Data Communication Part-3

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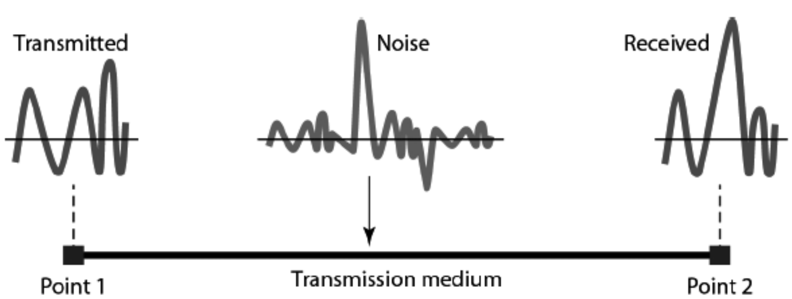
Content:

1. Noise
2. SNR
3. Noiseless Channel
4. Noise channel
5. Performance Parameter
6. Digital-to-Digital conversion
7. Digital-to-Analog Conversion

NOISE:

Noise is an another cause of impairment. Several type of noise such as thermal noise , induced noise , crosstalk and impulse noise , may corrupt the signal . Thermal noise is the random motions of electrons in a wire , which creates an extra signal not originally sent by transmitter. Induced noise comes from source such as appliances and motors. These devices act as a sending antenna , and the transmission mediums acts as the receiving antenna. Effect of one wire on the other is known as crosstalk . One wire acts as an sending antenna and the other as the receiving antenna. Impulse noise is a spike i.e. a signal with high energy in very short time that comes fromthe lightning, power lines and so on.



Signal-To-Noise Ration(SNR)

For finding the theoretical bit rate limit , we need to know the ratio of the signal power to the noise power . The signal-to-noise ratio is defined as

SNR = average signal power / average noise power.

SNR actually the ratio of what is wanted (signal) to what is not wanted(noise) . A high SNR means the signal is less corrupted by noise and a low SNR means the signal is more corrupted by noise.

SNR is the ratio of two powers , it is often described in the **decibel units** , SNR_{dB} defined as

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

Noiseless Channel: NYQUIST BIT RATE

The noiseless channel , the nyquist bit rate formula defines theoretical maximum bit rate i.e.

$$\mathbf{BitRate = 2 \times bandwidth \times \log_2 L}$$

Example : consider a noiseless channel with a bandwidth of 2000Hz transmitting a signal with two signal levels. The maximum bit rate can be calculated as

$$\mathbf{BitRate = 2 \times 2000 \times \log_2 2 = 4000bps}$$

Noisy Channel : Shannon Capacity

It determines the theoretical highest data rate for the noisy channel:

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

Example:

Consider a extremely noise channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that a signal is faint. For this channel the capacity C is calculated a**s follows:**

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

This means that the capacity of the given channel is zero regardless of the bandwidth . In other wordswe can say that, we cannot receive any data through this channel.

PERFORMANCE:

Bandwidth :

One characteristics that measures network performance is bandwidth. However , the term bandwidth can be used in two different context with two different measuring values : bandwidth in bits per second and bandwidth in hertz.

Bandwidth in Hertz :

Bandwidth in hertz is the range of frequencies contained in a single composite signal or the range of frequencies a channel can pass.

Bandwidth in Bits Per Second:

The term bandwidth can also refer to the number of bits per second that a link,a channel, or even a network can transmit .

Throughput:

The throughput is measure of how fast we can actually send the data through a network .

Latency (Delay) :

The delayorlatency is defines as 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 + queuing time + transmission time + processing delay

Propagation Time :

Propagation time measures at the time required for the bit to travel from source to the destination . The propagation time is calculated by dividing the distance by the propagation speed .

Propagation time = Distance / (Propagation speed)

The propagation speed of electromagnetic signals depends on the frequency of the signal and on the medium .

Example: what is the propagation time if the distance between the two points is 1200km? Assume the propagation speed in cable is 2.4 X 10^8 m/s.

Sol:

Propagation time = Distance / (Propagation speed)

Now ,

Propagation time = (1200 X 1000)/ 2.4 X 10^8 = 50 ms

Transmission speed:

In data communication we don't just send the 1 bit , we send the message . The first bit may take the propagation time to reach it's destination; the last bit also may take the same amount of time. However , there is a time between the fist bit leaving the sender and the last bit arriving at the receiver . The first bit leave earlier and arrive earlier ; the last bit leaves later and arrives later. Therefore , the transmission time of a message depends on the size of the message and the bandwidth of the channel.

Transmission time = (Message size/Bandwidth)

Example : what are the propagation time and the transmission time for 2.5KB message (an e-mail) if the bandwidth of the network is 1Gbps? Assume thedistance between the sender and receiver is 12000 Km and that of light travels at 2.4 X 10^8 m/s.

Sol:

Propagation time = (1200 X 1000)/ 2.4 X 10^8 = 50 ms

Transmission time = (2500 X 8) X 10^9 = 0.020 ms

Note: In this case because the message is short and bandwidth is high , the dominant factor is the propagation time not the transmission time . The transmission time can be ignored .

Queuing Time:-

It is the third component in latency, the time needed for each intermediate or end device to hold the message before it can be processed. The queuing time is not the fixed factor; it changed with the load imposed on the network. When there is heavy traffic on the network then the queuing time increases.

Digital-to-Digital Conversion

Line coding :

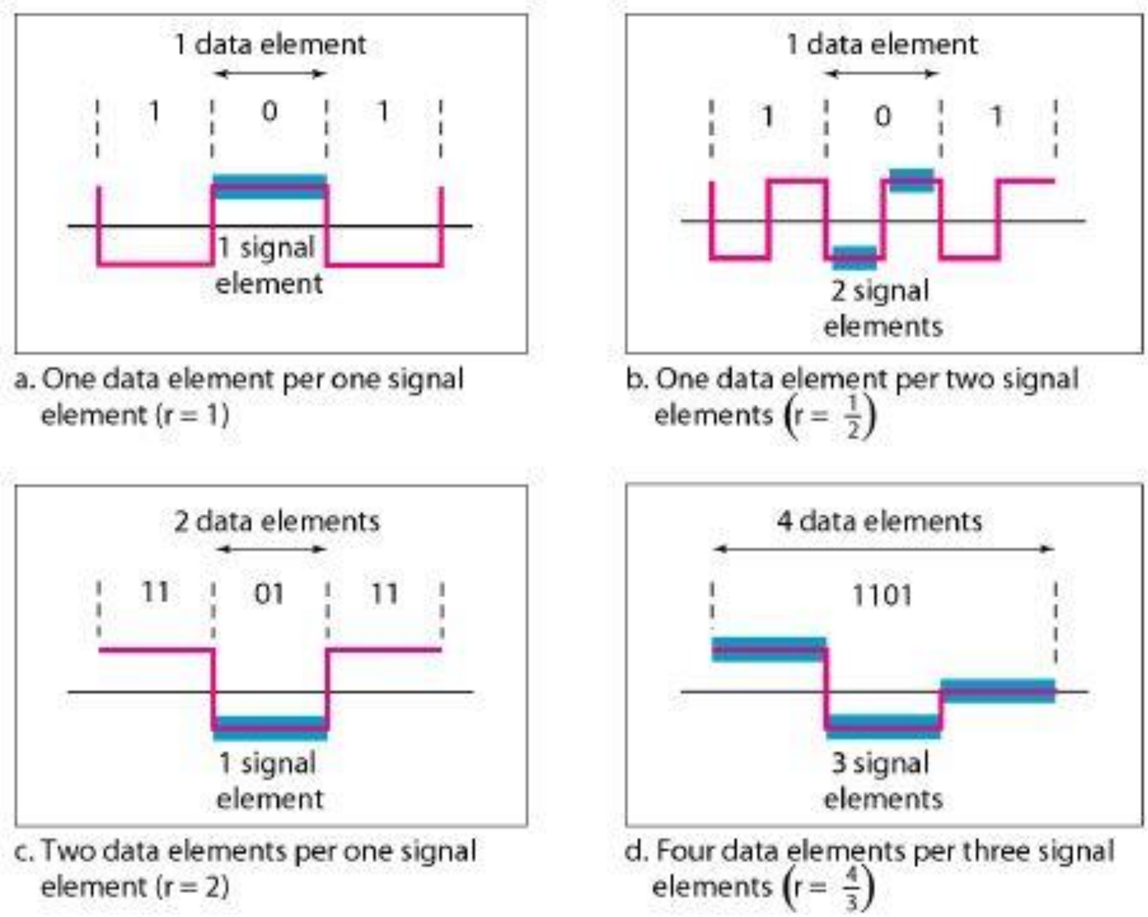
Line coding is the process of converting the digital data to the digital signal. We assume that data , is form of text, number ,graphic images , video or audio, are stored in computer memory as sequence of bits. Line coding converts a sequence of bits to a digital signal . At the sender , digital data are encoded into a digital signal ; at the receiver digital data is recreated by decoding the digital signal.

Signal Element Vs Data Element :

A data element is the smallest entity that can represented a piece of information ; this is the bit. In digital data communications , a signal element carries data element . Data elements are what we need to send; signal elements are what we can send . Data elements are to be carried; signal elements are the carriers.

We define a ratio r which is the number of data elements carried by the each signal element . One data element carried by the one signal element(r=1) . In part b of the diagram , we need two signal elements (two transitions) to carry each data element (r =1/2) . As signal element carries two data element (r=2)

Data element Signal element One data element carried by signal elements so r = ½	Data elements Signal elements One data element carried by signal element so r = 1/1 = 1	Data element Signal element 2 data elements carried by 1 signal element so r = 2/1 = 2



a. One data element per one signal element ($r = 1$)

b. One data element per two signal elements $\left(r = \frac{1}{2}\right)$

c. Two data elements per one signal element ($r = 2$)

d. Four data elements per three signal elements $\left(r = \frac{4}{3}\right)$

Data Rate(Bit Rate) vs signal Rate (Band Rate) :

The data rate defines the number of data elements(bit) sent in 1s, the unit is bit per second (bps). The signal rate is the number of signal elements send in 1s , the unit is the baud . There are several common terminology used in the literature . The data rate is sometimes also known as the bit rate; the signal rate is sometimes called the pulse rate , the modulation rate or the baud rate.

The relationship between data rate(N) and signal rate(S)

S = N/r

The worst case occurs when we need themaximum signal rate and the best case occurs when we need it minimum. In data communications we are usually , increased in the average case . We can formulate the relationship between data rate and signal rate as follows:

S_{ave} = c X N X (1/r)

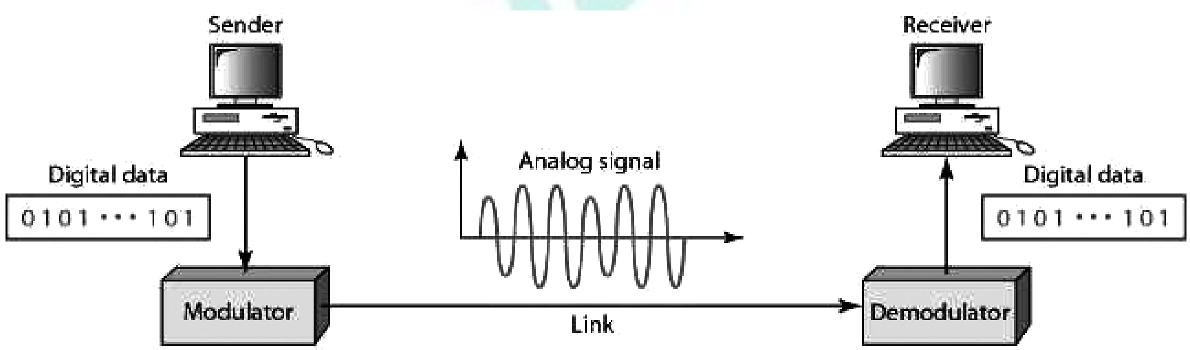
Example: Asignal is carrying data in which one data element is encoded as one signal element (r=1) . If the bit rate is 100kbps, what is the average value of the baud rate if c is between 0 and 1?

Sol: we assume that the average value of c = ½ . the baud rate is then

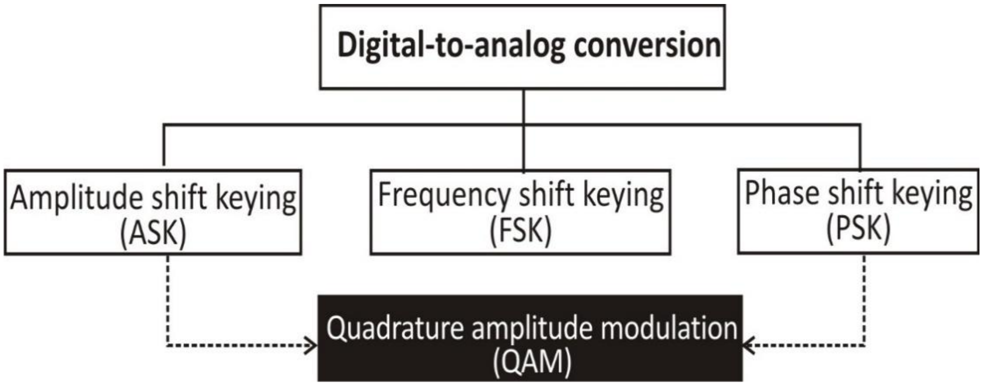
S = c X N X (1/r) = ½ X 100000 X1/1 = 50000 = 50kbaud .

Digital-To-Analog Conversion :

It is the process of changing one of the characteristics of an analog signal based on the information in digital data



Since wave is defined by the three characteristics : amplitude , phase and frequency. When we vary any one of these characteristics we create a different version of that particular wave. So , by changing one characteristics of simple electrical signal , we can use it to represent digital data. Any of the three characteristic can be altered in this way , giving us atleast three mechanisms for modulating digital data into analog signal: amplitude shift key(ASK) , phase shift key(PSK) and frequency shift key(FSK) . In addition , there is a fourth (and better) mechanism that combines changing both the amplitude and phase modulation (QAM) . QAM is the most efficient of the options and is the mechanism commonly used today.



Data Rate vs Signal Rate :

We define signal rate (baud rate) and the data rate (bit rate) as we did or digital transmission . the relationship between them is as follows :

$$S = N \times 1/r \text{ baud}$$

Where N is the data rate(bps) and r is number of data element carried in one signal element .

Example:

An analog signal carries 4 bits per signal element. if 1000 signal elements are sent per second , find the bit rate.

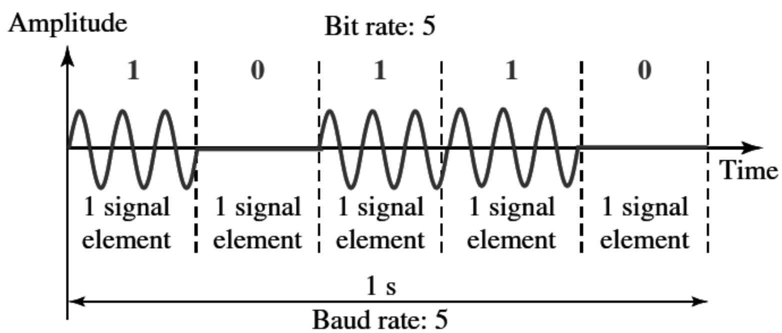
Sol:

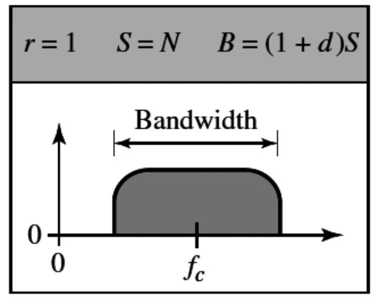
Here r = 4, S=1000 and N is unknown . we can find the value of N from

$S = N \times (1/r)$ or $N = S \times r = 1000 \times 4 = 4000$bps.

Amplitude Shift Keying :

In ASK , the amplitude of the carrier signal varied to create signal elements . Both the frequency and the phase remain constant while the amplitude changes .





Bandwidth for ASK:

The bandwidth is proportional to the signal rate i.e. baud rate, there is normally another factor involved, called d , which depends on the modulation and filtering process. The value of d , varies between 0 and 1.

Example:

We have an available bandwidth of 100kHz which spans from 200 to 300 kHz . what are the carrier frequency and bit rate if we modulated our data by using ASK with d = 1?

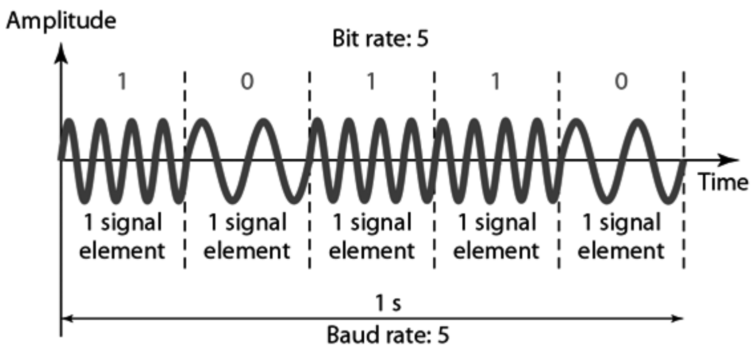
Sol:

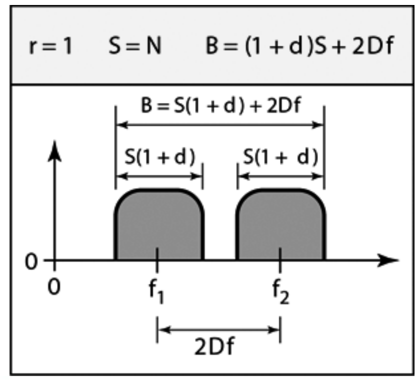
The middle of the bandwidth is located at 250kHz . This means that our carrier frequency can be as f_c = 250 kHz . we can use the formula for the bandwidth to find the bit rate (with d = 1 and r =1)

B = (1+d)X S = 2 X N = 100 → N = 50kbps

Frequency Shift Keying :

The frequency of the carrier signal is varied to represent the data. The frequency of modulated signal isconstant for the duration of one signal element but changes for the next signal element if data element changes





Bandwidth for FSK:

The modulation creates a non-periodic composite signal with the continuous frequencies. We can think of FSK as two ASK signal each with its own carrier frequency (f_1 or f_2) . If the difference between the two frequencies is $2\Delta_f$, then the required bandwidth is

$$B = (1 + d)\ X\ S + \Delta\Phi$$

Example: we have an available bandwidth of 100 kHz which spans from 200 to 300 kHz . what should be the carrier frequency and bit rate if we modulated or data by using FSK with d = 1?

Sol: we are modulating by using FSK . The midpoint of the bandwidth is at 250kHz . we choose $2\Delta_f$ to be 50 kHz ; this means :

$B = (1+d)\ X\ S + 2\Delta_f = 100 \rightarrow 2S = 50kHz \rightarrow S = 25kbaud \rightarrow N = 25kbps.$