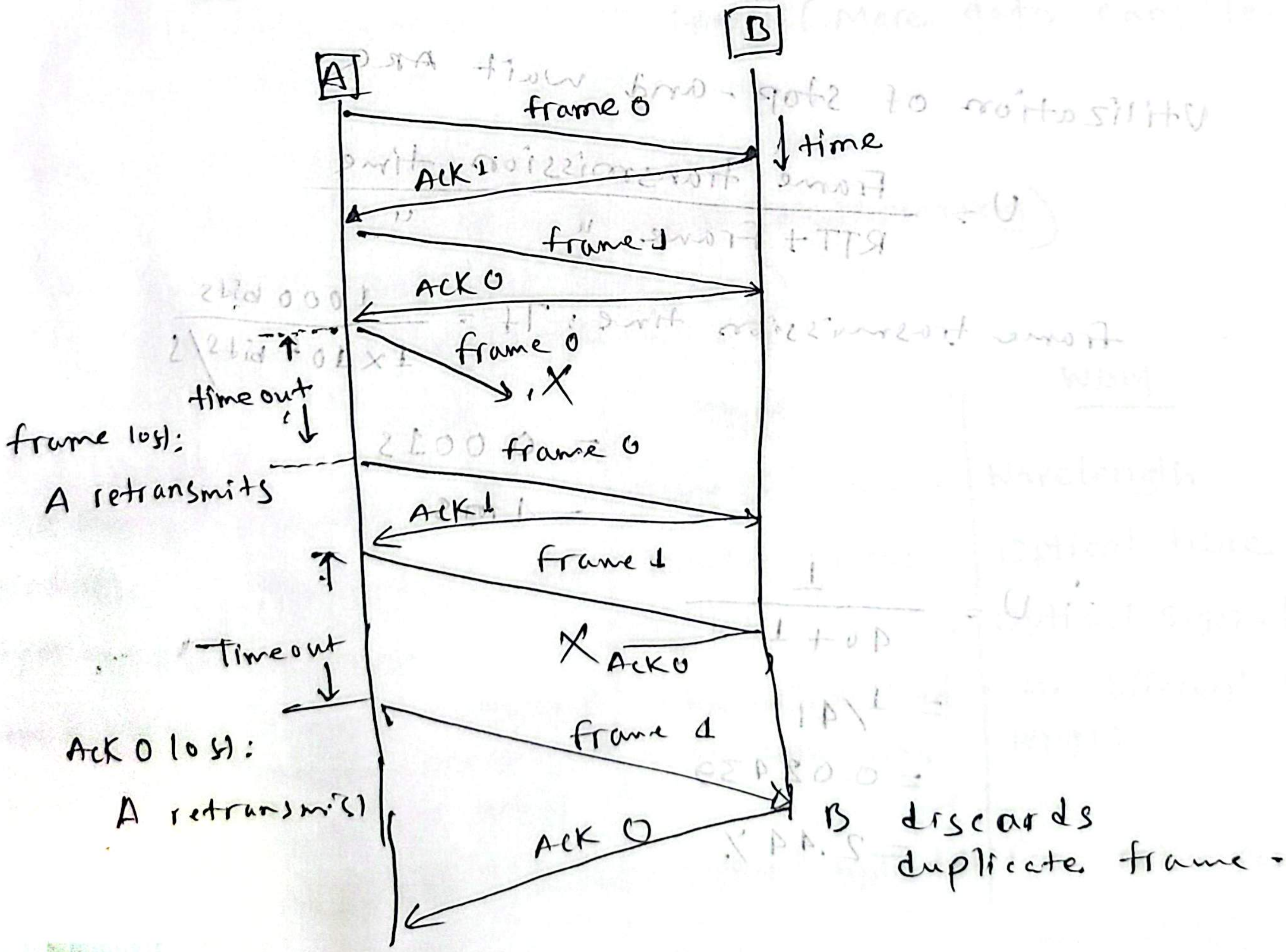
In Stop and Wait ARQ, the sender transmits one frame at a time and waits for an ACK (Acknowledge) from the receiver before sending the next frame.

If the frame o ACK is lost, the sender retransmits after a timeout.

- it ensures error detection + retransmission.

How it works:

- Sender sends frame Zero (0).
- Receiver Receive's it and sends back ACK 0.
- Only after getting ACK. sender sends ~~ACK 1~~ frame 1
- If ACK is not received, sender resends the same frame.



(c). Assume that, in a stop-and-wait ARQ system, the bandwidth of the line is 1 Mbps, and 1 bit takes 40 ms to make a round trip. What is the bandwidth-delay product? If the system data frame are 1000 bits in length, what is the utilization percentage of the link?

⇒

Bandwidth = 1 Mbps

Round trip time (RTT) = 40 ms

Frame size = 1000 bits.

Bandwidth-delay product (BDP)

$$BDP = \text{Bandwidth} \times RTT$$

$$= 1 \times 10^6 \text{ bits/s} \times 0.04 s$$

$$= 40{,}000 \text{ bits.}$$

Utilization of stop-and wait ARQ

$$U = \frac{\text{Frame transmission time}}{RTT + \text{Frame " "}}$$

frame trasmission time: $T_f = \dfrac{1000 \text{ bits}}{1 \times 10^4 \text{ bits/s}}$

$$= 0.001 s$$

$$= 4 ms.$$

$$\therefore U = \frac{1}{40 + 1}$$

$$= 1/41$$

$$= 0.02439$$

$$= 2.44\%$$

6 (xv). Why do you need to apply multiplexing technique in data communication? Mention three multiplexing techniques and differentiate them.

⇒ Multiplexing is needed because it allows multiple signals to share a single communication channel, increasing efficiency and reducing cost.

• Reasons for using multiplexing:

→ Efficient use of bandwidth (multiple users can share one channel instead of using seperate lines)

→ cost reduction (one high-capacity line is cheaper than multiple low capacity lines)

→ Increases channel capacity (Transmits many signals at the same time)

→ Improves comunication speed (More data can flow simutaneously)

• Three multiplexing techniques:

① FDM (Frequency Division Multiplexing)

② TDM (Time Division ")

③ WDM (Wavelength " ")

Feature	FDM	TDM	WDM
Full form	Frequency Division....	Time Division ---	Navelength ------
Medium	Electrical/RF Signals	Digital Signals	Optical fibre
types of signal	Analog	Digital	optical signal
How it works	channel bandwidth divided into different frequency bands	channel divided into time Slots	uses different wave lengths
Example use	Radio & TV broadcasting	Telephony, digital data	fibre-optic communi
Bandwidth efficiency	Moderate	High	Very high.

(b). Five channels, Each with a 100 KHZ bandwidth, are to multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 KHZ between the channels to prevent interference?

⇒ Number of channel = 5

Bandwidth of each channel = 100 KHZ

Guard band between channels = 10 KHZ

total bandwidth = 5 X 100

= 500 KHZ.

~~total guard band ne~~

number of guard bands = 5 - 1 = 4

So, total guard band = 4 X 10 = 40 KHZ

~~total~~ minimum band width

= 500 KHZ + 40 KHZ

= 540 KHZ.

(e). How to efficiently use TDM to remove the wastage of the bandwidth when one or more slots of TDM on the output link will go unused.

to remove bandwidth wastage in TDM when some users are silent, we use statistical TDM instead of synchronous TDM.

In synchronous TDM, each user gets a fixed time slot even if they have no data - causes wastage.

Statistical TDM fixes this by:

- Assigning time slot only to users who ~~act~~ actually have data to send.
- Time slots are dynamic, not fixed.
- improve channel efficiency.
- reduces idle slots.

How Statistical TDM Works:

Synchronous TDM:

Slot 1	Slot 2	Slot 3	Slot 4
user1	user2 (empty)	user3	user 4 (empty)

⇒ Wastage 2 empty slot

Statistical TDM:

Slot 1	Slot 2
user 1	user 3

⇒ no wastage!

In Statistical TDM:—

- slots allocated dynamically
- A multiplexer keeps a buffer of incoming data
- only filled buffers get time slots.
- uses address information inside each slot to identify the sender.

1). What are the three strategies that can be used to overcome the data rate mismatch in all input links during multiplexing?

When input links have different data rates, the multiplexer uses the following three storategies to match them:

- Bit stuffing / padding:
  - Extra dummy bits are added to slower input streams
  - makes all inputs appear to have the same rate.
  - used in TDM systems.
- Repetition of slow signal: (Slot Repetition).
  - slower channel are given multiple time slots in each TDM frame.
  - Faster channel may get fewer slots, balancing the rates.
- Use of a Buffer (Elastic Buffering):
  - Each input stream stores arriving data in a buffer.
  - Multiplexer reads data from buffers at a common fixed rate.
  - smooths out variations in data rates.