A Text Book Of

DATA COMMUNICATION AND COMPUTER NETWORK

(COURSE CODE : 314318)

Semester - IV

SECOND YEAR DIPLOMA IN COMPUTER ENGINEERING GROUP
(AI / AN / BD / CM / CO / CW / DS / HA / IF / IH / SE)

As Per MSBTE's 'K' Scheme Syllabus w.e.f. Academic Year 2024

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Preface ...

We take an opportunity to present this book entitled as **"Data Communication and Computer Network"** to the students of Fourth Semester (Second Year Diploma in Computer Engineering Group (AI / AN / BD / CM / CO / CW / DS / HA / IF / IH / SE). The book is written strictly according to the Revised Syllabus (K-Scheme) prepared by Maharashtra State Board of Technical Education (MSBTE).

The book has its own unique features. It brings out the subject in a very simple and lucid manner for easy and comprehensive understanding of the basic concepts. The book covers theory of Fundamentals of Data Communication and Computer Network, Transmission Media and Switching, Error Detection and Correction, Network Communication Models, Network Topologies and Network Devices.

A special word of thank to Shri. Dineshbhai Furia, Mr. Jignesh Furia for showing full faith in us to write this text book. We also thank to Mr. Amar Salunkhe and Mrs. Prachi Sawant of M/s Nirali Prakashan for their excellent co-operation.

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We welcome constructive suggestions from our colleagues and students.

Authors

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Fundamentals of Data Communication and Computer Network

Learning Outcomes...

- Describe the role of the given component in the process of data communication.
- Compare the characteristics of analog and digital signals on the given parameter.
- Explain the process of data communication using the given mode.
- Classify computer networks on the specified parameter.

1.0 INTRODUCTION

- Data communications and computer networks are two of the fastest growing technological areas in today's modern world because of unlimited demand for information transfer.
- Data communications and computer networks are foundational concepts in modern computing, enabling the transfer and exchange of data across the world.
- Data communications and computer networks deal with data/information transmission. Data refers to the raw facts that are collected while processed data refers to information.
- Data can be represented in many ways such as a human voice, text, numbers, images (graphics), audio, and video etc.
- The internet is an example of data communications and computer networks for the data transfer over the globe.
- Data communication is a process of exchanging data or information between two devices (a sender and a receiver) through some kind of transmission medium such as co-axial cable or fiber optic cable (wired communication) and/or air (wireless communication).
- A computer network is a collection of interconnected devices that communicate with each other to share resources, data and applications.

Overview of Data Communication:

- A communication involves the transfer/exchange of information. Communication means the transfer of information between humans, computers or machines in a meaningful way.
- Data communication can be defined as, "the exchange of information between two computers capable of generating processing and interpreting data".
- The data communication process is shown in the Fig. 1.1.

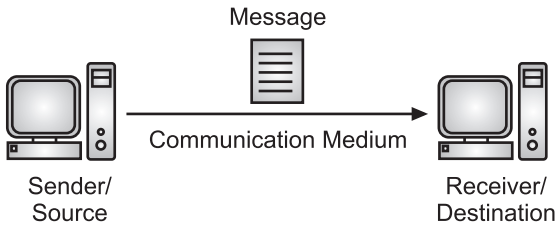


Fig. 1.1: Communication between two Computers

- The Fig. 1.1 shows communication between one computer (sender/source) sending a message to another computer (receiver/destination) over a wire or radio waves called as transmission media/medium.
- The objective of data communication and networking is to enable seamless exchange of data between any two points in the world. This exchange of data takes place over a computer network.

Overview of Computer Network: **[S-22]**

- A group of computers and other devices such as printers, modems, hubs, etc., connected together is called a network. The interconnected computers can share resources, which called networking.
- Networking is linking of two or more different entities together to form a group or network to perform some specific task.
- A computer network provides the facility of information exchange/transfer/share among the computers, connected to it.
- A network is a set of devices (often referred to as nodes) connected by communication media links. A node can be a computer, printer, or any other device capable of sending and/or receiving data generated by other nodes on the network.
- The links connecting the devices are often called communication channels. The term channel refers to a communication path between two communicating devices. It can be either refer to the physical medium (wire/cables).

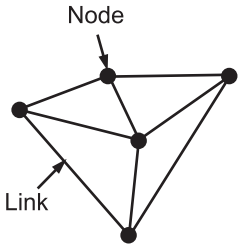


Fig. 1.2: A Typical Network

- Fig. 1.3 shows diagrammatic representation of computer network (wired and wireless).
  - A **wired computer network** uses physical cables (twisted-pair cable or co-axial cable or fiber optic cable) to connect devices, such as laptop or desktop computers to the Internet.
  - A **wireless computer network** uses wireless media [air (radio waves or infrared signals or micro waves or Bluetooth)] to connect devices such as laptops and mobile phones to the Internet.

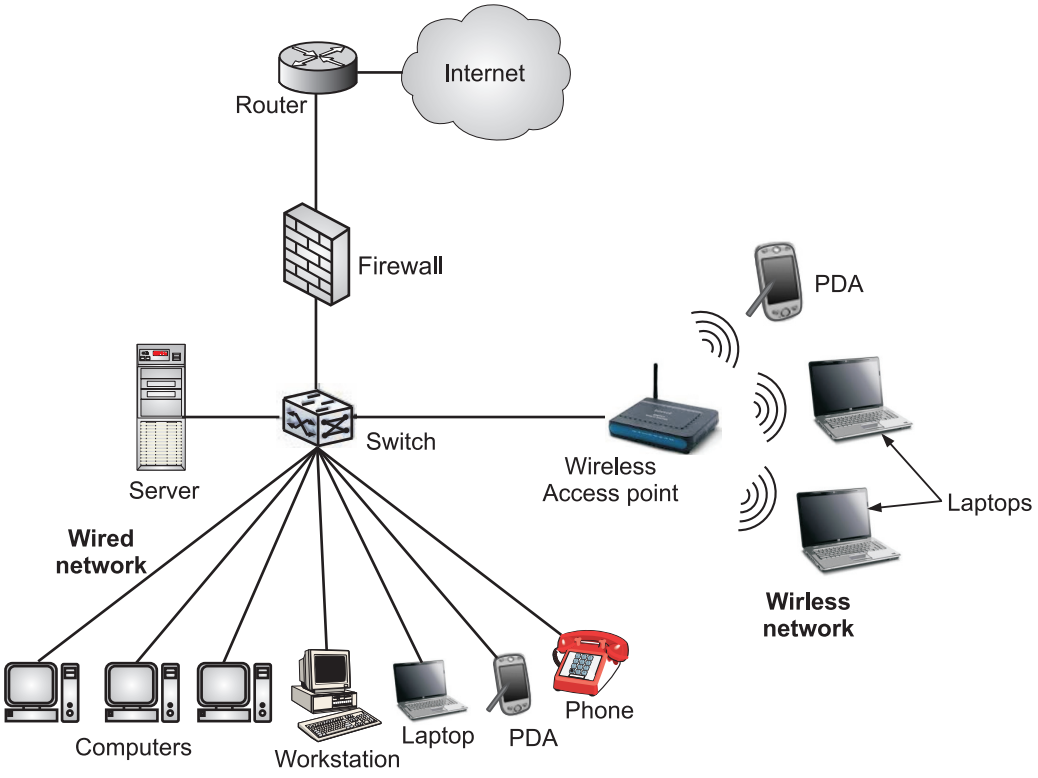


Fig. 1.3: Computer Network (Wired and Wireless)

1.1 PROCESS OF DATA COMMUNICATION AND ITS COMPONENTS [W-22]

- Communication is the basic process of information exchange. Communication, whether between human beings or computer systems, involves transfer of information from a sender (source) to a receiver (destination).
- The process of sending or receiving data between two points of a computer networks is known as data communication.

1.1.1 Process of Data Communication [S-22, W-22, W-23]

- Fig. 1.4 shows process of data communication. A data communication process is made up of five components namely message, sender, receiver, transmission medium and protocol.
- The **functions of each component in data communication process** are as follows: [S-22, W-22]

1. The **message** is the information in the form of data to be communicated. It can take various forms including text, audio, video or images.
2. The **sender** is the device that sends the data message. It can be computers, workstation, telephone handset, video camera and so on.
3. The **receiver** is the device that receives the message. It can be computer, workstation, telephone handset, television and so on.

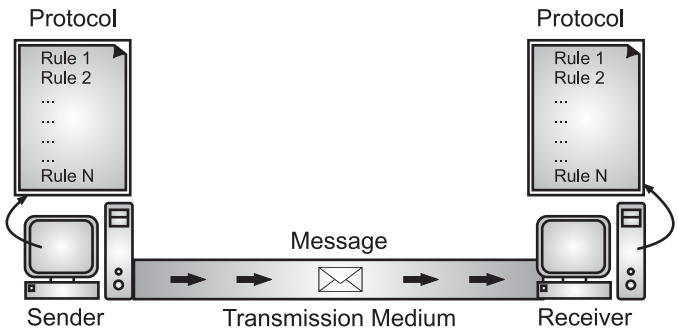


Fig. 1.4: Process of Data Communication between two Computers

4. The **transmission medium** is the physical path by which a message travels from sender to receiver. It can consist of twisted-pair wire/cable, coaxial cable, fiber-optic cable or radio waves.
5. A **protocol** is a set of rules that govern data communications. Without the protocol, the sender and the receiver cannot communicate each other.

Concept of Communications System:

- A data communication system is the combination of hardware, software and data transfer links that make up a communication facility for transferring or exchanging data.
- The communication system transfers information from one place to another in the form of signal as shown in Fig. 1.5.



Fig. 1.5: Simple Data Communication System

1.1.2 Components of Data Communication System [W-22, S-23, S-24]

- In the case of sending and receiving messages or data or data from one place to another, we have many elements/components working together all these elements put together to work efficiently is known as a system.
- The communication system has the sole purpose of passing data or information in the most effective manner.
- A communication system itself can be either analog or digital (or a combination of two). The information can be transmitted in either in analog from or in digital form within the communication networks.
- For data communication to take place, the communicating devices must be part of a communication system. Fig. 1.6 shows components of data communication system.

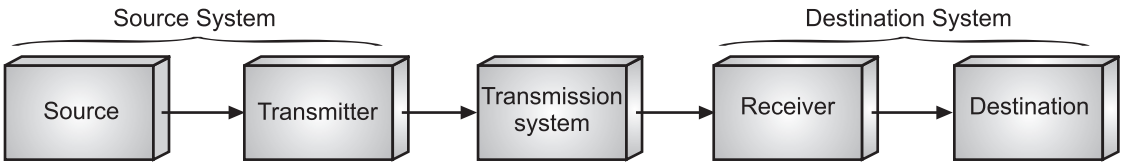


Fig. 1.6: Components of Data Communication

- Following are the building blocks (components) of Data Communication System:
  1. **Source:** Source generates the data which is to be transmitted. Examples of sources includes telephone terminal, personal computers, mainframes and so on.
  2. **Transmitter:** The data generated by a source system are not transmitted directly in the form in which they were generated. A transmitter transforms and encodes the information in the form which is suitable for the transmission and then transmit it across a transmission system.
  3. **Transmission System:** It is a single transmission line or network connecting source and destination. Examples includes cabling, microwave, fiber optics, radio waves and so on.
  4. **Receiver:** The receiver accepts the signal from the transmission system and converts it into a form that can be handled by the destination device (original form in which the data was generated by source).
  5. **Destination:** Destination is a device like computer that receives the data from the receiver.
- The efficiency of a data communication system depends on the following basic characteristics:
  1. **Delivery:** The communication system must deliver data to the correct destination. Data must be received by the intended device or user and only by that device or user.
  2. **Accuracy:** The communication system should be delivered data accurately, means without any error.
  3. **Timeliness:** The communication system must deliver data on time as required. Delay in data delivery might render data useless for the receiver.
  4. **Jitter:** It is the variation in the packet arrival time. Uneven Jitter may affect the timeliness of data being transmitted.

1.2 PROTOCOLS, STANDARDS AND STANDARD ORGANIZATIONS

- Protocols and standards are vital to the implementation of data communications and network. Network protocols standards are agreed-upon specifications that ensure compatibility and interoperability among different devices, vendors, and applications on a network.
- Network protocols and standards are important because they enable different devices and systems to communicate with each other on a network, regardless of their hardware, software, or location.
- Network protocols and standards also ensures consistency, efficiency and quality of service for computer network users and applications.
- In this section we will study protocols, standards and standard organizations for data communications are sets of rules that define how data is exchanged between devices on a network.
- Network and computer networks.

1.2.1 Protocols [S-22, S-24, W-24]

- Network protocols define the rules and procedures for the network communications. A protocol is a set of rules that governs data communications.
- A protocol defines what is to be communicated, how it is to be communicated and when it is to be communicated.
- A protocol is defined as, “a set of rules or standards that governs the communications between computers on a network”. **OR**
- A protocol is, “a formal set of rules, conventions and data structure that governs how computers and other network devices exchange information over a network”.

- The key **elements of protocols** include:
  1. **Syntax:** Refers to the structure or format of the data, meaning the order in which they are presented.
  2. **Semantics:** Refers to the meaning of each section of data of bits and how it should be interpreted.
  3. **Timing:** Refers to two characteristics namely, when data should be sent and how fast they can be sent.
- A protocol performs the following functions in communicating network:
  1. Protocol defines data sequencing rules.
  2. Protocol defines data routing rules which the most efficient path between the source and destination.
  3. Protocol defines data formatting rules which group of bits or characters within packet constitute data, control, addressing, or other information.
  4. Protocol defines flow control of information or data.
  5. It defines error control rules are designed to detect errors in messages and to ensure transmission of correct messages.
  6. Protocol facilitate connection establishment and termination rules that define how connections are established and terminated between networked devices.
  7. Protocols determine how devices are identified on a network (addressing).
- Network protocols are essential frameworks that govern how data is transmitted and managed across networks and ensure that devices can communicate effectively, securely, and efficiently.
- Some common protocols used in data communications and computer network include:
  1. **TCP (Transmission Control Protocol):** It is a connection-oriented protocol. TCP ensures reliable delivery of data between applications running on hosts communicating over an IP network.
  2. **FTP (File Transfer Protocol):** TCP is used for transferring files between a client and a server on a network. It supports both uploading and downloading files, making it essential for file management over the internet.
  3. **SMTP (Simple Mail Transfer Protocol):** SMTP is the standard protocol for sending emails across networks.
  4. **HTTP (Hypertext Transfer Protocol):** HTTP is used for transmitting hypertext via the Web. It facilitates communication between Web browsers and Web servers, allowing users to access websites and resources online.
  5. **User Datagram Protocol (UDP):** UDP is a connectionless protocol that allows for faster transmission of data without the overhead of establishing a connection or ensuring delivery.
  6. **Simple Mail Transfer Protocol (SMTP):** SMTP is the standard protocol for sending emails across networks. It specifies how email messages are formatted and transmitted between servers.
  7. **Post Office Protocol (POP3):** POP3 is used by email clients to retrieve emails from a remote server. It downloads emails to the local device, typically deleting them from the server after retrieval.
  8. **Dynamic Host Configuration Protocol (DHCP):** DHCP automates the assignment of IP addresses to devices on a network, allowing them to communicate effectively without manual configuration.
  9. **Border Gateway Protocol (BGP):** BGP is a standardized exterior gateway protocol used to exchange routing information between different autonomous systems on the internet, ensuring efficient data routing.
  10. **Internet Control Message Protocol (ICMP):** ICMP is used for diagnostic and control purposes in networking, such as sending error messages and operational information indicating success or failure when communicating with another host.

11. **Internet Protocol (IP):** IP is responsible for addressing and routing packets of data so they can travel across networks. It defines the format of packets and provides the addressing system that allows devices to identify each other on a network.

1.2.2 Protocol Standards

- Standards are essential in creating and maintaining an open and competitive market for equipment manufacturers and in guaranteeing national and international interoperability of data and telecommunications technology.
- Standards are guidelines or agreed upon ways for doing something to be followed by the vendors, manufacturers, government agencies, etc. to ensure the interconnectivity.
- Data communications standards can be classified into two types de facto (meaning "by fact" or "by convention") and de jure (meaning "by law" or "by regulation").
  - **De facto standards** that have not been approved by an organized body but have been adopted as standards through widespread use. For example, the QWERTY keyboard, Microsoft Word (.doc) and Excel (.xls) formats etc. are the de facto standards.
  - **De jure standards** are approved by an officially registered body. These De jure standards are usually led by governments or government-appointed agencies. The well-known examples of De jure standard include,
    - ASCII (American Standard Code for Information Interchange), the most common format for text files in computers and on the Internet.
    - TCP/IP (Transmission Control Protocol/Internet Protocol) is the IETF-endorsed standard communication language or protocol of the Internet.

1.2.3 Standards Organizations [S-23]

- Protocol standards organizations develop and maintain the specifications that define the protocols for communications, data exchange/transfer, and various technological processes.
- The standards organizations are guarantee national and international inter-operability of data/information and telecommunication technology and processes.
- Standards in data communication and network are developed through the cooperation of standards creation committees, forums and government regulatory agencies.

1. **Standards Creation Committees:** There are lot of organizations serving as standards creation committees. Some of them are explained below:
   - **International Organization for Standardization (ISO):** ISO is a multinational body whose membership is drawn mainly from the standards creation committees of various governments throughout the world. ISO formed in 23 February 1947, provides a range of standards to facilitate interoperability, reliability and security across diverse data communications and network systems and platforms. ISO comprises of 164 national standard bodies from various countries worldwide. The Open Systems Interconnection (OSI) model as a networking protocol is a major contribution of the ISO to the data communications world.
   - **International Telecommunications Union-Telecommunications Standards Sector (ITU-T):** ITU-T was earlier known as the Consultative Committee for International Telegraphy and Telephony (CCITT). ITU-T established in 1865, focuses on global telecommunications standards related to data communications. ITU-T standards are foundational for global telecommunications and Internet networks, helping ensure that systems and devices operate consistently and efficiently and securely across international boundaries. The ITU-T is a division of the International Telecommunication Union (ITU) that develops standards for telecommunication, Information and Communication Technologies (ICT), and related services. As a United Nations specialized agency, ITU-T coordinates globally recognized standards for telecommunications to ensure seamless, efficient, and secure communication across international networks.

- **Institute of Electrical and Electronics Engineers (IEEE):** The IEEE is a leading organization in the development of standards for data communication and computer networks. Established in 1884, IEEE focuses on fostering technological innovation and excellence, particularly in electrical engineering, electronics, and computer science. IEEE plays a major role in developing standards for data communications and computer network, specifically in the design and interoperability of networking hardware and protocols. Its standards for data communication, especially the IEEE 802 standards, are essential for wired, wireless, and broadband communications worldwide. IEEE also covers the development and adoption of international computer and communications standards.
- **American National Standards Institute (ANSI):** ANSI is a private non-profit organization that does not have any direct ties with the US federal government. Generally, all ANSI projects are undertaken for the social benefit of the US citizens. Professional groups, regulatory bodies, government, and consumer groups represent ANSI. The ANSI plays a significant role in data communication and networking by accrediting and coordinating the development of standards that address critical areas like data transfer, network infrastructure, security, and interoperability across telecommunications and IT systems.
- **Electronic Industries Association (EIA):** EIA is a non-profit organization that is aligned with ANSI. EIA focus is public awareness and lobbying for standards. The main contributions to the data communications technology are the development of interfaces for physical connections and electronic signal specifications for data communications. The standards created by EIA remain widely used and foundational to various aspects of modern communication networks. One of the notable standards of EIA is serial communication standard RS-232. The RS-232 defines the electrical characteristics and timing of signals for serial communication between computers and peripheral devices.
- **Telecommunications Industry Association (TIA):** TIA is the leading trade association in the communications and information technology industry. It represents manufacturers of communications and information technology products and also facilitates the convergence of new communications networks. TIA is a key organization in setting standards for data communication and networking, specifically focusing on telecommunications infrastructure, cabling, wireless communication, and emerging technologies such as 5G and IoT. TIA's standards, especially those developed with ANSI, are widely adopted in commercial buildings, data centers, and various industries for ensuring reliable, high-performance communication systems. TIA represents more than 400 companies involved in high-speed communications networks and aims to accelerate innovation in Information and Communication Technology (ICT). The TIA-942 standard provides guidelines for the design and implementation of data centers.

2. **Forums:**
   - The main drawback of standards committees is notorious for the slow pace of developments and decision-making.
   - The standards organizations also take too much time in completing the procedures and standardize the technology.
   - The forums dealing dedicatedly in a particular technology, they speed up and use the technology without waiting for the standards organizations.
   - Forums are basically community standards intending to accelerate the concerned technology innovation and creating standards.
   - User groups, industry representatives, university students and experts come together and set up forums to address the various issues and concerns of data communications technology, and come up with standards from time to time.
   - Examples of Forums include, Internet Society (ISOC), Internet Engineering Task Force (IETF), Frame Relay Forum and ATM Forum.

3. **Regulatory Agencies:**
   - Government appointed agencies, for example, Federal Communications Commission (FCC) of the US are always involved in regulating standards.
   - This Government appointed agencies help to protect the interests of the general public in areas such as radio, television and wired communications.
   - Every portion of communications technology must be approved by FCC before it can be sold in the market.
   - FCC periodically reviews the rates changed by service providers, technical specifications of communication hardware and divides and allocates ratio frequencies, etc.

1.2.4 Bandwidth [S-22, W-24]

- Bandwidth refers to the maximum rate at which data can be transmitted over a communication channel/medium, such as a wired or wireless network in a given amount of time.
- Bandwidth is a range of frequency in which the gain of the system or output signal. The bandwidth is depending upon the pulse width of data.
- If the pulse width decreases, the corresponding bandwidth required increases.
- Fig. 1.7 (a) shows 70.7% of the maximum value.
- For digital signal, the bandwidth is specified in terms of bits per second (bps), whereas for analog signal it is in cycles per second or Hertz (Hz).

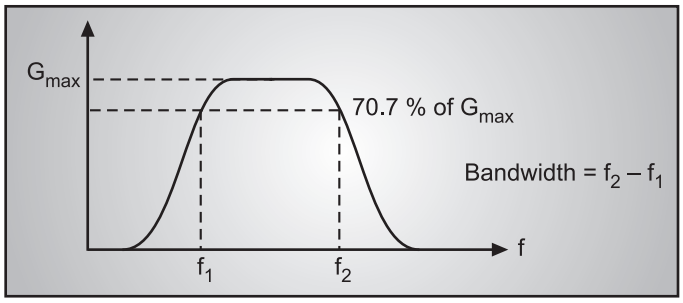


Fig. 1.7 (a)

1. Bandwidth of a Signal: [W-24]

- The maximum range of frequencies a message signal contains is known as signal bandwidth.
- Bandwidth of a signal is defined as, "the frequency range over which an information signal is transmitted".
- Bandwidth of analog and digital signals is calculated in separate ways; analog signal bandwidth is measured in terms of its frequency (Hz) but digital signal bandwidth is measured in terms of bit rate (bits per second, (bps)).
- Basically, the bandwidth is the difference between the upper and lower frequency limits of the signal.
- Each of these signals (voice, music etc. signals) will have its own frequency range and this frequency range of a signal is known as its bandwidth.
- The range of voice signal is 300 Hz to 3400 kHz as shown in Fig. 1.7 (b).
- Therefore, BW (Bandwidth) = $f_2 - f_1$
  = 3400 – 300
  = 3100 Hz

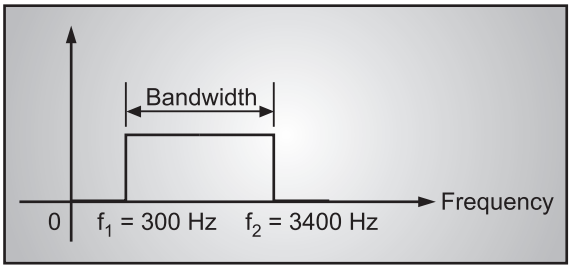


Fig. 1.7 (b): Bandwidth of Voice Signal

2. Bandwidth of a Medium: [W-24]

- The signal travels over some medium such as optical fiber, co-axial cable and so on. Bandwidth of a medium also known as channel bandwidth. The maximum range of frequencies a channel can allow to pass is known as channel bandwidth.
- A channel is the medium through which the signal carrying information will be passed. The channel bandwidth determines the type of signal to be transmitted i.e. analog or digital.

- Bandwidth of a medium is defined as, "the maximum frequency it can allow to pass through it without attenuating it and without distorting the shape of the signal".
- When the medium has less bandwidth than required, then signal distortion will take place as shown in Fig. 1.8.

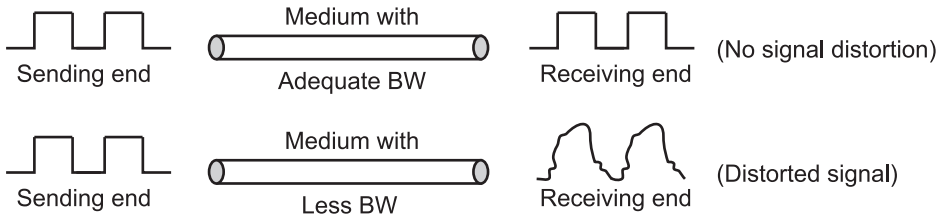


Fig. 1.8

Terms related to Bandwidth:

1. **Amplitude:** The maximum value of an AC (Alternating Current) quantity is called as amplitude. It is measured in volts, amperes or watts depending on the type of signal. Amplitude represents the strength or intensity of the signal.
2. **Frequency:** It is defined as the number of cycles completed by an AC quantity in one second. Its unit is Hz (Hertz). Frequency is the rate at which the signal oscillates.
3. **Phase:** Phase describes the position of the waveform with respect to time zero. It is measured in degree or radian. The position of the waveform in its cycle at a given point in time.
4. **Time Period:** It is defined as the time taken in seconds by the waveforms of an AC quantity to complete one cycle.
5. **Wavelength:** The wavelength of a signal refers to the relationship between frequency (or period) and propagation speed of the wave through a medium. The wavelength is the distance a signal travels in one period. It is given by Wavelength = Propagation Speed × Period.

1.2.5 Data Transmission Rate [S-22, W-22]

- Bandwidth is a range of frequencies available for data transmission. It refers to data transmission rate.
- Data transmission rate refers to the amount of digital data that can be transmitted from one device to another over a network or data channel within a given time period.
- Data rate depends on the following three factors:
  1. The bandwidth available,
  2. The level of the signals we use, and
  3. The quality of the channel (the level of noise).
- In computer data communication, the signal bandwidth and the required bandwidth of the medium increase with increase in bit rate. For this reason, bit rate and bandwidth are proportional to each other.
- The general relation between required bandwidth (B) and bit rate (n) is given below:

$$B \geq \frac{n}{2} \qquad \text{or} \qquad n \leq 2B$$

- Data transmission rate in bits per second (bps) is a standard measure of how much data is transmitted per second over a network or communication medium.

1.2.6 Baud Rate and Bits Per Second [S-22, W-24]

- The terms Baud Rate and Bit Rate are very commonly used terms in the field of data communication. The Bit rate refers to the amount (number) of bits that get transmitted in one second. The Baud rate refers to the total number of signal units transmitted in one second.

Bit Rate: **[S-22]**

- It is the number of bits transmitted in one second. It is expressed as bits per second (bps). Bits per second (bps) is a unit of measurement for data transfer rate, indicating how many bits of data are transmitted per second across a communication medium.
- Relation between bit rate and bit interval can be represented as Bit Rate = $\frac{1}{\text{Bit Interval}}$.
- Other units used to express bit rate are Kbps, Mbps and Gbps.
  - 1 kilobit per second (Kbps) = 1,000 bits per second.
  - 1 Megabit per second (Mbps) = 1,000,000 bits per second.
  - 1 Gigabit per second (Gbps) = 1,000,000,000 bits per second.
- Bit rate is also called as signaling rate. It is defined as, “the number of bits which can be transmitted in a second”.

Bit Interval:

- The bit interval is the time required to send one single bit (0 or 1).
- The bit rate is the number of bit intervals per second. This means that the bit rate is number of bits sent in one second, usually expressed in bits per second (bps).

Baud Rate: **[S-22, W-24]**

- Baud rate is the number of times the signal level changes in a channel per second. Baud rate is less than or equal to the bit rate.
- It is the rate of signal speed, i.e. the rate at which the signal changes.
- A digital signal with two levels '0' and '1' will have the same baud rate and bit rate.
- The Fig. 1.9 shows three signal of period (T) 1 second:
  - Signal with a bit rate of 8 bits/sec. and baud rate of 8 baud/sec.
  - Signal with a bit rate of 16 bits/sec. and baud rate of 8 baud/sec.
  - Signal with a bit rate of 16 bits/sec. and baud rate of 4 baud/sec.

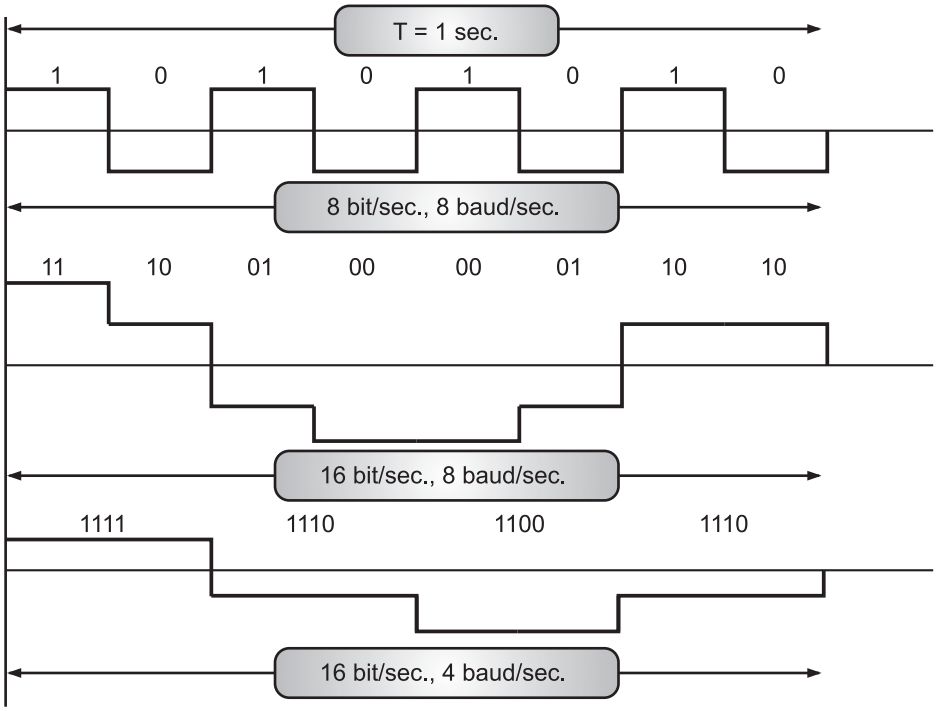


Fig. 1.9: Three Signals with different Bit Rates and Baud Rates

Example 1: A signal carries three bits in each signal element. If 1200 signal elements are sent per second, find the baud rate and the bit rate.

Solution:

Baud rate = Number of signal elements
= 1200 bps
Bit rate = baud rate × Number of bits per signal element
= 1200 × 3
= 3600 bps.

Example 2: The bit rate of a signal is 2000. If each signal element carries five bits, what is the baud rate?

Solution:

Baud rate = Bit rate / Number of bits per signal element
= 2000 / 5
= 400 bps.

1.3 MODES OF COMMUNICATION [S-22, W-22, S-23, W-23, S-24, W-24]

- Communication mode refers to the mechanism of transferring of data between two devices connected over a network.
- The direction of data flow between two linked devices in a network is called as mode of communication. Communication mode is also called transmission mode.
- There are three types of direction of data flow namely, simplex mode, half-duplex mode and full-duplex mode.

1.3.1 Simplex Communication Mode [S-22, W-22, W-23, S-24, W-24]

- In simplex communication mode, the communication can take place in only one direction i.e. data can be sent only in one direction.
- In simplex mode, a terminal can only send data and cannot receive it or it can only receive data but cannot send it.
- It means that in simplex mode communication is unidirectional.
- In computer system, the keyboard, monitor and printer are examples of simplex devices.
- The keyboard can only be used to enter data into computer, while monitor and printer can only accept (display/print) output.

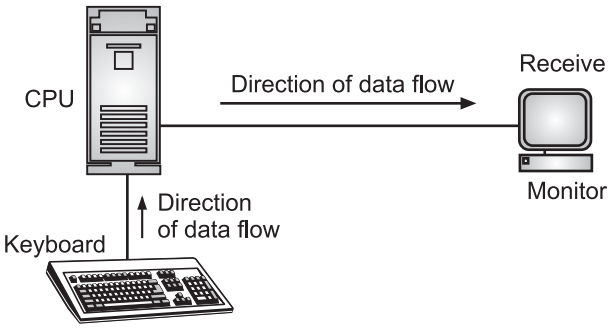


Fig. 1.10: Simplex Communication Mode

Advantages of Simplex Communication Mode:

1. Simplex communication mode generally, less expensive to implement due to their simplicity and lower hardware requirements.
2. Cheaper in cost because of requiring minimal hardware and software requirements.

Disadvantages of Simplex Communication Mode:

1. Simplex communication mode allows data to flow in only one direction.
2. In situations where feedback or responses are needed, simplex communication mode can be inadequate.