Data Communication

TRANSMISSION IMPAIRMENTS

Transmission Impairments

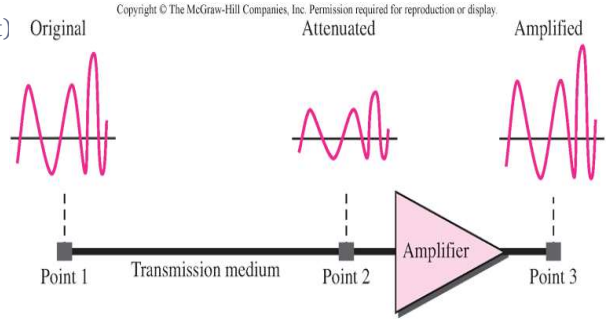
- signal received may differ from signal transmitted causing:
  - analog - degradation of signal quality
  - digital - bit errors
- most significant impairments are
  - attenuation and attenuation distortion
  - Limited bandwidth
  - delay distortion
  - noise

Attenuation

- where signal strength falls off with distance
- depends on medium
- received signal strength must be:
  - strong enough to be detected
  - sufficiently higher than noise to receive without error
- so increase strength using amplifiers/repeaters
- is also an increasing function of frequency
- so equalize attenuation across band of frequencies used
  - eg. using loading coils or amplifiers

Attenuation-2

- Decibel- Relative Power Measurement
  - **$dB=10 \log_{10} (P2/P1)$**
  - P1: transmitted signal power (watt)
  - P2: received power (watt)
  - if Negative it is attenuation
  - if Positive it is gain
  - No dimension (unit)



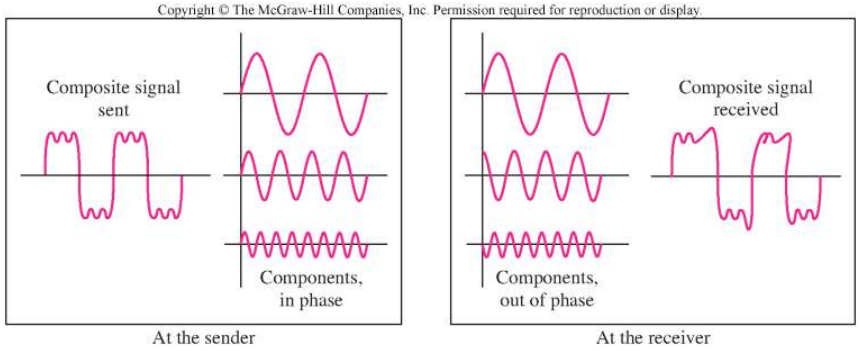
Limited Bandwidth

- A signal contains more frequency component.
- A transmission channel or medium has a limited bandwidth
- The signal, wanted to be transmitted, can be transmitted only the frequencies the channel or medium permits
- This impairment has a distortion on received signal

Delay Distortion

- only occurs in guided media
- propagation velocity varies with frequency
- hence various frequency components arrive at different times
- particularly critical for digital data
- since parts of one bit spill over into others
- causing intersymbol interference

Delay Distortion-2



Noise-1

- additional signals inserted between transmitter and receiver
- thermal
  - due to thermal agitation of electrons
  - uniformly distributed
  - Can not be eliminated
- intermodulation
  - signals that are the sum and difference of original frequencies sharing a medium

Noise-2

- crosstalk
  - a signal from one line is picked up by another line
- impulse
  - irregular pulses or spikes
    - eg. external electromagnetic interference
  - short duration
  - high amplitude
  - a minor problem for analog signals
  - but a major source of error in digital data
    - a noise spike could corrupt many bits

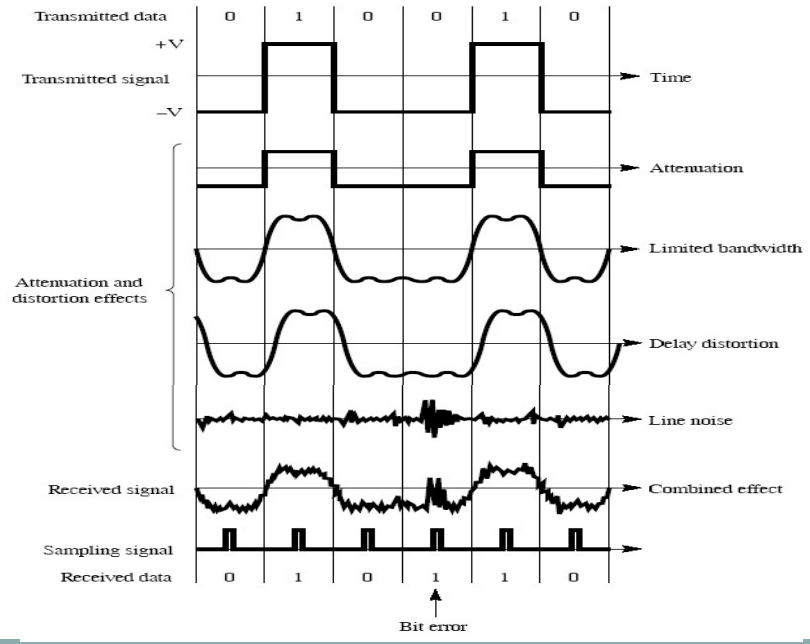
Channel Capacity-1

- max possible data rate on comms channel
- is a function of
  - data rate - in bits per second
  - bandwidth - in cycles per second or Hertz
  - noise - on comms link
  - error rate - of corrupted bits
- limitations due to physical properties
- want most efficient use of capacity

Channel Capacity-2

Concepts:

- data rate
  - in bits per second
  - The transmit and receive speed of data
- Bandwidth
  - in cycles per second or Hertz
  - Constrained by the transmitter and the nature of the medium.
- Noise
  - Average level of noise on communications link
- error rate
  - Rate of corrupted bits



Nyquist Bandwidth

- consider noise free channels
- if rate of signal transmission is 2B then can carry signal with frequencies no greater than B
  - ie. given bandwidth B, highest signal rate is 2B
  - for binary signals, 2B bps needs bandwidth B Hz
- can increase rate by using M signal levels
- Nyquist Formula is: $C = 2B \log_2 M$
- so increase rate by increasing signals
  - at cost of receiver complexity
  - limited by noise & other impairments

Ex: M=8 (used in some modems) and for B=3100 Hz, C is calculated as C=18600 bps

Shannon Capacity Formula

- consider relation of data rate, noise & error rate
  - faster data rate shortens each bit so bursts of noise affects more bits
  - given noise level, higher rates means higher errors
- Shannon developed formula relating these to signal to noise ratio (in decibels)
- $SNR_{db} = 10 \log_{10}(\text{signal/noise})$
- Capacity $C = B \log_2(1+SNR)$
  - theoretical maximum capacity
  - get lower in practise

Shannon Capacity Formula

- Suppose for a telephone line, BW=3000 Hz and S/N=35 dB (3126). What is the max bit rate?

$C=3000*\log^2(3127)$

C= 34.8 Kbps

Nyquist and Shannon Formula Example

For a channel spectrum between 3 Mhz and 4 Mhz, SNR is 24 dB.

B=4-3 = 1 MHz.

$SNR_{dB}=24=10*\log_{10}(SNR)$

SNR=251

- Using Shannon formula:

$C=10^6*\log2(1+251)=10^6*8=$ 8 Mbps

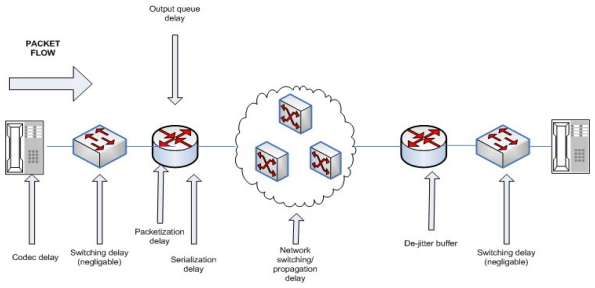
- What is M?

$C=2*B*\log_2 M$

$8*10^6=2*10^6*\log2M$ $4=\log_2 M$ M=16

Delay in Networks

- Delay is the time of data transmission between source and target.
- Delay is an important criteria of networks
- Delay varies according to traffic density, errors etc.
- Maximum delay, Mean delay, Delay Jitter (değişim, sapma)
- Delay sources:
  - Transmission Delay
  - Propagation Delay
  - ARQ Delay
  - Process Delay
  - Queue Delay



Transmission and Propagation Delay

- Propagation delay is usually constant on a network
- The best propagation is for light. it is 3x10^8 m/s
- For Twisted pair or coaxial cable it is about 2*10^8 m/s
- Tp=length of bus (m) / Propagation Speed (m/s)
- Transmission delay is time delay of sending frame at bitrate of bus. It depends on frame length.
- Tx=number of transmitting bits (N) / Bus speed (bps)

Example

- A frame bloke of 1000 bits is going to transmit between two DTE. Calculate the Tp and Tx for given mediums
  - 100 m twisted pair and 10 kbps transmission speed
  - 10 km coaxial cable and 1 Mbps transmission speed
  - 50000 km satallite line and 10 Mbps transmission speed
  - For electrical signals propagation speed is 2*10^8 m/s
  - For satellite line propagation speed is 3*10^8 m/s

İletim ve Yayılım Gecikmeleri - Örnek

- **Örnek1:** 2.5kbyte bir e-mail için 1Gbps bant genişliği olan ağda yayılım ve iletim gecikmesi değerleri nedir? Alıcı verici arası mesafe 12000km ve yayılım hızı $2.4*10^8$m/s'dir.
  - Yayılım gecikmesi = $(12000*10^3)/2.4*10^8$ = 50 ms
  - İletim gecikmesi = $(2500*8)/10^9$ = 0.02 ms
  - Mesaj boyutu kısa, bant genişliği yüksek olduğu için dominant (baskın) faktör yayılım gecikmesidir. İletim gecikmesi ihmal edilebilir.
- **Örnek2:** 5Mbyte bir resim için 1Mbps bant genişliği olan ağda yayılım ve iletim gecikmesi değerleri nedir? Alıcı verici arası mesafe 12000km ve yayılım hızı $2.4*10^8$m/s'dir.
  - Yayılım gecikmesi = $(12000*10^3)/2.4*10^8$ = 50 ms
  - İletim gecikmesi = $(5000000*8)/10^6$ = 40 s
  - Mesaj boyutu büyük, bant genişliği düşük olduğu için dominant (baskın) faktör iletim gecikmesidir. Yayılım gecikmesi ihmal edilebilir.

Automatic Repeat Request Delay

Ağ içerisinde düğümler arasında güvenli veri iletiminin sağlanamaması (verilerin bozulması, zamanında hedefine ulaşmaması) durumunda ilgili paketin/çerçevenin tekrar iletimi gerekir.

- Idle RQ
  - Send and Wait (Stop and Wait)
- Continuous RQ
  - Selective Repeat
  - Go Back N