Computer Networks (ITPC-205)

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Physical Layer

Data & Signal, Transmission Impairments, and Channel Capacity

Data and Data Types

- What is Data?

  Data is an entity that conveys some meaning based on some mutually agreed upon the rules/conventions between a sender and a receiver.

- Today's, data comes in a variety of forms such as text, graphics, audio, video and animation.
- Data types:
  - Data can be Analog and Digital.

Analog and Digital data

- Analog Data:

  Analog data refers to information that is continuous and take on continuous values.

- Digital data:

  Digital data refers to information that has discrete states and take on discrete values.

Analog and Digital Signals

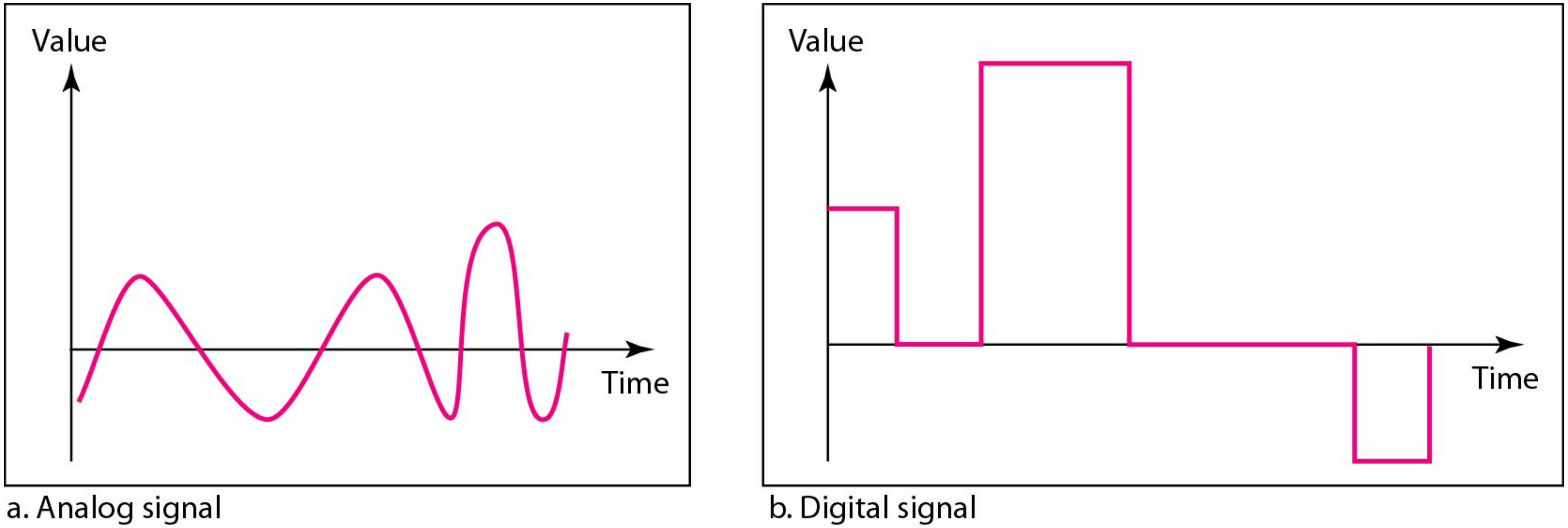
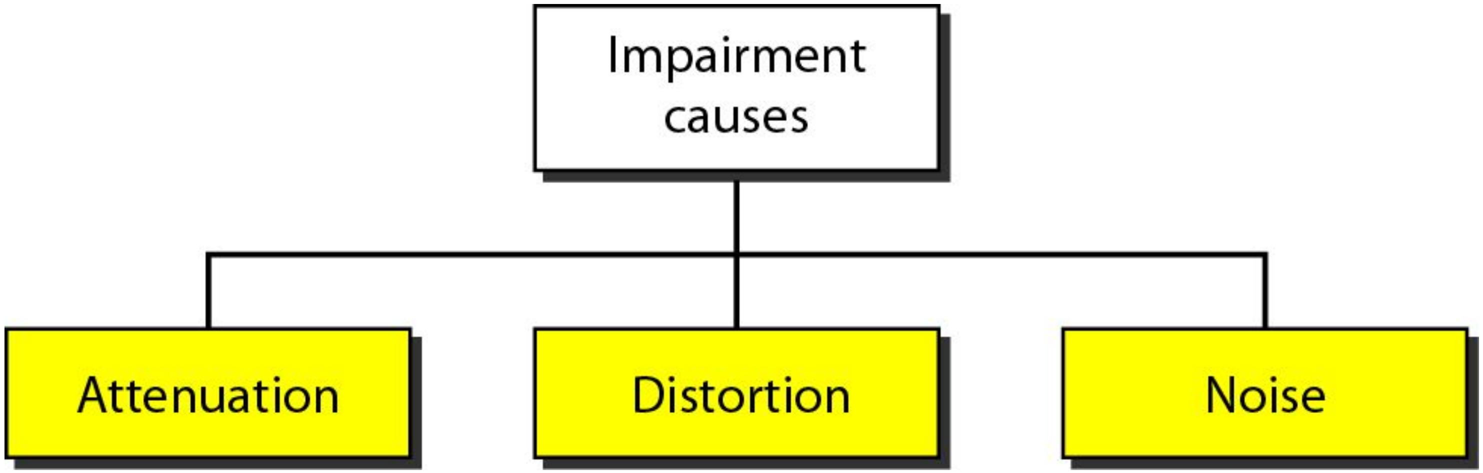


Figure: Analog signal can take infinite data values whereas digital signal takes limited number of discrete value

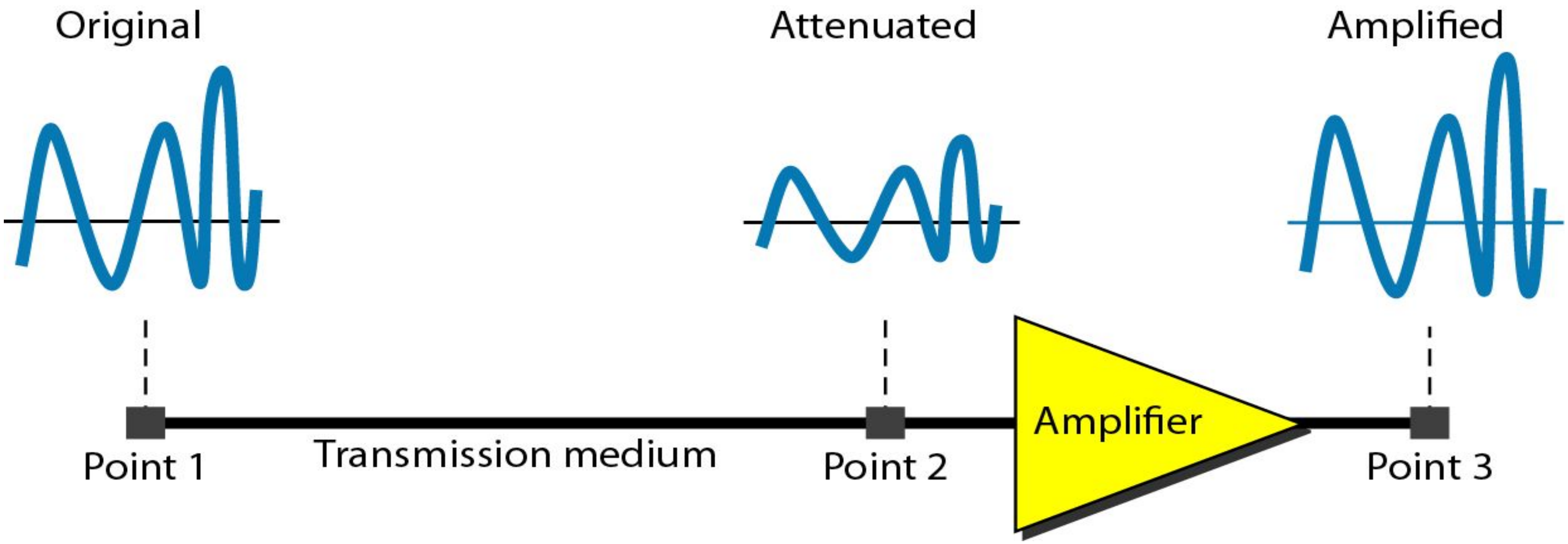
- Distinguish between data and signal.

Transmission Impairments

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



Attenuation



- Measurement of Attenuation: To show the loss or gain of energy the unit “decibel” is used.

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

P_1 - input signal

P_2 - output signal

Example 1

- Suppose a signal travels through a transmission medium and its power is reduced to one-half. This means that P2 is (1/2)P1. In this case, the attenuation (loss of power) can be calculated as

$$\boxed{10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{0.5 P_1}{P_1} = 10 \log_{10} 0.5 = 10(-0.3) = -3 \text{ dB}}$$

- A loss of 3 dB (–3 dB) is equivalent to losing one-half the power.

Example 2

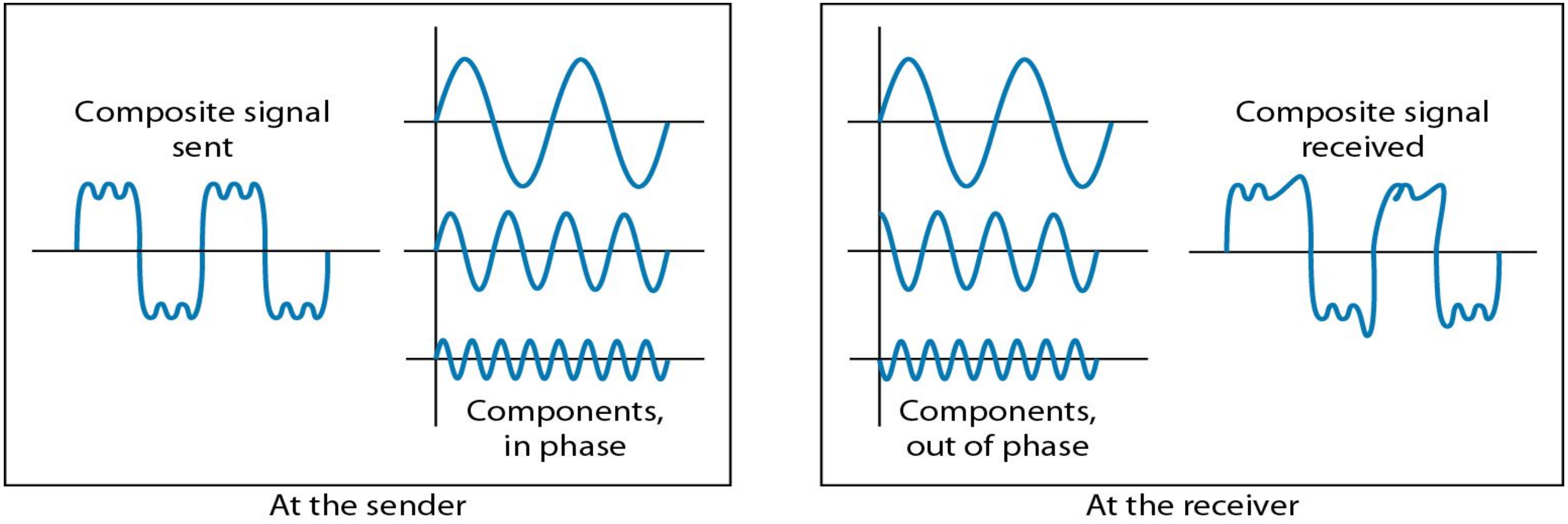
- A signal travels through an amplifier, and its power is increased 10 times. This means that P2 = 10P1 . In this case, the amplification (gain of power) can be calculated as

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

$$\boxed{= 10 \log_{10} 10 = 10(1) = 10 \text{ dB}}$$

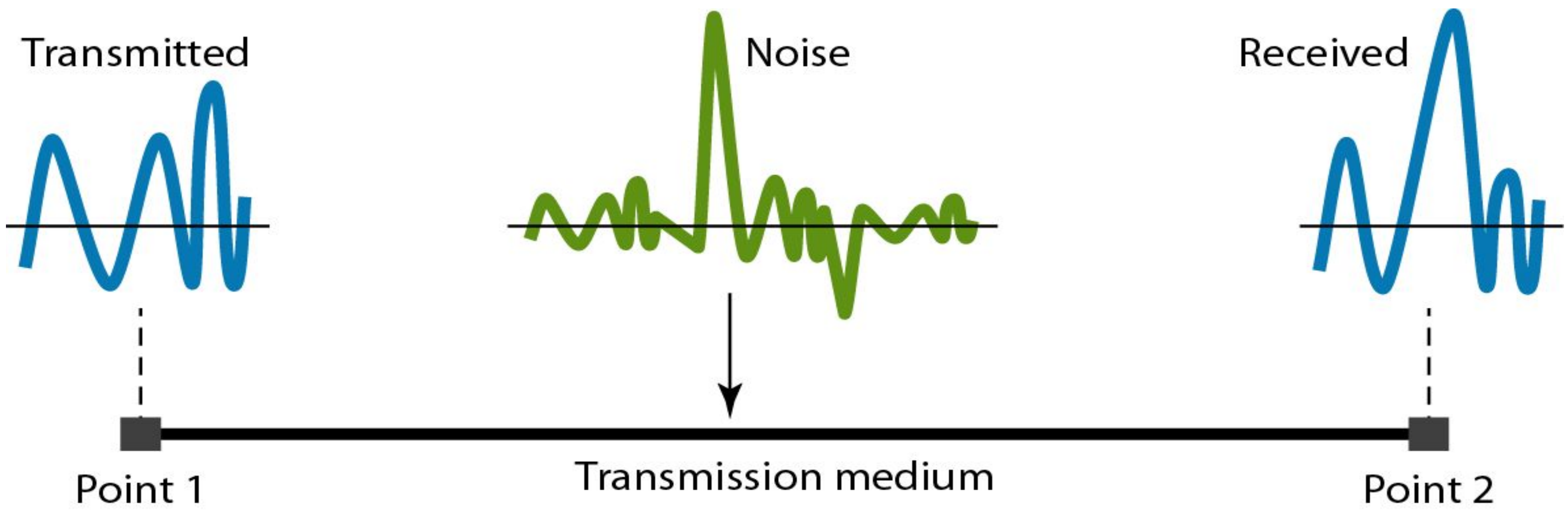
Distortion

- Distortion means that the signal changes its form or shape



Noise

- Several types of noise, such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal.



Channel Capacity

- Channel capacity is concerned with the information handling capacity of a given channel.
- A very important consideration in data communications is how fast we can send data over a channel.
- Data rate depends on three factors:
  - The bandwidth available
  - The level of the signals we use
  - The quality of the channel (the level of noise)

- We have two models to calculate the data rate :
  - Nyquist
  - Shannon

Nyquist Theorem

- It is always a Noiseless Channel.
- Nyquist theorem states that:

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

C= capacity in bps

B = bandwidth in Hz

L=No. of signal levels used to represent data

Example 3

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

$$\boxed{\text{BitRate} = 2 \times 3000 \times \log_2 2 = 6000 \text{ bps}}$$

- Consider the same noiseless channel transmitting a signal with four signal levels (for each level, we send 2 bits). The maximum bit rate can be calculated as

$$\boxed{\text{BitRate} = 2 \times 3000 \times \log_2 4 = 12{,}000 \text{ bps}}$$

Example 4

- We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need?
- Solution: We can use the Nyquist formula as shown:

$$265{,}000 = 2 \times 20{,}000 \times \log_2 L$$

$$\log_2 L = 6.625 \qquad L = 2^{6.625} = 98.7 \text{ levels}$$

Shannon Capacity

- It is always a Noisy Channel.
- Shannon's theorem gives the capacity of a system in the presence of noise.

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

- **Example 5:** Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is weak. For this channel the capacity C is calculated as

$$\boxed{C = B \log_2 (1 + \text{SNR}) = B \log_2 (1 + 0) = B \log_2 1 = B \times 0 = 0}$$

Example 6

- We can calculate the theoretical highest bit rate of a regular telephone line. A telephone line normally has a bandwidth of 3000. The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

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

Note

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