Course No: CSE 4255
Course Title: Telecommunication

Lecture 1: Introduction to Telecommunication

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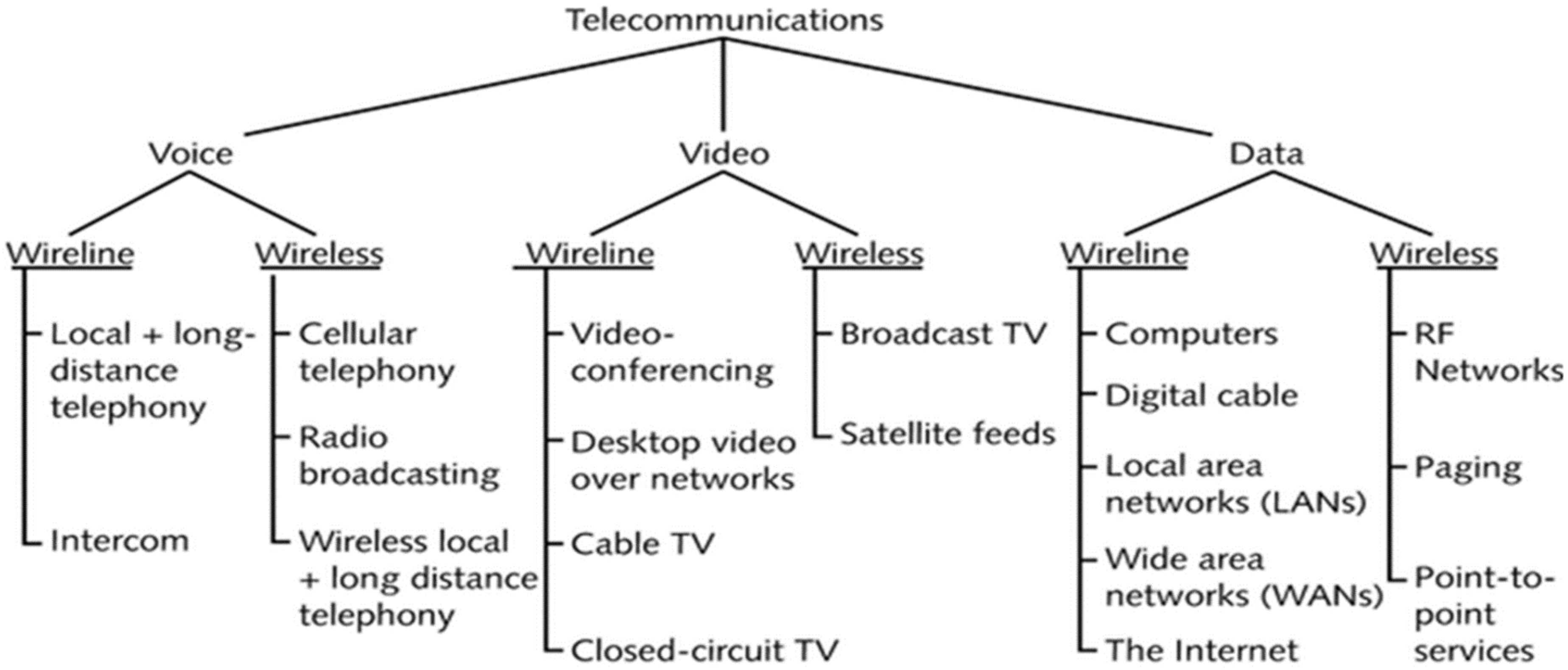
What is telecommunication?

- **Communication** is the sharing of information or messages between two or more entities.
- The word *tele* is Greek for "far off".
- The term ***telecommunication***, means communication at a distance.
- The information may be in the form of voice, video, and data:
  - **Voice telecommunication** - using electrical signals to transmit human voice across a distance, such as telephones and radio broadcasts.
  - **Video telecommunication** - the electrically-based transmission of moving pictures and sound across a distance.
  - **Data telecommunication** - the use of electrical signals to exchange encoded information between computerized devices across a distance.

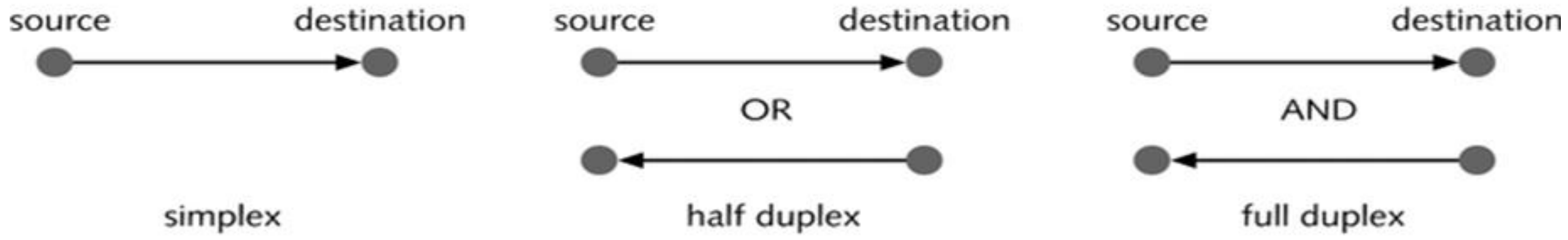
Types of Telecommunication Services



Elements of Telecommunication System

- **Source** - the originator of the message, whether it is a person or machine.
- **Transmitter** - the equipment that modifies the message (either data or voice) into the form required for transmission.
- **Communications channel** - the means of carrying the signal from the source to the destination.
- **Transmission media** - may be physical, like a copper wire or fiber optic cable, or atmospheric, like radio waves.
- **Receiver** - is the device that captures the message from the communications channel and converts it into a form that the person or machine at the destination can understand.
- **Destination** - the person or machine to whom the message is directed

Transmission Modes

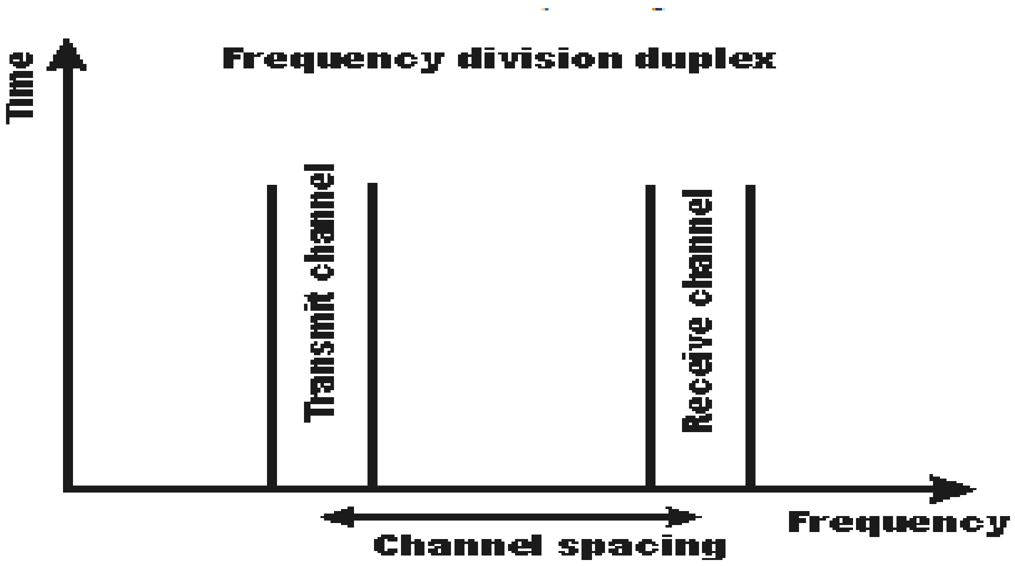


Signals can be transmitted though telecommunications media in a number of different ways:

- In ***simplex transmission***, data can flow only in one direction
- In ***half-duplex transmission***, data can flow in both directions but it can only flow in one direction at any point in time
- In ***full-duplex transmission***, data can flow in both directions at the same time
  - Frequency-division duplex (FDD) „
  - Time-division duplex (TDD): simulated full-duplex

FDD

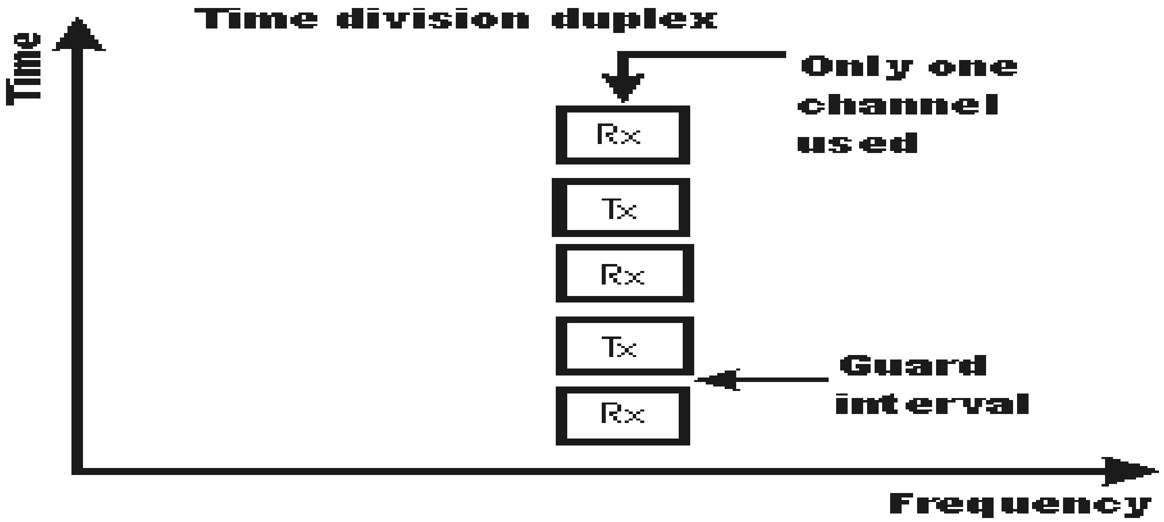
- Frequency-division duplexing (FDD) is a method for establishing a full-duplex communications link that uses two different radio frequencies for transmitter and receiver operation.
- The transmit direction and receive direction frequencies are separated by a defined frequency offset (guard band).



FDD - frequency division duplex

TDD

- Time-division duplexing (TDD) is a method for emulating full-duplex communication over a half-duplex communication link.
- TDD divides a data stream into frames and assigns different time slots to forward and reverse transmissions, thereby allowing both types of transmissions to share the same transmission medium.
- TDD schemes require a guard time or guard interval between transmission and reception.



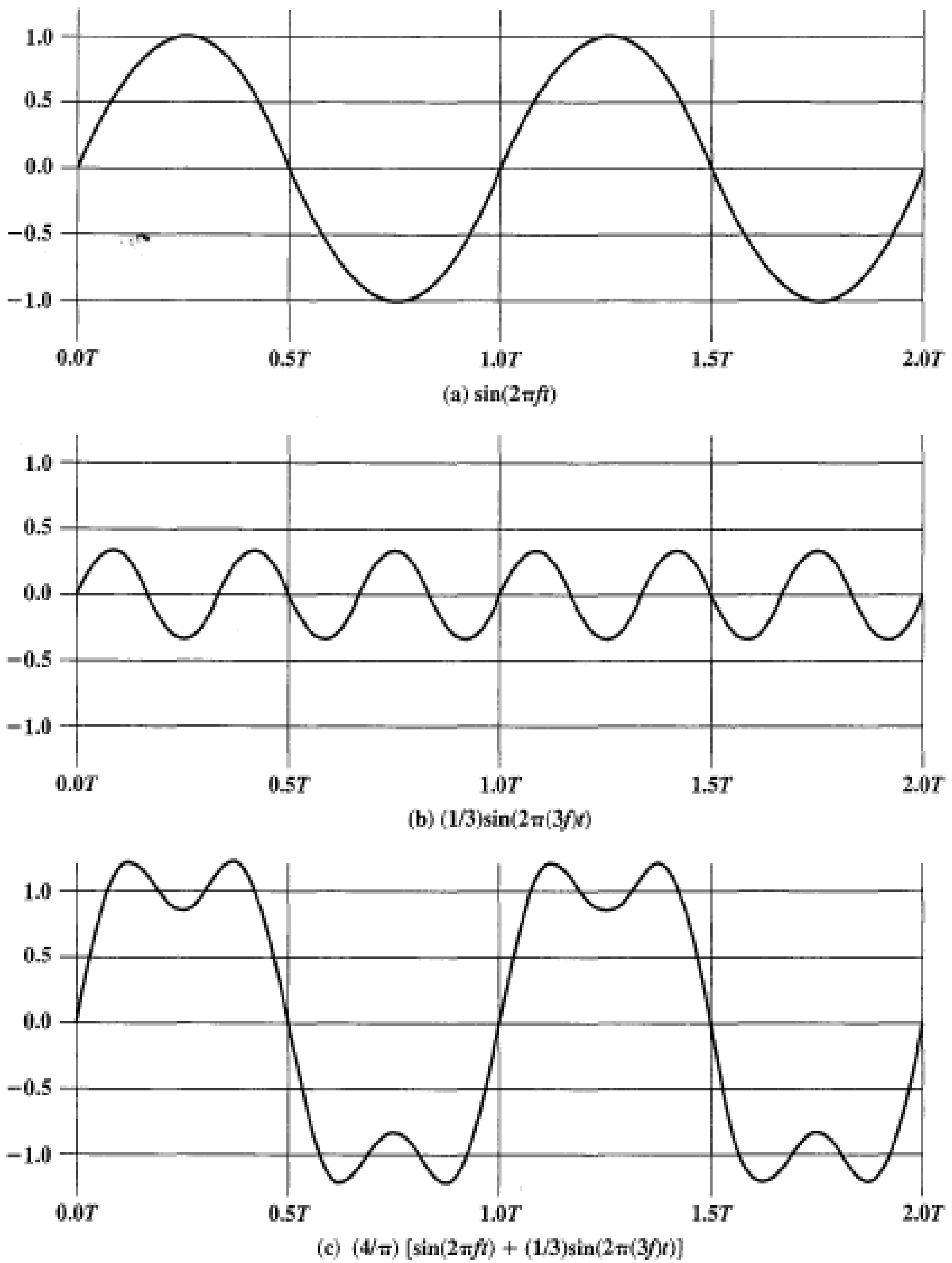
Related Terminologies

- **Bandwidth** in hertz, refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.
- **Data Rate** in bits per second, refers to the number of bits per second that a channel, a link, or even a network can transmit.
- **Throughput** is the actual amount of data that is successfully sent/received over the communication link.
- **Latency (Delay)** defines 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 + transmission time + queuing time + processing delay.**

Data Rate and Bandwidth

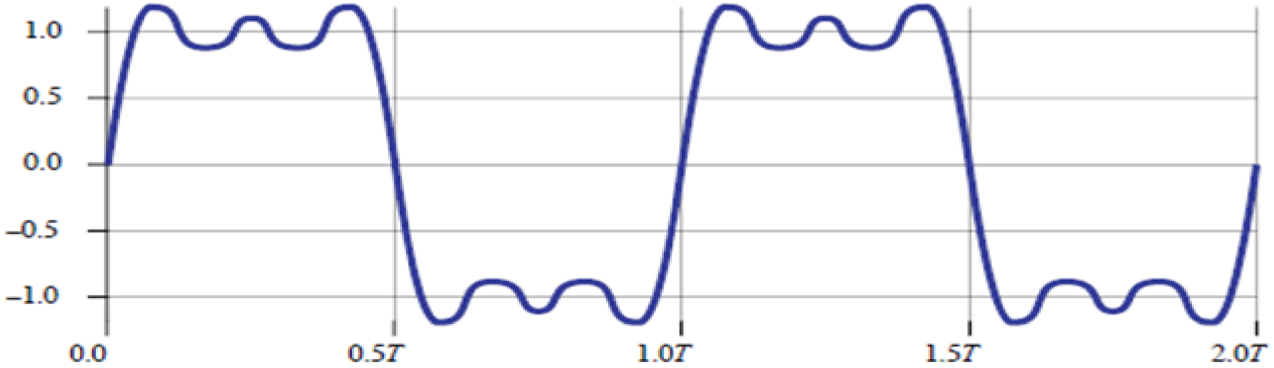
- Suppose:
  - Positive pulse → binary 0
  - Negative pulse → binary 1
- Duration of each pulse is 1/2f
- Data rate is 2f bps
- If more frequencies are added to the signal then the wave form approaches to the square wave
- The frequency components of the square wave with amplitude A and –A can be expressed as follows :

$$s(t) = \mathrm{A} \times (4/\pi) \times \sum_{k\,odd,k=1}^{\infty} sin(2\pi f t)/k$$



Data Rate Calculation

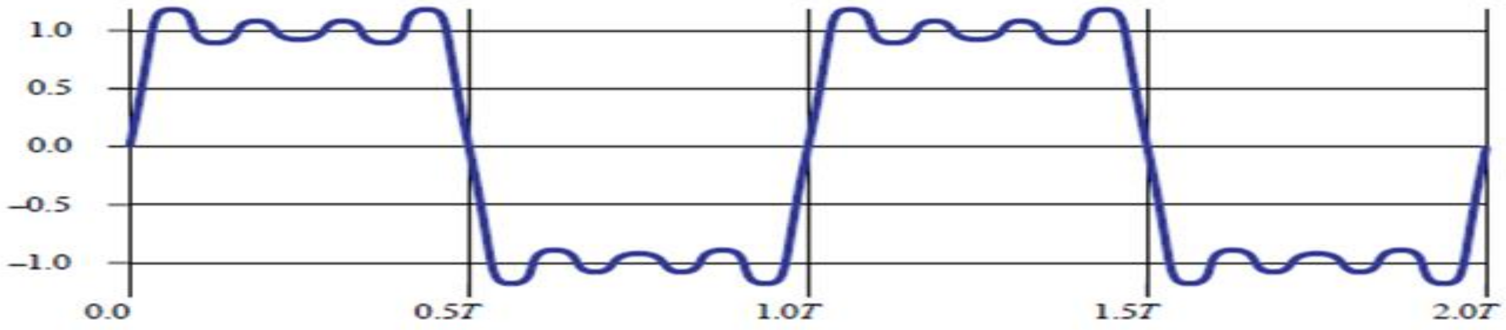
- Case 1: Figure a
  - Let f = 10^6 cycles/sec = 1 MHz
  - Frequency components = 1f, 3f, 5f
  - Bandwidth = 5f – f = 4f = 4 MHz
  - $T = 1/10^6 = 10^{-6} = 1\mu s$
  - If we treat this wave form as bit string of 1s and 0s, 1 bit occurs at every 0.5 μs, i.e duration of each pulse is $1/2 * 10^6$
  - Data rate = $2 * 10^6$ = 2Mbps
  - Thus for 4 MHz BW data rate is 2 Mbps



(a) $(4/\pi)\,[\sin(2\pi ft) + (1/3)\sin(2\pi(3f)t) + (1/5)\sin(2\pi(5f)t)]$

Data Rate Calculation

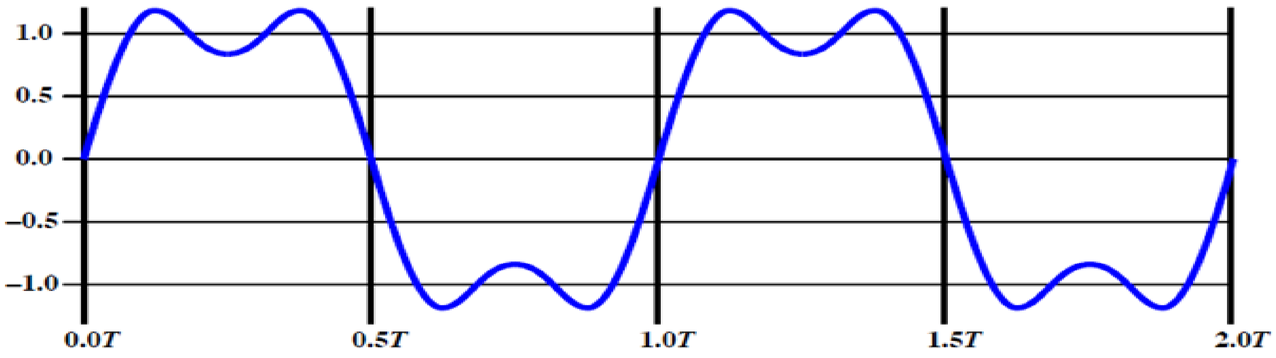
- Case 2: Figure b
  - Let f = $2*10^6$ cycles/sec = 2 MHz
  - Frequency components = 1f, 3f, 5f
  - Bandwidth = 5f – f = 4f = ($5*2*10^6$ - $2*10^6$) = 8 MHz
  - T= 1/ 2 $*10^6$ = 0 .5 μs
  - If we treat this wave form as bit string of 1s and 0s, 1 bit occurs at every 0.25 μs i.e duration of each pulse is 1/4* 10^6
  - Data rate = 4* 10^6 = 4Mbps
  - Thus for 8 MHz BW data rate is 4 Mbps



(b) $(4/\pi)$ [sin $(2\pi ft)$ + (1/3) sin $(2\pi(3f)t)$ + (1/5) sin $(2\pi(5f)t)$ + (1/7) sin $(2\pi(7f)t)$]

Data Rate Calculation

- Case 3: Figure c
  - Let f = $2*10^6$ cycles/sec = 2 MHz
  - Frequency components = 1f, 3f
  - Bandwidth = 3f – f = 2f = ($3*2*10^6$ - $2*10^6$) = 4MHz
  - T= 1/ 2 *10^6 = 0 .5 μs
  - I f we treat this wave form as bit string of 1s and 0s, 1 bit occurs at every 0.25 μs i.e. duration of pulse is 1/4* 10^6
  - Data rate = 4* 10^6 = 4Mbps
  - Thus for 4 MHz BW data rate is 4 Mbps



(c) $(4/\pi)\,[\sin(2\pi f t) + (1/3)\sin(2\pi(3f)t)]$

Data Rate Vs Bandwidth

- Bandwidth ↑
  - Data rate ↑ (compare case 1 and 2)
  - Same signal quality
- Same bandwidth
  - Higher signal quality → lower data rate
  - Compare case 1 and 3
- Same data rate
  - Bandwidth ↑ → better signal quality
  - Compare case 2 and 3

To summarize,

- **Case I:** Bandwidth = 4 MHz; data rate = 2 Mbps
- **Case II:** Bandwidth = 8 MHz; data rate = 4 Mbps
- **Case III:** Bandwidth = 4 MHz; data rate = 4 Mbps

Data Rate Vs Bandwidth

- Same signal quality (Compare case 1 and 2)
  - Bandwidth ↑
  - Data rate ↑

- Same bandwidth (Compare case 1 and 3)
  - Higher signal quality → Lower data rate
  - Lower signal quality → Higher data rate

- Same data rate (Compare case 2 and 3)
  - Bandwidth ↑
  - Higher signal quality

To summarize,

- **Case I:** Bandwidth = 4 MHz; data rate = 2 Mbps
- **Case II:** Bandwidth = 8 MHz; data rate = 4 Mbps
- **Case III:** Bandwidth = 4 MHz; data rate = 4 Mbps

Channel Capacity

- The maximum rate at which data can be transmitted over a given communication path, or channel, under given conditions.
- Impairments, such as noise, limit data rate that can be achieved.
- Nyquist Formula is: $C = 2B \log_2 M$
- Shannon Capacity Formula is: $C=B \log_2(1+SNR)$

Signal to Noise Ration

- Signal to noise ratio (SNR) = power of signal/power of noise
  - Typically measured at the receiver
  - SNR_{db}=10 $\log_{10}$ (signal/noise)
  - A high SNR means a high quality of signal

Example 1:

- Lets consider the spectrum of a channel is between 3 MHz and 4 MHz and SNR_{db} =24 dB. Then find the maximum capacity achieved by channel. If it is possible to achieved the limit then how many signal level is required?

Example 2:

- What are the propagation time and the transmission time for a 2.5-kbyte message if the bandwidth of the network is 1 Gbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at 2.4×10^8 m/s.