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COEN3193

DATA COMMUNICATIONS (Lecture)

INSTRUCTIONAL MATERIAL

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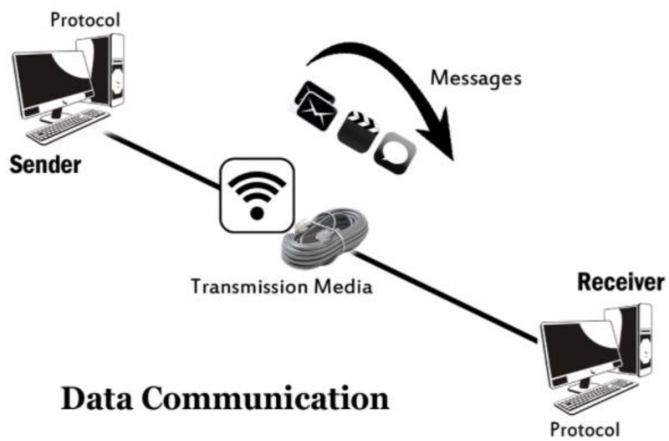
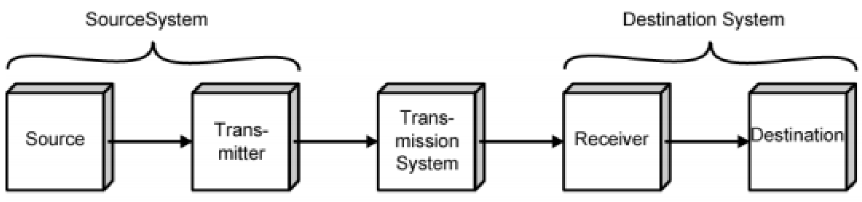
DATA COMMUNICATIONS

Communication can be defined as the exchange of information between two or more bodies. In engineering, exchange of information is not only between people, information exchange also takes place between machines or systems. Communication has increased significantly in importance in recent years.

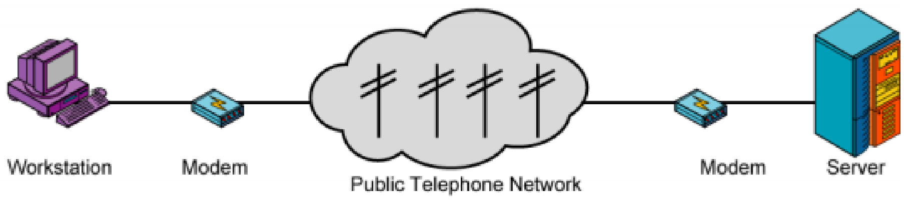


Data Communication Circuits

The underlying purpose of a digital communications circuit is to provide a transmission path between locations and to transfer digital information from one station (node, where computers or other digital equipment are located) to another using electronic circuits. Data communications circuits utilize electronic communications equipment and facilities to interconnect digital computer equipment. Communication facilities are physical means of interconnecting stations and are provided to data communications users through public telephone networks (PTN), public data networks (PDN), and a multitude of private data communications systems. The following figure shows a simple two-station data communications circuit. The main components are:



Block Diagram



Example

Source

This device generates the data to be transmitted; examples are mainframe computer, personal computer, workstation etc. The source equipment provides a means for humans to enter data into system.

Transmitter

A transmitter transforms and encodes the information in such a way as to produce electromagnetic signals that can be transmitted across some sort of transmission system. For example, a modem takes a digital bit stream from an attached device such as a personal computer and transforms that bit stream into an analog signal that can be handled by the telephone network.

Transmission medium

The transmission medium carries the encoded signals from the transmitter to the receiver. Different types of transmission media include free-space radio transmission (i.e. all forms of wireless transmission) and physical facilities such as metallic and optical fiber cables.

Receiver

The receiver accepts the signal from the transmission medium and converts it into a form that can be handled by the destination device. For example, a modem will accept an analog signal coming from a network or transmission line and convert it into a digital bit stream.

Destination

Takes the incoming data from the receiver and can be any kind of digital equipment like the source.

DATA COMMUNICATION CONCEPTS

DATA is referred to as a piece of information formatted in a special way. Data can exist in a variety of forms, such as numbers or text on pieces of paper, as bits and bytes stored in electronic memory, or as facts stored in a person's mind. Strictly speaking, data is the plural of datum , a single piece of information. In practice, however, people use data as both the singular and plural form of the word.

DATA COMMUNICATION CRITERIA

The effectiveness of data communications system depends on four fundamental characteristics:

1. **Delivery.** The system must deliver data to the correct destination
2. **Accuracy.** The system must deliver the data accurately.
3. **Timeliness.** The system must deliver data in a timely manner. Data delivered late are useless. In the case of video and audio, timely delivery means delivering data as they are produced, in the same order that they are produced, and without significant delay. This kind of delivery is called real - time transmission and this occurs in a real - time system.
4. **Jitter**. Jitter refers to the variation in the packet arrival time. It is the uneven delay of delivery of audio or video packets. For example, let us assume that video packets are sent every 20ms. If some of the packets arrive with 20ms delay and others with 30ms delay, an uneven quality in the video is the result.

DATA REPRESENTATION

Data representation is defined as the methods used to represent information in computers. Different types of data can be stored in the computer system. This includes numeric data, text, executable files, images, audio, video, etc. all these will look different to us as human. However, all types of information or data stored in the computer are represented as a sequence of 0s and 1s.

Decimal Numbers

As human we are used to writing numbers using digits 0 to 9. This is called base 10. This number system has been widely adopted, in large part because we have 10 fingers. However, other number systems still persist in modern society.

Text

American Standard Code for Information Interchange (ASCII code) defines 128 different symbols. The symbols are all the characters found on a standard keyboard, plus a few extra. Unique numeric code (0 to 127) is assigned to each character. In ASCII, “A” is 65, “B” is 66, “a” is 97, “b” is 98 and so forth. When a file is save as “plain text”, it is stored using ASCII. ASCII format uses 1 byte per character 1 byte gives only 256 (128 standard and 128 non-standard) possible characters. The code value for any character can be converter to base 2, so any written message made up of ASCII characters can be converted to a string of 0s and 1s.

Graphics

Graphics on computer screen are consists of pixels. The pixels are tiny dots of color that collectively paint a graphic image on a computer screen. It is physical point in a raster image, or the smallest addressable element in an all points addressable display device. Hence it is the smallest controllable element of a picture represented on the screen. The address of a pixel corresponds to its physical coordinates. LCD pixels are manufactured in two-dimensional grid, and are often represented using dots or squares, but CRT pixels correspond to their timing mechanism and sweep rates. The pixels are organized into many rows and columns on the screen.

DATA COMMUNICATIONS STANDARDIZATION

An association of organizations, governments, manufacturers and users form the standards organizations and are responsible for developing, coordinating and maintaining the standards. The purpose is that all data communications equipment manufacturers and users comply with these standards.

Protocol is a set of rules that governs the data communications

Standards are guidelines to manufacturers, government agencies, other service providers to ensure the kind of interconnectivity necessary in today's marketplace and international communications.

STANDARD MAKING-BODIES

International Telecommunication Union an international standards organization related to the United Nations that develops standards in telecommunications. ITU-T is one of the four permanent parts of the International Telecommunications Union based in Geneva, Switzerland. It has developed three sets of specifications: the V series for modem interfacing and data transmission over telephone lines, the X series for data transmission over public digital networks, email and directory services; the I and Q series for Integrated Services Digital Network (ISDN) and its extension Broadband ISDN. ITU-T membership consists of government authorities and representatives from many countries and it is the present standards organization for the United Nations.

American National Standard Institute a non-profit organization, is the US voting representative to both the ISO and ITU. EIA is a non-profit U.S. trade association that establishes and recommends industrial standards. EIA activities include standards development, increasing public awareness, and lobbying and it is responsible for developing the RS (recommended standard) series of standards for data and communications.

Institute of Electronics & Electrical Engineers is the largest national professional group involved in developing standards for computing, communications, electrical engineering and electronics. IEEE is an international professional organization founded in United States and is compromised of electronics, computer and communications engineers. It is currently the world's largest professional society with over 200,000 members. It develops communication and information processing standards with the underlying goal of advancing theory, creativity, and product quality in any field related to electrical engineering.

International Standard Organization (ISO) is the international organization for standardization on a wide range of subjects. It is comprised mainly of members from the standards committee of various governments throughout the world. It is even responsible for developing models which provides high level of system compatibility, quality enhancement, improved productivity and reduced costs. The ISO is also responsible for endorsing and coordinating the work of the other standards organizations.

Electronic Industries Association is an association of electronics manufacturers in the U.S. EIA is a non-profit U.S. trade association that establishes and recommends industrial standards. EIA activities include standards development, increasing public awareness, and lobbying and it is responsible for developing the RS (recommended standard) series of standards for data and communications.

Federal Communication Commission has the authority over interstate and international commerce as it relates to communications.

Telecommunications Industry Association (TIA) is the leading trade association in the communications and information technology industry. It facilitates business development opportunities through market development, trade promotion, trade shows, and standards development. It represents manufacturers of communications and information technology products and also facilitates the convergence of new communications networks.

REASON FOR STANDARDIZATION

- Ensure hardware / software compatibility
- Promote competition with high quality
- Consumer can hold down the prices
- It opened the possibility to build networks and share information. (interoperational of different networks)
- Ensure Reliable communication – “protocol”
- Determine standard methods of communications

DIGITAL AND DATA TRANSMISSIONS

A. DATA TRANSMISSIONS

Description of Data Flows and Transmission Mode

A transmission may be simplex, half duplex, or full duplex. In simplex transmission, signals are transmitted in only one direction; one station is transmitter and the other is receiver. In half-duplex operation, both stations may transmit, but only one at a time. In full-duplex operation, both stations may transmit simultaneously.

Types of Transmission Mode and Data Flow

Simplex Transmission

In simplex mode, the communication is unidirectional, as on a one-way street. Only one of the two devices on a link can transmit; the other can only receive. Keyboards and traditional monitors are examples of simplex devices. The keyboard can only introduce input; the monitor can only accept output.

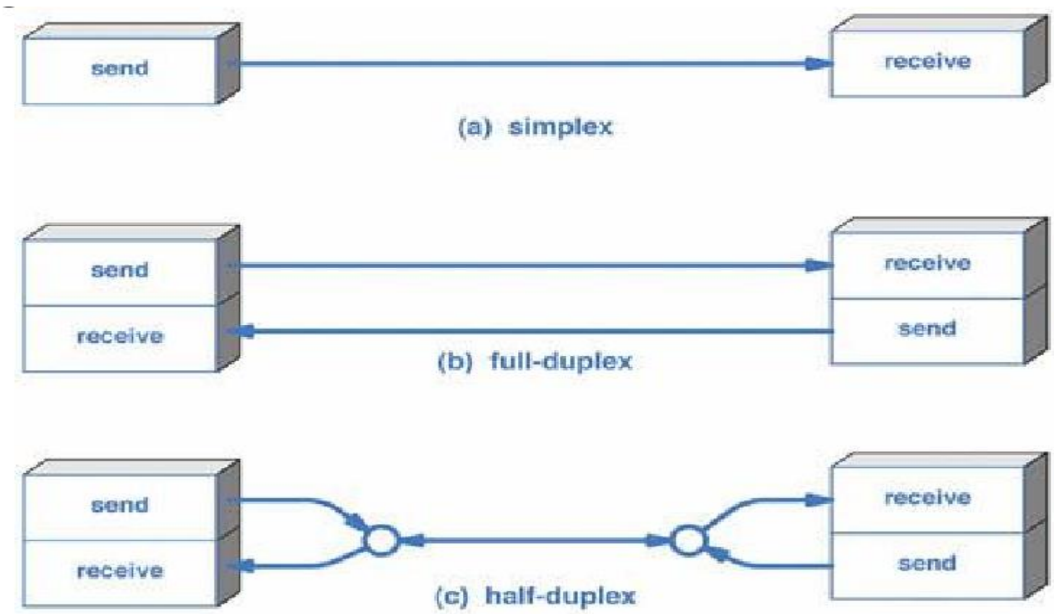
Half Duplex Transmission

In half-duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive, and vice versa. The half-duplex mode is like a one-lane road with traffic allowed in both directions.

Full-duplex Transmission

Full-duplex data transmission means that data can be transmitted in both directions on a signal carrier at the same time. For example, on a local area network with a technology that has full-duplex transmission, one workstation can be sending data on the line while another workstation is receiving data. Full-duplex transmission necessarily implies a bidirectional line (one that can move data in both directions).

DATA FLOW ILLUSTRATION

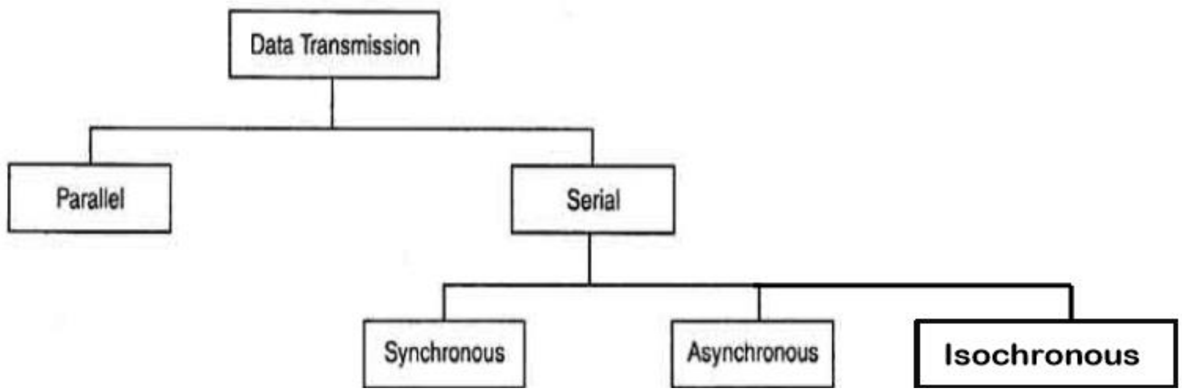


Digital Data Transmission Methods

We see that for communication to occur there will be a channel of communication through which the devices are interconnected. In digital data transmission where we have more than one bits to send from sender to receiver. Our primary when we are considering the wiring is the data stream.

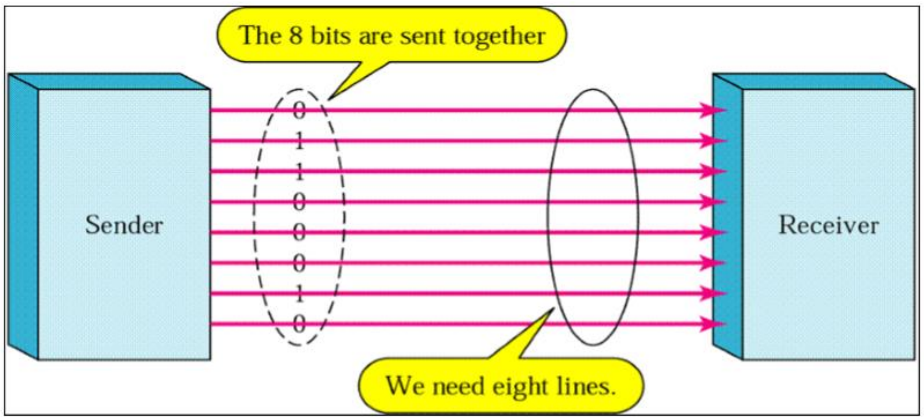
There are two methods of transmitting digital data namely parallel and serial transmissions. In parallel data transmission, all bits of the binary data are transmitted simultaneously. For example, to transmit an 8-bit binary number in parallel from one unit to another, eight transmission lines are required. Each bit requires its own separate data path. All bits of a word are transmitted at the same time. This method of transmission can move a significant amount of data in a given period of time. Its disadvantage is the large number of interconnecting cables between the two units. For large binary words, cabling becomes complex and expensive. This is particularly true if the distance between the two units is great. Long multiwire cables are not only expensive, but also require special interfacing to minimize noise and distortion problems. Serial data transmission is the process of transmitting binary words a bit at a time. Since the bits time-share the transmission medium, only one interconnecting lead is required.

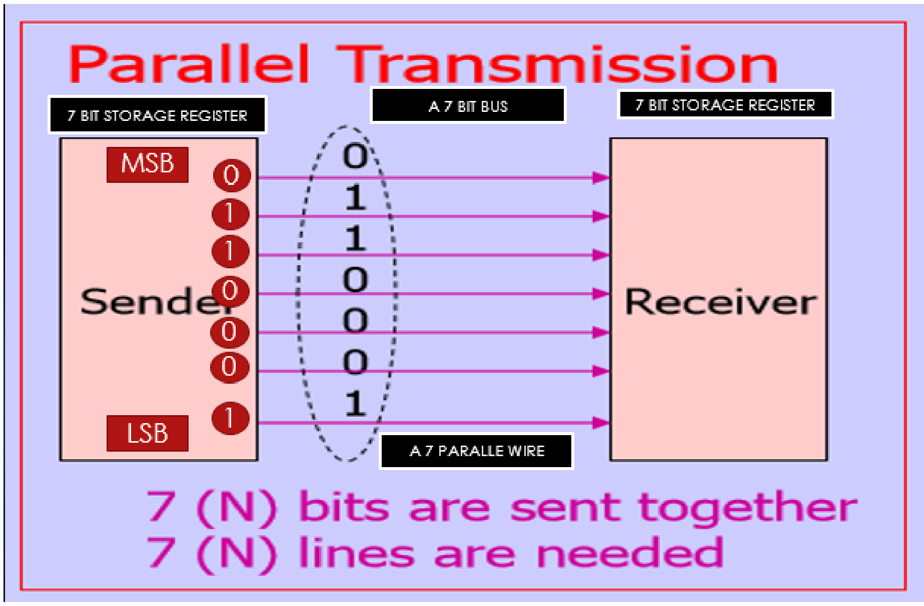
Digital Data Transmission



Parallel Transmission

Binary data, consisting of 1s and 0s, will be organized into groups of n bits each. Computers produce and consume data in groups of bits. By grouping, we can send data n bits at a time instead of 1. This is called parallel transmission. The advantage of parallel transmission is speed. All else being equal, parallel transmission can increase the transfer speed by a factor of n over serial transmission. Shortcoming of parallel transmission it requires n communication lines just to transmit the data stream. Hence it is expensive, parallel transmission is usually limited to short distances





AN EXAMPLE OF PARALLEL DATA TRANSFER OF THE ASCII CHARACTER F

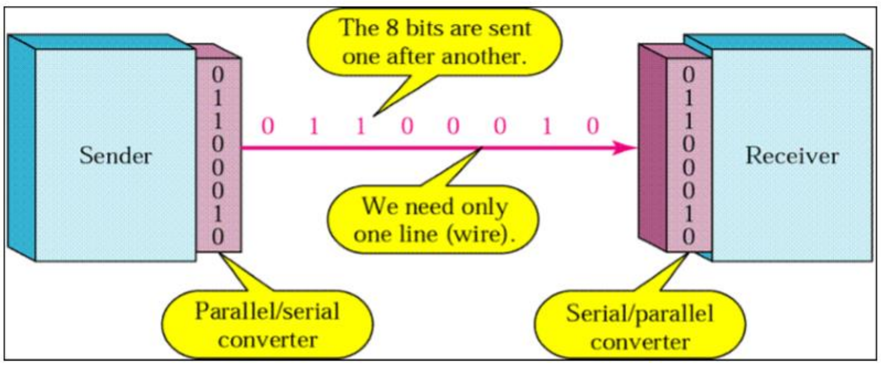
Parallel Transmission

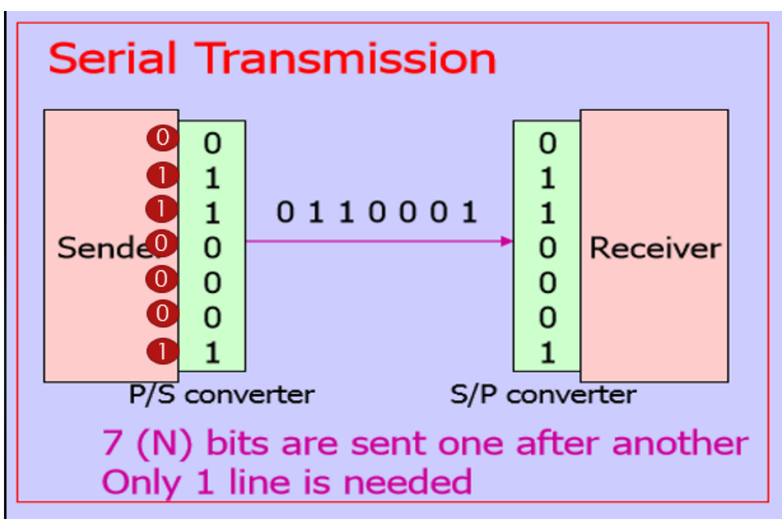
- In parallel data transfer, all the bits of a code word are transferred simultaneously.
- The binary word to be trasnmitted is usually loaded into a register containing one flip-flop outputs for each bit
- In parallel data transmission there is one wire for each bit of information to be transmitted. This means a multiwire cable must be used .
- MULTIPLE PARALLEL LINES THAT CARRY BNARY DATA ARE USUALLY REFERRED TO AS A <u>DATA BUS.</u>
- Parallel transmission is extremely fast since all the bits of the data word are transferred simultaneously.
- Parallel data transmission is not optical in long distance communication . To transfer an 8 bit data word from one place to another , 8 separate communications channels are needed for each bit.
- Parallel Transmission
- For practical long distance they are impractical beacause of cost and signal attenuation
- And of course, parallel data transmission by radio would be even more complex and expensive.

- Parallel transmission of data is obviously much faster than serial because all the bits are traveling at the same time, but because of the fine tolerance in the transmission, it is less reliable as the bits become mixed-up.

Serial Transmission

In serial transmission one bit follows another, so we need only one communication channel rather than n to transmit data between two communicating devices. The advantage of serial over parallel transmission is that with only one communication channel, serial transmission reduces the cost of transmission over parallel by roughly a factor of n. Since communication within devices is parallel, conversion devices are required at the interface between the sender and the line (parallel-to-serial) and between the line and the receiver (serial-to-parallel).





Serial Transmission

- In serial transmission, the various bits of data are transmitted serially one after the other.
- It requires only one communication line rather than lines to transmit data from sender to receiver.
- Less costly
- Long distance communication.

PARALLEL NOT SUITBALE FOR LONG DISTANCE

REASONS:

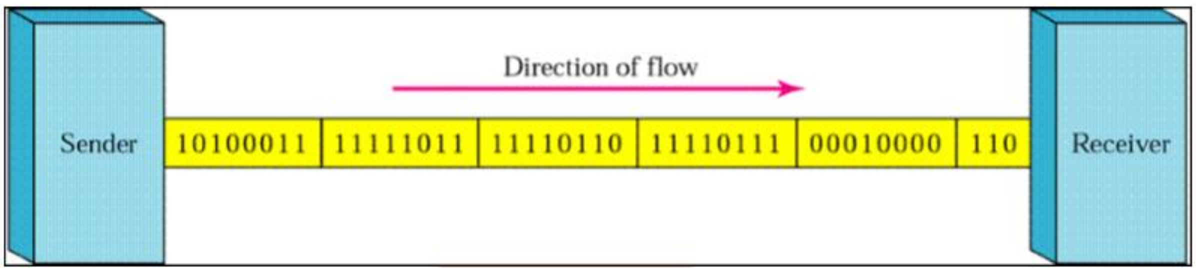
1. Cost
2. Varying delays among the different bits or signals
3. For long distance communication, it would be more cost-effective to transmit data using serial transmission. The telephone lines can be readily used for serial transmission
4. Since data inside a computer system move in parallel, it is necessary to convert them to serial before external communication takes place/
5. Parallel transmission is common for distances less than 10 feet. Serial transmission is ideal for distances greater than 10 feet.

Serial transmission occurs in one of three ways:

asynchronous, synchronous, and isochronous.

Synchronous Transmission

In synchronous transmission, we send bits one after another without start or stop bits or gaps. It is the responsibility of the receiver to group the bits.

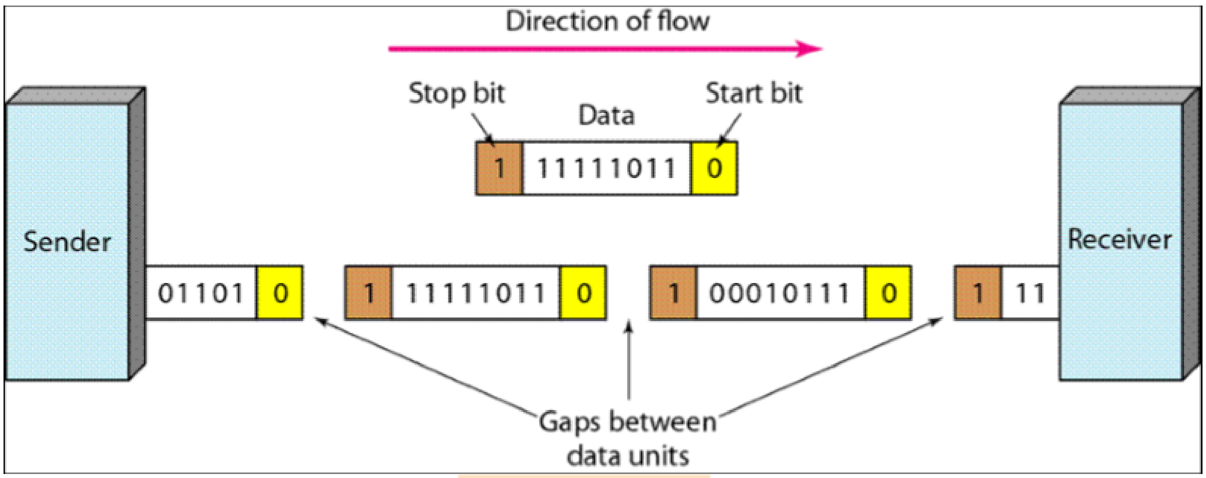


Isochronous Transmission

A sequence of events is isochronous if the events occur regularly, or at equal time intervals.

Asynchronous Transmission

In asynchronous transmission, we send 1 start bit (0) at the beginning and 1 or more stop bits (1) at the end of each byte.



B. DIGITAL TRANSMISSION

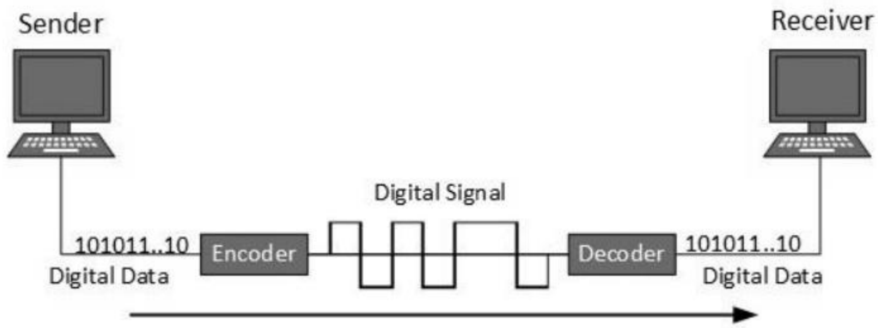
Data or information can be stored in two ways, analog and digital. For a computer to use the data, it must be in discrete digital form. Similar to data, signals can also be in analog and digital form. To transmit data digitally, it needs to be first converted to digital form.

Digital-to-Digital Conversion

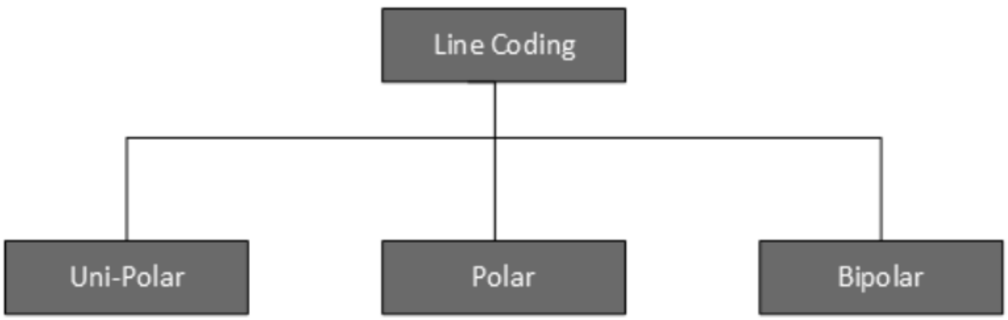
This section explains how to convert digital data into digital signals. It can be done in two ways, line coding and block coding. For all communications, line coding is necessary whereas block coding is optional.

Line Coding

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

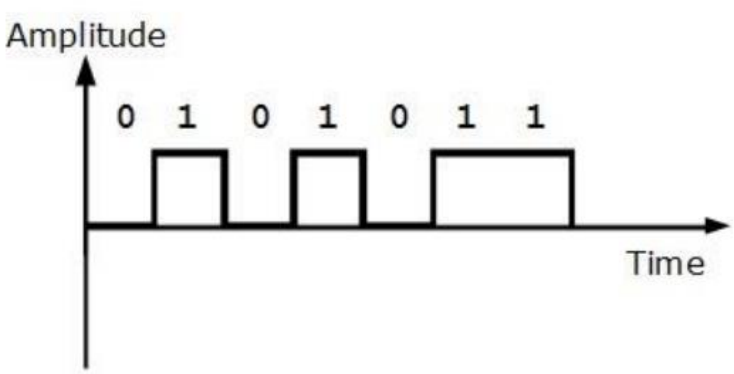


Digital signal is denoted by discreet signal, which represents digital data. There are three types of line coding schemes available:



Unipolar Encoding

Unipolar encoding schemes use 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 is no rest condition i.e. it either represents 1 or 0.



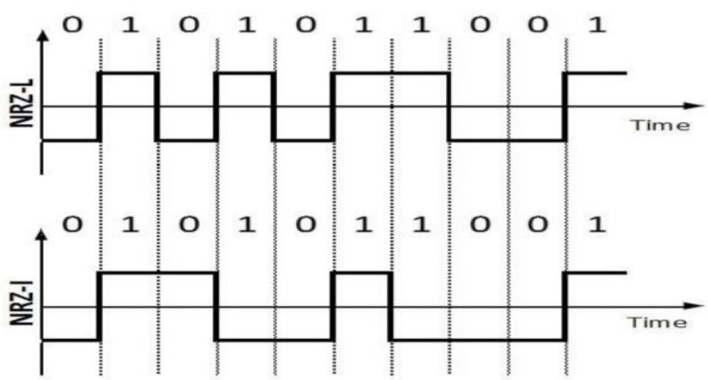
Polar Encoding

Polar encoding scheme uses multiple voltage levels to represent binary values. Polar encodings is available in four types:

Polar Non Return to Zero (Polar NRZ)

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 is no rest condition.

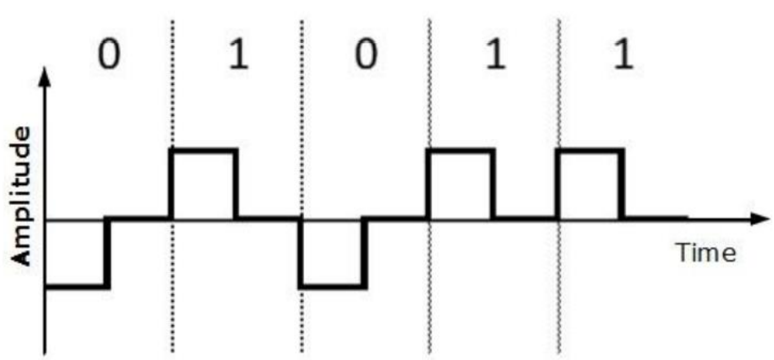
NRZ scheme has two variants: NRZ-L and NRZ-I.



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

Return to Zero (RZ)

Problem with NRZ is that 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.



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

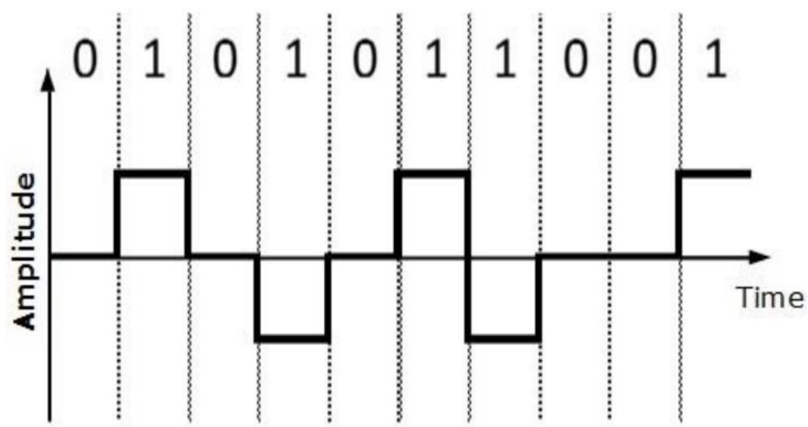
This encoding scheme is a combination of RZ and NRZ-L. Bit time is divided into two halves. It transits in the middle of the bit and changes phase when a different bit is encountered.

Differential Manchester

This encoding scheme is a combination of RZ and NRZ-I. It also transits 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.



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:

1. Division

2. Substitution

3. Combination.

Analog-to-Digital Conversion

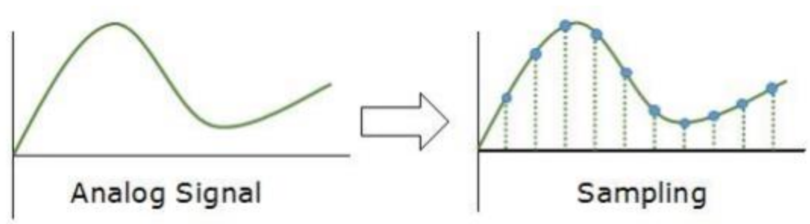
Microphones create analog voice and camera creates analog videos, which are treated is analog data. To transmit this analog data over digital signals, we need analog to digital conversion.

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:

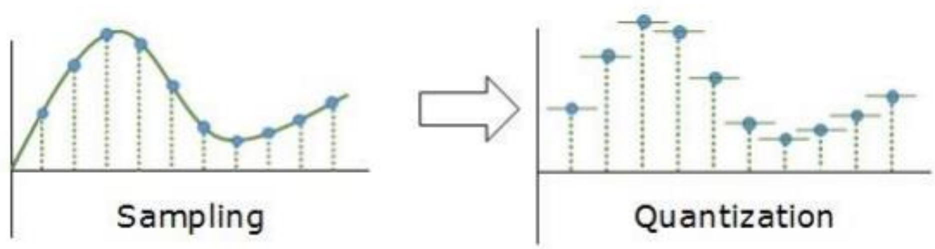
1. Sampling
2. Quantization
3. Encoding.

Sampling



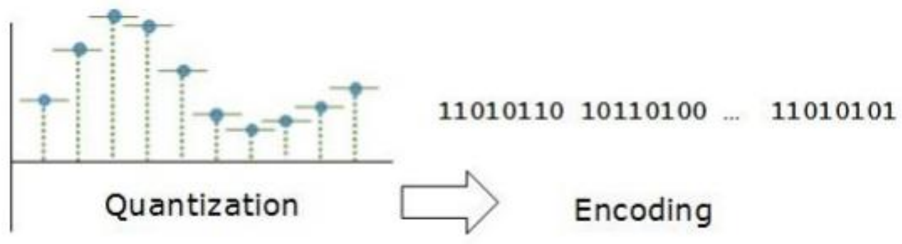
The analog signal is sampled every T interval. Most important factor in sampling is the rate at which analog signal is sampled. According to Nyquist Theorem, the sampling rate must be at least two times of the highest frequency of the signal.

Quantization



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.

ANALOG TRANSMISSION

To send the digital data over an analog media, it needs to be converted into analog signal. There can be two cases according to data formatting.

Bandpass: The filters are used to filter and pass frequencies of interest. A bandpass is a band of frequencies which can pass the filter.

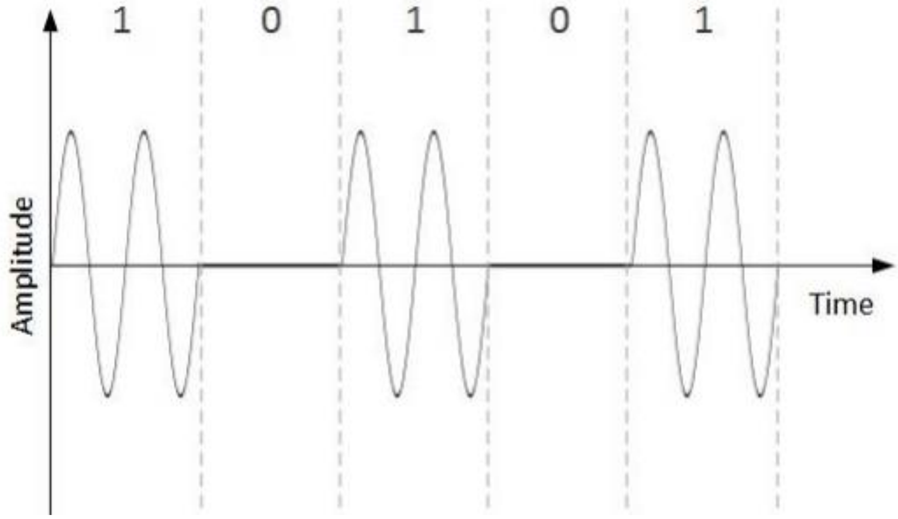
Low-pass: Low-pass is a filter that passes low frequencies signals.

When digital data is converted into a bandpass analog signal, it is called digital-toanalog conversion. When low-pass analog signal is converted into bandpass 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. An analog signal is characterized by its amplitude, frequency, and phase. There are three kinds of digital-to-analog conversions:

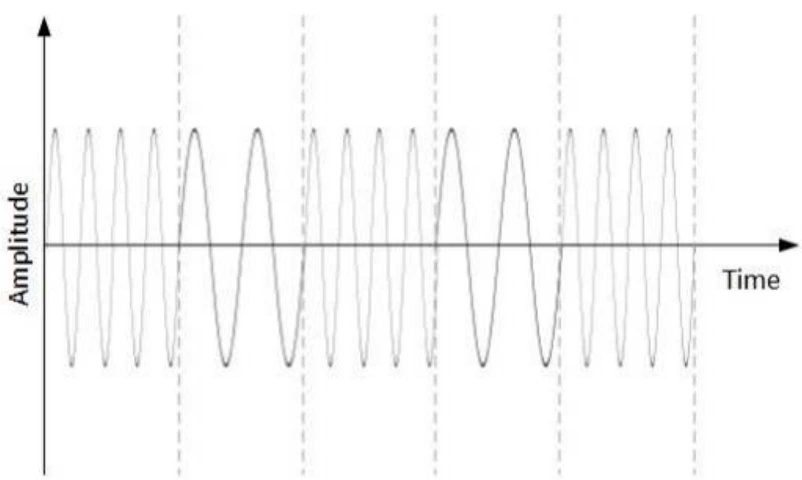
Amplitude Shift Keying In this conversion technique, the amplitude of analog carrier signal is modified to reflect binary data.



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

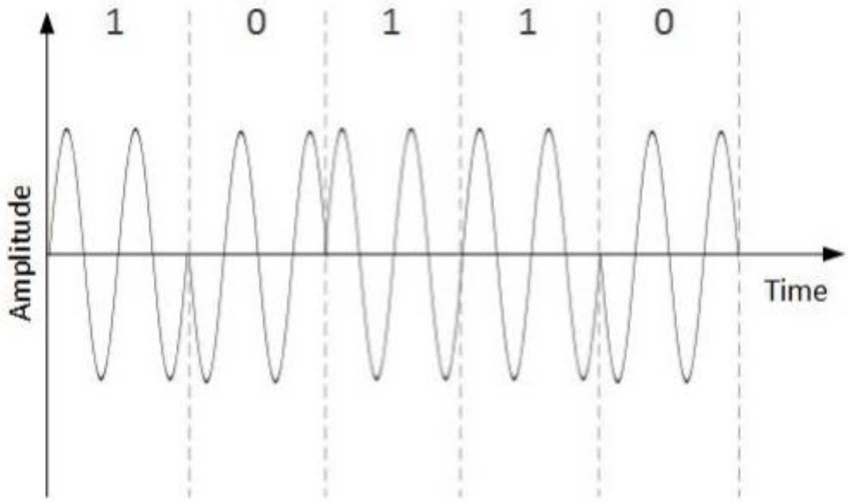
In this conversion technique, the frequency of the analog carrier signal is modified to reflect binary data.



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.



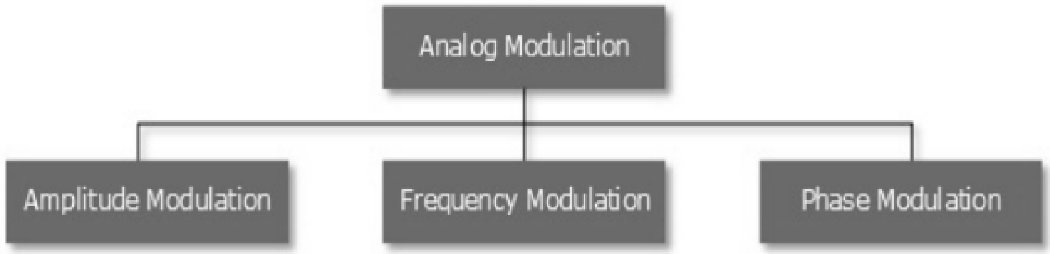
When a new binary symbol is encountered, the phase of the signal is altered. Amplitude and frequency of the original carrier signal is kept intact.

Quadrature Phase Shift Keying

QPSK alters the phase to reflect two 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.

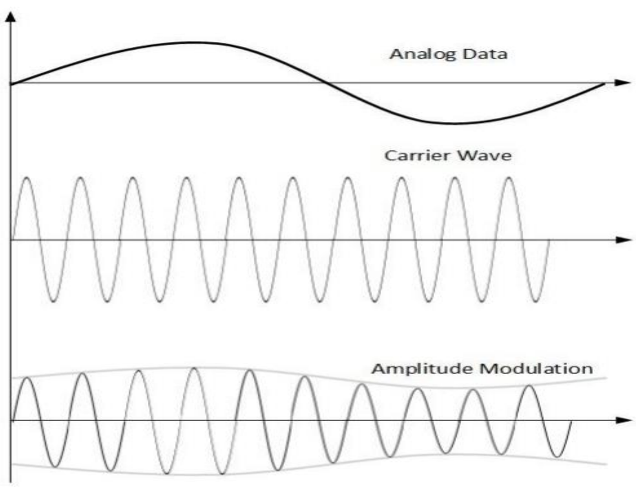
Analog-to-Analog Conversion

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



Amplitude Modulation

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

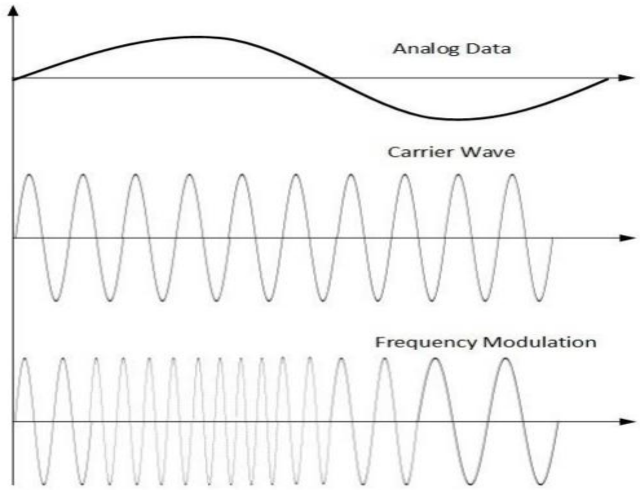


Amplitude modulation is implemented by means of a multiplier. The amplitude of modulating signal (analog data) is multiplied by the amplitude of carrier frequency, which then reflects analog data.

The frequency and phase of carrier signal remain unchanged.

Frequency Modulation

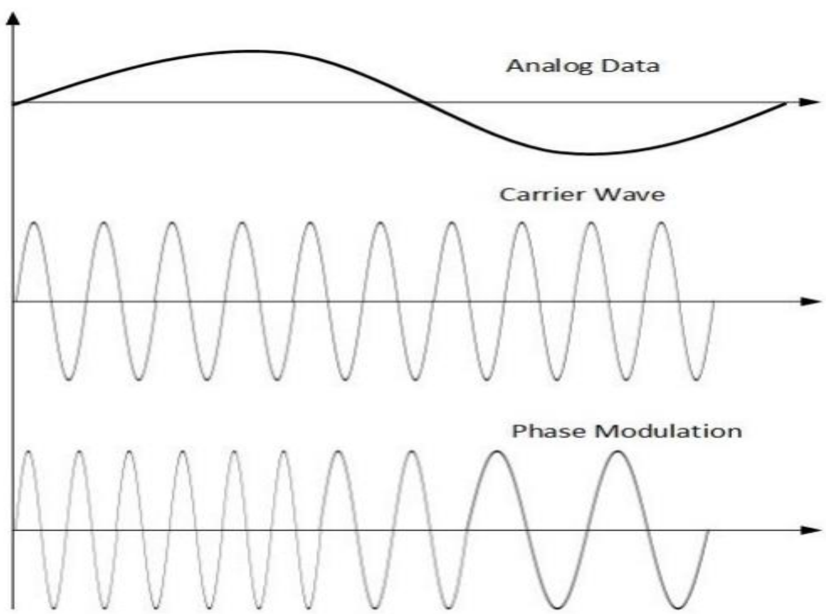
In this modulation technique, the frequency of the carrier signal is modified to reflect the change in the voltage levels of the modulating signal (analog data).



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.



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

LEARNING-ASSESSMENT

A. From the pool of words below, choose the appropriate answer and write it on the space provided.

AM and FM *TV broadcasting* *Cable television* *Facsimile*

Wireless Remote Finding Services *Control Paging Services* *Navigation and Direction*

Telemetry *Radio Astronomy* *Music Services* *Telephones*

Two-way radio *Radar* *Sonar* *LAN*

Citizen Band

SIMPLEX	**DUPLEX** **(Half and Full-Duplex)**

B. List down what are asked for each of the following.

Advantages of Digital Signal over Analog Signal

1.
2.
3.
4.
5.

Disadvantages of Digital Signal

6.
7.
8.
9.
10.

C. Write T if the statement is TRUE and F if otherwise.

1. Data can be sent either in serial format or in parallel format.
2. For practical reasons, virtually all data communications is done in serial format.
3. The first binary code was invented in 1914.
4. A "mark" is the same as a binary 1.
5. Synchronous transmission is much more efficient than asynchronous transmission.
6. In synchronous transmission, the data stream is used to "lock" the receiver's clock onto the transmitter's clock.
7. Due to recent advances in high speed communication networks, the information lag, or the time it takes for information to be disseminated around the world, has been significantly shortened.
8. Protocols are rules that govern a communication exchange.
9. Data communication is the transfer of data from one device to another via some form of transmission medium.
10. A data communication system must transmit data to the correct destination in an accurate and timely manner.
11. Collaborative processing provides for many computers and users to interact on a task either synchronously or asynchronously.

12. Standards are basic, insignificant rules that standards bodies create for strictly intellectual and not practical reasons.
13. An asynchronous frame begins with the start bit.
14. An asynchronous frame ends with the stop bit.
15. At the end of an asynchronous frame, the line will be at the binary 1 level.

***D.* Instruction: Choose the letter of the correct answer and encircle.**

1. In practical terms, parallel data transmission is sent:

a. over short distances only
b. over any distance
c. usually over long distances
d. usually over a coaxial cable

2. Digital data that is not being used to carry characters is called:

a. FIGS data
b. numerical data
c. binary data
d. all of the above

3. The international organization for standardization. It creates the sets of rules and standards for graphics, document exchange, and related technologies. Responsible for endorsing and coordinating the work of the other standards organizations.

a. ANSI
b. ISO
c. OSI
d. IEEE

4. What is the transmission mode between the DCE and DTE?

a. Parallel transmission
b. Serial transmission
c. Both serial and parallel
d. None of the above

5. The information to be communicated in a data communications system is the _______.

b. Medium
c. Protocol
d. Message
e. Transmission

6. Which agency developed standards for physical connection interfaces and electronic signaling specifications?
a. ISO
b. ITU-T
c. ANSI
d. EIA

7. Which organization has authority over interstate and international commerce in the communications field?
a. FCC
b. IEEE
c. ITU-T
d. ISOC
8. The _______ is the physical path over which a message travels.
a. Protocol
b. Signal
c. Medium
d. All the above

9. In _______ transmission, the channel capacity is shared by both communicating devices at all times.
a. simplex
b. half-duplex
c. full-duplex
d. half-simplex

10. Data flow between two devices can occur in a _______ way.
a. simplex
b. half-duplex

c. full-duplex
d. all of the above

Organization Standards of Data Communications

11.
12.
13.
14.
15.

Reasons for Standardization

16.
17.
18.
19.
20.

A.

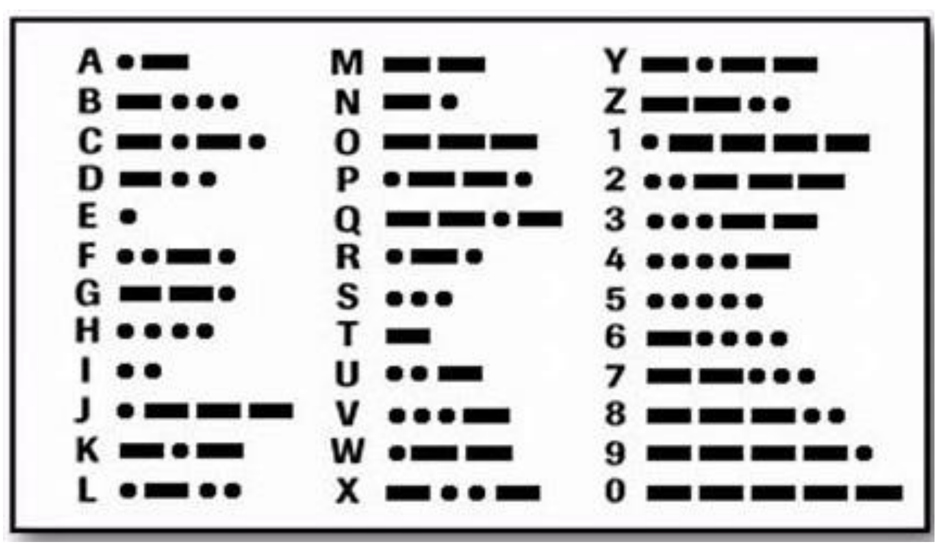
DATA COMMUNICATION CODES

DATA COMMUNICATION CODES

Data communications codes are often used to represent characters and symbols, such as letters, numbers, digits and punctuation marks. Therefore, data communications codes are also called character codes, symbol codes, character language, character sets.

BASIC CODES

1. **MORSE CODE**
   - ➢ a character encoding scheme used in telecommunication that encodes text characters as standardized sequences of two different signal durations called dots and dashes or dits and dash. Morse code is named for Samuel F. B. Morse, an inventor of the telegraph.



Key elements of the code

• The length of a dot is one unit.

• A dash is three units.

• The space between parts of the same letter is one unit.

• The space between letters is three units.

• The space between words is seven units.

Sending the code

Make sure the letters and dots/dashes are clearly written out in front of the person before they start the first letter. Allow clear pauses between each letter (three units) and word (seven units). A unit is a count of one in your head.

Receiving the code

Make sure every sound you hear is written down as a dot/dash and all pauses are written down. After the message has finished, translate the dots/dashes into letters or numbers

2. BAUDOT CODE

Sometimes called Telex code. The first FIXED LENGTH CHARACTER CODE develop for machines rather than for people. Thomas Murray a French postal engineer developed the baudot code in 1875. Named the code after EMILE BAUDOT- an early pioneer in telegraph printing. The Baudot Code (Pronounced ***baw-dough)*** . Uses 5 bits to represent character

Número de orden	Grupo de bits	Grupo de letras	Grupo de figuras
01	00011	A	-
02	11001	B	?
03	01110	C	:
04	01001	D	$
05	00001	E	3
06	01101	F	!
07	11010	G	&
08	10100	H	#
09	00110	I	8
10	01011	J	' o timbre
11	01111	K	(
12	10010	L	)
13	11100	M	.
14	01100	N	,
15	11000	O	9
16	10110	P	0
17	10111	Q	1
18	01010	R	4
19	00101	S	timbre o '
20	10000	T	5
21	00111	U	7
22	11110	V	; o =
23	10011	W	2
24	11101	X	/
25	10101	Y	6
26	10001	Z	+ o ”
27	01000	CR	retorno de carro
28	00010	LF	avance de línea
29	11111	LTRS	cambio a letras
30	11011	FIGS	cambio a figuras
31	00100	SP	espacio
32	00000	BLK	blanco

Example:

BAUDOT CIPHERED BINARY TEXT

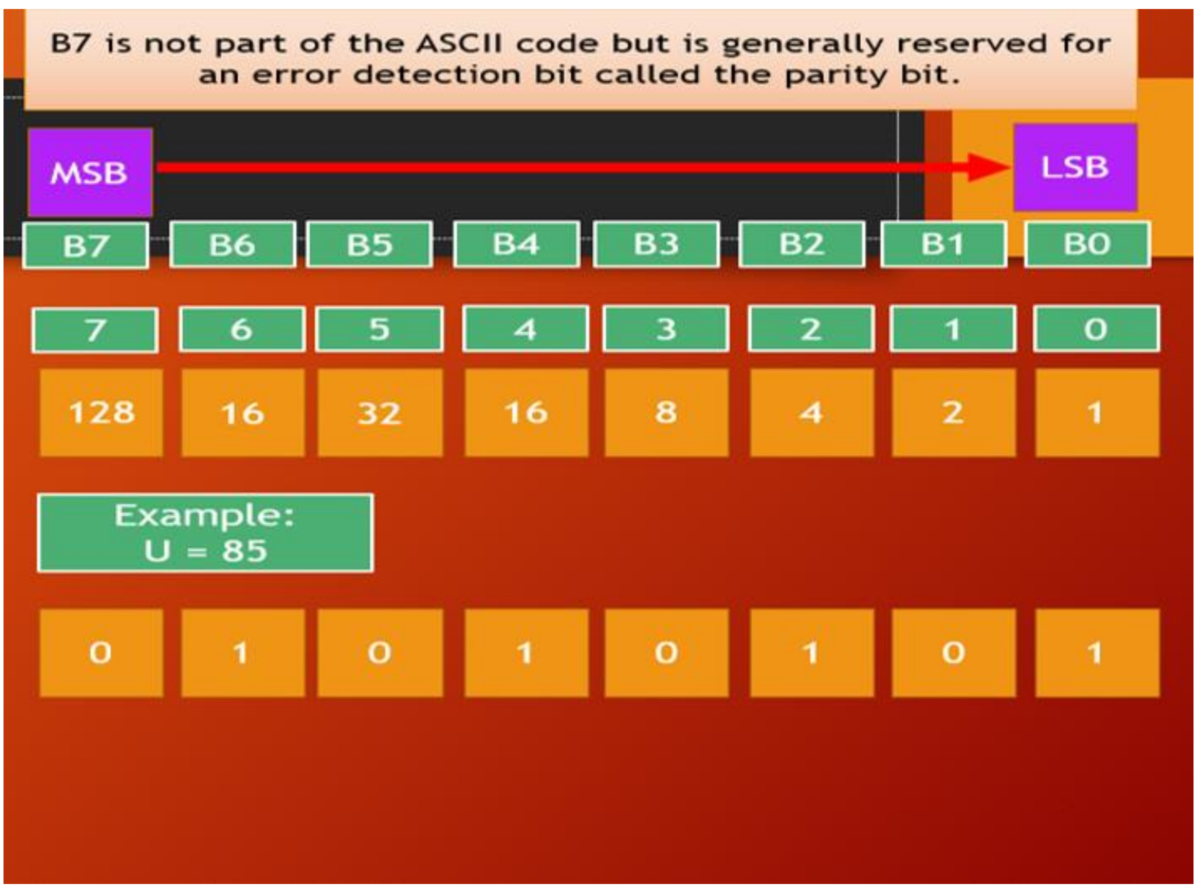
01001 01110 11000 01001 00001 00100 11001 00011 00111 01001 11000 10000 11011 01101

DECRYPTED BAUDOT CODE

dCode Baudot

3. ASCII CODES

- AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE
- 128 specified characters OR 2 raised to 7
- 7 bit binary
- A numbers from 0 to 9
- A letters from a to z and A to Z
- Known as ASCII-63 was adopted in the US in 1963 to standardize data communications code in America.



ASCII – Binary Character Table

Letter	ASCII Code	Binary	Letter	ASCII Code	Binary
a	097	01100001	A	065	01000001
b	098	01100010	B	066	01000010
c	099	01100011	C	067	01000011
d	100	01100100	D	068	01000100
e	101	01100101	E	069	01000101
f	102	01100110	F	070	01000110
g	103	01100111	G	071	01000111
h	104	01101000	H	072	01001000
i	105	01101001	I	073	01001001
j	106	01101010	J	074	01001010
k	107	01101011	K	075	01001011
l	108	01101100	L	076	01001100
m	109	01101101	M	077	01001101
n	110	01101110	N	078	01001110
o	111	01101111	O	079	01001111
p	112	01110000	P	080	01010000
q	113	01110001	Q	081	01010001
r	114	01110010	R	082	01010010
s	115	01110011	S	083	01010011
t	116	01110100	T	084	01010100
u	117	01110101	U	085	01010101
v	118	01110110	V	086	01010110
w	119	01110111	W	087	01010111
x	120	01111000	X	088	01011000
y	121	01111001	Y	089	01011001
z	122	01111010	Z	090	01011010

4. EBCDIC

- True 8 bit character set or coding scheme
- Representing 2 raised 8 or 256 alphanumeric and special character
- Develop by IBM in 1962

Dec	Bin	Hex	Char	Dec	Bin	Hex	Char	Dec	Bin	Hex	Char	Dec	Bin	Hex	Char
0	0000 0000	00	[NUL]	32	0010 0000	20	space	64	0100 0000	40	@	96	0110 0000	60	`
1	0000 0001	01	[SOH]	33	0010 0001	21	!	65	0100 0001	41	A	97	0110 0001	61	a
2	0000 0010	02	[STX]	34	0010 0010	22	"	66	0100 0010	42	B	98	0110 0010	62	b
3	0000 0011	03	[ETX]	35	0010 0011	23	#	67	0100 0011	43	C	99	0110 0011	63	c
4	0000 0100	04	[EOT]	36	0010 0100	24	$	68	0100 0100	44	D	100	0110 0100	64	d
5	0000 0101	05	[ENQ]	37	0010 0101	25	%	69	0100 0101	45	E	101	0110 0101	65	e
6	0000 0110	06	[ACK]	38	0010 0110	26	&	70	0100 0110	46	F	102	0110 0110	66	f
7	0000 0111	07	[BEL]	39	0010 0111	27	'	71	0100 0111	47	G	103	0110 0111	67	g
8	0000 1000	08	[BS]	40	0010 1000	28	(	72	0100 1000	48	H	104	0110 1000	68	h
9	0000 1001	09	[TAB]	41	0010 1001	29	)	73	0100 1001	49	I	105	0110 1001	69	i
10	0000 1010	0A	[LF]	42	0010 1010	2A	*	74	0100 1010	4A	J	106	0110 1010	6A	j
11	0000 1011	0B	[VT]	43	0010 1011	2B	+	75	0100 1011	4B	K	107	0110 1011	6B	k
12	0000 1100	0C	[FF]	44	0010 1100	2C	,	76	0100 1100	4C	L	108	0110 1100	6C	l
13	0000 1101	0D	[CR]	45	0010 1101	2D	−	77	0100 1101	4D	M	109	0110 1101	6D	m
14	0000 1110	0E	[SO]	46	0010 1110	2E	.	78	0100 1110	4E	N	110	0110 1110	6E	n
15	0000 1111	0F	[SI]	47	0010 1111	2F	/	79	0100 1111	4F	O	111	0110 1111	6F	o
16	0001 0000	10	[DLE]	48	0011 0000	30	0	80	0101 0000	50	P	112	0111 0000	70	p
17	0001 0001	11	[DC1]	49	0011 0001	31	1	81	0101 0001	51	Q	113	0111 0001	71	q
18	0001 0010	12	[DC2]	50	0011 0010	32	2	82	0101 0010	52	R	114	0111 0010	72	r
19	0001 0011	13	[DC3]	51	0011 0011	33	3	83	0101 0011	53	S	115	0111 0011	73	s
20	0001 0100	14	[DC4]	52	0011 0100	34	4	84	0101 0100	54	T	116	0111 0100	74	t
21	0001 0101	15	[NAK]	53	0011 0101	35	5	85	0101 0101	55	U	117	0111 0101	75	u
22	0001 0110	16	[SYN]	54	0011 0110	36	6	86	0101 0110	56	V	118	0111 0110	76	v
23	0001 0111	17	[ETB]	55	0011 0111	37	7	87	0101 0111	57	W	119	0111 0111	77	w
24	0001 1000	18	[CAN]	56	0011 1000	38	8	88	0101 1000	58	X	120	0111 1000	78	x
25	0001 1001	19	[EM]	57	0011 1001	39	9	89	0101 1001	59	Y	121	0111 1001	79	y
26	0001 1010	1A	[SUB]	58	0011 1010	3A	:	90	0101 1010	5A	Z	122	0111 1010	7A	z
27	0001 1011	1B	[ESC]	59	0011 1011	3B	;	91	0101 1011	5B	[	123	0111 1011	7B	{
28	0001 1100	1C	[FS]	60	0011 1100	3C	<	92	0101 1100	5C	\	124	0111 1100	7C	|
29	0001 1101	1D	[GS]	61	0011 1101	3D	=	93	0101 1101	5D	]	125	0111 1101	7D	}
30	0001 1110	1E	[RS]	62	0011 1110	3E	>	94	0101 1110	5E	^	126	0111 1110	7E	~
31	0001 1111	1F	[US]	63	0011 1111	3F	?	95	0101 1111	5F	_	127	0111 1111	7F	[DEL]

LEARNING-ASSESSMENT

DATA COMMUNICATION CODES CONVERSION/TRANSLATION

a. MORSE CODE
Instruction: Convert the following text using MORSE Code.

1. SMS

2. BANDWIDTH101

3. 101DATA

4. BINARY

5. COMMUNICATION

6. CALL999

7. DATA RATE

b. BAUDOT CODE
Instruction: Use Baudot Code to translate the following text to BINARY.

TELECOMMUNICATIONS

STANDARD BODY ORGANIZATION

c. ASCII CODE
Instruction: Use ASCII Code to translate the following text to BINARY.

ProTOcOLs

STaNdARDS

d. EBCDIC CODE

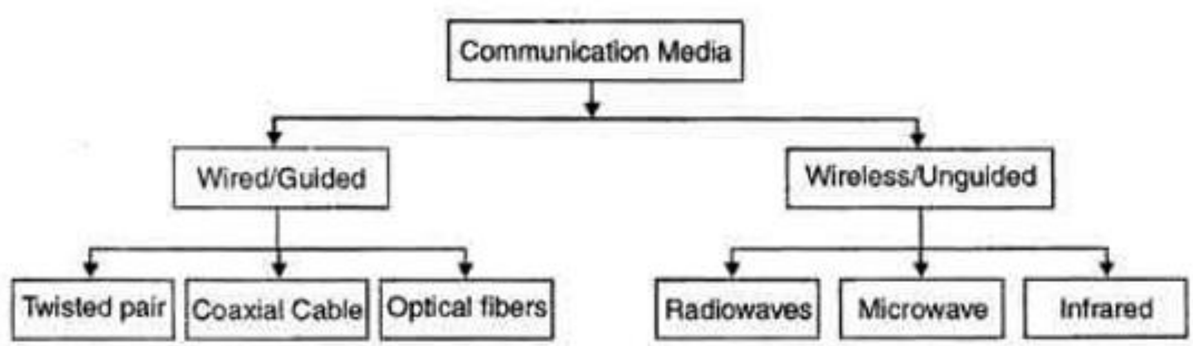
Instruction: Use ASCII Code to translate the following text to BINARY.

//COEN3193 #DATA ?COMMUNICATION

DATA COMMUNICATION CONNECTION MEDIA

DATA COMMUNICATION CONNECTION MEDIA

Transmission media is a pathway that carries the information from sender to receiver. We use different types of cables or waves to transmit data. Data is transmitted normally through electrical or electromagnetic signals. An electrical signal is in the form of current.



The data transmission capabilities of various Medias vary differently upon:

Bandwidth. It refers to the data carrying capacity of a channel or medium. Higher bandwidth communication channels support higher data rates.

Noise Absorption. It refers to the susceptibility of the media to external electrical noise that can cause distortion of data signal.

Attenuation. It refers to loss of energy as signal propagates outwards. The amount of energy lost depends on frequency. Radiations and physical characteristics of media contribute to attenuation.

TRANSMISSION CHANNEL PARAMETERS

Some parameters are required in description of transmission channel. Some of the parameter is discussed below.

Bandwidth: The range of frequencies contained in a composite signal is its bandwidth. The bandwidth is normally a difference between two numbers. For example, if a composite signal contains frequencies between 2000 and 6000, its bandwidth is 6000 - 2000, or 4000. The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal. The bandwidth determines the channel capacity.

Bit Rate: Most digital signals are non-periodic, and thus period and frequency are not appropriate characteristics. Bit rate is used to describe digital signals. The bit rate is the number of bits sent in 1s, expressed in bits per second (bps).

Bit Length: The bit length is the distance one bit occupies on the transmission medium. Bit length=propagation speed x bit duration

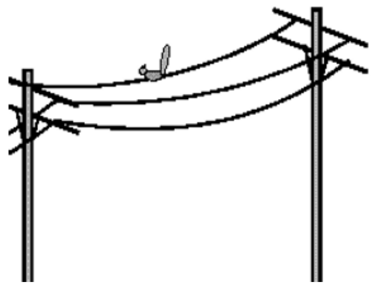
Data Rate Limits: one of the most important consideration in data communications is how fast we can send data, in bits per second over a channel. Data rate depends on three factors: a. The bandwidth available b. The level of the signals we use c. The quality of the channel (the level of noise)

Noisy Channel: In reality, we cannot have a noiseless channel; the channel is always noisy. In 1944, Claude Shannon introduced a formula, called the Shannon capacity, to determine the theoretical highest data rate for a noisy channel:

Guided Transmission Media

Wired or Guided Media or Bound Transmission Media: Bound transmission media are the cables that are tangible or have physical existence and are limited by the physical geography. Popular bound transmission media in use are twisted pair cable, co-axial cable and fiber optical cable. Each of them has its own characteristics like transmission speed, effect of noise, physical appearance, cost etc. Open Wire is traditionally used to describe the electrical wire strung along power poles. There is a single wire strung between poles. No shielding or protection from noise interference is used. We are going to extend the traditional definition of Open Wire to include any data signal path without shielding or protection from noise interference. This can include multiconductor cables or single wires. This media is susceptible to a large degree of noise and interference and consequently not acceptable for data transmission except for short distances under 20 ft.

OPEN WIRE



A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in below figure. One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference. The receiver uses the difference between the two. In addition to the signal sent by the sender on one of the wires, interference (noise) and crosstalk may affect both wires and create unwanted signals. Each pair would consist of a wire used for the +ve data signal and a wire used for the ve data signal.

OPTICAL FIBER:

Optical fiber is a cable that accepts and transports signals in the form of light. Optical fiber consists of thin glass fiber that can carry information at frequencies in the visible light spectrum.

ADVANTAGES

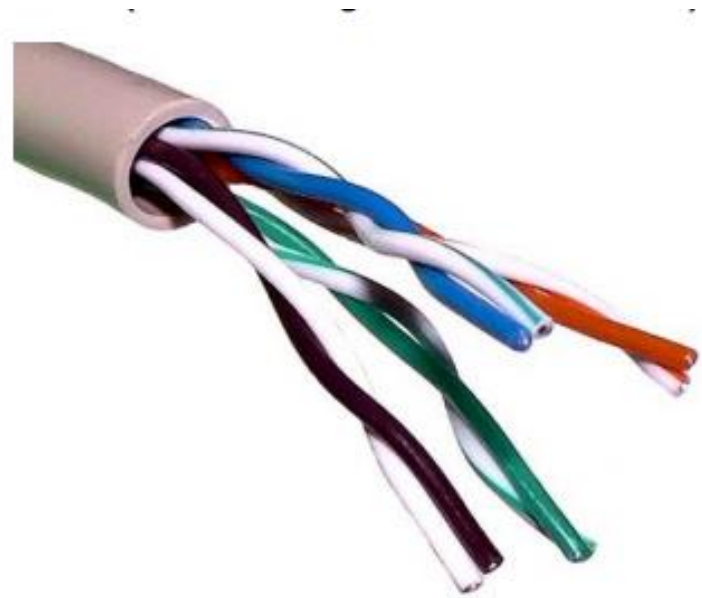
1. Small size and light weight
2. Easy availability and low cost
3. No electrical or electromagnetic interference
4. Bandwidth
5. No cross talk inside the optical fiber cable

Disadvantages of optical fiber cable include the following.

1. Physical vibration will show up as signal noise.
2. Limited physical arc of cable. Bend it too much & it will break.
3. Difficult to splice

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.



There are two types of twisted pair cables:

- 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, Cat5, Cat-5e, and Cat-6 cables are mostly used. UTP cables are connected by RJ45 connectors.

Coaxial Cable

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

Because of its structure, the coax cable is capable of carrying high frequency signals than that of twisted pair cable. 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.

Unguided Transmission Media

In unguided Transmission Media data signals flows through the air. Wireless or Unguided Media or Unbound Transmission Media: Unbound transmission media are the ways of transmitting data without using any cables. These media are not bounded by physical geography. This type of transmission is called Wireless communication.

Wireless Signal Propagation

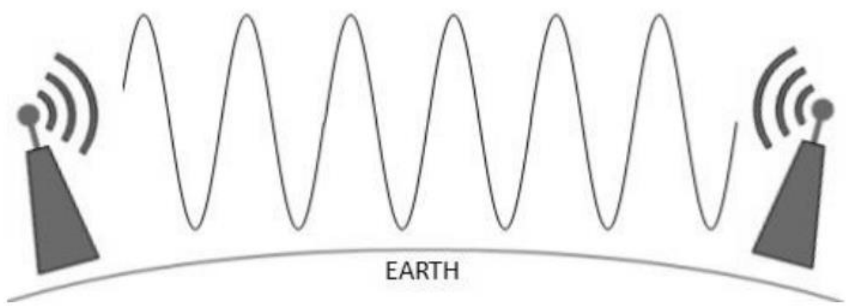
Wireless signals travel or propagated in three ways:

- GROUNDWAVE PROPAGATION
- SKYWAVE PROPAGTION
- SPACE WAVE PROPAGATION
- GROUNDWAVE PROPAGATION:

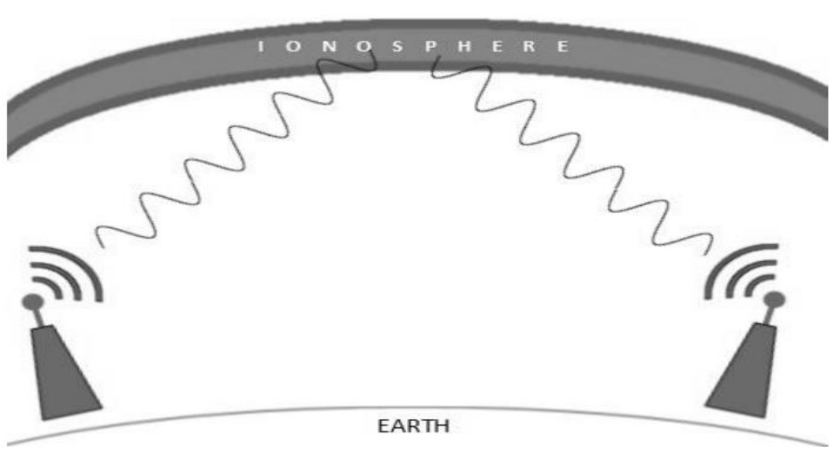
- Ground Wave Propagation follows the curvature of the Earth. Ground Waves have carrier frequencies up to 2MHz. AM radio is an example of Ground Wave Propagation.

Radio Transmission

Radio frequency is easier to generate and because of its large wavelength it can penetrate through walls and structures alike. Radio waves can have wavelength from 1mm – 100,000km and have frequency ranging from 3Hz (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 can travel in straight line and bounce back. The power of low frequency waves decreases sharply as they cover long distance. High frequency radio waves have more power. Lower frequencies such as VLF, LF, MF bands can travel on the ground up to 1000 kilometers, over the earth's surface.

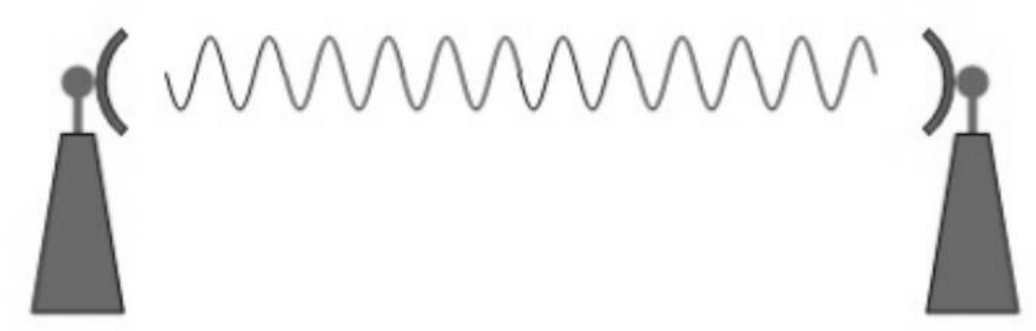


Radio waves of high frequencies are prone to be absorbed by rain and other obstacles. They use Ionosphere of earth atmosphere. High frequency radio waves such as HF and VHF bands are spread upwards. When they reach Ionosphere, they are refracted back to the earth.



Microwave Transmission

Electromagnetic waves above 100MHz 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 1mm – 1meter and frequency ranging from 300MHz to 300GHz.



Microwave antennas concentrate the waves making a beam of it. As shown in picture above, multiple antennas can be aligned to reach farther. Microwaves have higher frequencies and do not penetrate wall like obstacles. Microwave transmission depends highly upon the weather conditions and the frequency it is using.

Infrared Transmission

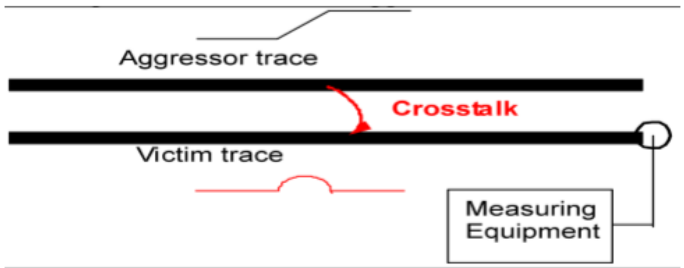
Infrared wave lies in between visible light spectrum and microwaves. It has wavelength of 700nm to 1mm and frequency ranges from 300GHz to 430THz. Infrared wave is used for very short range communication purposes such as television and its remote. Infrared travels in a straight line hence it is directional by nature. Because of high frequency range, Infrared cannot cross wall-like obstacles.

TRANSMISSION CHANNEL PARAMETERS

Data is transmitted through transmission medium which are not perfect. The imperfection causes signal impairment. Some of the transmission media/impairment problems are:

CROSSTALK:

Crosstalk is when one line induces a signal into another line. In voice communications, we often hear this as another conversation going on in the background. In digital communication, this can cause severe disruption of the data transfer.



CROSSTALK IMPAIREMANENT

ECHO AND SIGNAL RETURN:

All media have a preferred termination condition for perfect transfer of signal power. The signal arriving at the end of a transmission line should be fully absorbed otherwise it will be reflected back down the line to the sender and appear as an Echo.

NOISE :

Noise is any unwanted signal that is mixed or combined with the original signal during transmission. Due to noise the original signal is altered and signal received is not same as the one sent.

A data communication circuit can be a short as a few feet or as long as several thousand miles, and the transmission medium can be as simple as a pair of wires or as complex as a microwave, satellite, or optical fiber communication system.

LEARNING-ASSESSMENT

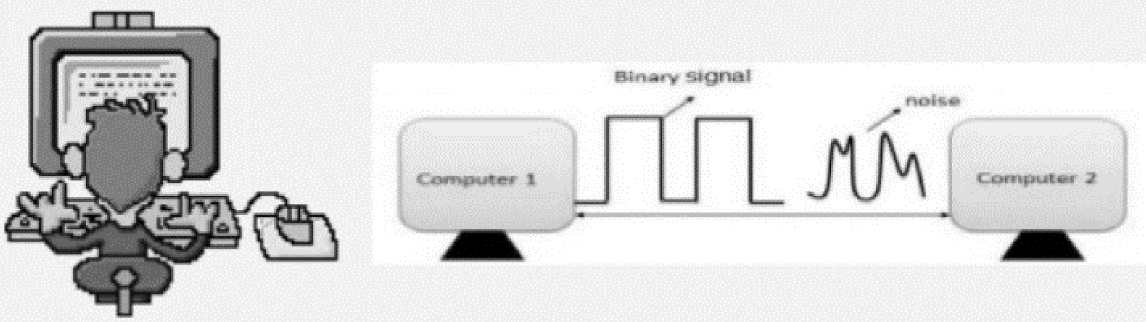
1. Briefly explain the difference between guided transmission media and unguided transmission media.

2. Describe an open-wire transmission line.

DATA ERROR CONTROL

WHAT IS AN ERROR?

Ans: Error is a condition when the output information does not match with the input information. During transmission, digital signals suffer from noise that ca introduce errors in the binary bits travelling from one system to other.
That means a 0 bit may change to **1** or a **1** bit may change to 0.



TRANSMISSION ERRORS are caused by electrical interference from natural sources, such as lighting, as well as from man-made sources, such as motors, generators, power lines and flourecents lights.

Error Detection: Error detection is the detection of errors caused by noise or other impairments during transmission from the transmitter to the receiver.

Error correction: Error correction is the detection of errors and reconstruction of the original, error-free data.

DATA COMMUNICATION ERRORS can be generally classified as

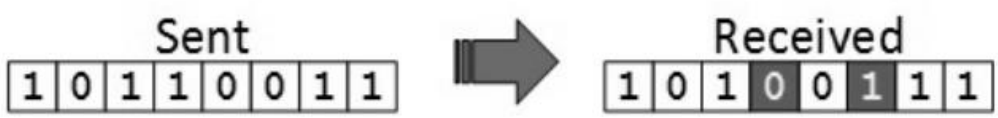
SINGLE BIT ERROR

It means only one bit or data unit is changed from 0 to 1 and or 1 to 0.

Single bit error can happen in parallel transmission where all data bits are transmitted using separate wire

MULTIPLE BIT ERROR

It means that two or more non- consecutive bits in a data unit have changed form 1 to 0 or 0 to 1



BURST BIT ERROR

It means that two or more consecutive bits in a data unit have changed form 1 to 0 or 0 to 1

Frame contains more than1 consecutive bits corrupted.

Error control mechanism may involve two possible ways:

- Error detection
- Error correction

DATA ERROR DETECTION

Is the process of monitoring data transmission and determining when errors have occurred.

Error detection techniques neither correct nor identify which bits are in error – they indicate only when an error has occurred. Errors in the received frames are detected by means of Parity Check and Cyclic Redundancy Check (CRC). In both cases, few extra bits are sent along with actual data to confirm that bits received at other end are same as they were sent. If the counter-check at receiver end fails, the bits are considered corrupted.

REDUNDANCY CHECKING

Is the main technique to detect errors

It is also a group of bits adding to end of data unit

VERTICAL REDUNDANCY CHECKING

Is probably the simplest error-detection scheme and is generally referred to as character parity or simple parity

With character parity, each character has its own error detection bit called PARITY BIT

Since the parity bit is not actually part of the character , it is considered a redundant bit.

VERTICAL REDUNDANCY CHECKING

Append a single bit at the end of data block such that the number of ones is even

→Even Parity(odd parity is similar)

0110011→0110011**0**

0110001 → 0110001**1**

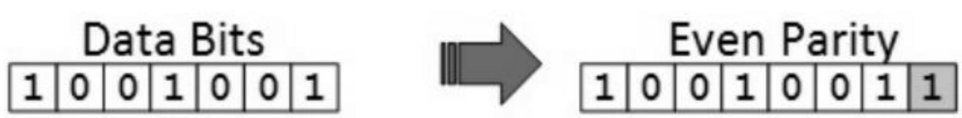
VRC is also known as **Parity Check**

Performance:

Detects all odd-number errors in a data block

Parity Check

One extra bit is sent along with the original bits to make number of 1s either even in case of even parity, or odd in case of odd parity. The sender while creating a frame counts the number of 1s in it. For example, if even parity is used and number of 1s is even then one bit with value 0 is added. This way number of 1s remains even. If the number of 1s is odd, to make it even a bit with value 1 is added.



The receiver simply counts the number of 1s in a frame. If the count of 1s is even and even parity is used, the frame is considered to be not-corrupted and is accepted. If the count of 1s is odd and odd parity is used, the frame is still not corrupted. If a single bit flips in transit, the receiver can detect it by counting the number of 1s. But when more than one bits are erroneous, then it is very hard for the receiver to detect the error.

EXAMPLE:

DETERMINE THE ODD PARITY AND EVEN PARITY OF THE ASCII CHARACTER **R.**

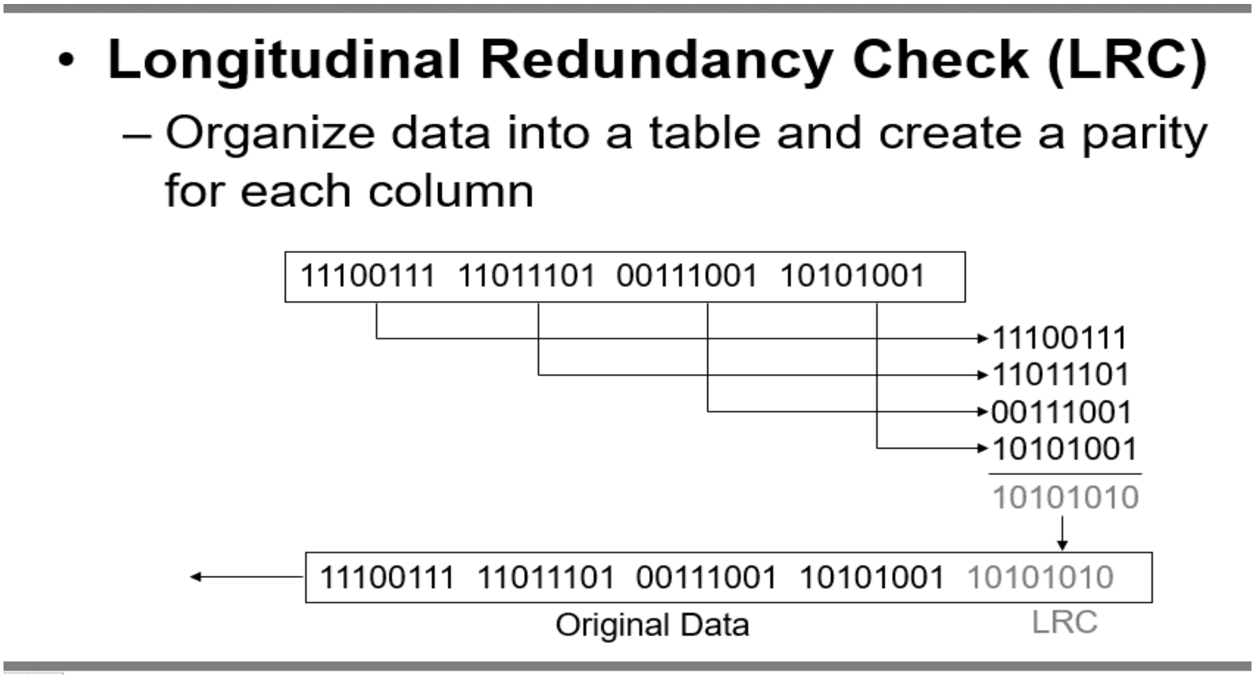
ANSWER:

EVEN PARITY **: 0**1010010

ODD PARITY **: 1**1010010

LONGITUDINAL REDUNDANCY CHECKING

Is an error detection method for determining the correctness of transmitted and stored data



LRC verifies the accuracy of stored and transmitted data using parity bits. It is redundancy check applied to a parallel group of bits streams. The data to be transmitted is divided into transmission blocks into which additional data is inserted. The term is also known as horizontal redundancy check.

Determine the VRC's and LRC for the following ASCII-encoded message: THE CAT. Use odd parity for VRC's and even parity for the LRC

E R R O R D E T E C T I O N									LRC
Character		T	H	E	sp	C	A	T	/
Decimal									
Hexadecimal									
ASCII code	b0								
	b1								
	b2								
	b3								
	b4								
	b5								
	b6								
Parity bit(VRC)	b7								

CHECKSUM

A simple type of redundancy check that is used to detect errors in data. Errors frequently occur in data when it is written to a disk, transmitted across a network or otherwise manipulated. Errors are typically very small, for example,a single incorrect bit, but even such a small errors can greatly affect the quality of data, and even make it useless.

EXAMPLE:

If the data unit to be transmitted is 10101001 00111001, the following procedure is used at Sender site and Receiver site.

SOLUTION:

Sender side:

10101001 subunit 1

00111001 subunit 2

11100010 sum (using 1s complement)

00011101 checksum (complement of sum)

Data transmitted to Receiver is –

Receiver Site :

10101001 subunit 1

00111001 subunit 2

00011101 checksum

11111111 sum

00000000 sum's complement

Result is zero, it means no error.

Advantage :

The checksum detects all the errors involving an odd number of bits as well as the error involving an even number of bits.

Disadvantage :

The main problem is that the error goes undetected if one or more bits of a subunit is damaged and the corresponding bit or bits of a subunit are damaged and the corresponding bit or bits of opposite value in second subunit are also damaged. This is because the sum of those columns remains unchanged.

Example

If the data transmitted along with checksum is 10101001 00111001 00011101. But the data received at destination is **0**0101001 **1**0111001 00011101.

Receiver Site :

00101001 1st bit of subunit 1 is damaged
10111001 1st bit of subunit 2 is damaged
00011101 checksum
11111111 sum
00000000 Ok 1's complement

CYCLIC REDUNDANCY CHECKING

The most reliable redundancy checking technique for error detection. With CRC, approximately 99.999% of all transmission errors are detected.

Mathematically, CRC can be expressed as $\frac{\boldsymbol{G(x)}}{\boldsymbol{P(x)}} = \boldsymbol{Q(x)} + \boldsymbol{R(x)}$

Where G(x) = message polynomial

P(x) = generator polynomial

Q(x) = quotient

R(x) = remainder

The generator polynomial for CRC-16 is

$$P(x)= x^{16} + x^{15} + x^2 + x^0$$

The number of bits in the CRC code is equal to the highest exponent of the generating polynomial. The exponents identify the bit position in the generating polynomial that contain a logic 1. Therefore, for CRC-16 , $b_{16} + b_{15} + b_2$ and b_0 are logic 1s, and all other bits in a data are logic 0s.

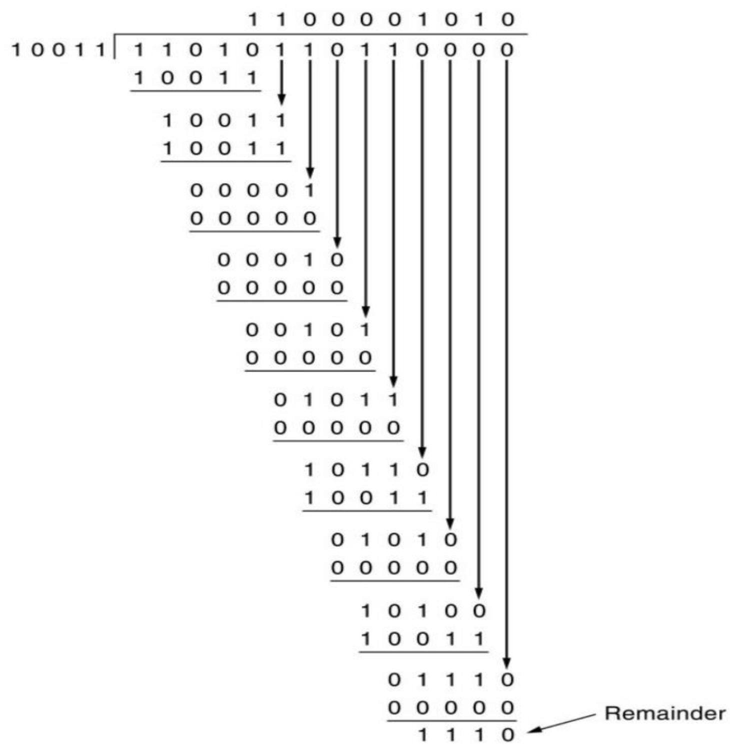
Sample Problem;

110011 A bit stream 1101011011 is transmitted using the standard CRC method. The generator polynomial is x^4+x+1. What is the actual bit string transmitted?

Solution

- The generator polynomial G(x) = x^4 + x + 1 is encoded as 10011.
- Clearly, the generator polynomial consists of 5 bits.
- So, a string of 4 zeroes is appended to the bit stream to be transmitted.
- The resulting bit stream is 1101011011**0000**.

Now, the binary division is performed as



From here, CRC = 1110.

Now,

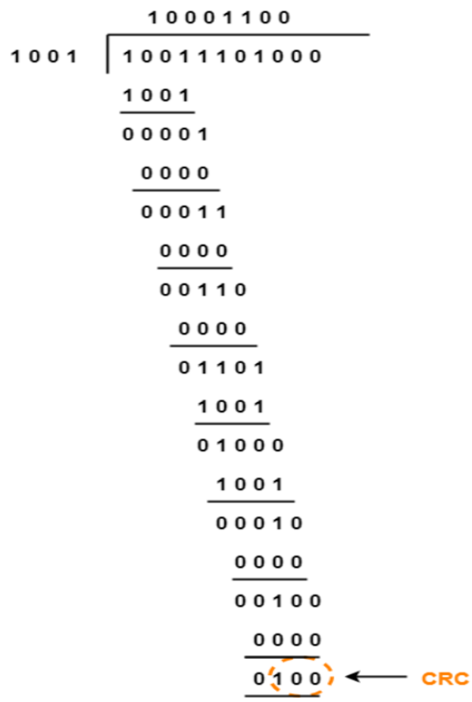
- The code word to be transmitted is obtained by replacing the last 4 zeroes of 1101011011**0000** with the CRC.
- Thus, the code word transmitted to the receiver = 1101011011**1110**.

2. A bit stream 10011101 is transmitted using the standard CRC method. The generator polynomial is x^3+1.

   1. What is the actual bit string transmitted?
   2. Suppose the third bit from the left is inverted during transmission. How will receiver detect this error?

- The generator polynomial $G(x) = x^3 + 1$ is encoded as 1001.
- Clearly, the generator polynomial consists of 4 bits.
- So, a string of 3 zeroes is appended to the bit stream to be transmitted.
- The resulting bit stream is 10011101**000**.

Now, the binary division is performed as



From here, CRC = 100.

Now,

- The code word to be transmitted is obtained by replacing the last 3 zeroes of 10011101**000** with the CRC.
- Thus, the code word transmitted to the receiver = 10011101**100**

LEARNING-ASSESSMENT

1. Determine the VRC's and LRC for the following ASCII-encoded message: DATA COMMUNICATIONS. Use odd parity for VRC's and even parity for the LRC

Character		D	A	T	A	Sp	C	O	M	M	U	N	I	C	A	T	I	O	N	S	
Decimal																					
Hexadecimal																					
ASCII code	b0																				
	b1																				
	b2																				
	b3																				
	b4																				
	b5																				
	b6																				
Parity bit(VRC)	b7																				

2. CHECK SUM REDUNDANCY CHECKING

110101011101010011, 110101011110101111,
111111101101010101, 101101010101011111,
111010011101101011, 100100111110101100

3. CYCLIC REDUNDANCY CHECKING

Data G(x) = 1010101010011101011011010

CRC GENERATOR = 11101

4. For a 25-bit data string of 1110101010111010101011011

a. Determine the number of hamming bits
b. Arbitrarily place the hamming bits into the data string
c. Determine the logic condition of each hamming bit.
d. Assume an arbitrary single-bit error (bit position number 15)
e. Prove that the hamming code will successfully detect the error

DATA ERROR CORRECTION

Although detecting errors is an important aspect in data communications, determining what to do with data that contains errors is another consideration.

Two basic types of error message

1. Lost message
2. Damaged message

Lost message

A lost message is one that never arrives at the destination or one that arrives but is damaged to the extent that it is unrecognizable.

Damaged message

A damaged message is one that is recognized at the destination but it contains one or more transmission errors.

Data communications network designers have developed two basic strategies for handling transmission errors:

ERROR-DETECTING CODES and ERROR CORRECTING CODES.

Error-detecting codes includes enough redundant information with each transmitted message to enable the receiver to determine when an error has occurred.. Parity bits, block and frame check characters , and cyclic redundancy characters are examples of error-detecting codes.Error-correcting codes include sufficient extraneous information along with each message to enable the receiver to determine when an error has occurred and which bit is in error

Two primary methods use for error correction

RETRANSMISSION (Backward Error Correction), as the name implies is when a receive station requests the transmit station to resend a message (or a portion of a message)when the message is received in error.

FORWARD ERROR CORRECTION

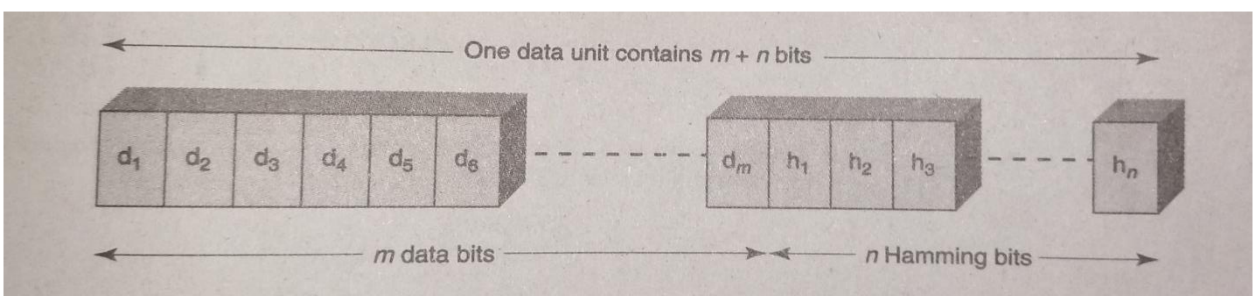
When the receiver detects some error in the data received, it executes errorcorrecting code, which helps it to auto-recover and to correct some kinds of errors. The first one, Backward Error Correction, is simple and can only be efficiently used where retransmitting is not expensive. For example, fiber optics. But in case of wireless transmission retransmitting may cost too much. In the latter case, Forward Error Correction is used. To correct the error in data frame, the receiver must know exactly which bit in the frame is corrupted. To locate the bit in error, redundant bits are used as parity bits for error detection. For example, we take ASCII words (7 bits data), then there could be 8 kind of information we need: first seven bits to tell us which bit is in error and one more bit to tell that there is no error.

Is the only error correction scheme that actually detects and corrects transmission errors when they are received without requiring a retransmission. With FEC, redundant bits are added to the message before transmission. When an error is detected, the redundant bits are used to determine which bits are in error. Limited to only , one , two or three bits errors. The purpose of FEC codes is to eliminate the time wasted for retransmission. Probably the most popular error-correction code is the HAMMING CODE. A mathematician named RICHARD W. HAMMING developed the hamming code while working at BELL TELEPHONE LABORATORIES

HAMMING CODE *is an error correcting code used for correcting transmission errors in synchronous data stream.*

The only stipulation on the placement of the hamming bits is both the sender and receiver must agree on where they are placed.

To calculate the number of redundant hamming bits necessary for a given character length, a relationship between the character bits and hamming bits must established.



The total number of bits in one data unit is m+n.

Hamming bits (sometimes called error bits) are inserted into a character at random locations.

The combination of data bits and hamming bits are called *hamming code.*

The number of hamming bits is determine by the following expression

$2^n \geq m+n+1$

n=number of hamming bits

m=number of bits in each data character

Example:

For a 12-bit data string of 101100010010,

a. Determine the number of hamming bits
b. Position the hamming bits in b17, b13, b9, b8, b4
c. Determine the logic condition of each hamming bit.
d. Assume an arbitrary single-bit error
e. Prove that the hamming code will successfully detect the error

Solution Substituting $m = 12$ into Equation 22-2, the number of Hamming bits is

$$\text{for } n = 4 \qquad 2^4 = 16 \geq 12 + 4 + 1 = 17$$

Because 16 < 17, four Hamming bits are insufficient:

$$\text{for } n = 5 \qquad 2^5 = 32 \geq 12 + 5 + 1 = 18$$

Because 32 > 18, five Hamming bits are sufficient, and a total of 17 bits make up the data stream (12 data plus five Hamming).

Arbitrarily placing five Hamming bits into bit positions 4, 8, 9, 13, and 17 yields

bit position	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	H	1	0	1	H	1	0	0	H	H	0	1	0	H	0	1	0

To determine the logic condition of the Hamming bits, express all bit positions that contain a logic 1 as a five-bit binary number and XOR them together:

Bit position	Binary number
2	00010
6	00110
XOR	00100
12	01100
XOR	01000
14	01110
XOR	00110
16	10000
XOR	10110 = Hamming bits

$$b_{17} = 1, \qquad b_{13} = 0, \qquad b_9 = 1, \qquad b_8 = 1, \qquad b_4 = 0$$

The 17-bit Hamming code is

```
H                       H                         H     H                     H
1     1     0     1     0     1     0     0     1     1     0     1     0     0     0     1     0
```

Assume that during transmission, an error occurs in bit position 14. The received data stream is

$$1\ 1\ 0\ \underbrace{\underline{0}}_{\text{error}}\ 0\ 1\ 0\ 0\ 1\ 1\ 0\ 1\ 0\ 0\ 0\ 1\ 0$$

At the receiver, to determine the bit position in error, extract the Hamming bits and XOR them with the binary code for each data bit position that contains a logic 1:

Bit position	Binary number
Hamming bits	10110
2	00010
XOR	10100
6	00110
XOR	10010
12	01100
XOR	11110
16	10000
XOR	01110 = 14

Therefore, bit position 14 contains an error.

LEARNING-ASESSMENT

1. How many hamming bits are required for a single EBCDIC Character?

2. Determine the hamming Bits for the ASCII character B. Insert the hamming bits in every other bit location starting form left.

3. Determine the hamming Bits for the ASCII character C.(use odd parity and two stop bits). Insert the hamming bits in every other bit location starting at the right.

DATA TERMINAL EQUIPMENT AND DATA COMMUNICATION EQUIPMENT

DATA TERMINAL EQUUPMENT AND DATA COMMUNICATION EQUIPMENT

Data Terminal Equipment – is any equipment that is either a source or destination for digital data. DTE do not generally communicate with each other to do so they need to use DCE to carry out the communication.

DTE DOES NOT NEED TO KNOW HOW THE DATA IS SENT OR RECEIVED; the communication details are left to the DCE.

A Typical example of DTE COMPUTER, PRINTERS, FILE AND APPLICATION SERVERS, DUMB TERMINALS AND ROUTERS.

Data COMMUNICATION Equipment – can be classified as equipment that transmit or receives analogue or digital signals through a network.

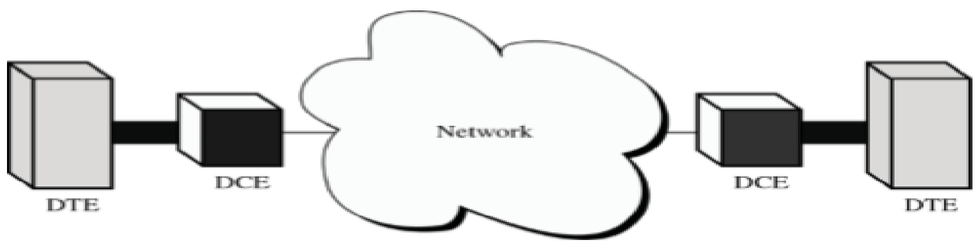
DCE works at the physical layer of the OSI model taking data generated by DTE and converting it into a signal that can be transmitted over a communication link. A common DCE equipment which works as a translator of digital and analogue signals. Other common DCE examples: ISDN adapters, satellite, microwave stations, NIC. Sometimes called DATA CIRCUIT TERMINATING EQUIPMENT.

DTE-DCE INTERFACING

There are 4 basic functional units involved in communication of data:
–A DTE and DCE on one end
–A DTE and DCE on the other end
DTE: Any device that is a source of or destination of digital data
DCE: Any device that transmits/receives signal through network

Development of DTE-DCE Standards

- To define the connection between the DTE-DCE, each standard provides a model for the mechanical, electrical, and the functional characteristics of the connection.
- The EIA and the ITU-T have been involved in developing DTE-DCE interface standards. The ITU-T standards are called the V series and X series. The EIA standards are the following:



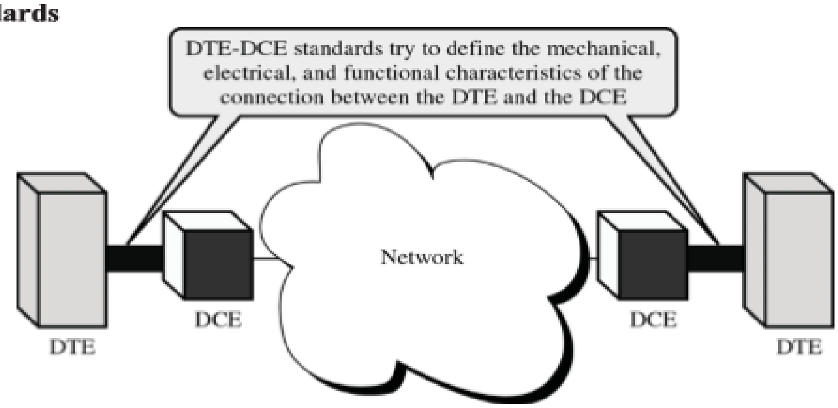
o The DTE generates the data and passes it along with any control information to a DCE

o The DCE converts the signal to a format appropriate to the TX medium and introduces it onto the network link

o When the signal arrives at the receiving end this process is reversed

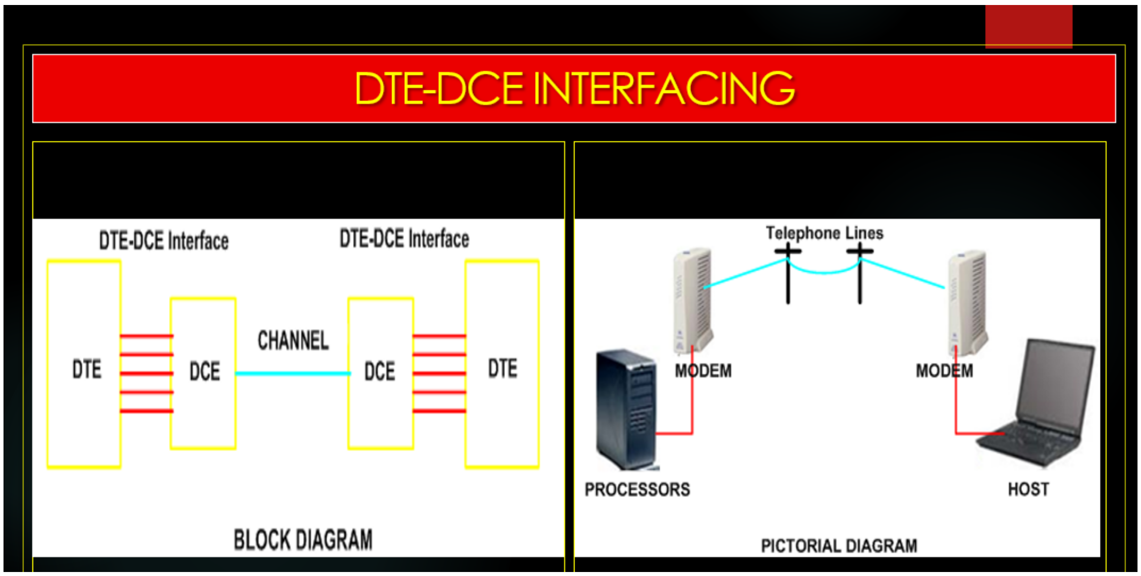
The two DTEs need not be coordinated with each other but they need to be coordinated with their respective DCEs and the DCEs must be coordinated so that data translation occurs w/o loss of integrity

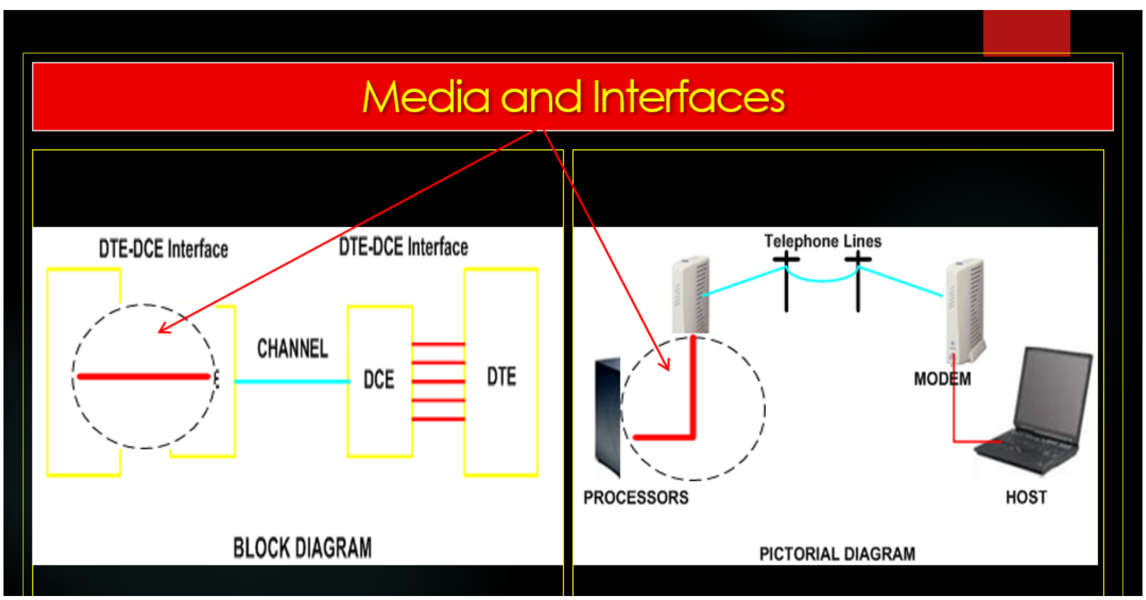
❖ **Standards**

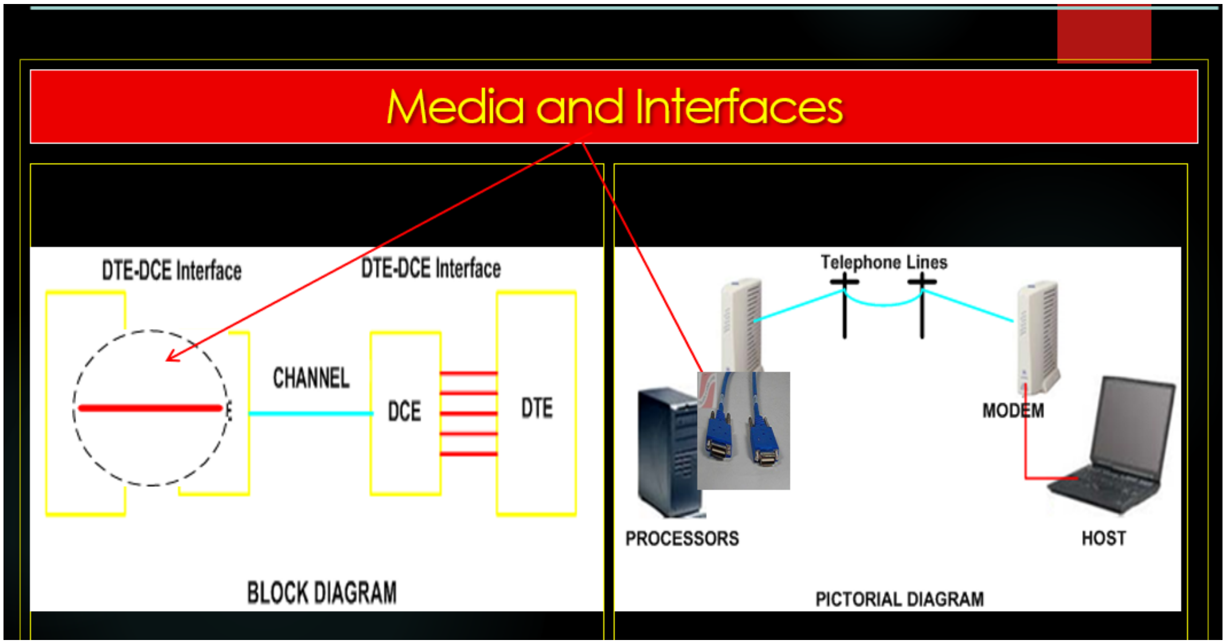


Many standards have been developed to define the connection b/w the DTE and a DCE

- Though the solution differ, each standard provides a model for mechanical, electrical and functional characteristics of the connection
- Electronic Industries Organization (EIA) and ITU-T







EIA-232 Interface

Originally issued in 1962 as the RS-232 (Recommended Standard), the EIA has revised several times, the recent is the EIA-232D, defines not only the type of connectors to be used but also the specific cable and plugs and the functionality of each pin.

Mechanical Specification

Originally issued in 1962 as the RS-232 (Recommended Standard), the EIA has revised several times, the recent is the EIA-232D, defines not only the type of connectors to be used but also the specific cable and plugs and the functionality of each pin.

- Defines the interface as a 25 wire cable with male and female DB-25 pin or receptacles connector attached to either end, at each which is attached to a single wire with a specific function.
- The length of the cable may not exceed 15 meters (50 feet)
- Male connector refers to a plug with each wire in the cable connecting to a pin.
- Female connector refers to a receptacle with each wire in the cable connecting to a metal tube, or sheath.
- DB-25 pins and tubes are arranged in two rows, with 13 on the top and 12 on the bottom.

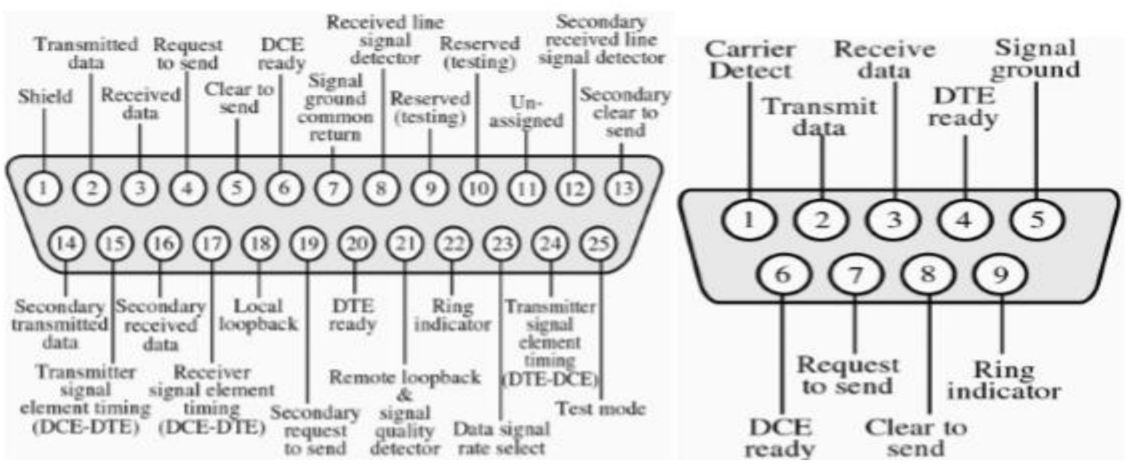
Electrical Specification

- ➢ Defines the voltage levels and the type of signal to be transmitted in either direction between the DTE and the DCE.
- ➢ All data must be transmitted as logical 1s and 0s (called mark and space) using non-return to zero, level encoding, with 0 defined as a positive voltage and 1 defined as a negative voltage.
- ➢ The electrical specification that signals other than data must be sent using OFF is less than -3 volts and ON is greater than 3 volts.

➢ **Functional Specifications**

- o Two different implementations of EIA 232 are available:
  —DB 25
  —DB 9
- o DB 25 connector defines the functions assigned to each of the 25 pins in the DB 25 connector

Functional Specifications



EIA Standards for Interfacing

RS 232C

- ▶ It is an interface between the DTE (Data Terminal Equipment) and DCE (Data Communications Equipment) employing serial binary data interchange
- ▶ It is a first level protocol standard as well as an electrical standard specifying handshaking and functions between the DTE and DCE

- Transmission rate is 20 kbps for a distance not more than 50 ft.; load impedance at terminator side is between 3000 to 7000 ohms

RS 422A

- It defines electrical characteristics of balanced-voltage digital interface circuits.
- It is a differential balanced voltage interface standard capable of significantly higher data rates over long distances.
- It can accommodate 100 kbps over a distance of 4000 ft (1200 m) or rates up to 10 Mbps over a maximum distance of 40 ft (12 m)

RS 423A

- It defines electrical characteristics of unbalanced-voltage digital interface circuits
- Single-ended, bipolar and unterminated voltage circuit like RS 232C
- It extends the distance and data rate capabilities to distances up to 4000 ft (1200 m) at a data rate of 3 kbps or at higher data rates of up to 300 kbps over a maximum distance of 40 ft (12 m)

RS 357

- It defines interface between Facsimile Terminal Equipment and VF Data Terminal Equipment

RS 366

- It defines interface between DTE and Automatic Calling Equipment for Data Communications

RS 408

- It recommends the standardization of the two interfaces between the numerical control equipment (such as tape reader) and the serial-to-parallel converter with less than 40 ft (12 m) distance.

RS 408

- It recommends the standardization of the two interfaces between the numerical control equipment (such as tape reader) and the serial-to-parallel converter with less than 40 ft (12 m) distance.

RS 449

- It is general-purpose 37-position and 9-position interface for DTE and DCE employing serial binary data interchange.
- It offers greater immunity to noise and increase the data signaling rate to 2 Mbps and permits an increase up to 200 m in the length of the interconnecting cable.

CCITT Rec. V.10 / X.26

- It defines electrical characteristics of Unbalanced Double Current Interchange Circuits for General Use with IC Equipment in the field of Data Communications.

CCITT Rec. V.11 / X.27

- It defines electrical characteristics of Unbalanced Double Current Interchange Circuits for General Use with IC Equipment in the field of Data Communications.

CCITT Rec. V.24

- It gives the list of definitions for interfacing circuits between DTE and DCE for transfer of binary data and control and timing signals.
- The definitions are applicable to synchronous and asynchronous data communications.

CCITT Rec. V.28

- It defines the electrical characteristics for Unbalanced Double-Current Interchange Circuits .
- Electrical characteristics specified are applicable to interchange circuits operating with data signaling rates below 20 kbps.

CCITT Rec. V.35

- Defines interface circuits similar to RS 232C and Rec. V.24 with balanced line on Transmit Data, Receive Data, Transmit Clock, and Receive Clock.

CCITT Rec. V.57

- Comprehensive Data Test Set for High Data Signaling Rates.

CCITT Rec. V.36

- It covers the synchronous data transmission modems using 60-108 kHz group band circuits and is applicable to the extension of a PCM channel at 64 kbps, extension of the Single Channel Per Carrier, SCPC circuit from a satellite earth station, and the transmission of a multiplex aggregate bit stream for telegraph and data signals.

CCITT SS 4

- System in Europe only for operator-controlled and full automatic international services on unidirectional circuits.

CCITT SS 5

- Uses two in band frequencies for line and supervisory signals (2400-2600 Hz).

CCITT SS 6

- International specification for common channel signaling

CCITT SS 7

- Common channel signaling system use between SPC exchanges
- Designed for use in a digital environment

X.21

- Interface between DTE and Data Terminating Equipment for Synchronous operation on Public Data Networks

X.24

- List of Definitions for Interchange Circuits between Data Terminal equipment and Data Terminating Equipment on Public Data Networks

X.25

- Interface between DTE and DCE for Terminals Operating in the Packet Mode on Public data Networks.
- It is a standard protocol for interfacing a terminal to packet network.

- Defines the architecture of three levels of protocols existing in the serial interface cable between a packet mode terminal and give away to a packet network.

X.26

- Electrical characteristics for Unbalanced Double Current Interchange Circuits for General Use with Integrated Circuit equipment in the field of Data Communications

DATA COMMUNICATION MODEMS

The most communication type of data communication equipment is data communication modem.

Other name:

Datasets

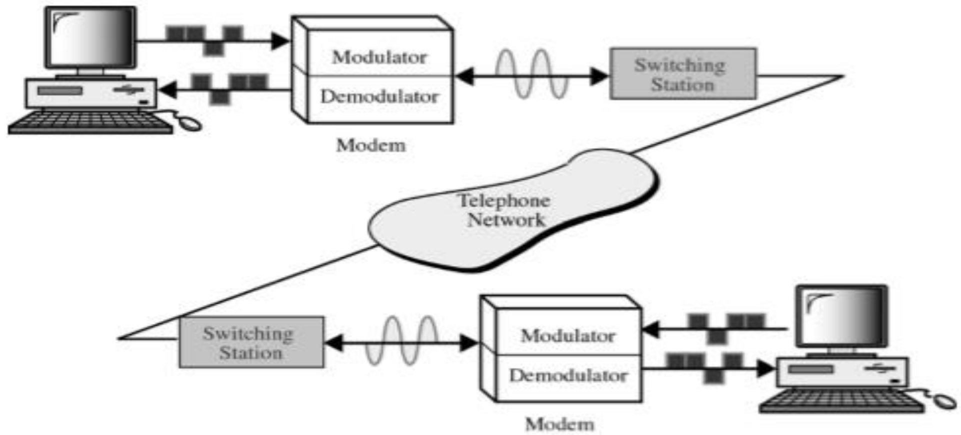
Dataphones

Or simply modems

Because digital information cannot be transported directly over analog transmission media (atleast not in digital form). The primary purpose of data communication modems is to interface computers, computer networks and other digital equipment terminal equipment to analog communications facilities.. Modems are also used when computers are too far apart to be directly interconnected using standard computer cables

MODEM

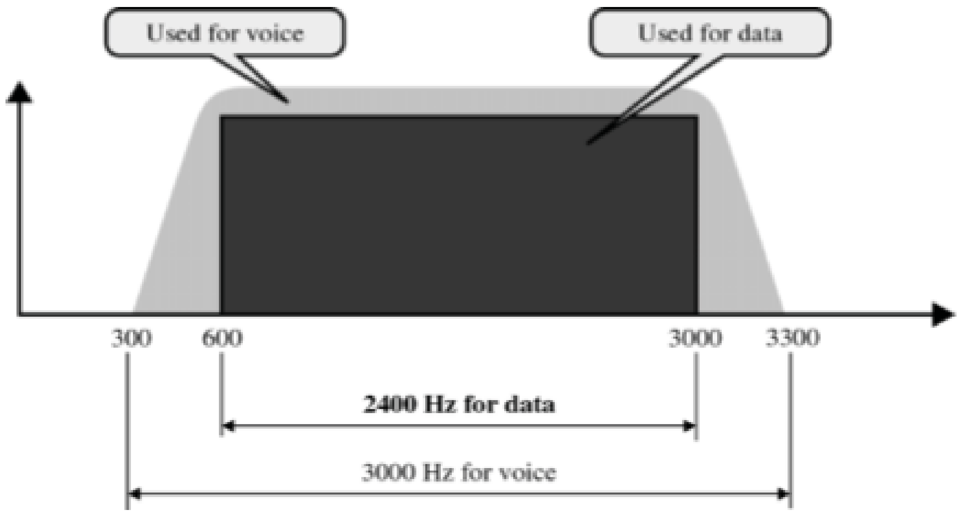
- Most familiar type of a DCE
- We require modem to connect to the internet
- MODEM is a composite word for modulator and Demodulator
- Modulator converts a digital signal into an analog signal using ASK, FSK, PSK or QAM
- A demodulator converts an analog signal into a digital signal
- While a demodulator resembles an analog-to-digital converter, it is not infact a converter of any kind
- It does not sample the signal to create a digital signal
- It just reverses the process of modulation that is it performs demodulation



- Shows the relationship of a modulator with a demodulator
- Two PCs at the end are DTEs, and the modems are the DCEs

- DTE creates a digital signal and relays it to the Modem via an interface via an interface
- Modulated signal is received by the demodulation function of the second modem
- This modem takes this ASK, FSK, PSK or QAM signal and decodes it into whatever format its computer can accept
- It then relays the digital signal to the computer via an interface
- Each DCE must be compatible with both its own DTE and the other DCE

- **Transmission Rate**
- Modems are often described as high speed or low speed to indicate how many bits per second a specific device is capable of transmitting or receiving
- Limitations on the transmission rate of the Modem
- **Bandwidth**
- Data rate of a link depends upon the type of encoding uses and the bandwidth of the medium
- The medium bandwidth is related to the inherent limitation of the physical property of the medium
- Every line has a range of frequencies it can pass
- If the frequency of a signal is too ow, it cannot overcome the capacitance of the line
- If frequency is too high, it can be impeded by the inductance of the line
- So every line has an upper limit and a lower limit on frequencies of the signals
- This limited range is called Bandwidth



- Traditional telephone lines can carry fre's b/w 300 Hz and 3300 Hz giving them a BW of 3000Hz
- All of this range is used for transmitting voice where a great deal of interference and distortion can be accepted w/o any loss of intelligibility
- Data signal require a high degree of accuracy , so edges of this range are not used for data comm
- Effective BW of telephone line used for data transmission is 2400 Hz covering a range from 600 Hz to 3000Hz

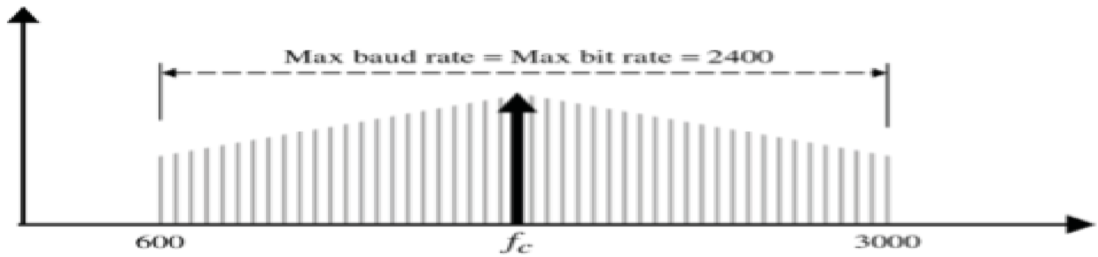
❖ **Modem Speed**

- Each type of Analog conversion manipulates signal differently:

  - ASK manipulated Amplitude
  - FSK manipulates Frequency
  - PSK manipulates Phase
  - QAM manipulate both phase and amplitude

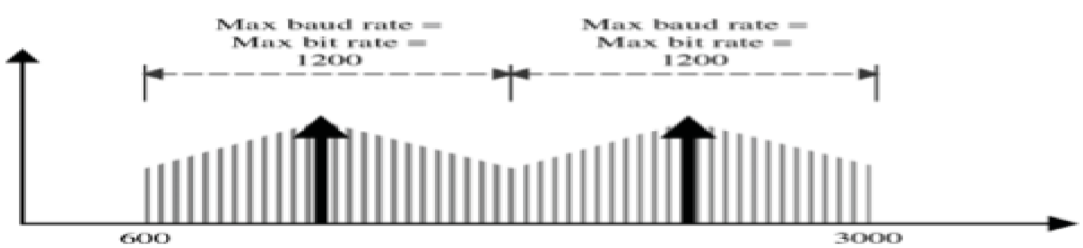
- **Modem Speed-ASK**

- BW required for ASK is equal to the baud rate of the signal
- Assuming that entire link is being used by one signal, as in Simplex or Half Duplex, the maximum baud rate for ASK modulation is equal to the entire BW of the transmission medium



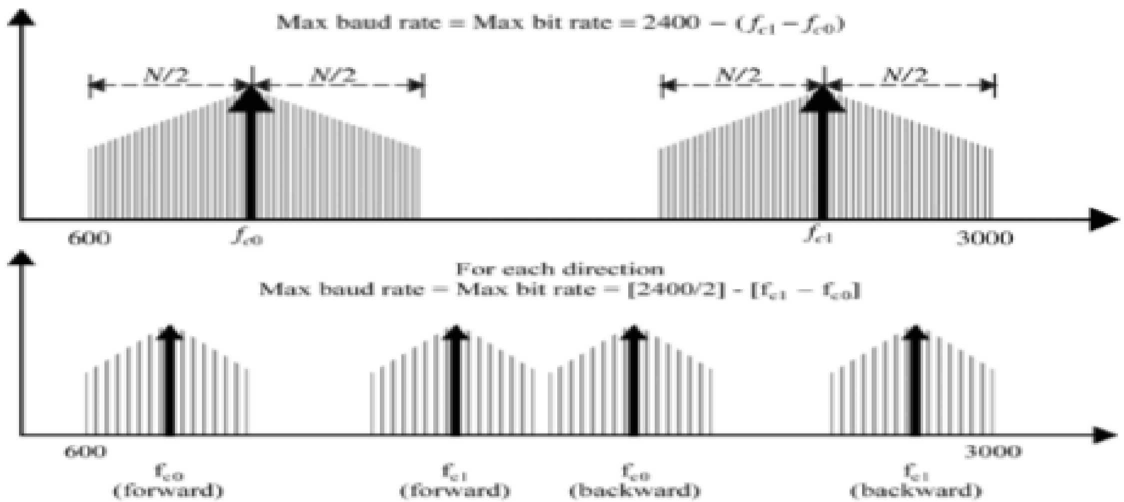
- Because the effective BW of a telephone line IS 2400 Hz, the maximum baud rate is also 2400
- Baud rate and bit rate are equal for ASK, so maximum bit rate is also 2400 bps

Modem Speed-ASK (Full Duplex)



- For full duplex TX, only half of the total bandwidth cab be used in either directions
- Therefore the maximum speed for ASK in full duplex mode is 1200 bps
- Noise problem makes it impractical for use in Modems

- **Modem Speed-FSK**
  - BW required for FSK is equal to the baud rate of the signal plus the frequency shift
  - So maximum baud rate becomes equal to the BW transmission medium minus the frequency shift



- Maximum Baud rate is therefore 2400 minus the frequency shift
- And bit rate is also 2400 minus frequency shift
- In full duplex mode it is equal to 1200 minus the frequency shift

- **Modem Speed-PSK & QAM**
  - Minimum BW for PSK or QAM is the same as for ASK but the bit rate can be greater depending upon the number of bits that can be represented by each signal unit
    - **Modem Speed-PSK & QAM on two wire Twisted pair Telephone line**

Comparisons of bit rates: HDX and FDX

2-PSK	2400	1200
4-PSK,4-QAM	4800	2400
8-PSK,8-QAM	7200	3600
16-QAM	9600	4800
32-QAM	12000	6000

Modem Standards

Bell Modems

Standard	Tx Mode	Baud Rate	Bit Rate	No. of Wire	Modulation
Bell 103	FDX	300 baud	300 bps	2-wire	FSK
Bell 202	HDX	1200 baud	1200 bps	2-wire	FSK
Bell 212	FDX	600 baud	1200 bps	2-wire	4-PSK
Bell 201	HDX/FDX	1200 baud	2400 bps	2/4wire	4-PSK
Bell 208	FDX	1600 baud	4800 bps	4-wire	8-PSK
Bell 209	FDX	2400 baud	9600 bps	4-wire	16-QAM

ITU-T Modems

Standard	Tx Mode	Baud Rate	Bit Rate	No. of Wire	Modulation
V.22 bis	FDX	600 baud	1200/2400 bps	2-wire	4-DPSK/16-QAM
V.32	FDX	2400 baud	9600 bps	2-wire	32-QAM (trellis)
V.32bis	FDX	2400 baud	14400 bps	4-wire	64-QAM
V.32terbo	FDX	2400 baud	19200 bps	4-wire	256-QAM
V.33	FDX	2400 baud	14400 bps	4-wire	128-QAM (trellis)
V.34	FDX	2400 baud	28800 bps	4-wire	4096-QAM

NULL MODEM

- Suppose you need to connect two DTEs in the same building, for example two workstations
- Modems are not needed to connect two compatible devices directly
- The TX never needs to cross analog lines, such as telephone lines and therefore does not need to be modulated
- But you do need an interface to handle the exchanging , just as EIA 232 DTE-DCE cable does
- The solution is a NULL Modem
- A null modem provide DTA –DTE interface w/o DCEs
- But why use a Null Modem
- If all you need is the interface, why not just a a standard EIA 232 cable?

a. DTEs connected through DCEs

b. DTEs connected directly

- Part a shows a connection using a telephone network
- Part b shows what happens when we use the same connections between two DTEs
- The receive circuit is void because it has been isolated completely for the TX
- The tx cct 2 endsup full of collision noise

LEARNING ASSESSEMNT

1. Define and give some examples of DTE.

2. Define and give some examples of DCE.

3. Describe data communications modem and explain where they are used in data communications circuits.

4. Describe the physical, electrical, and functional characteristics of the RS-232 Interface

5. Describe RS-449 interface and the give the primary difference between it and the RS-232 interface.

INTRODUCTION TO COMPUTER NETWORKS

INTRODUCTION TO COMPUTER NETWORKS

A system of interconnected computers and computerized peripherals such as printers is called computer network. This interconnection among computers facilitates information sharing among them. Computers may connect to each other by either wired or wireless media.

Classification of Computer Networks

Computer networks are classified based on various factors. They include:

- Geographical span
- Inter-connectivity
- Administration
- Architecture

Geographical Span

Geographically a network can be seen in one of the following categories:

It may be spanned across your table, among Bluetooth enabled devices, Ranging not more than few meters.

- It may be spanned across a whole building, including intermediate devices to connect all floors.
- It may be spanned across a whole city.
- It may be spanned across multiple cities or provinces.
- It may be one network covering whole world.

Inter-Connectivity

Components of a network can be connected to each other differently in some fashion. By connectedness we mean either logically, physically, or both ways. Every single device can be connected to every other device on network, making the network mesh.

- All devices can be connected to a single medium but geographically disconnected, created bus-like structure.
- Each device is connected to its left and right peers only, creating linear structure.
- All devices connected together with a single device, creating star-like structure.
- All devices connected arbitrarily using all previous ways to connect each other, resulting in a hybrid structure.

Administration

From an administrator's point of view, a network can be private network which belongs a single autonomous system and cannot be accessed outside its physical or logical domain. A network can be public, which is accessed by all.

Network Architecture

Computer networks can be discriminated into various types such as Client-Server, peer-to-peer or hybrid, depending upon its architecture.

- There can be one or more systems acting as Server. Other being Client, requests the Server to serve requests. Server takes and processes request on behalf of Clients.
- Two systems can be connected Point-to-Point, or in back-to-back fashion. They both reside at the same level and called peers.
- There can be hybrid network which involves network architecture of both the above types

Network Applications

- Computer systems and peripherals are connected to form a network. They provide numerous advantages:
- Resource sharing such as printers and storage devices
- Exchange of information by means of e-Mails and FTP
- Information sharing by using Web or Internet
- Interaction with other users using dynamic web pages
- IP phones

- Video conferences
- Parallel computing
- Instant messaging

TYPES OF COMPUTER NETWORKS

Generally, networks are distinguished based on their geographical span. A network can be as small as distance between your mobile phone and its Bluetooth headphone and as large as the internet itself, covering the whole geographical world.

Personal Area Network

A Personal Area Network (PAN) is smallest network which is very personal to a user. This may include Bluetooth enabled devices or infra-red enabled devices. PAN has connectivity range up to 10 meters. PAN may include wireless computer keyboard and mouse, Bluetooth enabled headphones, wireless printers, and TV remotes. For example, Piconet is Bluetooth-enabled Personal Area Network which may contain up to 8 devices connected together in a master-slave fashion.

Local Area Network

A computer network spanned inside a building and operated under single administrative system is generally termed as Local Area Network (LAN). Usually, LAN covers an organization offices, schools, colleges or universities. Number of systems connected in LAN may vary from as least as two to as much as 16 million. LAN provides a useful way of sharing the resources between end users. The resources such as printers, file servers, scanners, and internet are easily sharable among computers. LANs are composed of inexpensive networking and routing equipment. It may contains local servers serving file storage and other locally shared applications. It mostly operates on private IP addresses and does not involve heavy routing. LAN works under its own local domain and controlled centrally. LAN uses either Ethernet or Token-ring technology. Ethernet is most widely employed LAN technology and uses Star topology, while Token-ring is rarely seen. LAN can be wired, wireless, or in both forms at once.

Metropolitan Area Network

The Metropolitan Area Network (MAN) generally expands throughout a city such as cable TV network. It can be in the form of Ethernet, Token-ring, ATM, or Fiber Distributed Data Interface (FDDI). Metro Ethernet is a service which is provided by ISPs. This service enables its users to expand their Local Area Networks. For example, MAN can help an organization to connect all of its offices in a city. Backbone of MAN is high-capacity and high-speed fiber optics. MAN works in between Local Area Network and Wide Area Network. MAN provides uplink for LANs to WANs or internet.

Wide Area Network

As the name suggests, the Wide Area Network (WAN) covers a wide area which may span across provinces and even a whole country. Generally, telecommunication networks are Wide Area Network. These networks provide connectivity to MANs and LANs. Since they are equipped with very high speed backbone, WANs use very expensive network equipment. WAN may use advanced technologies such as Asynchronous Transfer Mode (ATM), Frame Relay, and Synchronous Optical Network (SONET). WAN may be managed by multiple administration.

Internetwork

A network of networks is called an internetwork, or simply the internet. It is the largest network in existence on this planet. The internet hugely connects all WANs and it can have connection to LANs and Home networks. Internet uses TCP/IP protocol suite and uses IP as its addressing protocol. Present day, Internet is widely implemented using IPv4. Because of shortage of address spaces, it is gradually migrating from IPv4 to IPv6. Internet enables its users to share and access enormous amount of information worldwide. It uses WWW, FTP, email services, audio, and video streaming etc. At huge level, internet works on Client-Server model. Internet uses very high speed backbone of fiber optics. To inter-connect various continents, fibers are laid under sea known to us as submarine communication cable. Internet is widely deployed on World Wide Web services using HTML linked pages and is accessible by client software known as Web Browsers. When a user requests a page using some web browser located on some Web Server anywhere in the world, the Web Server responds with the proper HTML page. The communication delay is very low. Internet is serving many proposes and is involved in many aspects of life. Some of them are:

Web sites, E-mail , Instant Messaging, Blogging, Social Media, Marketing, Networking, Resource Sharing, Audio and Video Streaming

NETWORK LAN TECHNOLOGIES

Ethernet

Ethernet is a widely deployed LAN technology. This technology was invented by Bob Metcalfe and D.R. Boggs in the year 1970. It was standardized in IEEE 802.3 in 1980. Ethernet shares media. Network which uses shared media has high probability of data collision. Ethernet uses Carrier Sense Multi Access/Collision Detection (CSMA/CD) technology to detect collisions. On the occurrence of collision in Ethernet, all its hosts roll back, wait for some random amount of time, and then re-transmit the data. Ethernet connector is network interface card equipped with 48-bits MAC address. This helps other Ethernet devices to identify and communicate with remote devices in Ethernet. Traditional Ethernet uses 10BASE-T specifications. The number 10 depicts 10MBPS speed, BASE stands for baseband, and T stands for Thick Ethernet. 10BASE-T Ethernet provides transmission speed up to 10MBPS and uses coaxial cable or Cat-5 twisted pair cable with RJ-5 connector. Ethernet follows Star topology with segment length up to 100 meters. All devices are connected to a hub/switch in a star fashion.

Fast-Ethernet

To encompass need of fast emerging software and hardware technologies, Ethernet extends itself as Fast-Ethernet. It can run on UTP, Optical Fiber, and wirelessly too. It can provide speed up to 100MBPS. This standard is named as 100BASE-T in IEEE 803.2 using Cat-5 twisted pair cable. It uses CSMA/CD technique for wired media sharing among the Ethernet hosts and CSMA/CA (CA stands for Collision Avoidance) technique for wireless Ethernet LAN. Fast Ethernet on fiber is defined under 100BASE-FX standard which provides speed up to 100MBPS on fiber. Ethernet over fiber can be extended up to 100 meters in half-duplex mode and can reach maximum of 2000 meters in full-duplex over multimode fibers.

Giga-Ethernet

After being introduced in 1995, Fast-Ethernet retained its high speed status only for three years till Giga-Ethernet introduced. Giga-Ethernet provides speed up to 1000 mbits/seconds. IEEE802.3ab standardizes Giga-Ethernet over UTP using Cat-5, Cat5e and Cat-6 cables. IEEE802.3ah defines Giga-Ethernet over Fiber.

Virtual LAN

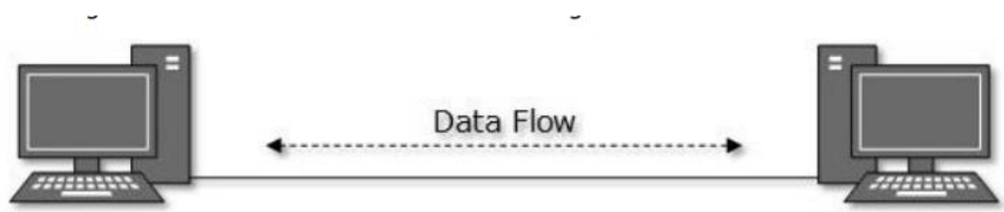
LAN uses Ethernet which in turn works on shared media. Shared media in Ethernet create one single Broadcast domain and one single Collision domain. Introduction of switches to Ethernet has removed single collision domain issue and each device connected to switch works in its separate collision domain. But even Switches cannot divide a network into separate Broadcast domains. Virtual LAN is a solution to divide a single Broadcast domain into multiple Broadcast domains. Host in one VLAN cannot speak to a host in another. By default, all hosts are placed into the same VLAN. In this diagram, different VLANs are depicted in different color codes. Hosts in one VLAN, even if connected on the same Switch cannot see or speak to other hosts in different VLANs. VLAN is Layer-2 technology which works closely on Ethernet. To route packets between two different VLANs, a Layer-3 device such as Router is required.

COMPUTER NETWORK TOPOLOGIES

A Network Topology is the arrangement with which computer systems or network devices are connected to each other. Topologies may define both physical and logical aspect of the network. Both logical and physical topologies could be same or different in a same network.

Point-to-Point

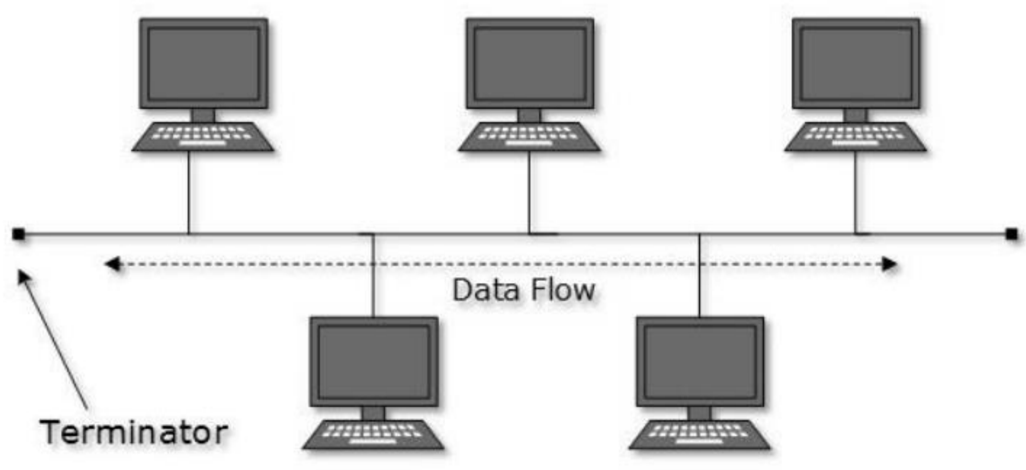
Point-to-point networks contains exactly two hosts such as computer, switches, routers, or servers connected back to back using a single piece of cable. Often, the receiving end of one host is connected to sending end of the other and vice versa.



If the hosts are connected point-to-point logically, then may have multiple intermediate devices. But the end hosts are unaware of underlying network and see each other as if they are connected directly.

Bus Topology

In case of Bus topology, all devices share single communication line or cable. Bus topology may have problem while multiple hosts sending data at the same time. Therefore, Bus topology either uses CSMA/CD technology or recognizes one host as Bus Master to solve the issue. It is one of the simple forms of networking where a failure of a device does not affect the other devices. But failure of the shared communication line can make all other devices stop functioning. Both ends of the shared channel have line terminator. The data is sent in only one direction and as soon as it reaches the extreme end, the terminator removes the data from the line.

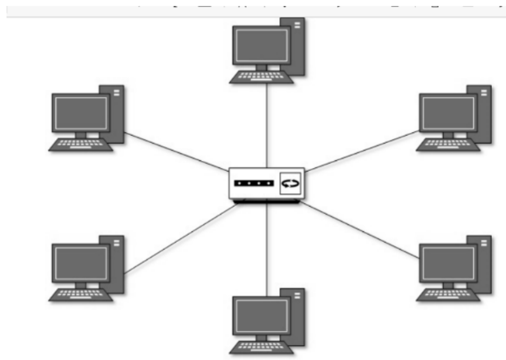


Star Topology

All hosts in Star topology are connected to a central device, known as hub device, using a point-to-point connection. That is, there exists a point to point connection between hosts and hub. The hub device can be any of the following:

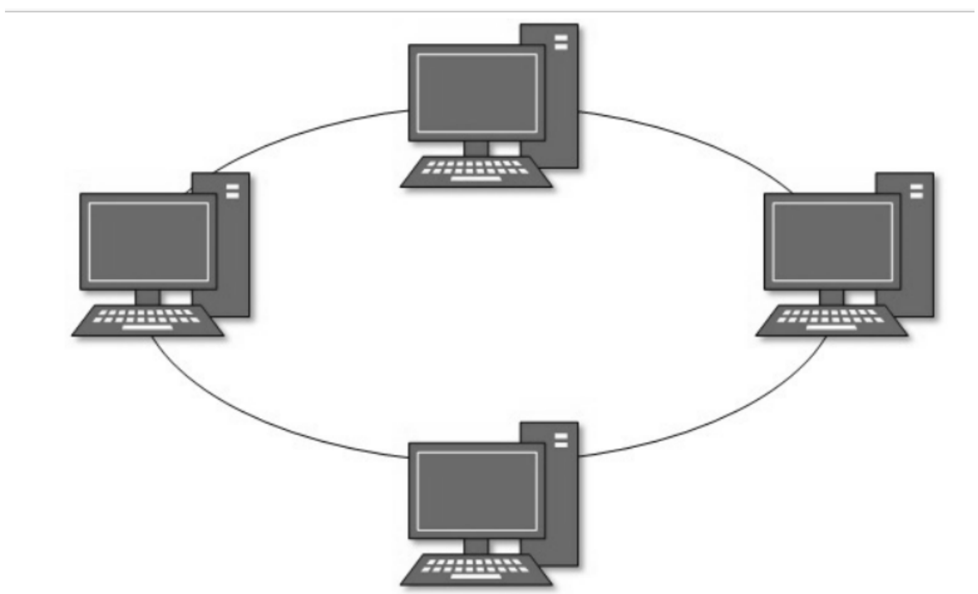
- Layer-1 device such as hub or repeater
- Layer-2 device such as switch or bridge
- Layer-3 device such as router or gatew

As in Bus topology, hub acts as single point of failure. If hub fails, connectivity of all hosts to all other hosts fails. Every communication between hosts takes place through only the hub. Star topology is not expensive as to connect one more host, only one cable is required and configuration is simple.



Ring Topology

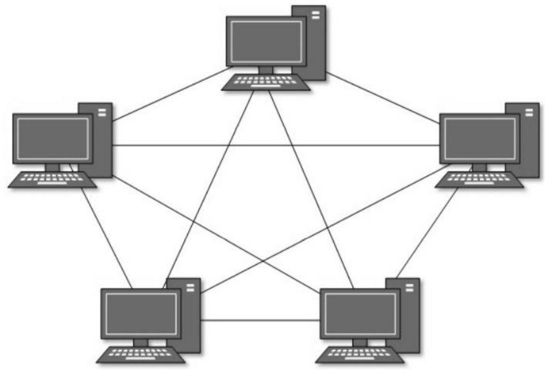
In ring topology, each host machine connects to exactly two other machines, creating a circular network structure. When one host tries to communicate or send message to a host which is not adjacent to it, the data travels through all intermediate hosts. To connect one more host in the existing structure, the administrator may need only one more extra cable.



Failure of any host results in failure of the whole ring. Thus, every connection in the ring is a point of failure. There are methods which employ one more backup ring.

Mesh Topology

In this type of topology, a host is connected to one or multiple hosts. This topology has hosts in point-to-point connection with every other host or may also have hosts which are in point-to-point connection with few hosts only.



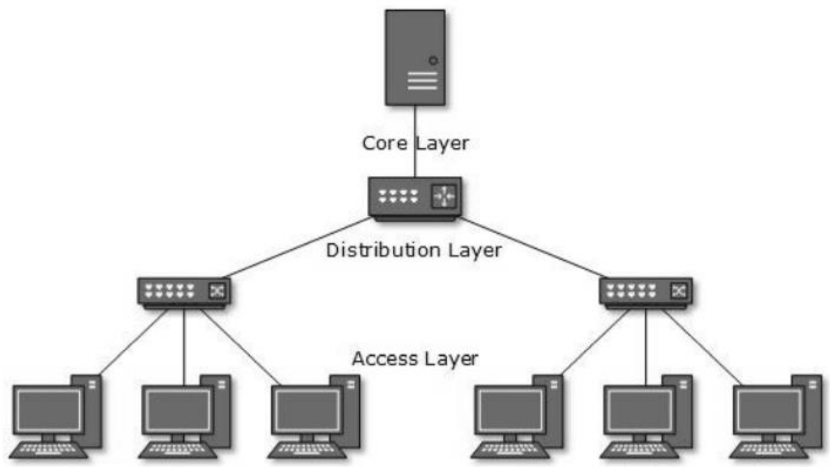
Hosts in Mesh topology also work as relay for other hosts which do not have direct point-to-point links. Mesh technology comes into two types:

- Full Mesh: All hosts have a point-to-point connection to every other host in the network. Thus for every new host n(n-1)/2 connections are required. It provides the most reliable network structure among all network topologies.
- Partially Mesh: Not all hosts have point-to-point connection to every other host. Hosts connect to each other in some arbitrarily fashion. This topology exists where we need to provide reliability to some hosts out of all.

Tree Topology

Also known as Hierarchical Topology, this is the most common form of network topology in use presently. This topology imitates as extended Star topology and inherits properties of Bus topology.

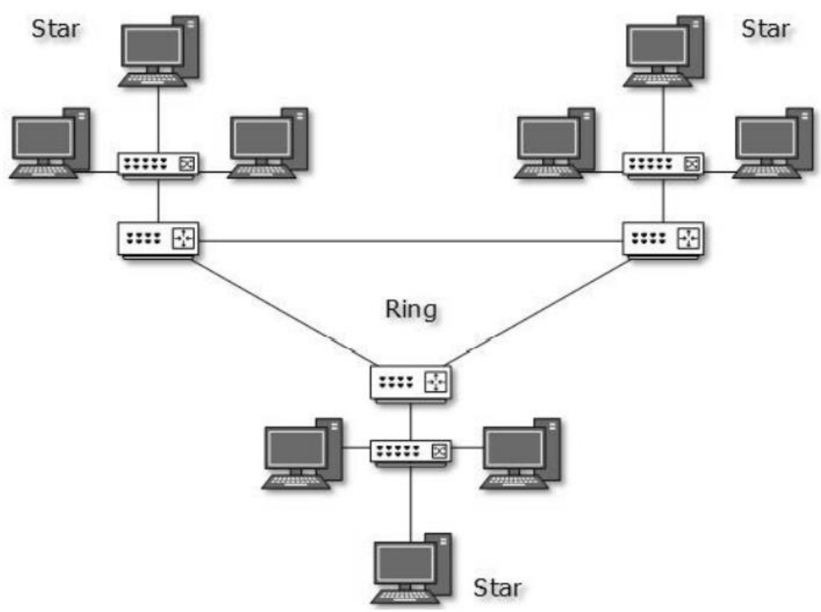
This topology divides the network into multiple levels/layers of network. Mainly in LANs, a network is bifurcated into three types of network devices. The lowermost is access-layer where computers are attached. The middle layer is known as distribution layer, which works as mediator between upper layer and lower layer. The highest layer is known as core layer, and is central point of the network, i.e. root of the tree from which all nodes fork.



All neighboring hosts have point-to-point connection between them. Similar to the Bus topology, if the root goes down, then the entire network suffers even though it is not the single point of failure. Every connection serves as point of failure, failing of which divides the network into unreachable segment.

Hybrid Topology

A network structure whose design contains more than one topology is said to be hybrid topology. Hybrid topology inherits merits and demerits of all the incorporating topologies.



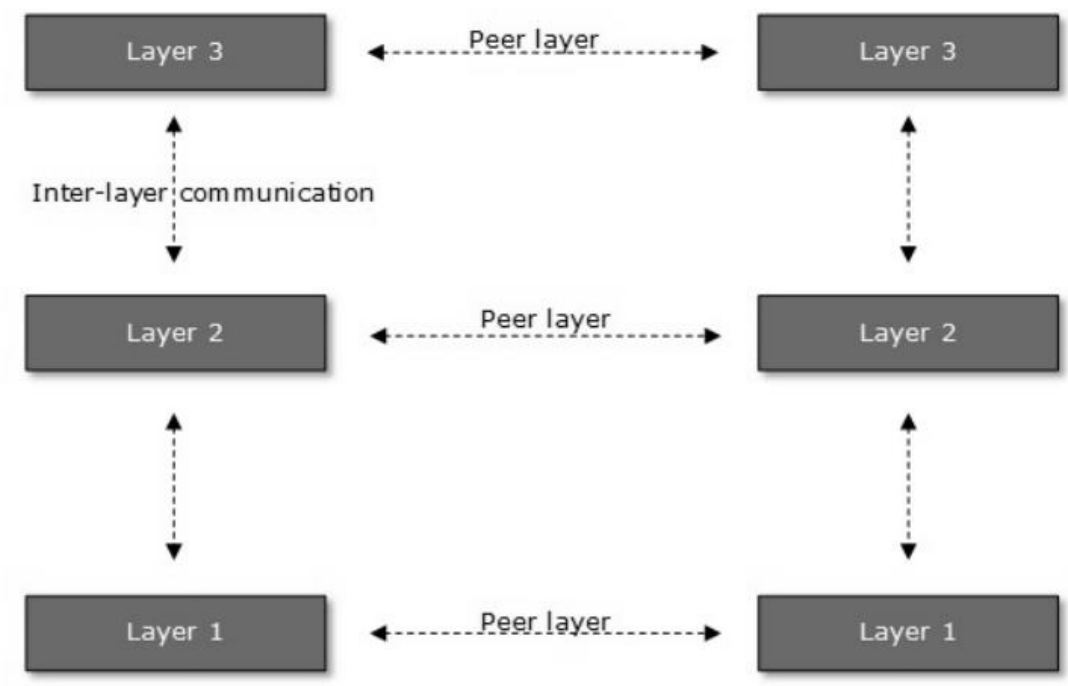
The above picture represents an arbitrarily hybrid topology. The combining topologies may contain attributes of Star, Ring, Bus, and Daisy-chain topologies. Most WANs are connected by means of Dual-Ring topology and networks connected to them are mostly Star topology networks. Internet is the best example of largest Hybrid topology.

COMPUTER NETWORK MODEL

Network engineering is a complicated task, which involves software, firmware, chip level engineering, hardware, and electric pulses. To ease network engineering, the whole networking concept is divided into multiple layers. Each layer is involved in some particular task and is independent of all other layers. But as a whole, almost all networking tasks depend on all of these layers. Layers share data between them and they depend on each other only to take input and send output.

Layered Tasks

In layered architecture of Network Model, one whole network process is divided into small tasks. Each small task is then assigned to a particular layer which works dedicatedly to process the task only. Every layer does only specific work. In layered communication system, one layer of a host deals with the task done by or to be done by its peer layer at the same level on the remote host. The task is either initiated by layer at the lowest level or at the top most level. If the task is initiated by the topmost layer, it is passed on to the layer below it for further processing. The lower layer does the same thing, it processes the task and passes on to lower layer. If the task is initiated by lowermost layer, then the reverse path is taken.



Every layer clubs together all procedures, protocols, and methods which it requires to execute its piece of task. All layers identify their counterparts by means of encapsulation header and tail.

OSI Model

Open System Interconnect is an open standard for all communication systems. OSI model is established by International Standard Organization (ISO). This model has seven layers:

Application Layer: This layer is responsible for providing interface to the application user. This layer encompasses protocols which directly interact with the user.

Presentation Layer: This layer defines how data in the native format of remote host should be presented in the native format of host.

Session Layer: This layer maintains sessions between remote hosts. For example, once user/password authentication is done, the remote host maintains this session for a while and does not ask for authentication again in that time span.

Transport Layer: This layer is responsible for end-to-end delivery between hosts.

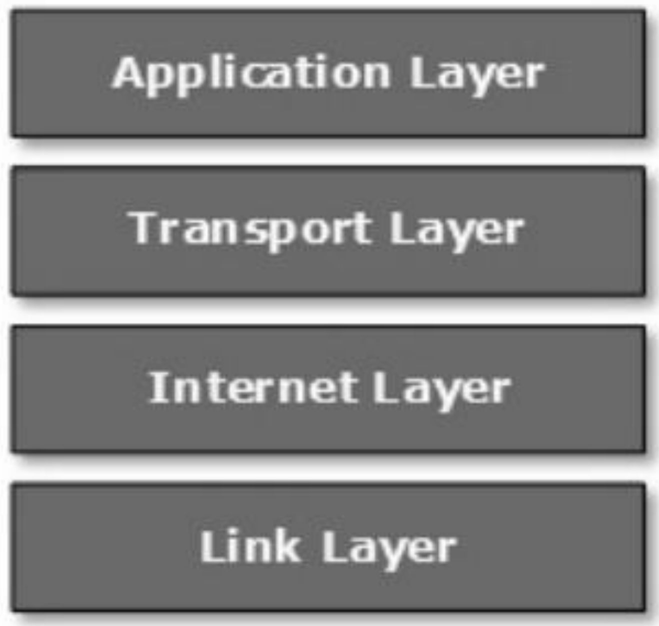
Network Layer: This layer is responsible for address assignment and uniquely addressing hosts in a network.

Data Link Layer: This layer is responsible for reading and writing data from and onto the line. Link errors are detected at this layer.

Physical Layer: This layer defines the hardware, cabling, wiring, power output, pulse rate etc.

Internet Model

Internet uses TCP/IP protocol suite, also known as Internet suite. This defines Internet Model which contains four layered architecture. OSI Model is general communication model but Internet Model is what the internet uses for all its communication. The internet is independent of its underlying network architecture so is its Model. This model has the following layers:



Application Layer: This layer defines the protocol which enables user to interact with the network. For example, FTP, HTTP etc.

Transport Layer: This layer defines how data should flow between hosts. Major protocol at this layer is Transmission Control Protocol (TCP). This layer ensures data delivered between hosts is in-order and is responsible for endto-end delivery.

Internet Layer: Internet Protocol (IP) works on this layer. This layer facilitates host addressing and recognition. This layer defines routing.

Link Layer: This layer provides mechanism of sending and receiving actual data. Unlike its OSI Model counterpart, this layer is independent of underlying network architecture and hardware.

LEARNING-ASSESSMENT

1. Your company has three divisions. Each group has a network, and all the networks are joined together. Is this still a LAN? Or is it something else?

2. The company adds a retail division. There is a head office and six branch offices. What type of network is this?