Topic 2: Physical Layer

Digital Transmission in Computer Networks

- The purpose is to transfer a data sequence of 0s and 1s from a transmitter to a receiver
- It uses pulses or sinusoids to transmit binary information over a physical transmission medium
- We are particularly interested in the bit rate measured in bits/second

Bit Rate vs. Baud Rate

- Definitions
  - Bit Rate = # of bits transmitted per second
  - Baud Rate = # of signal transitions per second

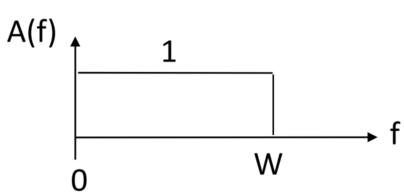
- Baud Rate depends on the channel bandwidth

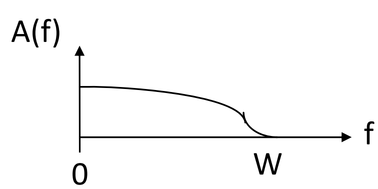
- Bit Rate = (Baud Rate) × (# bits per pulse)
  - It depends on the channel bandwidth as well as the coding scheme

Transmission Channel and Channel Bandwidth

- A transmission channel can be characterized by its effect on input sinusoidal signals (tones) of various frequencies

- The ability of the channel to transfer a tone of frequency f is given by the amplitude-response function (A(f)), which is defined as the ratio of the amplitude of the output tone to the amplitude of the input tone





- The bandwidth of a transmission channel (W) is the range of frequencies that is passed by the channel

Nyquist Rate

- The fastest rate at which (ideal) pulses can be transmitted over the channel (called the Nyquist Rate) is:

$$r_{max} = 2W \text{ pulses/second}$$

Multilevel Pulse Transmission

- Assume channel bandwidth of W
- If pulse amplitudes are either -A or +A, then each pulse conveys 1 bit,
  Bit Rate = (2W pulses/sec) $\times$ (1 bit/pulse) = 2W bps
- If amplitudes are from {-A, -A/3, +A/3, +A}, then each pulse conveys 2 bits,
  Bit Rate = (2W pulses/sec) $\times$ (2 bits/pulse) = 4W bps
- By going with $M = 2^m$ amplitude levels, we achieve
  Bit Rate = (2W pulses/sec) $\times$ (m bits/pulse) = 2mW bps
- In the absence of noise, the bit rate can be increased without limit by increasing the pulse level m

Noise & Reliable Communication

- All physical systems have noise
  - Electrons always vibrate at non-zero temperature
  - Motion of electrons induces noise
- Presence of noise limits the accuracy of measurement of received signal amplitude
- Noise places a limit on how many amplitude levels can be used in multilevel pulse transmission
- Errors occur if signal separation is comparable to noise level

- Bit Error Rate (BER) increases with decreasing Signal-to-Noise Ratio (SNR)

Shannon Channel Capacity

$$C = W \log_2 (1 + SNR) \text{ bps}$$

- Channel Bandwidth (W) & Signal to Noise Ratio (SNR) determine C

- If transmission rate R > C, reliable communication is not possible
- If transmission rate $R \leq C$, arbitrarily reliable communication is possible
  - "Arbitrarily reliable" means the BER can be made arbitrarily small through sufficiently complex coding

- The relation between R_{max} and C is used as a measure of how well a communication system is designed

Example

- Find the Shannon channel capacity for a telephone channel with $W = 3.4$ KHz and SNR (dB) = 40 dB