What are Analog and Digital Signals in a Computer Network?

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What is Signal?

A Signal is an electromagnetic wave that is used to communicate system-to-system by sending data from one network to another network is basically known as **"Signal"**.

In a computer network there are mainly two types of signals are:

1. Analog Signal
2. Digital Signal

What is Analog Signal?

An Analog signal is a signal which is continuous and has a time-varying feature. It is a representation of time-varying quantity. For example, the Human voice can be considered an analog signal because the signal of the human voice flows in a continuous manner.

Analog Signal

In other words, we can say that the analog signal is represented by the continuous variable which transmits the information/data as a response to physical phenomenon. It is known as an **"Analog Signal"**

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Examples of Analog signals are **Temperature, Pressure, Flow Measurement**, etc.

Types of Analog Signal

1. Simple Analog Signal
2. Composite Analog Signal

What is Digital Signal?

As the word suggests **“Digital”** which means it describes the electronic technology that generates signals. It is a physical signal that is represented by two discrete values “0” & “1”, these discrete values are known as bitstream.

In simple words, we can say that the binary signals are known as “Digital signals” where the signals are converted into a small bit form which is represented by a series of “0” & “1”.

Digital Signal
Examples of digital signals are **Motor, Digital Phones, Digital pens**, etc

Difference between Analog and Digital Signal

	Analog Signal	**Digital Signal**
Signal	1) In an Analog, signals are continuous.	1) In a Digital, Signals are discrete.
Transformation	2) In analog systems electronic circuits are used for the transformation of signals.	2) In Digital Signals, the transformation is done using the logic circuit.
Transmission	3) Data transmission is not of high quality.	3) Data transmission has high quality.

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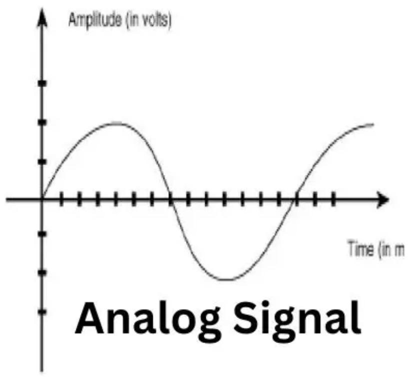
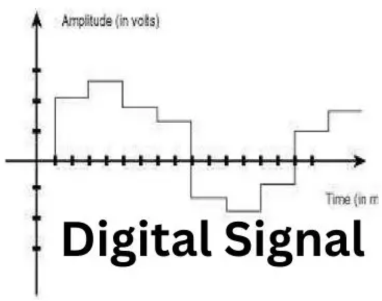
Flexibility	4) In an Analog signal, their hardware is not flexible.	4) In Digital signals, their hardware is not flexible.
Noise	5) Analog signals are more likely to get affected and result in reduced accuracy.	5) Digital signals are discrete time signals that are generated by digital modulation.
Power Consumptions	6) Analog signals use more power.	6) Digital signals use less power compared to analog.
Waves	7) It is denoted by the sine waves(ups and down).	7) It is denoted by the square form.
Example	8) Human Voice, Tape recorder, Temperature, etc.	8) Mp3 players, Digital phones, computers, etc.





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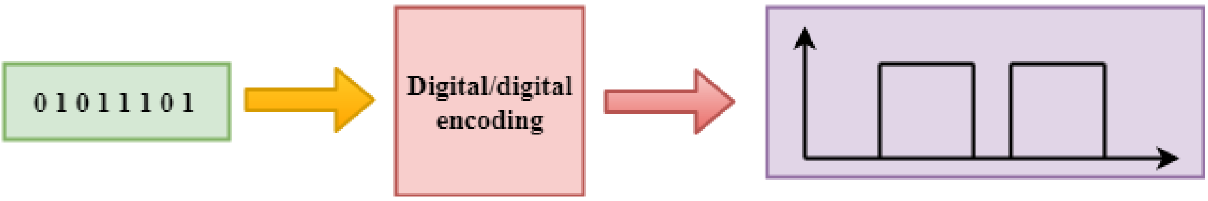
Digital Transmission

Data can be represented either in analog or digital form. The computers used the digital form to store the information. Therefore, the data needs to be converted in digital form so that it can be used by a computer.

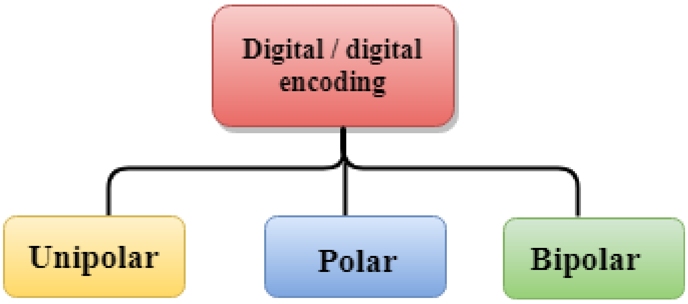
DIGITAL-TO-DIGITAL CONVERSION

Digital-to-digital encoding is the representation of digital information by a digital signal. When binary 1s and 0s generated by the computer are translated into a sequence of voltage pulses that can be propagated over a wire, this process is known as digital-to-digital encoding.



Digital-to-digital encoding is divided into three categories:

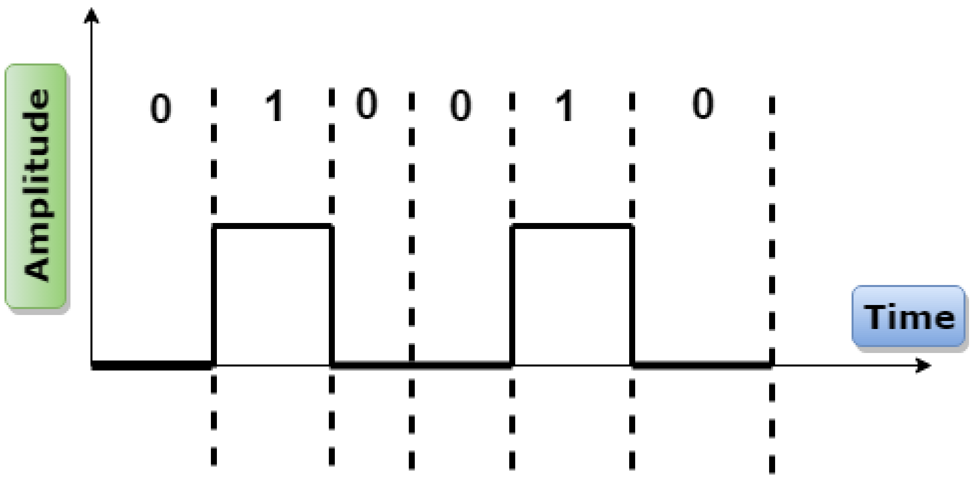
- Unipolar Encoding
- Polar Encoding
- Bipolar Encoding



Unipolar

- Digital transmission system sends the voltage pulses over the medium link such as wire or cable.
- In most types of encoding, one voltage level represents 0, and another voltage level represents 1.
- The polarity of each pulse determines whether it is positive or negative.

- This type of encoding is known as Unipolar encoding as it uses only one polarity.
- In Unipolar encoding, the polarity is assigned to the 1 binary state.
- In this, 1s are represented as a positive value and 0s are represented as a zero value.
- In Unipolar Encoding, '1' is considered as a high voltage and '0' is considered as a zero voltage.
- Unipolar encoding is simpler and inexpensive to implement.



Unipolar encoding has two problems that make this scheme less desirable:

- DC Component

  The main difference between AC and DC lies in the direction in which the electrons flow. In DC, the electrons flow steadily in a single direction, while electrons keep switching directions, going forward and then backwards in AC.

- Synchronization

  The main objective of process synchronization is to ensure that multiple processes access shared resources without interfering with each other

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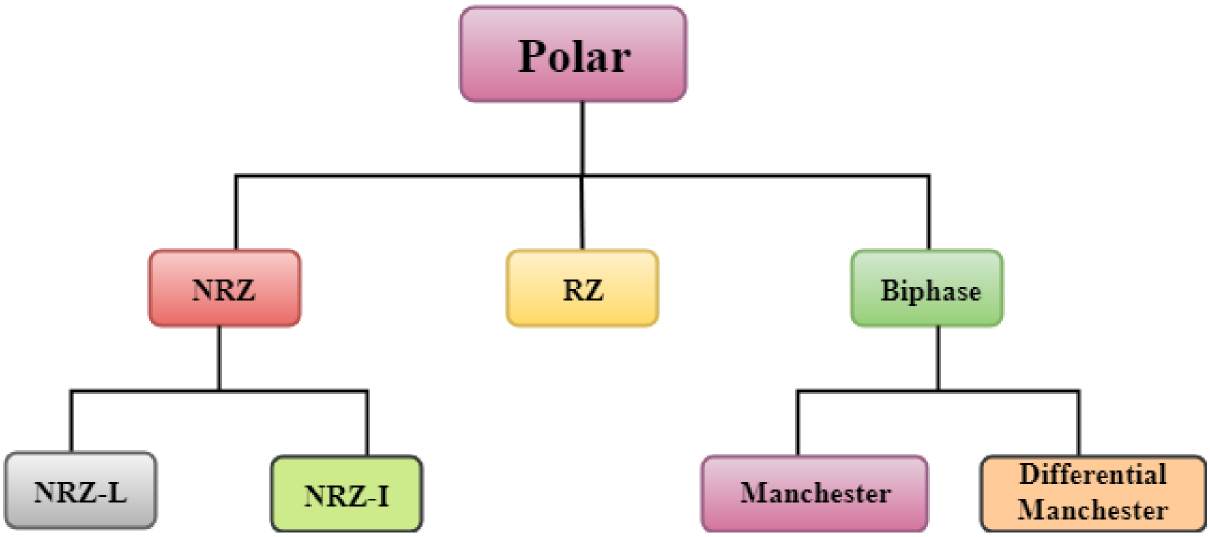
Polar

- Polar encoding is an encoding scheme that uses two voltage levels: one is positive, and another is negative.
- By using two voltage levels, an average voltage level is reduced, and the DC component problem of unipolar encoding scheme is lessened.



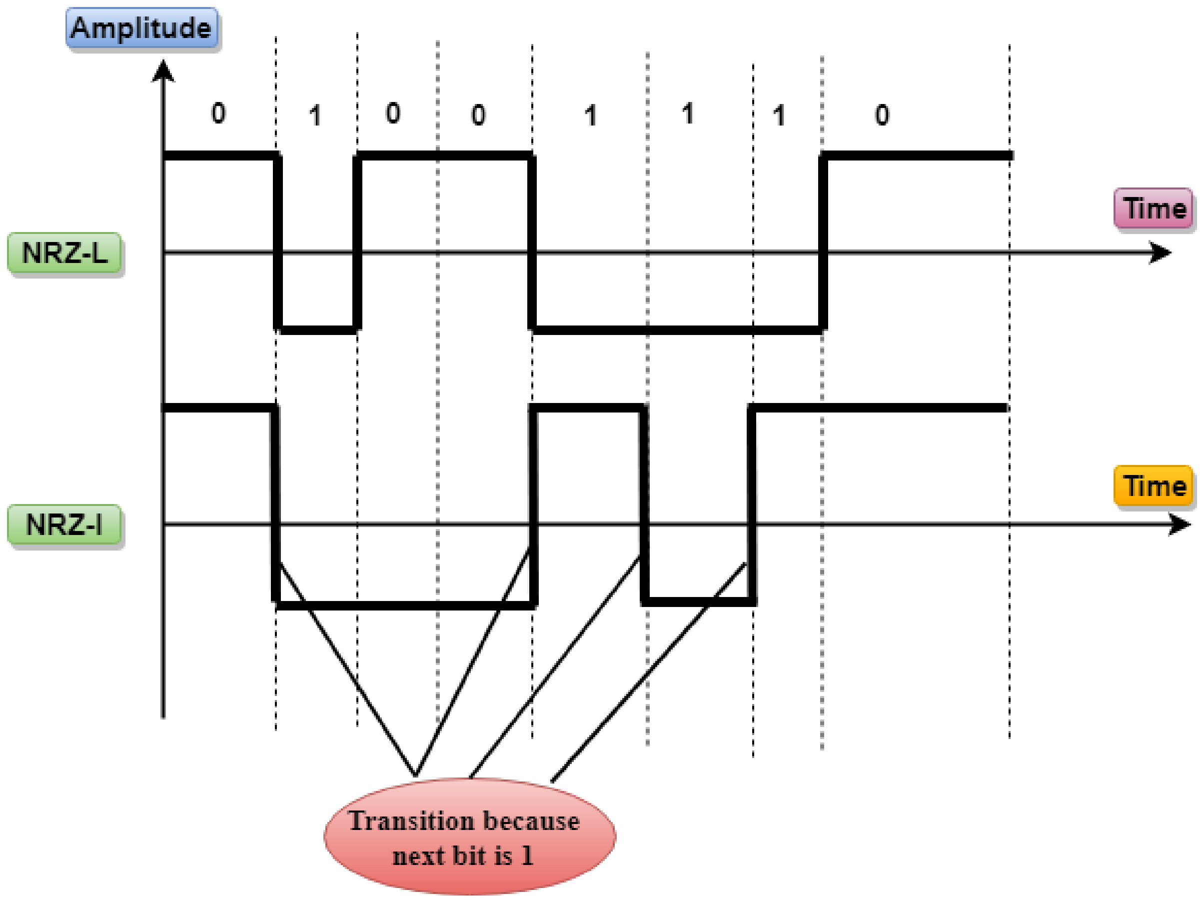
NRZ

- NRZ stands for Non-return zero.
- In NRZ encoding, the level of the signal can be represented either positive or negative.

The two most common methods used in NRZ are:

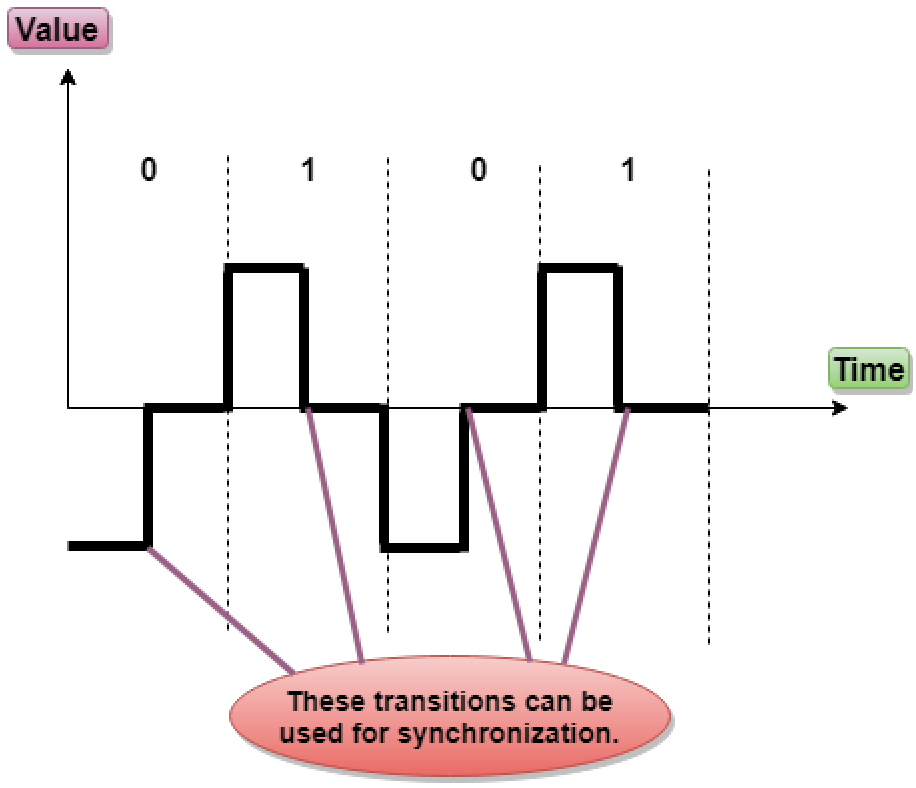
NRZ-L: In NRZ-L encoding, the level of the signal depends on the type of the bit that it represents. If a bit is 0 or 1, then their voltages will be positive and negative respectively. Therefore, we can say that the level of the signal is dependent on the state of the bit.

NRZ-I: NRZ-I is an inversion of the voltage level that represents 1 bit. In the NRZ-I encoding scheme, a transition occurs between the positive and negative voltage that represents 1 bit. In this scheme, 0 bit represents no change and 1 bit represents a change in voltage level.



RZ

- RZ stands for Return to zero.
- There must be a signal change for each bit to achieve synchronization. However, to change with every bit, we need to have three values: positive, negative and zero.
- RZ is an encoding scheme that provides three values, positive voltage represents 1, the negative voltage represents 0, and zero voltage represents none.
- In the RZ scheme, halfway through each interval, the signal returns to zero.
- In RZ scheme, 1 bit is represented by positive-to-zero and 0 bit is represented by negative-to-zero.



Disadvantage of RZ:

It performs two signal changes to encode one bit that acquires more bandwidth.

Biphase

- Biphase is an encoding scheme in which signal changes at the middle of the bit interval but does not return to zero.

Biphase encoding is implemented in two different ways:

Manchester

- It changes the signal at the middle of the bit interval but does not return to zero for synchronization.
- In Manchester encoding, a negative-to-positive transition represents binary 1, and positive-to-negative transition represents 0.
- Manchester has the same level of synchronization as RZ scheme except that it has two levels of amplitude.

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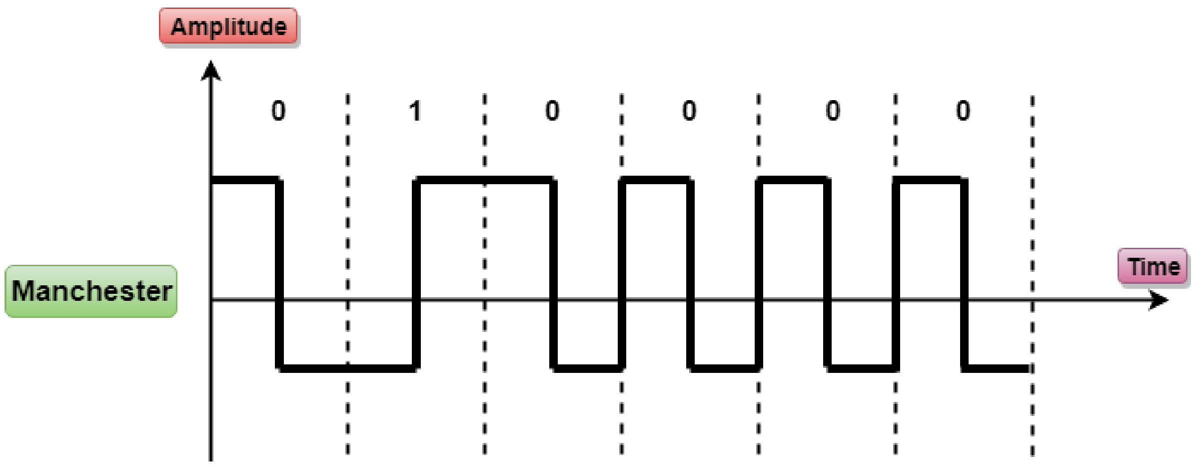
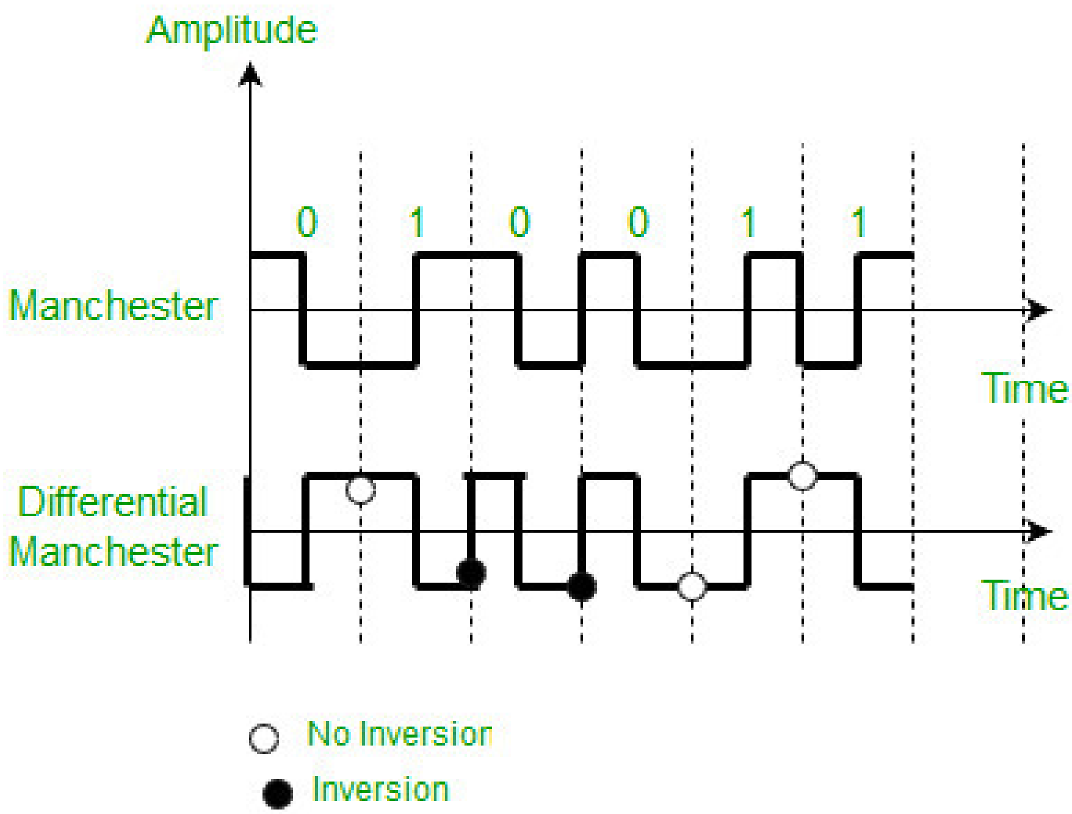
Differential Manchester

- It changes the signal at the middle of the bit interval for synchronization, but the presence or absence of the transition at the beginning of the interval determines the bit. A transition means binary 0 and no transition means binary 1.
- In Manchester Encoding scheme, two signal changes represent 0 and one signal change represent 1.





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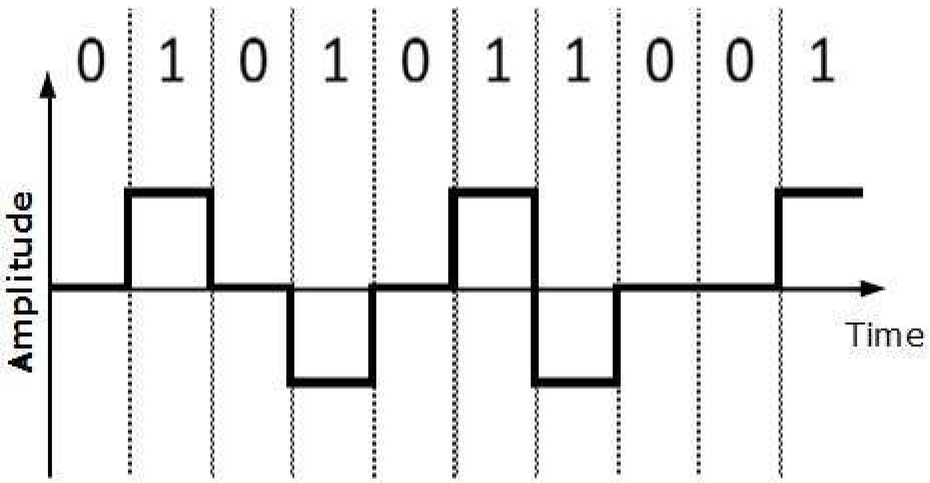
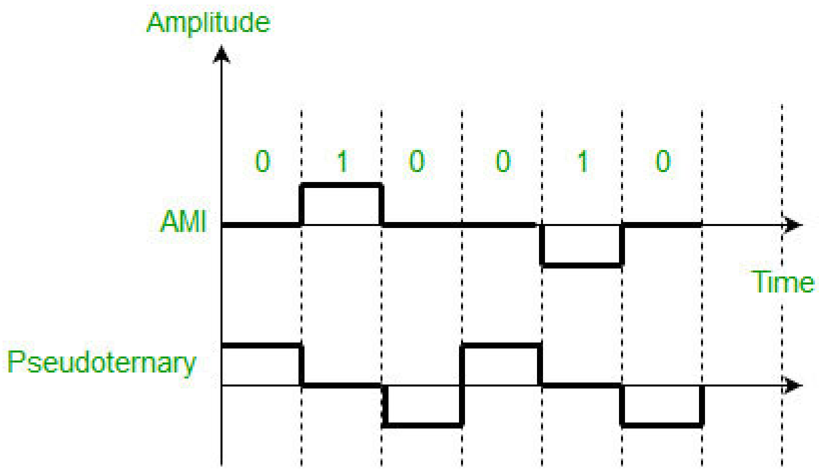
Bipolar Encoding

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.



Bipolar schemes – In this scheme there are three voltage levels positive, negative, and zero. The voltage level for one data element is at zero, while the voltage level for the other element alternates between positive and negative.

- **Alternate Mark Inversion (AMI)** – A neutral zero voltage represents binary 0. Binary 1's are represented by alternating positive and negative voltages.
- **Pseudoternary** – Bit 1 is encoded as a zero voltage and the bit 0 is encoded as alternating positive and negative voltages i.e., opposite of AMI scheme. Example: Data = 010010.



Advantages and disadvantages of Unipolar Line Coding Scheme:
Advantages:

- **Simple receiver circuit:** The receiver circuit for unipolar line coding is simple, as it only needs to detect the presence or absence of a voltage.
- **Low DC component:** The unipolar line coding scheme has a low DC component, which is desirable for some communication systems.
- **Low cost:** Unipolar line coding scheme uses only a single voltage level, so it is easy to implement and requires fewer components, making it a cost-effective solution.

Disadvantages:

- **Poor noise immunity:** The unipolar line coding scheme has poor noise immunity and is susceptible to errors, as it does not have a differential signal.
- **Limited dynamic range:** The unipolar line coding scheme has a limited dynamic range, as it only uses positive voltage levels.

Advantages and disadvantages of Polar Line Coding Scheme:

Advantages:

- **High noise immunity:** The polar line coding scheme has a high noise immunity, as it uses a differential signal.
- **Error resistance:** The polar line coding scheme is less susceptible to errors, as it uses a differential signal.

Disadvantages:

- **Complex receiver circuit:** The receiver circuit for polar line coding is complex, as it needs to detect the positive and negative voltage levels.
- **Limited data rate:** The polar line coding scheme has a limited data rate, as it requires a larger number of bits to represent the same information as the unipolar or bipolar line coding schemes.

Advantages and disadvantages of Bipolar Line Coding Scheme:

Advantages:

- **High data rate:** The bipolar line coding scheme has a high data rate, as it uses positive and negative voltage levels to represent the digital signal.
- **Differential signal**: The bipolar line coding scheme uses a differential signal, which improves noise immunity and error resistance.

Disadvantages:

- **Complex receiver circuit:** The receiver circuit for bipolar line coding is complex, as it needs to detect the positive and negative voltage levels.
- **Limited dynamic range:** The bipolar line coding scheme has a limited dynamic range, as it uses positive and negative voltage levels to represent the digital signal.

Block Coding

To ensure accuracy of the received data frame 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 number of bits is increased. It is called Block Coding.

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

- Division,

- Substitution
- Combination.

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

Analog-to-Digital Conversion

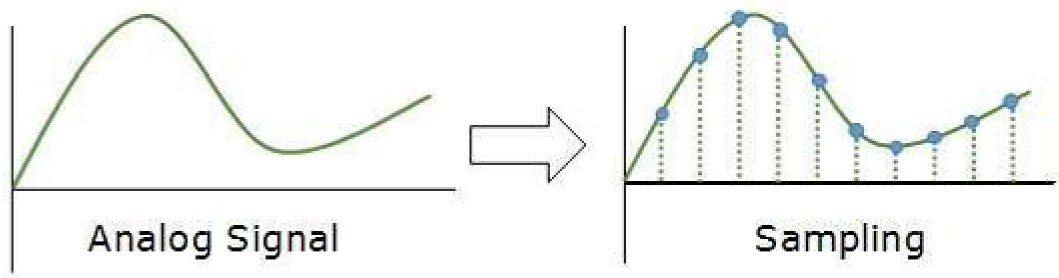
Microphones create analog voice and camera creates analog videos, which are treated is analog data. To transmit this analog data over digital signals, we need analog to digital conversion.

Analog data is a continuous stream of data in the wave form whereas digital data is discrete. To convert analog wave into digital data, we use Pulse Code Modulation (PCM).

PCM is one of the most commonly used method to convert analog data into digital form. It involves three steps:

- Sampling
- Quantization
- Encoding.

Sampling



The analog signal is sampled every T interval. Most important factor in sampling is the rate at 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

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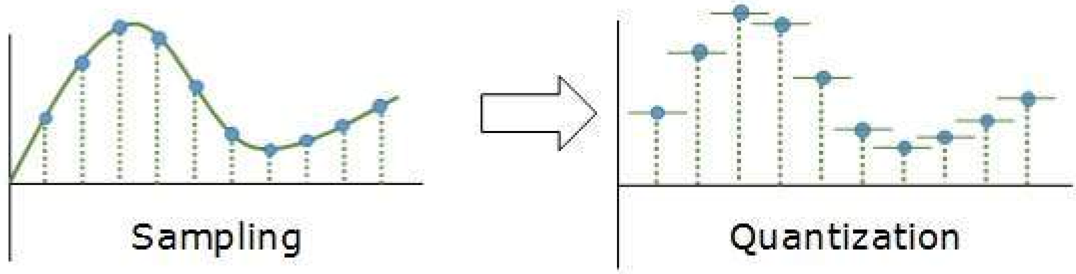
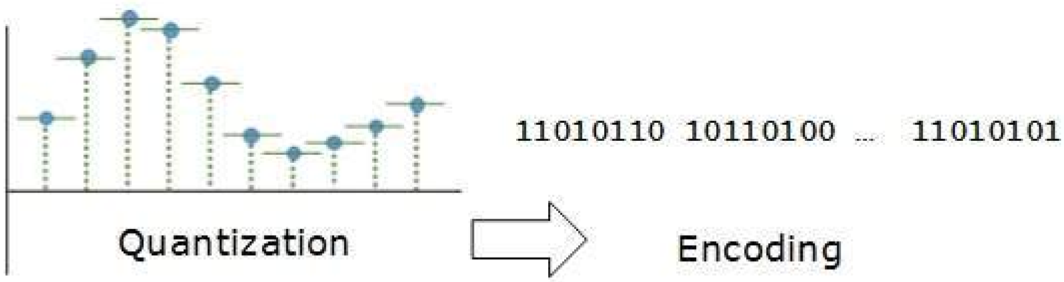


Sampling yields discrete form of continuous analog signal. Every discrete pattern shows the amplitude of the analog signal at that instance. The quantization is done between the maximum amplitude value and the minimum amplitude value. Quantization is approximation of the instantaneous analog value.

Encoding



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

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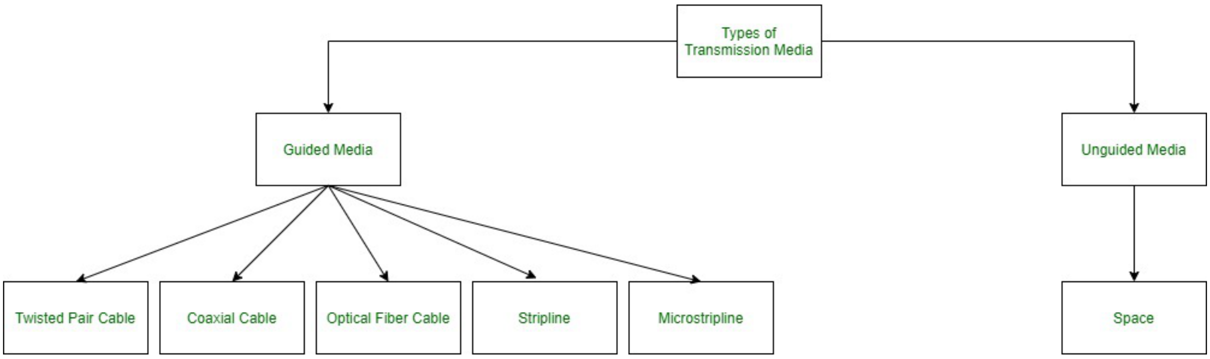
Types of Guided and Unguided Transmission Media

In data communication terminology, a transmission medium is a physical path between the transmitter and the receiver i.e. it is the channel through which data is sent from one place to another. Transmission Media is broadly classified into the following types:



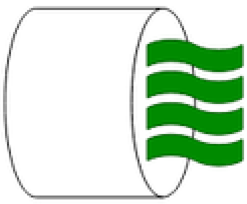
1. Guided Media: It is also referred to as Wired or Bounded transmission media. Signals being transmitted are directed and confined in a narrow pathway by using physical links.
Features:

- High Speed
- Secure
- Used for comparatively shorter distances

There are 3 major types of Guided Media:

(i) Twisted Pair Cable –
It consists of 2 separately insulated conductor wires wound about each other. Generally, several such pairs are bundled together in a protective sheath. They are the most widely used Transmission Media. Twisted Pair is of two types:

- **Unshielded Twisted Pair (UTP):**
  UTP consists of two insulated copper wires twisted around one another. This type of cable has the ability to block interference and does not depend on a physical shield for this purpose. It is used for telephonic applications.



Unshielded Twisted Pair

Advantages:

⇢ Least expensive

⇢ Easy to install

⇢ High-speed capacity

Disadvantages:

⇢ Susceptible to external interference

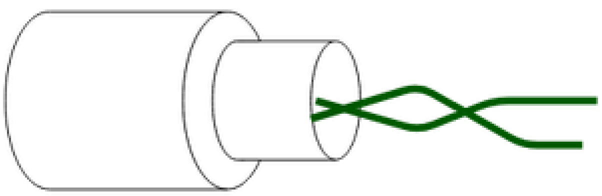
⇢ Lower capacity and performance in comparison to STP

⇢ Short distance transmission due to attenuation

Applications:

Used in telephone connections and LAN networks

- **Shielded Twisted Pair (STP):**
  This type of cable consists of a special jacket (a copper braid covering or a foil shield) to block external interference. It is used in fast-data-rate Ethernet and in voice and data channels of telephone lines.



Shielded Twisted Pair

Advantages:

⇢ Better performance at a higher data rate in comparison to UTP

⇢ Eliminates crosstalk

⇢ Comparatively faster

Disadvantages:

⇢ Comparatively difficult to install and manufacture

⇢ More expensive

⇢ Bulky

Applications:

The shielded twisted pair type of cable is most frequently used in extremely cold climates, where the additional layer of outer covering makes it perfect for withstanding such temperatures or for shielding the interior components.

(ii) Coaxial Cable –
It has an outer plastic covering containing an insulation layer made of PVC or Teflon and 2 parallel

conductors each having a separate insulated protection cover. The coaxial cable transmits information in two modes: Baseband mode(dedicated cable bandwidth) and Broadband mode(cable bandwidth is split into separate ranges). Cable TVs and analog television networks widely use Coaxial cables.

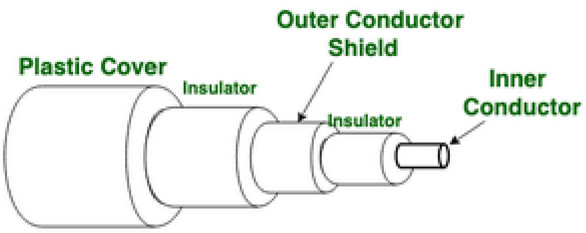


Figure of Coaxial Cable

Advantages:

- High Bandwidth
- Better noise Immunity
- Easy to install and expand
- Inexpensive

Disadvantages:

- Single cable failure can disrupt the entire network

Applications:

Radio frequency signals are sent over coaxial wire. It can be used for cable television signal distribution, digital audio (S/PDIF), computer network connections (like Ethernet), and feedlines that connect radio transmitters and receivers to their antennas.

(iii) Optical Fiber Cable –
It uses the concept of refraction of light through a core made up of glass or plastic. The core is surrounded by a less dense glass or plastic covering called the cladding. It is used for the transmission of large volumes of data.

The cable can be unidirectional or bidirectional. The WDM (Wavelength Division Multiplexer) supports two modes, namely unidirectional and bidirectional mode.

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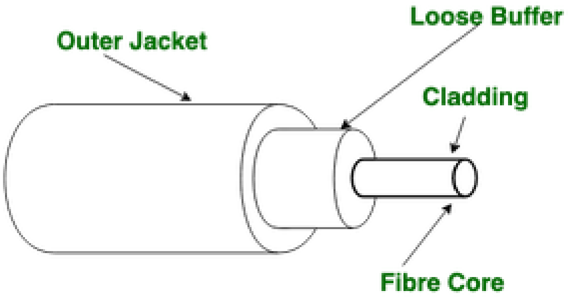

Figure of Optical Fibre Cable

Advantages:

- Increased capacity and bandwidth
- Lightweight
- Less signal attenuation
- Immunity to electromagnetic interference
- Resistance to corrosive materials

Disadvantages:

- Difficult to install and maintain
- High cost
- Fragile

Applications:

- Medical Purpose: Used in several types of medical instruments.
- Defence Purpose: Used in transmission of data in aerospace.
- For Communication: This is largely used in formation of internet cables.
- Industrial Purpose: Used for lighting purposes and safety measures in designing the interior and exterior of automobiles.

(iv) Stripline

Stripline is a transverse electromagnetic (TEM) transmission line medium invented by Robert M. Barrett of the Air Force Cambridge Research Centre in the 1950s. Stripline is the earliest form of the planar transmission line. It uses a conducting material to transmit high-frequency waves it is also called a waveguide. This conducting material is sandwiched between two layers of the ground plane which are usually shorted to provide EMI immunity.

(v) Microstripline

In this, the conducting material is separated from the ground plane by a layer of dielectric.

2. Unguided Media:

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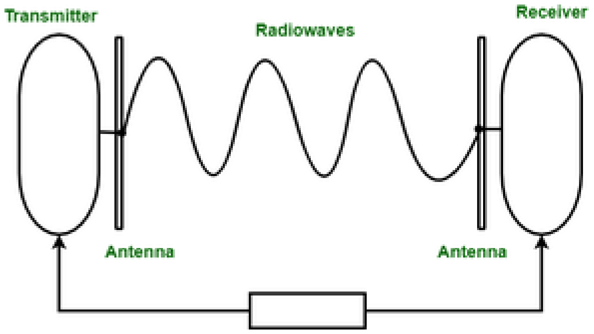
It is also referred to as Wireless or Unbounded transmission media. No physical medium is required for the transmission of electromagnetic signals.

Features:

- The signal is broadcasted through air
- Less Secure
- Used for larger distances

There are 3 types of Signals transmitted through unguided media:

(i) Radio waves –
These are easy to generate and can penetrate through buildings. The sending and receiving antennas need not be aligned. Frequency Range:3KHz – 1GHz. AM and FM radios and cordless phones use Radio waves for transmission.



Further Categorized as (i) Terrestrial and (ii) Satellite.

(ii) Microwaves –
It is a line of sight transmission i.e. the sending and receiving antennas need to be properly aligned with each other. The distance covered by the signal is directly proportional to the height of the antenna. Frequency Range:1GHz – 300GHz. These are majorly used for mobile phone communication and television distribution.

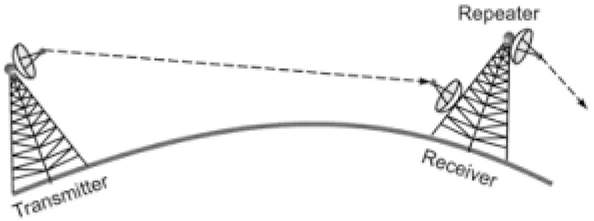


Fig: Microwave Transmission

Microwave Transmission

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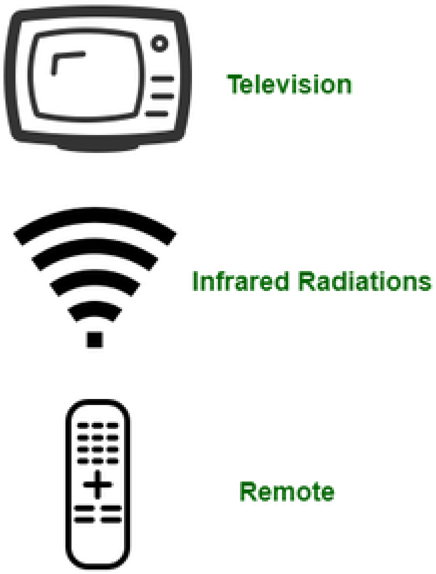
(iii) Infrared –

Infrared waves are used for very short distance communication. They cannot penetrate through obstacles. This prevents interference between systems. Frequency Range:300GHz – 400THz. It is used in TV remotes, wireless mouse, keyboard, printer, etc.



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What is Switching?

In computer networking, **Switching** is the process of transferring data packets from one device to another in a network, or from one network to another, using specific devices called **switches**. A computer user experiences switching all the time for example, accessing the Internet from your computer device, whenever a user requests a webpage to open, the request is processed through switching of data packets only.

Switching takes place at the Data Link layer of the OSI Model. This means that after the generation of data packets in the Physical Layer, switching is the immediate next process in data communication. In this article, we shall discuss different processes involved in switching, what kind of hardware is used in switching, etc.

What is a Network Switching?

A switch is a dedicated piece of computer hardware that facilitates the process of switching i.e., incoming data packets and transferring them to their destination. A switch works at the Data Link layer of the OSI Model. A switch primarily handles the incoming data packets from a source computer or network and decides the appropriate port through which the data packets will reach their target computer or network.

A switch decides the port through which a data packet shall pass with the help of its destination MAC(Media Access Control) Address. A switch does this effectively by maintaining a switching table, (also known as forwarding table).

A network switch is more efficient than a network Hub or repeater because it maintains a switching table, which simplifies its task and reduces congestion on a network, which effectively improves the performance of the network.

Process of Switching

The switching process involves the following steps:

Frame Reception: The switch receives a data frame or packet from a computer connected to its ports.

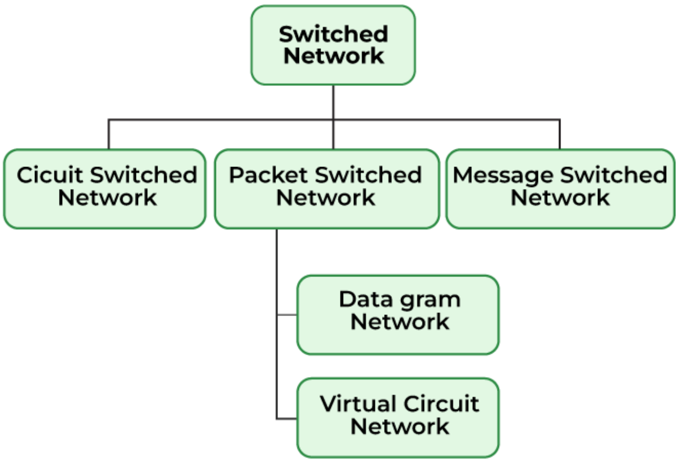
- **MAC Address Extraction:** The switch reads the header of the data frame and collects the destination MAC Address from it.
- **MAC Address Table Lookup:** Once the switch has retrieved the MAC Address, it performs a lookup in its Switching table to find a port that leads to the MAC Address of the data frame.
- **Forwarding Decision and Switching Table Update:** If the switch matches the destination MAC Address of the frame to the MAC address in its switching table, it forwards the data frame to the respective port. However, if the destination MAC Address does not exist in its forwarding table, it follows the flooding process, in which it sends the data frame to all its ports except the one it came from and records all the MAC Addresses to which the frame was delivered. This way, the switch finds the new MAC Address and updates its forwarding table.

- **Frame Transition:** Once the destination port is found, the switch sends the data frame to that port and forwards it to its target computer/network.

Types of Switching

There are three types of switching methods:

- Message Switching
- Circuit Switching
- Packet Switching
  - Datagram Packet Switching
  - Virtual Circuit Packet Switching



Let us now discuss them individually:

Message Switching: This is an older switching technique that has become old-fashioned. In message switching technique, the entire data block/message is forwarded across the entire network thus, making it highly inefficient.

Circuit Switching: In this type of switching, a connection is established between the source and destination beforehand. This connection receives the complete bandwidth of the network until the data is transferred completely.
This approach is better than message switching as it does not involve sending data to the entire network, instead of its destination only.

Packet Switching: This technique requires the data to be broken down into smaller components, data frames, or packets. These data frames are then transferred to their destinations according to the available resources in the network at a particular time.
This switching type is used in modern computers and even the Internet. Here, each data frame contains additional information about the destination and other information required for proper transfer through network components.

Datagram Packet Switching: In Datagram Packet switching, each data frame is taken as an individual entity and thus, they are processed separately. Here, no connection is established before data transmission occurs. Although this approach provides flexibility in data transfer, it may cause a loss of data frames or late delivery of the data frames.

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Virtual-Circuit Packet Switching: In Virtual-Circuit Packet switching, a logical connection between the source and destination is made before transmitting any data. These logical connections are called virtual circuits. Each data frame follows these logical paths and provides a reliable way of transmitting data with less chance of data loss.

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Error Detection in Computer Networks

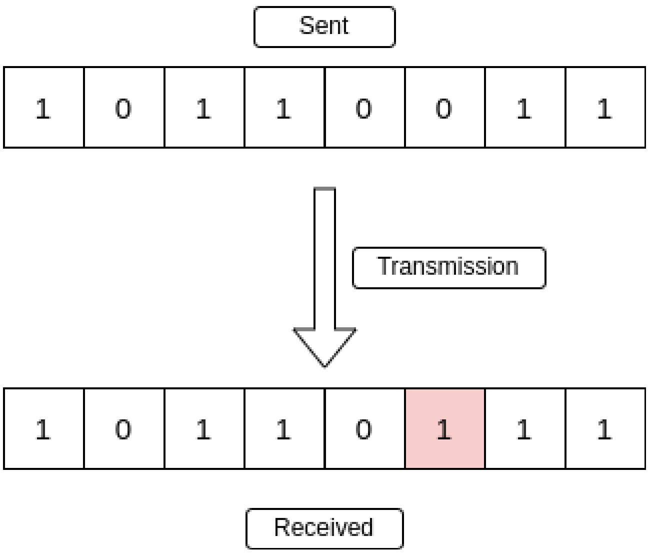
Error is a condition when the receiver's information does not match the sender's information. During transmission, digital signals suffer from noise that can introduce errors in the binary bits traveling from sender to receiver. That means a 0 bit may change to 1 or a 1 bit may change to 0.

Data (Implemented either at the Data link layer or Transport Layer of the OSI Model) may get scrambled by noise or get corrupted whenever a message is transmitted. To prevent such errors, error-detection codes are added as extra data to digital messages. This helps in detecting any errors that may have occurred during message transmission.

Types of Errors

Single-Bit Error

A single-bit error refers to a type of data transmission error that occurs when one bit (i.e., a single binary digit) of a transmitted data unit is altered during transmission, resulting in an incorrect or corrupted data unit.



Single-Bit Error

Multiple-Bit Error

A multiple-bit error is an error type that arises when more than one bit in a data transmission is affected. Although multiple-bit errors are relatively rare when compared to single-bit errors, they can still occur, particularly in high-noise or high-interference digital environments.

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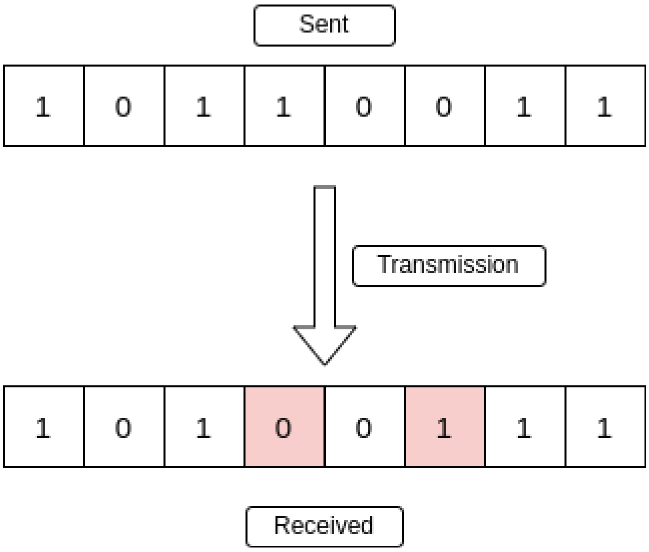
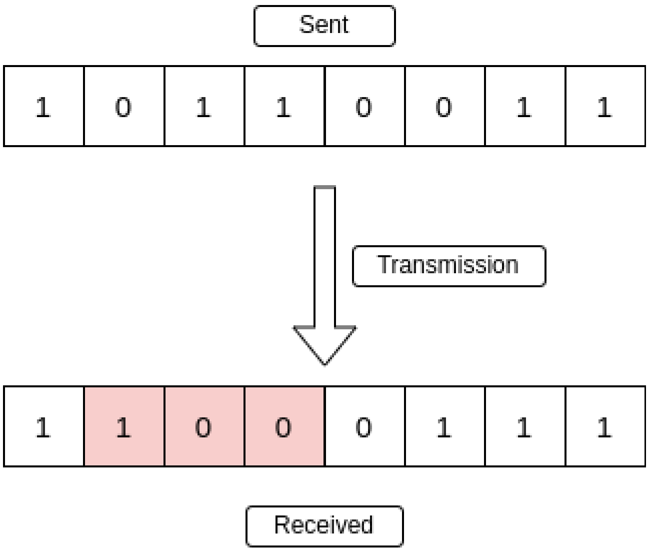


Multiple-Bit Error

Burst Error

When several consecutive bits are flipped mistakenly in digital transmission, it creates a burst error. This error causes a sequence of consecutive incorrect values.



Burst Error

To detect errors, a common technique is to introduce redundancy bits that provide additional information. Various techniques for error detection include:

1. Simple Parity Check
2. Two-dimensional Parity Check
3. Checksum
4. Cyclic Redundancy Check (CRC)

Error Detection Methods

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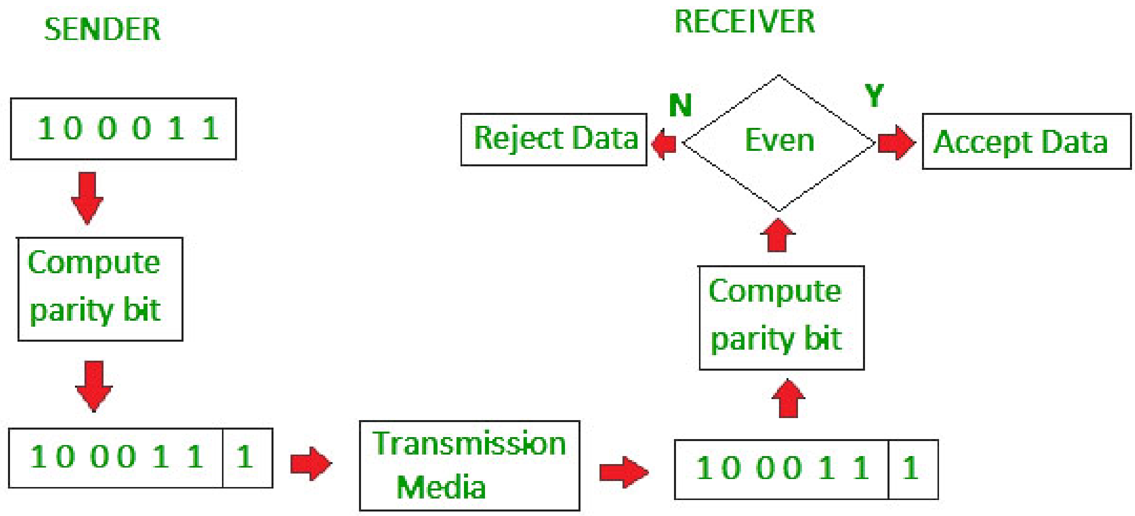
Simple Parity Check

Simple-bit parity is a simple error detection method that involves adding an extra bit to a data transmission. It works as:

- 1 is added to the block if it contains an odd number of 1's, and
- 0 is added if it contains an even number of 1's

This scheme makes the total number of 1's even, that is why it is called even parity checking.

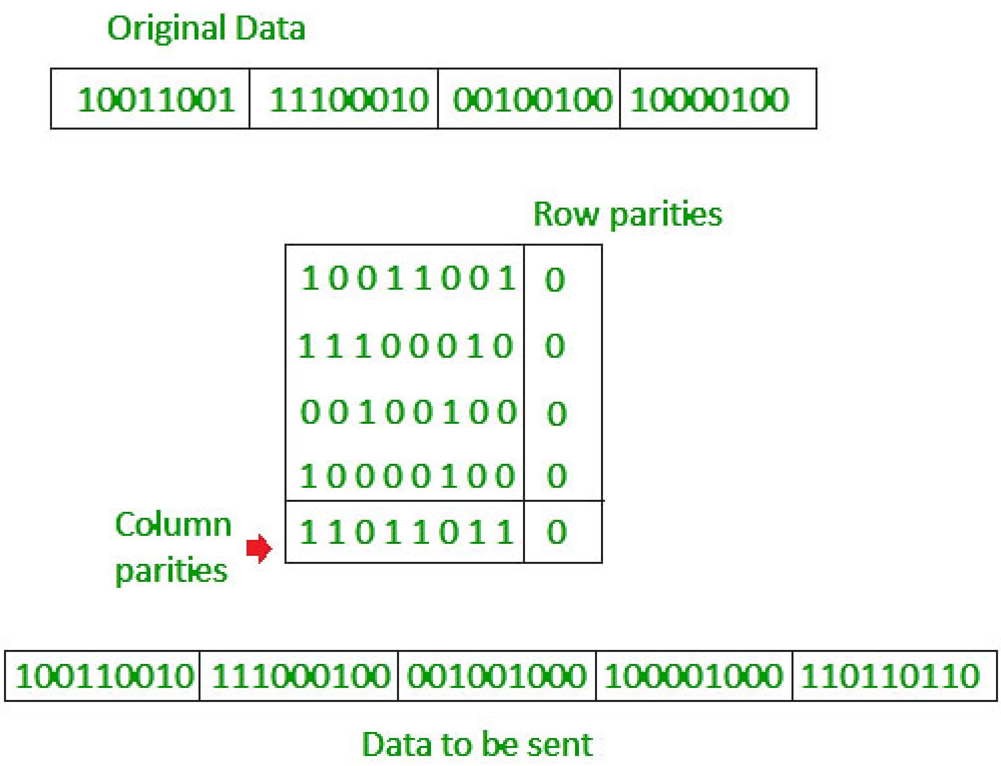


Disadvantages

- Single Parity check is not able to detect even no. of bit error.
- **For example,** the Data to be transmitted is **101010**. Codeword transmitted to the receiver is 1010101 (we have used even parity).
  Let's assume that during transmission, two of the bits of code word flipped to 1111101.
  On receiving the code word, the receiver finds the no. of ones to be even and hence **no error,** *which is a wrong assumption.*

Two-dimensional Parity Check

Two-dimensional Parity check bits are calculated for each row, which is equivalent to a simple parity check bit. Parity check bits are also calculated for all columns, then both are sent along with the data. At the receiving end, these are compared with the parity bits calculated on the received data.



Drawbacks Of 2D Parity Check

- If two bits in one data unit are corrupted and two bits exactly the same position in another data unit are also corrupted, then 2D Parity checker will not be able to detect the error.
- This technique cannot be used to detect the 4-bit errors or more in some cases.

Checksum

Checksum error detection is a method used to identify errors in transmitted data. The process involves dividing the data into equally sized segments and using a 1's complement to calculate the sum of these segments. The calculated sum is then sent along with the data to the receiver. At the receiver's end, the same process is repeated and if all zeroes are obtained in the sum, it means that the data is correct.

Checksum – Operation at Sender's Side

- Firstly, the data is divided into k segments each of m bits.
- On the sender's end, the segments are added using 1's complement arithmetic to get the sum. The sum is complemented to get the checksum.
- The checksum segment is sent along with the data segments.

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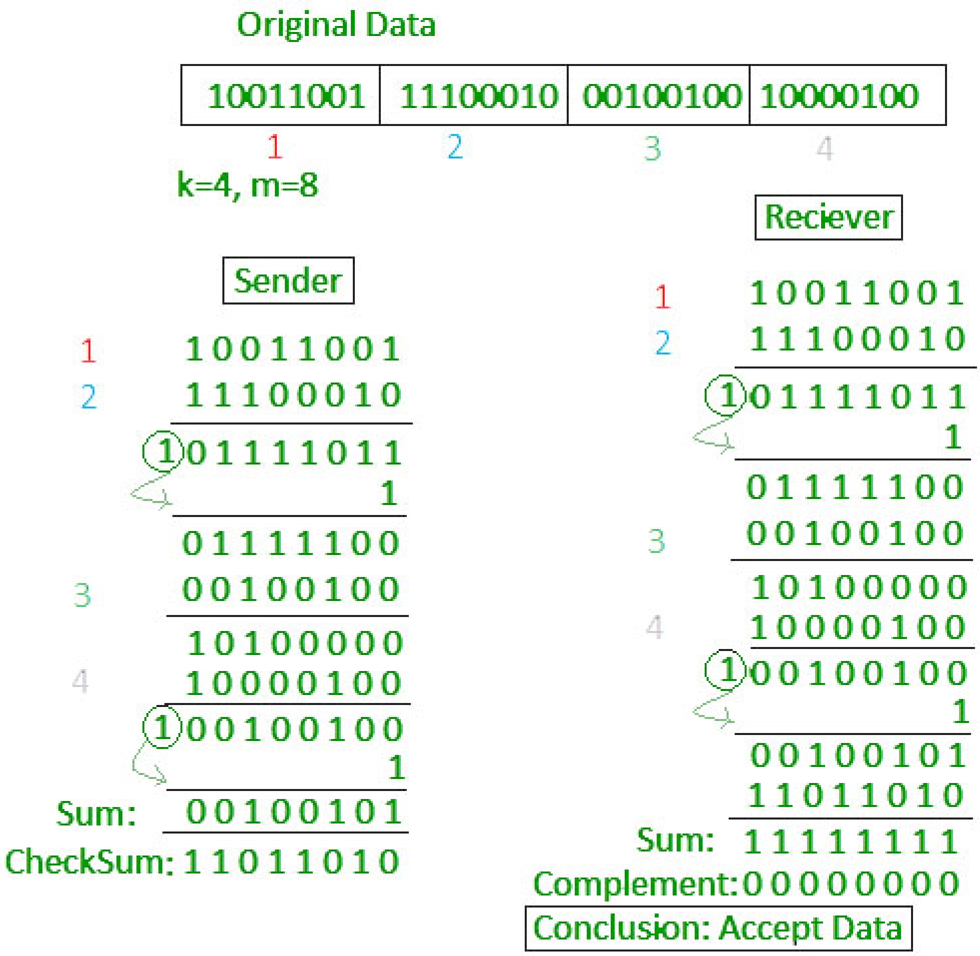
Checksum – Operation at Receiver's Side

- At the receiver's end, all received segments are added using 1's complement arithmetic to get the sum. The sum is complemented.
- If the result is zero, the received data is accepted; otherwise discarded.



Disadvantages

- If one or more bits of a segment are damaged and the corresponding bit or bits of opposite value in a second segment are also damaged.

Cyclic Redundancy Check (CRC)

CRC is a redundancy error technique used to determine the error.

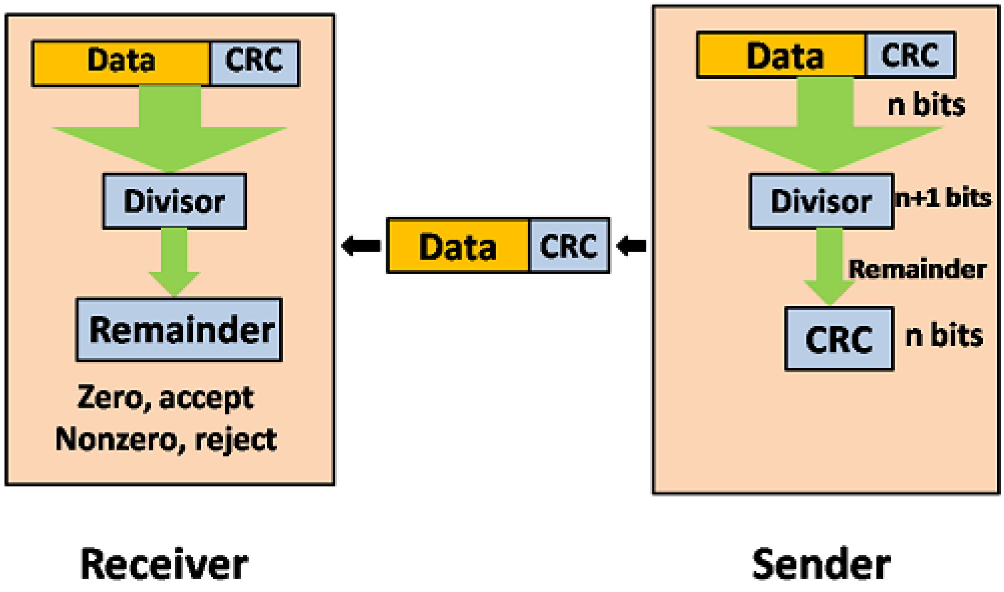
Following are the steps used in CRC for error detection:

- In CRC technique, a string of n 0s is appended to the data unit, and this n number is less than the number of bits in a predetermined number, known as division which is n+1 bits.

- Secondly, the newly extended data is divided by a divisor using a process is known as binary division. The remainder generated from this division is known as CRC remainder.
- Thirdly, the CRC remainder replaces the appended 0s at the end of the original data. This newly generated unit is sent to the receiver.
- The receiver receives the data followed by the CRC remainder. The receiver will treat this whole unit as a single unit, and it is divided by the same divisor that was used to find the CRC remainder.

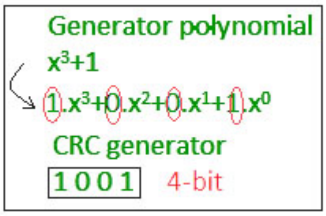
If the resultant of this division is zero which means that it has no error, and the data is accepted.

If the resultant of this division is not zero which means that the data consists of an error. Therefore, the data is discarded.



Let's understand this concept through an example:

Suppose the original data is 11100 and divisor is 1001.



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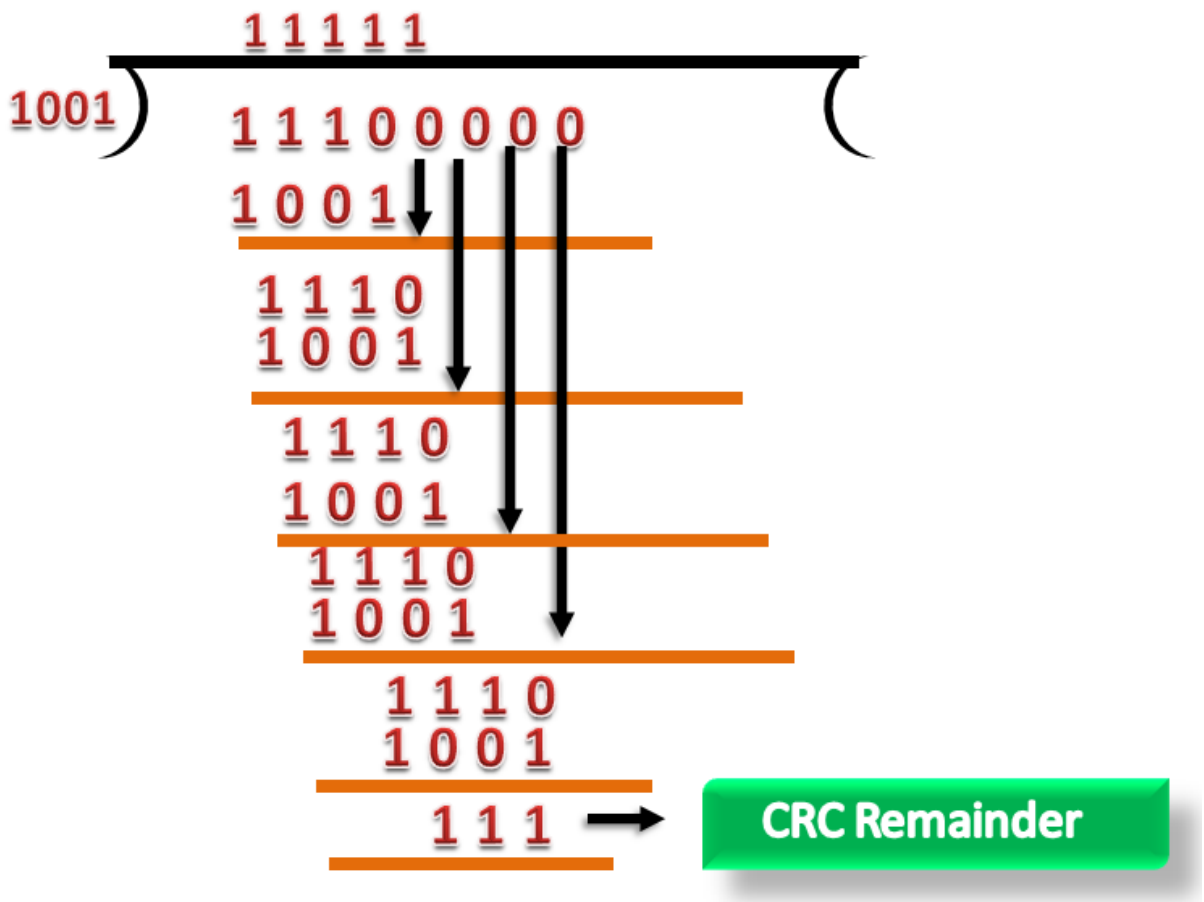
CRC Generator

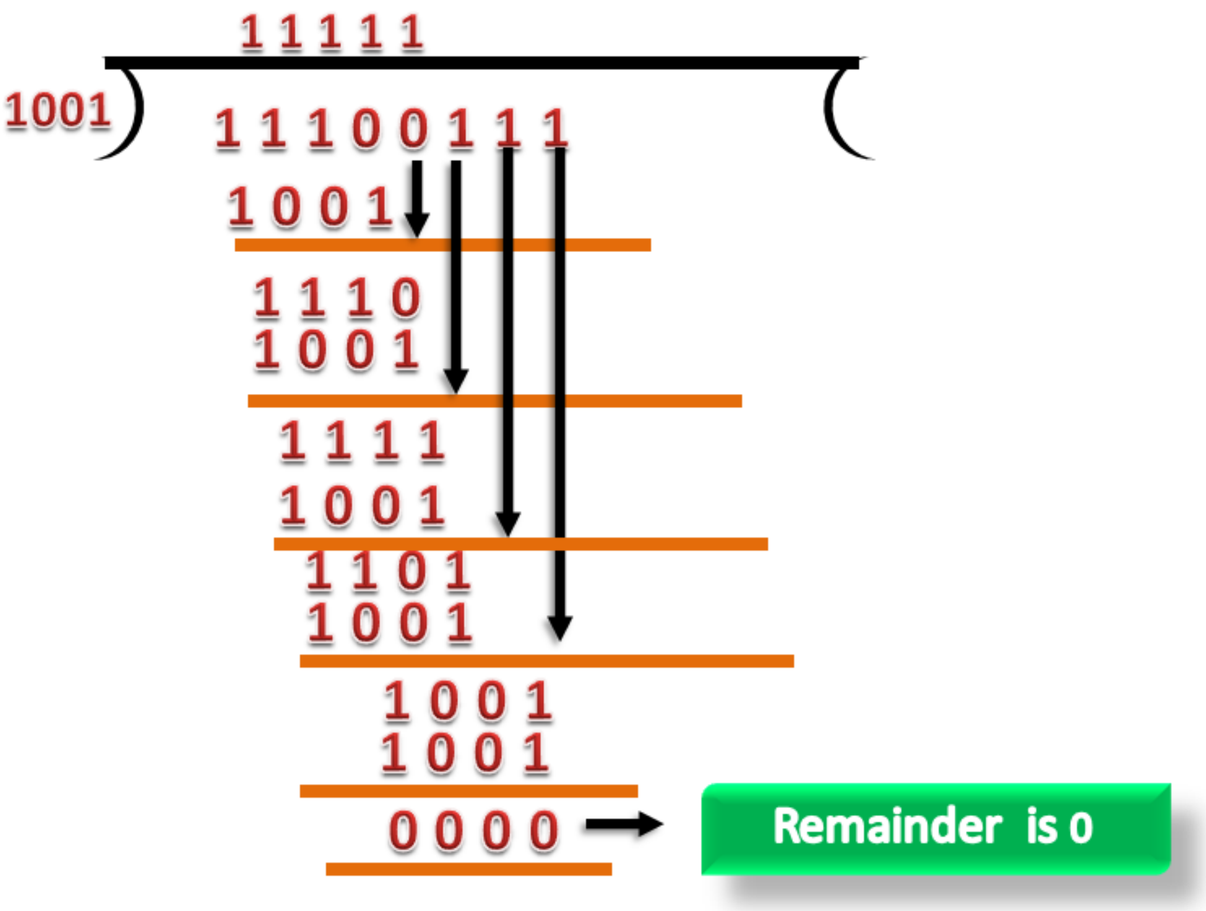
- A CRC generator uses a modulo-2 division. Firstly, three zeroes are appended at the end of the data as the length of the divisor is 4 and we know that the length of the string 0s to be appended is always one less than the length of the divisor.
- Now, the string becomes 11100000, and the resultant string is divided by the divisor 1001.
- The remainder generated from the binary division is known as CRC remainder. The generated value of the CRC remainder is 111.
- CRC remainder replaces the appended string of 0s at the end of the data unit, and the final string would be 11100111 which is sent across the network.



CRC Checker

- The functionality of the CRC checker is similar to the CRC generator.
- When the string 11100111 is received at the receiving end, then CRC checker performs the modulo-2 division.

- A string is divided by the same divisor, i.e., 1001.
- In this case, CRC checker generates the remainder of zero. Therefore, the data is accepted.



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Types of Multiplexing in Data Communications

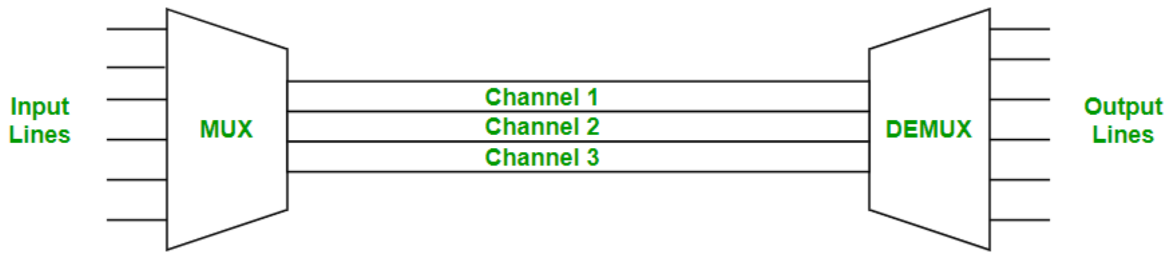
What is Multiplexing?
Multiplexing is the sharing of a medium or bandwidth. It is the process in which multiple signals coming from multiple sources are combined and transmitted over a single communication/physical line.

Types of Multiplexing
There are Five types of Multiplexing :

1. Frequency Division Multiplexing (FDM)
2. Time-Division Multiplexing (TDM)
3. Wavelength Division Multiplexing (WDM)
4. Code-division multiplexing (CDM)
5. Space-division multiplexing (SDM):

1. Frequency Division Multiplexing :

Frequency division multiplexing is defined as a type of multiplexing where the bandwidth of a single physical medium is divided into a number of smaller, independent frequency channels.



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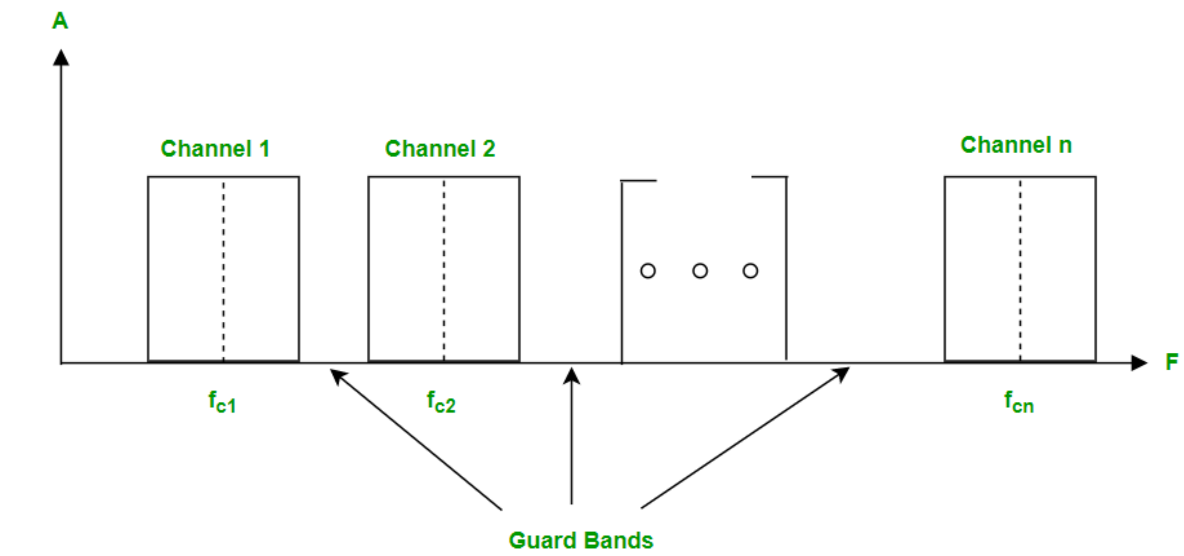
Frequency Division Multiplexing is used in radio and television transmission.

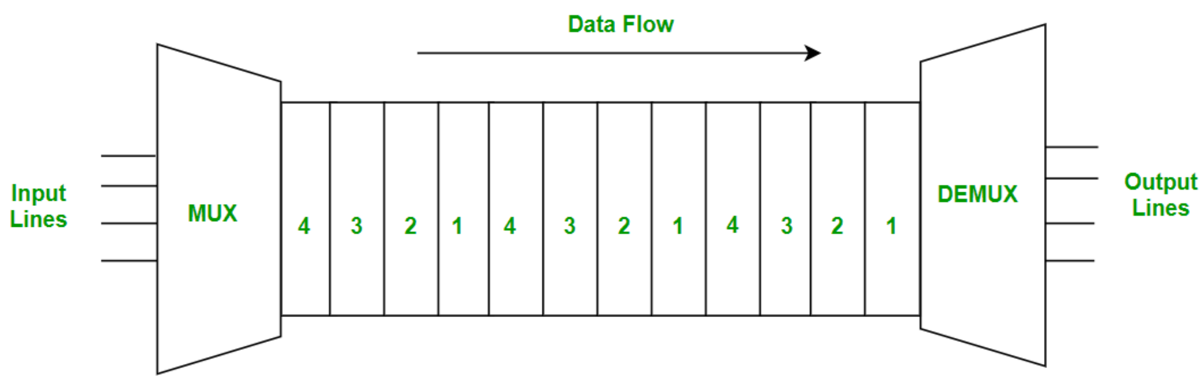
In FDM, we can observe a lot of inter-channel cross-talk, due to the fact that in this type of multiplexing the bandwidth is divided into frequency channels. In order to prevent the inter-channel cross talk, unused strips of bandwidth must be placed between each channel. These unused strips between each channel are known as guard bands.



2. Time Division Multiplexing :

Time-division multiplexing is defined as a type of multiplexing wherein FDM, instead of sharing a portion of the bandwidth in the form of channels, in TDM, time is shared. Each connection occupies a portion of time in the link.

In Time Division Multiplexing, all signals operate with the same frequency (bandwidth) at different times.



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There are two types of Time Division Multiplexing :

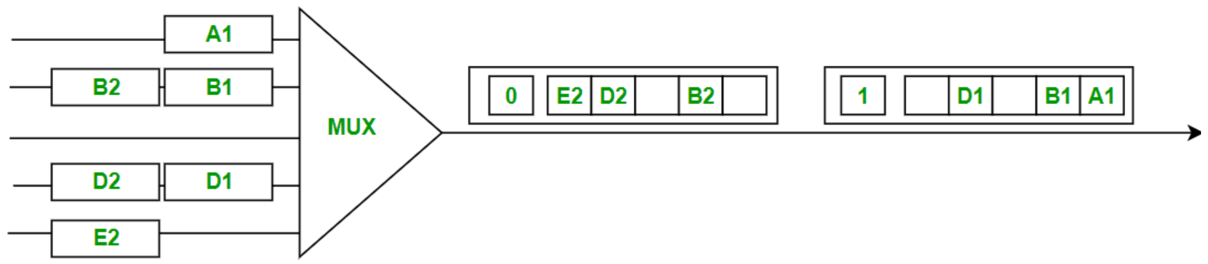
1. Synchronous Time Division Multiplexing
2. Statistical (or Asynchronous) Time Division Multiplexing

Synchronous TDM :

Synchronous TDM is a type of Time Division Multiplexing where the input frame already has a slot in the output frame. Time slots are grouped into frames. One frame consists of one cycle of time slots.

Synchronous TDM is not efficient because if the input frame has no data to send, a slot remains empty in the output frame.

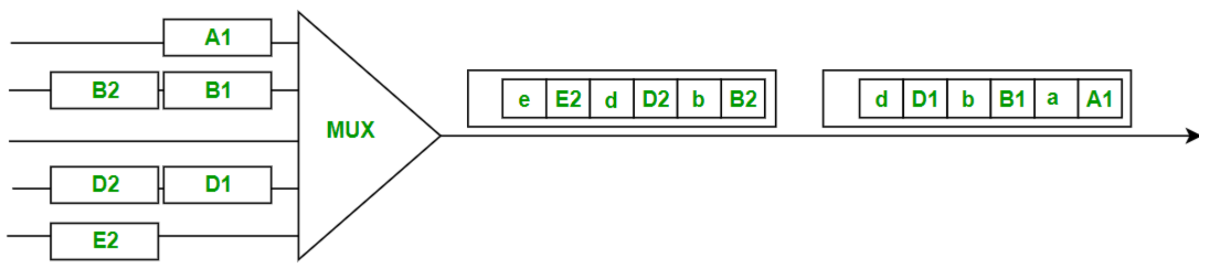
In synchronous TDM, we need to mention the synchronous bit at the beginning of each frame.



Statistical TDM :

Statistical TDM is a type of Time Division Multiplexing where the output frame collects data from the input frame till it is full, not leaving an empty slot like in Synchronous TDM.

In statistical TDM, we need to include the address of each particular data in the slot that is being sent to the output frame.



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Statistical TDM is a more efficient type of time-division multiplexing as the channel capacity is fully utilized and improves the bandwidth efficiency.

3. Wavelength Division Multiplexing :

Wavelength Division Multiplexing (WDM) is a multiplexing technology used to increase the capacity of optical fiber by transmitting multiple optical signals simultaneously over a single optical fiber, each with a different wavelength. Each signal is carried on a different wavelength of light, and the resulting signals are combined onto a single optical fiber for transmission. At the receiving end, the signals are separated by their wavelengths, demultiplexed and routed to their respective destinations.

WDM can be divided into two categories: Dense Wavelength Division Multiplexing (DWDM) and Coarse Wavelength Division Multiplexing (CWDM).

DWDM is used to multiplex a large number of optical signals onto a single fiber, typically up to 80 channels with a spacing of 0.8 nm or less between the channels.

CWDM is used for lower-capacity applications, typically up to 18 channels with a spacing of 20 nm between the channels.

WDM has several advantages over other multiplexing technologies such as Time Division Multiplexing (TDM). WDM allows for higher data rates and capacity, lower power consumption, and reduced equipment complexity. WDM is also flexible, allowing for easy upgrades and expansions to existing networks.

WDM is used in a wide range of applications, including telecommunications, cable TV, internet service providers, and data centers. It enables the transmission of large amounts of data over long distances with high speed and efficiency.

Wavelength Division Multiplexing is used on fiber optics to increase the capacity of a single fiber. It is an analog multiplexing technique. Optical signals from the different sources are combined to form a wider band of light with the help of multiplexers. At the receiving end, the De-multiplexer separates the signals to transmit them to their respective destinations.

4. Space-division multiplexing (SDM) :

Space Division Multiplexing (SDM) is a technique used in wireless communication systems to increase the capacity of the system by exploiting the physical separation of users.

In SDM, multiple antennas are used at both the transmitter and receiver ends to create parallel communication channels. These channels are independent of each other, which allows for multiple users to transmit data simultaneously in the same frequency band without interference. The capacity of the system can be increased by adding more antennas, which creates more independent channels.

SDM is commonly used in wireless communication systems such as cellular networks, Wi-Fi, and satellite communication systems. In cellular networks, SDM is used in the form of Multiple Input Multiple Output (MIMO) technology, which uses multiple antennas at both the transmitter and receiver ends to improve the quality and capacity of the communication link.

5. Code-division multiplexing (CDM) :

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Code division multiplexing (CDM) is a technique used in telecommunications to allow multiple users to transmit data simultaneously over a single communication channel. In CDM, each user is assigned a unique code that is used to modulate their signal. The modulated signals are then combined and transmitted over the same channel. At the receiving end, each user's signal is demodulated using their unique code to retrieve their original data.

In CDM, each user is assigned a unique spreading code that is used to spread the data signal. This spreading code is typically a binary sequence that is much longer than the original data signal. The spreading code is multiplied with the data signal to generate a spread spectrum signal that has a much wider bandwidth than the original data signal. The spread spectrum signals of all users are then combined and transmitted over the same channel.

At the receiving end, the received signal is multiplied with the same spreading code used at the transmitting end to dispread the signal. The resulting dispread signal is then demodulated to retrieve the original data signal. Because each user's data signal is spread using a unique code, it is possible to separate the signals of different users even though they are transmitted over the same channel.

CDM is commonly used in wireless communication systems such as cellular networks and satellite communication systems. It allows multiple users to share the same frequency band and increases the capacity of the communication channel. CDM also provides some level of security as the signals of different users are difficult to intercept or jam.