Parul® University

Mobile Computing

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CHAPTER-1

INTRODUCTION OF TRANSMISSION

DATA TRANSMISSION

TRANSMISSION TERMINOLOGY:

Data transmission occurs between a transmitter & receiver via some medium

Guided medium

eg. twisted pair, coaxial cable, optical fiber

unguided / wireless medium

eg. air, water, vacuum

DATA TRANSMISSION

TRANSMISSION TERMINOLOGY:

Direct link

no intermediate devices

Point-to-Point

direct link

only 2 devices share link[2]

Multi-point

more than two devices share the link

DATA TRANSMISSION

TRANSMISSION TERMINOLOGY:

Simplex

one direction

eg. Television

Half duplex

either direction, but only one way at a time

eg. police radio[2]

Full duplex

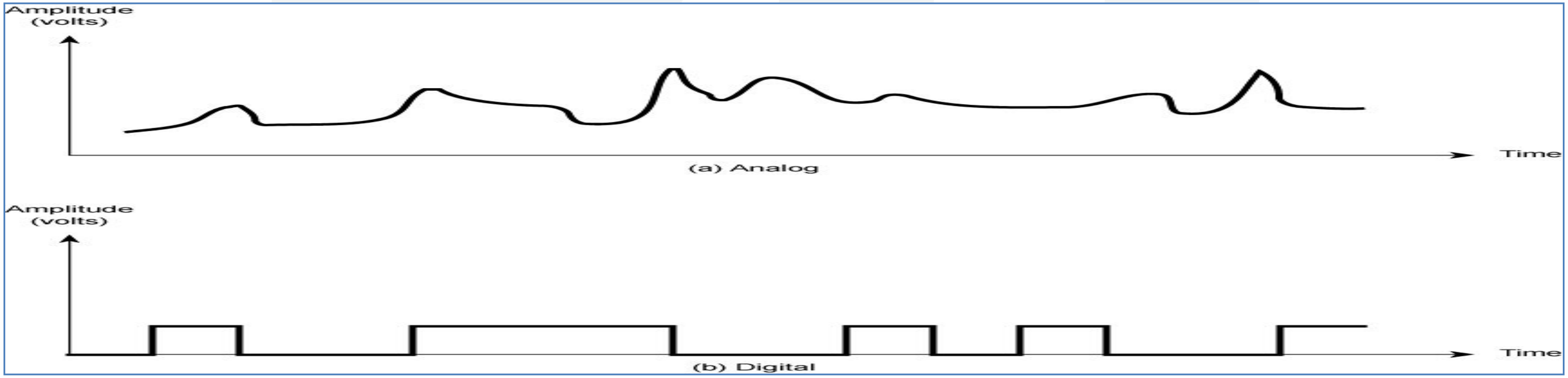
both directions at the same time

eg. Telephone

Frequency, Spectrum and Bandwidth

Time domain concepts:

Analog signal- varies in a smooth way over time
Digital signal- maintains a constant level then changes to another constant level
Periodic signal- pattern repeated over time
Aperiodic signal- pattern not repeated over time



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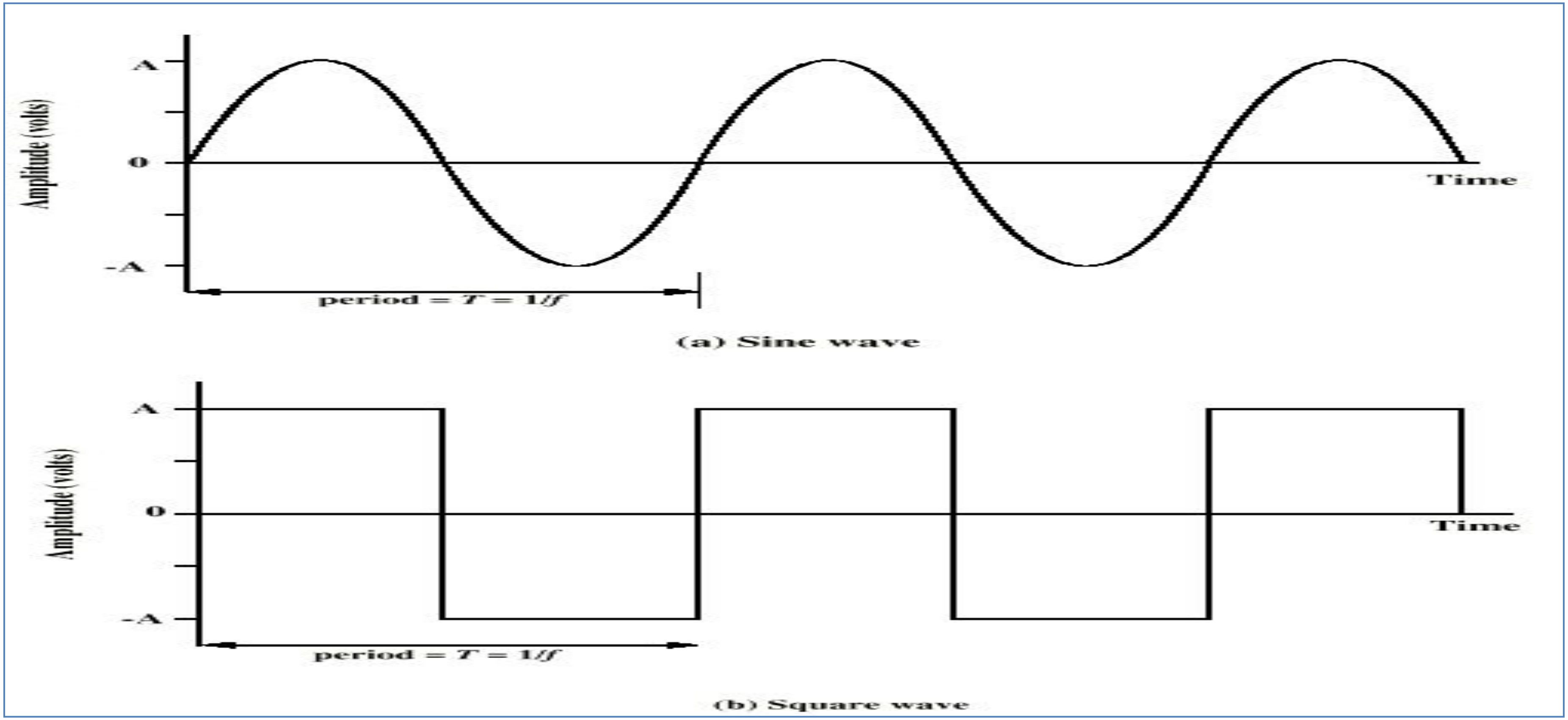
Periodic Signals



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Sine Wave

peak amplitude (A)
- maximum strength of signal
- Volts

frequency (f)
- rate of change of signal
- Hertz (Hz) or cycles per second
- period = time for one repetition (T)
- $T = 1/f$

phase (φ)
- relative position in time

Analog and Digital Data Transmission

Data

entities that convey meaning

Signals & Signaling

electric or electromagnetic representations of data, physically propagates along medium

Transmission

communication of data by propagation and processing of signals

Audio Signals

Frequency range 20Hz-20kHz (speech 100Hz-7kHz)

Easily converted into electromagnetic signals

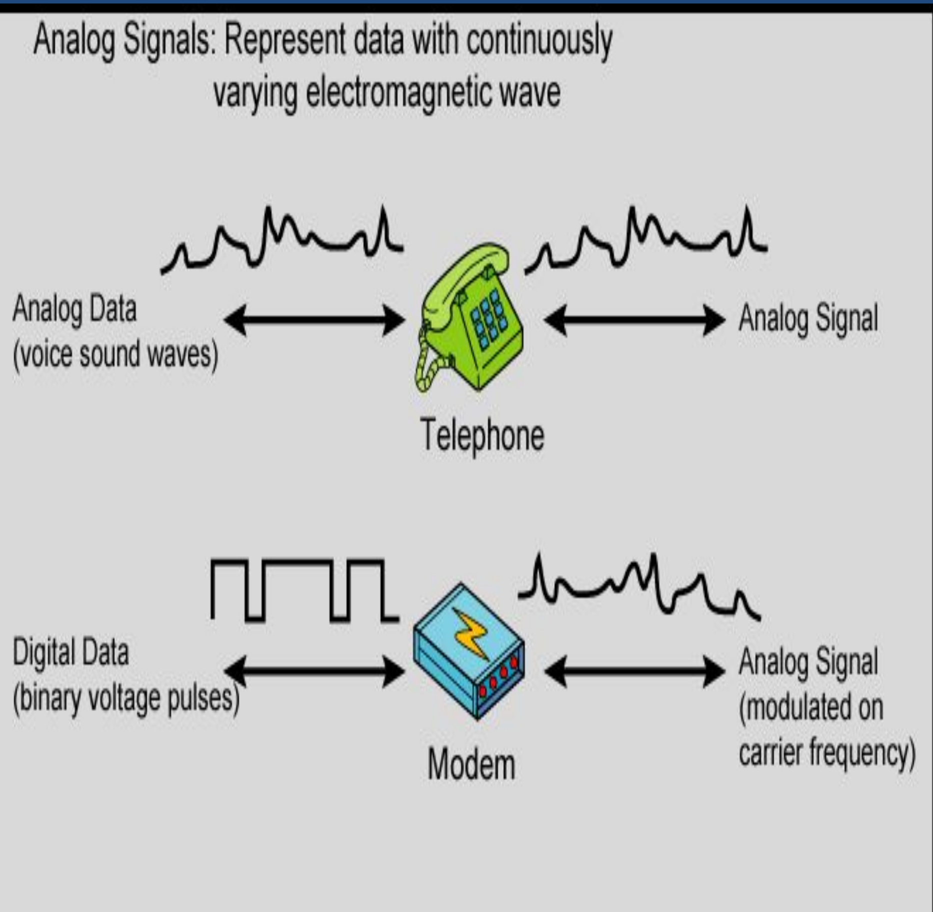
Varying volume converted to varying voltage can limit frequency range for voice channel to 300-3400Hz

In this graph of a typical analog signal, the variations in amplitude and frequency convey the gradations of loudness and pitch in speech or music. Similar signals are used to transmit television pictures, but at much higher frequencies.

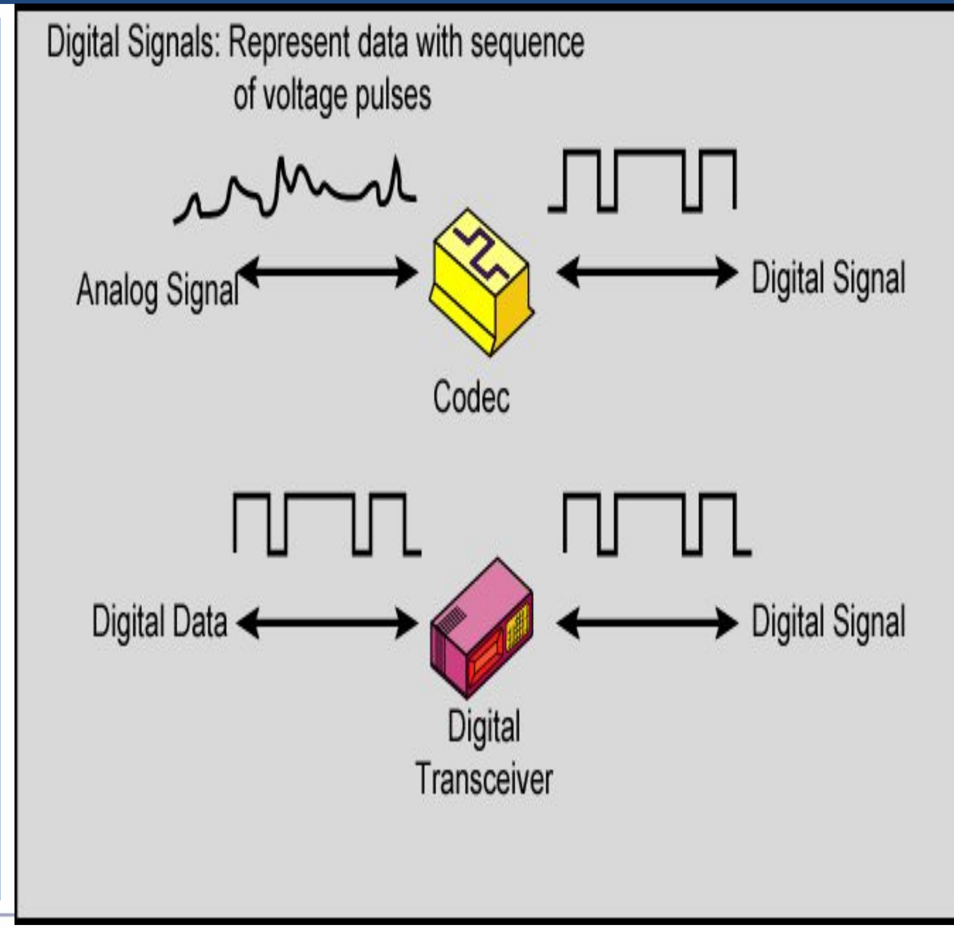
Digital Data

- as generated by computers etc.
- has two dc components
- bandwidth depends on data rate

Analog Signals



Digital Signals



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Transmission Impairments

Signal received may differ from signal transmitted causing:

- **analog** - degradation of signal quality
- **digital** - bit errors

Most significant impairments are

- **attenuation**
- **delay**
- **noise**

Attenuation

- where signal strength falls off with distance
- depends on medium and received signal strength must be:
  - strong enough to be detected
  - sufficiently higher than noise to receive without error

increase strength using amplifiers/repeaters.

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[1]
- since parts of one bit spill over into others
- causing inter symbol interference

Noise

- Additional signals inserted between transmitter and receiver
- **Thermal**- due to thermal agitation of electrons, uniformly distributed, white noise
- **Intermodulation**- signals that are the sum and difference of original frequencies sharing a medium[2]
- Eg: Crosstalk, impulse- irregular pulses or spikes

Channel Capacity

Max possible data rate on communication channel is a function of

- **data rate** - in bits per second
- **bandwidth** - in cycles per second or Hertz
- **noise** - on communication link
- **error rate** - of corrupted bits

Wavelength

Distance occupied by one cycle

- Distance between two points of corresponding phase in two consecutive cycles(λ)
- Assuming signal velocity *v*

  $\lambda = v/f$

  $\lambda f = v$

  $c = 3*10^8\ ms^{-1}$ (speed of light in free space)

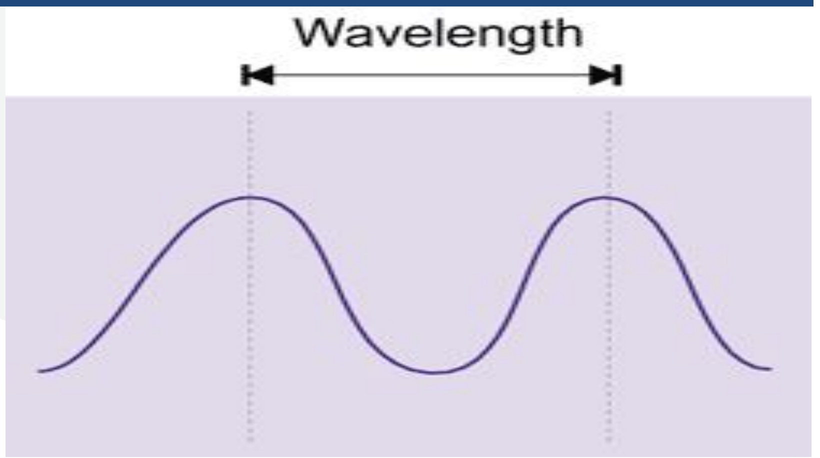


Image Source: tutorialspoint.com

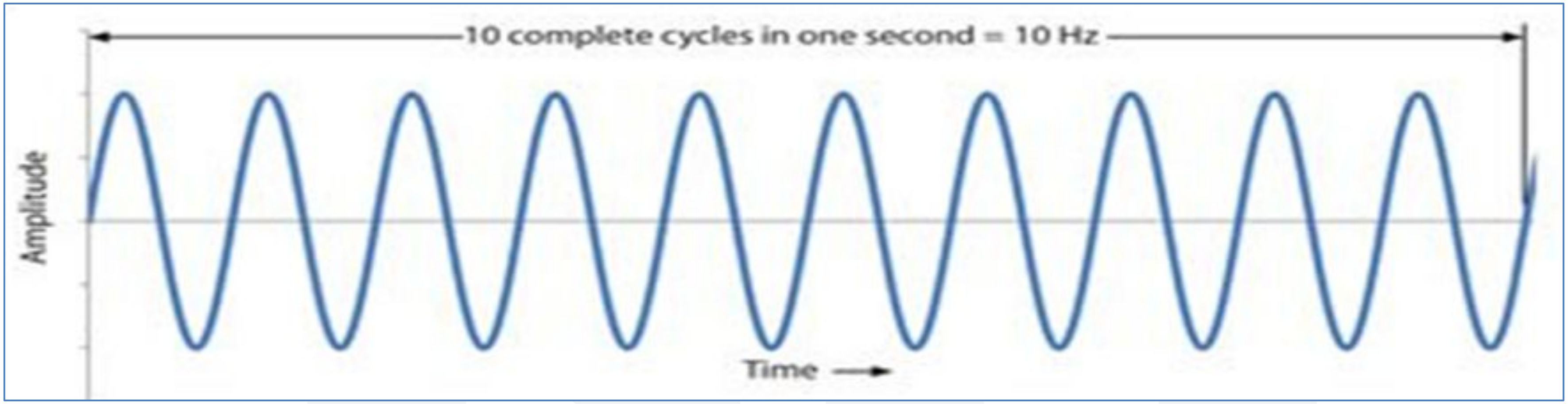
Spectrum & Bandwidth

Spectrum: range of frequencies contained in signal

Absolute bandwidth: width of spectrum

Effective bandwidth: Often just *bandwidth*
Narrow band of frequencies containing most of the energy

- In terms of computing bandwidth refers to the rate at which data can transfer. This basically means the amount of data that can be transferred from one location to another location in a given timeframe, usually expressed in bits per second.
- The second definition, commonly used in signal processing, is the range of frequencies an electronic signal uses on a given transmission medium.
- The term bandwidth refers to difference between the highest-frequency signal component and the lowest-frequency signal component.



Data Rate & Bandwidth

Any transmission system has a limited band of frequencies which limits the data rate that can be carried. Data rate depends on three factors:

1. The bandwidth available
2. The level of the signals we use
3. The quality of the channel (the level of noise).

Capacity Of a System

The bit rate of a system increases with an increase in the number of signal levels we use to denote a symbol.

A symbol can consist of a single bit or "n" bits.

The number of signal levels = 2^n.
As the number of levels goes up, the spacing between level decreases -> increasing the probability of an error occurring in the presence of transmission impairments.[2]

Nyquist Theorem

- Nyquist gives the upper bound for the bit rate of a transmission system by calculating the bit rate directly from the number of bits in a symbol (or signal levels) and the bandwidth of the system (assuming 2 symbols/per cycle and first harmonic).
- Nyquist theorem states that for a noiseless channel:

  $C = 2\,B \log_2 L$

  C= capacity in bps

  B = bandwidth in Hz
- Example

  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:

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

Examples:

1) 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:

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

2) 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:

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

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

Since this result is not a power of 2, we need to either increase the number of levels or reduce the bit rate. If we have 128 levels, the bit rate is 280 kbps. If we have 64 levels, the bit rate is 240 kbps.

Shannon Theorem

- Nyquist gives the upper bound for the bit rate of a transmission system by calculating the bit rate directly from the number of bits in a symbol (or signal levels) and the bandwidth of the system (assuming 2 symbols/per cycle and first harmonic).
- Nyquist theorem states that for a noiseless channel:

  $C = 2 B \log_2 L$

  C= capacity in bps

  B = bandwidth in Hz
- Example

  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:

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

Shannon Theorem continues…

Shannon's theorem gives the capacity of a system in the presence of noise.

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

Example

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 faint. For this channel the capacity C is calculated as

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

This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel.

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

Example:

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:

$$C = B \log_2 (1 + \mathrm{SNR}) = 3000 \log_2 (1 + 3162) = 3000 \log_2 3163$$
$$= 3000 \times 11.62 = 34{,}860 \text{ bps}$$

This means that the highest bit rate for a telephone line is 34.860 kbps. If we want to send data faster than this, we can either increase the bandwidth of the line or improve the signal-to-noise ratio.

Example:

The signal-to-noise ratio is often given in decibels. Assume that SNR_{dB} = 36 and the channel bandwidth is 2 MHz. The theoretical channel capacity can be calculated as

$$\mathrm{SNR}_{dB} = 10 \log_{10} \mathrm{SNR} \rightarrow \mathrm{SNR} = 10^{\mathrm{SNR}_{dB}/10} \rightarrow \mathrm{SNR} = 10^{3.6} = 3981$$
$$C = B \log_2 (1+ \mathrm{SNR}) = 2 \times 10^6 \times \log_2 3982 = 24 \text{ Mbps}$$

Example:

We have a channel with a 1-MHz bandwidth. The SNR for this channel is 63. What are the appropriate bit rate and signal level?

Solution

First, we use the Shannon formula to find the upper limit.

$$\boxed{C = B \log_2 (1 + \text{SNR}) = 10^6 \log_2 (1 + 63) = 10^6 \log_2 64 = 6 \text{ Mbps}}$$

Example:

The Shannon formula gives us 6 Mbps, the upper limit. For better performance we choose something lower, 4 Mbps, for example. Then we use the Nyquist formula to find the number of signal levels.

$$\boxed{4 \text{ Mbps} = 2 \times 1 \text{ MHz} \times \log_2 L \quad \rightarrow \quad L = 4}$$

Transmission Media

Guided Transmission Media

Twisted Pair

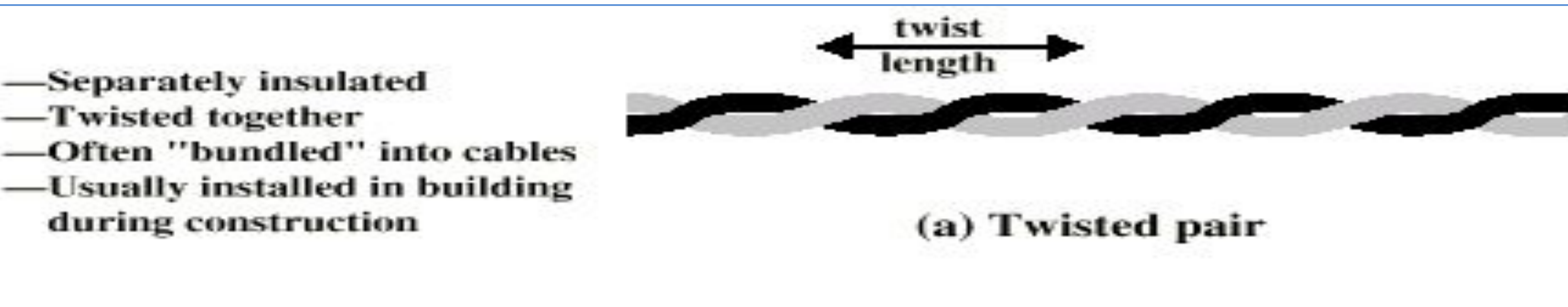
Coaxial cable

Optical fiber

Transmission Characteristics of Guided Media

	Frequency Range	Typical Attenuation	Typical Delay	Repeater Spacing
Twisted pair (with loading)	0 to 3.5 kHz	0.2 dB/km @ 1 kHz	50 µs/km	2 km
Twisted pairs (multi-pair cables)	0 to 1 MHz	0.7 dB/km @ 1 kHz	5 µs/km	2 km
Coaxial cable	0 to 500 MHz	7 dB/km @ 10 MHz	4 µs/km	1 to 9 km
Optical fiber	186 to 370 THz	0.2 to 0.5 dB/km	5 µs/km	40 km

Twisted Pair



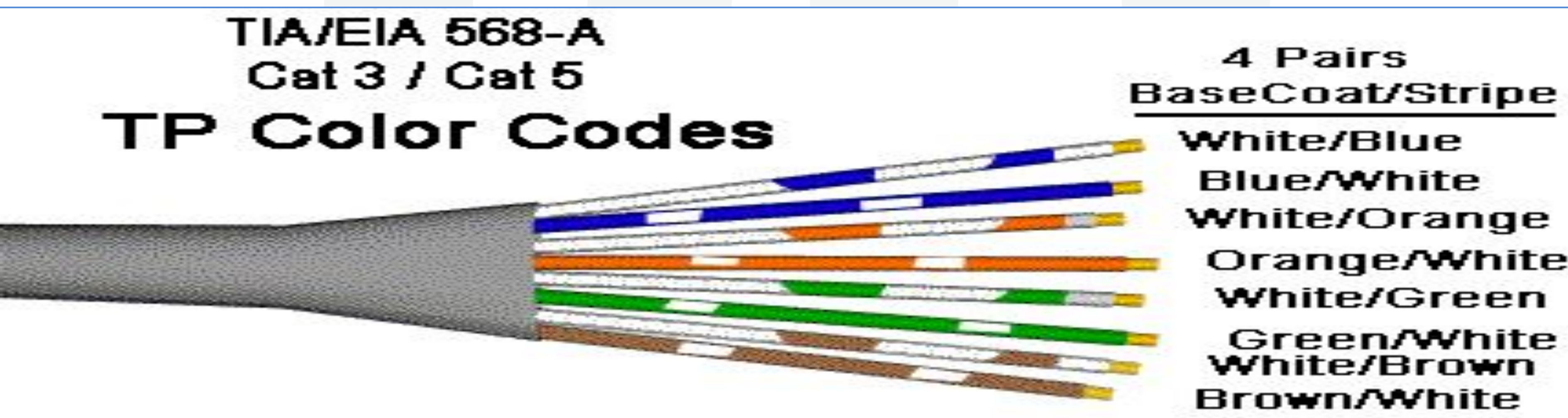


Image Source: google.com

Twisted Pair - Applications

- Most common medium
- Telephone network
- Between house and local exchange (subscriber loop), Within buildings
- To private branch exchange (PBX)
- For local area networks (LAN): 10Mbps or 100Mbps[2]

Twisted Pair – Pros & Cons

- Cheap
- Easy to work with
- Low data rate
- Short range

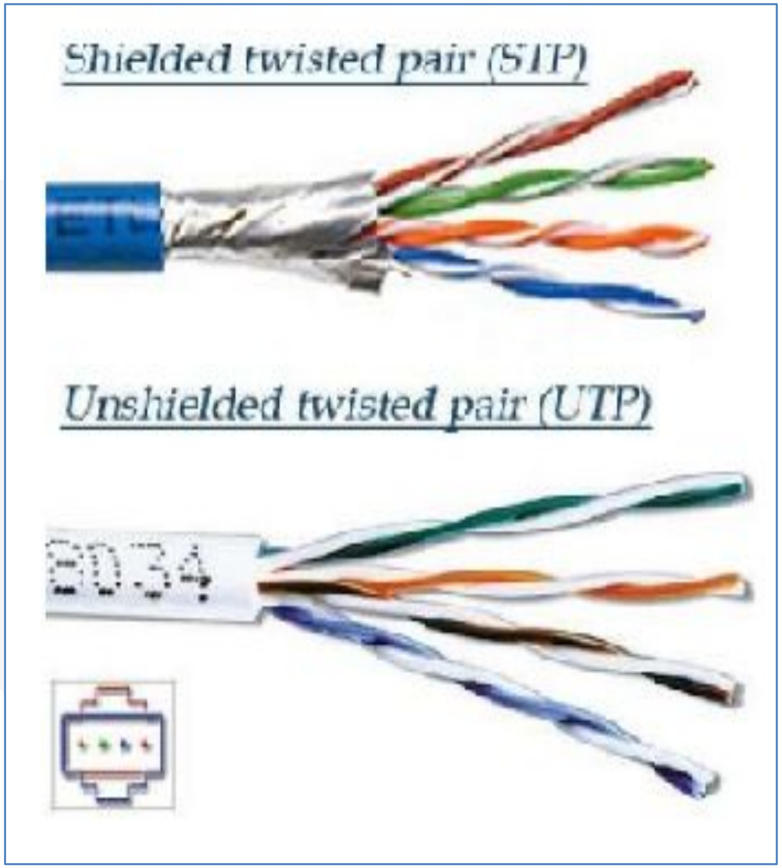
Unshielded and Shielded TP

Unshielded Twisted Pair (UTP)

- Ordinary telephone wire
- Cheapest
- Easiest to install
- Suffers from external interference

Shielded Twisted Pair (STP)

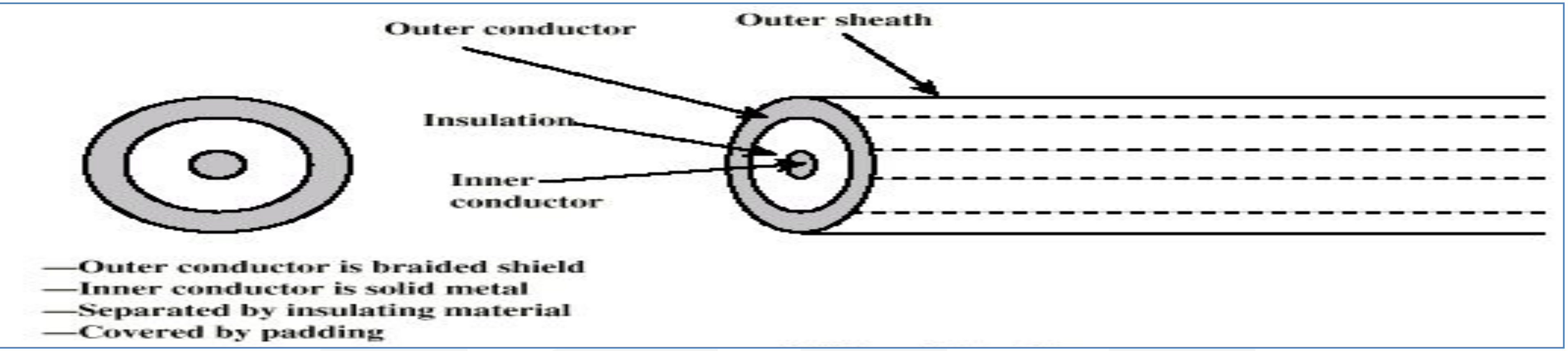
- Metal braid or sheathing that reduces interference
- More expensive
- Harder to handle (thick, heavy)



UTP Categories

- **Cat 3**
  - up to 16MHz
  - Voice grade found in most offices
  - Twist length of 7.5 cm to 10 cm
- **Cat 4**
  - up to 20 MHz
- **Cat 5**
  - up to 100MHz
  - Commonly pre-installed in new office buildings
  - Twist length 0.6 cm to 0.85 cm
- **Cat 5E (Enhanced)**
- **Cat 6**
- **Cat 7**

Coaxial Cables



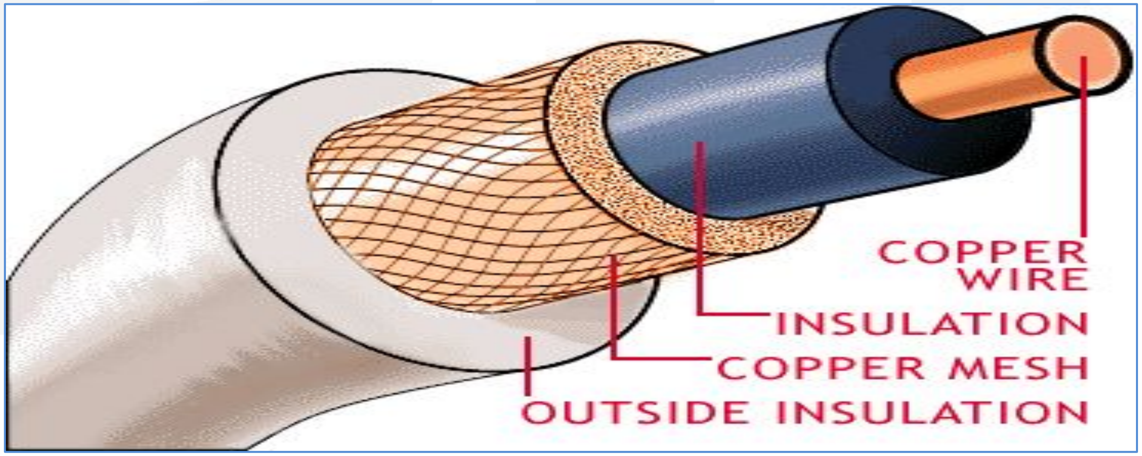
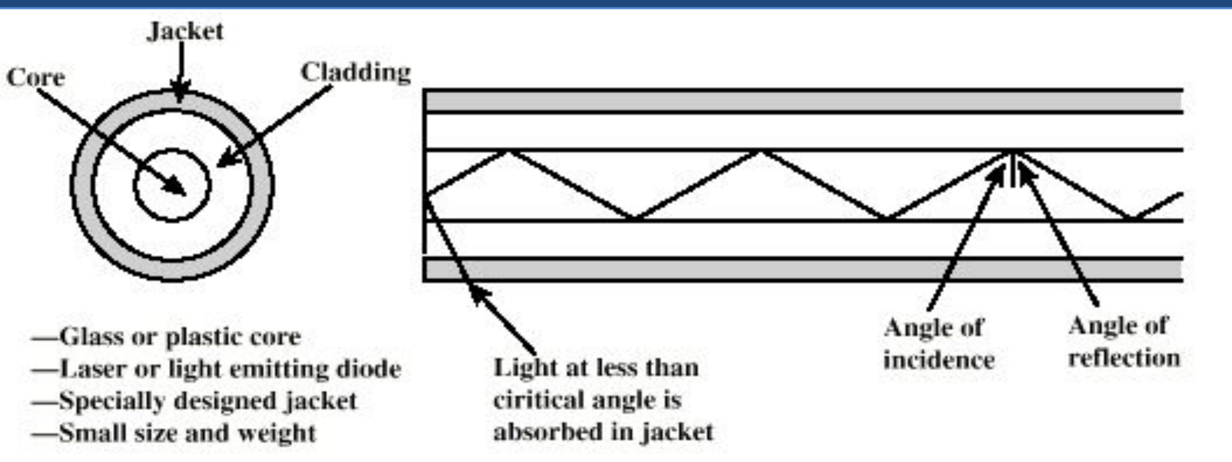


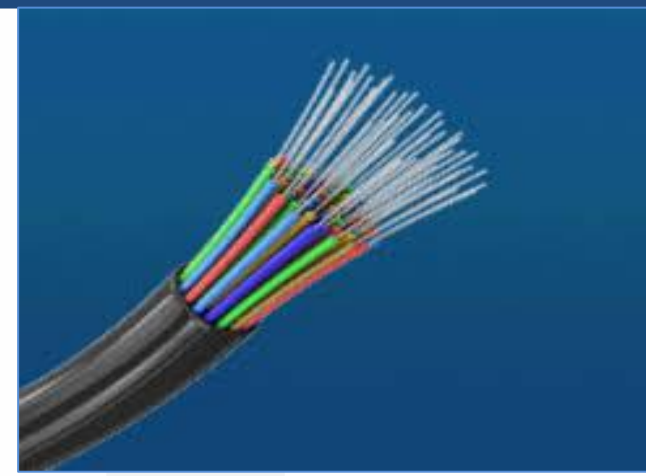
Image Source: google.com

Coaxial Cable Applications

- Most versatile medium
- Television distribution
  - Ariel to TV
  - Cable TV
- Long distance telephone transmission
  - Can carry 10,000 voice calls simultaneously
  - Being replaced by fiber optic
- Short distance computer systems links
- Local area networks

Optical Fiber





Benefits:

- Greater capacity(Data rates of hundreds of Gbps)
- Smaller size & weight
- Lower attenuation
- Electromagnetic isolation
- Greater repeater spacing: 10s of km at least

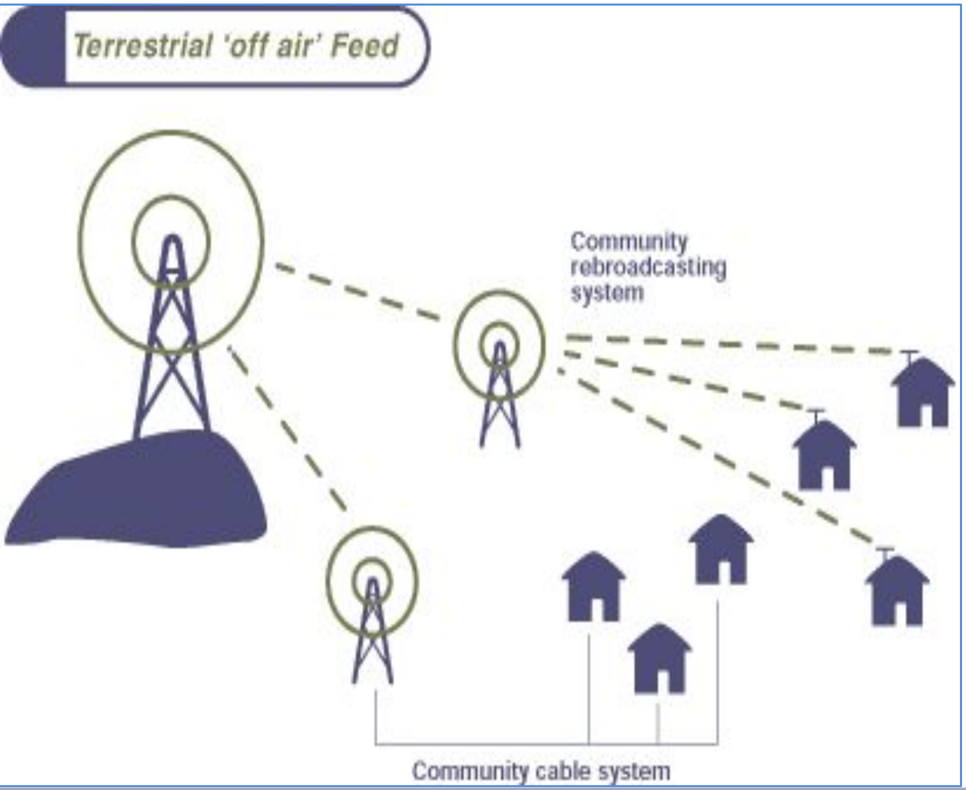
Applications:

- Long-haul trunks
- Metropolitan trunks
- Rural exchange trunks
- Subscriber loops
- LANs

Image Source: google.com

Unguided Media

(1)Terrestrial communication using Microwaves.-Transmission Tower



(2)Using Satellite

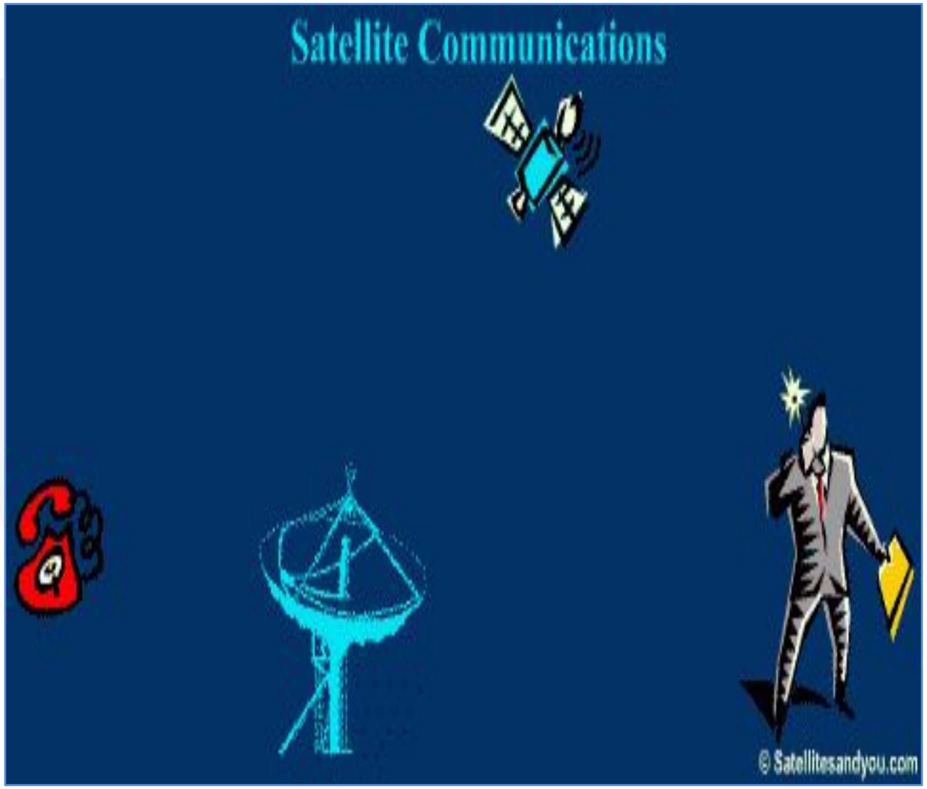
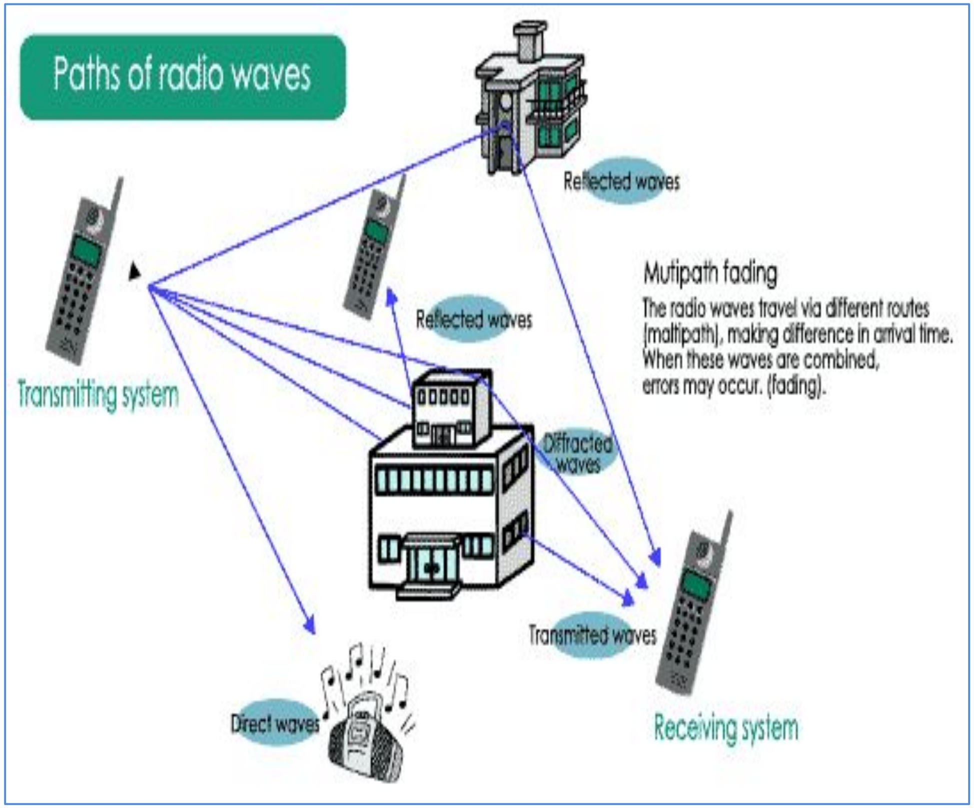


Image Source: google.com

Unguided Media continues…

(3) Radio waves



(4) Infrared

Image Source: google.com

Multiplexing

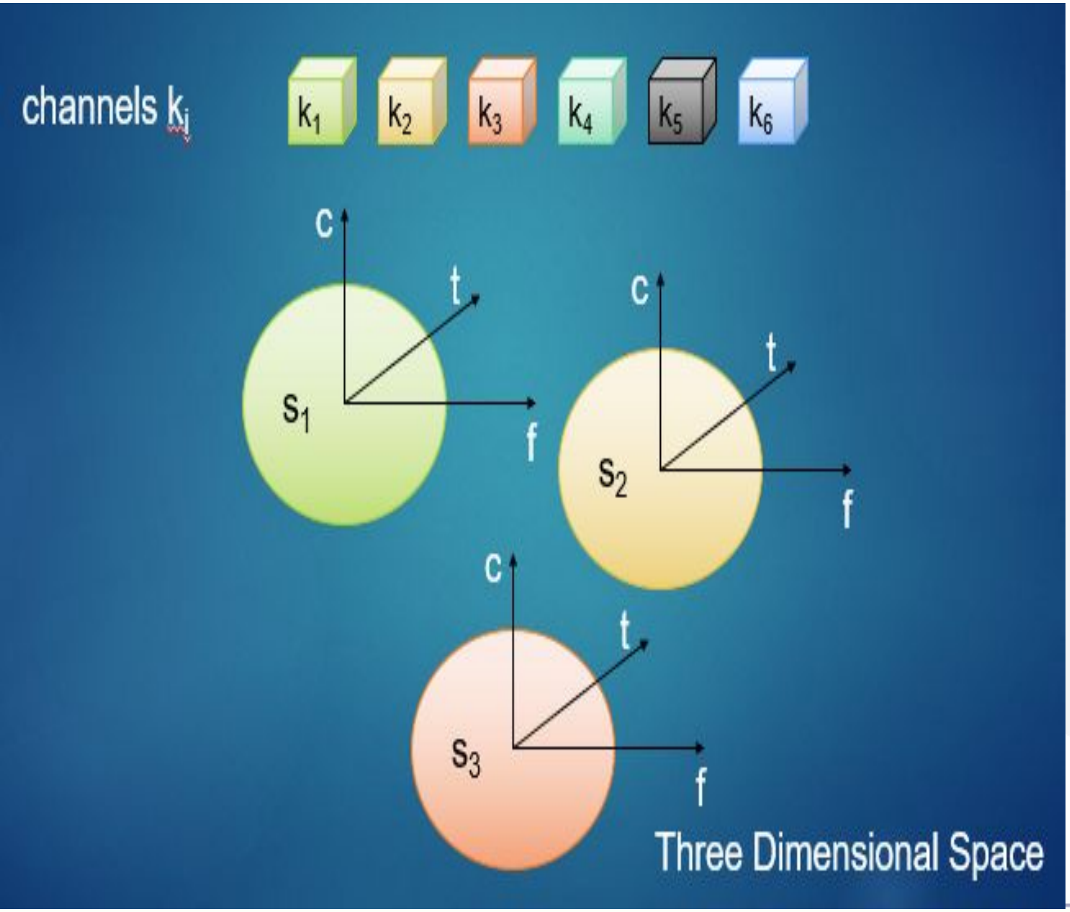
Goal: Multiple use of a shared medium with minimum or no interference.

Important: guard spaces needed!

Multiplexing in 4 dimensions

- space (s_i)
- time (t)
- frequency (f)
- code (c)

Space Division Multiplexing



This is used by the old analog telephone system:

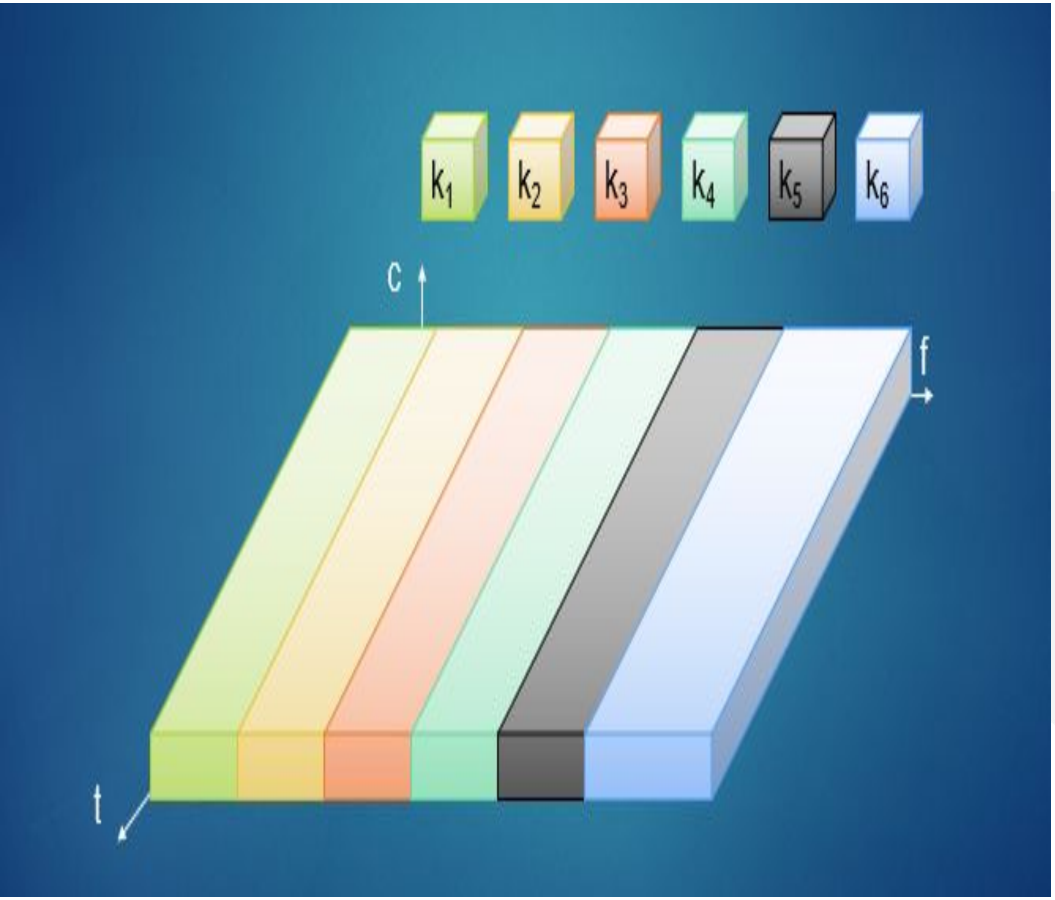
Each subscriber is given a separate pair of copper wires to the local exchange.

Used in FM radio stations where the transmission range is limited to a certain region.

Problems arise if two or more channels were established within the same space.

Image Source: google.com

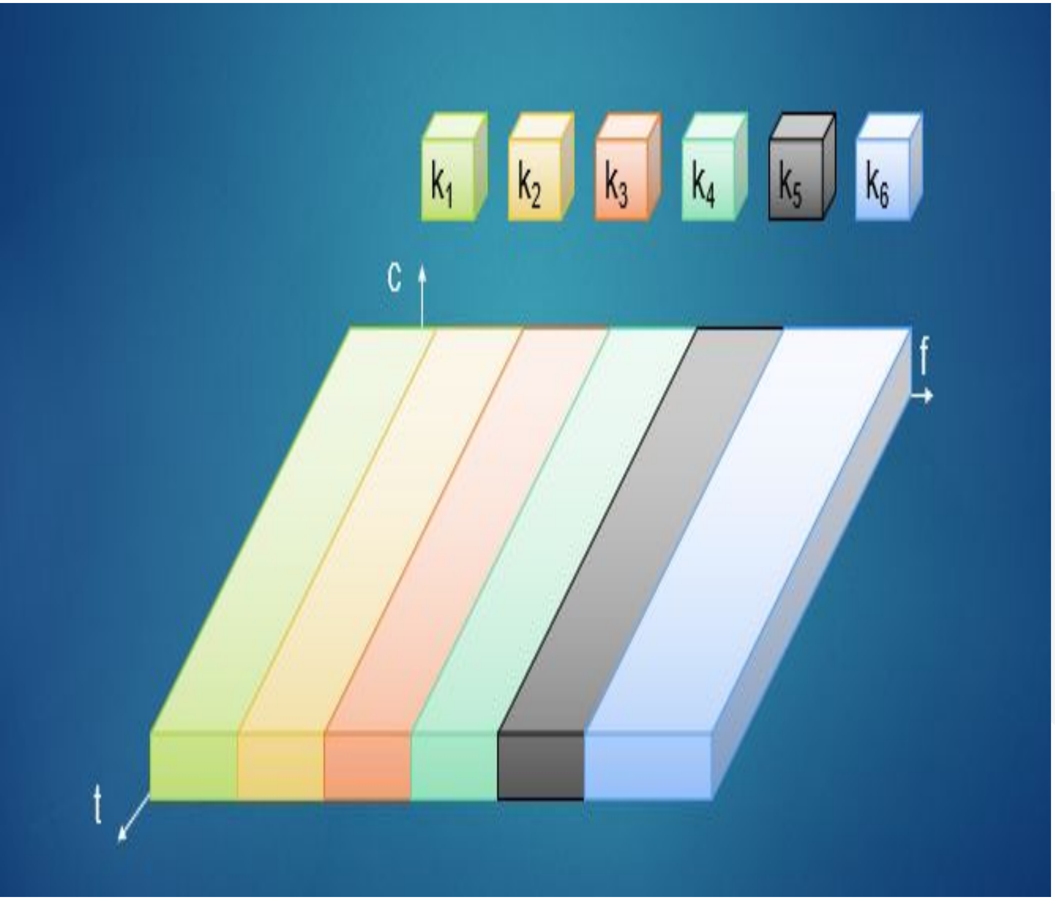
Frequency Division Multiplexing



- Separation of the whole spectrum into smaller frequency bands
- A channel gets a certain band of the spectrum for the whole time
- **Guard spaces** are needed to avoid frequency band overlapping (also called **adjacent channel interference**).

Image Source: google.com

Frequency Division Multiplexing



- Separation of the whole spectrum into smaller frequency bands
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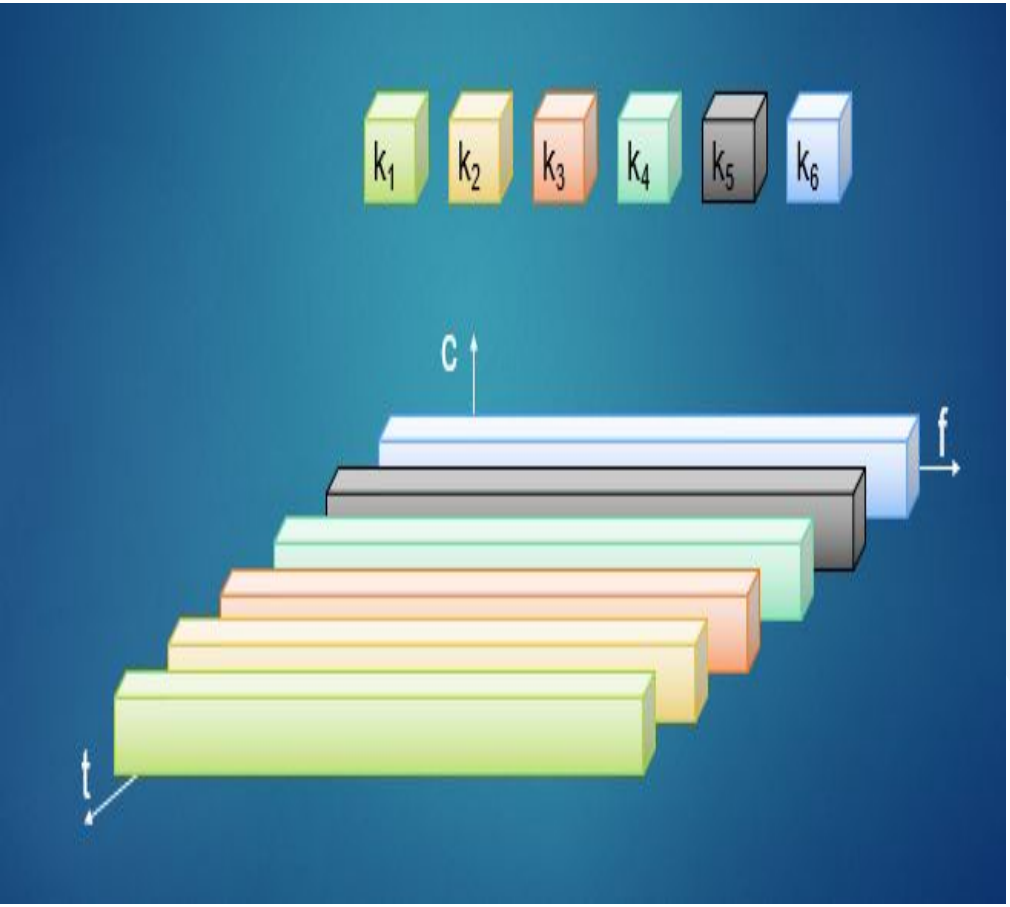
Image Source: google.com

Advantages & Disadvantages

- The receiver only has to tune in to the specific sender.
- Hence, does not need complex coordination between sender and receiver.

- While radio stations broadcast 24 hours a day, mobile communication typically takes place for only a few minutes at a time.
- Waste of (scarce) frequency resources.
- Limited number of senders.

Time Division Multiplexing



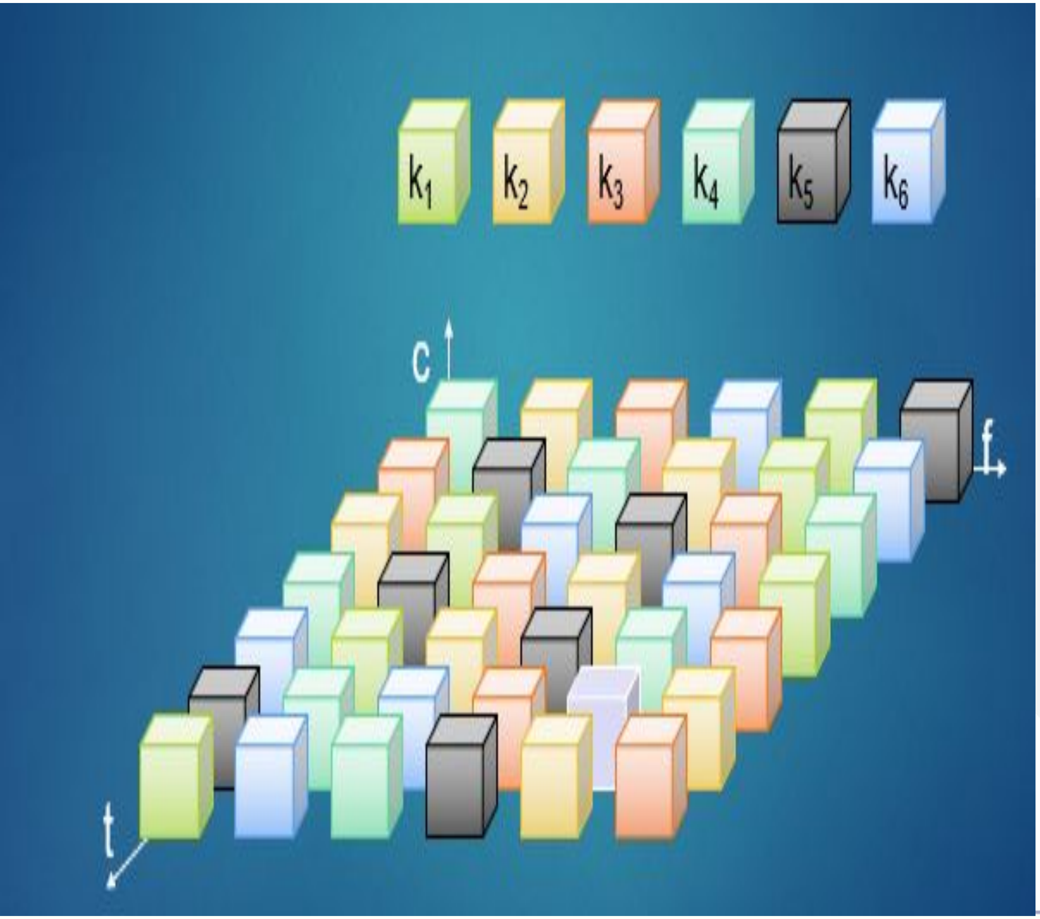
- A channel gets the whole spectrum for a certain amount of time.
- **Guard spaces**, which now represent time gaps, have to separate the different periods when the senders use the medium.[3]
- If two transmissions overlap in time, this is called co-channel interference.
- To avoid this type of interference, precise synchronization between different senders is necessary.

Image Source: google.com

Continues…

- All senders need precise clocks or, alternatively, a way has to be found to distribute a synchronization signal to all senders.
- For a receiver tuning in to a sender this does not just involve adjusting the frequency, but involves listening at exactly the right point in time.
- Flexible - as one can assign more sending time to senders with a heavy load and less to those with a light load.

Time & Frequency Division Multiplexing



A channel gets a certain frequency band for a certain amount of time.
Example: GSM

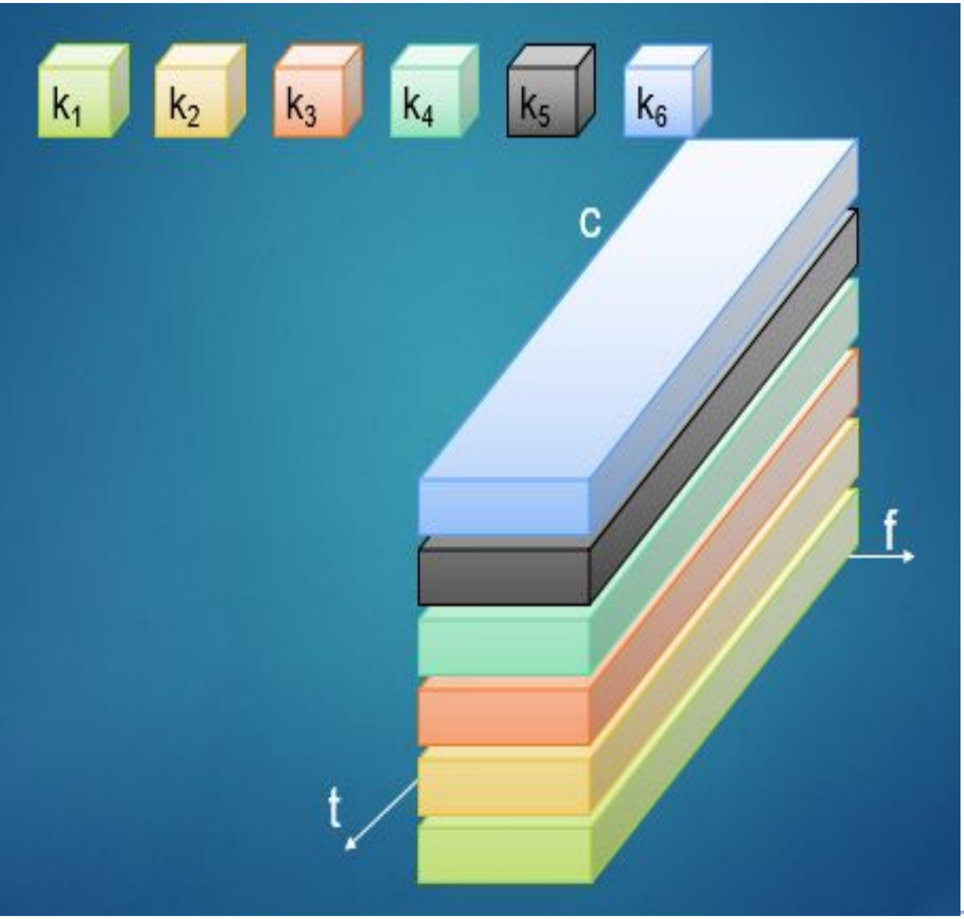
Advantages

- ❖better protection against tapping
- ❖protection against frequency selective interference

but precise coordination required (Frequency Hopping should be fast enough). [3]

Image Source: google.com

Code Division Multiplexing



Each channel has a unique code.

All channels use the same spectrum at the same time.

Guard spaces are realized by using codes with the necessary 'distance' in code space, e.g., **orthogonal codes**.

Image Source: google.com

Advantages & Disadvantages

- It gives good protection against interference and tapping.
- Different codes have to be assigned, but code space is huge compared to the frequency space.

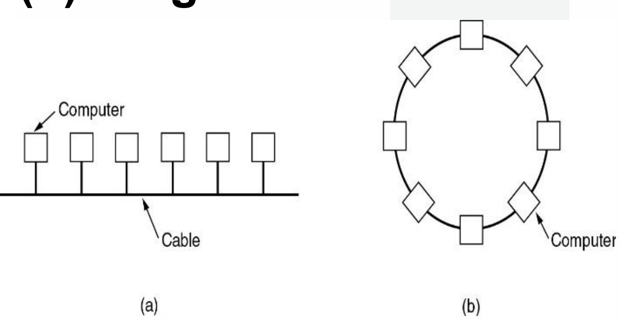
- Relatively high complexity of the receiver - has to know the code and must separate the channel from the background noise.
- A receiver must be precisely synchronized with the transmitter to apply the decoding correctly.

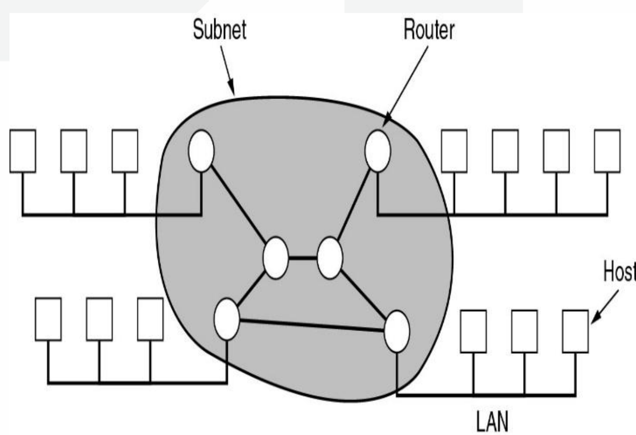
Classification of Networks

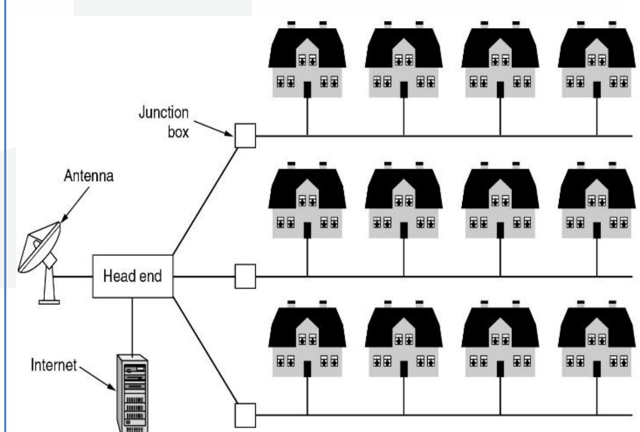
- Personal Area Network
- Local Area Networks
- Metropolitan Area Networks
- Wide Area Networks
- Wireless Networks
- Home Networks
- Internetworks

LAN	WAN	MAN
The inter processor distance is 10 meters to 1 kilometer and the processors are located in a room or a building or a campus.[2]	The inter processor distance is from 100 kilometers to 1000 kilometers and the processors are located in a country or a continent. Relation between hosts on LANs and the subnet.[2]	The inter processor distance is 10 kilometers and the processors are located in a city. A metropolitan area network based on cable TV.[2]

Two broadcast networks
(a) Bus
(b) Ring







Switching Techniques

Introduction

In large networks there might be multiple paths linking sender and receiver. Information may be switched as it travels through various communication channels. There are three typical switching techniques available for digital traffic.

- Circuit Switching
- Message Switching
- Packet Switching

Simple Switched Network

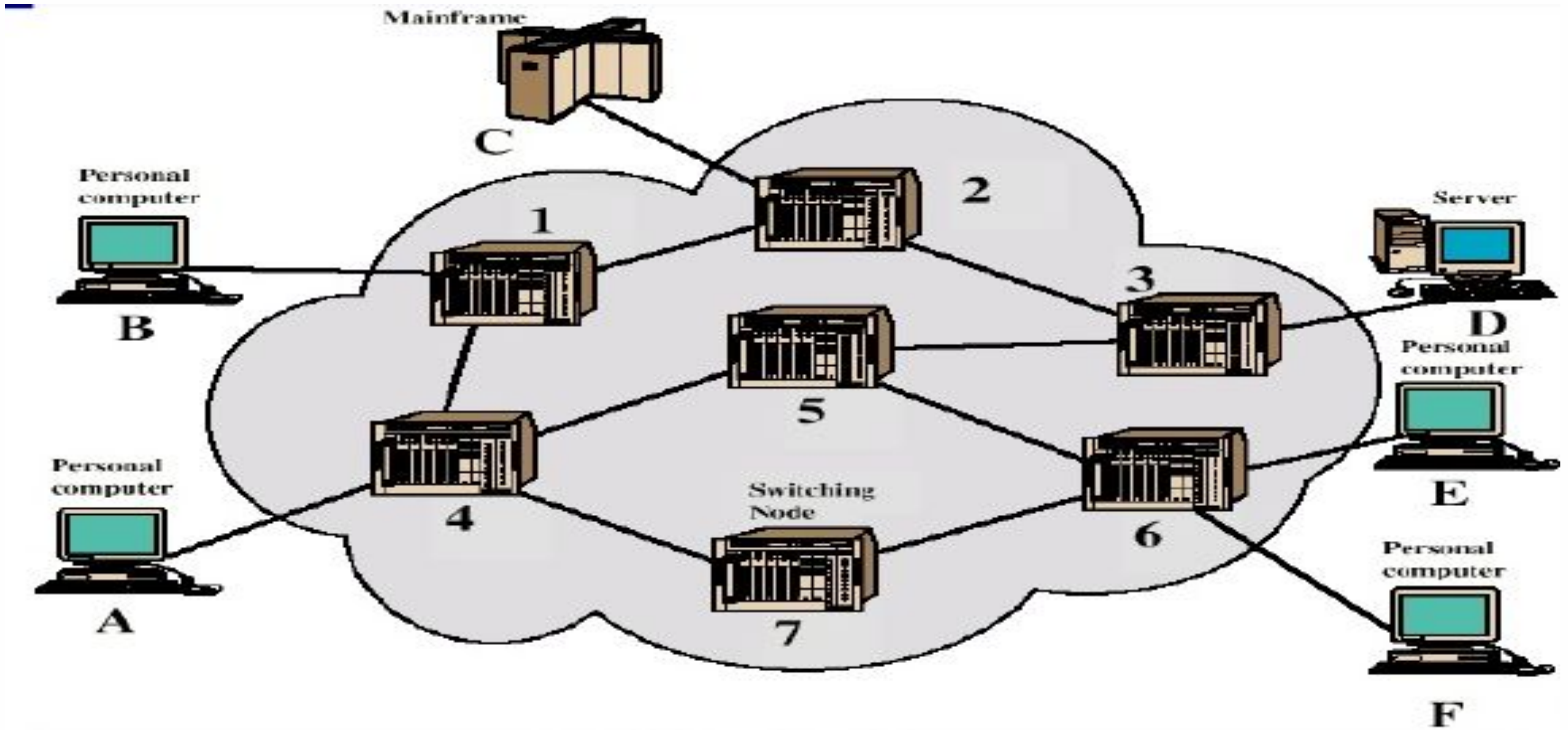


Image Source: google.com

Circuit switching

- Circuit switching is a method that links the sender and the receiver directly in an unbroken direction.
- For instance, telephone switching equipment creates a route that links the telephone of the caller to the telephone of the receiver by making a physical connection.
- If a connection is formed in this method of switching technique, a dedicated route remains between both ends until the connection is terminated.
- When the circuit is first created, routing decisions must be made, but decisions cannot be made after that.
- Before the establishment of the connection, the destination must send the acknowledge to the source node to indicate that it is ready and willing to send/receive data.[1]

Circuit switching continues…

Communication via circuit switching has three phases:

—Circuit establishment (link by link)

• Routing & resource allocation (FDM or TDM)

—Data transfer

—Circuit disconnect

• Deallocate the dedicated resources

• The switches must know how to find the route to the destination and how to allocate bandwidth (channel) to establish a connection.[3]

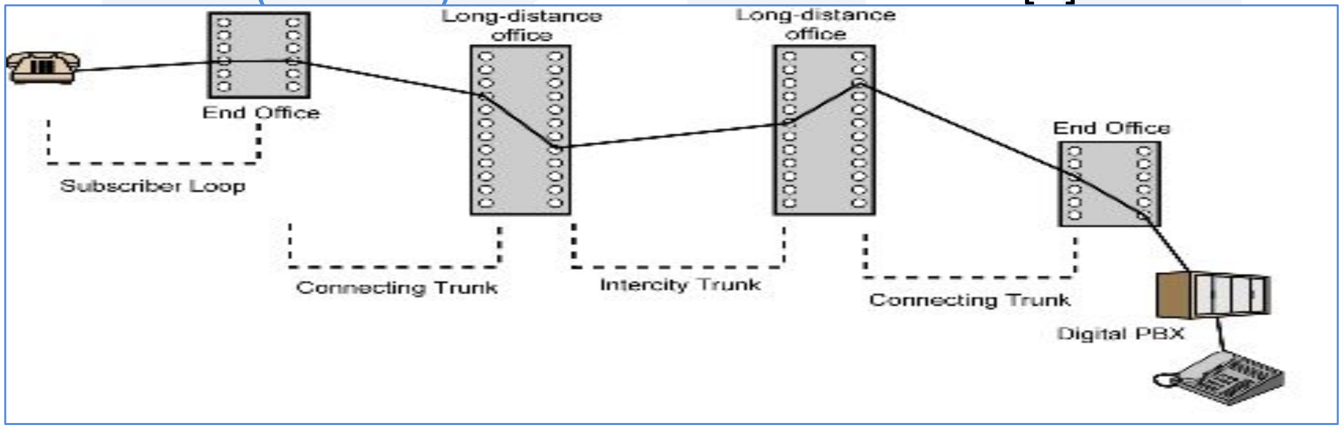


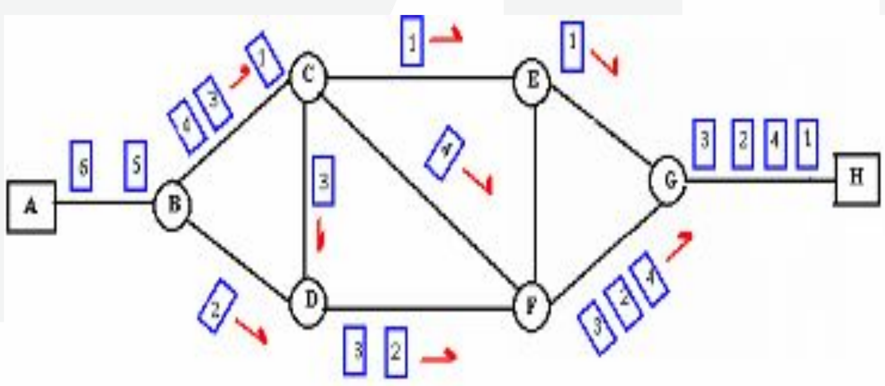
Image Source: google.com

Packet Switching

- It is possible to see packet switching as a solution that seeks to combine the advantages of the swapping of messages and circuits and to reduce the the drawbacks in both. [3]

There are two ways of switching packets:

- Datagram
- Virtual circuit.



Packet Switching

Image Source: google.com

Packet Switching

- A message is split into small pieces , called packets, in both packet switching methods.
- Each packet is tagged with the source and destination addresses that are necessary. Since packets have a clearly specified maximum duration, they can be stored in the main memory instead of the disc, reducing access delay and cost. The speeds of transmission are also optimised between nodes.
- With current technology, on a first-come , first-served basis, packets are usually accepted on the network. [2]
- Packets are delayed or discarded if the network becomes overwhelmed-(“dropp ed").

Packet Size

The size of the packet can be:

- 180 bits for the Datakit® virtual circuit switch designed by Bell Labs for communications and business applications.
- 1,024 or 2,048 bits for the 1PSS® switch, also designed by Bell Labs for public data networking.
- 53 bytes for ATM switching, such as Lucent Technologies' packet switches.

Packet Switching - DATAGRAM

- Datagram packet swapping is equivalent to swapping messages in that each packet is a complete self-contained unit with tackling the attached information.[1]
- This enables packets to follow a number of possible routes, by way of the network. So packets, each with the same destination address, do not have the same destination address.
- The same route is followed, and they can arrive out of sequence at the node (or destination) of the exit point.

Packet Switching - DATAGRAM

- At the destination stage, reordering is performed based on the packet sequence number.
- It is possible for a packet to be destroyed if one of the nodes on its way is crashed momentarily. Thus all its queued packets may be lost.[2]

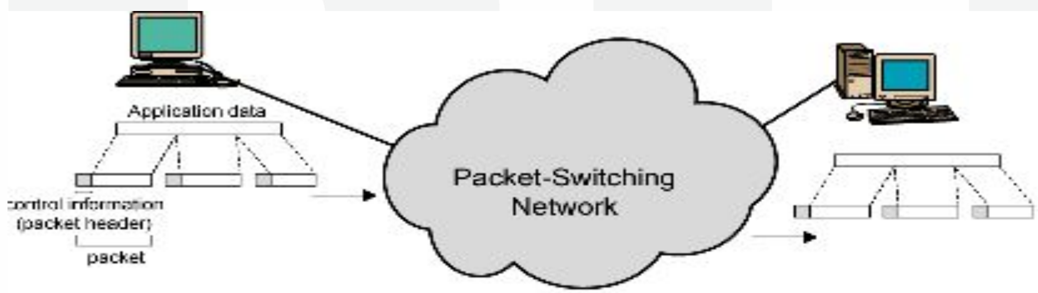


Image Source: google.com

Packet Switching – VIRTUAL CIRCUIT

- In the virtual circuit approach, a pre-organized route is established before any data packets are sent.[2]
- A logical connection is established when
- A sender send a "call request packet" to the receiver and
- The receiver send back an acknowledge packet "call accepted packet" to the sender if the receiver approves on conversational parameters[2].
- The conversational parameters can be maximum packet sizes, path to be taken, and other variables necessary to establish and maintain the conversation.
- They imply acknowledgements, flow control, and error control, so virtual circuits are reliable.
- They have the capability to inform upper-protocol layers if a transmission problem occurs.

Comparison

Circuit Switching	Datagram Packet Switching	Virtual Circuit Packet Switching
Dedicated transmission path	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Messages are not stored	Packets may be stored until delivered	Packets stored until delivered
The path is established for entire conversation	Route established for each packet	Route established for entire conversation
Call setup delay; negligible transmission delay	Packet transmission delay	Call setup delay; packet transmission delay
Busy signal if called party busy	Sender may be notified if packet not delivered	Sender notified of connection denial
Overload may block call setup; no delay for established calls	Overload increases packet delay	Overload may block call setup; increases packet delay
Electromechanical or computerized switching nodes	Small switching nodes	Small switching nodes
User responsible for message loss protection	Network may be responsible for individual packets	Network may be responsible for packet sequences
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call setup	Overhead bits in each packet	Overhead bits in each packet

DIGITAL LEARNING CONTENT

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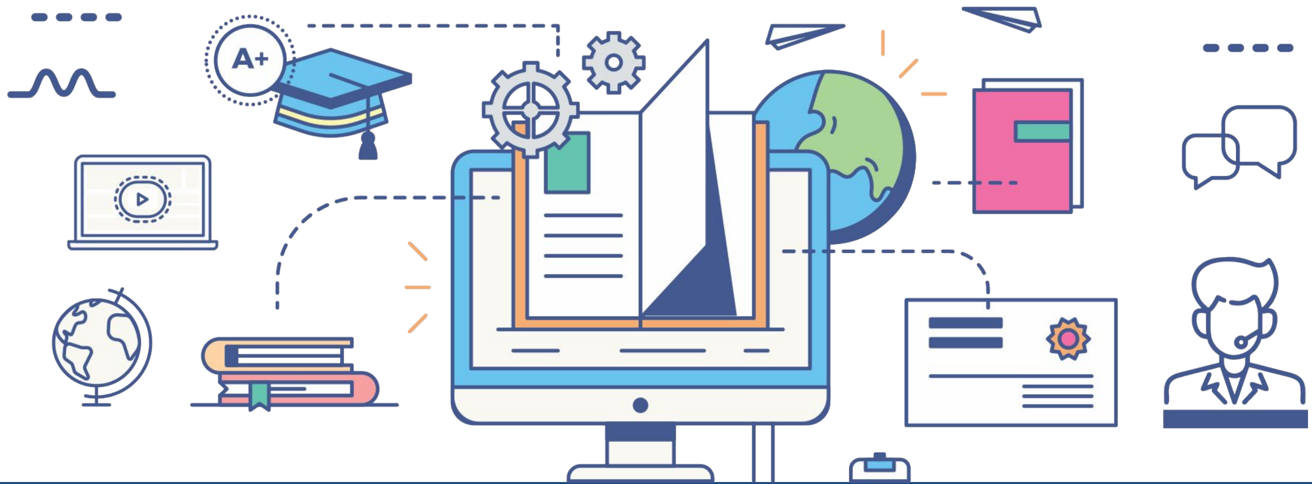

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