Badji Mokhtar University Annaba
Electronics Department

Level 3: Telecommunication
Module: Telecommunication systems and networks

Telecommunication systems and networks, Lecture 2

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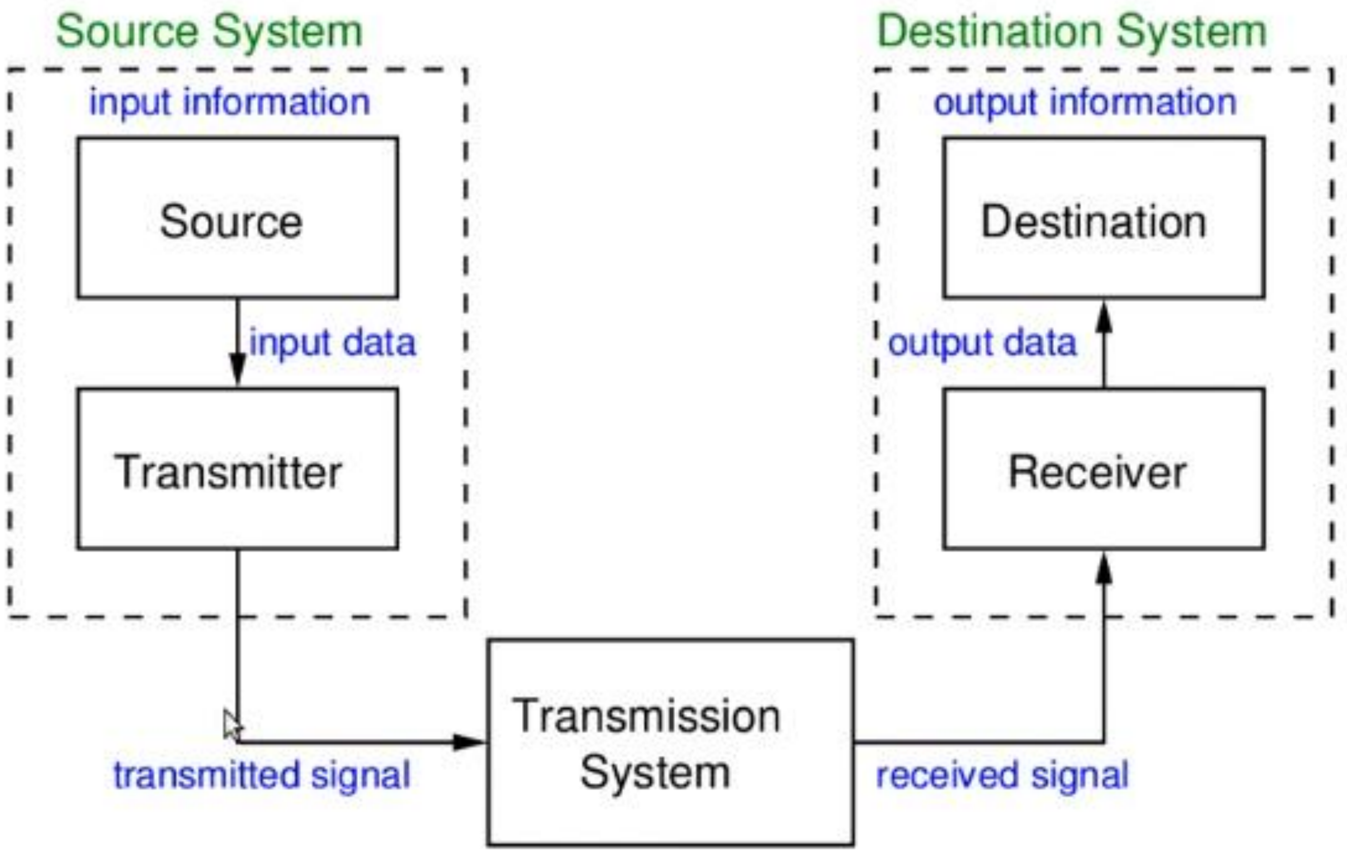
Outline

- Communication system
- Terminology
- Analog to Digital
- Bandwidth and bitrate
- Impairments
- Capacity

Communication system



Communication system

Aim: transfer information from source to destination

Source: Device that generates data to be transmitted

Transmitter: Converts data from source into transmittable signals

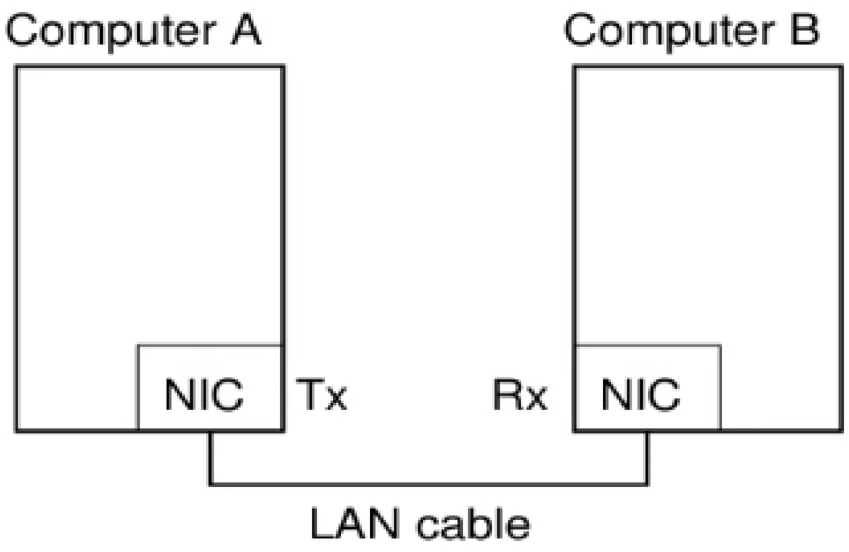
Transmission system: Carries data from source to destination

- Maybe simple as a single link/cable
- Or a complex network, e.g. the Internet

Receiver: Converts received signal into data

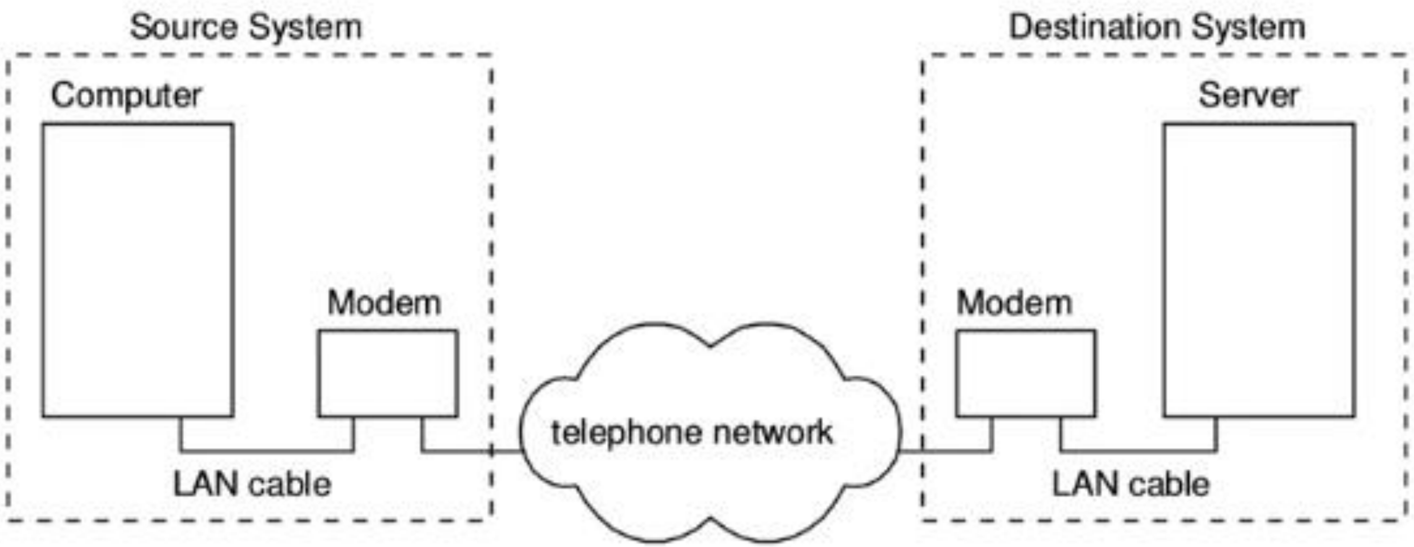
Destination: Takes and uses incoming data

Example: Computer to Computer



- Transmitter (Tx) is built into source computer (Network Interface Card)
- Recevier (Rx) is built into destination computer
- Transmission system is single link between two computers

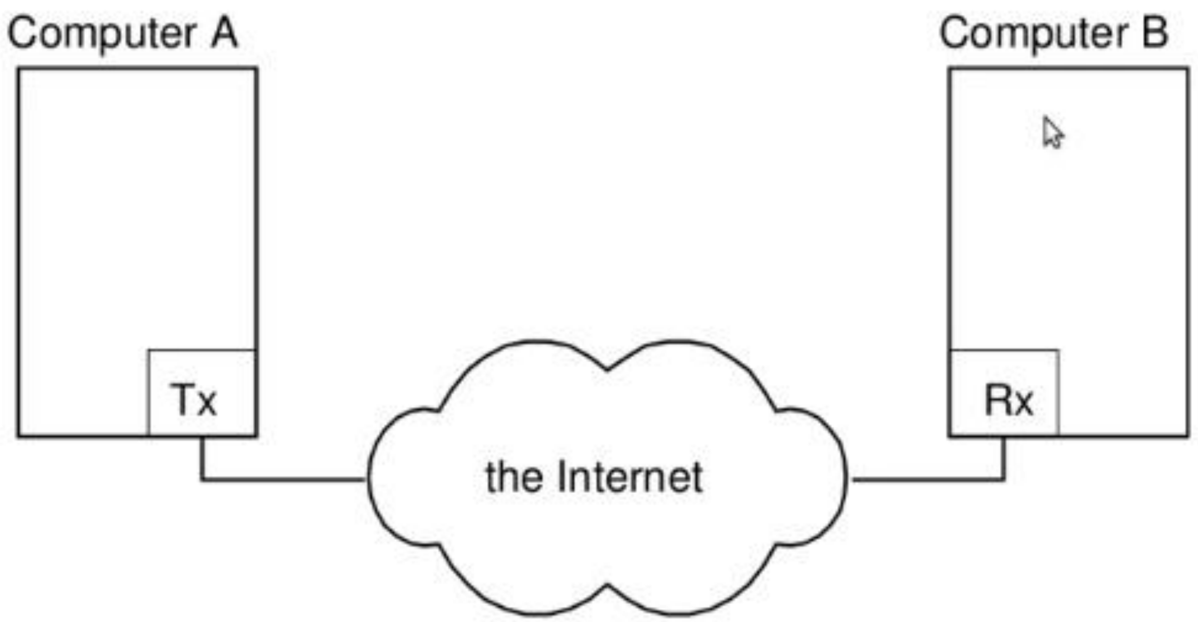
Example: Old Dialup Connection



- Source and transmitter are separate devices (similar at destination)
- Transmission system is telephone network

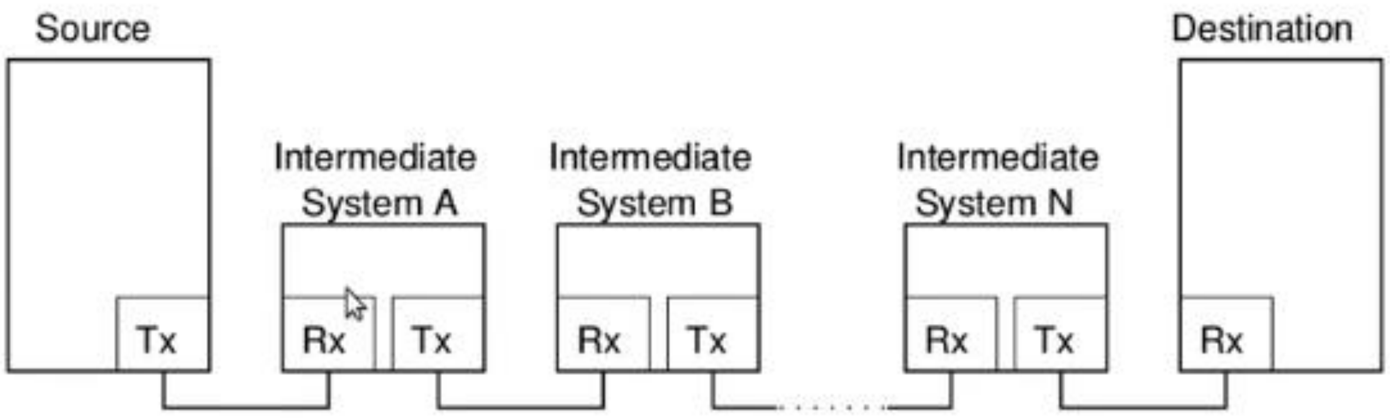
Communication system

Example: Communications via the Internet



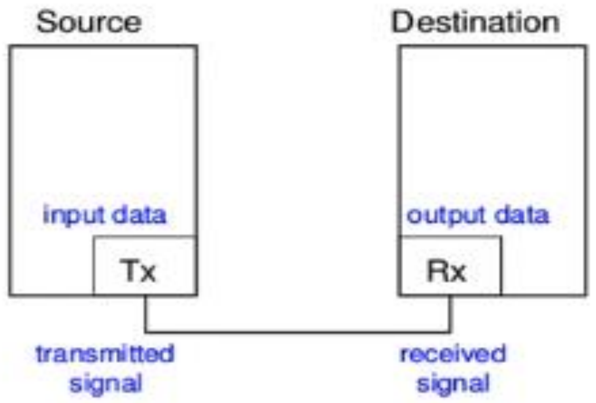
- Source and transmitter may support different technologies
- Transmission system is the Internet

General Model for Communications via a Network



- Source system generates data
- Intermediate systems receive signal from previous system and then transmit to next system
- Destination system receives and processes the data
- Source and destination are connected via multiple transmission systems (or links) to form a network

Challenges with Link Communications



- How to convert information into transmittable signals?
- What are the characteristics of signals?
- What transmission media to use?
- How to efficiently encode data as signals?
- How to know who is at other end?
- How to deal with errors?
- How to share media amongst two or more transmitters?

How big is a ...

- Web page?
- Email?
- Photo?
- Song?
- Audio CD?
- TV show?
- Movie?

Effective Data Communications

Delivery: the data must be delivered to the correct destination

Accuracy: the data received must be accurate representation of the data sent

Timeliness: the data should be delivered within a reasonable time

Types of Internet Applications

Traditional Internet-Based Applications

- File transfer, email, web browsing, remote login, database
- Accuracy is most important

Multimedia or Real-time Applications

- Audio/video streaming, voice/video calls, gaming, collaborations
- Timeliness is most important

Transmission Terminology

- Data transmission occurs between a transmitter and a receiver via a medium.
- Data is transmitted in form of electromagnetic waves or signals

- Medium may be:
  - Guided: wires/cables, e.g. twisted pair, coaxial cable, optical fibre.
  - Unguided: wireless, e.g. air, water, vacuum.

- Configuration may be:
  - Point-to-point: only 2 devices share the same medium.
  - Multipoint: more than 2 devices share the medium

- Direction of communication may be:
  - Simplex: one direction, e.g. television.
  - Half duplex: both directions, but only one way at a time.
  - Full duplex: both directions at the same time, e.g. telephone.

Electromagnetic waves

- Transmitter generates electromagnetic signals, which is transmitted over the medium
- Electromagnetic signals represent data
- Electromagnetic signal consists of one or more signal component.
- Electromagnetic signals can be represented in two domains:
  - Time domain: signal intensity vs time
  - Frequency domain: Peak signal intensity of component vs frequency

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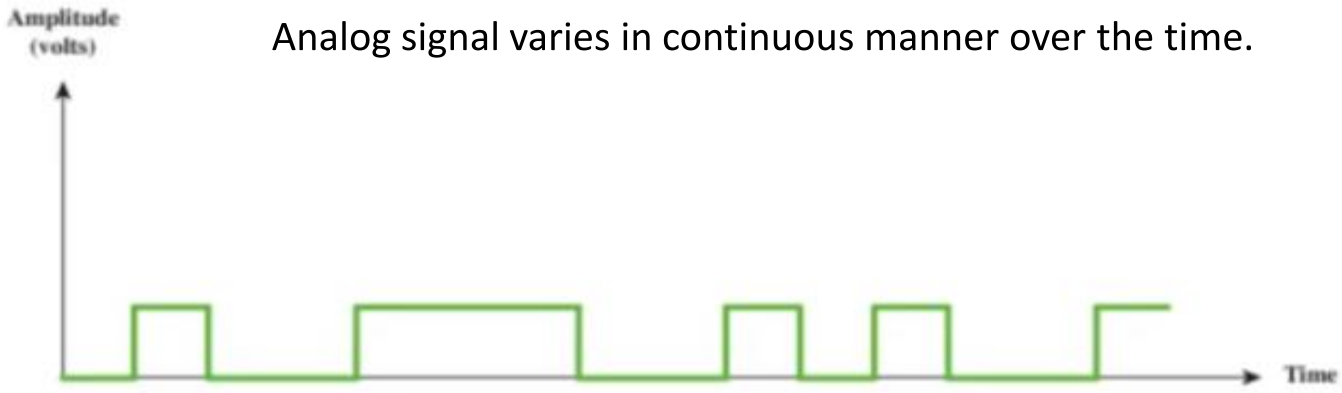
Analog to Digital

Analog and Digital waveforms

(a) Analog

Analog signal varies in continuous manner over the time.



(b) Digital

Digital signal maintains constant level for some period then changes to another constant level, in a discrete manner.

Trade-offs

Bandwidth

- Digital signal has infinite bandwidth; transmission systems impose limits of transmitted signals.
- Bandwidth is a limited resource
- Greater the bandwidth, greater the cost.

Data Rate

- Digital data is approximated signal if limited bandwidth.
- Greater the bandwidth, greater the data rate

Accuracy

Receiver must be able to interpret received signal, even with transmission impairments.

Transmission impairments

- Received signal may be different from the transmitted signal causing:
  - Analog: degradation of the signal quality
  - Digital: bit errors

- Most important impairements:
  - Attenuation and attenuation distortion
  - Delay distortion
  - Noise

Attenuation

- Signal strength decreases gradually with extended distances
- Important conditions to Manufacturing a transmission system:
    1. Received signal has sufficient strength to be interpreted by the received
    2. Power of the received signal is significantly higher than the power of the received noise.
- Attenuation distortion is a problem of analog signals:
    - Attenuation along different frequencies
    - Received signal has different strengths
    - Apply equalisation to overcome

Noise

Thermal Noise

- Due to thermal agitation of electrons
- Present in all transmission devices and media
- Function of temparature:

$$N = kTB$$

Where k= Boltzmnan's constant ($1.38 \times 20^{-23} J/K$),B is bandwidth and T is temperature in kelvins.

Intermodulation noise

- Caused when signals of diffrent frequencies share the same medium

Noise

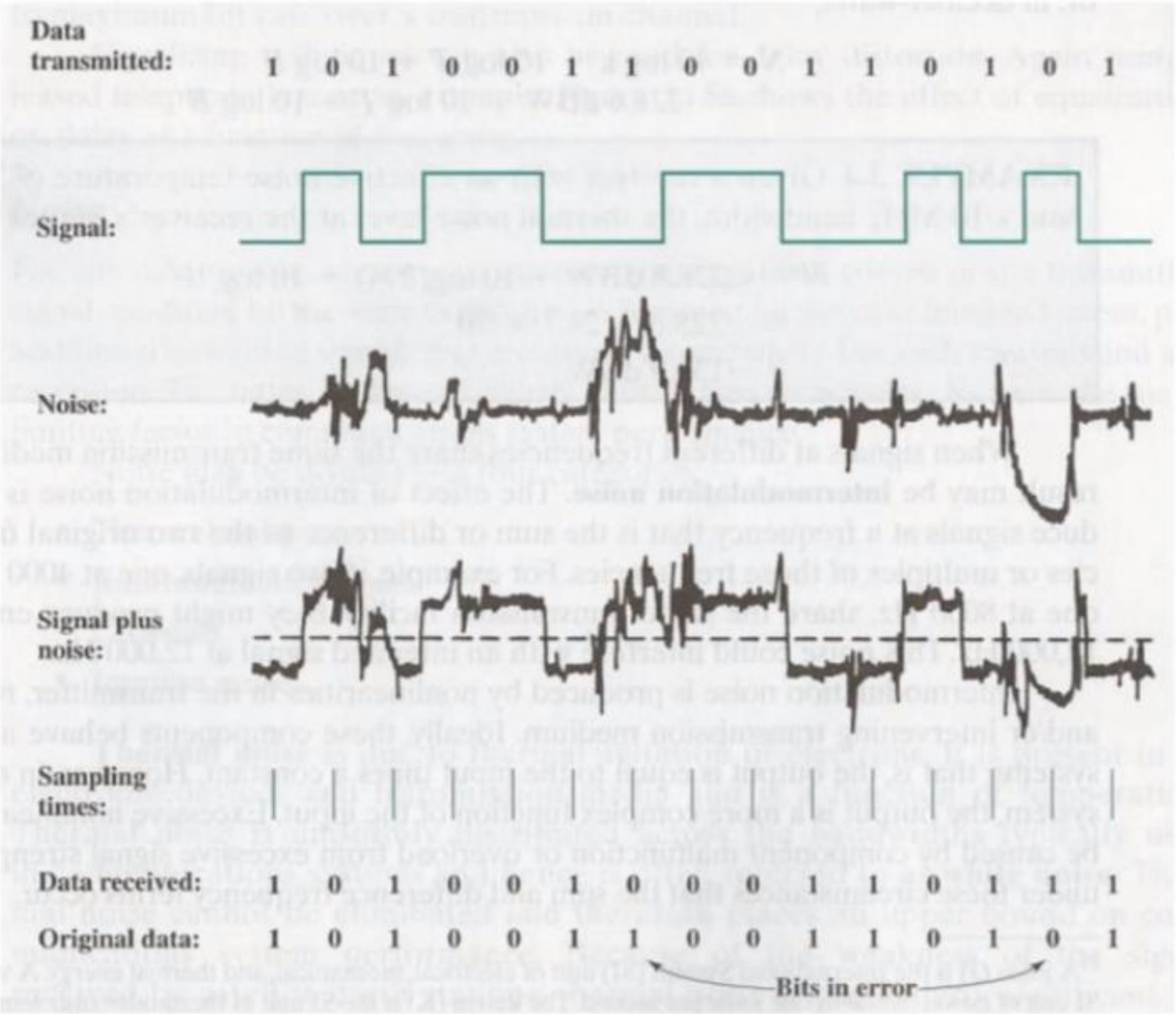
Crosstalk

- Unwanted coupling of different signals

Impulse noise

- Short peak of noise, e.g. lightning, electrical disturbances, flaws in communications system.

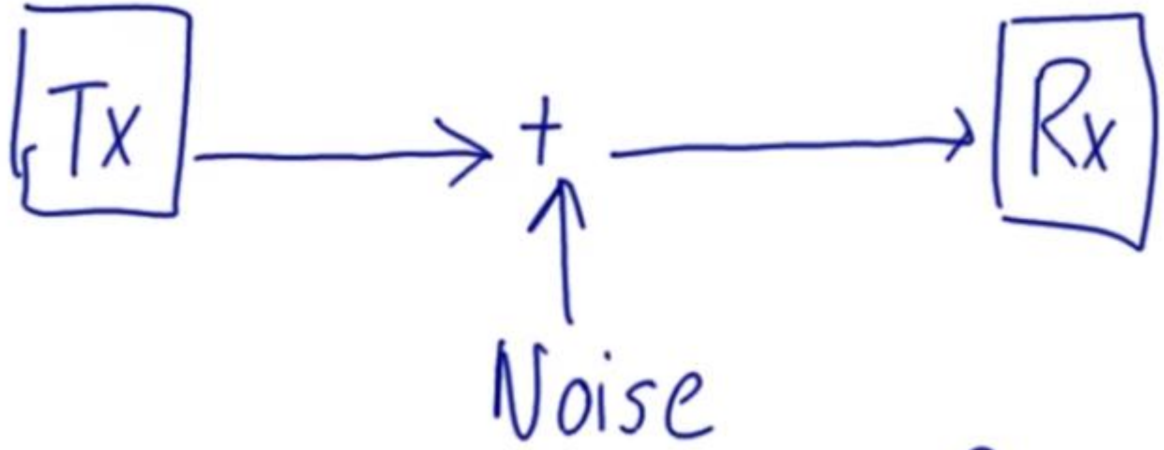
Effect of noise on a digital signal



Example

Tx: 1 −5v
0 +5v

1bit: 1ms



Rx: if −ve, 1
if +ve, 0

Channel Capacity

- Channel capacity: maximum data rate at which data can be transmitted over a given communication channel.

- Relates:
  - Data rate, C [bits per second]
  - Bandwidth, B [Hertz]
  - Noise
  - Error rate

- Two theoretical models:
  Nyquist Capacity: assumes noise-free (noiseless) enviroment
  Shannon Capacity: considers noise

Nyquist Capacity

- Assumes that channel is noise free
- Given a bandwidth of B, the highest signal rate is 2B.
- Single signal element may carry more than 1 bit; signal with M levels may carry $\log_2 M$ bits

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

- Tradeoffs
  - Increasing the bandwidth, increases the data rate
  - Increasing the signal levels, increases the data rate
  - Increase the signal levels, harder for receiver to interpret the bits

Example

modem $\quad B = 3100\ Hz$

$M = 2$

$$C = 2B \times \log_2(M)$$
$$= 2 \times 3100 \times \log_2(2)$$
$$= 6200\ b/s$$

Example

$m = 3$

$+1$	:	1	11
0	:	—	10
-1	:	0	00

$$M = 4 : \quad C = 2 \times 3100 \times \log_2(4)$$

$$= 12{,}400 \text{ b/s}$$

$$B = 3100\ Hz\ ,\ C = 55{,}800\ b/s$$

$$C = 2 \times B \times \log_2(m)$$

$$55{,}800 = 2 \times 3{,}100 \times \log_2(m)$$

$$\log_2(M) = \frac{55{,}800}{2 \times 3100}$$

$$= 9$$

$$M = 512$$

Shannon Capacity

- With noise, some bits may be corrupted; higher data rate, more corrupted bits
- Increasing signal strength to overcome noise
- Signal-to-noise ration:

$$SNR = \frac{\mathrm{signalpower}}{noisepower}$$

- Shannon Capacity:

$$C = \mathrm{B}\log_2(1 + SNR)$$

- Tradeoffs:
  - Increasing the bandwidth or signal power, increases the data rate
  - Increase of noise, reduces the data rate
  - Increasing bandwidth, allows more noise
  - Increasing the signal power may cause intermodulation noise

Example

s(t) volts

Watts $P = V \times A$

Tx Signal : 10 W

Attenuated Signal : 5 W

Noise signal : 1 W

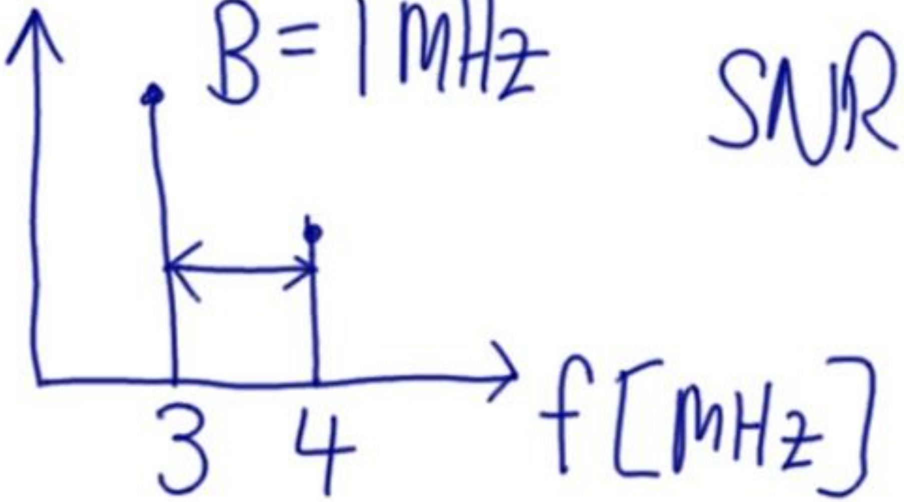
Signal-to-noise ratio, SNR : $\frac{5W}{1W}$

Example

Tx :

$B = 1\,MHz$

$SNR = 251$



$$C = B \log_2(1 + SNR)$$
$$= 1 \times 10^6 \times \log_2(1 + 251)$$
$$= 8\ Mb/s$$

Shannon:

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

$$= 1 \times 10^6 \times \log_2(1 + 251)$$

$$= 8 \text{ mb/s}$$

Nyquist:

$$C = 2B \log_2(m)$$

$$8 \times 10^6 = 2 \times 1 \times 10^6 \times \log_2(m)$$

$$4 = \log_2(m) \Rightarrow m = 16$$

Thank you for your attention