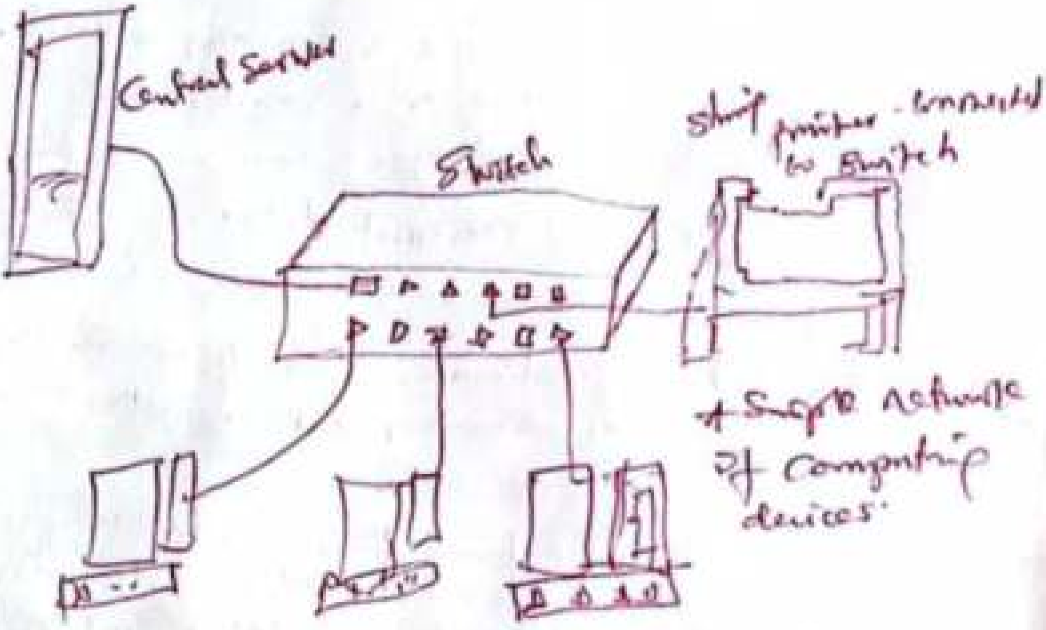
* Data Communication refers to the exchange of data b/w two or more connected devices via a communication channel



Components of data communication

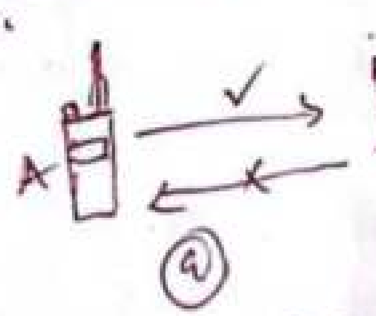
- Sender; is a computer or any device capable of sending data over a network. e.g video recording device, smartwatch, server, router etc.
- Receiver; A receiver is a computer or any device capable of receiving data from a network e.g television, mobile phone, printer etc..
- Message; Data or information that is to be exchanged b/w a sender and the receiver over a network.
- Communication media; this is the path through which the message travels b/w source and destination. It is also called medium or link which is either wired or wireless. e.g (unbounded) television cable, telephone cable, ethernet cable, satellite link, microwaves etc.
- protocols; this is a set of rules that governed a reliable and successful data communication b/w two or more parties. e.g HTTP, Ethernet, TCP/IP protocols.

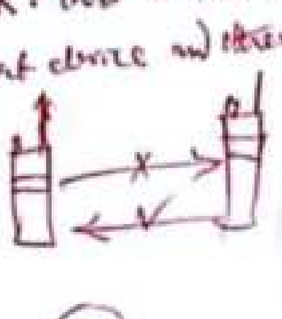
Types of data communication

Data communication happens in form of signals b/w 2 or more nodes.

— Simplex Communication: this a one way or unidirectional communication b/w 2 devices in which one is a sender and the other is the receiver. The devices involved in this type of communication use the entire capacity of the link to transmit data. e.g data entered through a keyboard or audio sent to a speaker, are one way communication and controlling home appliances (IOT) (fans, lights, fridge, oven etc) while sitting in the office or driving a car is another example.

— Half-duplex Communication: this is a two way or bidirectional communication b/w 2 devices in which both send and receive data or control signals in both directions, but not at the same time. one device will send data, the other one will receive and vice-versa. e.g example is found in walkie-talkie where one can press the push-to-talk button and talk. This enables the transmitter and turns off the receiver in that device and others can only listen.





— Full-duplex Communication: It is two way or bidirectional communication in which both devices can send and receive data simultaneously. for examples mobile phones and landline telephones. The capacity of the transmission link is shared b/w the signals going in both directions.

Data?

Data is anything that is represented in bits. while information refers to manipulated or transformed data that gives insights.

* Data Communication refers to the process of exchanging digital data or communication ~~resource sharing~~ b/w two or more connected devices via a transmission medium.

Data processing Systems (hardware, software & processes)

Data processing system refers to systems designed to process, manipulate, and manage data to produce meaningful information or insights. Key aspect or components of data processing systems are:

- Data Collection: processing systems collect data from various sources such as sensors, databases, files, and external systems. These data could be structured (tables) or unstructured (e.g. text doc., images).
- Data Storage: the collected could be stored in cloud storage services, databases, data warehouses etc..
- Data processing: data processing systems perform operations on the collected data to transform it into a usable form. This operations include data cleaning and preprocessing to remove errors & inconsistencies, data integration, aggregating or summarizing data, calculations or computations and extracting relevant features.
- Data analysis: data processing systems need ~~analytical tools and machine algorithms~~ statistical analysis, machine learning algorithms, data mining techniques or other methods to identify patterns, trends, correlations or anomalies in the data to extract insights.

- Data Visualization: the results of data analysis is communicated using charts, graphs, dashboards and reports to visualise the insights derived from data.

- Data Security: data processing systems ensure the security & privacy of data by implementing measures such as access controls, encryption, authentication, and data masking to protect sensitive information from unauthorized access.

Examples of data processing systems are: E-Commerce and Online Transaction Processing Systems, Business Intelligence and Analytics platforms, Customer relationship Management Systems etc.

Data Communication Systems

Data Communication Systems facilitates the exchange of data b/w two or more devices or entities over a transmission channel. These systems ensure that data is interchanged reliably, efficiently, and securely across communication networks.

Key Components of Data Communication System

- Transmitters and Receivers: Transmitters converts data into electrical signals for transmission, while receivers decode received signals back into data. Examples include network interface cards, modems, routers, and switches.

- Communication/Transmission Medium: This is the communication path through which data is transmitted. Examples are: cables (e.g copper, fiber optic), wireless (radio wave,) or satellite links.

- protocols: These are set of rules & conventions for data transmission, addressing, error detection and correction and flow control. e.g TCP/IP protocol, Ethernet, WiFi and HTTP (Hypertext Transfer protocol).

- Networking Infrastructure: this is the physical and logical infrastructure that supports data communication including cables, routers, switches, servers, accesspoints, hubs, and network operating systems.

Networking?

Networking is the process of designing and implementing a computer network. A computer network consists of a number of interconnected computers or devices known as nodes. The main function of a computer network is to allow a reliable interchange of data/information b/w nodes. ~~For a network with n hosts, each host must have (n-1) physical interfaces or links and for a network containing n nodes hosts/nodes, $\frac{n(n-1)}{2}$ links are required.~~

Types of Computer Networks

Computer networks are classified based on the geographical area that they cover:

- LAN: a local Area Network which interconnects hosts/nodes that are few kilometers apart (e.g 1km, 2km, 3km .... 6km apart).
- MAN: a Metropolitan area network interconnects nodes that are up to a few hundred kilometers apart (e.g 100km, 150km, etc.
- WAN: Wide area network interconnects hosts that can be located anywhere on earth. The distance could be national.
- Internet: this network is international. internet? → the scope is local.

Components of Computer network

- Hardware: this include, hosts (PCs, Laptops, handhelds etc), routers & switches (IP routers & Ethernet switch.) Links (wired & wireless).
- Software: this include OS (windows, Unix etc), Protocols and algorithms, other applications.
- [illegible]

(4)

Signals

A Signal is a function or an electromagnetic waveform that conveys information through a transmission medium. Signal processing techniques such as fourier transform, modulation, filtering etc are used to manipulate signals for communication purpose. Xtics of signals: Amplitude, frequency and phase

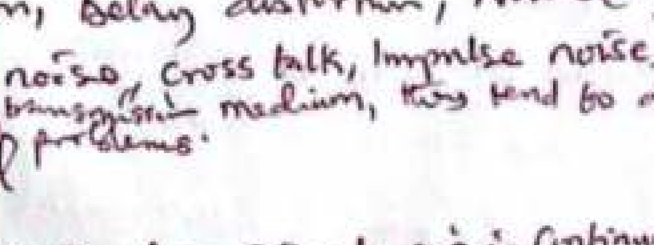
Types of Signal

~~Analog Signal~~:

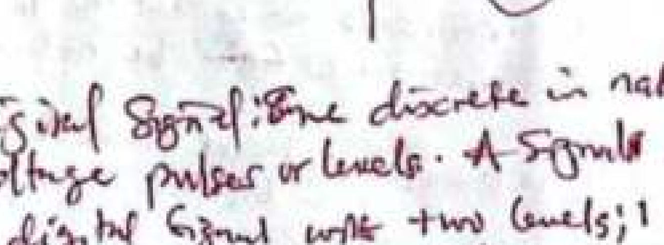
Communications use two types of wave to send signals; periodic Analog and non-periodic Digital. All signals suffer from three main problems that distort the waveforms which limit the ability of the signal to carry data. These problems are; Attenuation, Delay distortion, Noise (thermal noise, intermodulation noise, cross talk, Impulse noise). i.e when signal travels through the transmission medium, they tend to deteriorate because of above mentioned problems.

~~Analog Signal~~

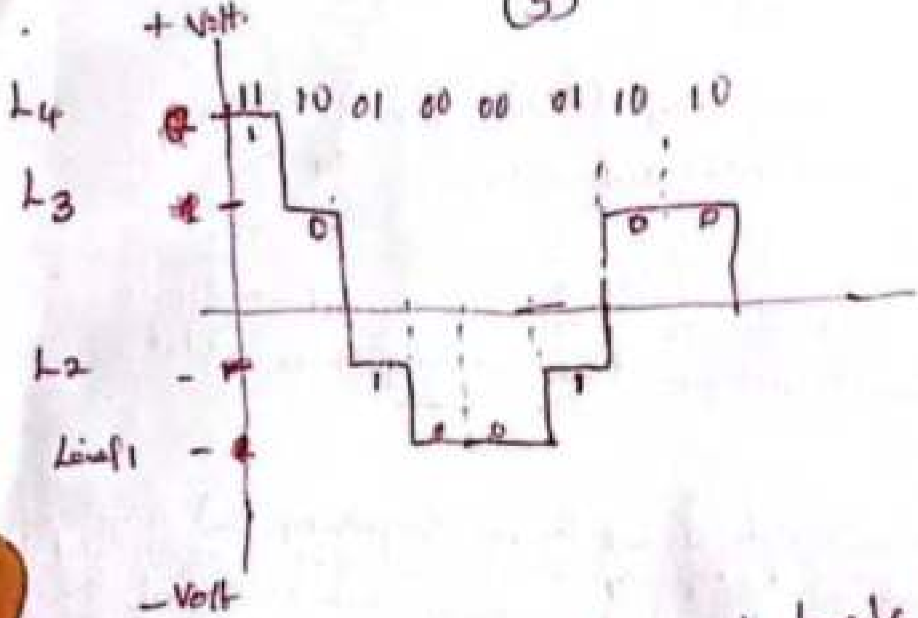
- Analog Signals: Analog signals are in continuous waveform and it is represented by continuous electromagnetic waves. A simple analog signal is a sine wave.



- Digital Signal: are discrete in nature and represent sequences of voltage pulses or levels. A signals can have more than two levels. A digital signal with two levels; 1 represented by a +ve voltage & 0 represented by a -ve voltage is shown below:



And the diagram below show a digital signal with four levels



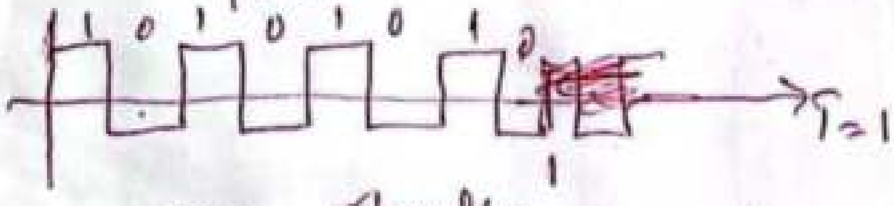
In general, if a signal has L levels then each level need $\log_2 L$ bits.

Example: Consider a digital signal with four levels, how many bits are required to be transmitted per level?

<u>Soln</u>

Number of bits per level $= \log_2 L = \log_2 4 = 2$, Hence two bits are required per level for a signal with four levels.

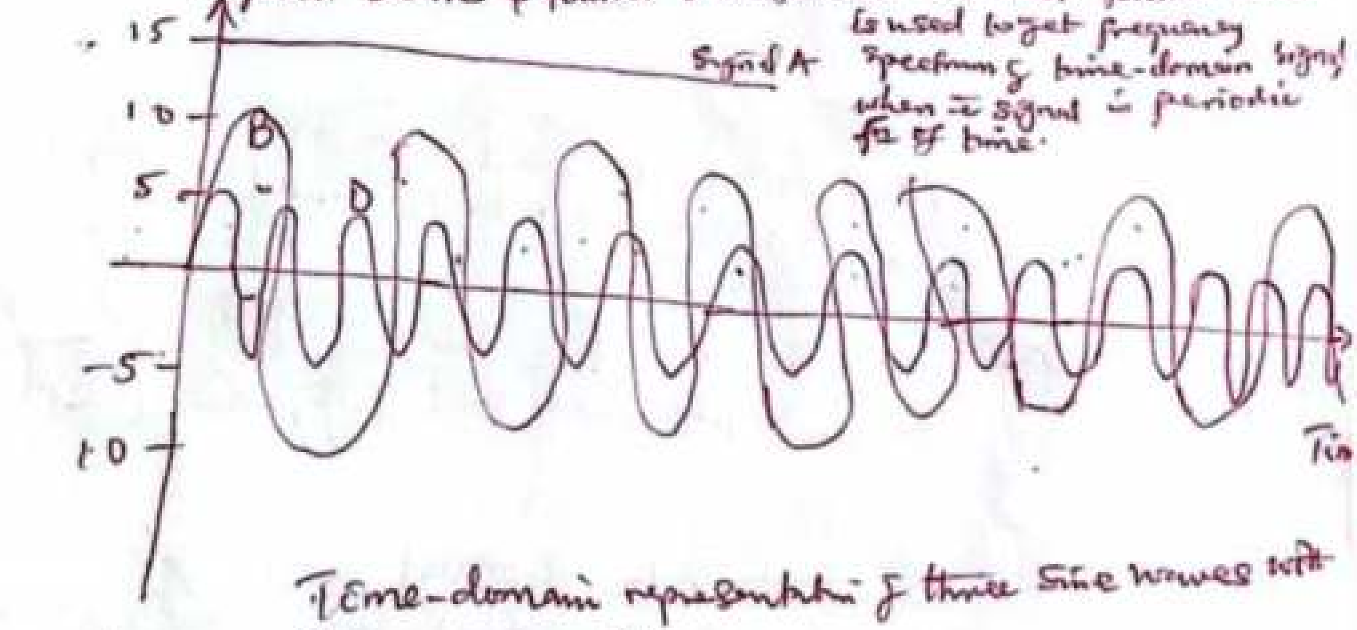
<u>Baud Rate</u>: This is the rate of signal speed, i.e the rate at which the signal changes. A digital signal with two levels 0 & 1 will have the same baud rate and bit rate (no of bit transmitted in 1 second, bps)



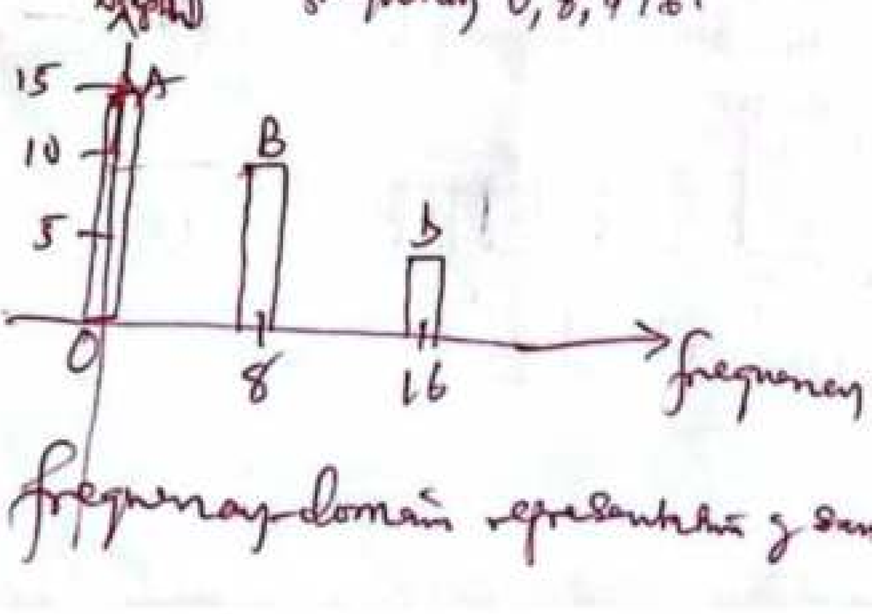
8 bit/sec, 8 baud/sec

Time Domain and frequency domain representation of signals

- A sine wave (signal) can be represented either in the time domain or frequency domain.
- The time-domain plot shows changes in signal amplitude with respect to time. It indicates time and amplitude relation of a signal.
- The frequency-domain plot shows signal frequency and amplitude. See the figure below. In frequency domain, a signal is represented by its frequency spectrum. To obtained frequency spectrum of a signal, Fourier series & Fourier transformation we need. Fourier series is used to get frequency spectrum of time-domain signal when the signal is periodic fn of time.



Time-domain representation of three sine waves with frequency 0, 8, & 16.



frequency-domain representation of same three signals

(7)

Analog-to-Digital Conversion

Microphones create analog voice and camera creates analog videos, which are treated as analog data. To transmit this analog data ~~as digital~~ over digital signals, we need analog to digital conversion.

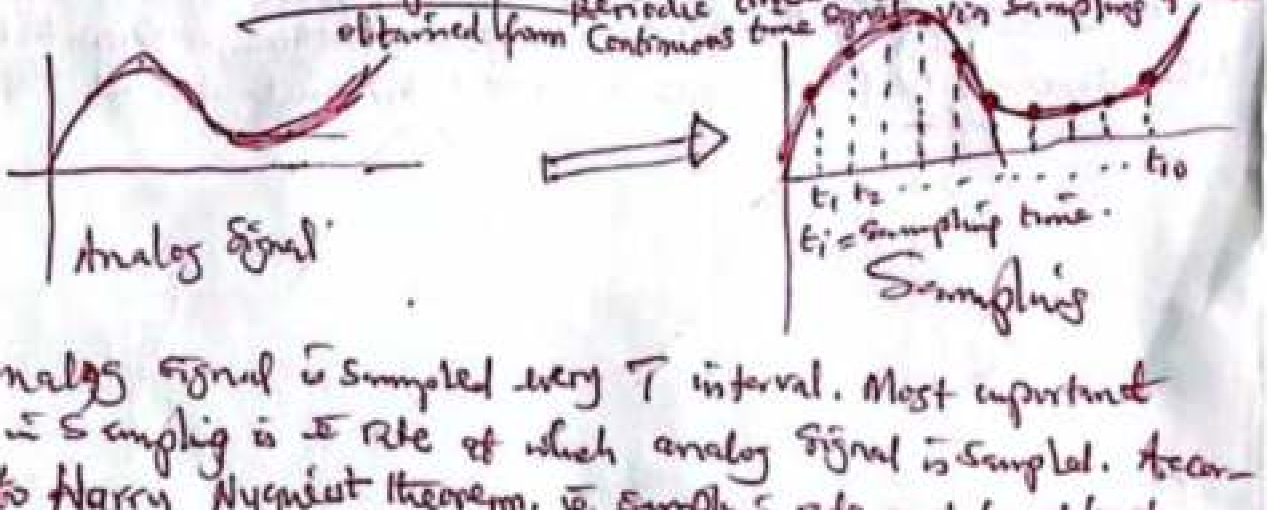
Analog data is a continuous stream of data in ~~a~~ waveform whereas digital data is discrete. To convert analog wave into digital data, we use Pulse code modulation (PCM).

PCM is one of the most commonly used method to convert analog data into digital form. PCM involves 3 steps:

① Sampling ② Quantization ③ Encoding.

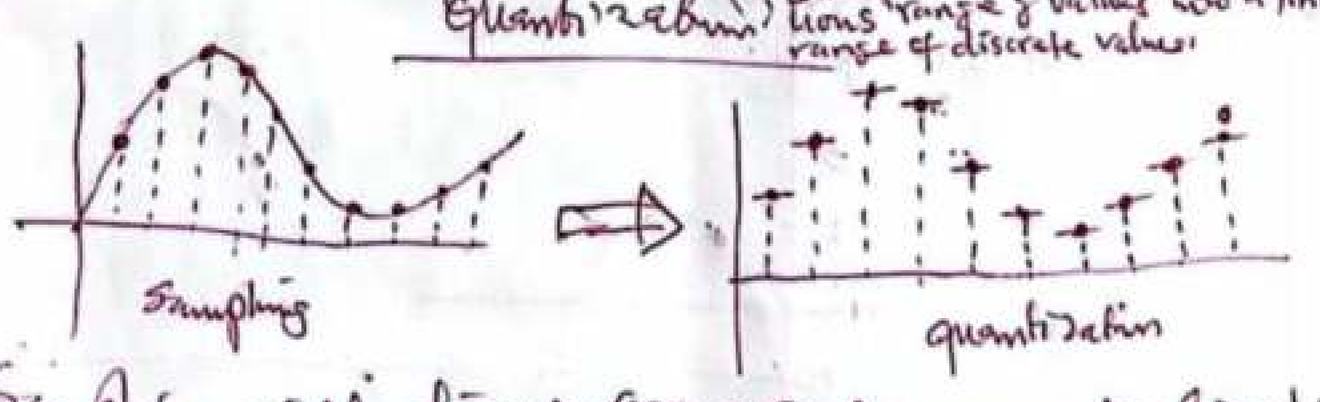
Sampling: Natural sampling, Flat-top sampling

Sampling: Sampling is the process of measuring the amplitude of a continuous time signal at periodic time intervals. Digital signal are obtained from continuous time signal via sampling process.



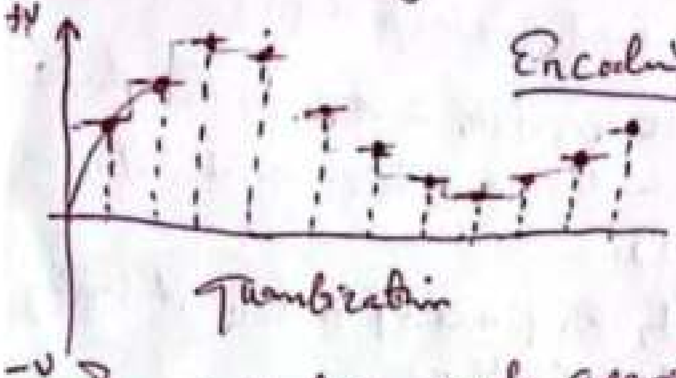
The analog signal is sampled every T interval. Most important factor in sampling is the rate at which analog signal is sampled. According to Harry Nyquist theorem, the sampling rate must be at least two times of the highest frequency of the signal.

Quantization: is the process of converting a continuous range of values into a finite range of discrete values.



Sampling yields discrete form of continuous analog signal. Every discrete pattern shows the amplitude of the analog signal at that instance.

The quantization is done b/w the maximum amplitude value and the minimum amplitude value. Quantization is approximating the instantaneous analog value.



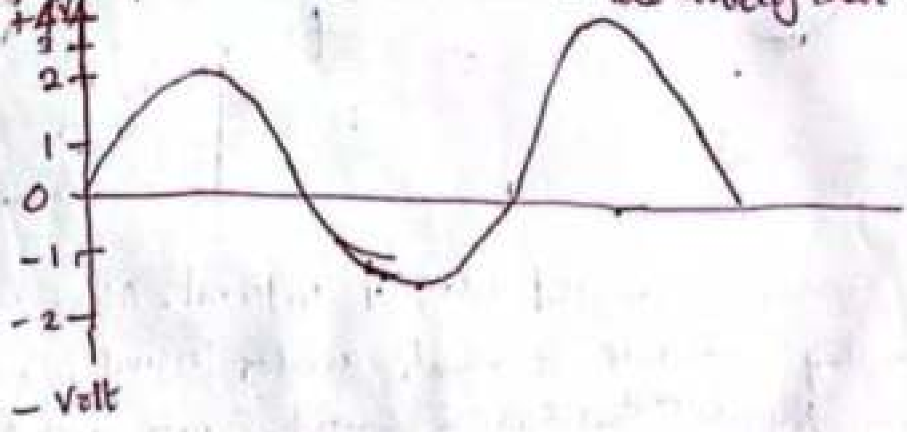
Encoding

11010110 10110100 ....
11010101

Quantization ⟹ Encoding

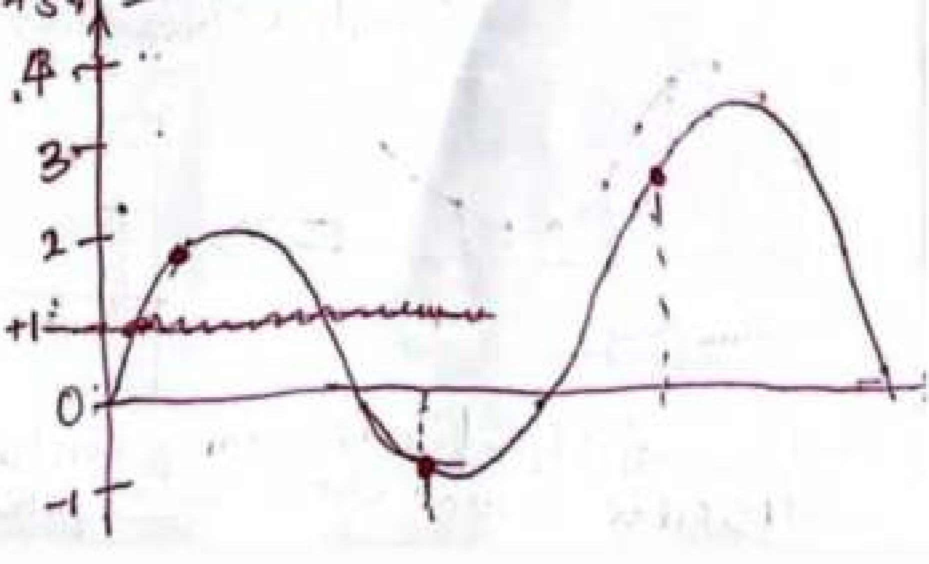
In encoding, each approximated value is then converted into binary format.

Example: A sine wave with peak amplitude of 5v, varying b/w +5v and -5v passing through every amplitude b/w them, as shown below. Use three-bits PCM code to convert the analog data into digital form.



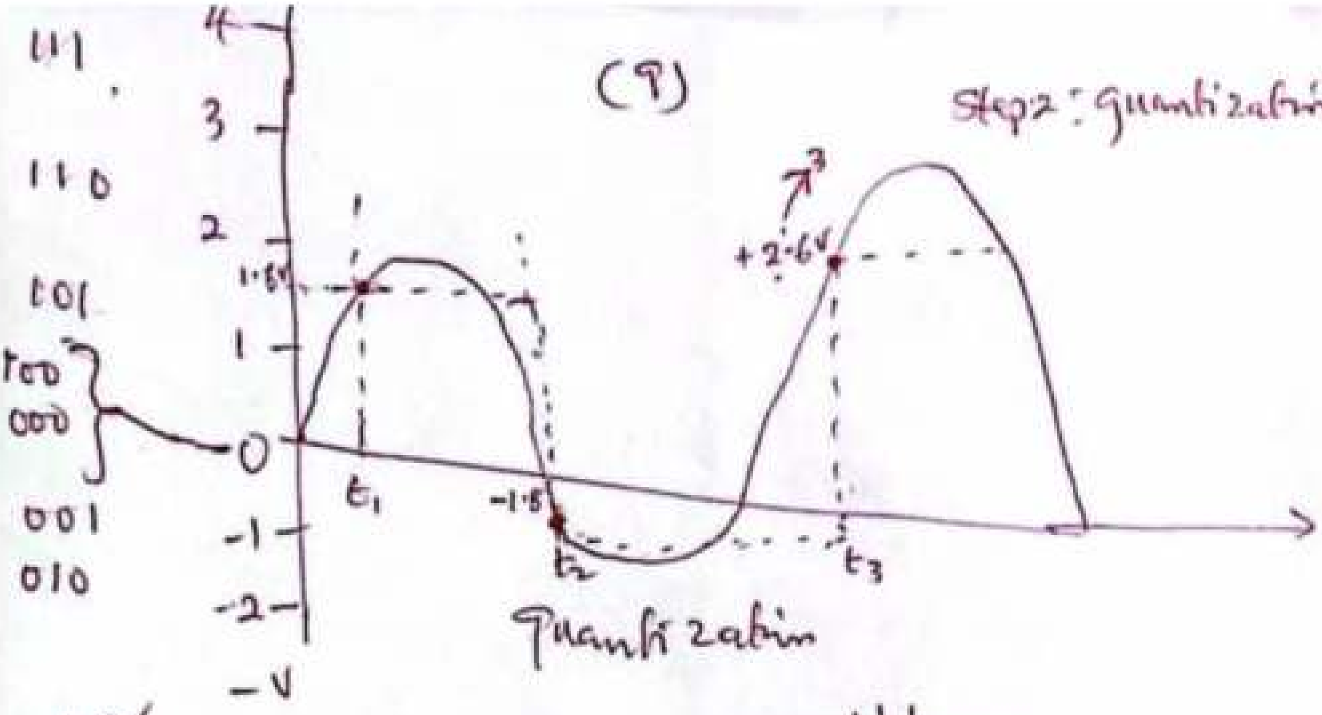
Solution

Step 1: Sampling:

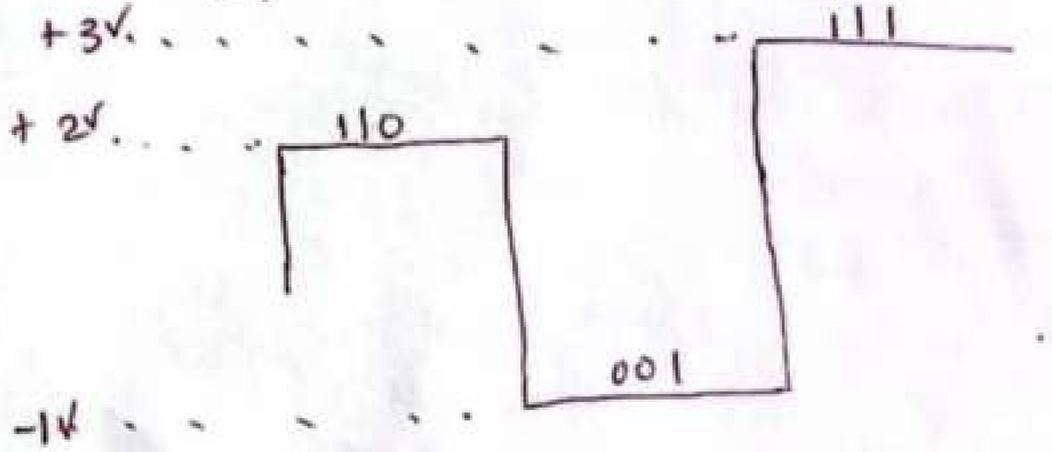


(9)

Step 2 : quantization



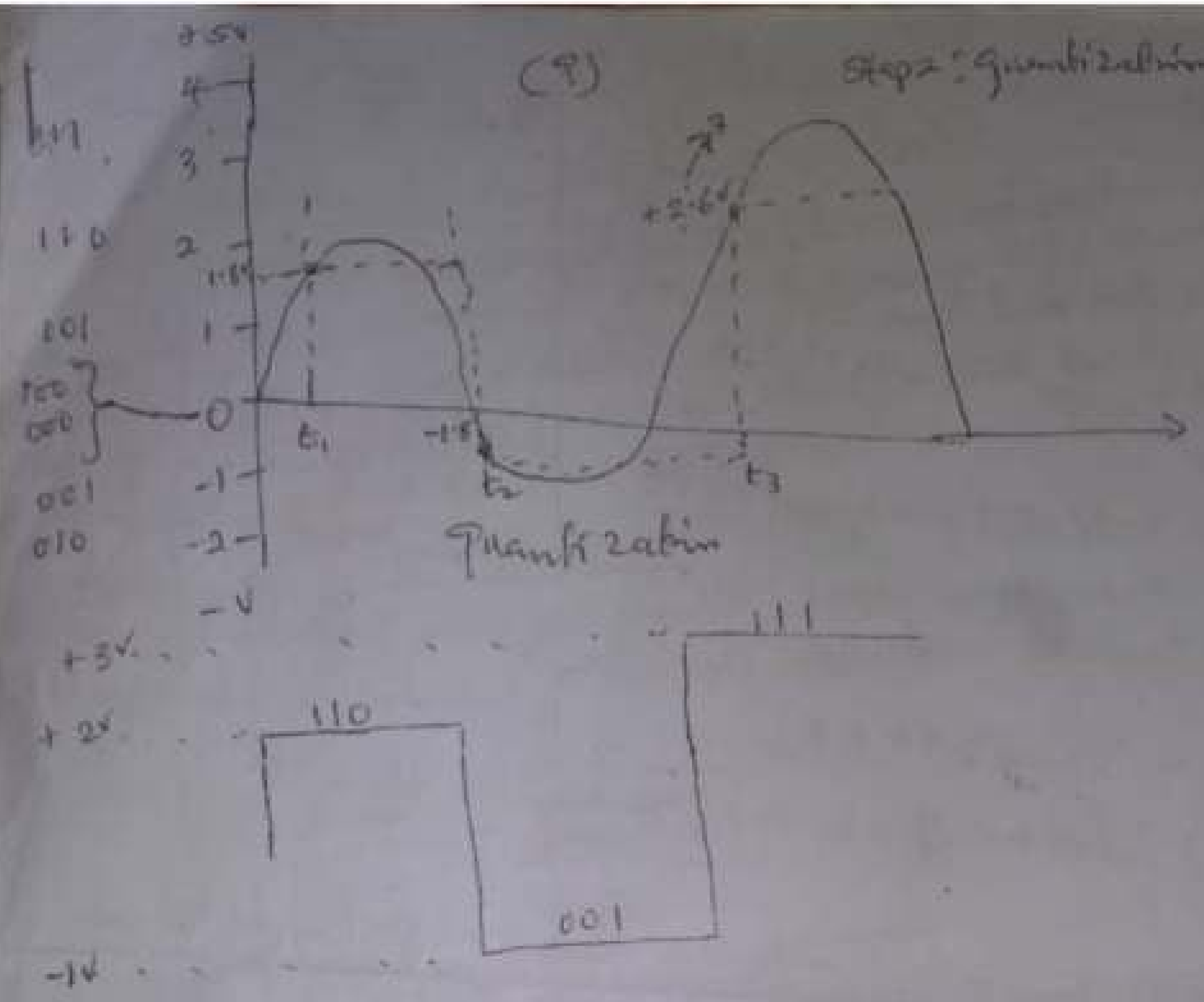
Quantization



Encoding = 110 001 111, using 3-bit PCM

Fourier Series and Fourier Transform

(9) Step 2 : Quantization



Encoding ⟶ = 110 001 111, using 3-bit PCM

Fourier Series and Fourier Transform (FS & FT)

The general form of representing sinusoidal composites and periodic signals $x(t)$ is given by

$$x(t) = a_0 + \sum_{n=1}^{\infty}\left[a_n\cos\left(\frac{2\pi n t}{T}\right) + b_n \sin\left(\frac{2\pi n t}{T}\right)\right]$$

OR $x(t) = A\cos(\omega_0 t \pm \phi)$ and $x(t) = A\sin(\omega_0 t \pm \phi)$

Where $x(t)$ n = harmonic number, a_0 is the average (DC) component of the signals, a_n and b_n are the fourier coefficients, representing the amplitudes of the sine and cosine terms. Alternatively using complex exponentials, it is given by

$$x(t) = \sum_{k=-\infty}^{\infty} a_k e^{j w_0 k t} = \sum_{k=-\infty}^{\infty} a_k e^{\frac{j 2\pi k t}{T}} \quad (10)$$

Examples the ff are ways to represent signals in Fourier Series

- $x(t) = \frac{4}{n\pi} \sin\left(\frac{2\pi n t}{T}\right)$

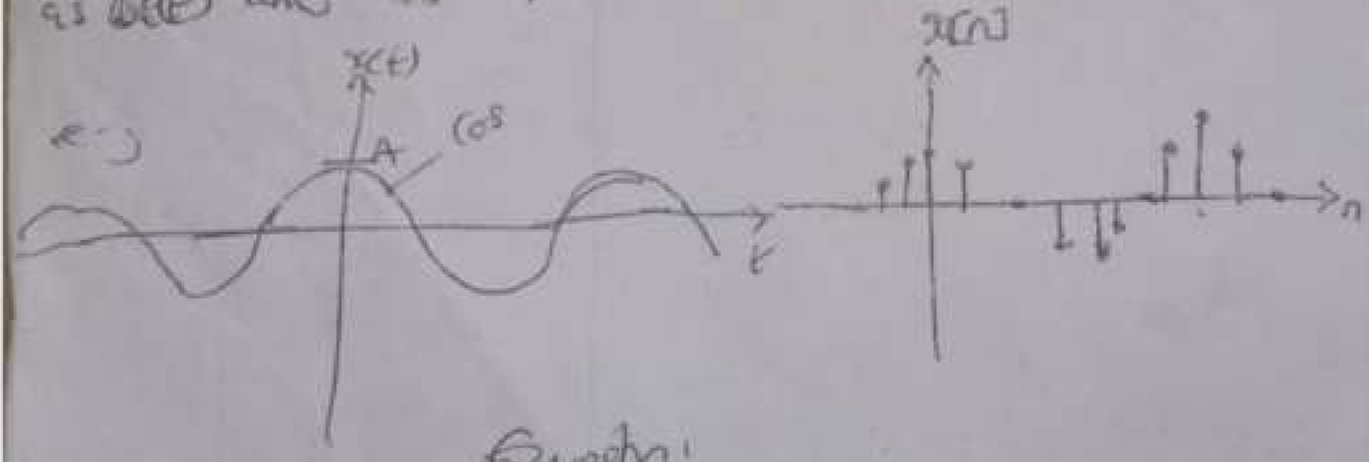
- $x(t) = \cos\left(\frac{2\pi t}{T}\right) + \frac{1}{3}\cos\left(\frac{2\pi 3 t}{T}\right) + \frac{1}{5}\cos\left(\frac{2\pi 5 t}{T}\right)$

  of cosine form signal with fundamental frequency
  hence the fourier coefficients; $a_1 = 1$, $a_3 = \frac{1}{3}$, $a_5 = \frac{1}{5}$, $a_n = 0$, $b_n = 0$

- $x(t) = 3\cos(7\pi t + \pi)$

- $x(t) = \cos t$; $\phi = 0$, $A = 1$, $w_0 = 1$, $T = \frac{2\pi}{w_0} = 2\pi$

In fourier series in represent signals in continuous manner as $x(t)$ and as $x[n]$ in discrete manner or form



Question

An electromagnetic signal given by $\sin(25t)$ is used to transmit analog data through digital transmitter. What is the sample rate that can be used to deliver for the signal to be recovered at the receiver's end?

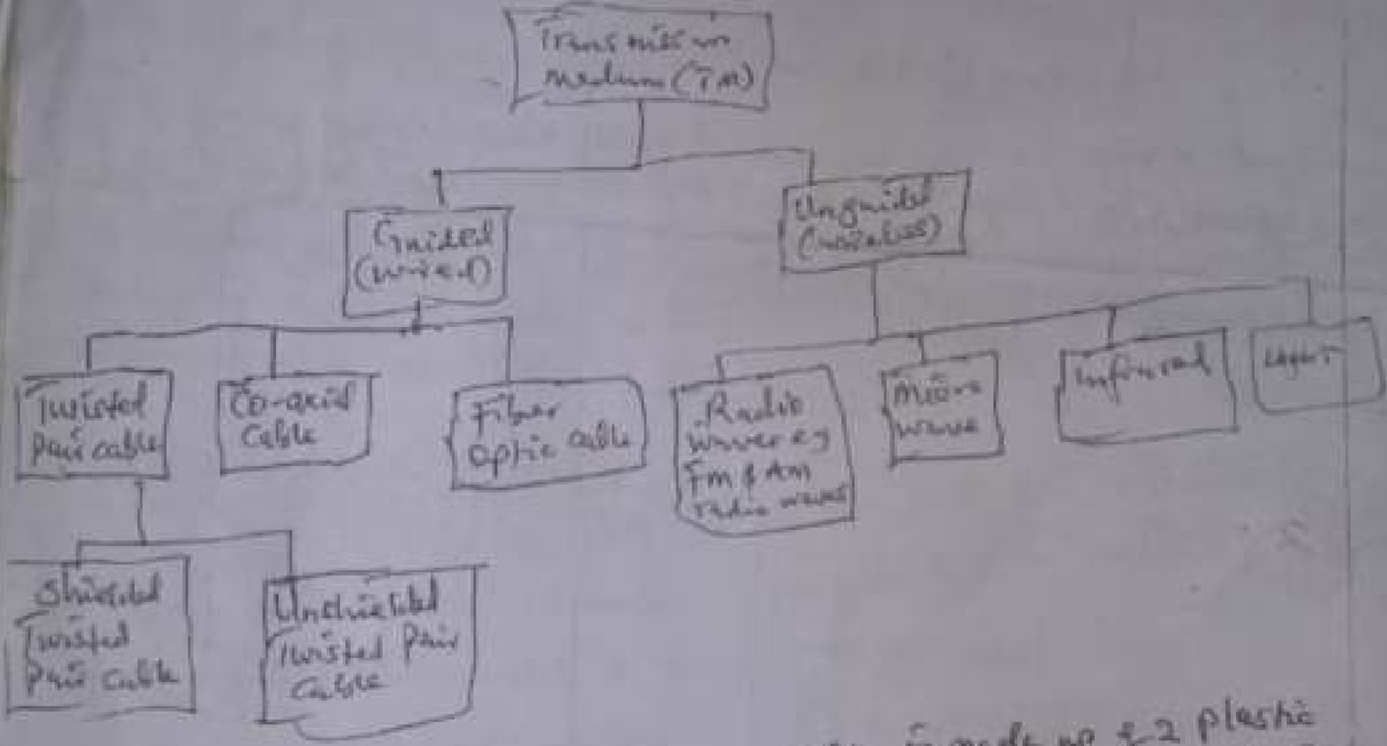
Transmission media/channel

Transmission media ~~is a link or physical means~~ are the links that carry messages b/w 2 or more communicating devices. This is a physical layer or medium that transport bits from one machine to another. The transmission media lies in the first layer of the OSI reference model or the TCP/IP reference model.

Types of Transmission Media

(a) Guided or bound or wired media

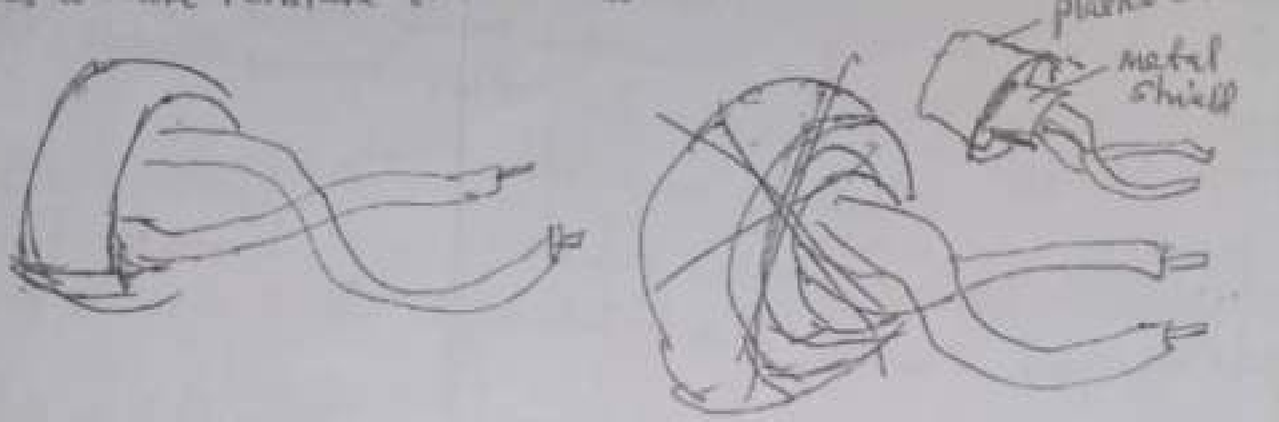
(b) Unguided or unbound or wireless media.



* Twisted pair cable : A twisted pair cable is made up of 2 plastic insulated copper wires twisted together to form a single media. The twists b/w wires is helpful in reducing noise (electromagnetic interference) and crosstalk.

There are 2 types of twisted pair cables;
- Shielded Twisted pair (STP) cable
- Unshielded Twisted pair (UTP) cable; they are connected by RJ-45 connectors.

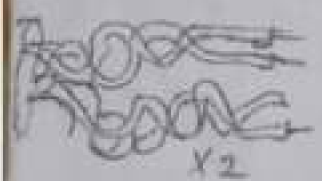
UTP has seven categories but cat-5, cat-5e & cat-6 are used in Networking.
STP cables comes with twisted wire pair covered in metal foil - this makes it more resistive to noise and crosstalk.



UTP cable and STP cable

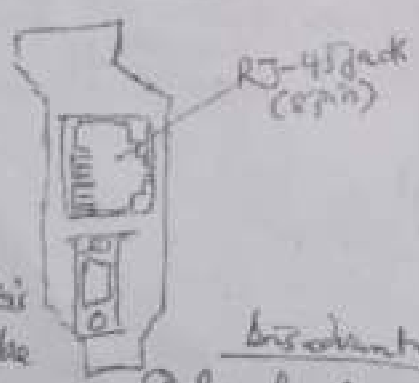
Twisted pairs are less expensive & mostly used in telephone line and LANs. LANs such as 10Base-T and 100Base-T also use twisted pair cables.

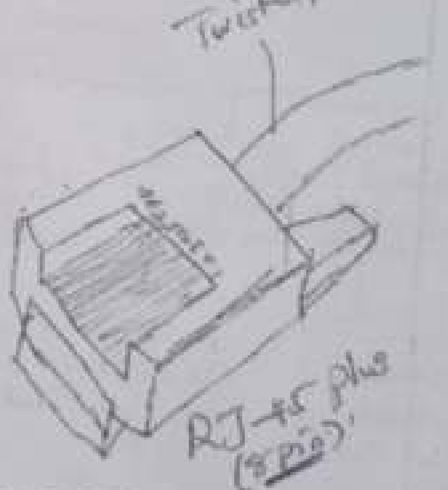
~~Coaxial cable~~



UTP cableing

RJ-45 Connectors





Advantages of Twisted pair
① Easy installation ② flexible
③ Cheap than coaxial cable
④ higher grades of UTP are used in LAN technologies like Ethernet.
⑤ 100 meter limit. ⑥ STP cable can be used for analog or digital transmission
⑦ STP has higher capacity P-T-O than UTP. ⑧ STP eliminate Crosstalk

Disadvantages of TP
① Bandwidth of UTP is low compare to coaxial cable ② UTP provides less protection from interference.
③ STP cable is difficult to manufacture
④ STP is heavy.

Coaxial Cable: Coaxial cabling consists of a copper-centred conducting core. There are two types of coaxial cable such as
- 50-ohm cable which is use in data networks
- 75 ohm which is use in cable TV and Broadband systems and for analog transmission.

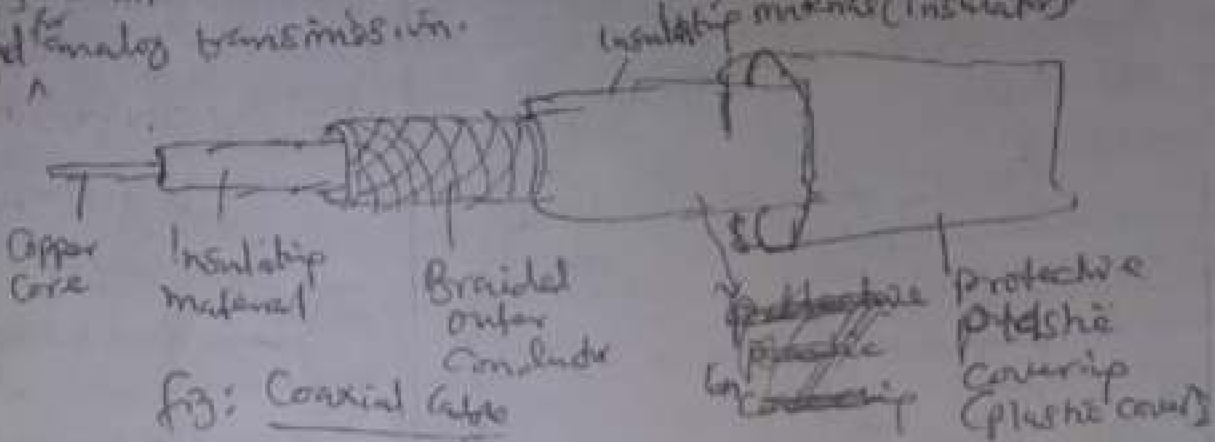


fig: Coaxial Cable

Advantages of Coaxial Cable

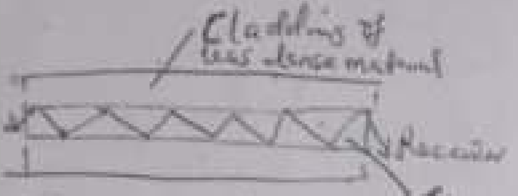
- Its has high Bandwidth
- used in long distance telephone lines
- transmits digital signals at a very high rate of up to 1Gbps
- Has higher noise immunity and has ~~same~~ better resistance to interference
- ~~Ethernet LANs use~~ It can be use in ethernet LANs.

Disadvantages of Coaxial Cable

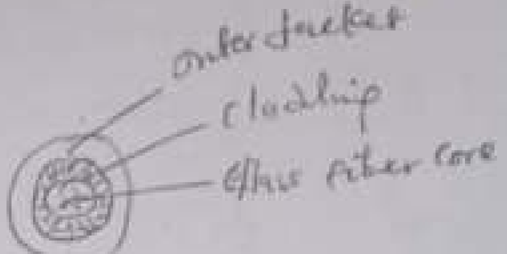
- Single cable failure can fail the entire network.
- difficult to install and expensive compared to TP
- If the shield is imperfect, it can lead to grounded loop

Optical fiber cables (Fibre Optic Cable)

An optical communication system is one that uses light as the carrier of information. A fiber optic cable is made of a core of hair like glass strands and transmits signals in form of light. The core is surrounded by a cladding and an outer jacket. The cladding of glass or plastic is less denser than the core of glass. It comes in 2 types; single mode or multimode, this relates to the number of glass strands that comprise the core of the cable. The fibre core propagates the transmitted signal using the ~~ppty~~ property of total internal reflection (TIR) of signals. The single-mode fiber carries light pulses along a single path while in ~~the~~ multi-mode fiber, many pulses travel at different angles. Fiber optic comes in uni-directional ~~and bi-directional~~ capability. To connect and access fiber optic there are two types of connectors use. These connectors are Subscriber Channel (SC), and Straight Tip (ST) or MT-RJ.



Single-mode
fiber optic cable



End View of fiber optic cable

Advantages of fiber optic

1. Higher bandwidth and greater information capacity (Light wave has frequency range b/w 2×10^{12} Hz to 37×10^{12} Hz).
2. Less signal attenuation (Loss of signal strength with time).
3. Immunity (Glass and plastic fibers are not conductor of electricity) to electromagnetic interference
4. Resistance to corrosive materials ⑤ Light Weight ⑥ Greater immunity to tapping.

Unguided/Unbound media

Wireless signals are spread over in the air and are received and interpreted by appropriate antennas.

When an ~~all~~ antenna is attached to electrical circuit of a computer or wireless device, it converts the digital data into wireless signals and spread all over within its frequency range. The receptor on the other end receives these signals and converts them back to digital data

Copper Vs fiber optic cable

1) Fibre has a greater bandwidth capacity than copper, it has a lower attenuation rate and so can span long distances than copper before requiring signal boosting or retiming

2) ~~Fiber~~/fibre is not affected by EMI or power surges. It is thinner and lighter than copper. It is more difficult to tap into fiber cable so it has better security.

3) Copper is easier to use and install, can run in either bidirection or unidirection and is cheaper.

4) Copper can transmit analog and digital signals, fibre optic can transmit only digital.

~~There are a number of cabling standards in LAN;~~ Standards & implementations in LAN 10Base2, 100BaseT & Token Ring

Unguided/unbound/Wireless media

Wireless signals are spread over in the air and are received & interpreted by appropriate antennas. When an antenna is attached to electrical circuit of a computer or wireless device, it converts the digital data into wireless signals and spread all over within its frequency range or its bandwidth. The receptor on the other ~~hand~~ end, receives these signals and converts them back to digital data.

Wireless systems have 2 xtics; frequency and wavelength, all use analog based transmission. Most of the electromagnetic spectrum is used by wireless systems and transmission is ~~are~~ achieved by modulating the amplitude, frequency or phase of the wireless waves or signals.

Types of wireless systems/signals

1) Radio wave (wavelength from 1mm – 100,000 km), & 3Hz – 300GHz)
2) Microwave (wavelength: 1mm – 1meter & freq: 300MHz – 300GHz)
3) Infra Red (wavelength: 700nm – 1mm & freq: 300GHz – 430THz)
4) Light (laser) (wavelength:

~~The general form of representing~~ sinusoidal ~~periodic composite~~ ~~signals or functions $x(t)$~~

* Radio Wave

- Radio signals are easy to generate, can travel long distances and penetrate buildings.
- Radio signal are Omni-directional (these waves can moves in all direction).
- Radio wave are used in AM and FM, television etc
- Radio wave of HF (HF & VHF bands) are prone to interference and can be absorbed by rain and are spread upwards
- Example; wireless LAN (is numbered as IEEE 802.11 and its also known as Wi-Fi
- FM & AM radio signals are nonperiodic composite signals.

Microwave

- Microwaves travel in straight lines and cover long distances but do not penetrate buildings easily.
- Transmitter/receiver pairs must be aligned (must be in a direction of each other) and transmitters need to be tall or high up (e.g Satellite) if they have to transmit over long distances.
- they are Unidirectional (i.e can move in only one direction).
- they are used in point-to-point communication or Unicast Communication such as radar & satellite.
- provide very large information-carrying capacity.
- Microwave are electromagnetic waves of frequency range of 1GHz – 300GHz

P.T.O

Parameter for (17A)

Xtics, Measuring Communication Channels

Real physical media are characterized by several
parameters including;
① Attenuation ② bandwidth ③ distortion ④ Noise

- Attenuation: is the decrease in power or strength of a
signal in propagation in the transmission medium. The
attenuation is expressed in decibels (dB) per kilometer and
varies depending on the type of medium and the frequency
of the signal. Attenuation increases with the length of the
cable and with the square root of the frequency. The attenuation
signals suffered in the air is less than that suffered in a
guided medium.

- Bandwidth: It is the range of frequencies of the signals that
can be transmitted without undergoing excessive attenuation
or constant attenuation. A transmission channel is called a
bandpass when it is able to transmit signals with frequencies
within a range given by $f_{min} \leq f \leq f_{max}$ $(B = f_{max} - f_{min})$,
while a channel is called a baseband when it is able to
transmit signals of frequencies in the range $0 \leq f \leq f_{max}$
(Here $B = f_{max}$). The bandwidth is linked to the capacity of
a channel. Channel capacity is the maximum amount of info
ration (number of bits) that can be sent through the transmission
medium in unit of time. Digital signal bandwidth is measured in
terms of bitrate (bps). Bandwidth of signals is different from the bandwi
dth of the medium/channel. So the bandwidth of a digital signal
is the maximum bit rate of the signal to be transmitted. The bandwidth
of a medium should always be greater than the bandwidth of the
signal to be transmitted else the transmitted signal will either be
attenuated or distorted or even both leading in loss of information.

(17B)

- Distortion or delay distortion: distortion occurs when there is an interference of the different frequencies propagating the medium with different speed. So, it's important to have a space b/w the different frequencies. ~~It can also~~ Distortion could be amplitude distortion, frequency distortion or phase distortion. Amplitude distortion is the alteration of amplitude of a propagating signal, frequency distortion is the alteration of frequency of a signal and phase distortion is due to change in phase of a propagating signal.

- Noise: is defined as an unwanted data when a some electromagnetic signal gets inserted during the transmission is called noise. Noise is due to the overlapping of external signals and the ~~signal~~ internal signal (internal signal is the signal carrying information/data).

There are different types of noise such as:

- Thermal noise: this is ~~caused~~ caused by heat generated by the conductor of transmission medium.
- Cross talk: disturbance generated by a cable adjacent to the transmission cable i.e ~~occurs~~ when foreign signal enters into the medium
- Intermodulation Noise: this is when multiple frequencies share a medium and their interference causes noise in the medium.
- Impulse noise: this noise is introduced because of ~~irregular~~ irregular uncertain disturbances such as lightning, electricity, short-circuit, or faulty components.

Infrared Waves

- Infrared are Electromagnetic waves of frequency range of 300GHz – 400THz (Very high frequency waves)
- Cannot penetrate walls or buildings
- They are used for short-distance point-point communication such as mobile-to-mobile, mobile-to-printer, remote-control-to-TV, and Bluetooth-enabled devices to other devices like mouse, keyboards etc.

Light (Low intensity laser)

these are unidirectional and need to be tightly focused.
- they are expensive and can't penetrate rain or walls
- they are only suitable for short-distance transmission.

* See ~~that~~ page 18A

Nyquist and Shannon Information Capacity or Bitrate

A very important consideration in data communications is how fast we can send data in bits per second over a channel called data rate or capacity of channel. Data rate or data transfer rate or capacity of a channel depends on 3 factors;
- the bandwidth available
- The level of the ~~carrier~~ signals used
- The quality of the channel (level of noise or error rate).
- Two theoretical formulas were developed to calculate the data rate or channel capacity One by Nyquist for a noiseless channel, another by Shannon for a noisy channel.

P.T.O

Noiseless channel: Nyquist Bit rate (or channel capacity in bits per second)

For a noiseless channel, the Nyquist bit rate formula defines the theoretical maximum bit rate as:

Capacity (C) or BitRate = 2 × bandwidth × $\log_2 L$ = $2B\log_2 L$

Where bandwidth is the bandwidth of the channel, L is the number of signal level used to represent data, and BitRate is the bit transfer rate in bits per second (bps). Practically there is a limit on the signal levels. Increasing the levels of a signal may reduce the reliability of the system.

Example (1): Consider a noiseless channel with a bandwidth of 3000 Hz, transmitting a signal with four signal levels (for each level, we send 2 bits). The maximum bit rate can be calculated as follow

Soln

$$\text{BitRate} = 2B\log_2 L = 2\times 3000 \times \log_2 4 = 6000\times 2$$
$$= 12000\,\text{bps} = 12\,\text{Kbps}$$

Example 2: 265 Kbps was transmitted over a noiseless channel with a bandwidth of 20 KHz. How many signal levels were used to transmit the data?

Soln

$$\text{BitRat} = 2B\log_2 L \Rightarrow 265\,\text{KHz} = 2\times 20000 \times \log_2 L$$
$$\Rightarrow 265\times 1000 = 40\times 1000 \times \log_2 L \Rightarrow \log_2 L = \frac{265\times 1000}{40\times 1000}$$
$$\Rightarrow \log_2 L = 6.625 \Rightarrow L = 2^{6.625} = 98.7 \approx 99\,\text{levels}$$

Since this result is not a power of 2, we need to either increase the no. of levels or reduce the bit rate.

$C = B\log_2(1+SNR)$ $\quad D\,l_m(1+S/N)$

(19)

A noiseless medium with a bandwidth 20KHz transmit data (with Nyquist computing capacity) of 280Kbps. Calculate the signal level used.

Soln

$$280\times10^3 = 2\times20\times10^3\times\log_2 L \Rightarrow \log_2 L = \frac{280\times10^3}{40\times10^3}$$

$$\Rightarrow \log_2 L = 7 \Rightarrow L = 2^7 = 128 \text{ levels.}$$

Takehome: what is the maximum bit rate of a perfect channel with a bandwidth of 5000 Hz transmitting a signal with 15 signal levels?

Shannon Information Capacity

In reality, we cannot have a noiseless channel; the channel is always noisy. In 1944, Claude Shannon introduced a formula, called the Shannon capacity to determine the highest data rate for a noisy channel:

$$\text{Capacity}(C) = \text{bandwidth}\times\log_2(1+SNR)$$

Where SNR is the signal-to-noise ratio in decibels and C is the capacity of the channel in bps. For instance, a telephone line normally has a bandwidth of 3000Hz (300 – 3300Hz) assigned for data communications. The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

$$C = B\log_2(1+SNR) = 3000\log_2(1+3162) = 3000\times\log_2 3163$$

$$= 3000\times11.62 = 34,860 \text{ bps}$$

This means that the highest bit rate for a telephone line is 34.860 Kbps.

If we want to send data faster than this, we can either increase the bandwidth of the line or improve the signal-to-noise ratio.

The SNR is given by $10\log_{10}(P_s/P_n)$ in decibels.

$SNR_{(dB)} = 10\log S/N$

Example ①: The Signal-to-noise ratio of a channel (SNR dB) is 36 dB and the bandwidth is 2 MHz. Then the channel capacity can be calculated as

Soln

$SNR_{dB} = 10\log_{10}^{S/N} \Rightarrow \frac{SNR}{10} = \log_{10}^{S/N} = 3.6$

$\Rightarrow SNR = 10^{3.6} = 3981$

$\Rightarrow C = B\log_2^{(1+SNR)} = 2\times10^6 \times \log_2^{3982} = 24\ Mbps$

Note; use the value of SNR that is not in decibels (dB). But if the SNR is given in dB, convert to Normal or linear form SNR before using it, as shown above.

$\Rightarrow$ SNR in linear form $= 10^{\frac{SNR(dB)}{10}}$

Example ② Calculate the bit rate for a noisy channel with SNR 300 and bandwidth of 3000 Hz

Soln

the SNR is not in dB. So go ahead

$Capacity = B\times\log_2^{(1+SNR)} = 3000\times\log_2^{(1+300)} = 3000\times\log_2^{301}$

$= 3000\times8.23 = 24,690\ bps$

③ Calculate the capacity of a noise channel with a signal-to-noise ratio $S/N = 1000$ (30 dB) and a bandwidth of 2.7 KHz.

Soln

using $S/N = 1000$, and $B = 2.7\ KHz$

$\Rightarrow C = B\times\log_2^{(1+1000)} = 2700\times\frac{\log_{10}^{1001}}{\log_{10}^{2}} = 2700\times\frac{3.0004}{0.3010}$

$= 2700\times9.9682 = 2700\times10 = 27000\ bps$

$= 27\ Kbps$

Shannon Information Capacity (19)

Shannon Capacity for calculating the maximum bit rate for a noisy channel does not consider the number of levels of the signals being transmitted as considered in the Nyquist bit rate. Shannon Capacity is given by

$$C = B\log_2(1+SNR) = B\log_2(1+S/N)$$

where SNR or S/N is the signal-to-noise ratio. The SNR is measured in decibels (dB) but in calculation of Shannon capacity we use the value of SNR in linear form (i.e the value not in dB.

Example (1): Calculate the bit rate for a noisy channel with SNR 300 and bandwidth of 3000Hz

Soln

$$C = B \times \log_2(1+SNR) = 3000 \times \log_2 301 = 3000 \times 8.23$$
$$= 24{,}690 \text{ bps}$$

Example (2): Calculate the highest bit rate of a regular telephone line with a bandwidth of 3000Hz assigned for data communication. The signal-to-noise ratio is 3162.

Soln

$$C = B\log_2(1+SNR) = 3000\log_2(1+3162) = 3000 \times \log_2 3163$$
$$= 3000 \times 11.62 = 34{,}860 \text{ bps}$$

Example (3): Assume that $SNR_{dB} = 36$ and the channel bandwidth is 2 MHz. Calculate the theoretical channel capacity.

Soln

$$SNR_{dB} = 10\log_{10}^{SNR} \Rightarrow SNR = 10^{\frac{SNR_{dB}}{10}} = 10^{3.6} = 3981$$

After converting SNR_{dB} to SNR, that is not in decibels, use the value to calculate the capacity;

$$\Rightarrow C = B\log_2^{(1+SNR)} = 2\times10^6 \times \log_2^{(1+3981)}$$

$$= 2\times10^6 \times \log_2^{3982} = 2\times10^6 \times \frac{\log_{10}^{3982}}{\log_{10}^{2}} =$$

$$= 2\times10^6 \times \frac{\log_{10}^{3982}}{0.3010} = 24\,Mbps$$

Throughput/~~...~~

In computer network, throughput is defined as the actual number of bits that flows through a network connection in a given period of time. Throughput is always less than or equal to bandwidth but can never exceed bandwidth. In a computer network, the throughput can be affected by the following factors;

- Network congestion due to heavy network usage.
- Too many users are accessing the same server
- Low bandwidth allocation b/w network devices.
- Medium loss of a computer network
- Resources (CPU, RAM) of network devices

- Take home: Given that a channel has the following parameters. Calculate the channel capacity

Bandwidth (B) = 2 MHz

Signal power (P_s) = 50mW

noise power (P_n) = 5mW

Modulation and Demodulation

Modulation can be defined as the process of impressing low frequency information or message signals (baseband signals) onto a high-frequency carrier signal. The reverse process is called demodulation.

It can also be defined as the process of varying one or more properties of a carrier signal (periodic waveform), with a modulating signal or message signal to be transmitted. The properties of the carrier signal that can be varied are amplitude, frequency or phase. Modulation is crucial in transmitting information over long distances. It enhances signal strength, reduces noise and interference and allows multiple signals to be transmitted simultaneously over a single channel (multiplexing). Modulating signal could be audio, video, music.

Types of modulation techniques

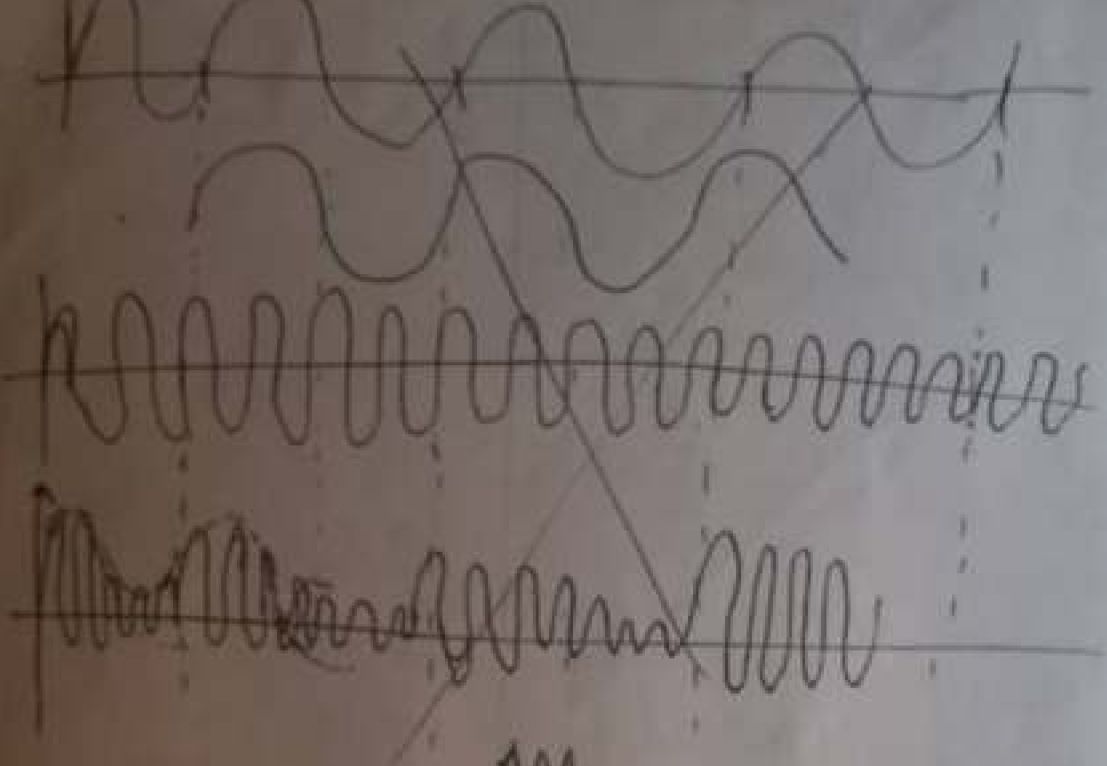
- Analog modulation: this is when the modulating signal is analog in nature.
- Digital modulation: this is when the modulating signal is digital in nature or form.

Analog modulation

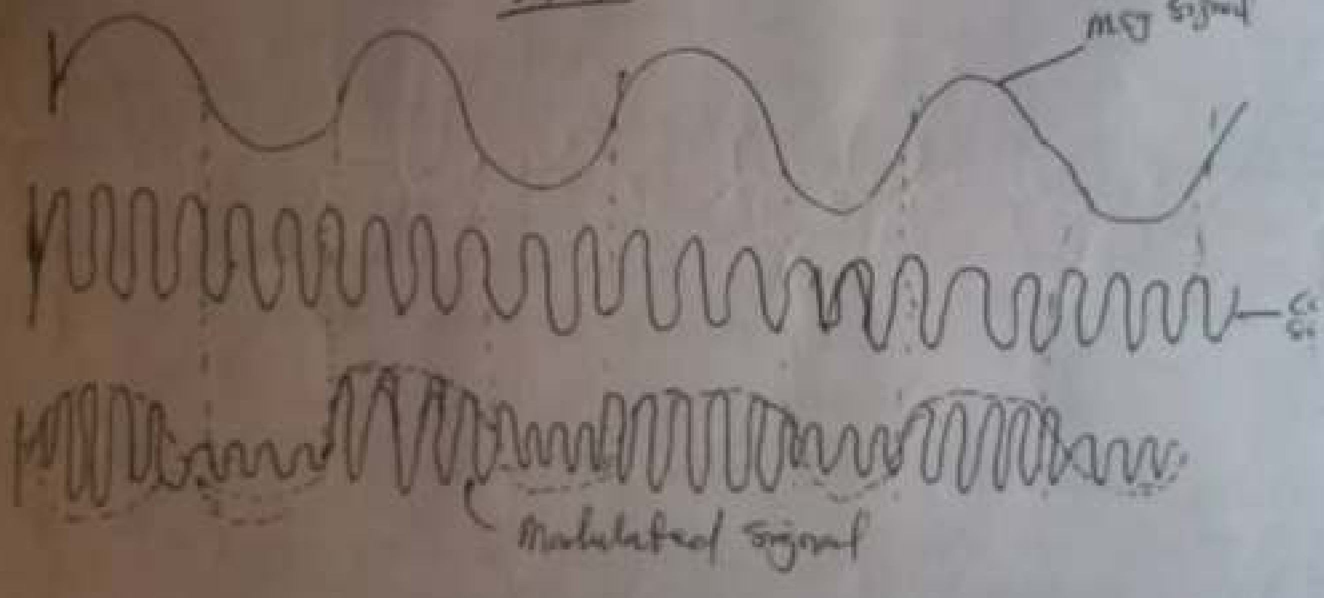
Analog modulation include the following;

1. Amplitude Modulation (AM): in AM, the amplitude of the carrier signal is varied in proportion to the message signal while the frequency remains constant.
2. Frequency modulation; in FM, the frequency of the carrier signal changes according to the information signal.

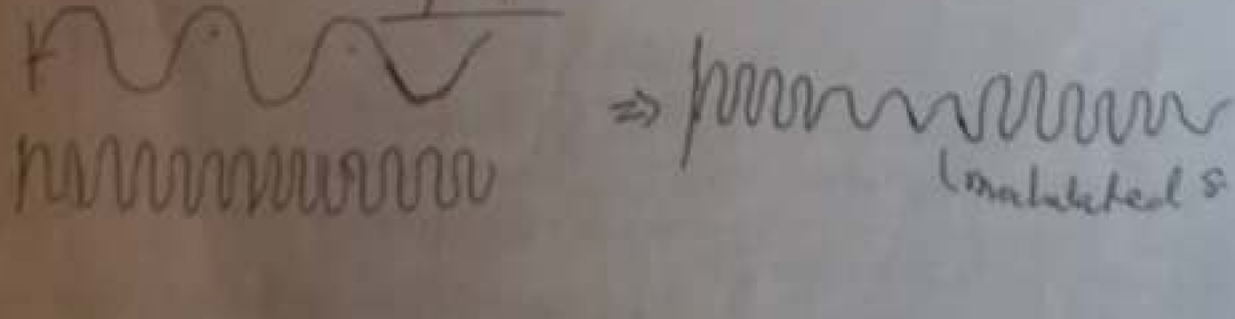
(Q2)



AM

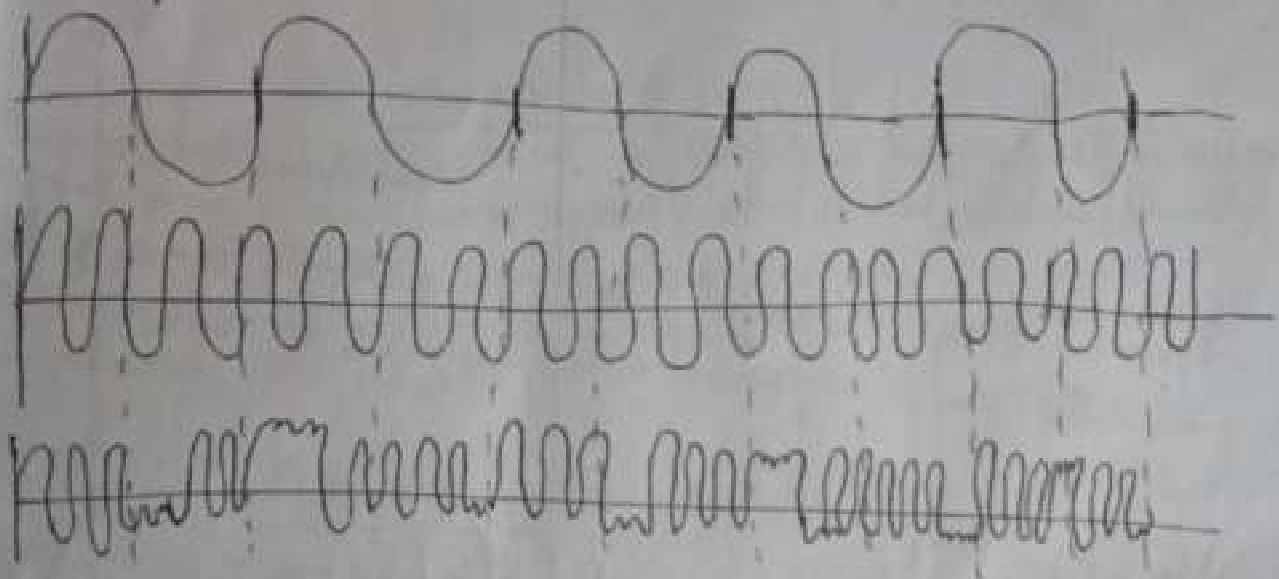


FM



Phase modulation (PM)

In PM, the phase of the carrier signal varies based on the information or message signal. i.e the phase of the carrier signal changes according to the phase of the modulating signal.



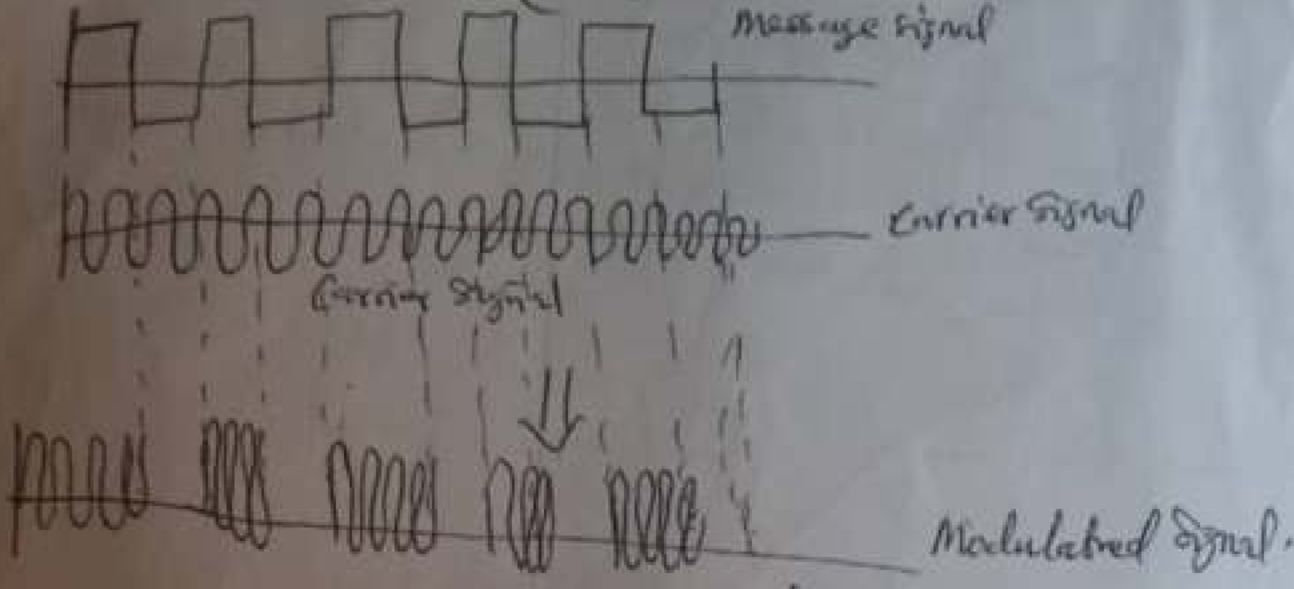
* Pulse modulation

There are four (4) types of pulse modulation which include;
① PCM (Pulse code mod.) ② Pulse width modulation (PWM)
③ Pulse Amplitude modulation (PAM)

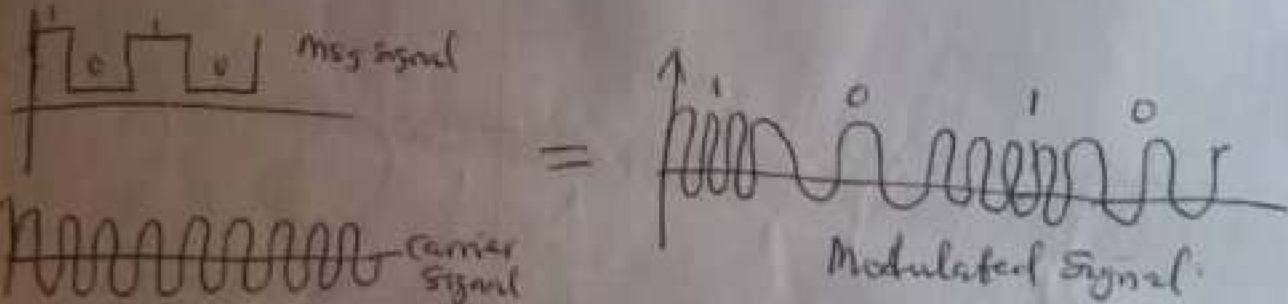
~~Quadrature Amplitude Mod (QAM)~~
~~Digital modulation (QAM)~~

Digital Modulation

There are four (4) types of Digital modulation which are;
① Amplitude Shift Keying (ASK): in ASK, the amplitude of the modulating signal changes according to the bit stream.

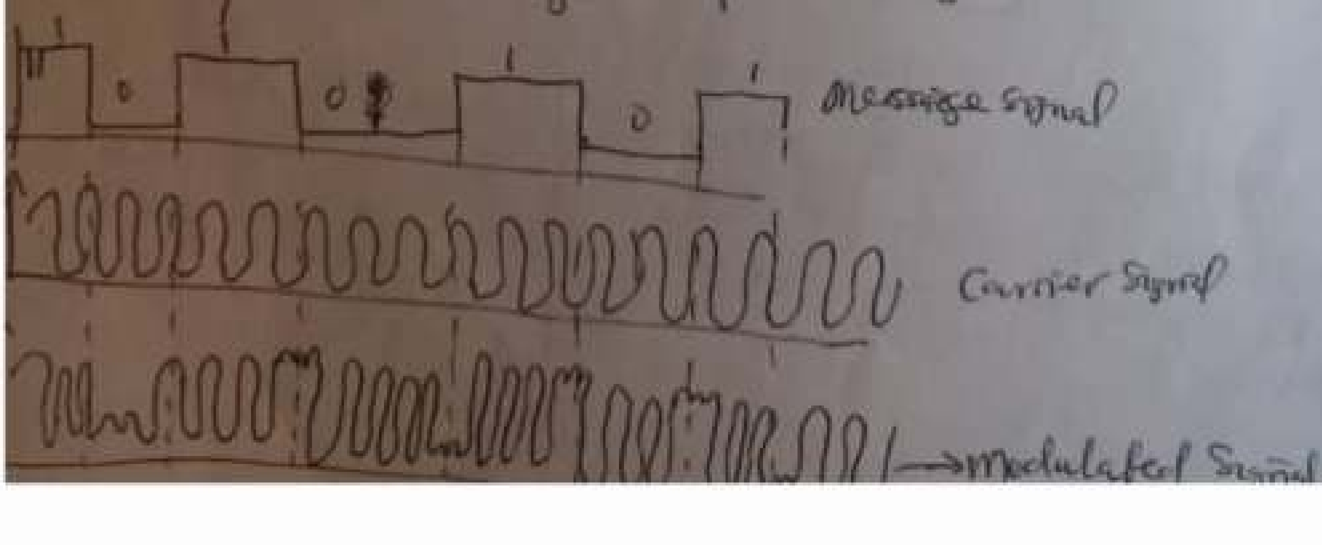


② Frequency Shift Keying (FSK): In FSK, the frequency of the modulated signal changes or varies according to digital wave stream.



③ Phase Shift Keying (PSK)

In PSK, the phase of the modulated signal ~~changed~~ varies around according to the message or information signal.



f) Quadrature phase shift keying (QPSK): this is a form of digital modulation that represents data by changing the phase of a carrier signal.

there is also BPSK — Basic phase shift keying.

Demodulation

Demodulation is the process of extracting the original information signal from a modulated ~~signal~~ carrier signal. It can also be define as the process of converting a modulated signal back into its original baseband or information signal which contains the message to be processed or displayed.

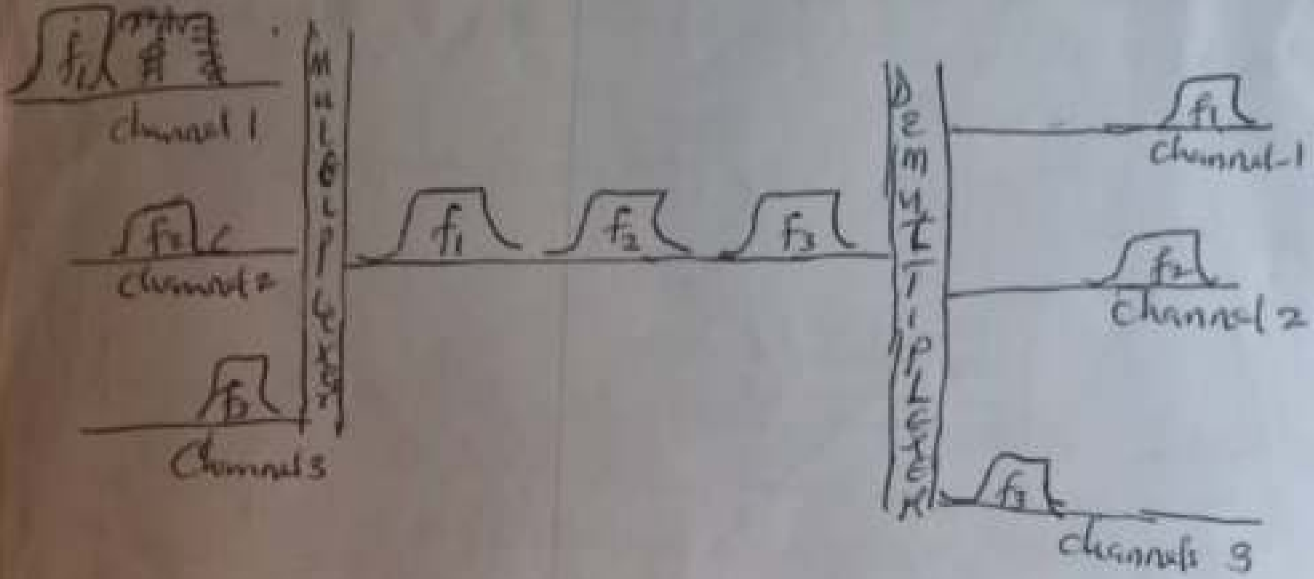
Multiplexing and Demultiplexing

multiplexing is the technique used in telecommunications and networking to combine multiple data signals (analog & digital) or streams into a single transmission channel. Multiplexing divides the high capacity medium into low capacity logical medium which is then shared by different streams or message signals. It can also be seen as the transmission of information from more than one source to more than one destination over the same medium.

When multiple senders send data over a single medium, a device called multiplexer divides the physical channel into multiple channels and allocates one to each data sent by the senders. On the other end of communication a demultiplexer receives the data from a single medium, identifies each, and sends to different receivers.

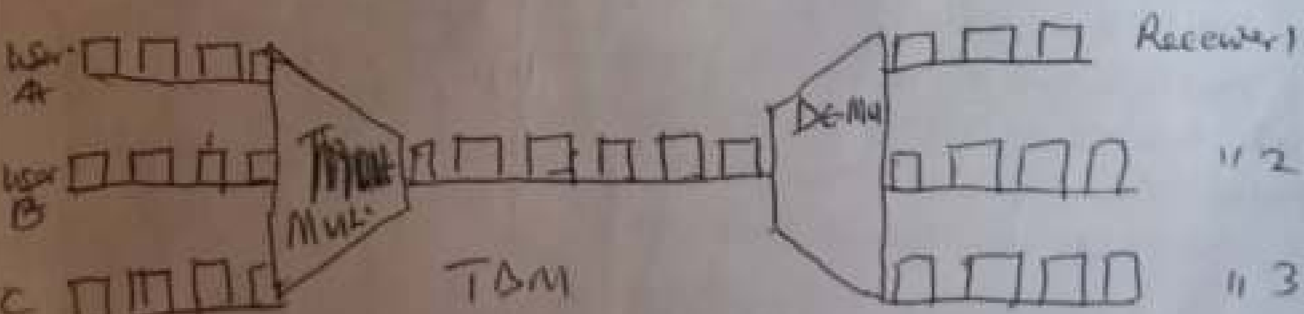
Types of Multiplexing

1) Frequency Division Multiplexing (FDM): FDM divides the available bandwidth of a transmission medium into multiple non-overlapping frequency bands. Each data signal from a sender is assigned or allocated to a band for transmission.



(2) Time Division Multiplexing (TDM)

In TDM, the shared channel is divided among its users by means of ~~time~~ discrete time slots. Each user can transmit data within the provided time slot only. Digital signals are divided in frames, equivalent to time slot, which can be transmitted in given time slot. TDM works in synchronized mode. Both ends (i.e multiplexer and De-multiplexer are timely synchronized, and both switch to next channel simultaneously. See the diagram below



When channel A transmits its frame at one end, the De-multiplexer provides media to channel A on the other end. As soon as the channel A's time slot expires, the multiplexer switch to channel B. On the other end the De-multiplexer works in synchronized manner and provide media to channel B. Signals [illegible] travel the same path but not at the same

(3) Code Division Multiplexing (CDM): CDM assigns a unique code to each data signal from different senders, allowing them to be transmitted simultaneously over the same frequency band. CDM uses orthogonal codes to spread signals. The receiver knows in advance the unique code of the signal it has to recei

Wavelength Division Multiplexing (WDM): In fiber optic mode, multiple optical carrier signals are multiplexed into an optical fiber by using different wavelengths.

De-multiplexing

~~Synchronous and Asynchronous data transmission~~

Demultiplexing is the process of separating multiple signals multiplexed together for transmission over a single channel. It can also be define as the process of extracting individual data signals or streams from a combined signal. It involves extracting individual signals from a composite signal. For example Time Division Demultiplexing (TDD), FDD etc.

Synchronous and A-Synchronous Data Transmission

In synchronous data transmission, the sender and receiver are synchronized (they have common master clock or clock frequency) and data bits are sent one bit after another in a queue manner without maintaining gap between bytes. There is no header/footer bits or start/end bits before and after each byte of data frame. Therefore, timing is relevant? in synchronous data transmission as there is no mechanism to recognize start and stop data bits.

The advantage of synchronous transmission is that, it offers high speed, [no overhead of extra header and footer bits] and it is use for very long distance transmission than asynchronous data transmission

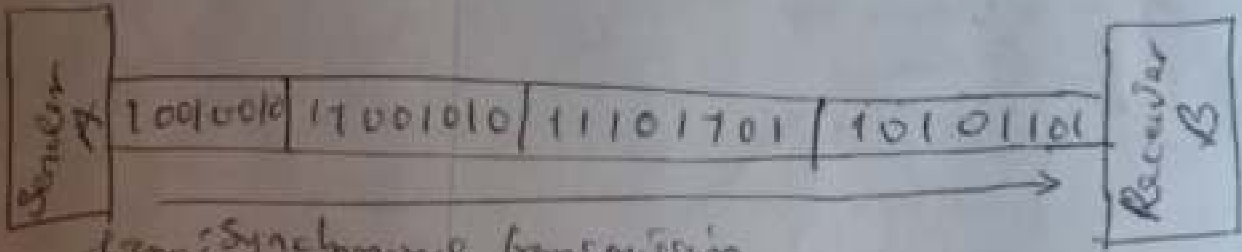


figure: Synchronous transmission

Asynchronous data transmission

In asynchronous data transmission, timing is not important, there is a header and footer bits attached to dataframes and there is space or gap ~~between~~ between each byte. This pattern enable the receiver to recognize the start and end bits

(29)

Error detection and Control Techniques

An error is when a data frame is corrupted, damaged or even duplicated or modified during transit. This transmission error could be due to attenuation, noise or interference. There are different types of error such as:

① Single bit error or : Sent 10110011 → Received 10110111 error

Random single bit error: In single bit error, a frame is corrupted or modified if only one bit is changed from one bit value to another.

② Multiple bit error: In multiple bit error, a frame is received with more than one bits in corrupted or damaged state. ~~multiple bit error can also be called burst error~~ The affected bits can be randomly position in the data frame bits. See below

Sent 10110011 → Received 10100111 (2 non-consecutive bit changed)

or → 11100010 (3 non-consecutive bits changed)

③ Burst error: is when a received frame contains more than one consecutive bits corrupted.

e.g. Sent 10110011 → Received 11000111 (3 consecutive bits damaged or modified)

To control the errors, the possible error control mechanism or technique that could be apply may involve the ff:
① Error detection and ② Error correction.

Error detection

Beside framing, datalink layers of the OSI reference model also includes mechanisms to detect and sometimes even recover from transmission errors.

To allow a receiver and a sender to detect errors, a sender must add some redundant information or extra data bits as an error detection code to the data frame to be sent. An error ~~detec~~ detection code is a function that computes the r redundant bits corresponding to each string of n bits.
This error detection code is computed by the sender on the frame that the sender will transmit. When a receiver, receives a frame with an error detection code, ~~it rec~~ the receiver recomputes it and verifies whether the received error detection code matches the redundant information added by the sender. If they matched, the frame is considered valid or not corrupted, otherwise it is invalid or corrupted.

There are different type of scheme or error detection scheme for computing error detection code such as;

① ~~Single~~ Parity check:
- Even parity check } Single parity check
- Odd parity check }

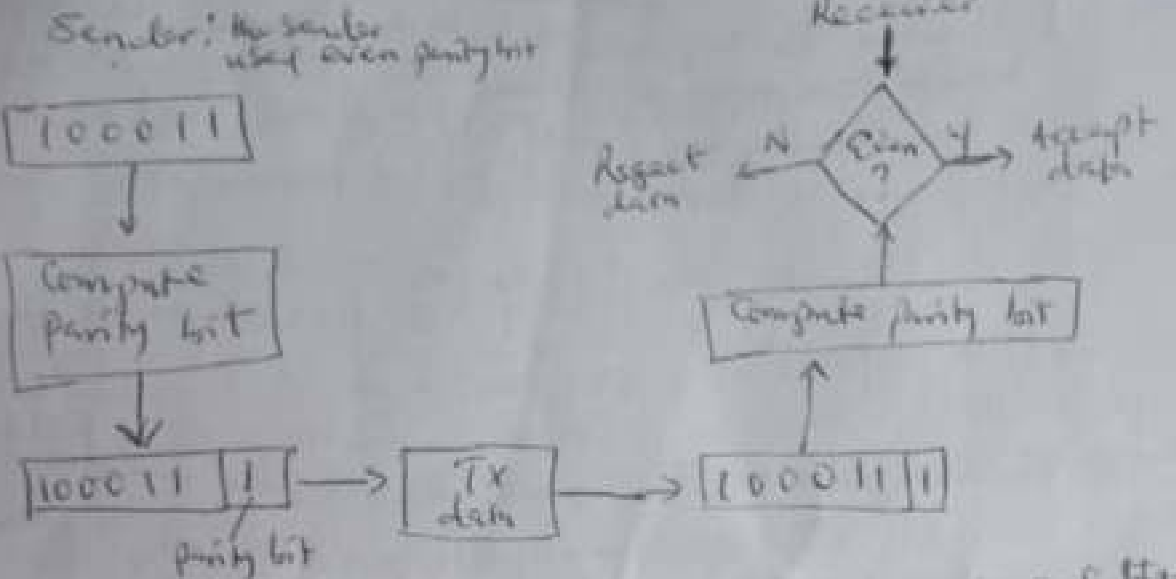
— Two-dimensional parity check:

② Check sum ③ Cyclic or Cyclical Redundancy Check (CRC)
~~④ Parity Hamming check~~ ~~⑤ Reed-Solomon Code~~ ~~⑥ Automatic Repeat Request (ARQ)~~

Parity check or Parity bit check

There are three types of parity check which are single bit even parity check, single bit odd parity check and two dimensional parity check.

Single-bit even parity check: Here, the sender computes parity bit using even parity approach as shown in the diagram below. For even parity computation, the parity bit value is added such that the number of 1s in the data frame or data bit stream to be sent is even.



Example: if the data is '101000l' and even parity is used, the parity bit added would make the number of 1s even. So the transmitted data becomes '10100011'

Single bit odd parity check: Here, the sender adds a single parity bit to the data, making the total number of 1s odd (odd parity). Using the same example above, if the data is '101000l' and odd parity is used, the parity bit added would be 0. So the transmitted data becomes '10100010'.

NOTE: In Single parity check, add a single parity bit to the data making the total number of 1s either even (even parity) or odd (odd parity).

The drawback of single parity check is that it can't detects multiple bit errors.

P-T-O

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Question: Suppose a bit sequence 110001010111 is received and assume odd parity bit method is applied, find whether the received bit sequence is correct or not.

Solution

Step 1: Arrange the sequence of bit horizontally, indexing/numbering them from righthand side. The bits with even position(s) are indicated as power of two i.e. parity bits (P_1, P_2, --- P_n) and the remaining bit serve as data or message bits. See below:

M_{12}	M_{11}	M_{10}	M_9	P_8	M_7	M_6	M_5	P_4	M_3	P_2	P_1
1	1	0	0	0	1	0	1	0	1	1	1
12	11	10	9	8	7	6	5	4	3	2	1

Step 2: Compute the binary of the positions (i = 1 to 12) and Compute the parity (P_1, P_2, P_4 and P_8) as shown below:

Decimal	Binary (8 4 2 1)
1	0 0 0 1
2	0 0 1 0
3	0 0 1 1
4	0 1 0 0
5	0 1 0 1
6	0 1 1 0
7	0 1 1 1
8	1 0 0 0
9	1 0 0 1
10	1 0 1 0
11	1 0 1 1
12	1 1 0 0

Parity Computation

P_1 — Code with rightmost bit equal 1,
— 1, 3, 5, 7, 9, 11

P_2 — binary code with 2nd rightmost bit equal 1
— 2, 3, 6, 7, 10, 11

P_4 — Code with 3rd rightmost bit equal 1
— 4, 5, 6, 7, 12

P_8 — 8, 9, 10, 11, 12

		odd	parity bit
P_1	111101	✓	0
P_2	110101	×	1
P_4	01011	✓	0
P_8	00011	×	1

P.T.O

Compare the new values of P_1, P_2, P_4, and P_8 with their values in the received data. After comparing, we found that P_1 & P_8 was changed in transit, meaning that the received data is corrupted or incorrect.

take home

Compute or find out whether the sequence is correct or not assuming even parity bit is used by the sender.

Two-dimensional parity check

Two-dimensional parity checks help in detecting multiple bit errors. In this approach or method, a block of bits is organised in a table (rows and columns). First we calculate the parity bit for each data unit. Then organize them into a table. After organizing each data unit a tabular form, compute the the parity bit for each column, creating a new row of 8 bits.

Example: We have four data unit to send: 0110110 1101001 1110011 0001110. Before sending, the sender does the ff: Assumed the sender uses even parity

								row parities
	0	1	1	0	1	1	0	0
	1	1	0	1	0	0	1	0
	1	1	1	0	0	1	1	1
	0	0	0	1	1	1	0	1
→ Column parities →	0	1	0	0	0	1	0	0 ~~column~~ parities

So, the data that will be send is

01101100 11010010 11100111 00011101 01000100

Two-dimensional parity check increases the likelihood of detecting burst errors.

Checksum

- In checksum error detection scheme, the data is divided into k segments each of m bits. In the sender's end, the segments are added using 1's complement arithmetic to get the sum. The sum is complemented to get the checksum. The checksum sequence is sent along with data sequence.
At the receiver's end, all received ~~segments~~ sequence are added using 1's complement arithmetic to get the sum. The sum is complemented. If the result is equal 0, accepted data, otherwise reject data.

Example: Assume we want to sender 10011001111000100010010010000100 using checksum scheme.

* Sender

10011001	11100010	00100100	10000100	11011010
1	2	3	4	checksum

→ sent data

K=4, n=8 bits

1 ⇒ 10011001
2 ⇒ +11100010
1 01111011
+1
01111100
3 ⇒ +00100100
10100000
4 ⇒ +10000100
1 00100100
+1
00100101 — Sum

Compliment the sum at the sender's end:

⇒ 00100101 ⇒ 11011010

Sum — Checksum

P.T.O

On the receiver's end

The receiver performs the same operation on the data

i.e

```
   10011001
   11100010
  ----------
 (1)01111011
           1
  ----------
   01111100
      .
      .
      .
4⇒ 10000100
  ----------
 (1)00100100
           1
  ----------
   00100101  → Sum
 + 11011010  → Check Sum
  ----------
   11111111  → Sum on the receiver end
```

1's compliment operation

The receiver will compliment the sum, and if the result of compliment is all zeros (0s), the data is accepted else the data is rejected.

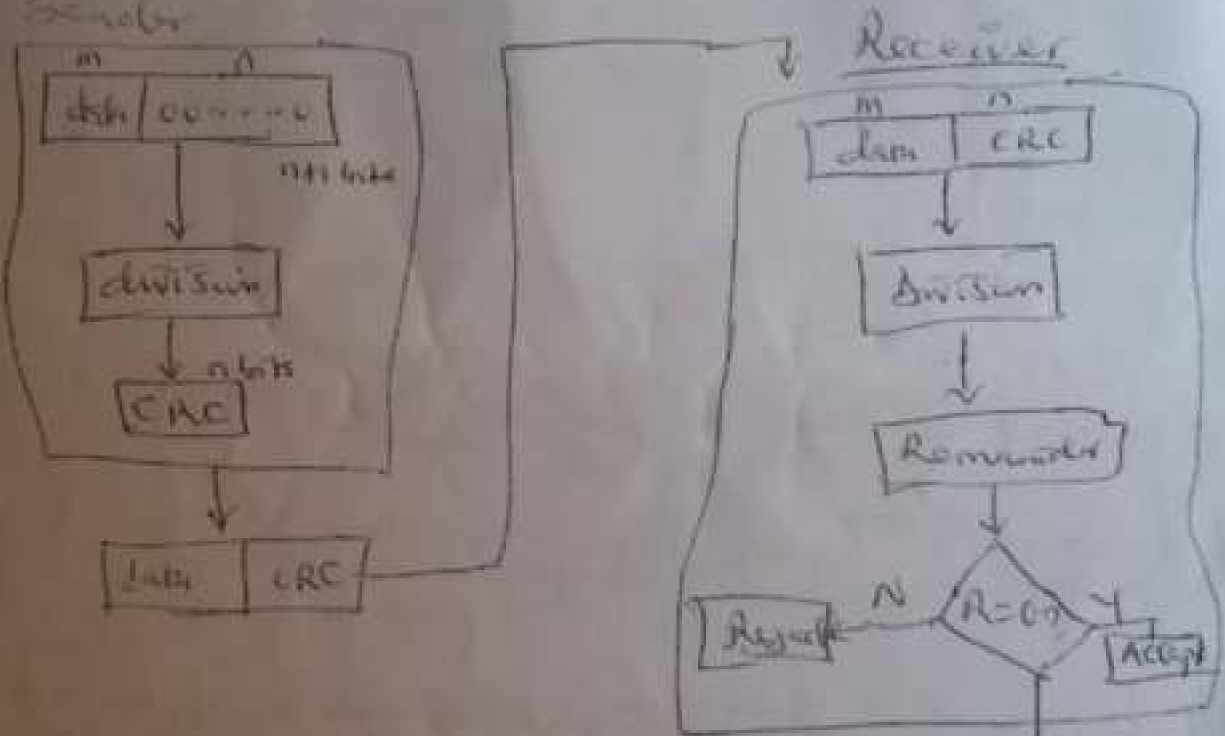
So, 11111111 ⇒ 00000000

this means that the data ~~on the~~ received are valid data

(36)

Cyclic Redundancy Check (CRC)

This is an error detection method based on binary division. In CRC, a sequence of redundant bits called cyclic redundancy check bits are appended to the end of data, so that the resulting data unit becomes exactly divisible by second predetermined binary no. At the destination, the incoming data is divided by the same no. If the remainder is zero (0) then the data is accepted otherwise the data is rejected.



Example: transmit 1101011011 using CRC method with cyclic generated polynomial function $x^4 + x + 1$.

the divisor generated polynomial is $1x^4 + 0\cdot x^3 + 0x^2 + 1x^1 + 1x^0$

$1 \quad 0 \quad 0 \quad 1 \quad 1$

Since there are 5 bits generated from the polynomial, append 4 zeros to the end of the original bit stream then divide it with 10011.

P.T.O

ii. on the sender's side do the ff;

```
            1100001010
      ________________
10011 ) 1101011011 0000  — Appended zeros at the sender side
        10011
        ·10011
         10011
         ·00001
          00000
          ·00010
           00000
           ·00101
            00000
            ·01011
             00000
             ·10110
              10011
              ·01010
               0000
               ·10100
                10011
                ·01110
                 00000
                 ·1110 — Remainder
```

Replace the four (4) zeros appended before division with the remainder or the CRC and send it to the receiver
i.e 11010110111110 — this is the transmitting bit stream

P.T.O

Receiver Side

On the receiver's side, the receiver will receive 11010110111110 and divide it with 10011.

```
           1100001010
      _______________
10011 ) 11010110111110
        10011
        -----
         10011
         10011
         -----
          00001
          00000
          -----
           00010
           00000
           -----
            00101
            00000
            -----
             01011
               :
               :
               :
             -----
             00000
             00000
             -----
              0000 = 0  => Remainder on
                           the receiver's side
                           is 0
```

This means, that the data is accepted because it is not corrupted or changed or damaged.

Exercise

(a) Briefly discuss the term Cyclic Redundancy check.

(b) ~~check~~ Find out the CRC for the data polynomial $x^5+x^4+x^2+1$ with a generator polynomial x^3+1.

Error Correction techniques

The error correction schemes are;
- Hamming code
- Reed-Solomon code
- Automatic Repeat request (ARQ)
  - Stop-and-wait ARQ
  - Go-Back-N ARQ
  - ~~Stop-and-wa~~ Selective Repeat ARQ.

(1)

Hamming code

It can be applied to data unit of any length. Hamming code is used to detect and correct single bit errors.

Hamming code structure

- All bit positions that are power of 2 are marked as parity bits (i.e 1, 2, 4, 8, ...), other bits are for data or message.

D_7	D_6	D_5	P_4	D_3	P_2	P_1

— 7-bit

7-bits Hamming code structure

We have to determine the value of parity bits. The rule is that, the value of parity bit is determined by the sequence of bits that is alternate checks & skips

e.g Sender $\xrightarrow{1101}$ receiver; use 7-bit Hamming code to send the data

D_7	D_6	D_5	P_4	D_3	P_2	P_1
1	1	0		1		

Calculating P_1, P_2 & P_4;

P_1: check 1 bit, skip 1 bit, check 1 bit, skip 1 bit .....
— 1, 3, 5, 7, 9, ...

P.T.O

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P_2 : check 2 bits, skip 2 bits, check 2 bit, skip 2 bit, ...
: (2, 3, 6, 7, 10, 11, ...)

P_4 : check 4 bits, skip 4 bits, check 4 bits, skip 4 bits, ...
: (4, 5, 6, 7, 12, 13, 14, 15, 20, 21, 22, 23, ...)

$P_1 - D_3 D_5 D_7$: 101 — even ~~parity~~ no. of 1s

$\Rightarrow P_1 = 0$

$P_2 - D_3 D_6 D_7$: 111 — odd no. of 1s

$\Rightarrow P_2 = 1$

$P_4 - D_5 D_6 D_7$: 011 — even no. of 1s

$\Rightarrow P_4 = 0$

So the sender will send the data as

m_7	m_6	m_5	P_4	m_3	P_2	P_1
1	1	0	0	1	1	0

— this is the Hamming code that is going to be send.

for even parity.

The receiver have to check P_1, P_2, & P_4, trying to detect if there was an error in transit.

After checking for even parity ($P_1 = 0$, $P_2 = 0$, $P_4 = 0$) means no error.

Detecting errors

Consider a 7 bit Hamming code — Hamming (7,4):

D_7 D_6 D_5 P_4 D_3 P_2 P_1

At receiver end, bits (1, 3, 5, 7), (2, 3, 6, 7) & (4, 5, 6, 7) are checked for even parity.

Correcting the errors if detected:

An error is located by forming a 3 bit no. out of 3 parity check:

P_4	P_2	P_1

finding P_1: We check parity of ($P_1 D_3 D_5$ & D_7)

If it is odd, error exists $P_1 = 1$

If it is Even, ~~error~~ no error $P_1 = 0$

Similarly P_2 & P_4

⇒ After we have found the error word, we find its decimal value

⇒ Then we invert the incorrect bit to obtain the correct word

Example: A 7 bit Hamming Code is received as 1011011. Assume Even parity, ~~and~~ state whether the received code is correct or wrong. If wrong locate the bit in error.

Solution

Received HC:

D_7	D_6	D_5	P_4	D_3	P_2	P_1
1	0	1	1	0	1	1

(1) Detecting error:

Step 1: Analyzing bit 1, 3, 5, 7

We have $P_1 D_3 D_5 D_7$: 1011 — odd parity error exist

to make it even parity, $P_1 = 1$

Step 2: Analyzing bits 2, 3, 6 & 7

$P_2 D_3 D_6 D_7 = 1001 \longrightarrow$ Even parity, no error

then $P_2 = 0$

Step 3: Analyzing bits 4, 5, 6 & 7 = 1101 — odd parity, error exist

We put $P_4 = 1$

From the analysis, P_1 & P_4 are not equal to zero, so the received code is wrong.

Correcting the error

Error word

P_4	P_2	P_1
1	0	1

the decimal value $E = 5$, which shows that the 5^{th} bit is in error.

So, the correct data is gotten by inverting the 5^{th} bits

$\Rightarrow$ the correct word = 1001011 and not 1011011.

N°2

To determine the number of parity bits (r) required for a given number of data bits (d), we use the formula

$$2^r \geq d + r + 1$$

$\Rightarrow$ for 4 data bits, $d = 4$, start with $r = 2$,

$\Rightarrow 2^2 \geq 4 + 2 + 1$

$\Rightarrow 2^2 \geq 7$ not true ✗

take $r = 3$

$\Rightarrow 2^3 \geq 4 + 3 + 1$

$2^3 \geq 8$ ✓

So we need $r = 3$ for 4 data bits.

Bus Structure and loop System

* Bus Structure

In bus topology a single cable or link connects all the network devices and the connected computers shares the bus network capacities. When more computers are added to the bus network, the ~~excess~~ network speed drops or reduces. In bus network structure, the connected devices share responsibility for conveying data from one point to another in the network.

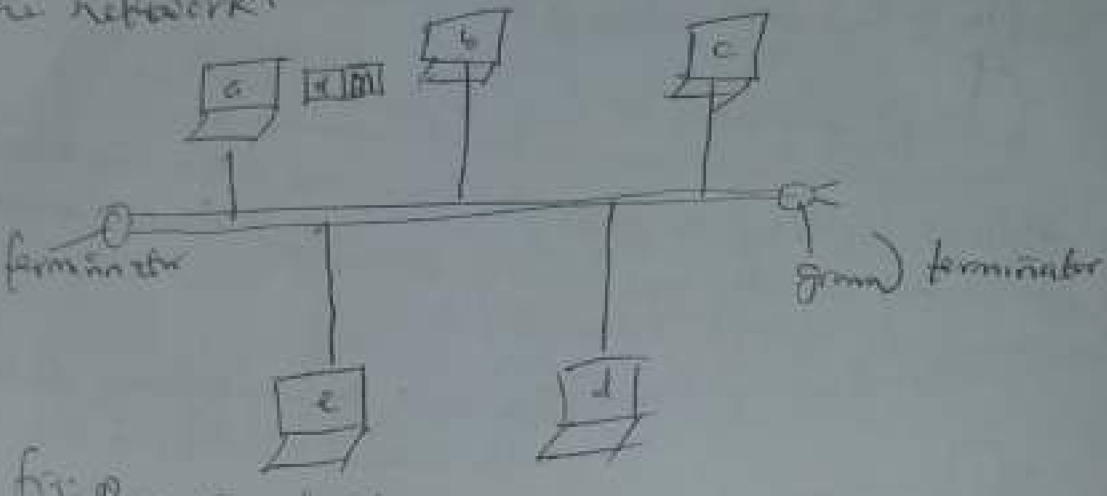


fig: Bus structure

- The terminator stop signals ~~after~~ at the end of the communication link or wire, so as to prevent signal bounce.
- Each computer communicates to other computers on the bus network independently. this is referred to as a peer-to-peer communication (i.e ~~each~~ computer with an address 'a' that wants to message another computer with an address d, will simply attach the receiver address to the message. Each computer checks the message to compare its own address with the address attached to the message. If the address on the message matches the address of any of the connected computers, the matched computer receives the message, ~~other~~ If there is no match, the message is passed on ~~[illegible]~~ along the network, until the receivers receive it.

Advantages of bus topology

① It works well for small network ② Relatively inexpensive to implement ③ Easy to add more computers to the network

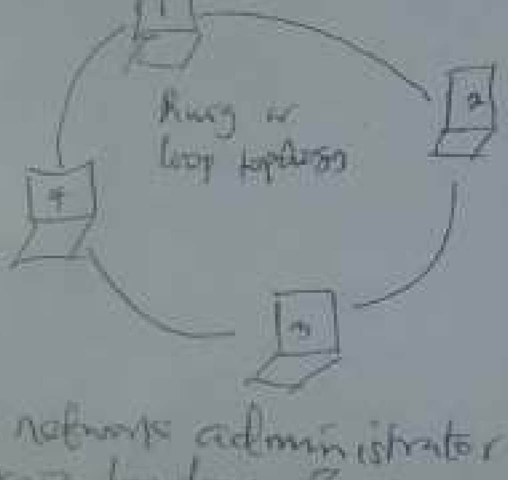
Disadvantage

① Management cost can be high ② Congestion and network traffic is likely to occur ③ It is not fault tolerance: a defect ~~wire~~ or a break of any of the computers may result in the break or ~~defect~~ of the whole network

One example of bus technology is the Ethernet

Loop topology or Loop System or Ring

Ring or loop topology is used for LAN and WAN in which every connected device has exactly two other devices or neighbours to communicate with or connected to.



In ring or loop systems, data ~~trave~~ travels around the ring in one direction. Assume node 1 wants to send data to node 3, the data travels from node 1 to node 2 then to node 3:

node 1 ⟶ node 2
node 2 ⟶ node 3

A network administrator can easily add or remove nodes from the ring topology. To connect/add more host or node, we only need one extra cable or wire to connect it. A failure in any host/node in ring network results in the whole loop network ~~failure~~ failure because the token/data travels in one direction.

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Examples of Computer Network

Recall: A computer network is a system in which multiple computers are connected to each other to share information and resources.

Distance b/w the interconnected devices		Example of Network
1m	Square meter	→ Personal Area Network PAN
10m	Room	LAN ← Bus - Ethernet, Token ring by IBM.
100m	Building	LAN
1km	Campus	LAN
10km	City	→ MAN
100km	Country	WAN
1000km	Continent	WAN
10,000km	Planet	→ Internet

Data Switching principle

Data switching principles are methods used to transfer data across a network from source to destination. The main data switching techniques are

- Circuit switching: in circuit switching method, a dedicated communication path is established b/w 2 devices or nodes through a series of connected switches. It is use in traditional telephony system.

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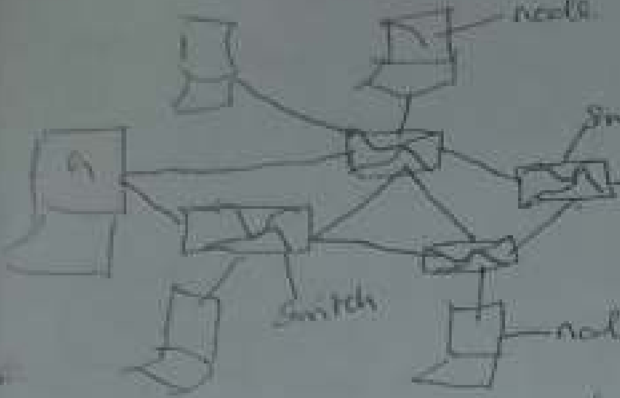

fig: Circuit switching

Advantage: provide consistent reliable connection with guaranteed bandwidth

Disadvantage: Inefficient use of resources as the dedicated path remains reserved for the duration of the connection, even when no data is being transferred.

- Packet Switching: in packet switching technique or ~~method~~ principle, data is divided into packets each of which is routed independently through the network to the destination. It is widely use in computer networks, including the internet.
- Advantage: Efficient use of network resources, scalable and robust. If packet is lost only the lost packet is resent.
- Disadvantage: potential for variable delay and packet loss due to congestion.

- Message Switching

- Cell Switching: Data is divided into fixed-size cells, each 53 bytes long. Cells are routed independently through the network.