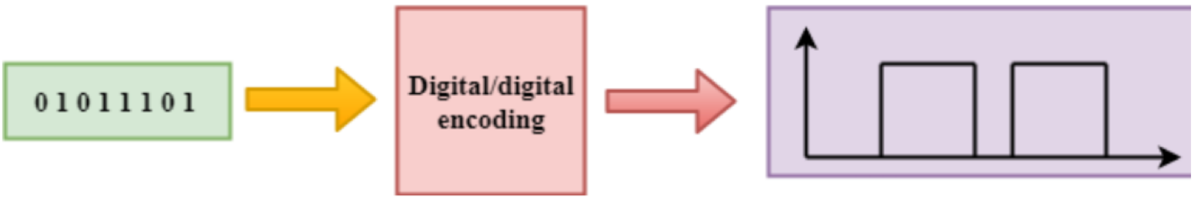
Unit - 1 - Data Encoding & Modulations

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:

Difference between Unipolar, Polar and Bipolar Line Coding Schemes

Data as well as **signals** that represents data can either be digital or analog. **Line coding** is the process of converting **digital data to digital signals**. By this technique we converts a sequence of bits to a digital signal. At the sender side digital data are encoded into a digital signal and at the receiver side the digital data are recreated by decoding the digital signal.
We can roughly divide line coding schemes into five categories:

1. Unipolar (eg. NRZ scheme).
2. Polar (eg. NRZ-L, NRZ-I, RZ, and Biphase – Manchester and differential Manchester).
3. Bipolar (eg. AMI and Pseudoternary).
4. Multilevel
5. Multitransition

But, before learning difference between first three schemes we should first know the **characteristic** of these line coding techniques:

- There should be **self-synchronizing** i.e., both receiver and sender clock should be synchronized.
- There should have some error-detecting capability.
- There should be immunity to noise and interference.
- There should be less complexity.
- There should be no low frequency component (**DC-component**) as long distance transfer is not feasible for low frequency component signal.
- There should be less base line wandering.

Modulation & Multiplexing

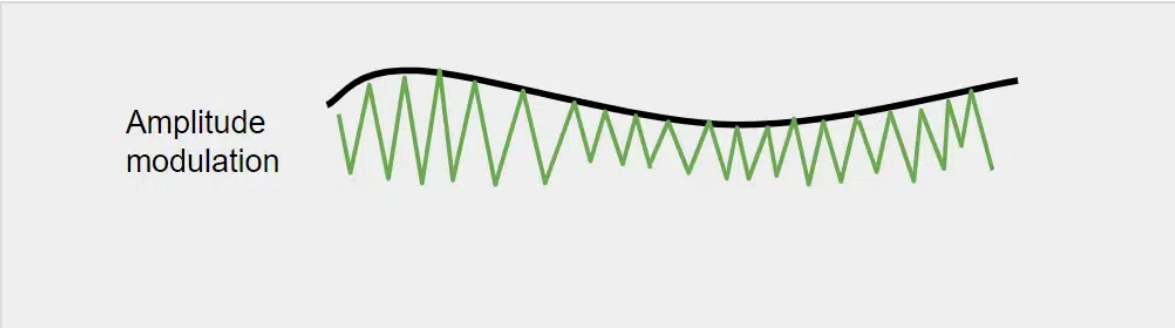
Modulation

The process by which data is converted into electrical/digital signals for transferring that signal over a medium is called modulation. It increases strength for maximum reach of the signals. The process of extracting data from the transmitted signal is called demodulation. A Modem is a device that performs both modulation and demodulation processes. The various forms of modulation are designed to alter the characteristics of carrier waves. The most commonly altered characteristics of modulation include amplitude, frequency, and phase.

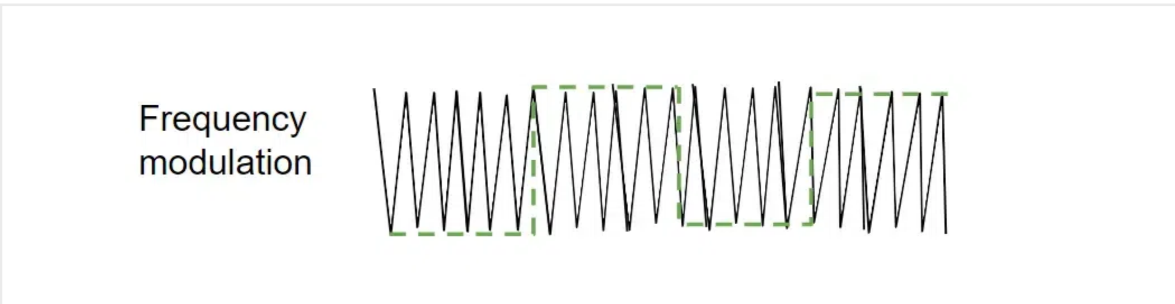
- Carrier signal: The signals that contain no information but have a certain phase, frequency, and amplitude are called carrier signals.
- Modulated signals: The signals which are the combination of the carrier signals and modulation signals are modulated signals. The modulated signal is obtained after the modulation of the signals.

Types of Modulation

- Amplitude Modulation: It is a type of modulation in which only the amplitude of the carrier signal is varied to represent the data being added to the signals whereas the phase and the frequency of the signal are kept unchanged.



- Frequency Modulation: It is a type of modulation in which only the frequency of the carrier signal is varied to represent the frequency of the data whereas the phase and the amplitude of the signals are kept unchanged.



- Phase Modulation: It is a type of modulation in which the phase of the carrier signal is varied to represent the data being added to the signal. Different information values are represented by different phases. For example: '1' may be represented by 0° while '0' by 180°.

- Polarisation Modulation: Polarisation modulation involves varying the angle of rotation of an optical carrier signal to reflect transmitted data.
- Pulse-Code Modulation: An analog signal is sampled to generate a data stream, which is then utilized to modulate a digital carrier signal.
- Quadrature Amplitude Modulation (QAM): Quadrature amplitude modulation employs two AM carriers to encode two or more bits in a single transmission.

What is the Need of Modulation?

- Size of Antenna: As we know that the size of the antenna is inversely proportional to the frequency of the radiated signal and antenna size must be 1/10th of the wavelength. If the frequency signals are more than 5KHz in that case it is quite impossible to set up an antenna of that size. So, by using the modulation technique the size of the antenna is reduced.
- Wireless Communication: Modulation provides a wireless connection to transmit the signals to a longer distance. Earlier we used wire systems (like the telephone) to transfer information with the help of telephonic wires but it was not possible to spread the wires all over the world for communication. By using the modulation technique, the cost of wire is saved and even information can be transferred to longer distances faster.

Working of Modulation

Data can be added to the carrier signal by varying its amplitude, frequency, and phase. Basically, modulation is applied to electromagnetic signals like radio waves, optics, and computer networks. It can also be applied to direct current that can be treated as a degenerate carrier wave with a fixed amplitude and frequency of 0 Hz by turning it off and on as in a digital current loop and in Morse code telegraphy.

Why use Modulation in Communication?

Multiple carriers of various frequencies can frequently be sent across the same medium, with each carrier modulated by a separate signal. For Example Wi-Fi employs individual channels to transmit and receive data from several customers at the same time. A carrier signal is used to decrease the wavelength for more effective transmission and reception. Because the ideal antenna size is one-half or one-quarter of a wavelength, an audio frequency of 3000 Hz needs a wavelength of 100 kilometers and a 25-kilometer antenna. Instead, with a 100 MHz FM carrier and a wavelength of 3 meters, the antenna would only need to be 80 cm long.

Advantages of Modulation

- It reduces the size of the antenna.
- It reduces the cost of wires.
- It prohibits the mixing of signals.
- It increases the range of communication.
- It improves the reception quality.
- It easily multiplexes the signals.
- It also allows the adjustment of the bandwidth.
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Disadvantages of Modulation

- The cost of the equipment is higher.
- The receiver and the transmitter are very complicated.
- For better communication, the antennas for the FM system must be kept closed.
- It is not efficient for large bandwidth.
- Power wastage takes place.

What is Demodulation?

The Demodulation is the process of extracting the original information from a modulated carrier wave. It is an important function used in the communication systems which allows the recovery of transmitted data at the receiver end. Demodulation is the technique to recover the original signal from the modulated signal. The demodulation is done with the help of a demodulator. A demodulator will convert the carrier variation of amplitude, frequency, or phase back to the message signal. There are three different types of demodulators for converting the AM (amplitude modulation), FM (frequency modulation), and PM (phase modulation) modulation schemes.

Difference Between Modulation and Demodulation

Modulation	Demodulation

The process by which data is converted into electrical/digital signals for transferring that signal over a medium is called modulation.	The process of extracting data from the transmitted signal is called demodulation.
Modulation is connected from transmitting end.	Demodulation is connected from Receiving end.
Modulation converts digital signal to analog signal.	Demodulation converts analog signal to digital signal.
The transmission of frequency in modulation goes low to high.	The transmission of frequency in demodulation goes high to low.
In modulation, the circuit used is modulator.	In demodulation, the circuit used is demodulator.

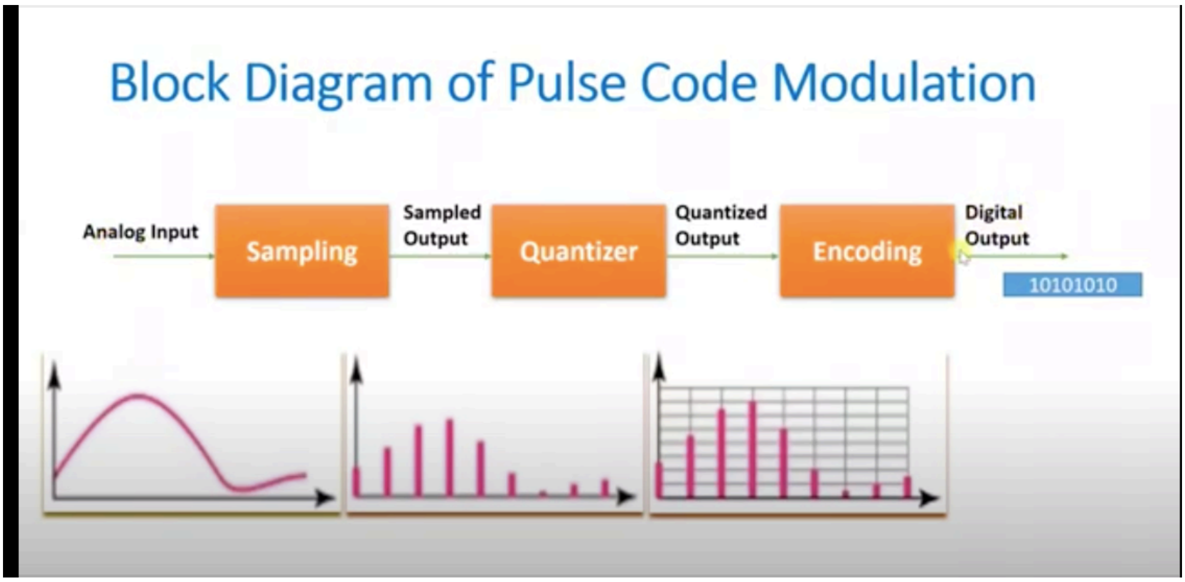
Difference between Broadband and Baseband Transmission

Basis of Comparison	Baseband Transmission	Broadband Transmission
Type of Signal	In baseband transmission, the type of signaling used is digital.	In broadband transmission, the type of signaling used is analog.
Direction Type	Baseband Transmission is bidirectional in nature.	Broadband Transmission is unidirectional in nature.
Signal Transmission	The Signal can be sent in both directions.	Sending of Signal in one direction only.

Distance covered by the signal	Signals can only travel over short distances. For long distances, attenuation is required.	Signals can be traveled over long distances without being attenuated.
Topology	It works well with bus topology.	It is used with a bus as well as tree topology.
Device used to increase signal strength	Repeaters are used to enhance signal strength.	Amplifiers are used to enhance signal strength.
Type of Multiplexing used	It utilizes Time Division Multiplexing.	It utilizes Frequency Division Multiplexing.
Encoding Techniques	In baseband transmission, Manchester and Differential Manchester encoding are used.	Only PSK encoding is used.
Transfer medium	Ethernet 2bsae10, Twisted-pair cables, coaxial cables, and wires are used as a transfer medium for digital signals in baseband transmission.	Broadband signals were sent through optical fiber cables, coaxial cables, and radio waves.
Impedance	Baseband transmission has a 50-ohm impedance.	Broadband transmission has a 70-ohm impedance.
Data Streams	It can only transfer one data stream at a time in bi-directional mode.	It can send multiple signal waves at once but in one direction only.

Installation and Maintenance	Baseband transmission is easy to install and maintain.	Broadband transmission is difficult to install and maintain.
Cost	This transmission is cheaper to design.	This transmission is expensive to design.
Application	Typically seen in Ethernet LAN networks.	Typically found in cable and telephone networks.
Frequency	In this, capacity of frequency is less than 100 kHz.	In this, capacity of frequency is higher than 100 kHz.
Suitable for	It is best for wired networks.	It is best for non-wired networks.
Structure	The structure is very simple, and no special hardware is required.	The structure is complex as it needs unique hardware.

PULSE CODE MODULATION



Filtering : Here we Filters out high frequency by the help of low pass filter
Sampling: Here we divide the amplitude of wave into serveral

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sub parts which will be quantized after on , here will convert analog signals to discrete signals, after frequency = 1/ts , ts = time between the samples.
Quantized: Descred signal is converted into quantized signal and after that quantized signals will be converted to digital signal
Encoding: After that data in encoding to digital signals

Bandwidth

Bandwidth in Computer Networks
In computer networks, bandwidth refers to the maximum data transfer rate of a network or internet connection. It's essentially the capacity of a network to transmit data within a specific time frame.

Think of it like a highway:

- **Narrow road (low bandwidth):** Fewer cars can pass through per unit of time.
- **Wide highway (high bandwidth):** More cars can pass through per unit of time.

Units of Measurement:
Bandwidth is typically measured in bits per second (bps). Common units include:

- **Kilobits per second (Kbps):** 1,000 bits per second
- **Megabits per second (Mbps):** 1,000,000 bits per second
- **Gigabits per second (Gbps):** 1,000,000,000 bits per second

Channel

A channel in computer networks is the medium used to transport information from one network device to another. It's essentially the pathway through which data travels.

Types of Channels:

1. **Wired Channels:**
    - **Twisted-Pair Cable:** Common for telephone lines and Ethernet networks.
    - **Coaxial Cable:** Used for cable TV and older Ethernet

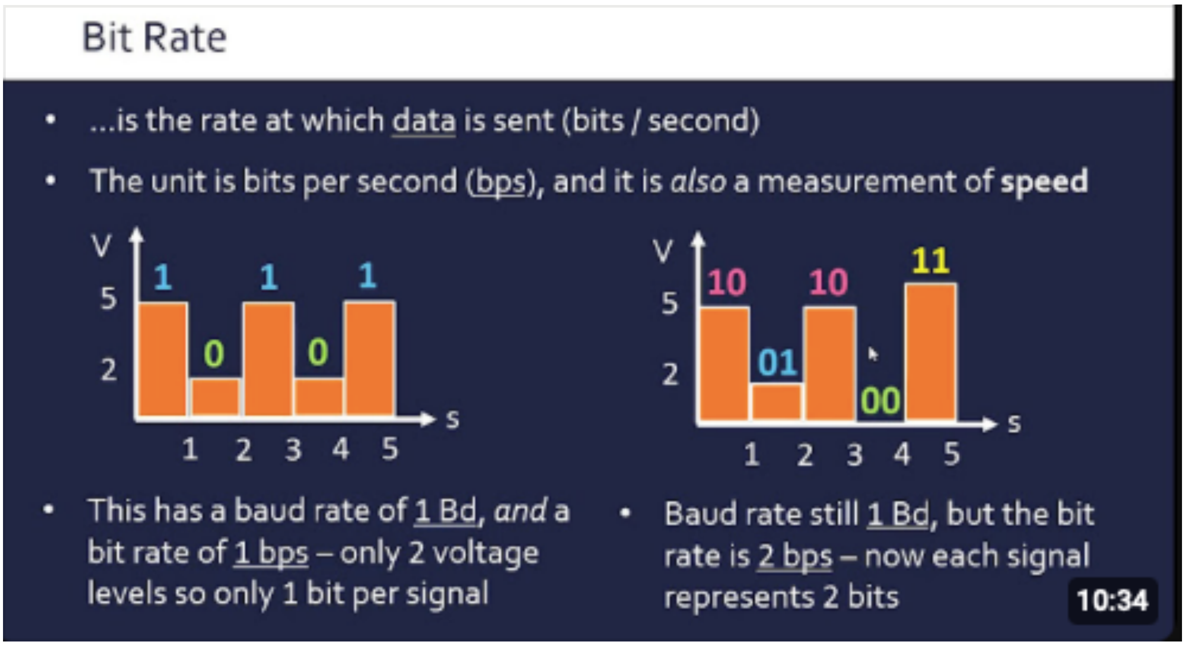
networks.
    - **Fiber-Optic Cable:** High-speed transmission of data over long distances.

2. **Wireless Channels:**
    - **Radio Waves:** Used in Wi-Fi, Bluetooth, and cellular networks.
    - **Microwaves:** Used for satellite communications and point-to-point links.
    - **Infrared:** Used for short-range communication, like remote controls.

Baud Rate Of Transmission

Bit rate is number of bits transferred per second
Baut Rate is number of symbols transferred per second

Bit rate >= Baut Rate, in a transmission . . .

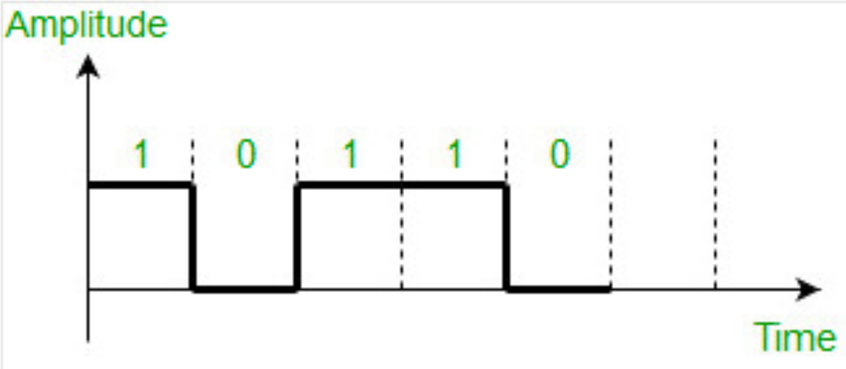


Unipolar scheme –

In this scheme, all the signal levels are either above or below the axis.

- **Non return to zero (NRZ) –** It is unipolar line coding scheme in which positive voltage defines bit 1 and the zero voltage defines bit 0. Signal does not return to zero at the middle of the bit thus it is called NRZ.

For example: Data =10110.

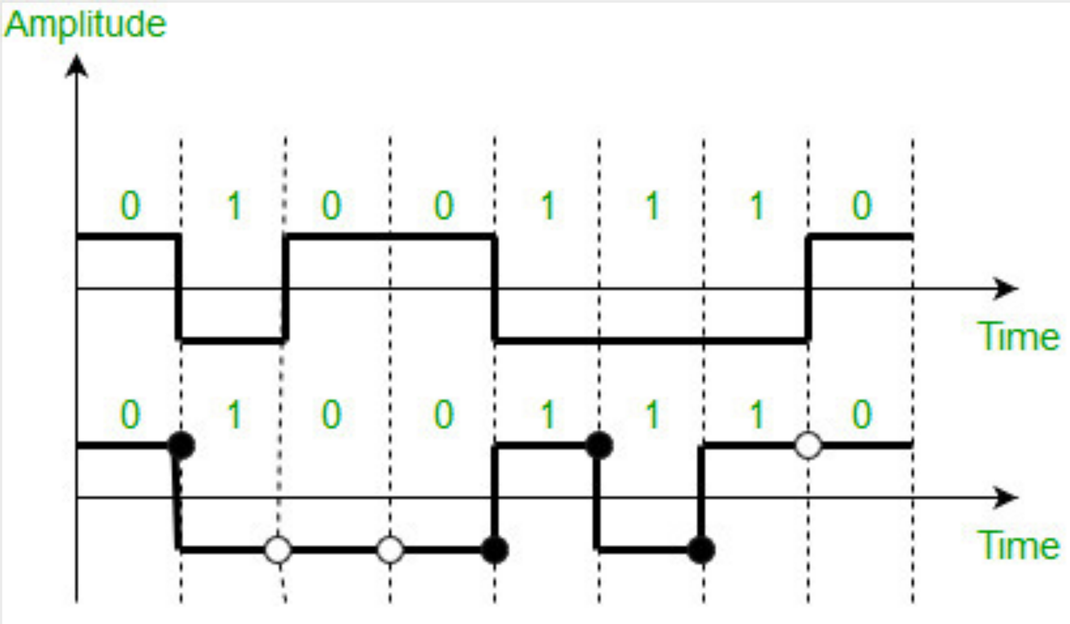


But this scheme uses more power as compared to polar scheme to send one bit per unit line resistance. Moreover for continuous set of zeros or ones there will be self-synchronization and base line wandering problem.

Polar schemes –

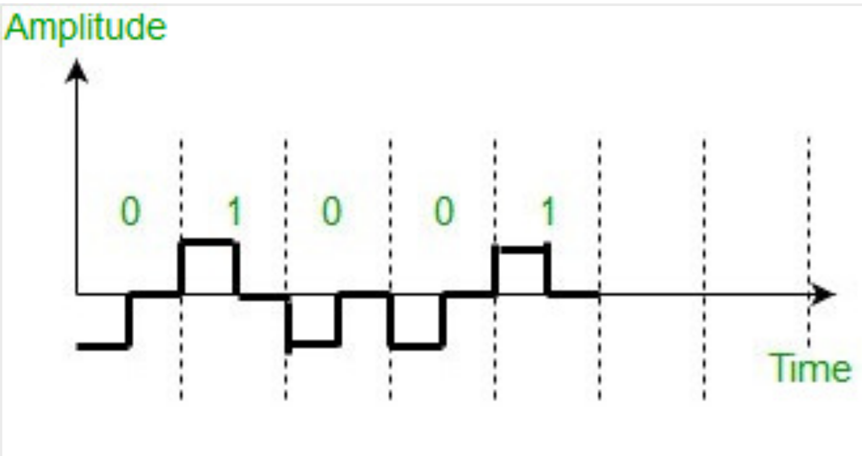
In polar schemes, the voltages are on the both sides of the axis.

- **NRZ-L and NRZ-I –** These are somewhat similar to unipolar NRZ scheme but here we use two levels of amplitude (voltages). For **NRZ-L(NRZ-Level)**, the level of the voltage determines the value of the bit, typically binary 1 maps to logic-level high, and binary 0 maps to logic-level low, and for **NRZ-I(NRZ-Invert)**, two-level signal has a transition at a boundary if the next bit that we are going to transmit is a logical 1, and does not have a transition if the next bit that we are going to transmit is a logical 0. **Note –** For NRZ-I we are assuming in the example that previous signal before starting of data set “01001110” was positive. Therefore, there is no transition at the beginning and first bit “0” in current data set “01001110” is starting from +V. Example: Data = 01001110.



Comparison between NRZ-L and NRZ-I: Baseline wandering is a problem for both of them, but for NRZ-L it is twice as bad as compared to NRZ-I. This is because of transition at the boundary for NRZ-I (if the next bit that we are going to transmit is a logical 1). Similarly self-synchronization problem is similar in both for long sequence of 0's, but for long sequence of 1's it is more severe in NRZ-L.

- **Return to zero (RZ) –** One solution to NRZ problem is the RZ scheme, which uses three values positive,negative,and zero. In this scheme signal goes to 0 in the middle of each bit. **Note –** The logic we are using here to represent data is that for bit 1 half of the signal is represented by +V and half by zero voltage and for bit 0 half of the signal is represented by -V and half by zero voltage. Example: Data = 01001.



Main disadvantage of RZ encoding is that it requires greater bandwidth. Another problem is the complexity as it uses three levels of voltage. As a result of all these deficiencies, this scheme is not used today. Instead, it has been replaced by the better-performing Manchester and differential Manchester schemes.

- **Biphase (Manchester and Differential Manchester) –**

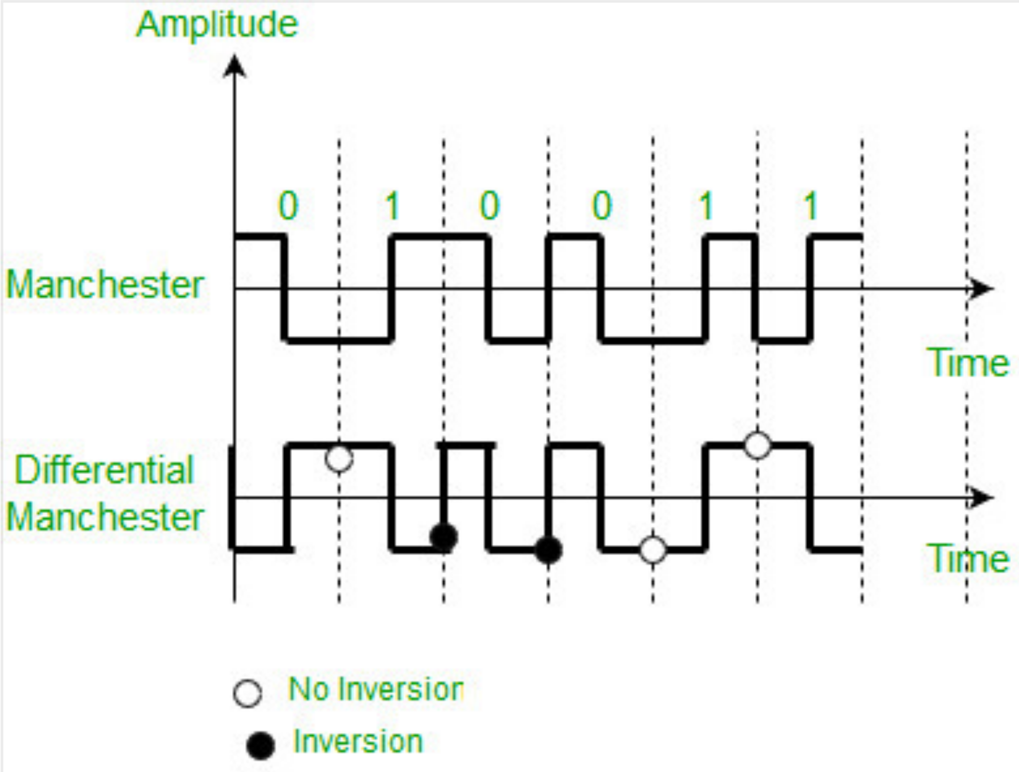
Manchester encoding
It is somewhat combination of the RZ (transition at the middle of the bit) and NRZ-L schemes. The duration of the bit is divided into two halves. The voltage remains at one level during the first half and moves to the other level in the second half. The transition at the middle of the bit provides synchronization.

Differential Manchester
It is somewhat combination of the RZ and NRZ-I schemes. There is always a transition at the middle of the bit but the bit values are determined at the beginning of the bit. If the next bit is 0, there is a transition, if the next bit is 1, there is no transition.

Note –

1. The logic we are using here to represent data using Manchester is that for bit 1 there is transition form -V to +V volts in the middle of the bit and for bit 0 there is transition from +V to -V volts in the middle of the bit.

2. For differential Manchester we are assuming in the example that previous signal before starting of data set “010011” was positive. Therefore there is transition at the beginning and first bit “0” in current data set “010011” is starting from -V. Example: Data = 010011.



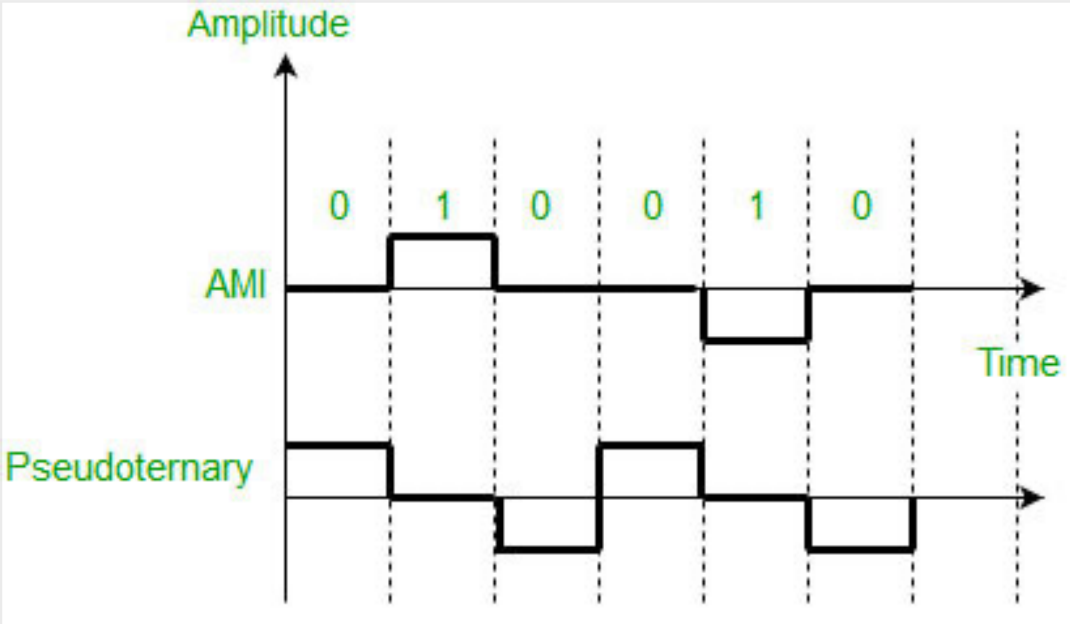
The Manchester scheme overcomes several problems associated with NRZ-L, and differential Manchester overcomes several problems associated with NRZ-I as there is no baseline wandering and no DC component because each bit has a positive and negative voltage contribution. Only limitation is that the minimum bandwidth of Manchester and differential Manchester is twice that of NRZ.

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.



The bipolar scheme is an alternative to NRZ.This scheme has the same signal rate as NRZ,but there is no DC component as one bit is represented by voltage zero and other alternates every time.

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.

Multiplexing
Multiplexing is a technique used to combine and send the multiple data streams over a single medium. The process of combining the data streams is known as multiplexing and hardware used for multiplexing is known as a multiplexer.
Multiplexing is achieved by using a device called Multiplexer (**MUX**) that combines n input lines to generate a single output line. Multiplexing follows many-to-one, i.e., n input lines and one output line.

Demultiplexing is achieved by using a device called Demultiplexer (**DEMUX**) available at the receiving end. DEMUX separates a signal into its component signals (one input and n outputs). Therefore, we can say that demultiplexing follows the one-to-many approach.

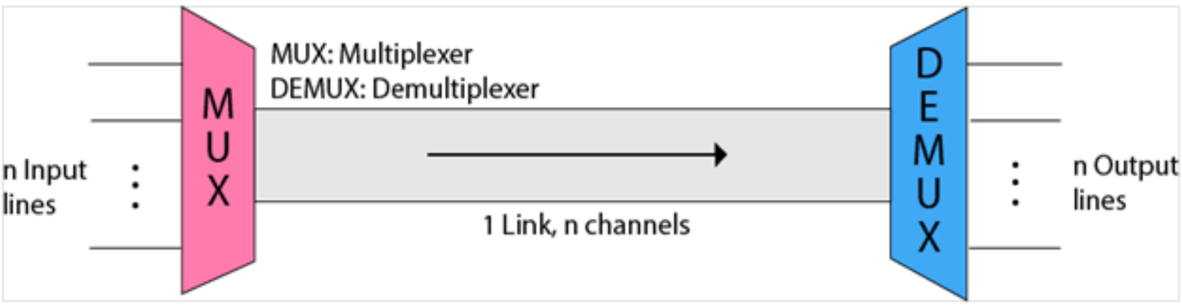
Why Multiplexing?

- The transmission medium is used to send the signal from sender to receiver. The medium can only have one signal at a time.
- If there are multiple signals to share one medium, then the medium must be divided in such a way that each signal is given some portion of the available bandwidth. For example: If there are 10 signals and bandwidth of medium is100 units, then the 10 unit is shared by each signal.
- When multiple signals share the common medium, there is a possibility of collision. Multiplexing concept is used to avoid such collision.
- Transmission services are very expensive.

History of Multiplexing

- Multiplexing technique is widely used in telecommunications in which several telephone calls are carried through a single wire.
- Multiplexing originated in telegraphy in the early 1870s and is now widely used in communication.
- George Owen Squier developed the **telephone carrier multiplexing** in 1910.

Concept of Multiplexing



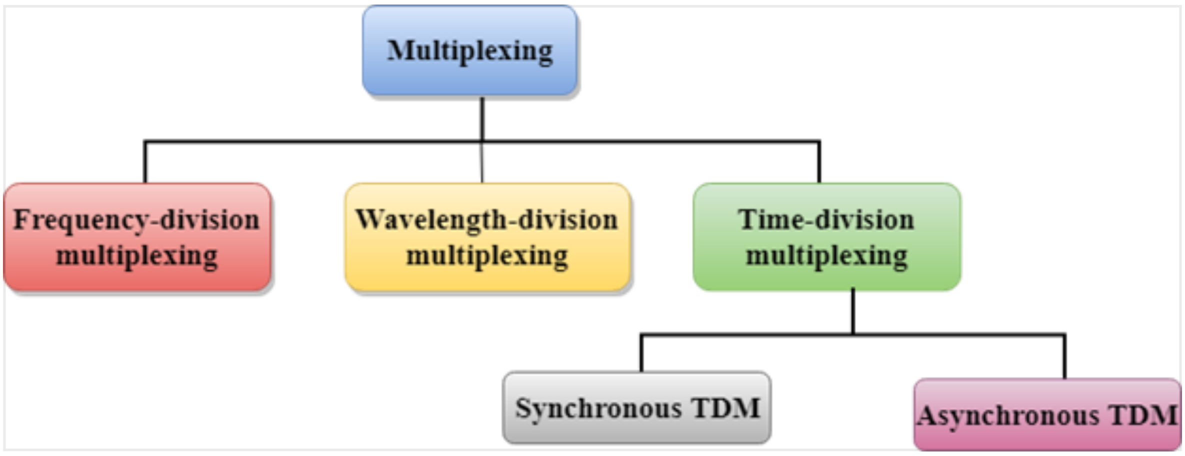
- The 'n' input lines are transmitted through a multiplexer and multiplexer combines the signals to form a composite signal.
- The composite signal is passed through a Demultiplexer and demultiplexer separates a signal to component signals and transfers them to their respective destinations.

Advantages of Multiplexing:

- More than one signal can be sent over a single medium.
- The bandwidth of a medium can be utilized effectively.

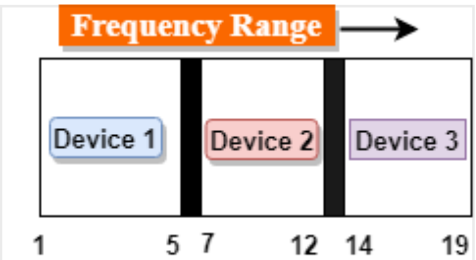
Multiplexing Techniques

Multiplexing techniques can be classified as:



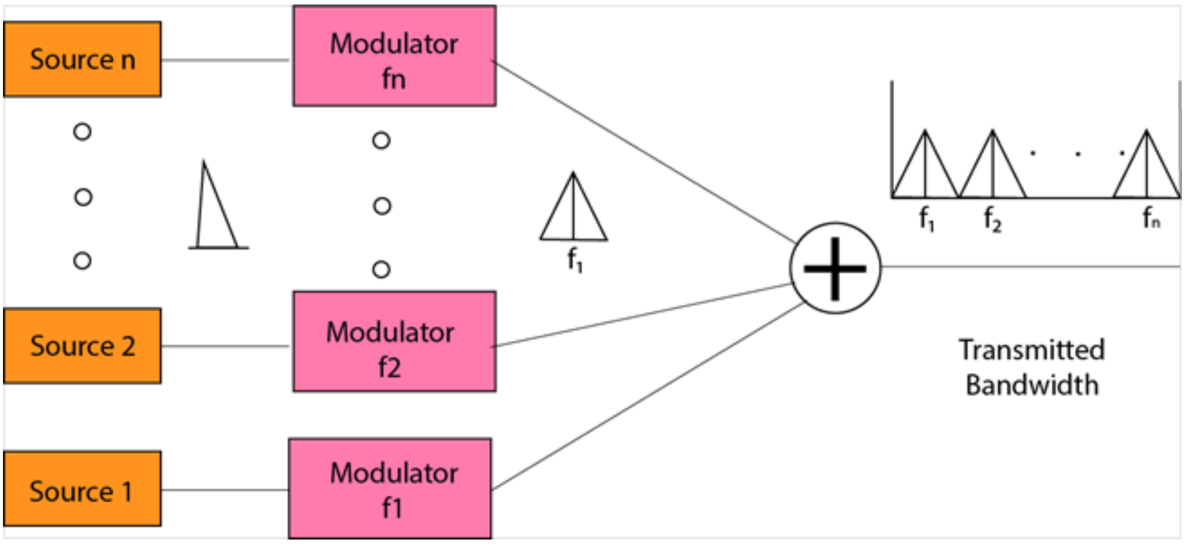
Frequency-division Multiplexing (FDM)

- It is an analog technique.
- **Frequency Division Multiplexing** is a technique in which the available bandwidth of a single transmission medium is subdivided into several channels.



- In the above diagram, a single transmission medium is subdivided into several frequency channels, and each frequency channel is given to different devices. Device 1 has a frequency channel of range from 1 to 5.
- The input signals are translated into frequency bands by using modulation techniques, and they are combined by a multiplexer to form a composite signal.
- The main aim of the FDM is to subdivide the available bandwidth into different frequency channels and allocate them to different devices.
- Using the modulation technique, the input signals are transmitted into frequency bands and then combined to form a composite signal.
- The carriers which are used for modulating the signals are known as **sub-carriers**. They are represented as f1,f2..fn.

- **FDM** is mainly used in radio broadcasts and TV networks.



Advantages Of FDM:

- FDM is used for analog signals.
- FDM process is very simple and easy modulation.
- A Large number of signals can be sent through an FDM simultaneously.
- It does not require any synchronization between sender and receiver.

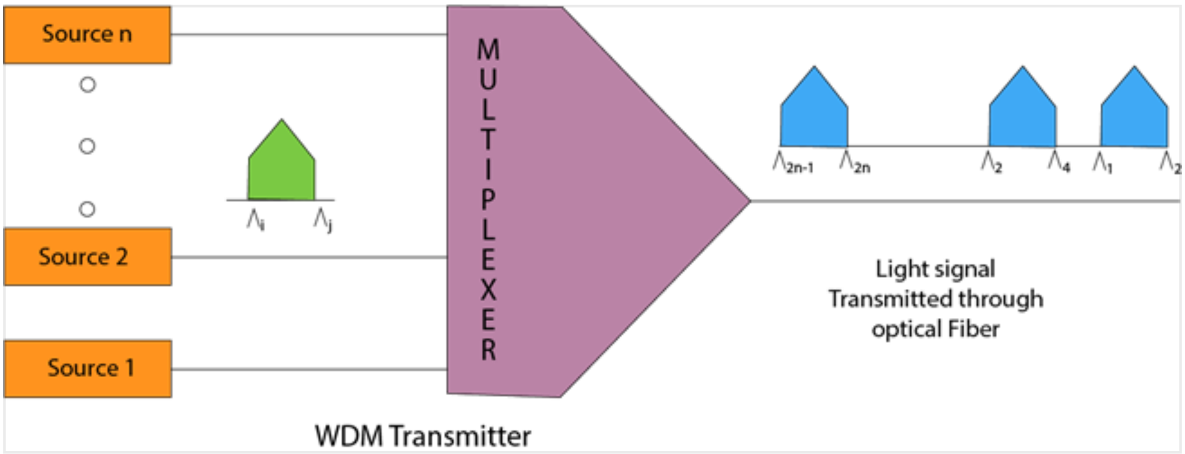
Disadvantages Of FDM:

- FDM technique is used only when low-speed channels are required.
- It suffers the problem of crosstalk.
- A Large number of modulators are required.
- It requires a high bandwidth channel.

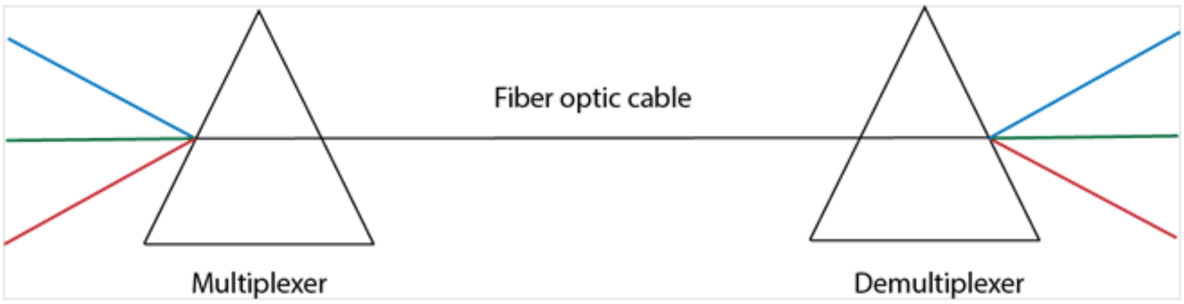
Applications Of FDM:

- FDM is commonly used in TV networks.
- It is used in FM and AM broadcasting. Each FM radio station has different frequencies, and they are multiplexed to form a composite signal. The multiplexed signal is transmitted in the air.

Wavelength Division Multiplexing (WDM)



- Wavelength Division Multiplexing is same as FDM except that the optical signals are transmitted through the fibre optic cable.
- WDM is used on fibre optics to increase the capacity of a single fibre.
- It is used to utilize the high data rate capability of fibre optic cable.
- It is an analog multiplexing technique.
- Optical signals from different source are combined to form a wider band of light with the help of multiplexer.
- At the receiving end, demultiplexer separates the signals to transmit them to their respective destinations.
- Multiplexing and Demultiplexing can be achieved by using a prism.
- Prism can perform a role of multiplexer by combining the various optical signals to form a composite signal, and the composite signal is transmitted through a fibre optical cable.
- Prism also performs a reverse operation, i.e., demultiplexing the signal.



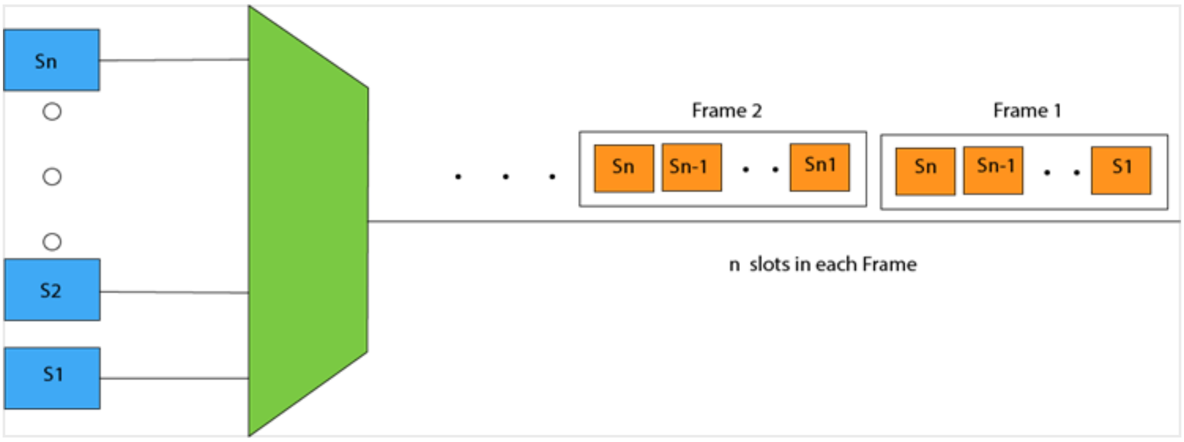
Time Division Multiplexing

- It is a digital technique.
- In Frequency Division Multiplexing Technique, all signals

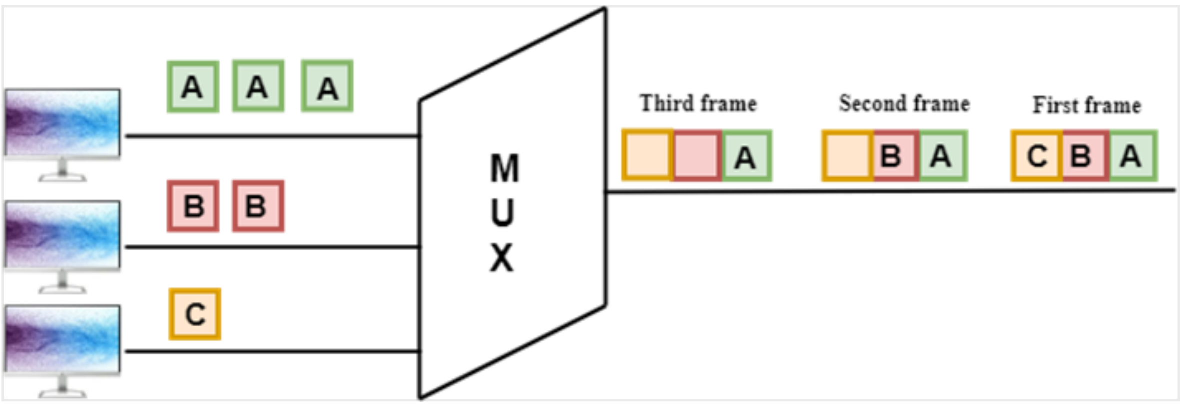
operate at the same time with different frequency, but in case of Time Division Multiplexing technique, all signals operate at the same frequency with different time.
- In **Time Division Multiplexing technique**, the total time available in the channel is distributed among different users. Therefore, each user is allocated with different time interval known as a Time slot at which data is to be transmitted by the sender.
- A user takes control of the channel for a fixed amount of time.
- In Time Division Multiplexing technique, data is not transmitted simultaneously rather the data is transmitted one-by-one.
- In TDM, the signal is transmitted in the form of frames. Frames contain a cycle of time slots in which each frame contains one or more slots dedicated to each user.
- It can be used to multiplex both digital and analog signals but mainly used to multiplex digital signals.

There are two types of TDM:
- Synchronous TDM
- Asynchronous TDM

Synchronous TDM
- A Synchronous TDM is a technique in which time slot is preassigned to every device.
- In Synchronous TDM, each device is given some time slot irrespective of the fact that the device contains the data or not.
- If the device does not have any data, then the slot will remain empty.
- In Synchronous TDM, signals are sent in the form of frames. Time slots are organized in the form of frames. If a device does not have data for a particular time slot, then the empty slot will be transmitted.
- The most popular Synchronous TDM are T-1 multiplexing, ISDN multiplexing, and SONET multiplexing.
- If there are n devices, then there are n slots.



Concept Of Synchronous TDM



In the above figure, the Synchronous TDM technique is implemented. Each device is allocated with some time slot. The time slots are transmitted irrespective of whether the sender has data to send or not.

Disadvantages Of Synchronous TDM:

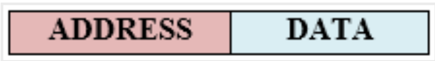
- The capacity of the channel is not fully utilized as the empty slots are also transmitted which is having no data. In the above figure, the first frame is completely filled, but in the last two frames, some slots are empty. Therefore, we can say that the capacity of the channel is not utilized efficiently.
- The speed of the transmission medium should be greater than the total speed of the input lines. An alternative approach to the Synchronous TDM is Asynchronous Time Division Multiplexing.

Asynchronous TDM

- An asynchronous TDM is also known as Statistical TDM.
- An asynchronous TDM is a technique in which time slots are not fixed as in the case of Synchronous TDM. Time slots are allocated to only those devices which have the data to send.

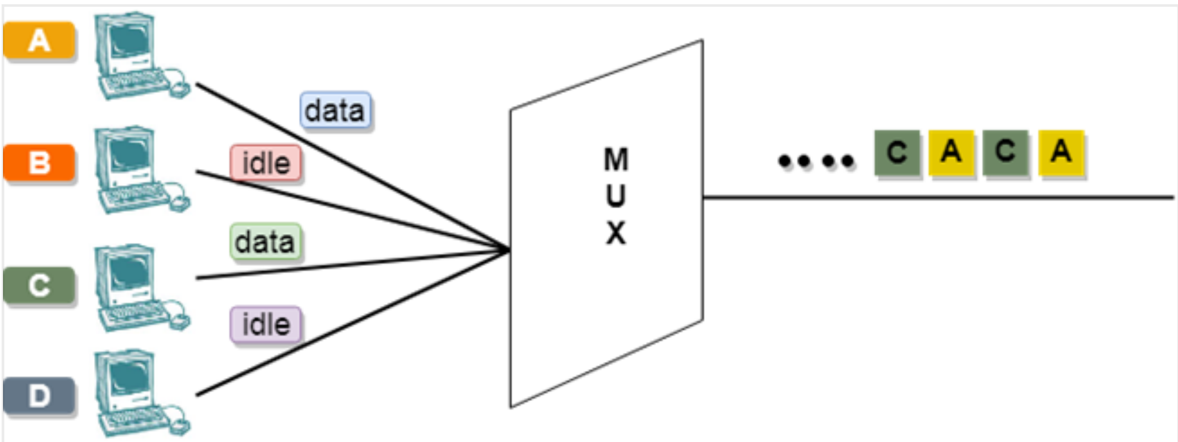
Therefore, we can say that Asynchronous Time Division multiplexor transmits only the data from active workstations.

- An asynchronous TDM technique dynamically allocates the time slots to the devices.
- In Asynchronous TDM, total speed of the input lines can be greater than the capacity of the channel.
- Asynchronous Time Division multiplexor accepts the incoming data streams and creates a frame that contains only data with no empty slots.
- In Asynchronous TDM, each slot contains an address part that identifies the source of the data.



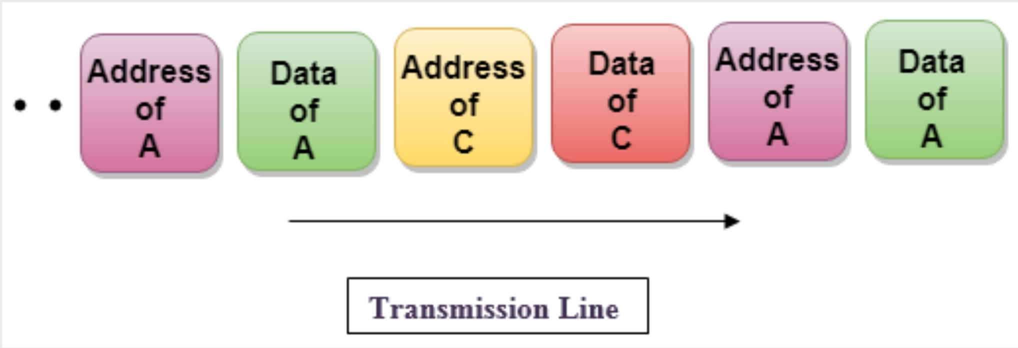
- The difference between Asynchronous TDM and Synchronous TDM is that many slots in Synchronous TDM are unutilized, but in Asynchronous TDM, slots are fully utilized. This leads to the smaller transmission time and efficient utilization of the capacity of the channel.
- In Synchronous TDM, if there are n sending devices, then there are n time slots. In Asynchronous TDM, if there are n sending devices, then there are m time slots where m is less than n (**m<n**).
- The number of slots in a frame depends on the statistical analysis of the number of input lines.

Concept Of Asynchronous TDM



In the above diagram, there are 4 devices, but only two devices are sending the data, i.e., A and C. Therefore, the data of A and C are only transmitted through the transmission line.

Frame of above diagram can be represented as:



The above figure shows that the data part contains the address to determine the source of the data.

Error Detection and Correction

When data is transmitted from one device to another device, the system does not guarantee whether the data received by the device is identical to the data transmitted by another device. An Error is a situation when the message received at the receiver end is not identical to the message transmitted.

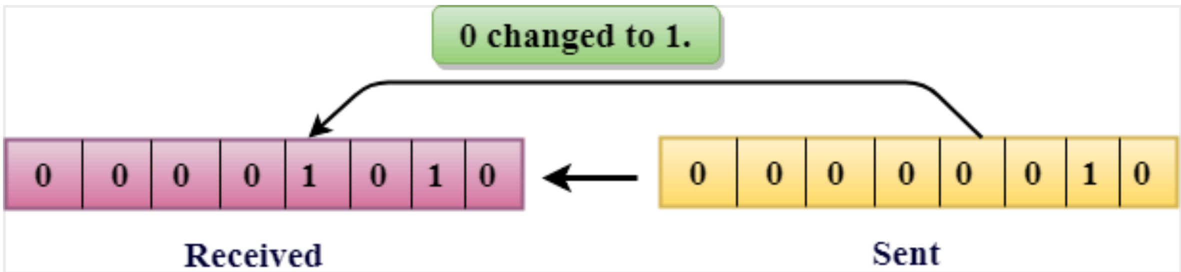
Types Of Errors

Errors can be classified into two categories:

- Single-Bit Error
- Burst Error

Single-Bit Error:

The only one bit of a given data unit is changed from 1 to 0 or from 0 to 1.

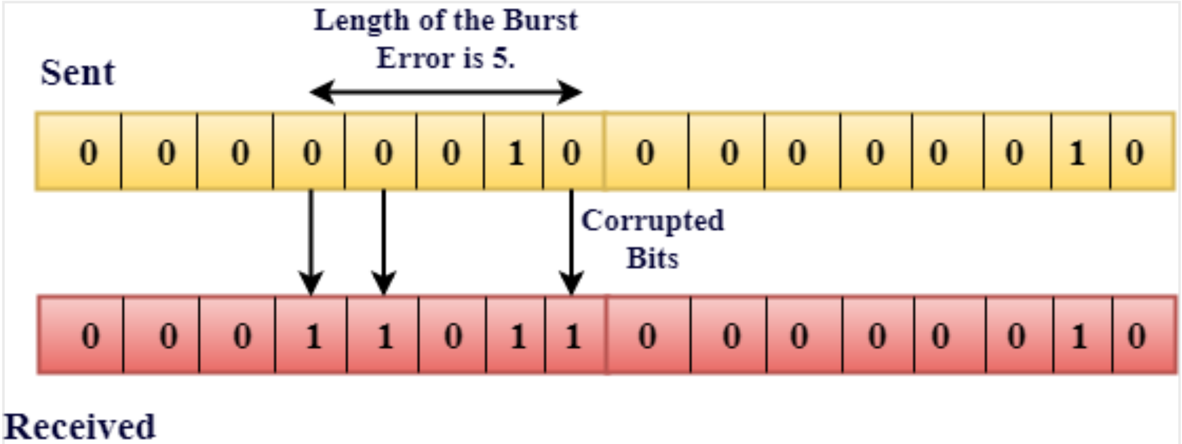


In the above figure, the message which is sent is corrupted as single-bit, i.e., 0 bit is changed to 1.

Single-Bit Error does not appear more likely in Serial Data Transmission. For example, Sender sends the data at 10 Mbps, this means that the bit lasts only for 1 ?s and for a single-bit error to occurred, a noise must be more than 1 ?s.

Single-Bit Error mainly occurs in Parallel Data Transmission. For example, if eight wires are used to send the eight bits of a byte, if one of the wire is noisy, then single-bit is corrupted per byte.

Burst Error:
The two or more bits are changed from 0 to 1 or from 1 to 0 is known as Burst Error.
The Burst Error is determined from the first corrupted bit to the last corrupted bit.



The duration of noise in Burst Error is more than the duration of noise in Single-Bit.
Burst Errors are most likely to occurr in Serial Data Transmission.
The number of affected bits depends on the duration of the noise and data rate.

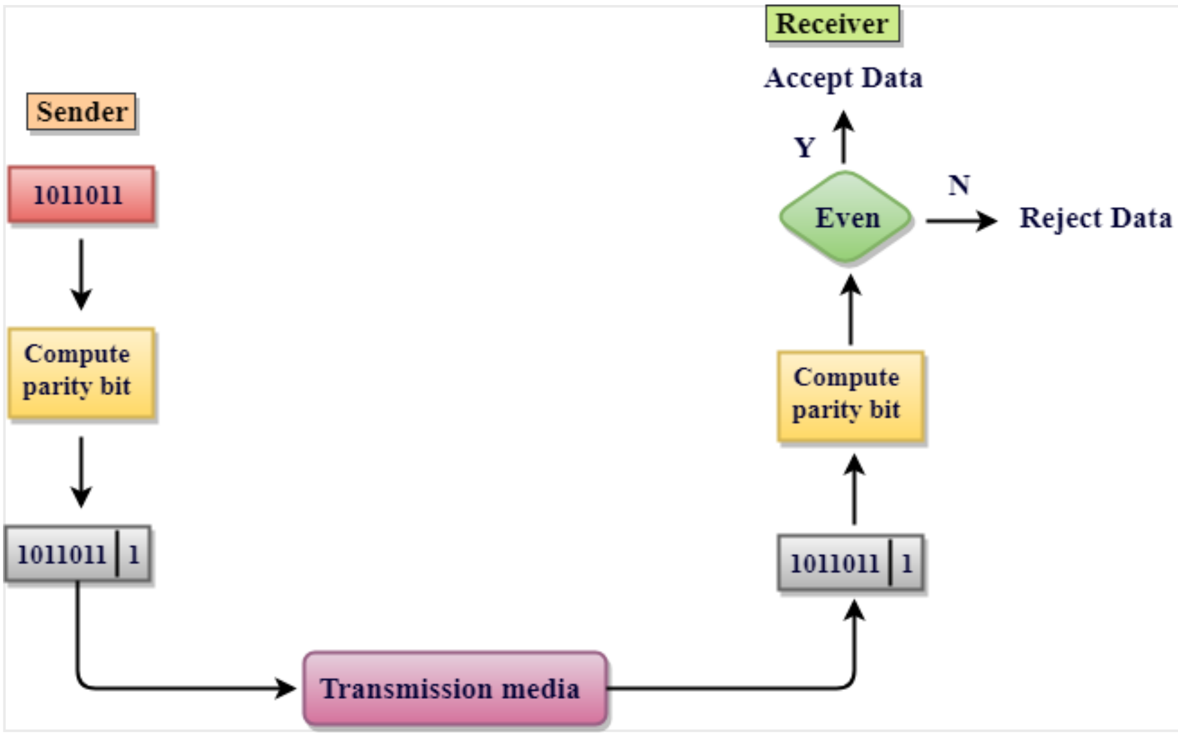
Error Detecting Techniques:
The most popular Error Detecting Techniques are:

- Single parity check
- Two-dimensional parity check
- Checksum
- Cyclic redundancy check

Single Parity Check

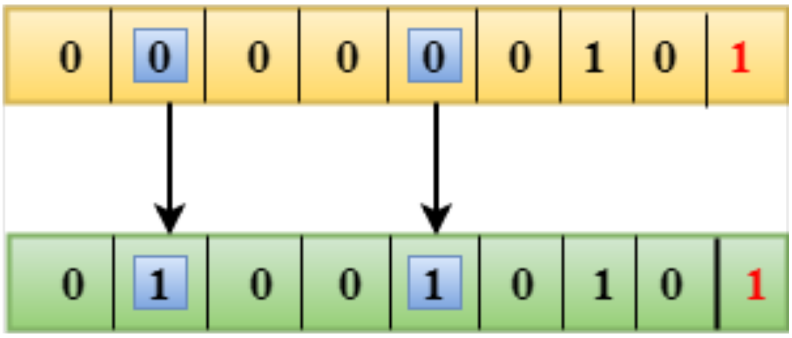
- Single Parity checking is the simple mechanism and inexpensive to detect the errors.
- In this technique, a redundant bit is also known as a parity bit which is appended at the end of the data unit so that the number of 1s becomes even. Therefore, the total number of transmitted bits would be 9 bits.
- If the number of 1s bits is odd, then parity bit 1 is appended and if the number of 1s bits is even, then parity bit 0 is appended at the end of the data unit.

- At the receiving end, the parity bit is calculated from the received data bits and compared with the received parity bit.
- This technique generates the total number of 1s even, so it is known as even-parity checking.



Drawbacks Of Single Parity Checking

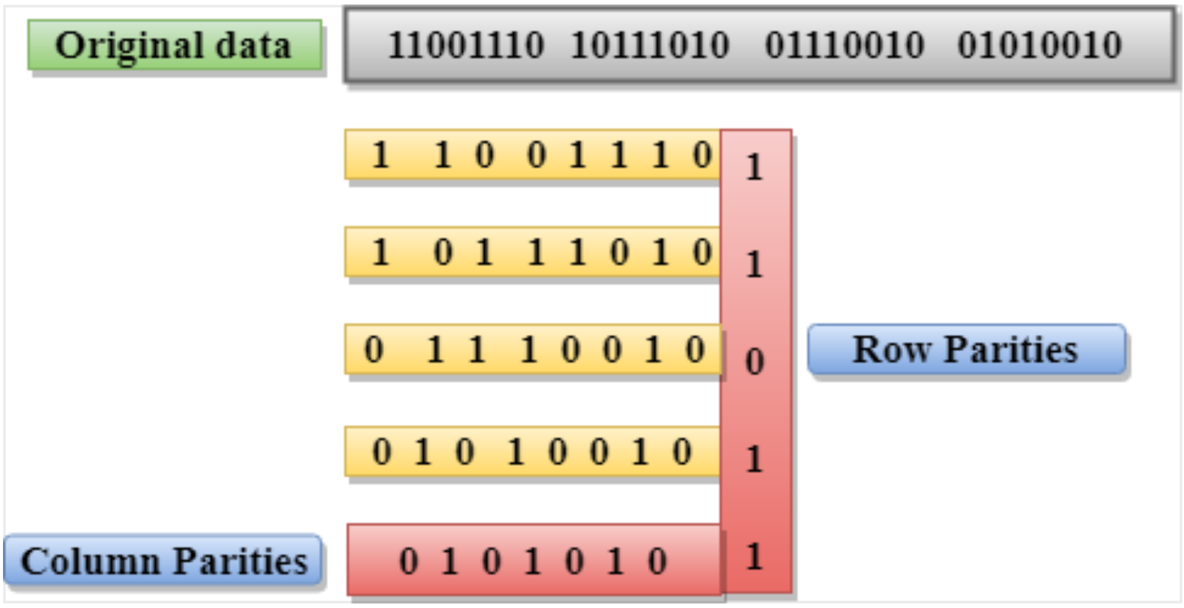
- It can only detect single-bit errors which are very rare.
- If two bits are interchanged, then it cannot detect the errors.



Two-Dimensional Parity Check

- Performance can be improved by using **Two-Dimensional Parity Check** which organizes the data in the form of a table.
- Parity check bits are computed for each row, which is equivalent to the single-parity check.
- In Two-Dimensional Parity check, a block of bits is divided into rows, and the redundant row of bits is added to the whole block.
- At the receiving end, the parity bits are compared with the

parity bits computed from 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

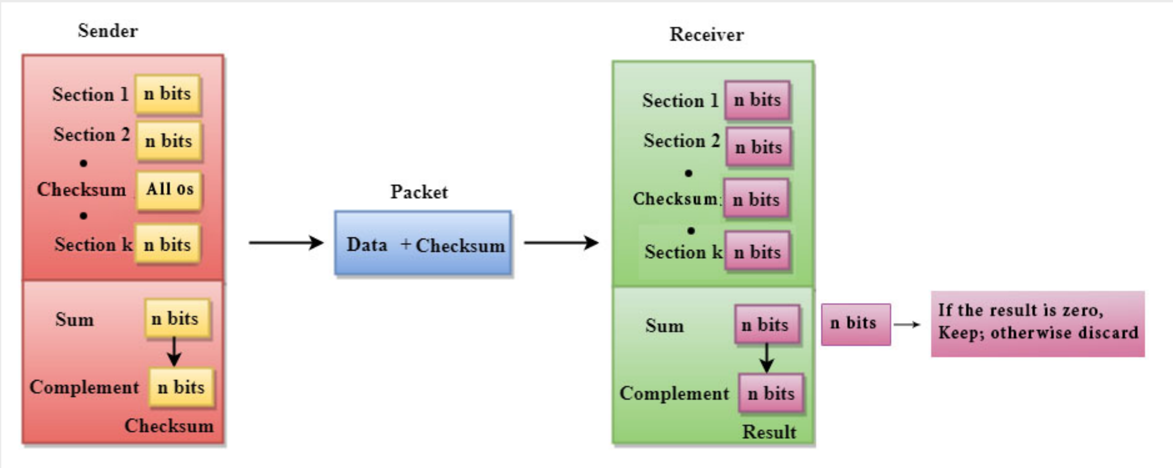
A Checksum is an error detection technique based on the concept of redundancy.

It is divided into two parts:

Checksum Generator

A Checksum is generated at the sending side. Checksum generator subdivides the data into equal segments of n bits each, and all these segments are added together by using one's complement arithmetic. The sum is complemented and appended to the original data, known as checksum field. The extended data is transmitted across the network.

Suppose L is the total sum of the data segments, then the checksum would be ?L



1. The Sender follows the given steps:
2. The block unit is divided into k sections, and each of n bits.
3. All the k sections are added together by using one's complement to get the sum.
4. The sum is complemented and it becomes the checksum field.
5. The original data and checksum field are sent across the network.

Checksum Checker

A Checksum is verified at the receiving side. The receiver subdivides the incoming data into equal segments of n bits each, and all these segments are added together, and then this sum is complemented. If the complement of the sum is zero, then the data is accepted otherwise data is rejected.

1. The Receiver follows the given steps:
2. The block unit is divided into k sections and each of n bits.
3. All the k sections are added together by using one's complement algorithm to get the sum.
4. The sum is complemented.
5. If the result of the sum is zero, then the data is accepted otherwise the data is discarded.

Cyclic Redundancy Check (CRC)

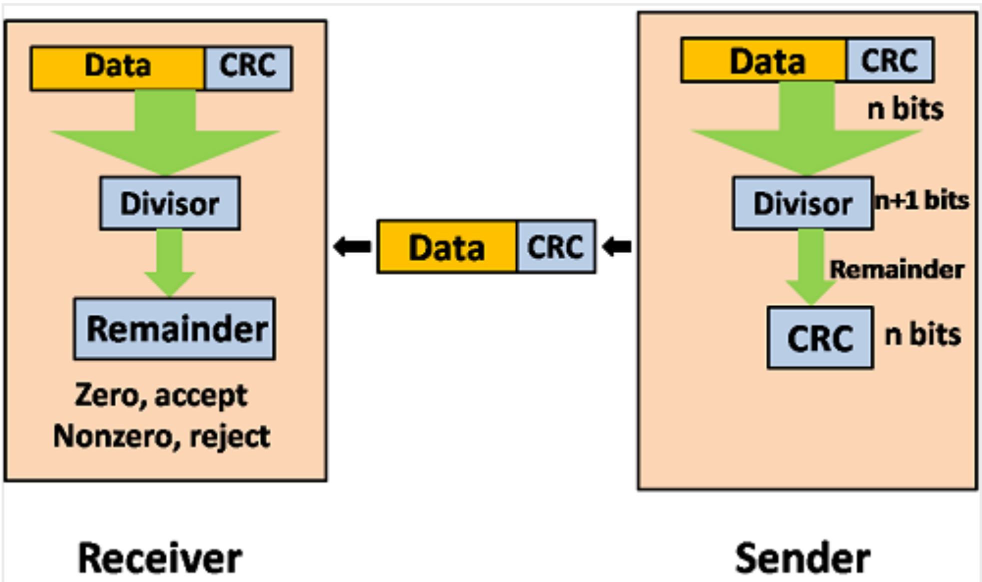
CRC is a redundancy error technique used to determine the error.

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.

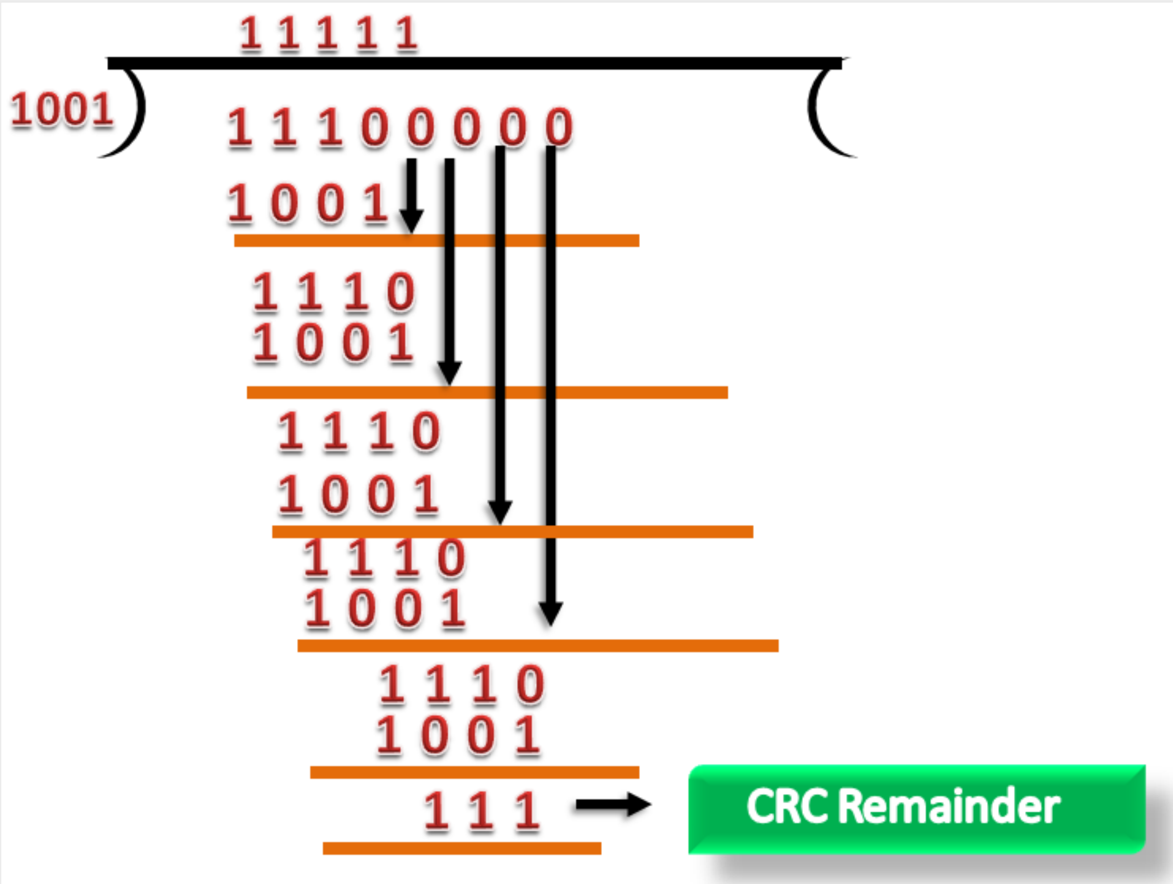
If the resultant of this division is zero which means that it has no error, and the data is accepted.
If the resultant of this division is not zero which means that the data consists of an error. Therefore, the data is discarded.



Let's understand this concept through an example:
Suppose the original data is 11100 and divisor is 1001.
CRC Generator

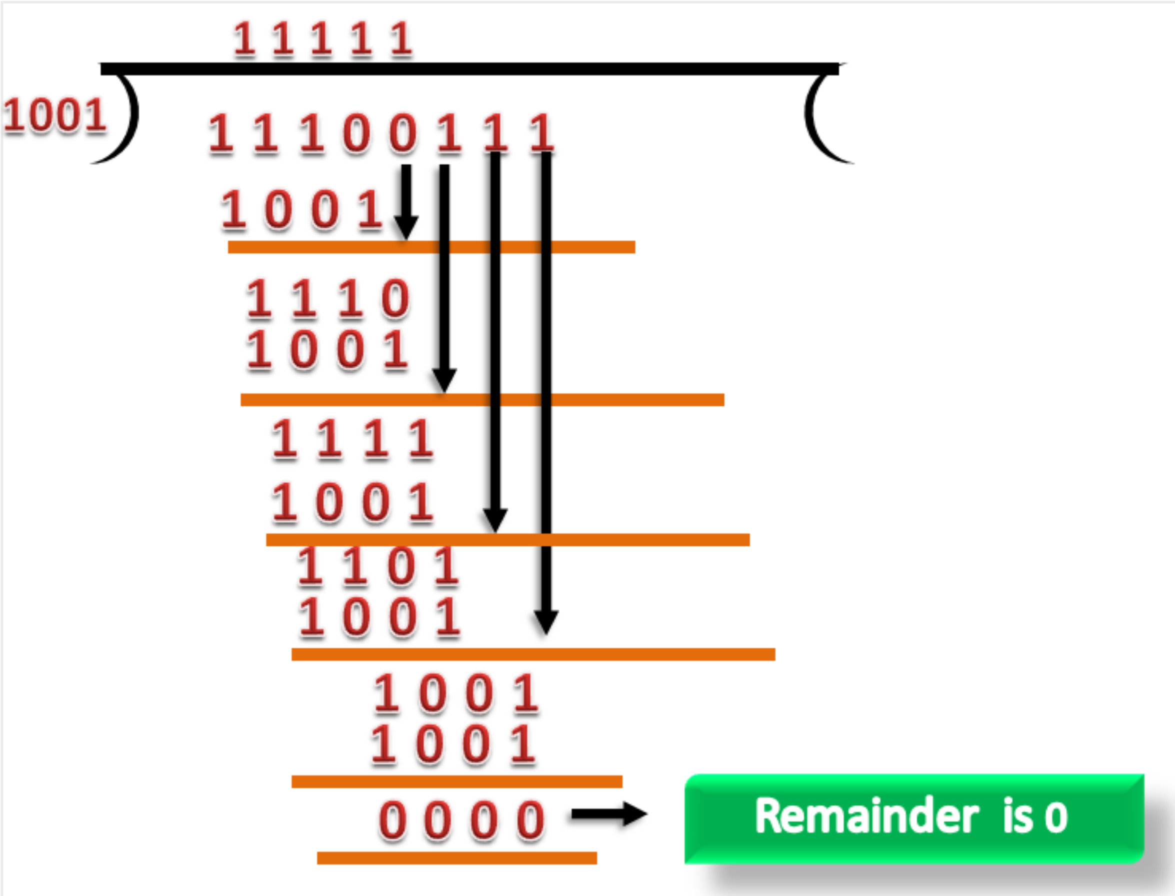
- A CRC generator uses a modulo-2 division. Firstly, three zeroes are appended at the end of the data as the length of the divisor is 4 and we know that the length of the string 0s to be appended is always one less than the length of the divisor.
- Now, the string becomes 11100000, and the resultant 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.


1 1 1 1 1
1001
1 1 1 0 0 1 1 1
1 0 0 1
1 1 1 0
1 0 0 1
1 1 1 1
1 0 0 1
1 1 0 1
1 0 0 1
1 0 0 1
1 0 0 1
0 0 0 0
Remainder is 0