Ch-03

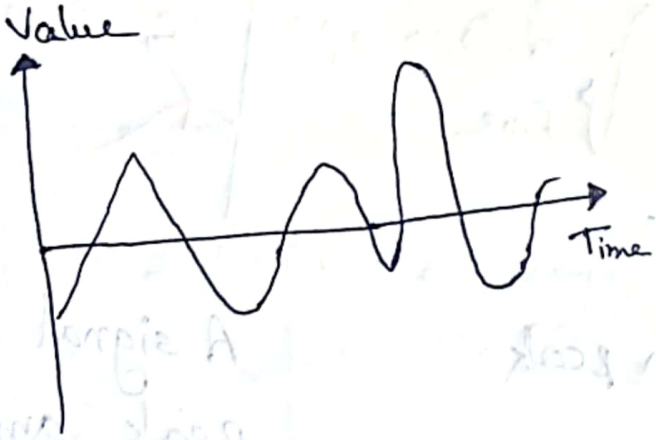
Digital vs Analog

- Analog data are continuous and take continuous values.

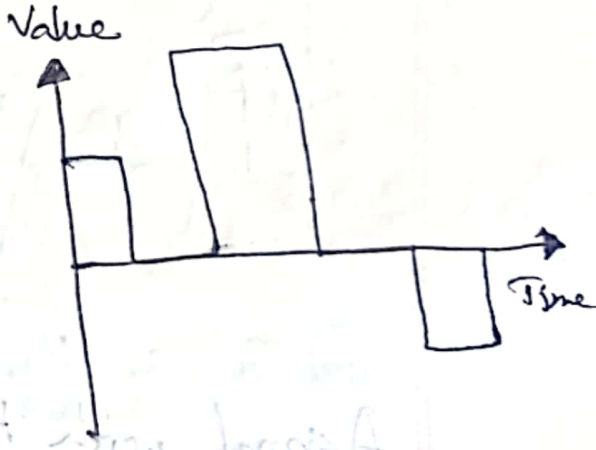
  Digital data have discrete states and take discrete values.

- Analog signals can have an infinite number of values in a range.

  Digital signals can have only a limited number of values.



Analog Signal



Digital Signal

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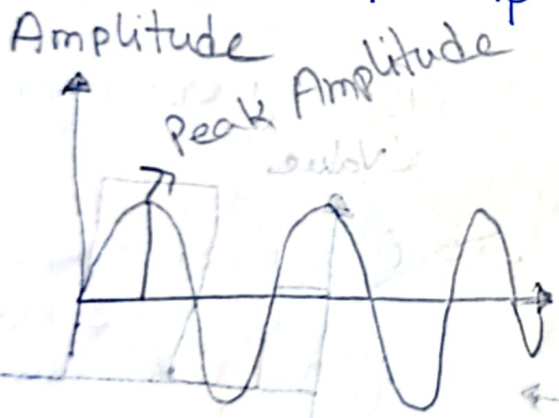
Periodic Analog Signal

(i) Periodic Analog signal can be classified as simple or composite

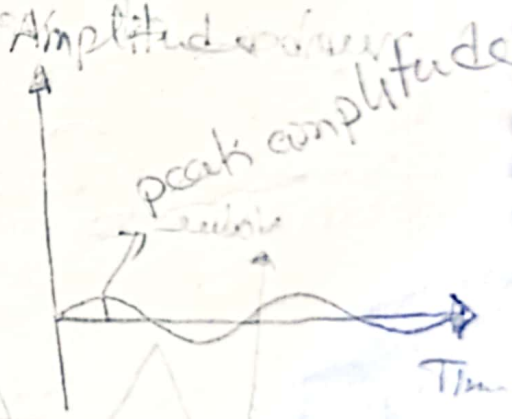
(ii) A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals

(iii) A composite periodic analog signal is ~~compo~~ composed of multiple sine waves.

- Two signals with the same phase and frequency but different amplitudes.



A signal with high peak amplitude.

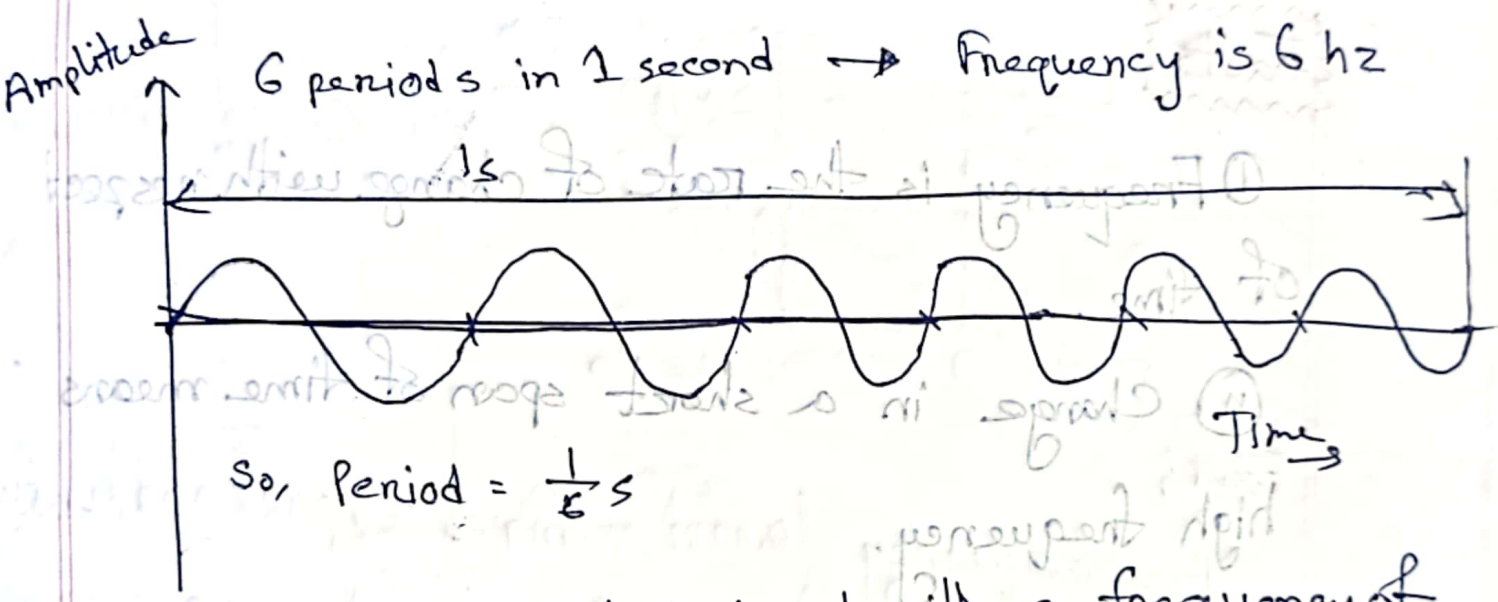


A signal with low peak amplitude

Frequency and Period are the inverse of each other.

$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$

- Two signals with the same amplitude and phase, but different frequencies.



∴ A signal with a frequency of 6 Hz

The power we use at home has a frequency of 60 Hz. The period = ?

Here, $f = 60\,Hz$; $T = \frac{1}{f} = \frac{1}{60}$

$= 0.0166\,s$

$= 0.0166 \times 10^3\,ms$

$= 16.6\,ms$

The period of a signal is 100 ms. What is its frequency in Kilohertz?

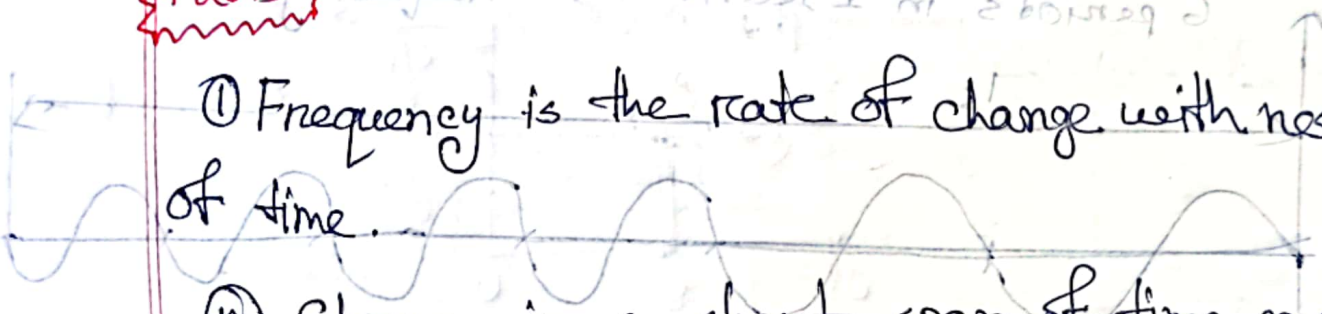
Here, $T = 100\,ms = 100 \times 10^{-3} s = 10^{-1} s$

$f = \frac{1}{T} = \frac{1}{10^{-1}} Hz = 10 Hz = 10 \times 10^{-3} KHz$

$= 10^{-2} KHz$

Facts

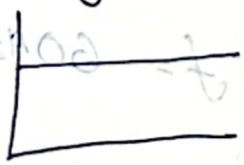
(i) Frequency is the rate of change with respect of time.



(ii) Change in a short span of time means high frequency.

(iii) Change over a long span of time means low frequency.

(iv) If a signal does not change at all, its frequency is zero (0).



(v) If a signal changes instantaneously, its frequency is infinite

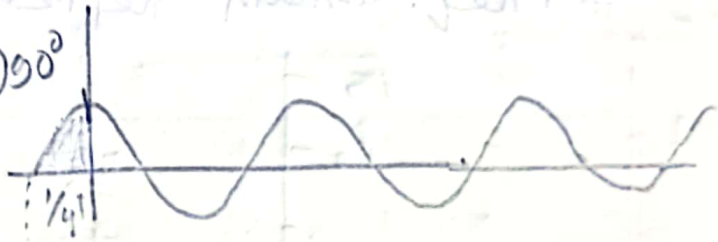
Phase

Phase describes the position of the waveform relative to time 0.

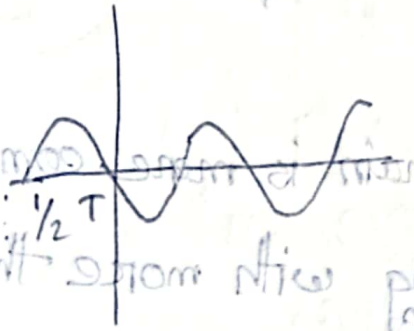
3 sine waves with the same amplitude and freq. but different phases.

ⓐ 0°

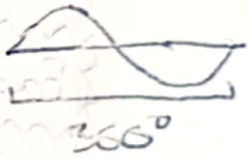
ⓑ 90°



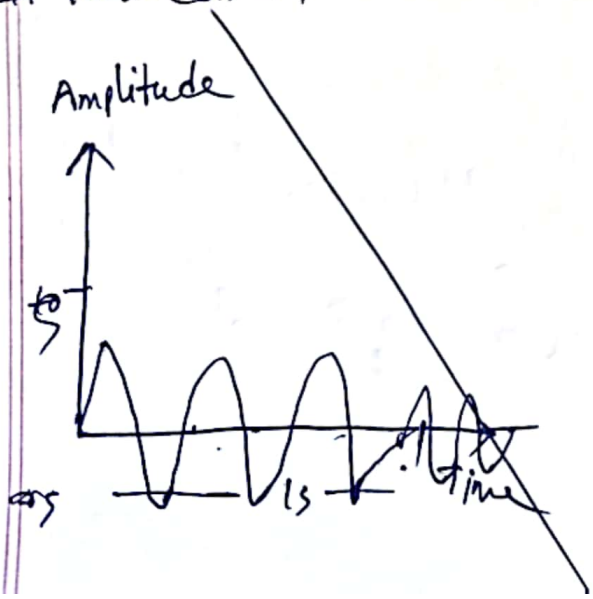
ⓒ = 180°



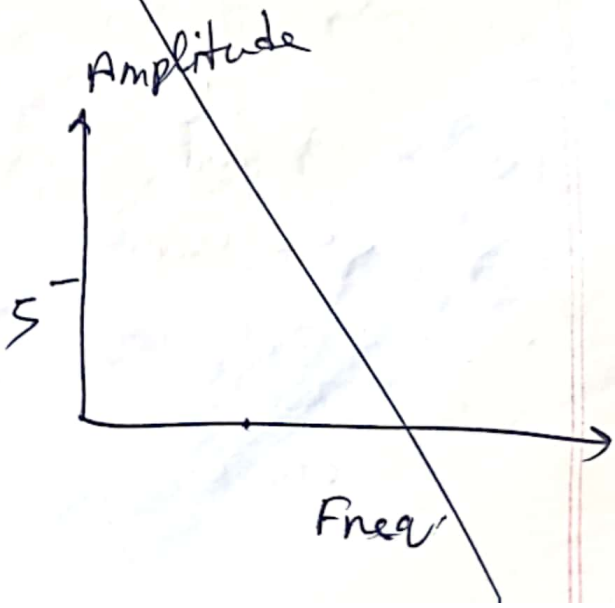
Ex



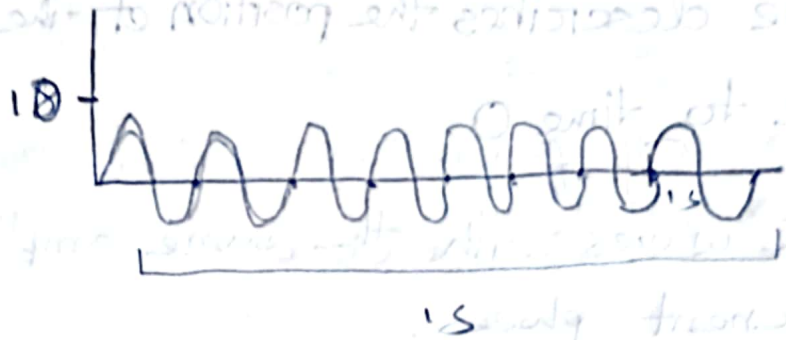
Time domain



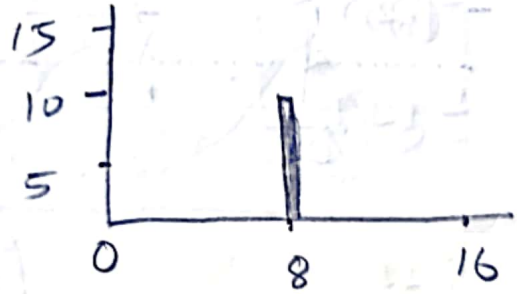
Freq. domain.



Time domain ~~freq of~~ representation — 8



Freq. domain representation.

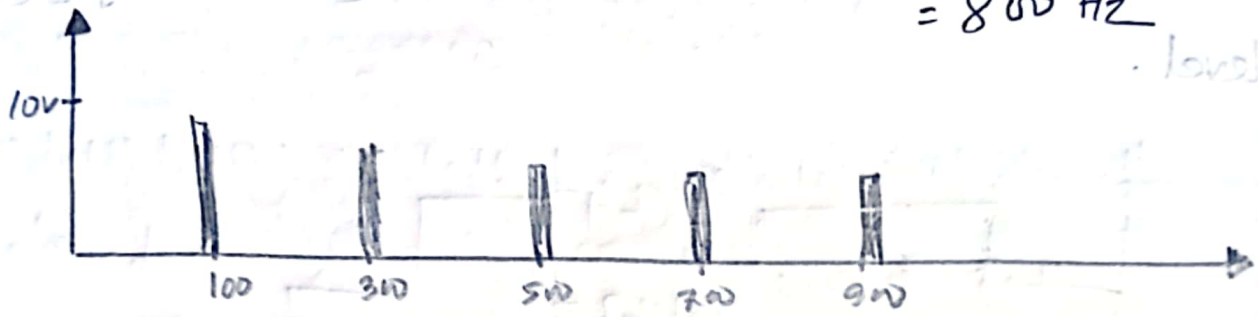


Fact

The frequency domain is more compact and useful when we are dealing with more than one sine wave.

If a periodic signal is decomposed into five sine waves with freq. of 100, 300, 500, 700 and 900 Hz. what is its Bandwidth? Draw the spectrum, Amplitude = 10V

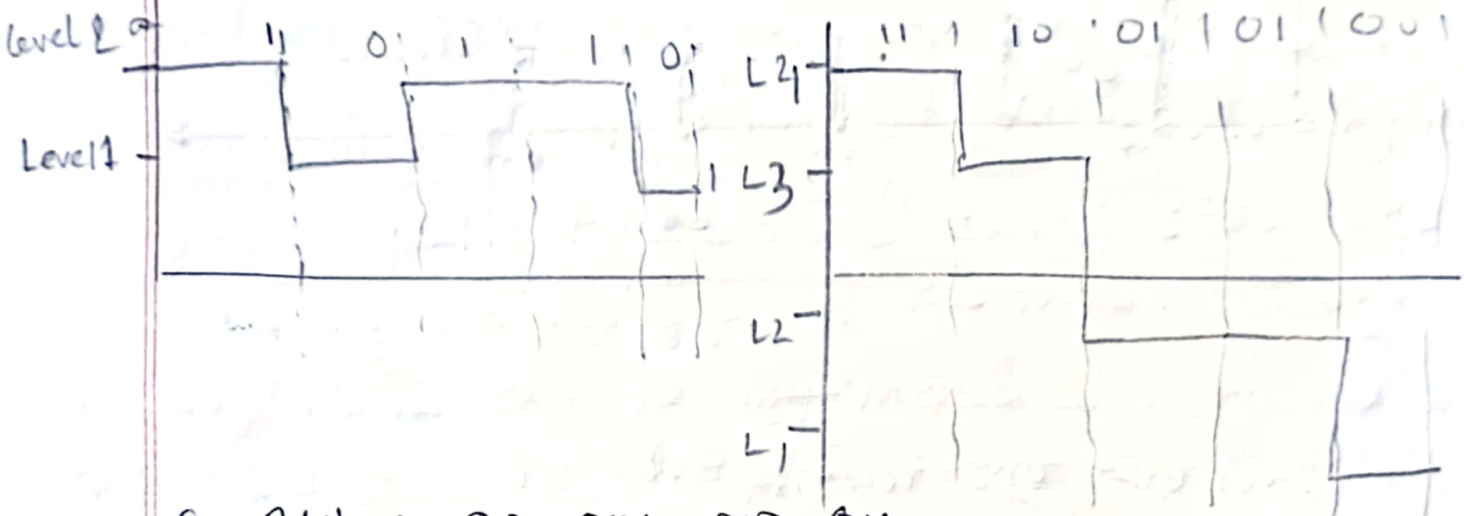
Here $f_h = 900$; $f_l = 100$; $B = f_h - f_l = 900 - 100$
$= 800$ Hz



Digital Signals

a 1 can be encoded as positive voltage and a 0 as zero voltage.

A digital signal can have more than two levels. In this case, we can send more than 1 bit for each level.



for 3bit → 000, 001, 010, 011, 100, 101, 110, 111 = 8

So, level = $2^{\text{no. of bits}}$

So, No of bits = $\log_2(\text{level})$

A digital signal has 8 levels. How many bits are needed per level?

Number of bits per level = $\log_2 8 = 3$

Assume we need to download text documents at the rate of 100 pages per second. What is the required bit rate of the channel?

A page is an average of 24 lines with 80 characters in each line, one character requires 8 bit, so, the bit rate is,

$$100 \times 24 \times 80 \times 8 = 1536000 \text{ bps}$$
$$= 1536000 \times 10^{-6} \text{ mbps}$$
$$= 1.5 \text{ mbps}$$

Transmission Impairment

Signals travel through transmission media, which are not perfect. These imperfection causes signal impairment.

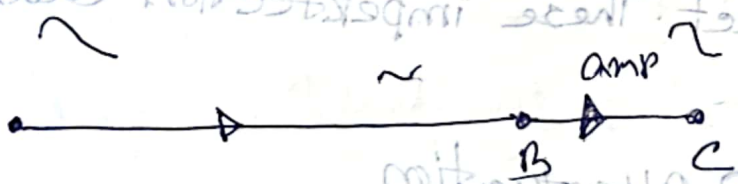
→ (i) Attenuation

→ (ii) Distortion

→ (iii) Noise

Attenuation

When the signal travels through the transmission media it experiences some resistance, the signal looses some of its energy to overcome the resistance. This loss of energy of a signal is called attenuation. It decreases amplitude of a signal obtained at the receiver. which reduces the volume of the sound.. The signals amplitude can be ~~imp~~ increased with devices called amplifiers. (Adjust ~~ampl~~ Ar.)



$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

$\begin{cases} -ve; \text{ attenuated} \\ +ve; \text{ amplified} \end{cases}$

A signal travel through a transmission medium and its power is reduced to one-half. So, P_2 is $\frac{1}{2}P_1$

Attentuation, $10\log_{10}\frac{P_2}{P_1} = 10\log_{10}\frac{0.5P_1}{P_1}$

$= -3.01\ dB$

Distortion

This occours in Composite Signal. A composite signal has multiple ~~freq.~~ sine waves with different freq. so each component have different propogation speed in the medium, therefore every component reaches the destination at diff. times, it creates a change in the signals phase at the receiver. The shape of the comp. signal is diff at the receiver. This is called distortion. Neutralize → Equalizers.

Noise

Noise affects the quality of a desired signals.

Signal to Noise Ratio (SNR)

* High SNR means The signal is less corrupted by noise
* low _____ more corrupted by noise.

$$SNR = \frac{P_{signal}}{P_{Noise}} \quad , \quad SNR_{dB} = 10 \log_{10} SNR$$

The power of a signal is 10mW and the power of the noise is 1 μW. What are the values of SNR and SNR_{dB}?

$$SNR = \frac{10mW}{1\mu W} = \frac{10000\ \mu W}{1\ \mu W}$$

$$= 10000 \qquad [1mW = 1000\mu W]$$

$$SNR_{dB} = 10 \log_{10} 10000 = 40.$$

Performance

#Bandwith

(I) Bandwith in hertz : Range of freq. in a composite signal or the range of frequencies that a channel can pass. (freq pass 2.5)

(II) Bandwith in bits per second : The speed of bit transmission in a channel or link. (speed pass 2.5)

#Latency (Delay)

Defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.

Latency = Propagation time + Transmission time + Queuing time + Processing delay

(i) Propagation Time

Time required for a bit to travel from the source to the destination.

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

(ii) Transmission Time

The time required for transmission of a message depends on the size of the message and the bandwith of the channel.

$$\text{Transmission time} = \frac{\text{Message size}}{\text{Bandwith}}$$

Ex-Math

size = 2.5k-byte
bandwith = 1gbps
distance = 12,000 km
Prop Speed = $2.4 \times 10^8 \, ms^{-1}$

$$P.t = \frac{12{,}000 \text{ km}}{2.4 \times 10^8} = \frac{12000 \times 10^3 \text{ m}}{2.4 \times 10^8} = 0.05 s = 50 ms$$

$$t.t = \frac{2.5 \text{ kbyte}}{1 \text{ gbPS}} = \frac{2.5 \times 8 \times 1000}{10^9} = 0.020 ms$$

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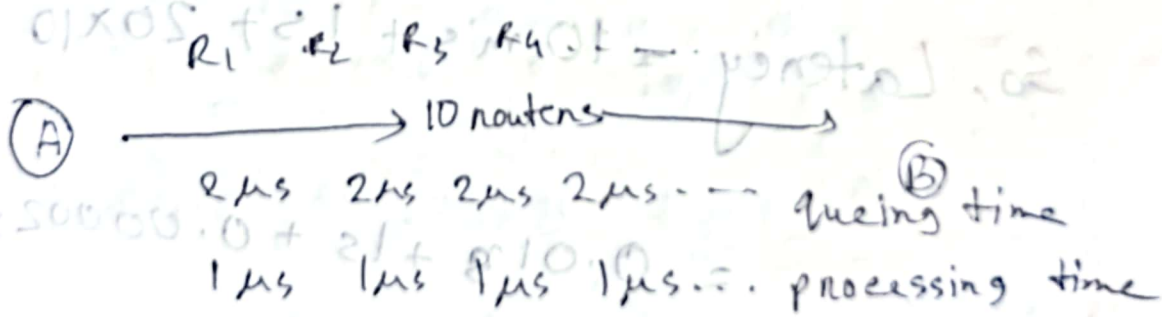
(iii) Queuing Time

The time needed for each intermediate or end device to hold the message before it can be processed.

(iv) Processing Delay

Time it takes network devices (routers) to process the packet header.

- What is the total delay (latency) for a frame of size 5 million bits that is being sent on a link with 10 routers each having a queuing time of 2 μs and a processing time of 1 μs. The length of the link is 2000 km. The speed of light inside the line is $2 \times 10^3 \, ms^{-1}$. The link has a bandwidth of 5 mbps.



distance = 2000 km

speed = $2 \times 10^8 \, ms^{-1}$

bandwidth = 5 mbps

propagation time $= \dfrac{2000 \times 10^3}{2 \times 10^8}$

$= 10\ ms$

transmission time $= \dfrac{5 \times 10^6}{5 \times 10^6}$

$= 1s$

queuing time $= 10 \times 2$ routers $= 20\ \mu s = 20 \times 10^{-6} s$

processing delay $= 10$ routers $\times 1\ \mu s = 10\ \mu s$
$= 10 \times 10^{-6} s$

So, Latency $= 10\ ms + 1s + 20 \times 10^{-6} s + 10 \times 10^{-6} s$

$= 0.01s + 1s + 0.00002s +$

$0.00001s$

$= 1s$

Bandwith defines highest speed u can acheive
Throughput defines the actual speed.

Jitter

Different packets of data encounter different delays and the application using the data at the receiver site is time-sensitive.

Network Throughput

- Measures how fast we can actually send the data through a network.
- Give us the idea of how many packets/data can be sent within a given time.

A network with bandwith of 10Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?

$$\text{Throughput} = \frac{12000 \times 10000}{60} = 2 \text{ Mbps}$$

The throughput is almost one-fifth of the bandwith in this case.

Data Rate Limits

A very important consideration in data communications is how fast we can send data, in bits per second, over a channel. Data rate depends on three factors:

(i) The bandwith available. [bandwith বেশি Data বেশি পাঠাতে পারি]

(ii) The level of the signals we use

(iii) The quality of the channel (the level of noise)

☐ Noiseless Channel → Nyquist Bit Rate

$C = 2 \times B \times \log_2 L$ (Channel Maximum Bitrate)

C ↑ Data rate, B ↑ Bandwith, L ↑ Number of signal levels

☐ Noisy Channel → Shannon Capacity

$C = B \times \log_2 (1 + SNR)$ (Practical Bitrate)

Fact

Increasing the levels of a signal may reduce the reliability of the system.

1 Byte = 8 Bits

Kilobytes = 1024 bytes / 10^3 bytes

Megabytes = 10^6 bytes

Gigabytes = 10^9 bytes

Terabyte = 10^{12} bytes

Microbyte (μ) = 10^{-6} bytes

1 Megahertz = 1×10^6 hertz

= 1×10^3 kilohertz

Consider a noiseless channel with a bandwith of 3000 Hz transmitting a signal with two signal levels. The maximum bit rate can be calculated as,

$$\text{Bitrate} = 2 \times B \times \log_2 L = 2 \times 3000 \times \log_2 2$$

$$= 6000 \text{ bps} = 6 \text{ Kbps}$$

We need to send 265 kbps over a noiseless channel with a bandwith of 20 KHz. How many signal levels do we need?

According to Nyquist formula,

$$C = 2B \times \log_2 L$$

$$\Rightarrow 265 \times 10^3 = 2 \times 20 \times 10^3 \times \log_2 L$$

$$\Rightarrow \log_2 L = \frac{265000}{40000} = 6.625$$

$$\therefore L = 2^{6.625} = 98.7 \text{ Levels}$$

We know, L এর value অবশ্যই 2^n হবে,

$\therefore$ 98.7 is not $2^{\text{something}}$. then the value will be either 64 or 128 ; 2^6 or 2^7

Bits per level $= \log_2 L$ | $\log_a b = c$ $\hookrightarrow b = a^c$

Since the result is not a power of 2, we need to either increase the number of levels or reduce the bit rate. If we have 128 levels, the bit rate is 280 kbps. If we have 64 levels, the bit rate is 240 kbps.

$; C = 2 \times 20000 \times \log_2 6$

$= \cancel{25000}\ 240$ kbps.

$\log_2 L = \frac{C}{2B}$; $L = 2^{\frac{C}{2B}}$

Questions

Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost 0. The noise is so strong that the signal is faint.

$C = B\log_2(1 + SNR) = B\log_2(1+0) = B\log_2 1 = B \times 0$

$= 0$

This means that the capacity of this channel is 0 regardless of the bandwith. In other words, we can't receive any data through this channel.

A telephone line normally has a bandwith of 3000. The signal-to-noice ratio is usually 3162.

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

$$= 34860 \text{ bps} = 34.860 \text{ Kbps}.$$

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 bandwith of the line or improve the signal-to-noise ratio.

If $SNR_{dB} = 36$ and $B = 2MHz$. $C = ?$

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

$$\therefore SNR = 10^{SNR_{dB}/10}$$

$$= 10^{36/10}$$

$$= 3981$$

$$C = B\log_2(1+SNR)$$

$$= 2\times10^6 \log(3982)$$

$$= 24 \text{ Mbps}$$

We have a channel with a 1-MHz bandwidth. The SNR for this channel is 63. What are the appropriate bit rate and signal level?

$$C = B \log_2(1+SNR) = 10^6 \log_2(1+63)$$

$$= 6000000 \text{ bps} = 6 \text{ Mbps}$$

The ~~Sharron~~ Shannon formula gives us 6 Mbps, the upper limit, for better performance we choose something lower (e.g. 4 mbps. Now we use the Nyquist formula to find the numbers of signal levels,

$$C = 2B \log_2 L$$

$$\Rightarrow 4 = 2 \times 1 \times \log_2 L$$

$$\Rightarrow L = 4$$

The Shannon capacity gives us the upper limit. the Nyquist formula tells us how many signal levels we need.