MEPL

IBPS SO Exam Preparation

Physical Layer

SHOBHIT BANDHU

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Physical Layer - Introduction

Introduction

Physical layer in the OSI model plays the role of interacting with actual hardware and signaling mechanism. Physical layer is the only layer of OSI which actually deals with the physical connectivity two different stations. This layer defines the hardware equipments, cabling, wiring, frequencies, pulses used to represent binary signals etc.

Physical layer provides its services to Data-link layer. Data-link layer hands over frames to physical layer and physical layer convert it to electrical pulses which represent binary data and sends over to the wired or wireless media.

Signals

When data is sent over physical medium it needs to be first converted into electromagnetic signals. Data itself can be analog such as human voice, or digital such as file on the disk. Data (both analog and digital) can be represented in digital or analog signals.

- **Digital Signals**

  Digital signals are discrete in nature and represents sequence of voltage pulses. Digital signals are used within the circuitry of a computer system.

- **Analog Signals**

  Analog signals are in continuous wave form in nature and represented by continuous electromagnetic waves.

Transmission impairment

When signals travel through the medium they tend to deteriorate. This may have many reasons:

- **Attenuation:**

  When signal passes through the medium it tends to get weaker as it covers distance. It loses is strength. For the receiver to interpret the data signal must be sufficiently strong.

- **Dispersion:**

  As signal travels through the media it tends to spread and overlaps. The amount of dispersion depends upon the frequency used.

- **Delay distortion:**

  Signals are sent over media with pre-defined speed and frequency. If the signal speed (velocity) and frequency does not match, there are possibilities that signal reach destination in arbitrary fashion. In digital media, this is very critical that some bits reach earlier than the previously sent.

- **Noise:**

  Random disturbance or fluctuation in analog or digital signals is said to be Noise in signal, which may distort the actual information being carried. Noise can be characterized in one of the following class:

  - **Thermal Noise:**

    Heat agitates the electronic conductors of a medium which may introduce noise in the media. Up to a certain level thermal noise is unavoidable.

  - **Inter modulation:**

    When more than frequency shares a medium their interference can cause noise in the media. Inter-modulation noise occurs say, if two different frequencies sharing a media and one of them have excessive strength or the component itself is not functioning properly, then the resultant frequency may not be delivered as expected.

  - **Crosstalk:**

    This sort of noise happens when a foreign signal enters into the media. This is because signal in one media is affecting the signal of second media.

  - **Impulse:**

    This noise is introduced because of irregular disturbances like lightening, electricity short-circuit or faulty components. Digital data is mostly affected by this sort of noise.

Transmission Media

The medium over which the information between two computer systems is sent, called Transmission Media. Transmission media comes in two forms.

- **Guided Media**

  All communication wires/cables comes into this type of media, such as UTP, Coaxial and Fiber Optics. In this media the sender and receiver are directly connected and the information is send (guided) through it.

- **Unguided Media**

  Wireless or open air space is said to be unguided media, because there is no connectivity between the sender and receiver. Information is spread over the air, and anyone including the actual recipient may collect the information.

Channel Capacity

The speed of transmission of information is said to be the channel capacity. We count it as data rate in digital world. It depends on numerous factors:

- **Bandwidth:** The physical limitation of underlying media.
- **Error-rate:** Incorrect reception of information because of noise.
- **Encoding:** number of levels used for signaling.

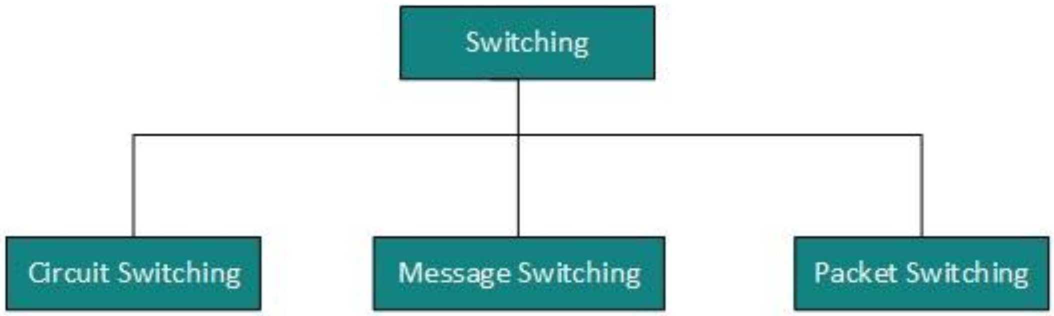
Multiplexing

Multiplexing is a technique to mix and send multiple data stream over a single media. This technique requires system hardware called Multiplexer for multiplexing streams and sending them on a media and De-Multiplexer which takes information from the media and distributes to different destinations.

Switching

Switching is a mechanism by which data/information sent from source towards destination which are not directly connected. Networks have interconnecting devices, which receives data from directly connected sources, stores data, analyze it and then forwards to the next interconnecting device closest to the destination.

Switching can be categorized as:



Digital Transmission

Introduction

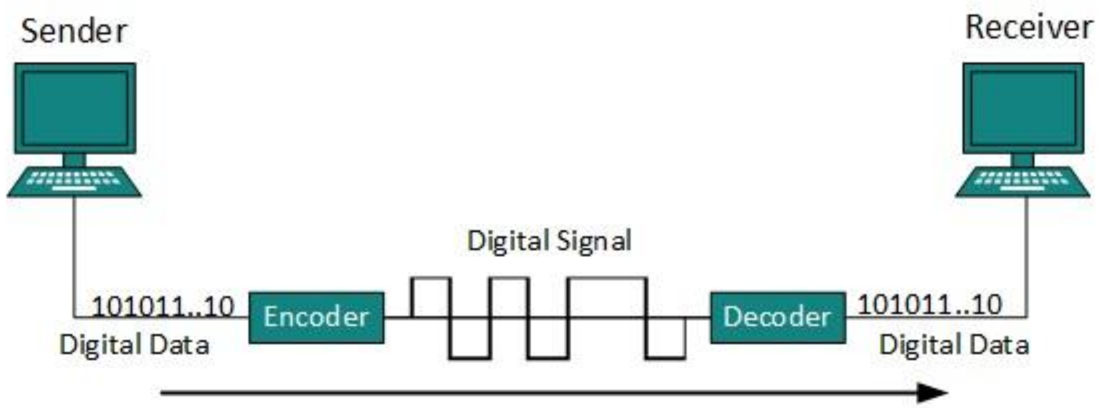
Data or information can be stored in two ways, analog and digital. For a computer to use that data is must be in discrete digital form. Like data, signals can also be in analog and digital form. To transmit data digitally it needs to be first converted to digital form.

Digital-to-digital conversion

This section explains how to convert digital data into digital signals. It can be done in two ways, line coding and block coding. For all communications, line coding is necessary whereas block coding is optional.

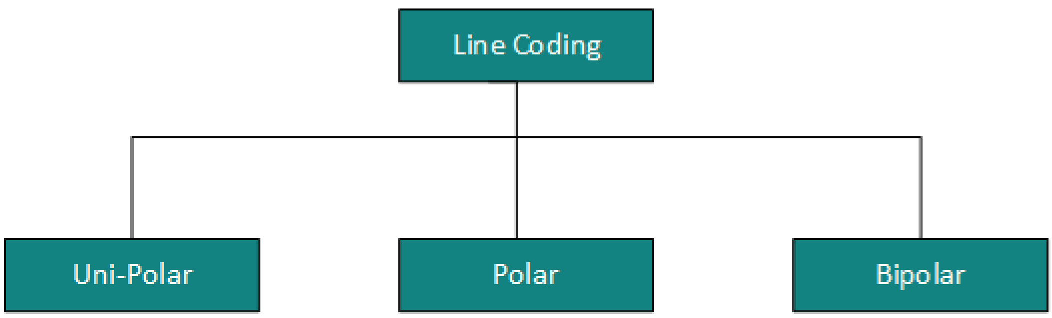
Line Coding

The process for converting digital data into digital signal is said to be Line Coding. Digital data is found in digital format, which are binary bits. It is represented *stored* internally as series of 1s and 0s.



[*Image: Line Coding*]

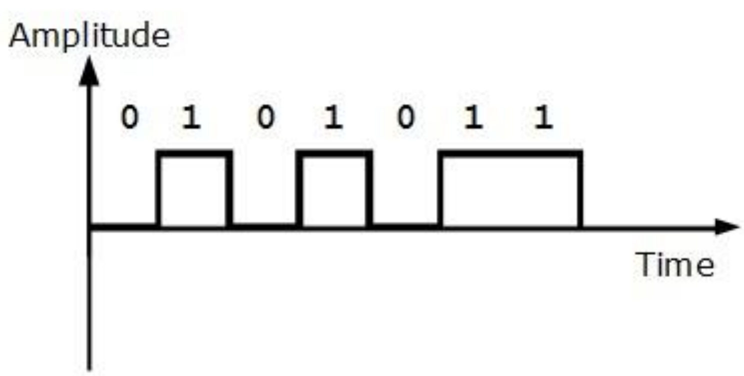
Digital signals which represents digital data, represented as discrete signals. There are three types of line coding schemes available:



[*Image: Line Coding Schemes*]

Uni-Polar Encoding

Unipolar encoding schemes uses single voltage level to represent data. In this case, to represent binary 1 high voltage is transmitted and to represent 0 no voltage is transmitted. It is also called Unipolar-Non-return-to-zero, because there's no rest condition i.e. it either represents 1 or 0.



[*Image: UniPolar NRZ Encoding*]

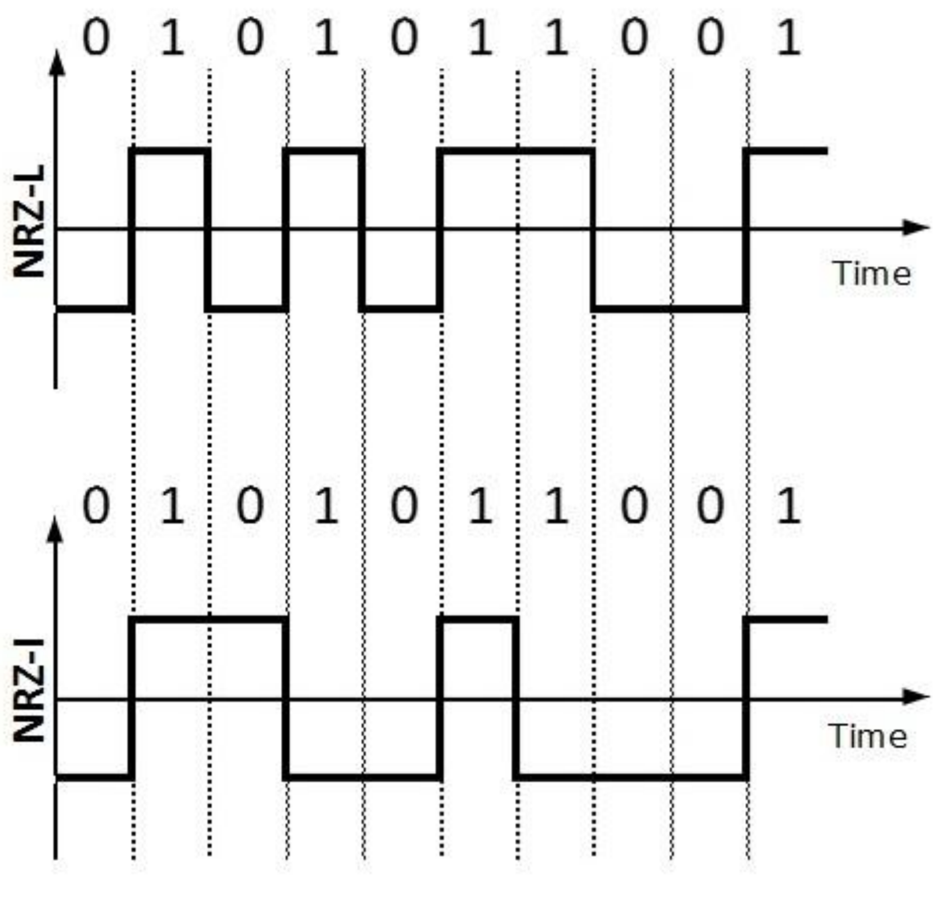
Polar Encoding

Polar encoding schemes multiple voltage levels are used to represent binary values. Polar encodings are available in four types:

- **Polar-NRZ** ***Non−return to zero***

  It uses two different voltage levels to represent binary values, generally positive voltage represents 1 and negative value represents 0. It is also NRZ because there's no rest condition.

  NRZ scheme has two variants: NRZ-L and NRZ-I.

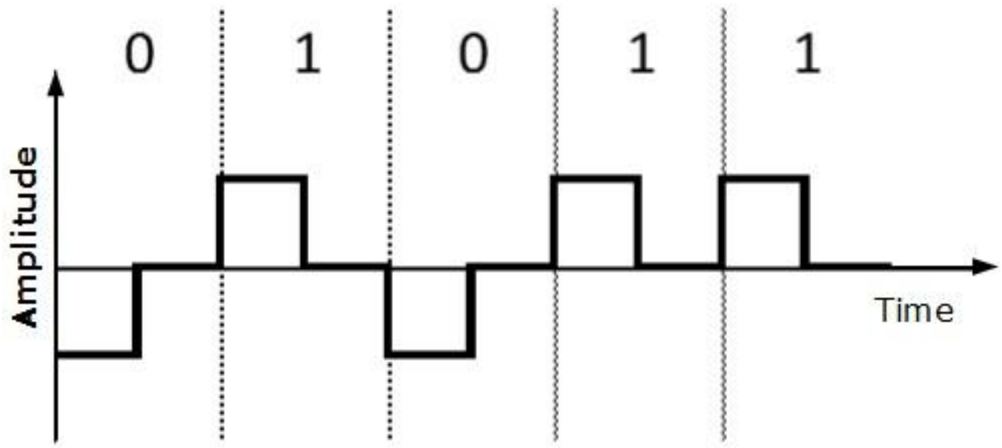


[*Image: NRZ-L and NRZ-I*]

NRZ-L changes voltage level at when a different bit is encountered whereas NRZ-I changes voltage when a 1 is encountered.

- RZ ***Return to zero***

  Problem with NRZ was the receiver cannot conclude when a bit ended and when the next bit is started, in case when sender and receiver's clock are not synchronized.



[*Image: Return-to-Zero Encoding*]

  RZ uses three voltage levels, positive voltage to represent 1, negative voltage to represent 0 and zero voltage for none. Signals change during bits not between bits.

- **Manchester**

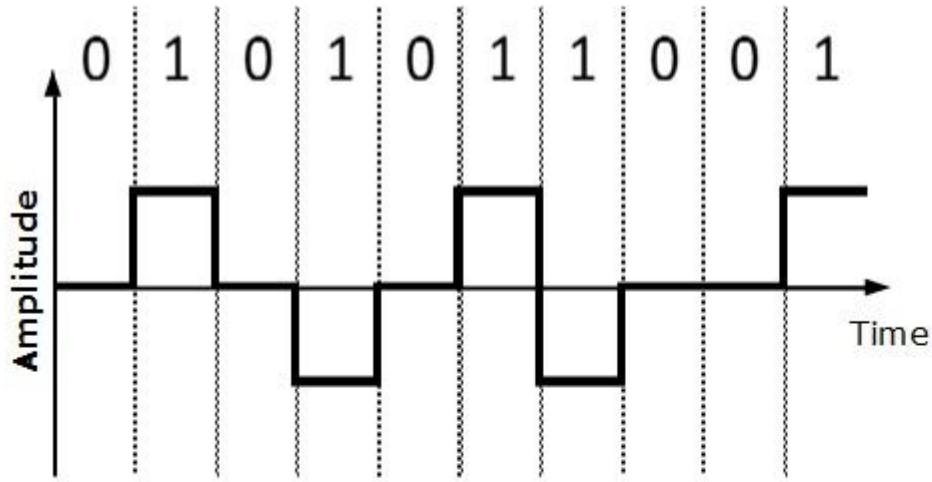
  This encoding scheme is a combination of RZ and NRZ-L. Bit time is divided into two halves. It transitions at the middle of the bit and changes phase when a different bit is encountered.

- **Differential Manchester**

  This encoding scheme is a combination of RZ and NRZ-I. It also transitions at the middle of the bit but changes phase only when 1 is encountered.

Bipolar Encoding

Bipolar encoding uses three voltage levels, positive, negative and zero. Zero voltage represents binary 0 and bit 1 is represented by altering positive and negative voltages.



[*Image: Bipolar Encoding*]

Block Coding

To ensure accuracy of data frame received, redundant bits are used. For example, in even parity one parity bit is added to make the count of 1s in the frame even. This way the original numbers of bits are increased. It is called Block Coding.

Block coding is represented by slash notation, mB/nB, that is m-bit block is substituted with n-bit block where n > m. Block coding involves three steps: division, substitution and combination.

After block coding is done it is line coded for transmission.

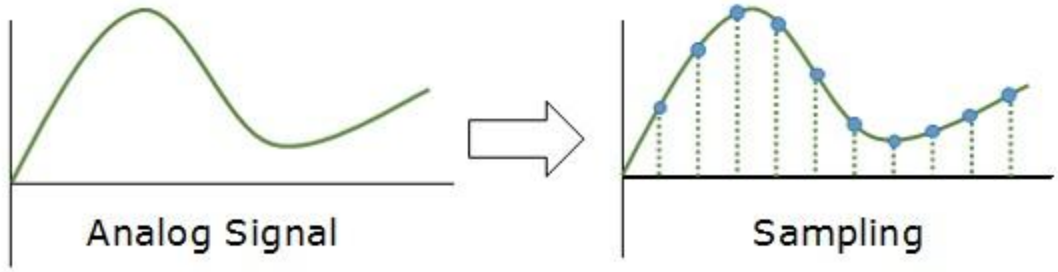
Analog-to-digital conversion

Microphones creates analog voice and camera creates analog videos, which here in our case is treated is analog data. To transmit this analog data over digital signals we need an analog to digital conversion.

Analog data is wave form continuous stream of data whereas digital data is discrete. To convert analog wave into digital data we use Pulse Code Modulation.

Pulse Code Modulation is one of the most commonly used method to convert analog data into digital form. It involves three steps: Sampling, Quantization and Encoding.

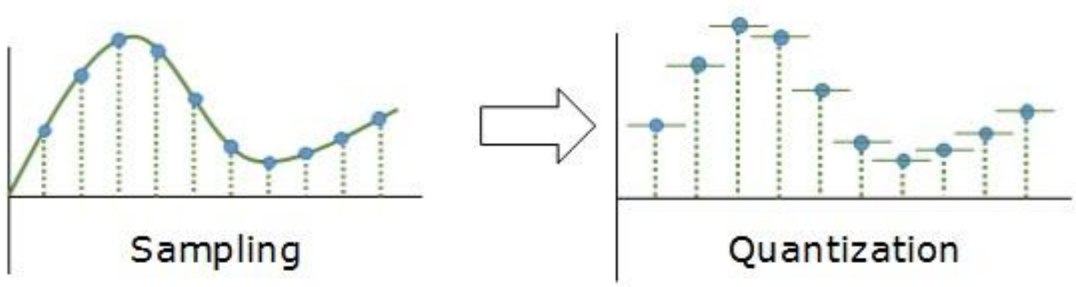
Sampling



[*Image: Sampling of Analog Signal*]

The analog signal is sampled every T interval. Most important factor in sampling is the rate on which analog signal is sampled. According to Nyquist Theorem, the sampling rate must be at least two times of the highest frequency of the signal.

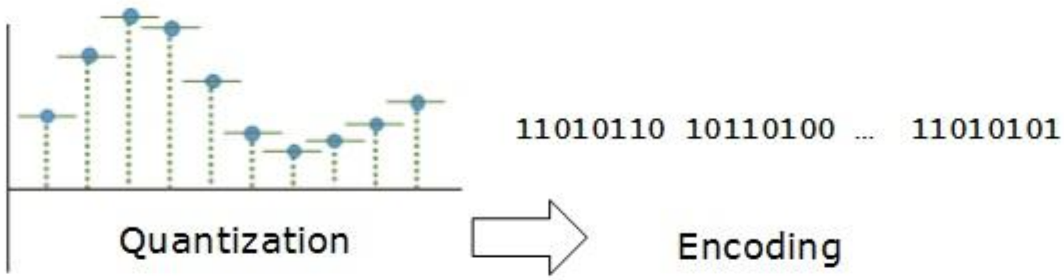
Quantization



[*Image: Quantization of sampled analog signal*]

Sampling yields discrete form of continuous analog signal. Every discrete pattern shows the amplitude of the analog signal at that instance. The quantization is done between the maximum amplitude value and the minimum amplitude value. Quantization is approximation of the instantaneous analog value.

Encoding



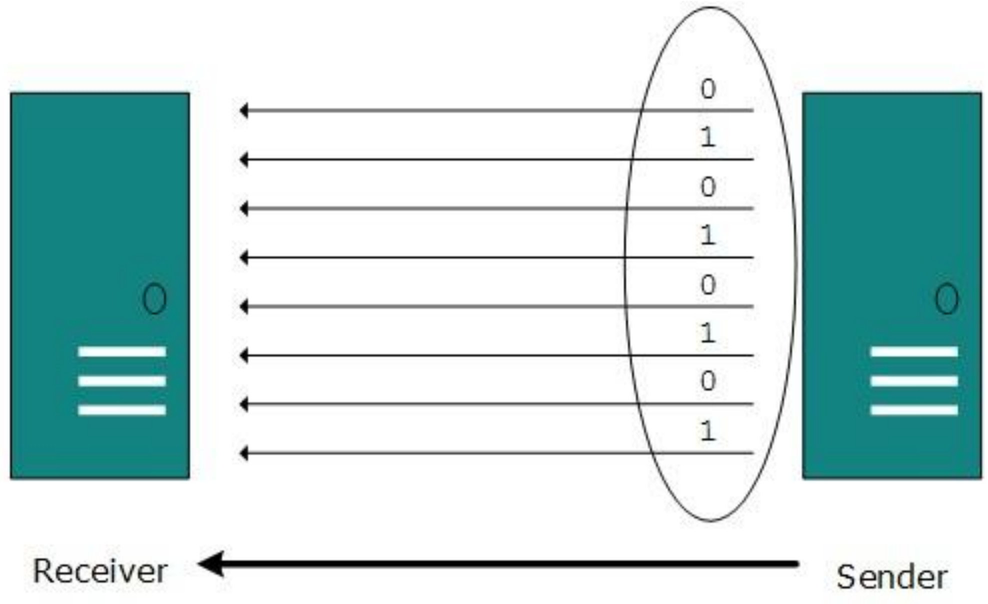
[*Image: Encoding from quantization*]

In encoding, each approximated value is then converted into binary format.

Transmission Modes

How data is to be transferred between to computer is decided by the transmission mode they are using. Binary data i.e. 1s and 0s can be sent in two different modes: Parallel and Serial.

Parallel Transmission

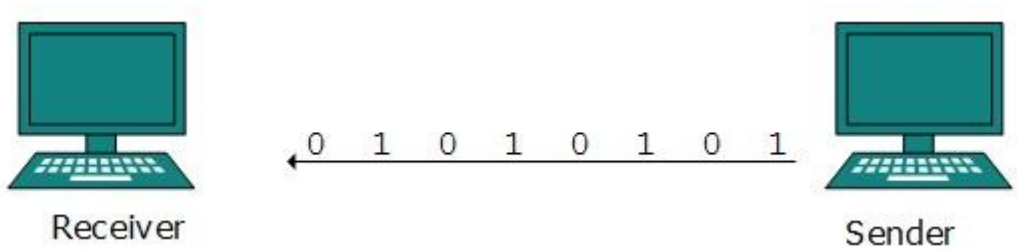


[*Image: Parallel Transmission*]

The binary bits are organized in to groups of fixed length. Both sender and receiver are connected in parallel with the equal number of data lines. Both computer distinguish between high order and low order data lines. The sender sends all the bits at once on all lines. Because data lines are equal to the number of bits in a group or data frame, a complete group of bits *dataframe* is sent in one go. Advantage of Parallel transmission is speed and disadvantage is the cost of wires, as it is equal to the number of bits needs to send parallelly.

Serial Transmission

In serial transmission, bits are sent one after another in a queue manner. Serial transmission requires only one communication channel as oppose parallel transmission where communication lines depends upon bit word length.



[*Image: Serial Transmission*]

Serial transmission can be either asynchronous or synchronous.

Asynchronous Serial Transmission

It is named so because there's no importance of timing. Data-bits have specific pattern and helps receiver recognize when the actual data bits start and where it ends. For example, a 0 is prefixed on every data byte and one or more 1s added at the end.

Two continuous data-frames *bytes* may have gap between them.

Synchronous Serial Transmission

It is up to the receiver to recognize and separate bits into bytes. The advantage of synchronous transmission is speed and it has no overhead of extra header and footer bits as in asynchronous transmission.

Analog Transmission

Introduction

When data in either digital or analog forms needs to be sent over an analog media it must first be converted into analog signals. There can be two cases according to data formatting.

Band pass: In real world scenarios, filters are used to filter and pass frequencies of interest. A band pass is a band of frequencies which can pass the filter.

Low-pass: Low-pass is a filter that passes low frequencies signals.

When digital data is converted into a band pass analog signal, it is called digital-to-analog conversion. When low-pass analog signal is converted into band-pass analog signal it is called analog-to-analog conversion.

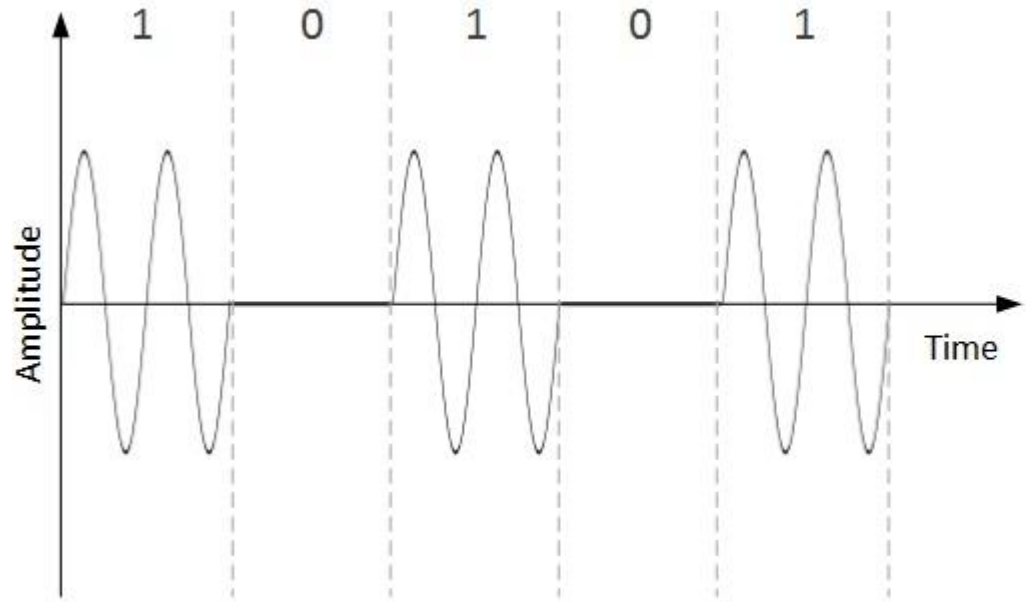
Digital-to-Analog Conversion

When data from one computer is sent to another via some analog carrier, it is first converted into analog signals. Analog signals are modified to reflect digital data, i.e. binary data.

An analog is characterized by its amplitude, frequency and phase. There are three kinds of digital-to-analog conversions possible:

- **Amplitude shift keying**

  In this conversion technique, the amplitude of analog carrier signal is modified to reflect binary data.

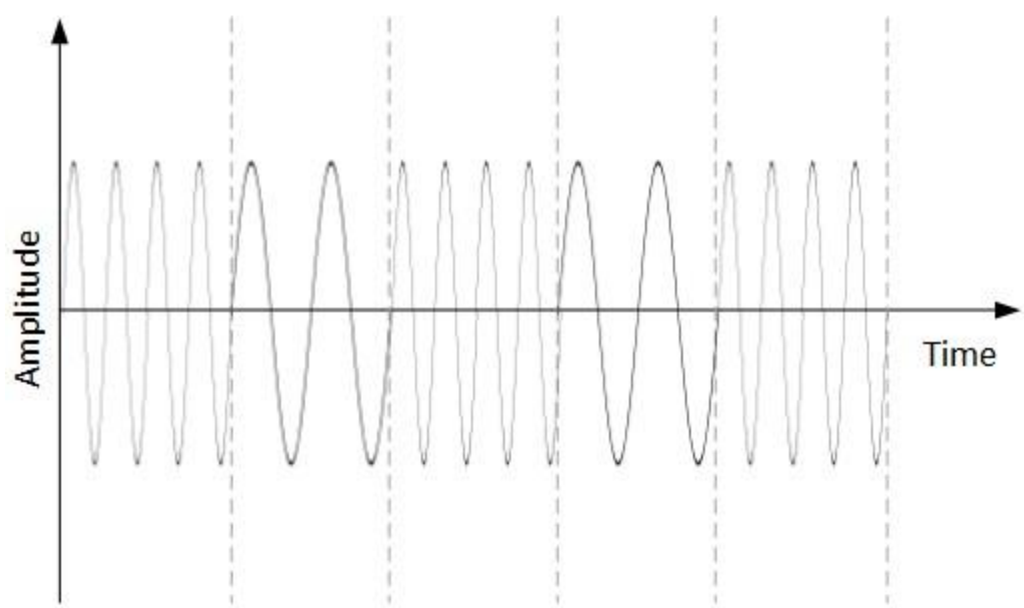


[*Image: Amplitude Shift Keying*]

When binary data represents digit 1, the amplitude is held otherwise it is set to 0. Both frequency and phase remain same as in the original carrier signal.

- **Frequency shift keying**

In this conversion technique, the frequency of the analog carrier signal is modified to reflect binary data.

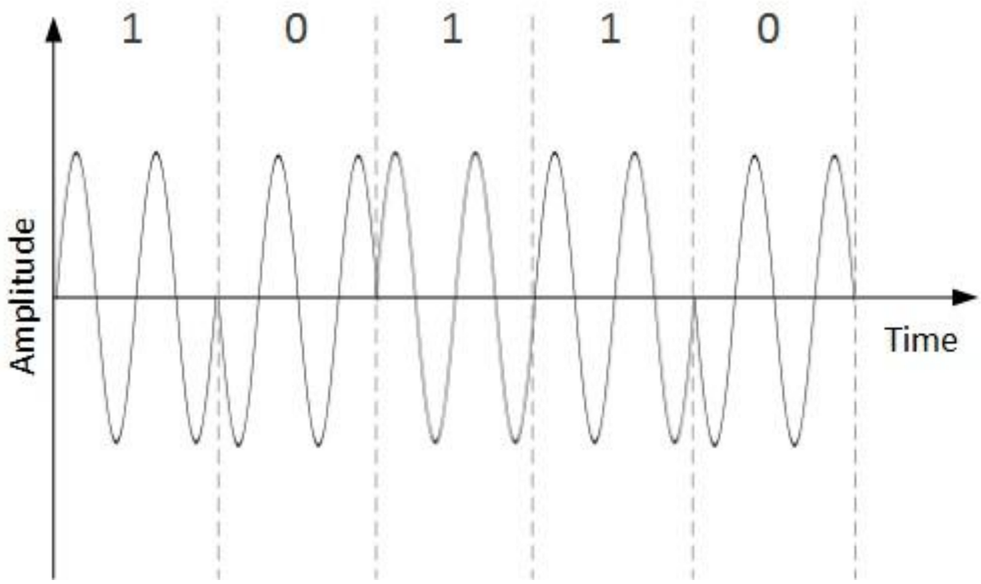


[*Image: Frequency shift keying*]

This technique uses two frequencies, f1 and f2. One of them, for example f1, is chosen to represent binary digit 1 and the other one is used to represent binary digit 0. Both amplitude and phase of the carrier wave are kept intact.

- **Phase shift keying**

In this conversion scheme, the phase of the original carrier signal is altered to reflect the binary data.



[*Image: Phase shift keying*]

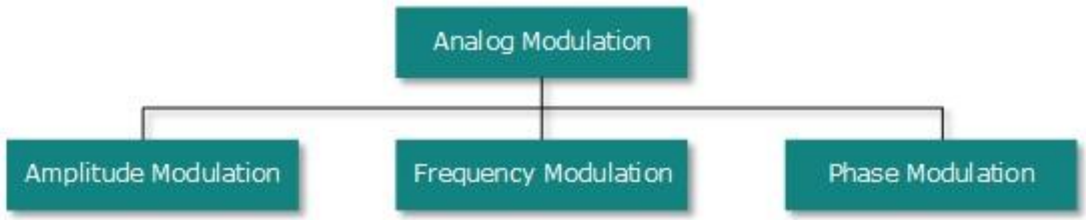
When a new binary symbol is encountered, the phase of the signal is altered. Amplitude and frequency of the original carrier signal is kept intact.

- **Quadrature Phase Shift Keying**

QPSK alters the phase to reflect 2 binary digits at once. This is done in two different phases. The main stream of binary data is divided equally into two sub-streams. The serial data is converted in to parallel in both sub-streams and then each stream is converted to digital signal using NRZ technique. Later, both the digital signals are merged together.

Analog-to-analog conversion

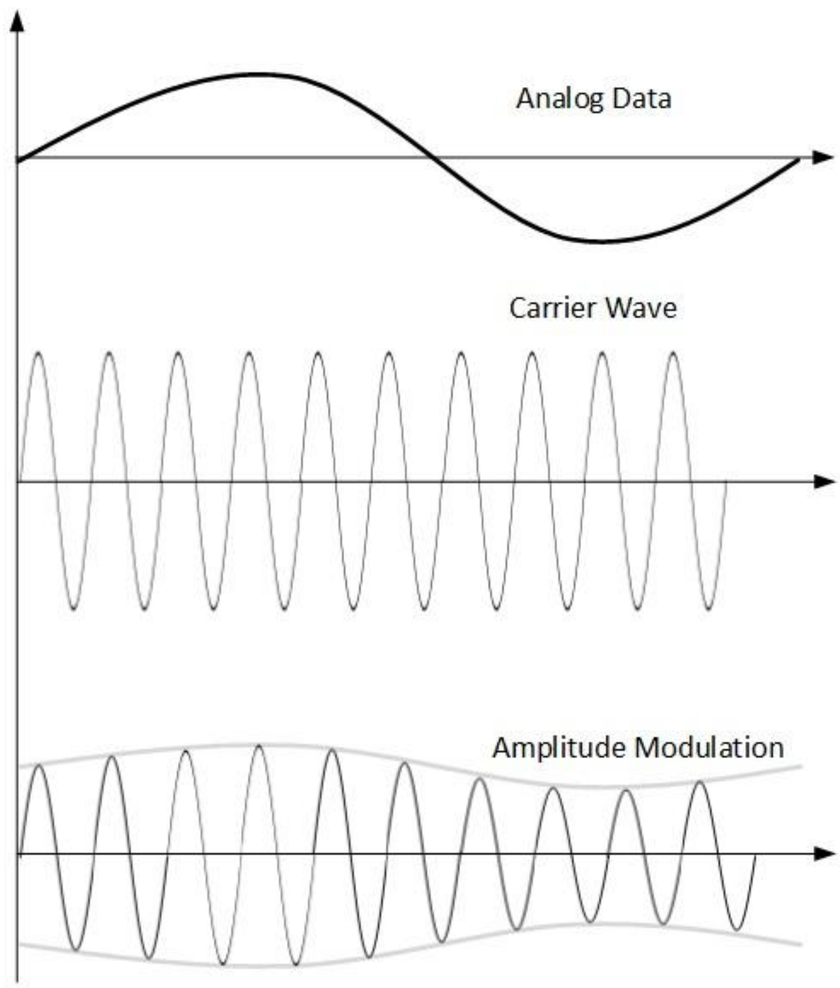
Analog signals are modified to represent analog data. This conversion is also known as Analog Modulation. Analog modulation is required when band-pass is used. Analog to analog conversion can be done in three ways:



[*Image: Types of Modulation*]

- **Amplitude Modulation**

  In this modulation, the amplitude of the carrier signal is modified to reflect the analog data.



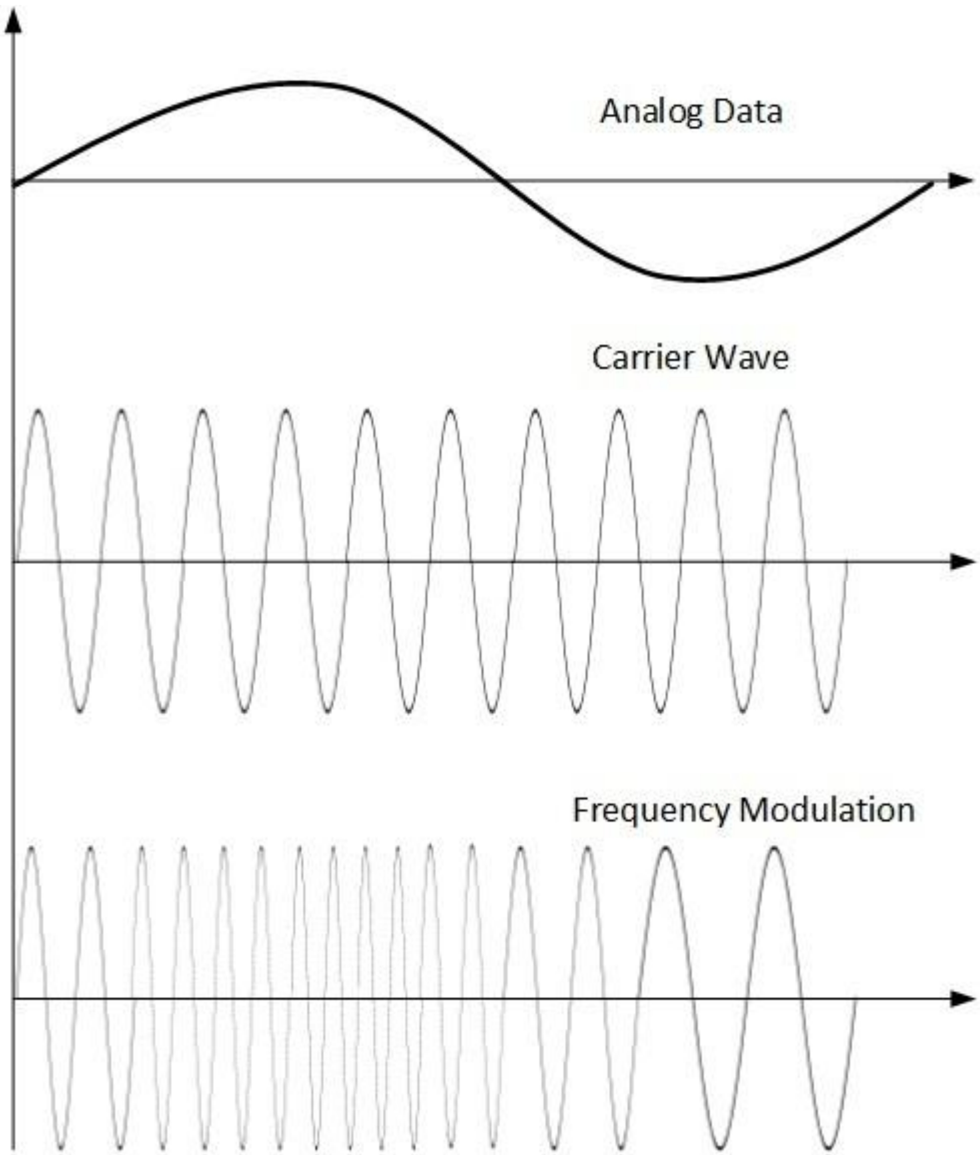
[*Image: Amplitude Modulation*]

Amplitude modulation is implemented by means of a multiplier. The amplitude of modulating signal *analog data* is multiplied by the amplitude of carrier frequency, which then reflects analog data.

The frequency and phase of carrier signal remain unchanged.

- **Frequency Modulation**

In this modulation technique, the frequency of the carrier signal is modified to reflect the change in the voltage levels of the modulating signal *analog data*.

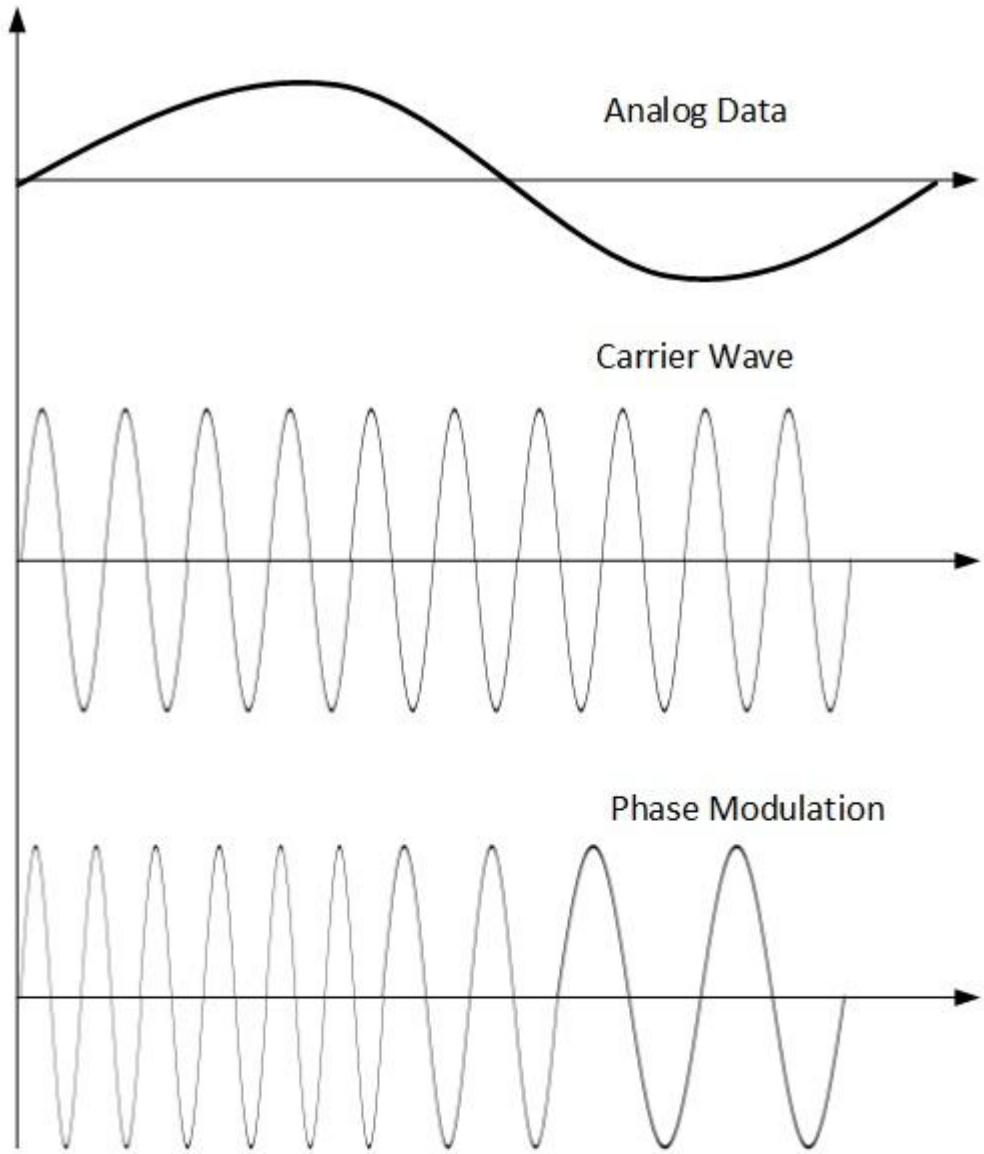


[*Image: Frequency Modulation*]

The amplitude and phase of the carrier signal are not altered.

- **Phase Modulation**

In the modulation technique, the phase of carrier signal is modulated in order to reflect the change in voltage *amplitude* of analog data signal.



[*Image: Phase Modulation*]

Phase modulation practically is similar to Frequency Modulation, but in Phase modulation frequency of the carrier signal is not increased. Frequency is carrier is signal is changed *made dense and sparse* to reflect voltage change in the amplitude of modulating signal.

Transmission Media

Magnetic Media

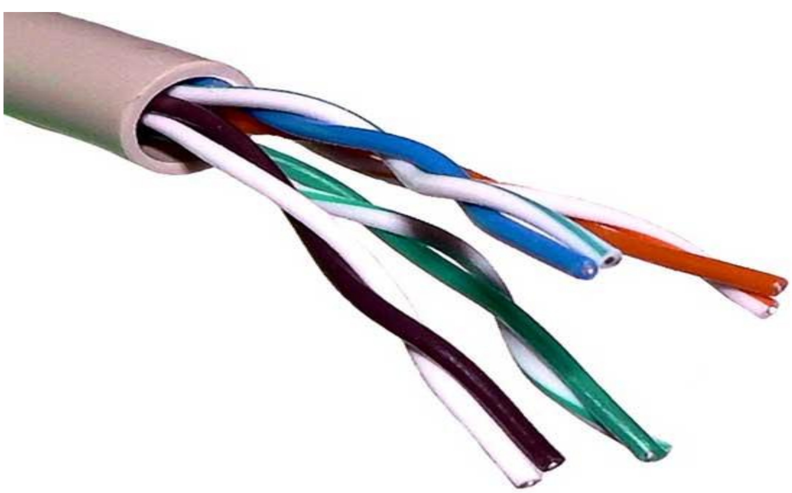
One of the most convenient ways to transfer data from one computer to another, even before the birth of networking, was to save it on some storage media and transfer physical from one station to another. Though it may seem odd in today's world of high speed Internet, but when the size of data to transfer is huge, Magnetic media comes into play.

For an example, say a Bank has Gigs of bytes of their customers' data which stores a backup copy of it at some geographically far place for security and uncertain reasons like war or tsunami. If the Bank needs to store its copy of data which is Hundreds of GBs, transfer through Internet is not feasible way. Even WAN links may not support such high speed or if they do cost will be too high to afford.

In these kinds of cases, data backup is stored onto magnetic tapes or magnetic discs and then shifted physically at remote places.

Twisted Pair Cable

A twisted pair cable is made of two plastic insulated copper wires twisted together to form a single media. Out of these two wires only one carries actual signal and another is used for ground reference. The twists between wires are helpful in reducing noise *electro−magnetic interference* and crosstalk.



[*Image: Twisted Pairs*]

There are two types of twisted pair cables available:

- Shielded Twisted Pair *STP* Cable
- Unshielded Twisted Pair *UTP* Cable

STP cables comes with twisted wire pair covered in metal foil. This makes it more indifferent to noise and crosstalk.

UTP has seven categories, each suitable for specific use. In computer networks, Cat-5, Cat-5e and Cat-6 cables are mostly used. UTP cables are connected by RJ45 connectors.

Coaxial Cable

Coaxial cables have two wires of copper. The core wire lies in center and is made of solid conductor. Core is enclosed in an insulating sheath. Over the sheath the second wire is wrapped around and that too in turn encased by insulator sheath. This all is covered by plastic cover.

[*Image: Coaxial Cable*]

Because of its structure coax cables are capable of carrying high frequency signals than that of twisted pair cables. The wrapped structure provides it a good shield against noise and cross talk. Coaxial cables provide high bandwidth rates of up to 450 mbps.

There are three categories of Coax cables namely, RG-59 *Cable-TV*, RG-58 *Thin-Ethernet* and RG-11 (Thick Ethernet. RG stands for Radio Government.

Cables are connected using BNC connector and BNC-T. BNC terminator is used to terminate the wire at the far ends.

Power Lines

Power Line communication is Layer-1 *Physical-Layer* technology which uses power cables to transmit data signals. Send in PLC modulates data and sent over the cables. The receiver on the other end de-modulates the data and interprets.

Because power lines are widely deployed, PLC can make all powered devices controlled and monitored. PLC works in half-duplex.

Two types of PLC exists:

- Narrow band PLC
- Broad band PLC

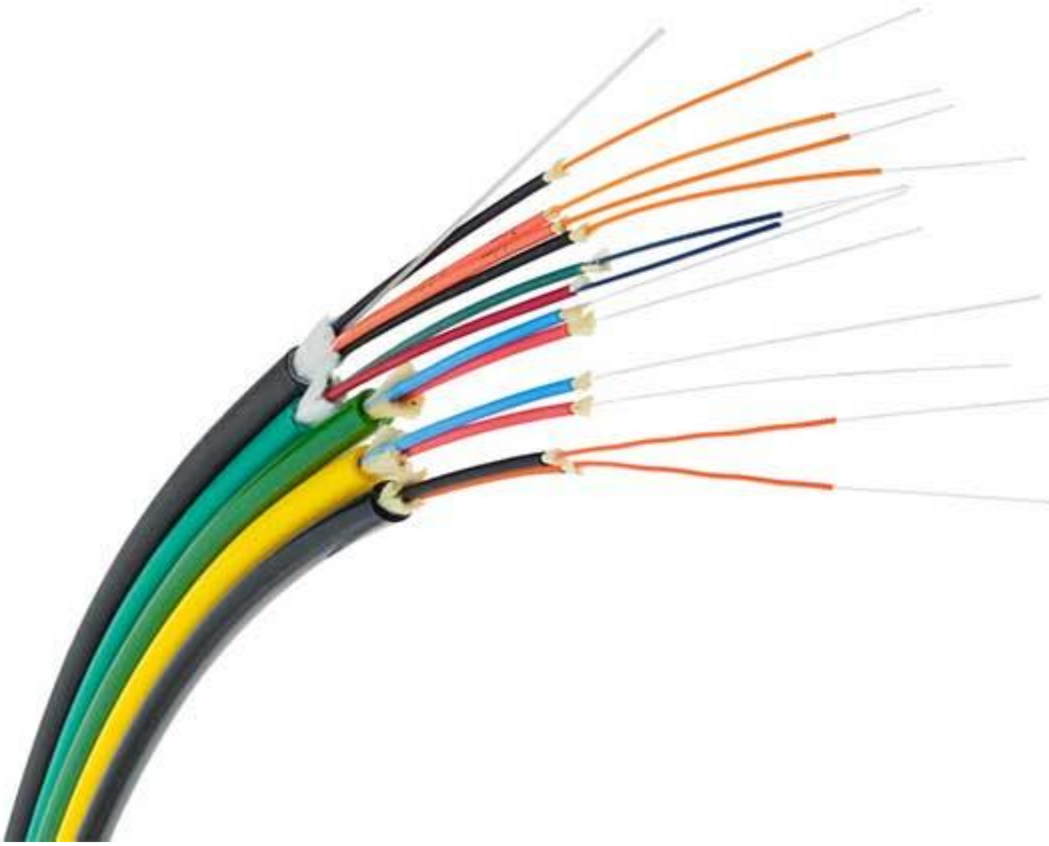
Narrow band PLC provides lower data rates up to 100s of kbps, as they work at lower frequencies $3-5000kHz$. But can be spread over several kilometers.

Broadband PLC provides higher data rates up to 100s of Mbps and works at higher frequencies $1.8–250MHz$. But cannot be much extended as Narrowband PLC.

Fiber Optics

Fiber Optic works on the properties of light. When light ray hits at critical angle it tends to refracts at 90 degree. This property has been used in fiber optic. The core of fiber optic cable is made of high quality glass or plastic. From one end of it light is emitted, it travels through it and at the other end light detector detects light stream and converts it to electric data form.

Fiber Optic provides the highest mode of speed. It comes in two modes; one is single mode fiber and second is multimode fiber. Single mode fiber can carries single ray of light whereas multimode is capable of carrying multiple beams of light.



[*Image: Fiber Optics*]

Fiber Optic also comes in unidirectional and bidirectional capabilities. To connect and access Fiber Optic special type of connectors are used. These can be SC *Subscriber Channel*, ST *Straight-Tip* or MT-RJ.

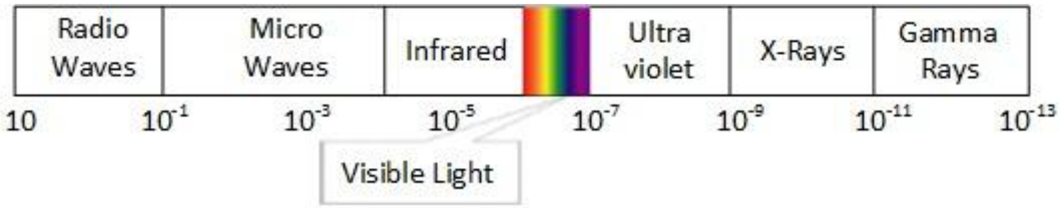
Wireless Transmission

Introduction

Wireless transmission is a form of unguided media. Wireless communication involves no physical link established between two or more devices, communicating wirelessly. Wireless signals are spread over in the air and are received and interpret by appropriate antennas.

When an antenna is attached to electrical circuit of a computer or wireless device, it converts the digital data into wireless signals and spread all over within its frequency range. The receptor on the other end receives these signals and converts them back to digital data.

A little part of electromagnetic spectrum can be used for wireless transmission.



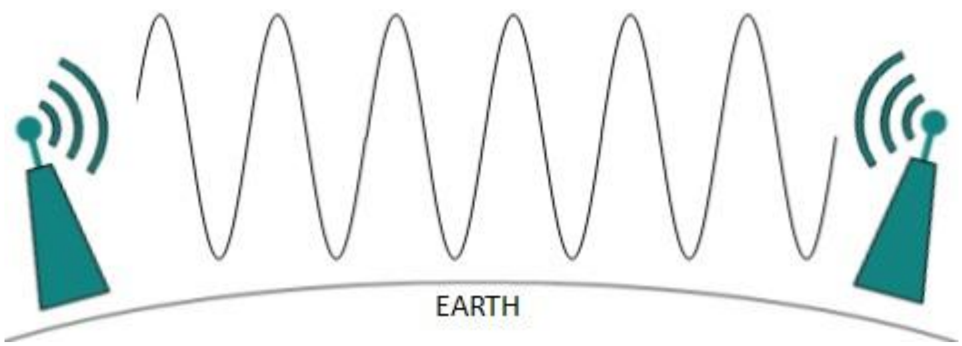
[*Image: Electromagnetic Spectrum*]

Radio Transmission

Radio frequency is easier to generate and because of its large wavelength it can penetrate through walls and alike structures. Radio waves can have wavelength from 1 mm – 100,000 km and have frequency ranging from 3 Hz (Extremely Low Frequency) to 300 GHz (Extremely High Frequency). Radio frequencies are sub-divided into six bands.

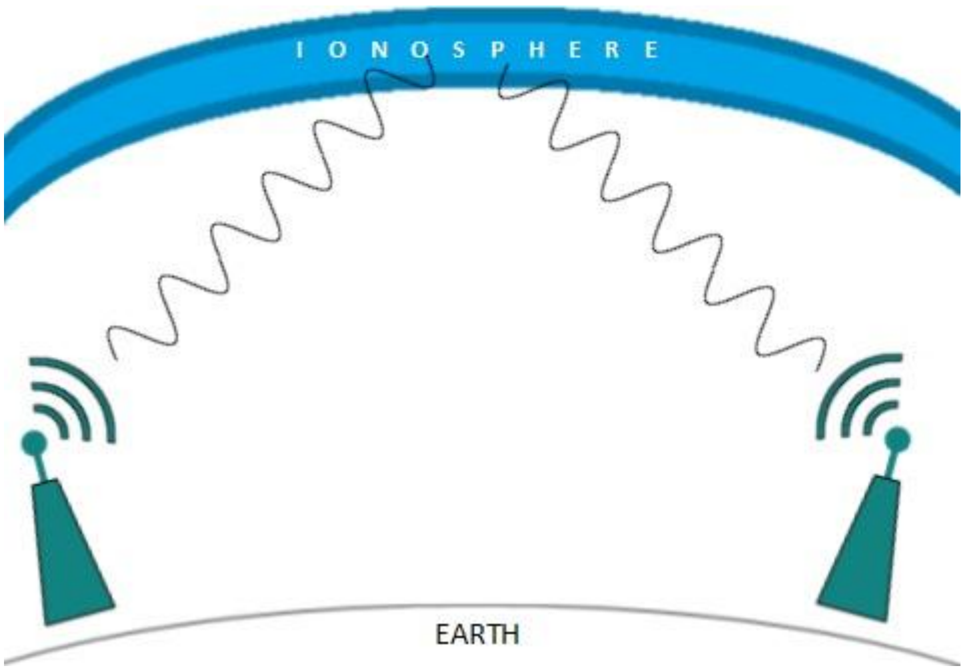
Radio waves at lower frequencies can travel through walls whereas higher RF travels in straight line and bounces back. The power of low frequency waves decreases sharply as it covers longer distance. High frequency radio waves have more power.

Lower frequencies like (VLF, LF, MF bands) can travel on the ground up to 1000 kilometers, over the earth's surface.



[*Image: Radio wave - grounded*]

Radio waves on high frequencies are prone to be absorbed by rain and other obstacles. They use Ionosphere of earth atmosphere. High frequency radio waves such as HF and VHF bands are spread upwards. When it reaches Ionosphere it is refracted back to the earth.

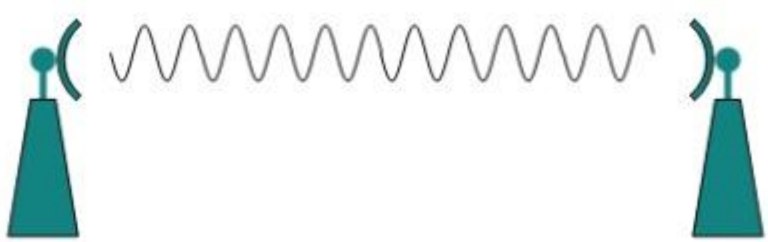


[*Image: Radio wave - Ionosphere*]

Microwave Transmission

Electromagnetic waves above 100 MHz tend to travel in a straight line and signals over them can be sent by beaming those waves towards one particular station. Because Microwaves travels in straight lines, both sender and receiver must be aligned to be strictly in line-of-sight.

Microwaves can have wavelength ranging from 1 mm – 1 meter and frequency ranging from 300 MHz to 300 GHz.



[*Image: Microwave Transmission*]

Microwave antennas concentrate the waves making a beam of it. As shown in picture above multiple antennas can be aligned to reach farther. Microwaves are higher frequencies and do not penetrate wall like obstacles.

Microwaves transmission depends highly upon the weather conditions and the frequency it is using.

Infrared Transmission

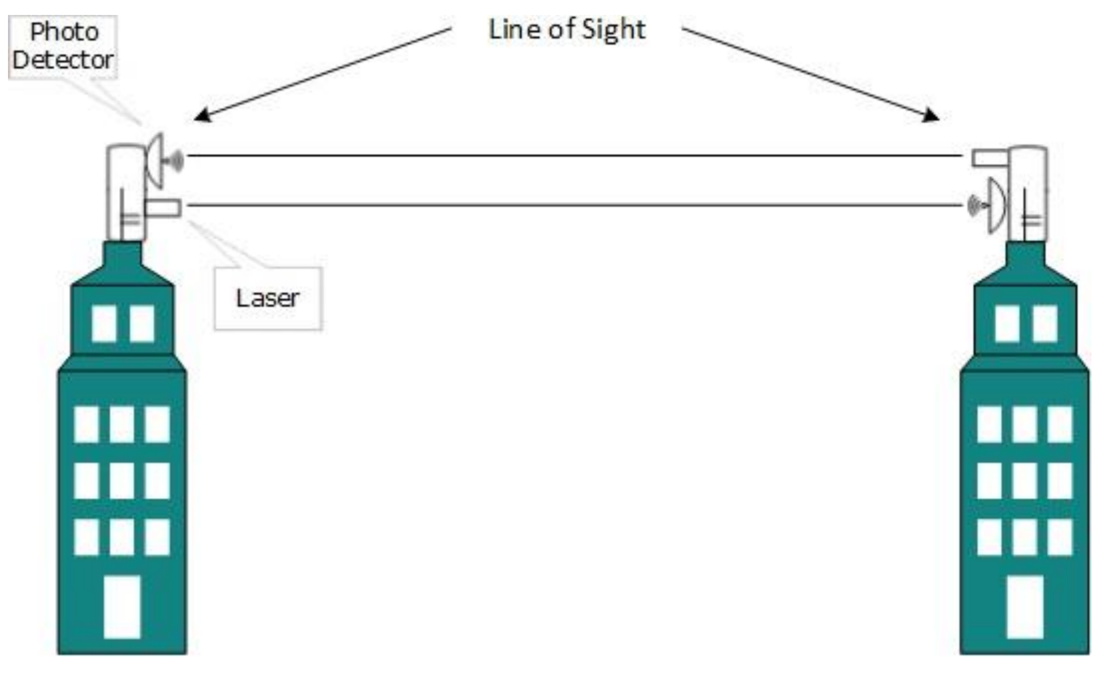
Infrared waves lie in between visible light spectrum and microwaves. It has wavelength of 700 nm to 1 mm and frequency ranges from 300 GHz to 430 THz.

Infrared waves are used for very short range communication purposes such as television and it's remote. Infrared travels in a straight line so they are directional by nature. Because of high frequency range, Infrared do not cross wall like obstacles.

Light Transmission

Highest most electromagnetic spectrum which can be used for data transmission is light or optical signaling. This is achieved by means of LASER.

Because of frequency light uses, it tends to travel strictly in straight line. So the sender and receiver must be in the line-of-sight. Because laser transmission is unidirectional, at both ends of communication laser and photo-detectors needs to be installed. Laser beam is generally 1mm wide so it is a work of precision to align two far receptors each pointing to lasers source.



[*Image: Light Transmission*]

Laser works as Tx (transmitter) and photo-detectors works as Rx (receiver).

Lasers cannot penetrate obstacles like walls, rain and thick fog. Additionally, laser beam is distorted by wind and atmosphere temperature or variation in temperature in the path.

Laser is safe for data transmission as it is very difficult to tap 1mm wide laser without interrupting the communication channel.

Multiplexing

Introduction

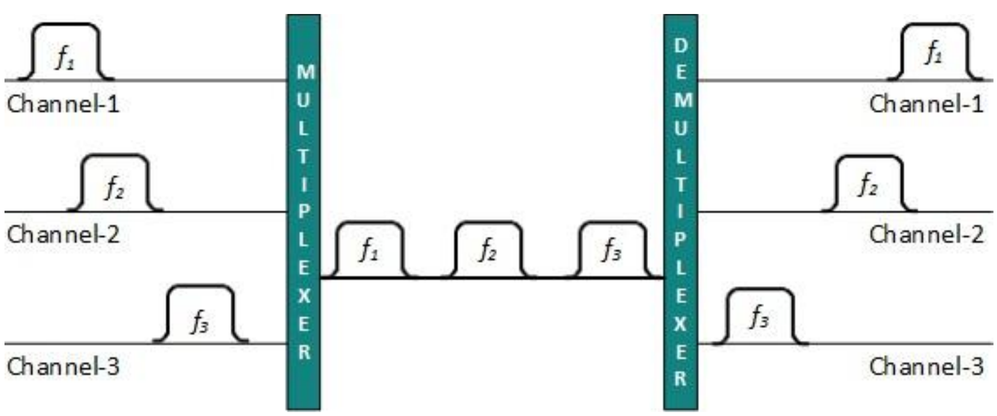
Multiplexing is a technique by which different analog and digital streams of transmission can be simultaneously processed over a shared link. Multiplexing divides the high capacity medium into low capacity logical medium which is then shared by different streams.

Communication is possible over the air *radio-frequency*, using a physical media *cable* and light *optical fiber*. All mediums are capable of multiplexing.

When more than one sender tries to send over single medium, a device called Multiplexer divides the physical channel and allocates one to each. On the other end of communication, a De-multiplexer receives data from a single medium and identifies each and sends to different receivers.

Frequency Division Multiplexing

When the carrier is frequency, FDM is used. FDM is an analog technology. FDM divides the spectrum or carrier bandwidth in logical channels and allocates one user to each channel. Each user can use the channel frequency independently and has exclusive access of it. All channels are divided such a way that they do not overlap with each other. Channels are separated by guard bands. Guard band is a frequency which is not used by either channel.

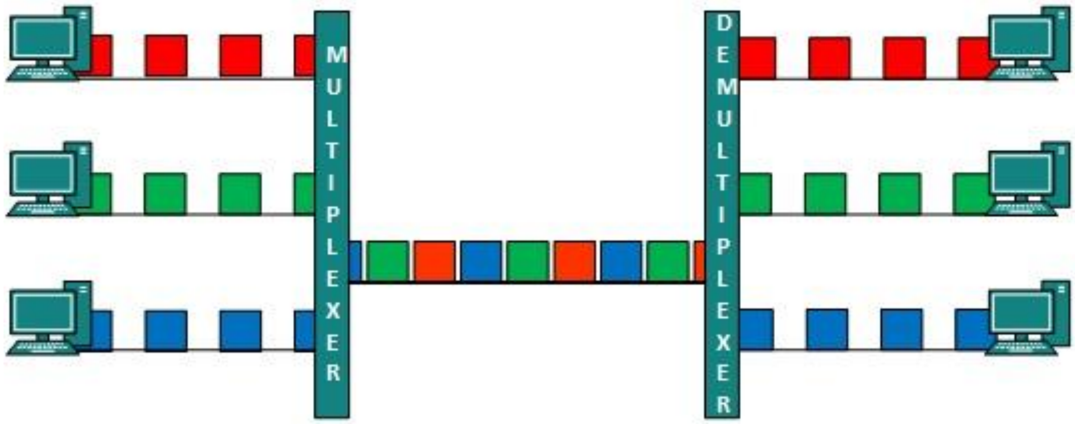


[*Image: Frequency Division Multiplexing*]

Time Division Multiplexing

TDM is applied primarily on digital signals but can be applied on analog signals as well. In TDM the shared channel is divided among its user by means of time slot. Each user can transmit data within the provided time slot only. Digital signals are divided in frames, equivalent to time slot i.e. frame of an optimal size which can be transmitted in given time slot.

TDM works in synchronized mode. Both ends, i.e. Multiplexer and De-multiplexer are timely synchronized and both switch to next channel simultaneously.



[*Image: Time Division Multiplexing*]

When at one side channel A is transmitting its frame, on the other end De-multiplexer providing media to channel A. As soon as its channel A's time slot expires this side switches to channel B. On the other end De-multiplexer behaves in a synchronized manner and provides media to channel B. Signals from different channels travels the path in interleaved manner.

Wavelength Division Multiplexing

Light has different wavelength *colors*. In fiber optic mode, multiple optical carrier signals are multiplexed into on optical fiber by using different wavelengths. This is an analog multiplexing technique and is done conceptually in the same manner as FDM but uses light as signals.

[*Image: Wavelength Division Multiplexing*]

Further, on each wavelength Time division multiplexing can be incorporated to accommodate more data signals.

Code Division Multiplexing

Multiple data signals can be transmitted over a single frequency by using Code Division Multiplexing. FDM divides the frequency in smaller channels but CDM allows its users to full bandwidth and transmit signals all the time using a unique Code. CDM uses orthogonal codes to spread signals.

Each station is assigned with a unique code, called chip. Signals travels with these codes independently travelling inside the whole bandwidth. The receiver in this case, knows in advance chip code signal it has to receive signals.

Network Switching

Introduction

Switching is process to forward packets coming in from one port to a port leading towards the destination. When data comes on a port it is called ingress, and when data leaves a port or goes out it is called egress. A communication system may include number of switches and nodes. At broad level, switching can be divided into two major categories:

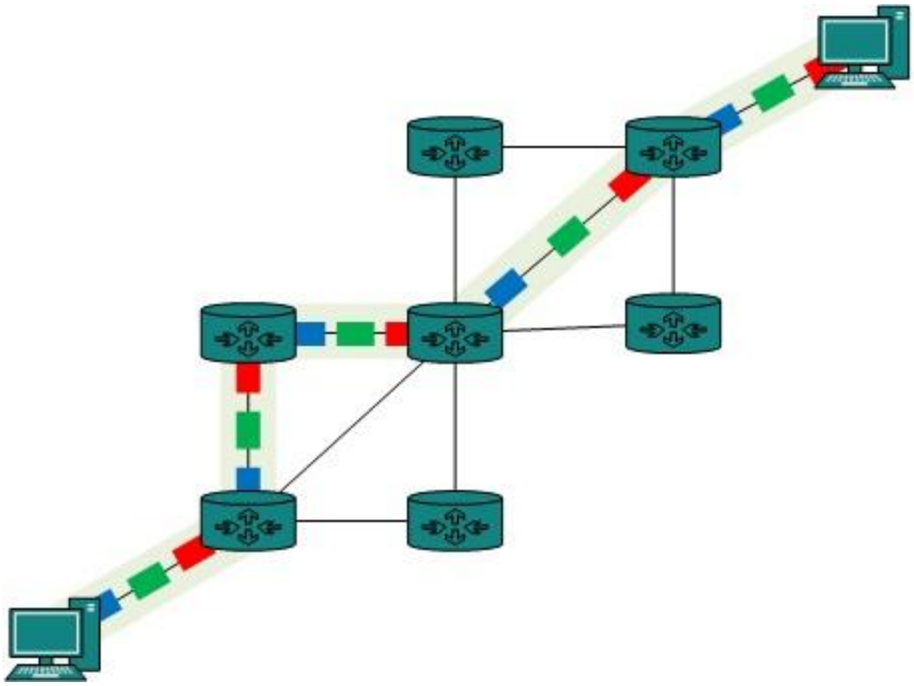
- **Connectionless:** Data is forwarded on behalf of forwarding tables. No previous handshaking is required and acknowledgements are optional.
- **Connection Oriented:** Before switching data to be forwarded to destination, there is a need to pre-establish circuit along the path between both endpoints. Data is then forwarded on that circuit. After the transfer is completed, circuits can be kept for future use or can be turned down immediately.

Circuit Switching

When two nodes communicate with each other over a dedicated communication path, it is called circuit switching. There's a need of pre-specified route from which data will travel and no other data will permitted. In simple words, in circuit switching, to transfer data circuit must established so that the data transfer can take place.

Circuits can be permanent or temporary. Applications which use circuit switching may have to go through three phases:

- Establish a circuit
- Transfer of data
- Disconnect the circuit



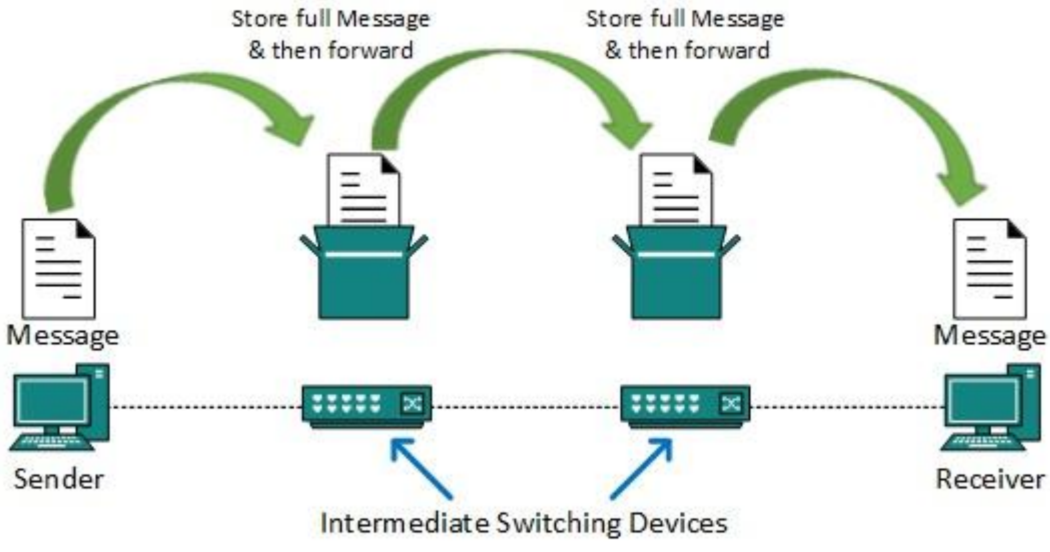
[*Image: Circuit Switching*]

Circuit switching was designed for voice applications. Telephone is the best suitable example of circuit switching. Before a user can make a call, a virtual path between caller and callee is established over the network.

Message Switching

This technique was somewhere in middle of circuit switching and packet switching. In message switching, the whole message is treated as a data unit and is switching / transferred in its entirety.

A switch working on message switching, first receives the whole message and buffers it until there are resources available to transfer it to the next hop. If the next hop is not having enough resource to accommodate large size message, the message is stored and switch waits.



[*Image: Message Switching*]

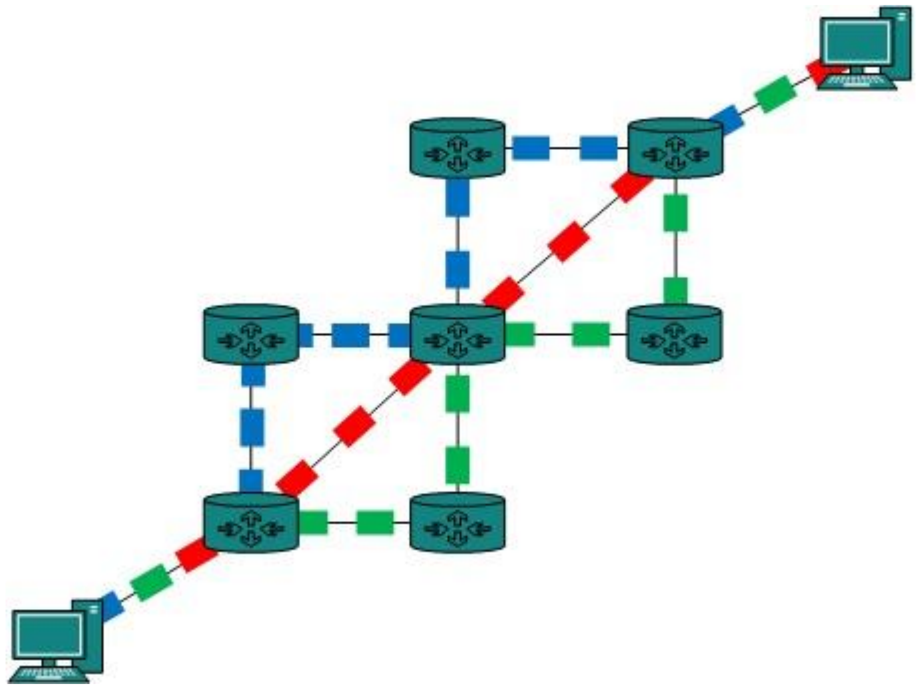
This technique was considered substitute to circuit switching. As in circuit switching the whole path is blocked for two entities only. Message switching is replaced by packet switching. Message switching has some drawbacks:

- Every switch in transit path needs enough storage to accommodate entire message.
- Because of store-and-forward technique and waits included until resources available, message switching is very slow.
- Message switching was not a solution for streaming media and real-time applications.

Packet Switching

Shortcomings of message switching gave birth to an idea of packet switching. The entire message is broken down into smaller chunks called packets. The switching information is added in the header of each packet and transmitted independently.

It is easier for intermediate networking devices to store smaller size packets and they do not take much resources either on carrier path or in the switches' internal memory.



[*Image: Packet Switching*]

Packet switching enhances line efficiency as packets from multiple applications can be multiplexed over the carrier. The internet uses packet switching technique. Packet switching enables the user to differentiate data streams based on priorities. Packets are stored and forward according to their priority to provide Quality of Service.