UNIT

01

Introduction to Data Communication

Names of Sub-Units

Introduction, Components of Data Communication, Data Representation and Data Flow. Network Devices, Types of Connection, Topology, Categories of Networks, Interconnection of Networks, Applications of Networks, History of Network, Protocols and Standards.

Overview

This unit begins by learning about the concept of data communication. Then, the unit discusses components of data communication. Next, the unit discusses the concept of data representation and data flow. Further, the unit discusses the network devices, types of connection, and network topology. This unit also discusses the categories of network and interconnection of networks. Then, the unit discusses the applications of network and history of network. Towards the end, the unit discusses the protocol and standards.

Learning Objectives

In this unit, you will learn to:

- Describe the concept of computer networks and their objectives
- Explain the concept of data representation, data flow, and network devices
- Describe the network topology, categories of networks, and interconnection of networks
- Define the applications of networks and history of network
- Explain the protocols and standards of network

Learning Outcomes

At the end of this unit you would:

- Assess the knowledge about data communication and computer networks
- Analyse the concept of data representation, data flow, and network devices
- Examine the significance of the network topology, categories of networks, and interconnection of networks
- Assess the applications of networks
- Examine the idea about network protocols and standards

Pre-Unit Preparatory Material

- https://archive.mu.ac.in/myweb_test/syllFybscit/dcn.pdf

1.1 INTRODUCTION

A computer network is a collection of interconnected computers and electronic devices such as printers. This connectivity allows computers to share information more easily. Computers can communicate with one another via wired or wireless medium.

1.2 DaTa aND INFORMaTION

Data is the collection of basic facts, whereas information is the processing of data that allows us to make judgments.

When the results of a particular test are announced, the data of all students is included, and when you find the marks you earned, you have the knowledge you need to know whether you have passed or failed. The term “data” refers to any information that is presented in a format that can be manipulated.

1.3 DaTa COMMUNICaTION

Data communication is the process of transferring data between two devices in a meaningful way through a communication medium.

Devices must be integrated into the communication system. The communication system is constructed of consisting of both hardware and software, to ensure efficient communication.

1.3.1 Characteristics of Data Communication

The following are the characteristics of data communication:

1. Delivery: The data to be transmitted must be supplied at the right place.
2. accuracy: The data should be supplied in its original form, with no changes.
3. Timeliness: The data must be sent without delay via the communication mechanism.
4. Jitter: In a network, data is divided into smaller groups (packets) and sent one at a time, individually. The difference in arrival times between two people.

1.3.2 Components of Data Communication

The following five components are critical to the communication system's success.

1. Data/Message: The data/message is the most important component of the communication system. The information exchanged between the source and the destination is referred to as data/message.
2. Source: A source is a device that creates and transmits data to the destination.
3. Destination: The device that receives the data is known as the destination.
4. Medium: It serves as a transport for data as it travels from the source to destination. The route is provided by the carrier, which might be wired or wireless.
5. Protocol: A protocol is a collection of rules that regulate the proper transmission of data manner.

1.4 DaTa REPRESENTaTION

Data is a collection of unprocessed facts that is used to derive information. Data may be represented in several different ways. The following are some examples of data types used in communications:

1. Text: The text consists of a blend of upper- and lower-case alphabets. It is saved as a bit pattern. ASCII and Unicode are the most widely used encoding systems.
2. Quantities: Numbers are made up of digits ranging from 0 to 9. It is saved as a bit pattern. ASCII and Unicode are the most widely used encoding systems.
3. Images: There is a popular adage that "a picture is worth a thousand words." Images are digitally saved in computers.

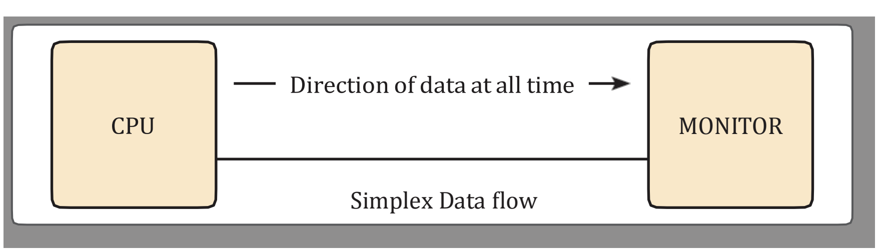
   The smallest constituent of a picture is a pixel. A picture or image is a matrix of pixel components, to put it simply.

   The bits are used to represent the pixels. Each pixel would require a variable number of bits to indicate the value of a pixel depending on the kind of picture (black and white or coloured).

   The number of pixels (also known as resolution) and the bit pattern used to represent the value of each pixel determine the size of a picture.
4. audio: Data can take the form of sound, which can be captured and disseminated. For example, what we hear on the radio is a data or information source. The data in audio is continuous rather than discrete.
5. Video: Use of video: The term "video" refers to the transmission of data in the form of an image or a movie.

1.5 DaTa FLOW

The data flow specifies the direction in which data flows between the source and the destination. Simplex, half-duplex, or full duplex data transfer are all possibilities. Figure 1 shows the three methods of the information stream:



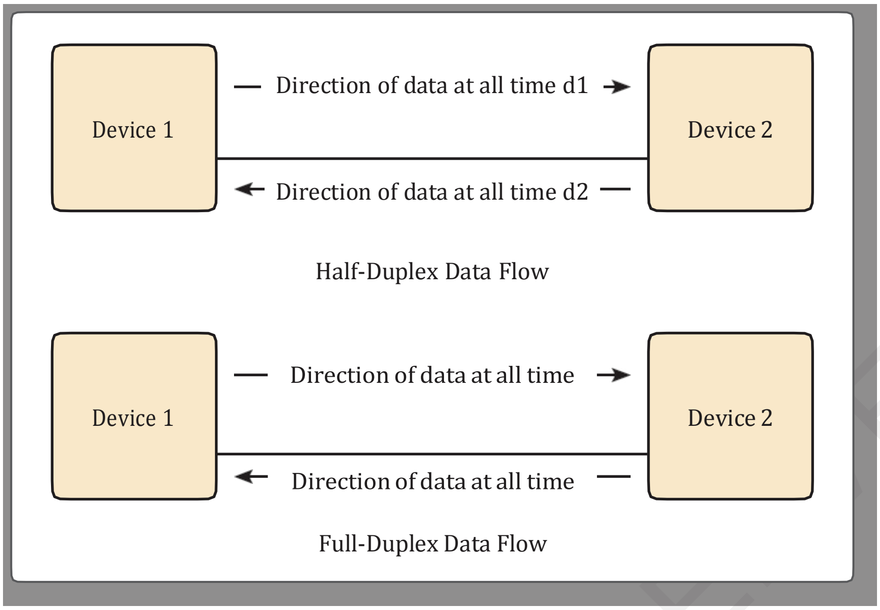


Figure 1: Methods of Information Stream

1.5.1 Simplex

In simplex mode, the course of the information stream is unidirectional. One of the gadgets can communicate the information and another gadget can get consistently (Figure 1 Part 1). A model is the CPU that sends the information to the screen constantly.

1.5.2 Half Duplex

Into equal parts duplex mode, the information can be communicated on both bearings yet not simultaneously (gadget 1 to gadget 2 or gadget 2 to gadget 1) (Figure 1 Part 2). One gadget can send, and another can receive at the same time. The model is a walkie-talkie. The whole medium is utilized for the single direction transmission.

1.5.3 Full Duplex

In full-duplex mode, the information can be sent on both bearings (gadget 1 to gadget 2 and gadget 2 to gadget 1) at the same time (Figure 1 Part 3). One gadget can send, and another can receive at the same time. The model is phone correspondence. In this, the whole medium is partitioned for the two-way transmission.

1.6 NETWORk DEVICES

Network devices, often known as networking hardware, are physical devices that allow hardware on a computer network to communicate and interact with one another. The following are common network devices:

- Bridge
- Gateway
- Modem
- Repeater

- Access Point
- Hub
- Switch Router

1.7 TYPES OF CONNECTION

A network, as we already know, is made up of two or more devices connected via a communication means. The medium serves as a physical connection between two devices. The devices' connection is divided into two types: Point-to-point and multipoint.

1.7.1 Point-to-Point

It establishes a direct and dedicated connection between two devices (usually the source and the destination). Only these two devices have access to the link's complete transmission capacity. For instance, a connection between a display and a computer.

Figure 2 shows the point-to-point connection:

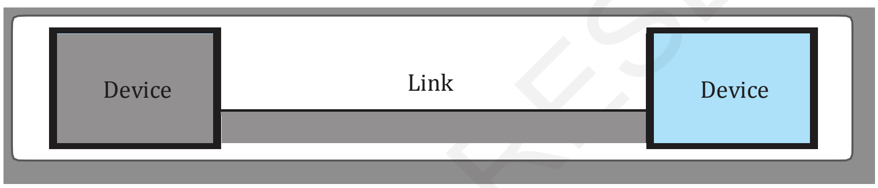


Figure 2: Point-to-Point Connection

1.7.2 Multiple Points

Many devices share a connection, and all devices share the transmission capacity connected. Consider a cable television network or a client-server network. Figure 3 shows the multipoint connection:

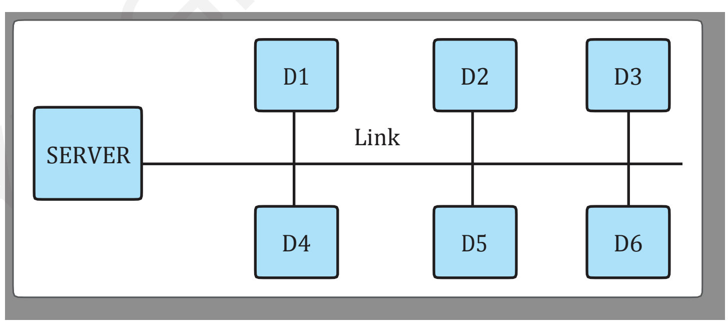


Figure 3: Multipoint Connection

1.8 NETWORk TOPOLOgY

The manner in which computer systems or network devices are connected is referred to as a network topology. Both the physical and conceptual features of a network may be defined by topologies. In the same network, logical and physical topologies might be the same or distinct. Some important points of network topology are listed below:

- Cost: For a network to be cost efficient, the installation cost should be kept as low as possible. This can be accomplished using well-understood media and, to a lesser extent, by reducing the distances involved.

- Flexibility: Because office furniture, internal walls, and other elements change often, the network architecture should allow for quick reconfiguration. This entails relocating existing nodes as well as creating new ones.
- Reliability: A network's failure might take two forms. To begin with, a single node might fail. This is not as bad as the second sort of failure, in which the network fails to function. The network architecture selected can assist by allowing the location of the issue to be discovered and some methods of isolating it.

1.8.1 Star Topology

The star topology is the most prevalent network topology, in which each device in the network is connected to a central hub. The central hub is the sole way for devices to interact with one another.

Advantages of Bus Topology

Star topologies are popular because they make it easy to control your whole network from one location. Because each node is connected to the central hub separately, if one fails, the remainder of the network will continue to operate normally, making the star topology a reliable and secure network structure. Devices can also be added, deleted, or updated without bringing the entire network down. On the physical side of things, the star topology's layout requires relatively minimal cable to properly link the network, allowing for simple deployment and maintenance as the network grows or shrinks. The network design's simplicity makes life simpler for administrators as well because it's simple to spot where mistakes or performance issues are occurring.

Disadvantages of Bus Topology

On the other hand, if the central hub goes down, the entire network falls with it. Administrators should not have too many problems provided the central hub is properly controlled and maintained. The central node's settings and technical requirements also limit the network's total bandwidth and performance, making star topologies costly to set up and manage.

1.8.2 Bus Topology

This design, also known as backbone network topology, uses drop lines to link all devices to a single cable. The advantages of a bus network architecture include its simplicity and ease of installation, as it requires less wire than alternative topologies.

advantages of Ring Topology

Because the layout is basic, all devices may be linked with a single coaxial or RJ45 cable, bus topologies are a suitable, cost-effective alternative for smaller networks. More nodes may be readily added to the network, if necessary, by connecting extra wires.

Disadvantages of Ring Topology

Bus topologies, on the other hand, are susceptible since they require a single connection to convey data. If a cable fails, the entire network falls, which may be time-consuming and costly to repair, but this is less of a concern with smaller networks. Because there is only so much capacity, bus topologies are best suited for small networks. Each additional node slows transmission speeds.

Furthermore, because data is "half-duplex," meaning it can't be delivered in two ways at the same time, this structure isn't ideal for networks with high traffic volumes.

1.8.3 Ring Topology

A device is connected to the two units on either side of it through two dedicated point-to-point links, forming a ring of devices through which data is passed via repeaters until it reaches the destination device.

advantages of Ring Topology

When data is transferred, packets move through the circle, passing through each of the intermediary nodes until they reach their destination, because each device is only linked to the ones on either side. Repeaters can be used to guarantee packets arrive accurately and without data loss when a big network is set up in a ring topology. Ring topologies are efficient in transmitting data without mistakes because only one station on the network may send data at a time, substantially reducing the possibility of packet collisions. Ring topologies are often cost-effective and quick to set up, and the detailed point-to-point connection of the nodes makes it reasonably easy to spot network problems or misconfigurations.

Disadvantages of Ring Topology

Ring topologies, despite their popularity, are prone to failure if not adequately controlled. Because data transfer between nodes along each ring is unidirectional, if one node goes down, the entire network goes down with it. As a result, it's vital to keep track of each node and ensure that it's in good functioning order. Even if you're diligent and attentive to node performance, a transmission line failure might bring your network to a halt.

The issue of scalability should be considered as well. Because all the devices on the network share bandwidth in a ring architecture, adding additional devices might cause overall communication delays. To avoid overburdening the network's resources and capabilities, network managers must be careful of the devices introduced to the topology. In order to reconfigure, add, or delete nodes, the entire network must be taken offline. While this isn't the end of the world, it may be unpleasant and costly to schedule network downtime.

1.8.4 Tree Topology

This architecture is made up of a parent-child hierarchy with bus networks connecting star networks. From a single root node, nodes branch out in a linear fashion, and two linked nodes have just one common connection.

advantages of Tree Topology

The insertion of nodes and network growth are made simple by combining aspects of the star and bus topologies. Errors on the network may also be easily troubleshooted because each branch can be separately examined for performance concerns.

Disadvantages of Tree Topology

In a tree topology structure, the health of the root node is as important as it is in a star topology structure. The different node branches will become disconnected if the central hub fails, while connection within but not between branch systems would continue. Adding more nodes to a tree topology may rapidly make appropriate administration a cumbersome, not to mention expensive, experience due to the hierarchical complexity and linear nature of the network layout. The enormous quantity of wiring necessary to link each item to the next inside the hierarchical arrangement makes tree topologies costly.

1.8.5 Hybrid Topology

A hybrid topology is one that combines two or more topologies.

advantages of Hybrid Topology

The major benefit of hybrid structures is the degree of flexibility they give, since there are few network architectural restrictions that a hybrid arrangement cannot handle.

Disadvantages of Hybrid Topology

However, each network architecture has its own set of drawbacks, and as a network develops in complexity, so does the amount of expertise and know-how required of the administrators to keep things running smoothly. When designing a hybrid network architecture, there's also the financial cost to consider.

1.9 CaTEgORIES OF NETWORkS

There are five different types of communication networks:

- Local area Network (LaN): It's meant for small physical regions like an office, a collection of buildings, or a factory. LANs are extensively utilised because they are simple to construct and troubleshoot. Local area networks (LANs) connect personal PCs and workstations. Through LAN, we may utilise many topologies such as Star, Ring, Bus, Tree, and so on. A local area network (LAN) can be as basic as linking two computers to share files and network, or as sophisticated as joining a full building. LAN networks are also commonly used to share resources like as printers, shared hard drives, and other such items.
- Metropolitan area Network (MaN): It was created in the 1980s. It's essentially a more powerful version of LAN. It's also known as MAN, and it's based on the same technology as LAN. It is intended to cover the entirety of the city. It might be a single cable or a way of linking many LANs into a bigger network. It is mostly owned and run by a single private or public corporation.
- Wide area Network (WaN): It's also known as WAN. A WAN can be either a private or a public leased network. It is used to describe a network that spans a vast area, such as a country's cover states. It takes plenty of time and effort to create and maintain. PSTN or satellite connections are the communication mediums utilized by WAN. Low data rates are used in WAN.
- Wireless Network: The concept of digital wireless communication is not new. Previously, wireless networks were implemented using Morse code. Modern digital wireless systems perform better, but the underlying concept remains the same.
- Inter Network: The Internet, sometimes known as the Inter Network, is a collection of two or more networks. Inter networks are created by connecting two or more separate networks using equipment such as routers, gateways, and bridges.

1.10 INTERCONNECTION OF NETWORkS

In a parallel computer, an interconnection network transmits data from any source node to any desired destination node. With as little delay as feasible, this task should be done. It should be able to handle a high number of such transfers at the same time. In addition, it should be cheap in comparison to the rest of the system. The network is made up of connections and switches that aid in the transmission of data from the source to the destination node. The topology, routing algorithm, switching strategy, and flow management mechanism of a network define it.

High-speed computer networks are interconnection networks, often known as Multi-Stage Interconnection Networks (or MINs). They're links between nodes, each of which can be a single CPU, a collection of processors, or a memory module.

These connections transmit data from one processor to another or from the processor to the memory, allowing the job to be split down and computed in parallel. You might, for example, have one network with a bunch of processors or computers on one end and a memory pool on the other.

Topology refers to the way in which nodes are connected to one another. Static and dynamic topology are the two basic forms of topology.

Switching elements make up interconnection networks. The pattern used to link individual switches to other elements such as processors, memory, and other switches is known as topology. Data can be exchanged between processors in a parallel system via a network.

- Direct Connection Networks: Direct connection networks are made up of nodes that are connected through point-to-point connections. The point-to-point links in these networks are fixed, making them static. Rings, meshes, and cubes are examples of direct networks.
- Indirect Connection Networks: Networks with no established neighbors are known as indirect networks. The connection topology can be dynamically modified to meet the needs of the application. Bus networks, multistage networks, and crossbar switches are the three types of indirect networks.
- Bus Networks: A bus network is made up of several bit lines that are connected to a number of resources. The data and address lines are time multiplexed when buses use the same physical lines for data and addresses. An arbitrator is necessary when there are several bus-masters attached to the vehicle.
- Multistage Networks: A multistage network is made up of several switch stages. It is made up of 'axb' switches linked in a specific interstage connection pattern (ISC). For many multistage networks, small 2x2 switch components are a popular choice. The network's delay is determined by the number of phases. Different interstage connection arrangements might be chosen. various types of multistage network can be created.
- Crossbar Switches: A crossbar switch is made up of a series of basic switch components that may be turned on and off to form or break a connection. A link between a processor and a memory can be established by turning on a switch element in the matrix. All communication possibilities are possible with crossbar switches since they are non-blocking.

The following three essential components make up interconnection networks:

- Links: A link is a cable made up of one or more optical fibres or electrical wires connected to a switch or network interface port at each end via a connector. The initial digital information stream is obtained by transmitting an analogue signal from one end and receiving it at the other.
- Switches: A switch is made up of a collection of input and output ports, an internal "cross-bar" that connects all input to all output, internal buffering, and control logic that affects the input-output connection at any given moment. The number of input ports is usually the same as the number of output ports.
- Network Interfaces: The network interface differs from switch nodes in that it may be linked via specific links. The packets are formatted by the network interface, which also produces routing and control information. In comparison to a switch, it may include input and output buffering. It can do end-to-end error checking as well as flow control. As a result, the cost is determined by the complexity of the processing, storage capacity, and number of ports.

1.11 aPPLICaTIONS OF NETWORkS

Data communication networks have quickly become an integral element of commerce, industry, and entertainment in the short time they've been around. The following are some examples of network applications in various fields:

- Sales and marketing: Both marketing and sales companies make considerable use of computer networks. They're used by marketing professionals to gather, exchange, and evaluate data on client demands and product development cycles. Teleshopping, which employs order entry computers or telephones connected to an order-processing network, and on-line reservation services for hotels, airlines, and other businesses are examples of sales applications.
- Banking and financial services: Financial services are now entirely reliant on computer networks. Credit history searches, foreign exchange and investment services, and electronic funds transfer (EFT), which lets a user to transfer money without visiting a bank, are all examples of applications (an automated teller machine is a kind of electronic funds transfer; automatic pay-check deposit is another).
- The manufacturing industry: Many parts of production, including the manufacturing process itself, use computer networks nowadays. Computer-assisted design (CAD) and computer-assisted manufacturing (CAM), both of which allow several people to work on a project at the same time, are two applications that leverage networks to offer vital services.
- Electronic messaging: Electronic mail is probably the most utilised network application (e-mail).
- Directory services: Directory services enable for the storage of lists of files in a central place to speed up global search operations.
- Information services: Bulletin boards and data banks are examples of network information services. An information service is a website that provides technical details for a new product.
- Electronic Data Exchange (EDI): EDI enables the movement of business data (including documents such as purchase orders and invoices) without the use of paper.
- Teleconferencing: Teleconferencing allows people to hold meetings without having to be in the same room. Simple text conferencing is one of the applications (where participants communicate through their keyboards and computer monitors). Voice conferencing (in which people from various places interact over the phone at the same time) and video conferencing (where participants can see as well as talk to one another).
- Cellular phone: Previously, two parties desiring to utilise the telephone company's services had to be connected by a fixed physical connection. Wireless phone connections may now be maintained even when travelling over long distances thanks to today's cellular networks.
- Cable television: Future cable television services may offer video on demand, as well as the same information, financial, and communications services that telephone companies and computer networks presently provide.

1.12 HISTORY OF NETWORk

A computer network is a type of digital telecommunications network that allows nodes to exchange resources among themselves. Data is exchanged between computing devices in computer networks via connections (data links) between nodes. These data connections are made via cable media such as wires or fiber optic cables, or wireless media like Wi-Fi. The Arpanet development in the late 1960s and early 1970s is credited for kickstarting computer networking as we know it today. There were "networks" built by computer vendors prior to that time to connect terminals and distant job entry stations to a mainframe.

In 1940, George Sitbit used a teletype machine for transporting instructions of a problem set from his model to his complex number calculator, and received results. Early networks of communicating computers were begun in the 1950s, including the military radar system Semi-Automatic Ground Environment (SAGE). Later, in the 1960s, the ARPAnet design incorporated the concept of networking between computers that saw each other as equal peers in order to accomplish "resource sharing." Another notable point of the Arpanet effort was its dependence on the then-novel technology of packet switching, rather than the more typical message or circuit switching, to efficiently distribute communication resources among "bursty" users.

Table 1 shows the progression of computer networks from network to internet throughout time:

Table 1: Progression of Computer Networks

Year	Event
1961	Leonard Kleinrock introduced the notion of ARPANET, one of the first computer networks, in his article "Information Flow in Large Communication Nets" in 1961.
1965	Donald Davies created the word "packet" to represent data transferred between computers via a network in 1965.
1969	The Internet was formally launched on October 29, 1969, at 10:30 p.m., when the first data transfer was transmitted between UCLA and SRI.
1970	NCP (NetWare Core Protocol) was created by Steve Crocker and a team at UCLA in 1970. NCP is a NetWare-based file sharing mechanism.
1971	In Hawaii, ALOHAnet, a UHF wireless packet network, is utilised to connect the islands. Although, it is not Wi-Fi, it aids in the establishment of Wi-Fi.
1973	In 1973, an experimental VoIP call was made, revealing VoIP technology and capabilities for the first time. However, it wasn't until 1995 that the first software allowing users to conduct VoIP calls became accessible.
1974	In 1974, Xerox introduced the first routers. These early routers, however, were not regarded genuine IP routers.
1976	In 1976, Ginny Strazisar created the first real IP router, dubbed a gateway at the time.
1978	In 1978, Bob Kahn devised the TCP/IP protocol for networks, which he developed with Vint Cerf's aid.
1981	The National Science Foundation of the United States created CSNET (Computer Science Network) in 1981.
1983	In 1983, Paul Mockapetris and Jon Postel created the first DNS.
1986	In 1986, BITNET II was established to overcome bandwidth difficulties with the first BITNET.
1988	The first publication on network firewall technology was in 1988. The first firewall, known as a packet filter firewall, was built by Digital Equipment Corporation the same year, according to the report.
1990	In 1990, Kalpana, a network hardware firm based in the United States, designed, and released the first network switch.

Year	Event
1996	IPv6 was launched in 1996 as an upgrade to IPv4 that included a larger number of IP addresses, better routing, and integrated encryption.
1997	In June 1997, the first version of the 802.11 Wi-Fi standard was released, with transmission rates of up to 2 Mbps.
1999	In September 1999, the WEP Wi-Fi encryption standard was released for use with 802.11b.
2003	In 2004, the WPA2 encryption technology was launched as an upgrade to and replacement for WPA. By the year 2006, all Wi-Fi devices must be WPA2 certified.
2009	In 2009, the Wi-Fi standard 802.11n became official. It can operate on the 2.4 GHz and 5 GHz bandwidths and has faster transmission rates than 802.11a and 802.11g.
2018	In January 2018, the Wi-Fi Alliance launched WPA3 encryption for Wi-Fi, which offers security improvements over WPA2.

1.13 PROTOCOLS

A procedure is essentially the same as a rule. Communication takes place between entities in various systems in computer networks. Anything that can transmit or receive data is considered an entity. Any two entities can't just transmit each other bitstreams and expect to be understood. In order for the communication to occur, the entities must agree on a protocol.

A protocol is a collection of rules that regulate the transmission of data. What is transmitted, how it is communicated, and when it is communicated are all defined by the protocol. A protocol's essential elements are as given below:

- Syntax: This word mostly relates to the data's structure or format, which essentially refers to the order in which information is displayed. A basic protocol, for example, may require the first 8 bits of data to be the sender's address, the second 8 bits to be the receiver's address, and the remainder of the stream to be the message itself.
- Semantics: The meaning of each chunk of bits is referred to by this word. How is a certain pattern should be understood, and what action should be performed based on that interpretation? Does an address, for example, specify the path to be travelled or the message's eventual destination?
- Timing: Timing is based on two aspects: when data should be provided and how quickly it can be sent. When a sender delivers data at 100 Mbps but the receiver can only take 1 Mbps, the receiver will be overloaded and some data will be lost.

Some rules and processes should be agreed upon at the transmitting and receiving ends of the system in order for communication between devices to be successful. Protocols are the names given to such regulations and processes. For different forms of communication, multiple protocols are employed.

Network Protocols are a collection of rules that control how information is exchanged in a simple, reliable, and secure manner. We need to understand how a network is logically structured or built before we can examine the most common protocols used to transmit and receive data over a network. The Open Systems Interface (OSI) proposed by ISO. paradigm is the most widely used methodology for establishing open communication between two systems. There are some protocols for different-different usability:

- OSI Model (Open Systems Interface Model)
- TCP/IP (Transmission Control Protocol/Internet Protocol)
- FTP (File Transfer Protocol)
- PPP (Point to Point Protocol)

1.13.1 OSI Model (Open Systems Interface Model)

Because it does not describe the precise services and protocols for each layer, the OSI model is not a network architecture. It simply defines the input and output data for each layer, indicating what it should perform. It is up to network architects to implement the layers based on their requirements and available resources. These are the seven layers of the OSI model:

- Physical layer
- Data link layer
- Network layer
- Transport layer
- Session layer
- Presentation layer
- Application layer

Figure 4 shows the OSI reference model:

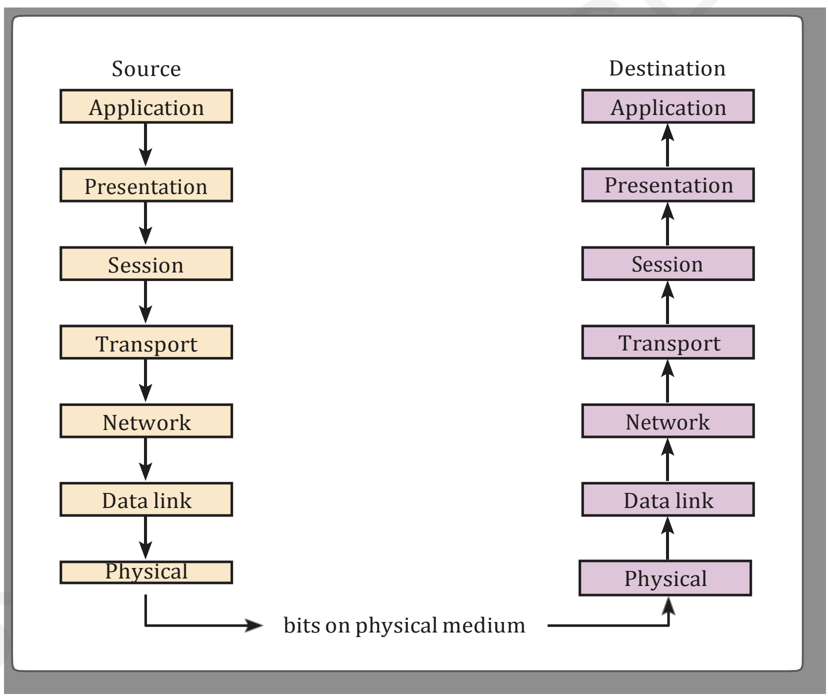


Figure 4: OSI Reference Model

1.13.2 TCP/IP

Transmission Control Protocol/Internet Protocol (TCP/IP) is the acronym for Transmission Control Protocol/Internet Protocol. TCP/IP is a collection of layered protocols used for Internet communication. This suite uses a client-server communication architecture. The client is the computer that submits the request, and the server is the computer that receives the request.

TCP/IP has four layers:

- Application Layer
- Transport Layer

- Network Layer
- Data Link Layer

Figure 5 shows the layers of TCP/IP model:

Application Layer
Transport Layer
Network Layer
Data Link Layer

Figure 5: TCP/IP Model

1.13.3 File Transfer Protocol (FTP)

File Transfer Protocol (FTP) is a network protocol for transferring files between computers via TCP/IP (Transmission Control Protocol/Internet Protocol) connections. FTP is classified as an application layer protocol in the TCP/IP series.

The end user's machine is usually referred to as the local host in an FTP transaction. A remote host, which is generally a server, is the second computer engaged in FTP. Both computers must be connected to the internet and correctly setup to transmit data using FTP. To access these services, servers must be set up to provide FTP services, and clients must have FTP software installed. Figure 6 shows the FTP:

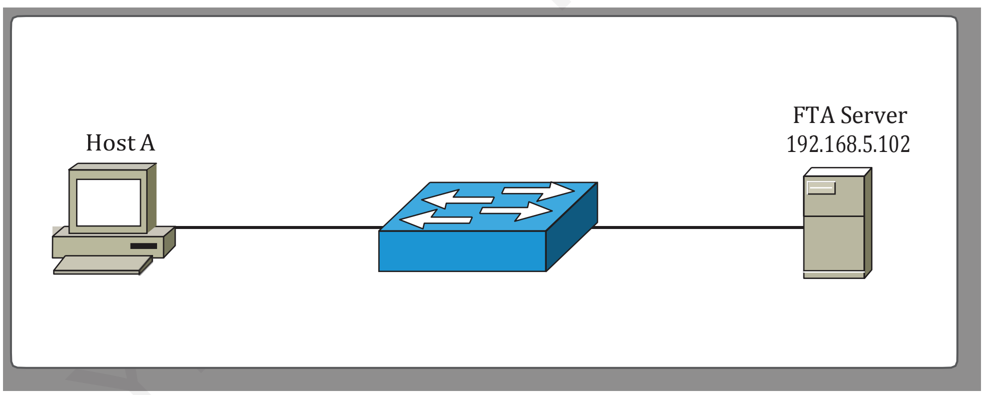


Figure 5: FTP

1.13.4 Point-to-Point Protocol (PPP)

Point-to-Point Protocol (PPP) is a data link layer protocol that allows TCP/IP traffic to be sent over a serial connection, such as a telephone line. PPP does this by defining the following three terms:

- A framing approach that clearly defines the end of one frame and the beginning of the next, as well as error detection.
- Link control protocol (LCP) is used to set up communication connections, authenticate them, and then shut them down when they are no longer needed.
- For each network layer protocol supported by other networks, there is a network control protocol (NCP).

PPP allows residential users to connect to the Internet through their telephone lines. Figure 7 shows the PPP model:

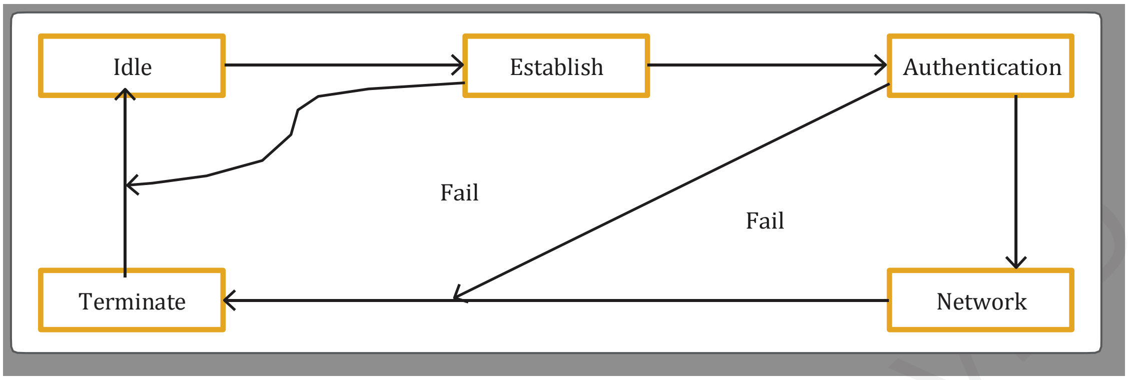


Figure 7: Poin-to-Point Protocol

1.14 NETWORk STaNDaRDS

Standards are necessary for developing and sustaining an open and creative market for equipment makers, as well as ensuring national and international data, communications technology, and process interoperability.

Standards are ethics for manufacturers, suppliers, government organisations, and other service providers to guarantee the interconnectivity essential for communications.

There are two types of data communication standards:

- de facto (which means "by fact"/ "by convention"): Are those standards have been recognised as standards despite the fact that they were not authorised by an established organisation. These kinds of standards are frequently developed by producers who are just trying to specify the functioning of a new product or technology.

  For example, Apple and Google are two firms that have developed their own set of regulations for their own goods. They also employ some of the same production standards for their products.

- de jure (Latin for "by law" or "by regulation"): Standards that have been enacted by an officially recognised authority are known as de jure standards.

For example, all data transmission standard protocols such as SMTP, TCP, IP, and UDP must be followed when they are required.

1.14.1 Standard Organisations

Most standards are produced through collaboration between standard-setting bodies, government regulatory agencies, and forums.

Examples of Standard Creation Committees:

1. International Organization for Standardization (ISO)
2. International Telecommunications Union

   Telecommunications Standard (ITU-T)
3. American National Standards Institute (ANSI)

4. Institute of Electrical & Electronics Engineers (IEEE)
5. Electronic Industries Associates (EIA)

Examples of Forums:

1. ATM Forum
2. MPLS Forum
3. Frame Relay Forum

Examples of Regulatory Agencies:

1. Federal Communications Committee (FCC)

1.15 CONCLUSION

- A computer network is a collection of interconnected computers and electronic devices such as printers.
- Data is the collection of basic facts, whereas information is the processing of data that allows us to make judgments.
- The term "data" refers to any information that is presented in a format that can be manipulated.
- Data communication is the process of transferring data between two devices in a meaningful way through a communication medium.
- A source is a device that creates and transmits data to the destination.
- The device that receives the data is known as the destination.
- Medium serves as a transport for data as it travels from source to destination.
- A protocol is a collection of rules that regulate the proper transmission of data manner.
- Data is a collection of unprocessed facts that is used to derive information.
- The data flow specifies the direction in which data flows between the source and the destination.
- In simplex mode, the course of the information stream is unidirectional.
- In full-duplex mode, the information can be sent on both bearings.
- Network devices, often known as networking hardware, are physical devices that allow hardware on a computer network to communicate and interact with one another.
- There are five different types of communication networks: Local Area Network (LAN), Metropolitan Area Network (MAN), Wide Area Network (WAN), Wireless, and Inter Network (Internet).
- Standards are necessary for developing and sustaining an open and creative market for equipment makers, as well as ensuring national and international data, communications

1.16 GLOSSARY

- Protocols: A set of norms and standards for sharing information.
- Topology: The layout of a computer network.
- Communication: The act of moving data, information from one location, person, or organization to another.
- Model: It is a design or architecture that allows disparate systems to communicate with one another.

- Standard: A standard is anything that has been set as a norm, for example, as a comparison point.
- Committee: A committee is a group of persons who have been put together specifically for a task.

1.17 SELF-ASSESSMENT QUESTIONS

A. Essay Type Questions

1. Data communication is the process of transferring data between two devices in a meaningful way through a communication medium. Discuss the characteristics of data communication.
2. Data may be represented in several different ways. Discuss.
3. The data flow specifies the direction in which data flows between the source and the destination. Explain the simplex and full duplex mode.
4. The manner in which computer systems or network devices are connected is referred to as a network topology. Discuss the important point related to network topology.
5. List down the applications of network.

1.18 ANSWERS AND HINTS FOR SELF-ASSESSMENT QUESTIONS

A. Hints for Essay Type Questions

1. The characteristics of data communication are as follows:
   - Delivery: The data to be transmitted must be supplied at the right place.
   - accuracy: The data should be supplied in its original form, with no changes.

   Refer to Section Data Communication
2. The following are some examples of data types used in communications:
   - Text: The text consists of a blend of upper- and lower-case alphabets. It is saved as a bit pattern. ASCII and Unicode are the most widely used encoding systems.
   - Quantities: Numbers are made up of digits ranging from 0 to 9. It is saved as a bit pattern. ASCII and Unicode are the most widely used encoding systems.

   Refer to Section Data Representation
3. In simplex mode, the course of the information stream is unidirectional. One of the gadgets can communicate the information and another gadget can get consistently. A model is the CPU that sends the information to the screen constantly. Refer to Section Data Flow
4. Some important points of Network Topology are listed below:
   - Cost: For a network to be cost efficient, the installation cost should be kept as low as possible. This can be accomplished using well-understood media and, to a lesser extent, by reducing the distances involved.

   Refer to Section Network Topology
5. Data communication networks have quickly become an integral element of commerce, industry, and entertainment in the short time they've been around. The following are some examples of network applications in various fields:

- Sales and marketing: Both marketing and sales companies make considerable use of computer networks. They're used by marketing professionals to gather, exchange, and evaluate data on client demands and product development cycles. Teleshopping, which employs order entry computers or telephones connected to an order-processing network, and on-line reservation services for hotels, airlines, and other businesses are examples of sales applications.

Refer to Section Applications of Network

1.19 POST-UNIT READING MATERIAL

- https://ecomputernotes.com/computernetworkingnotes/communication-networks/what-is-data-communication
- https://www.google.co.in/books/edition/Data_Communications_and_Networking/bwUNZvJbEeQC?hl=en&gbpv=1&dq=data+communication+forouzan+5th+edition+ppt&printsec=frontcover

1.20 TOPICS FOR DISCUSSION FORUMS

- Discuss with your friends about the importance of a data communication, what to you understand by th computer topologies and their application areas.

UNIT

02

Networks Models

Names of Sub-Units

Layered Tasks, The OSI Model, Layers in the OSI Model, TCP/IP Protocol Suite, Address in TCP/IP, TCP vs UDP

Overview

This unit begins by discussing about the concept of layered tasks. Next, the unit discusses the OSI model. Further the unit discusses the layers in the OSI model. Then, the unit discusses the TCP/IP protocol suite. This unit also discusses the addresses in the TCP/IP protocol suite. Towards the end, the unit discusses the difference between TCP and UDP.

Learning Objectives

In this unit, you will learn to:

⌘ Explain network architecture design
⌘ Describe the OSI model and its layers
⌘ Define the TCP/IP protocol suite and its layers
⌘ Identify the addresses in the TCP/IP protocol suite
⌘ Compare the TCP and UDP

Learning Outcomes

At the end of this unit you would:

⌘ Assess the knowledge about layered tasks
⌘ Analyses of OSI model and its layers
⌘ Explore the TCP/IP protocol suite and its layers
⌘ Evaluate the role of different types of addresses in the TCP/IP protocol suite
⌘ Assess the difference between TCP and UDP

2.1 INTRODUCTION

Network architecture refers to the layers and their protocols as a whole. The OSI model is a network design with seven layers. Connection-oriented and connectionless services are two types of services that a layer might provide to the layer above it. There are four levels in the TCP/IP network architecture paradigm. The TCP/IP paradigm is used in the majority of computer networks. For seamless communication between two computers, some sort of addressing mechanism is required.

2.2 LayeReD TaSkS

The primary goal of a computer network is to transport data from one sender to another. This work may be completed by dividing it down into small, well-defined subtasks. Each subtask will have its own set of procedures to follow, with particular inputs and outputs to the subtasks before and following it. These subtasks are referred to as layers in more technical terminology. Every work or job may be broken down into subtasks or layers in general. Consider the scenario of sending a letter to someone in City A and receiving it in City B. Figure 1 shows the letter-sending procedure:

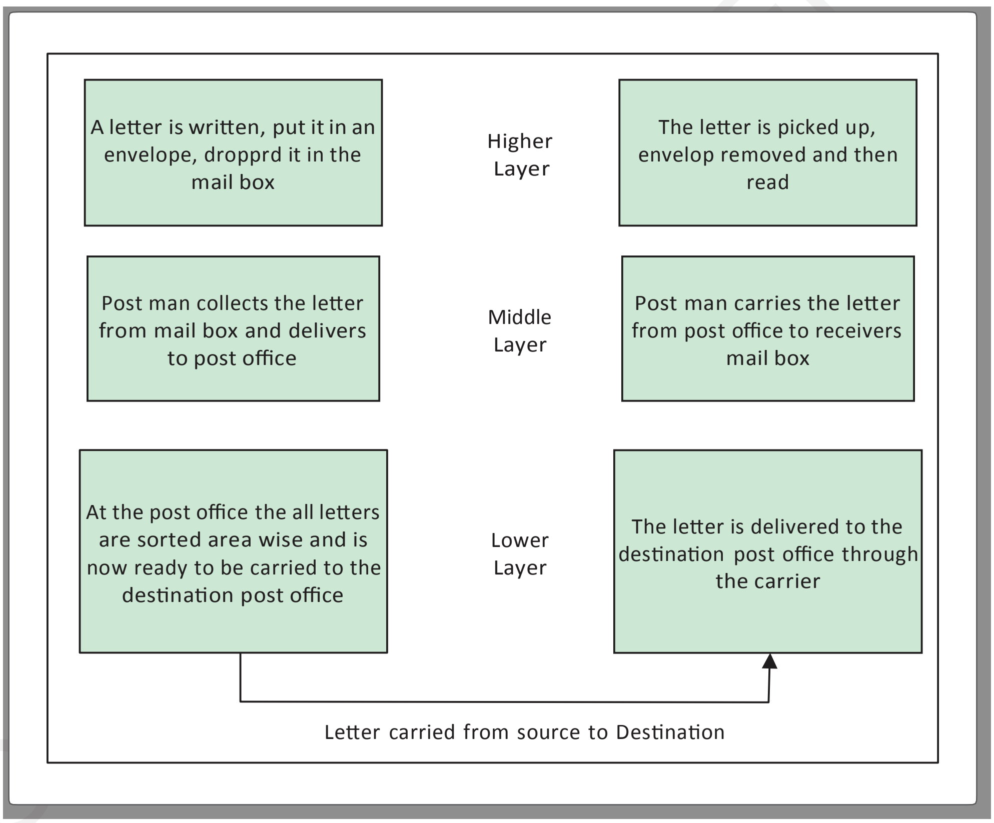


Figure 1: Concept of Layer Task Sending a Letter

The diagram above depicts: a. Sender, Receiver, and Carrier; and b. Layer Hierarchy. The actions at the sender location are carried out in the following order:

- Higher layer: The sender writes the letter, including the sender and receiver's addresses, and places it in an envelope, which he or she then drops in the mailbox.
- Middle layer: The letter is picked up and delivered to the post office by the postman.
- Lower layer: Letters are sorted at the post office and are ready to be delivered by a carrier.

Before arriving at the target post office, the letter may be transported by truck, plane, or ship, or a combination of modalities. The actions at the Receiver site are carried out in the following order:

- Lower layer: The letter is delivered to the destination post office by the carrier.
- Middle layer: The letter is delivered to the receiver's mail box after sorting.
- Higher layer: The letter is picked up, the envelope is opened, and the letter is read.

The activities in the entire task are organized into three layers. Each activity at the sender or receiver side occurs in a particular order at the hierarchy. The higher layer organises the essential and complicated activities, whereas the intermediate and lower layers organise the simpler ones.

2.3 THE OSI MODEL

The International Organization for Standardization (ISO) created the Open Systems Interconnection (OSI) Model (ISO). The organisation is ISO, and the model is OSI. It was created so that systems running on various platforms may interact with one another. The term "platform" can refer to hardware, software, or an operating system. It's a network model that specifies network communication protocols.

2.3.1 Layers in the OSI Model

This model contains seven levels, which are as follows:

i. Application layer

ii. Presentation layer

iii. Session layer

iv. Transport layer

v. Network layer

vi. Data link layer

vii. Physical layer

Physical Layer

Raw bits are sent over the communication channel via the physical layer. This layer ensures that a 1 bit from the transmitting computer is sent to the receiving computer as a 1 bit rather than a 0 bit. The physical layer also addresses issues such as how many bits per second will be transmitted; what voltage level will be used to represent 1 and 0; whether transmission will be unidirectional or bidirectional; how the initial connection will be established and terminated; how many pins a network connector has and which pin is for what, and so on.

Data Link Layer

The data connection layer takes the raw transmission facility and turns it into an error-free facility that the network layer may utilise. This layer divides the input data into frames by adding suitable frame boundaries, sends the frames in order, and processes the acknowledgment received from the destination computer. When a frame is entirely destroyed by a noise burst, the data link layer is responsible for retransmitting it from the originating computer. The data link layer also guarantees that a fast sender does not overwhelm a slow receiver by delivering data at a faster pace than the receiver can manage. This is referred to as flow control. In a broadcast network, the MAC (Medium Access Control) sub-layer of the data link layer is responsible for determining who has access to the transmission medium at any given time.

The Network Layer

The network layer is in charge of the subnet's operation. The layer's job is to figure out how packets get from point A to point B. Depending on the traffic load and channel availability, the routing may be static or dynamic.

Congestion (traffic jam) can occur when there are too many packets, and the network layer is responsible for preventing this. The cost of subnet operations necessitates the inclusion of some accounting functionality at the network layer. When a packet crosses a national border, the network layer must deal with additional accounting issues. Packets must travel between heterogeneous networks that operate on different platforms and use different network protocols, and the network layer is responsible for resolving all difficulties that emerge as a result of this.

The Transport Layer

The transport layer receives data from the session layer, breaks it down into smaller units if required, passes it on to the network layer and ensures that all of the pieces arrive to the recipient intact. The aforementioned tasks must be completed quickly and in such a way that they do not affect the higher layer in the event of a hardware upgrade. In most cases, the transport layer establishes a separate connection for each session. If high throughput is necessary, the transport layer may create several network connections, splitting the data across them and so increasing throughput.

The transport layer may multiplex many transport connections, on to the network connection, to save money. Multiple connections or multiplexing, on the other hand, must be invisible to the session layer. The transport layer also influences the sort of network service provided to the user. The most common transport layer service is an error-free point-to-point connection, in which messages or bytes are delivered in the order in which they were sent. The conveyance of isolated communications with no certainty of delivery is another type of transportation service. Between the source and the destination, the transport layer serves as a real end layer. Flow control is also performed by the transport layer.

The Session Layer

This layer allows several users on separate computers to create a session with each other. A session allows a user to log into a remote computer and transfer files between the two computers. To enable unidirectional communication, the session layer manages tokens. It also offers synchronization as a service.

The Presentation Layer

This layer is responsible for presenting data according to syntax and semantics guidelines. It transforms data into a suitable form before delivering it to the user. For example, if we write Sri Nilimoy Choudhury, it will be written Choudhury, Mr. Nilimoy in Europe or the United States. We use the format dd/mm/yyyy etc. So, these conversions are done by the presentation layer.

The application Layer

This is the layer that is the closest to all network users. It includes a wide range of procedures that are often used. It facilitates file transmission. In various computers with different data formats, different file systems have distinct meanings. The application layer takes the required steps to rectify anomalies when files are moved from one computer to another with a different file system.

2.4 TCP/IP PROTOCOL SUITE

The TCP/IP protocol suite, often known as the Internet protocol suite, is a collection of communications protocols that make up the protocol stack that powers the Internet and most commercial networks. The Transmission Control Protocol (TCP) and the Internet Protocol (IP) are the two most significant protocols in the suite (IP).

Like the OSI reference model, the TCP/IP protocol suite is made up of layers. Upper layers are logically closer to the user and deal with more abstract data, relying on lower layer protocols to convert data into formats that can be sent across the network physically.

2.4.1 Layers in the TCP/IP Model

The TCP/IP Reference Model is a four-layer communication protocol suite. The Department of Defense (DoD) created it in the 1960s. TCP and IP are the two primary protocols utilised in the concept, therefore the model is called after them. Transmission Control Protocol is abbreviated as TCP, whereas Internet Protocol is abbreviated as IP.

This model contains four levels, which are as follows:

- Host-to-network layer: The lowest layer, the host-to-network layer, is concerned with the physical transfer of data. TCP/IP does not specify any protocol in particular, although it does support all of the common protocols.
- Internet layer: It specifies the protocols for logical data transfer via the internet. The Internet Protocol (IP) is the major protocol in this layer, and it is backed by the protocols ICMP, IGMP, RARP, and ARP.
- Transport layer: It is in charge of ensuring that data is delivered without errors from beginning to end. Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) are the protocols discussed here (UDP).
- application layer: This is the uppermost layer, which specifies how host applications interact with transport layer services. Telnet, DNS, HTTP, FTP, SMTP, and other high-level protocols are included in this layer.

2.5 aDDRESS

Physical (link) addresses, logical (IP) addresses, port addresses, and particular addresses are the four tiers of addresses used in an internet using TCP/IP protocols, as shwon in Figure 2:

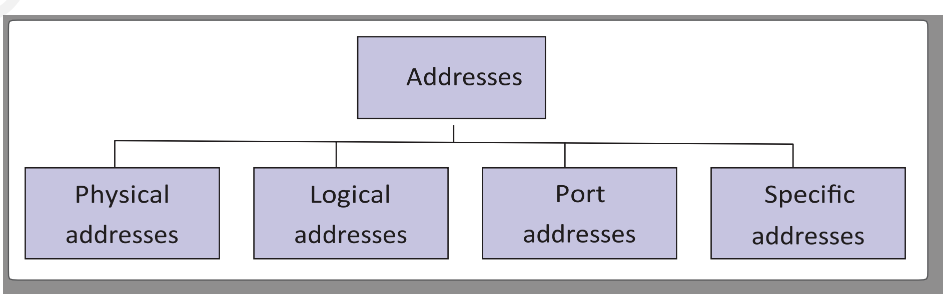


Figure 2: addresses in TCP/I P Protocol

Figure 3 shows the different types of address associated with the different layer of TCP/IP protocol:

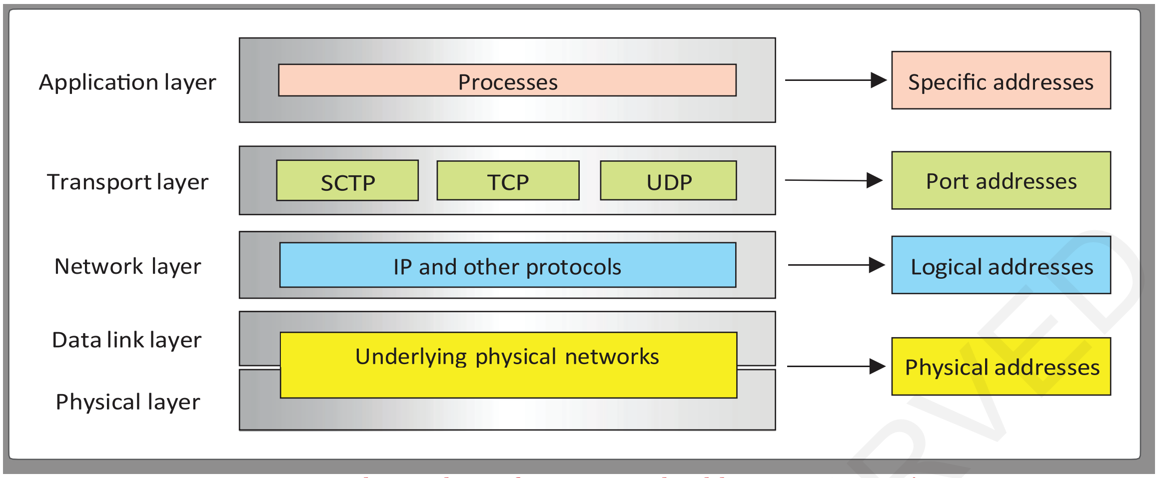


Figure 3: Relationship of Layers and addresses in TCP/IP

2.5.1 Physical addresses

The physical address, also known as the link address or mac address, is a 6-byte (48-bit) physical address that is imprinted on the network interface card in a local network (NIC).

Example: 2 07:01:02:01 A6 C:4B C:4B C:4B C:4B C

Physical address of a byte (12 hexadecimal digits)

2.5.2 Logical addresses

For network-to-network communication, logical addresses are required. In the Internet, a logical address is presently a 32-bit identifier that may uniquely identify a host connected to the Internet. On the Internet, no two are publicly addressed and visible hosts may have the same IP address.

2.5.3 Port addresses

It is implemented as a process to process delivery at the transport layer.

Computers are machines that can do several tasks at once. The goal of Internet communication is for one process to communicate with another. TELNET, for example, allows computer A to connect with computer C. At the same time, computer A and computer B interact using the File Transfer Protocol (FTP). We need a technique to mark the different processes so that they can get data at the same time.

To put it another way, they require addresses. A port address is a label allocated to a process in the TCP/IP architecture. In TCP/IP, a port address is 16 bits long.

A 16-bit port address is represented by a single decimal number.

2.5.4 Specific addresses

Some programmes offer user-friendly addresses that are tailored for that particular app.

The e-mail address (for example, cosci@yahoo.com) and the Universal Resource Locator (URL) are two examples (for example, www.mhhe.com). The first is used to specify the email recipient, while the second is utilized to locate a document on the Internet. The transmitting computer, on the other hand, changes these addresses to the matching port and logical addresses.

2.6 TCP VS UDP

Table 1 shows the difference between TCP and UDP:

Table 1: Different Between TCP vs UDP

TCP	UDP
It stands for Transmission Control Protocol.	It stands for User Datagram Protocol.
It's a connection-oriented protocol, which means the connection must be established before data can be sent over the network.	It's a connectionless protocol, which means it delivers data without first determining whether or not the system is ready to accept it.
TCP is a dependable protocol since it ensures the delivery of data packets.	UDP is an unreliable protocol since it does not provide a guarantee for packet delivery.
TCP is slower than UDP because it conducts error checking, flow management, and ensures that data is delivered correctly.	UDP is quicker than TCP since data packet delivery is not guaranteed.
The size of TCP is 20 bytes.	The size of the UDP is 8 bytes.
TCP uses a checksum to conduct error checking. The data is then retransmitted to the receiver, once it has been rectified.	It doesn't check for errors and doesn't resend data packets that have been lost.
This protocol is mostly utilized in military services, online surfing, and e-mail, where a safe and dependable communication mechanism is necessary.	This protocol is used in situations when quick communication is necessary but dependability is not a concern, such as VoIP, game streaming, video and music streaming, and so on.

2.7 CONCLUSION

- Network architecture refers to the layers and their protocols as a whole. the OSI model is a network design with seven layers.
- Connection-oriented and connectionless services are two types of services that a layer might provide to the layer above it.
- The primary goal of a computer network is to transport data from one sender to another.
- The International Organization for Standardization (ISO) created the Open Systems Interconnection (OSI) Model (ISO).
- OSI is a network model that specifies network communication protocols.
- OSI model contains seven levels, which are as follows:
    - Application layer
    - Presentation layer
    - Session layer
    - Transport layer

- Network layer
- Data link layer
- Physical layer

- The TCP/IP protocol suite, often known as the Internet protocol suite, is a collection of communications protocols that make up the protocol stack that powers the Internet and most commercial networks.
- The Transmission Control Protocol (TCP) and the Internet Protocol (IP) are the two most significant protocols in the suite (IP).
- The TCP/IP Reference model contains four levels, which are as follows:
  - Host-to-Network layer
  - Internet Layer
  - Transport layer
  - Application Layer
- Physical (link) addresses, logical (IP) addresses, port addresses, and particular addresses are the four tiers of addresses used in an internet using TCP/IP protocol.

2.8 GLOSSARY

- address: A unique identification for a node or host.
- Encapsulation: The concatenation of data and the algorithms that operate on it into a single entity.
- Connection-oriented: The establishment and termination of a data transmission link between two or more devices
- Integrity: Doing the correct thing in a consistent manner

2.9 SELF-ASSESSMENT QUESTIONS

A. Essay Type Questions

1. The International Organization for Standardization (ISO) created the Open Systems Interconnection (OSI) Model (ISO). Write a short note on OSI model.
2. The TCP/IP protocol suite, often known as the Internet protocol suite. Discuss the TCP/IP suite.
3. Discuss the addresses used in TCP/Ip protocol.
4. List down the layers of TCP/IP protocol suite.
5. Explain the transport layer of OSI model.

2.10 ANSWERS AND HINTS FOR SELF-ASSESSMENT QUESTIONS

A. Hints for Essay Type Questions

1. OSI was created so that systems running on various platforms may interact with one another. The term “platform” can refer to hardware, software, or an operating system. It’s a network model that specifies network communication protocols. Refers to Section The OSI Model

2. The TCP/IP protocol suite is a collection of communications protocols that make up the protocol stack that powers the Internet and most commercial networks. The Transmission Control Protocol (TCP) and the Internet Protocol (IP) are the two most significant protocols in the suite (IP). Refers to Section TCP/IP Protocol Suite

3. Physical (link) addresses, logical (IP) addresses, port addresses, and particular addresses are the four tiers of addresses used in an internet using TCP/IP protocols. Refers to Section Addresses

4. The TCP/IP protocol suite contains four levels, which are as follows:

   - Host-to-Network layer: The lowest layer, the host-to-network layer, is concerned with the physical transfer of data. TCP/IP does not specify any protocol in particular, although it does support all of the common protocols.

   Refers to Section TCP/IP Protocol Suite

5. The transport layer receives data from the session layer, breaks it down into smaller units if required, passes it on to the network layer and ensures that all of the pieces arrive to the recipient intact. The aforementioned tasks must be completed quickly and in such a way that they do not affect the higher layer in the event of a hardware upgrade. Refers to Section The OSI Model

2.11 POST-UNIT READING MATERIAL

- https://www.google.co.in/books/edition/Computer_Networks/b2HyGSu46lQC?hl=en&gbpv=1&dq=tanenbaum+networking&printsec=frontcover
- https://www.google.co.in/books/edition/Data_Communications_and_Networking/bwUNZvJbEeQC?hl=en&gbpv=1&dq= data+communication+forouzan+5th+edition+ppt&printsec=frontcover

2.12 TOPICS FOR DISCUSSION FORUMS

- Discuss with your classmates about the reference models in computer network. Also, do the online research to find out the comparison between OSI model and TCP/IP model.

UNIT

03

Introduction to Physical Layer

Names of Sub-Units

Introduction to Physical Layer, Analog and Digital Data, Analog and Digital Signals, Periodic Analog Signals, Transmission Impairment, Data Rate limits, Performance.

Overview

This unit begins by discussing the overview of physical layer. Next, the unit discusses the analog and digital data. Further the unit discusses the analog and digital signals. Then, the unit discusses the periodic analog signals. This unit also discusses the transmission impairment and data rate limits. Towards the end, the unit discusses the performance of signals.

Learning Objectives

In this unit, you will learn to:

- Explain the basic concept of physical layer
- Discuss the role of an algorithm in computing
- Explain the fundamentals of algorithmic used in solving problems
- Describe the different types of algorithms
- Discuss the basics of data structure

Learning Outcomes

At the end of this unit, you would:

- Assess the knowledge of analog and digital data and signals
- Analyse the role of periodic analog signals
- Examine the bit rate, bit length, and transmission of digital signals
- Assess the transmission impairment of signals
- Evaluate the bandwidth, throughput, latency (delay), and jitter

Pre-Unit Preparatory Material

- https://www.monolithicpower.com/en/analog-vs-digital-signal

3.1 INTRODUCTION

The physical layer is the sole layer of the OSI network architecture that deals with the physical connection of two separate stations. This layer specifies the hardware, cabling, wiring, frequencies, and pulses required to represent binary signals, among other things. It is made up of various networking gear, transmission medium, and computer network transmission methods. The physical layer serves as a service provider for the data connection layer. Raw bit transmission is maintained here across any hardware communication media. It connects to the network in three ways: electrically, mechanically, and procedurally. The major design difficulty in this layer is ensuring that if one bit is delivered from the source, it is received as one bit at the other end.

3.2 ANALOG AND DIGITAL

Analog is the inverse of digital. The original meaning of analog was anything that is comparable to another and the two are said to be analogous. In technology, it refers to something with an output that is proportionate or comparable to its input – often, a voltage. The term "digital" refers to electrical equipment that creates, stores, and analyses data in two states: positive and negative. The number 1 expresses or represents positive, while the number 0 expresses or represents negative. Data sent or saved via digital technology is thus represented as a string of 0's and 1's.

3.2.1 Analog and Digital Data

Analog data is data that is physically represented. Whereas digital data is kept as a collection of discrete symbols; analog data is saved in physical medium, such as the surface grooves on a vinyl record, magnetic tape on a VCR cassette, or other non-digital media. Analog data is sometimes referred to as organic data and real-world data. Sound is an excellent example of analog data. Sound waves shift in an extremely smooth manner. Figure 1 depicts an example of a sound wave that changes smoothly:

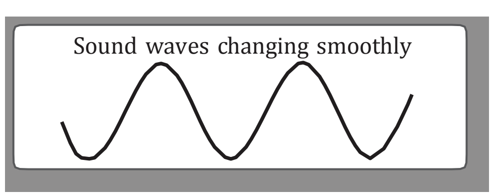


Figure 1: Sound Wave

Analog data is used by all analog devices. Microphones, headphones and speakers with a Loud Volume are examples of analog equipments. Sensors are type of devices that detect temperature, pressure, etc. Figure 2 shows the analog devices:

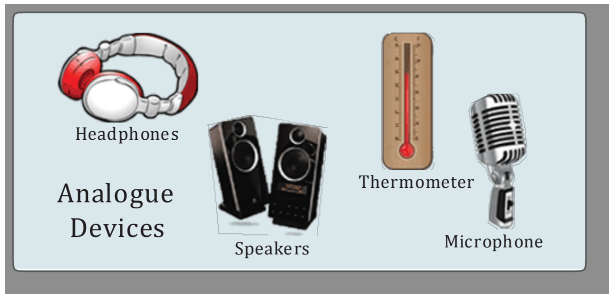


Figure 2: Analog Devices

Digital data is data that represents different types of data via the use of specialised machine language systems that may be understood by various technologies. A binary system is the most basic of these systems, simply storing sophisticated audio, video, or text information in a series of binary characters, usually ones and zeros, or "on" and "off" values. A digital clock is an excellent example of this. A digital clock moves from one second to the next in distinct increments. The transition isn't seamless or continuous. Digital data is used by all digital devices. Computers/laptops/iPads, Cellular Phone, Digital Camera with MP3 Player etc. are examples of digital devices. Figure 3 shows digital devices:

Figure 3: Digital Devices

All gadgets that store and process data in the form of "digits" are referred to as "digital" (numbers). These digits are referred to as 'Binary.'

3.2.2 Analog and Digital Signal

An analog signal is a continuously varying electromagnetic wave in which the time varying characteristic of the signal is a representation of some other time varying quantity that depending on spectrum, may be carried via a number of mediums. When someone talks, for example, an analog wave is generated in the air. A microphone may pick up on this and convert it into an analog signal. Over time, an analog signal can have an unlimited number of degrees of intensity. Figure 4 shows an analog signal:

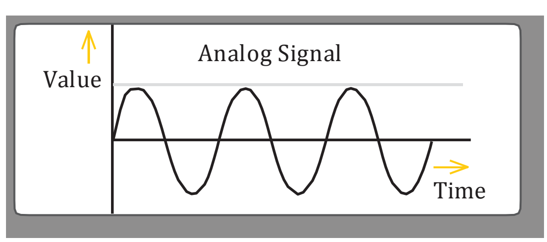


Figure 4: Analog Signal

A digital signal, on the other hand, is a physical signal that consists of a series of voltage pulses that may be transferred through a transmission channel. Data is stored in computer memory as 0s and 1s, which may be transformed to digital signals. Figure 5 shows an digital signal:

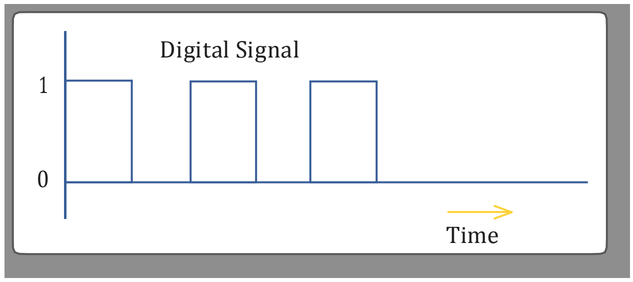


Figure 5: Digital Signal

The following are the advantages of digital signaling over analog signaling:

1. Digital signaling is often less expensive than analog signaling.
2. Noise interference has less of an impact on digital signaling than it does on analog transmission.

The drawback of digital signaling is that it suffers from higher attenuation than analog transmission. Table 1 shows the different between analog signal and digital signal:

Table 1: Difference between Analog and Digital Signal

Analog Signal	Digital Signal
A continuous signal that represents physical measurements is known as an analog signal.	Digital signals are time-separated signals produced by digital modulation.
It employs a continuous range of values to aid in the representation of information.	To represent information, digital signals employ discrete 0 and 1 values.
Analog signals include temperature sensors, FM radio transmissions, photocells, light sensors, and resistive touch screens.	Digital signals may be found in computers, CDs, and DVDs.
The analog signal bandwidth is low.	The digital signal bandwidth is high.
The processing of the analog signals can be done in real-time which requires less bandwidth.	It never guarantees that processing of the digital signal will be possible in real-time.

3.2.3 Periodic and Nonperiodic Signals

Both analog and digital signals can be either periodic or nonperiodic in form. A periodic signal accomplishes a pattern in a predetermined time frame termed as a period, and then repeats that pattern over and over again. A cycle is the completion of one entire pattern. A nonperiodic signal varies without repeating a pattern or cycle throughout time.

Periodic analog signals may be divided into two types: simple and composite. A sine wave is a basic periodic simple analog signal that cannot be broken into smaller signals. A composite periodic analog signal is made up of many sine waves.

3.3 PERIODIC ANALOG SIGNALS

We routinely employ periodic analog signals and non-periodic digital signals in data transfers. Periodic analog signals may be divided into two types: simple and composite. A sine wave is a basic periodic analog signal that cannot be broken into smaller signals. A composite periodic analog signal is made up of many sine waves.

3.3.1 Sine Wave

Sine wave is the most basic type of periodic analog signal. A sine wave is defined by three parameters, namely, peak amplitude, frequency, and phase. Figure 5 shows an sine wave:

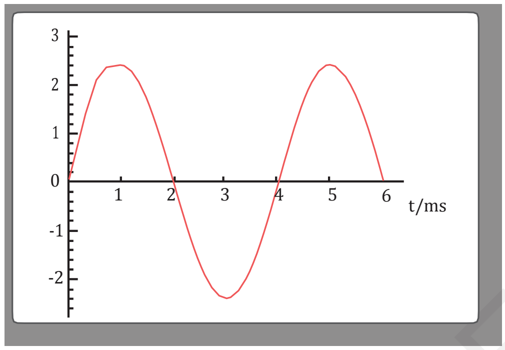


Figure 5: Sing Wave

The description of these parameters are as follows:

1. Peak Amplitude: A signal's amplitude is the absolute magnitude of its intensity at time 't'. A signal's peak amplitude is the absolute magnitude of its maximum intensity. A signal's amplitude is proportional to the energy carried by the signal. Figure 6 shows the peak amplitude:

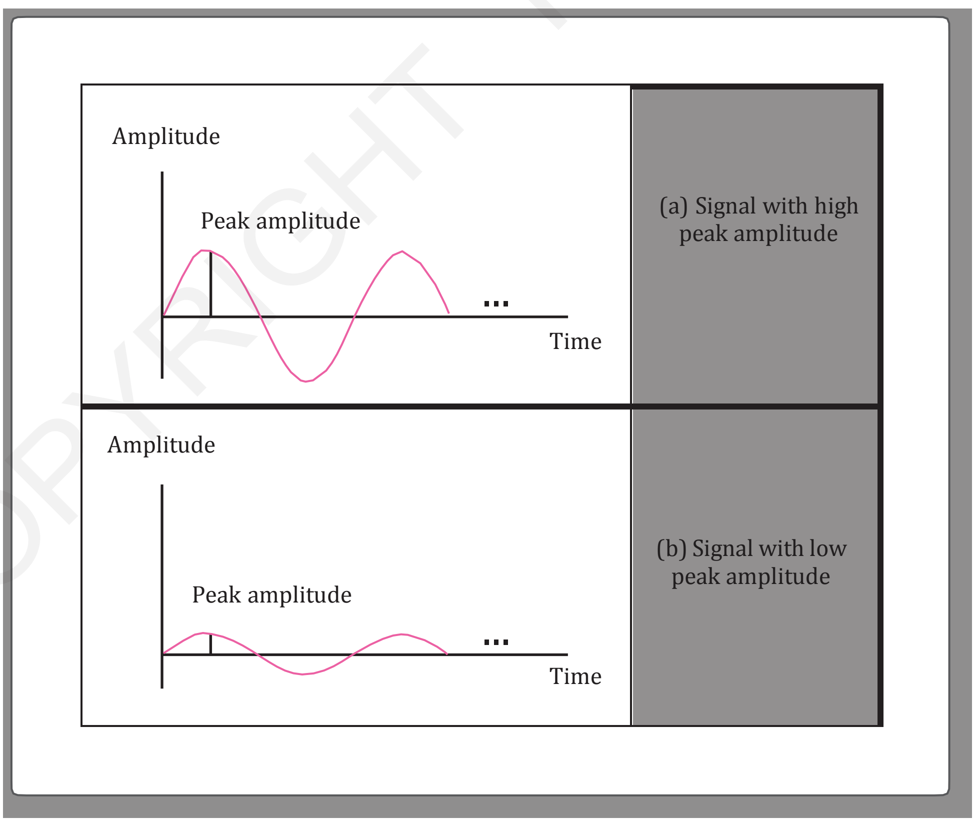


Figure 6: Amplitude of a sine wave

2. Frequency: The number of cycles completed by the wave in one second is referred to as its frequency.

The time it takes the wave to complete one second is referred to as its period. Figure 7 shows the frequency and period of a sine wave:

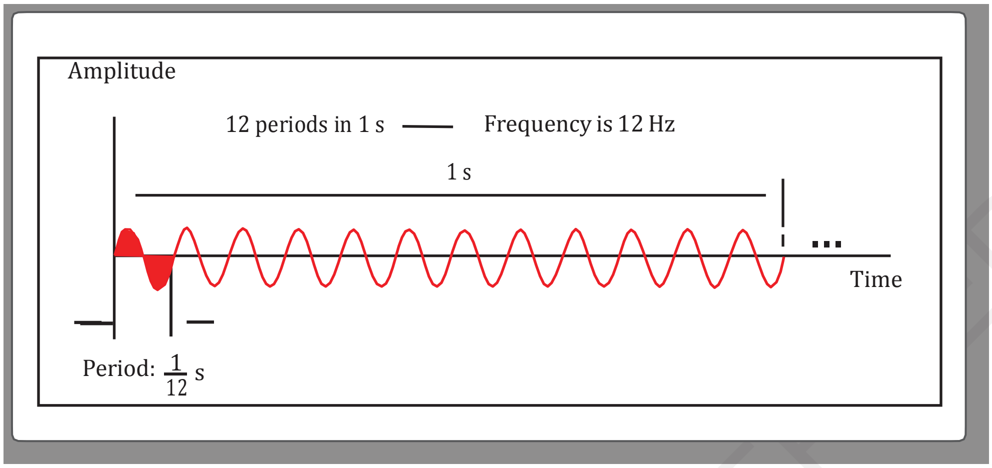


Figure 7: Frequency & Period of a Sine Wave

3. Phase: The phase of a waveform specifies its location with respect to time (specifically relative to time 0). Figure 8 shows the phase of sine wave:

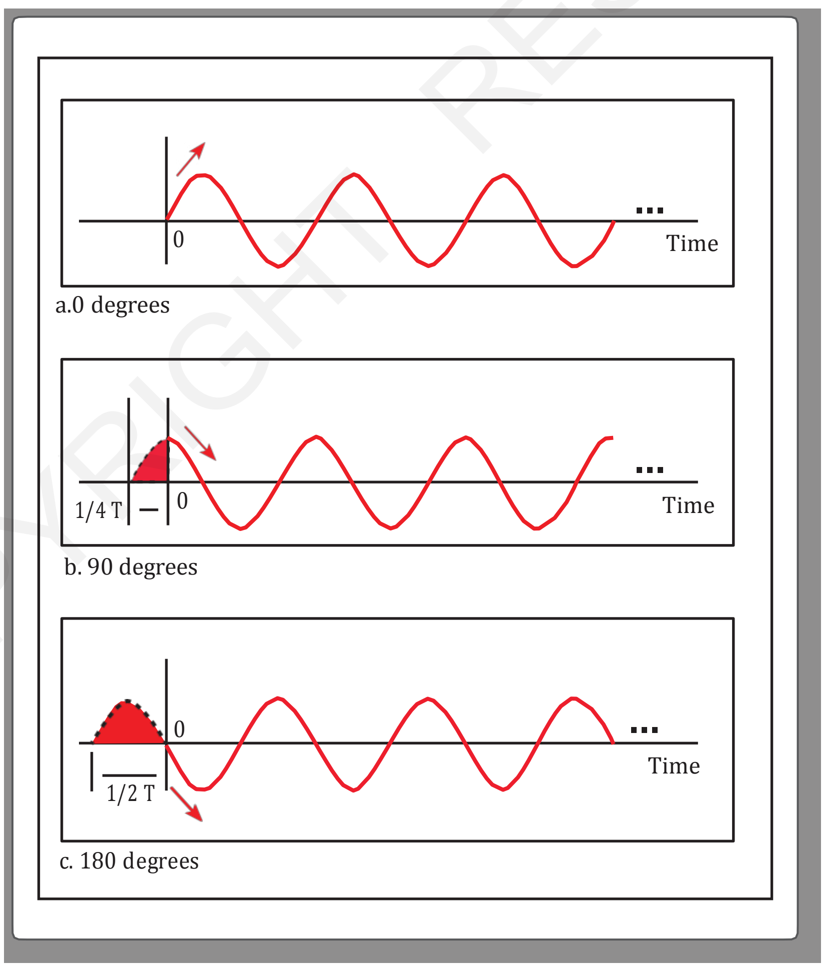


Figure 8: Phase of a Sine Wave

The phase of a waveform shows its forward or backward movement from the axis. It is expressed in degrees or radians. The sine waves in the graphic above have the same amplitude and frequency but distinct phases.

Relation between Frequency & Period

Frequency and Period are diametrically opposed. The following formula indicates it:

T=1/f

&

f=1/T

Example 1: A wave with a frequency of 100 hertz. T = 1/ F = 1/ 100 = 0.01 sec is its period (T).

Example 2: A wave goes through one cycle in 0.25 seconds. F = 1 / T = 1 / 0.25 = 4 Hz is its frequency.

Units of Period and Frequency

Table 2 shows the units of period and frequency:

Table 2: Units of Period and Frequency

Unit	Equivalent	Unit	Equivalent
Second (s)	1 s	Hertz (Hz)	1 Hz
Milliseconds (ms)	10^{-3} s	Kilohertz (kHz)	10^{3} Hz
Microseconds (ms)	10^{-6} s	Megahertz (MHz)	10^{6} Hz
Nanosecond (ms)	10^{-9} s	Gigahertz (GHz)	10^{9} Hz
Picoseconds (ms)	10^{-12} s	Terahertz (THz)	10^{12} Hz

Some important points related to period and frequency are as follows:

- The pace of change with regard to time is defined as frequency.
- Change in a short period of time indicates a high frequency.
- Change over a lengthy period of time indicates a low frequency.
- The frequency of a signal is 0 if it does not vary at all.
- The frequency of a signal is limitless if it changes instantly.
- The phase of a waveform specifies its location with relation to time zero.

3.3.2 Wavelength

The wavelength of a signal is defined as the connection between frequency (or period) and wave propagation speed across a medium. The wavelength is the distance travelled by a signal in one period. It is given by,

$$\text{Wavelength} = \text{Propagation Speed} \times \text{Period}$$

OR

$$\text{Wavelength} = \text{Propagation Speed} \times \frac{1}{\text{Frequency}}$$

It is denoted by the symbol: ● (pronounced as lamda). The micrometers are used to measure it. Figure 9 shows the wavelength:

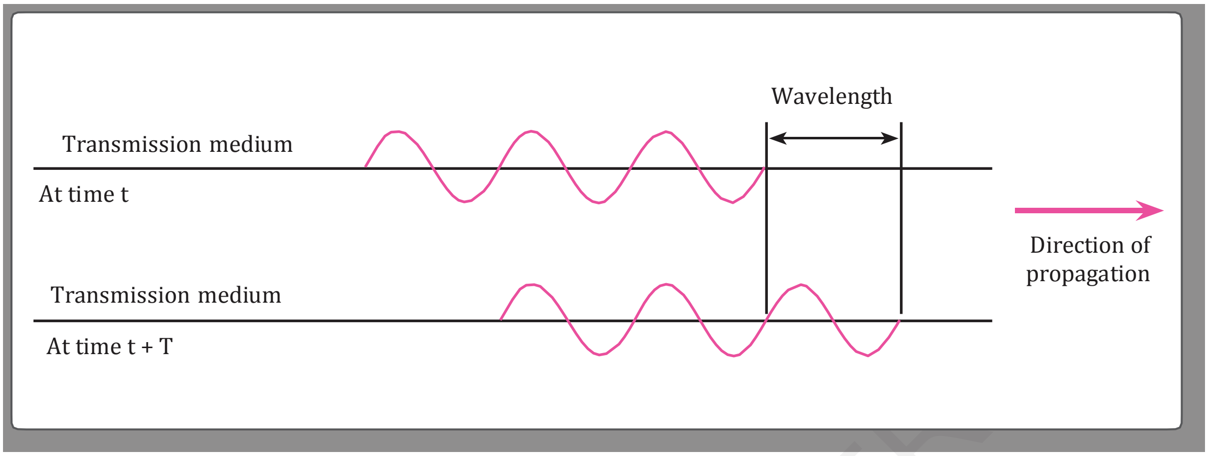
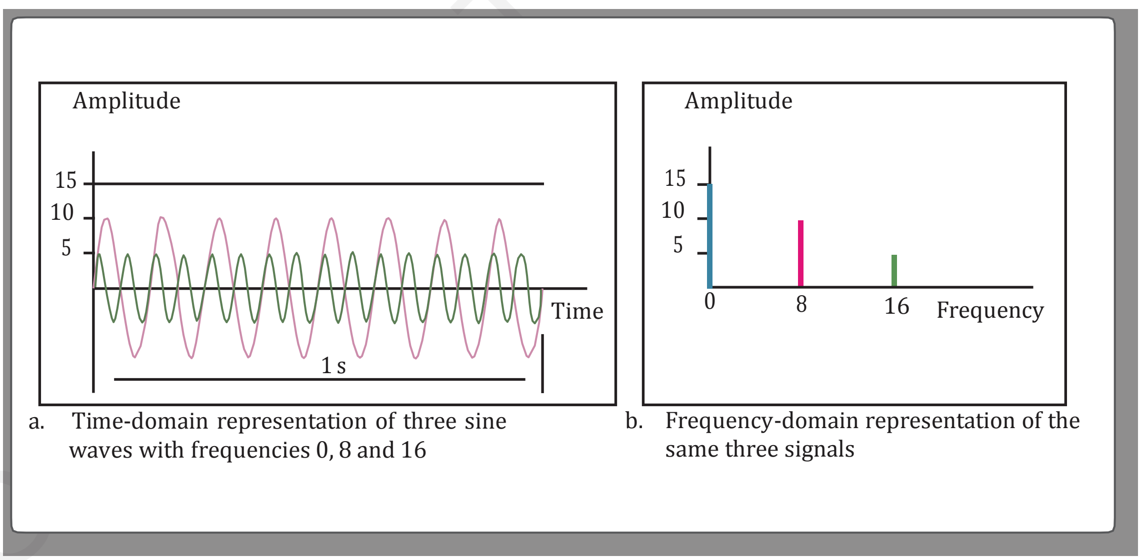


Figure 9: Wavelength

3.3.3 Time and Frequency Domain

A sine wave can be expressed in both the time and frequency domains. The time-domain graphic depicts variations in signal amplitude over time. It represents the time and amplitude relationship of a signal. The frequency-domain graphic displays the signal frequency as well as the peak amplitude. The time and frequency domain graphs of three sine waves are shown in the picture below. In the frequency domain, a full sine wave in the time domain can be represented by a single spike. Figure 10 shows the time and frequency domain:



a. Time-domain representation of three sine waves with frequencies 0, 8 and 16

b. Frequency-domain representation of the same three signals

Figure 10: Time domain and frequency domain plots of three sine waves

3.3.4 Composite Signals

A composite signal is made up of two or more basic sine waves that have distinct frequencies, phases, and amplitudes. If the composite signal is periodic, the decomposition produces a sequence of discrete signals; if the composite signal is non-periodic, the decomposition produces a mixture of sine waves with continuous frequencies.

Figure 11 shows the composite signals:

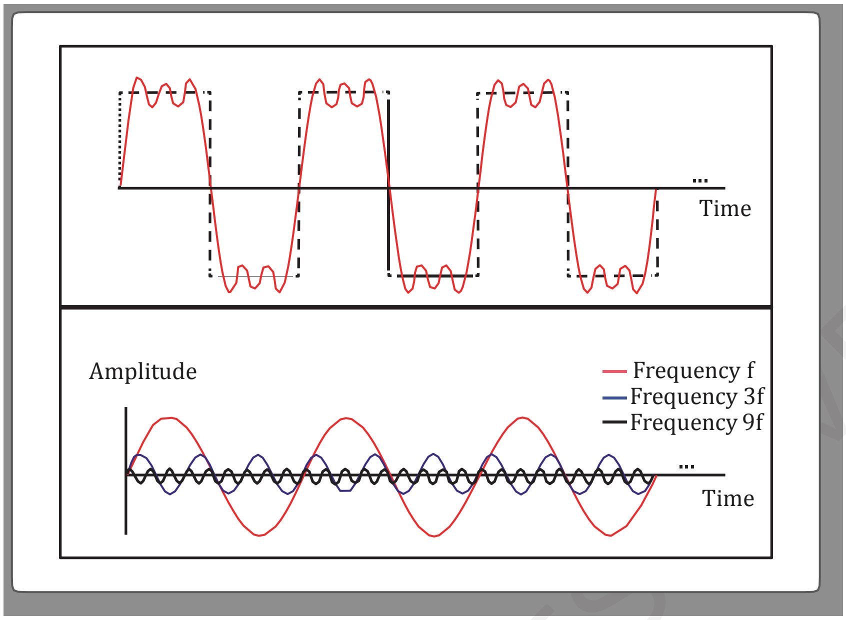


Figure 11: A Composite Signal with Three Component Signals

A basic sine wave is ineffective for data transfer; instead, a composite signal, which is a mixture of numerous simple sine waves, is employed. According to French mathematician Jean Baptist, any composite signal is a mixture of basic sine waves with varying amplitudes, frequencies, and phases. Composite signals can be either periodic or asynchronous. A periodic composite signal can be decomposed into a succession of discrete frequency signals. When a non-periodic signal is decomposed, it produces a mixture of sine waves with continuous frequencies. Figure 12 shows the time and frequency domains of a non-periodic composite analog signal:

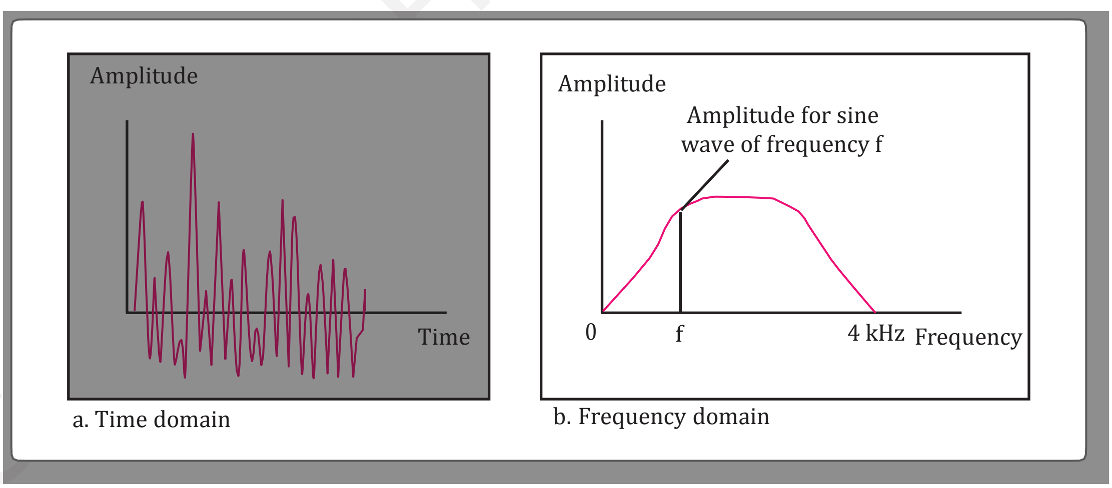


Figure 12: The Time and Frequency Domains of a Non-Periodic Composite Analog Signal

3.3.5 Bandwidth

The bandwidth of a composite signal is the range of frequencies present in it. The bandwidth is often defined as the difference between two integers. For example, if a composite signal has frequencies ranging from 1000 to 5000, the bandwidth is 5000 - 1000, or 4000. The bandwidth of a composite signal is the difference between the signal's highest and lowest frequencies.

Figure 13 shows the bandwidth of periodic and nonperiodic composite signals

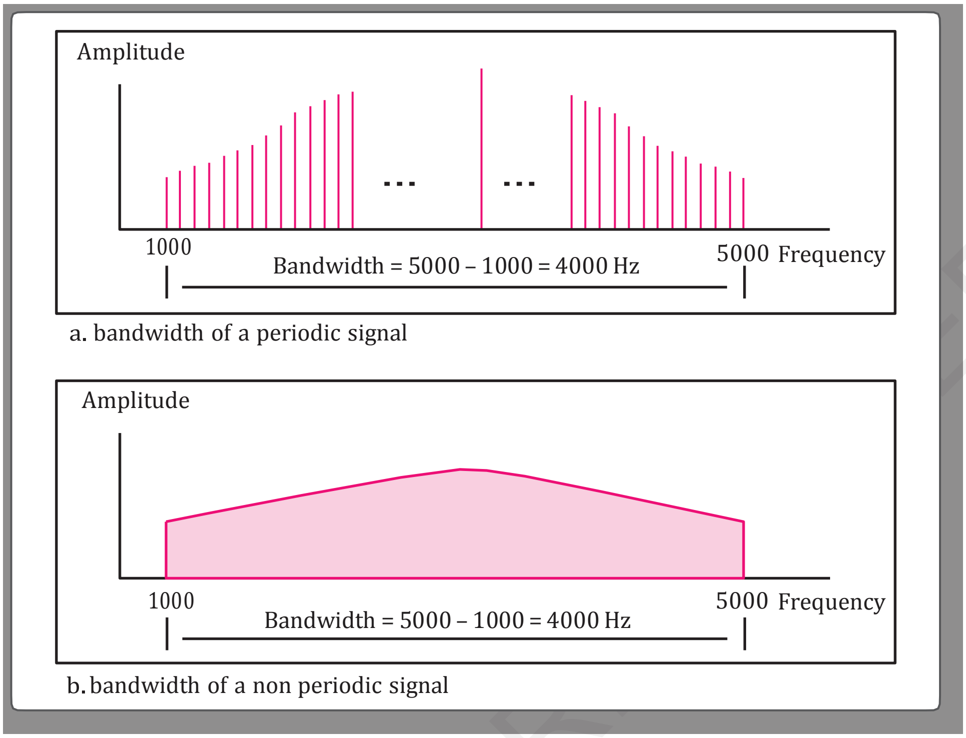


Figure 13: The Bandwidth of periodic and nonperiodic composite signal

3.4 DIGITAL SIGNALS

A digital signal can also be used to explain information. A digital signal is one that has discrete values. The signal will have a non-continuous value. Voltage levels can be used to represent information in a digital stream. A signal can have more than two levels. Figure 14 shows the digital signal with two labels:

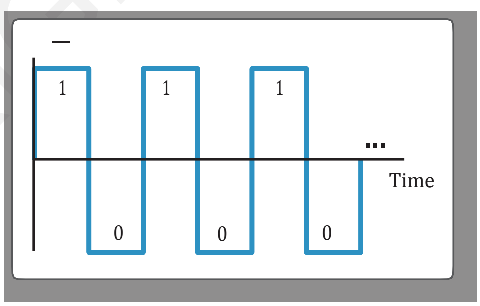


Figure 14: A Digital Signal with Two Levels.

In Figure 14, '1' represents a positive voltage and '0' represents a negative voltage. In general, if a signal has L levels then, each level need Log2L bits.

3.4.1 Bit Rate

The word bit rate refers to the number of bits transferred in one second via a communication channel for digital signals. It is measured in bits per second (bps). The following is a possible relationship between bit rate and bit interval:

$$\text{Bit interval} = 1 / \text{Bit rate}$$

3.4.2 Bit Length

A digital signal's bit length is the distance one bit occupies on the transmission media, which may be determined using the following equations:

$$\text{Bit length} = \text{Bit Duration} \times \text{Propagation Speed}$$

It is the time required to send one bit. It is measured in seconds.

3.4.3 Digital Signal as a Composite Analog Signal

A digital signal is a composite analog signal based on Fourier analysis. A digital signal in the time domain consists of linked vertical and horizontal line segments. Fourier analysis may be used to deconstruct a digital signal. If the digital signal is periodic, which is uncommon in data transfers, the decomposed signal has an infinite bandwidth and discrete frequencies. If the digital signal is non-periodic, the decomposed signal has an unlimited bandwidth but constant frequencies. Figure 15 shows the time and frequency domains of periodic and non-periodic digital signals:

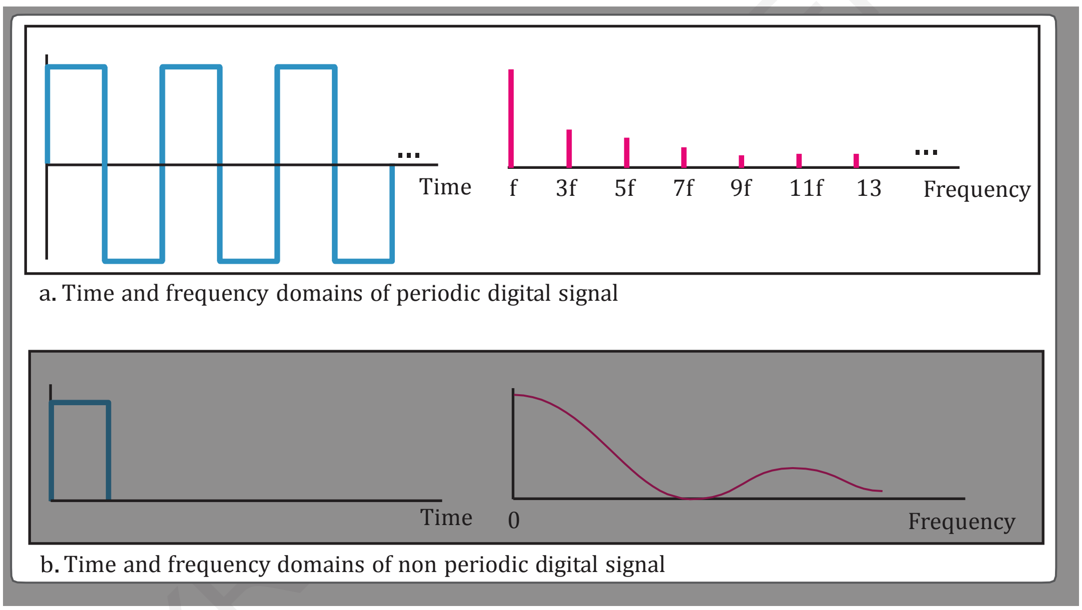


Figure 15: The Time and Frequency Domains of Periodic and Non-periodic Digital Signals

Note that a digital signal is a composite analog signal with an infinite bandwidth.

3.4.4 Transmission of Digital Signals

A digital signal can be sent in two different ways:

- Baseband Transmission
- Broadband Transmission

Baseband Transmission

The signal is sent without modification (i.e. Without modulation). The bandwidth of the signal to be sent must be smaller than the bandwidth of the channel in baseband transmission.

For example, consider a Baseband channel with a lower frequency of 0Hz and a higher frequency of 100Hz; its bandwidth is 100 (Bandwidth is computed by subtracting the highest and the lowest frequencies).

We can easily send a signal with a frequency lower than 100Hz; a channel having a bandwidth greater than the signal's bandwidth is known as a wideband channel. Logically, a signal with a frequency of 120Hz will be blocked, resulting in information loss; such a channel with a bandwidth smaller than the signal's bandwidth is known as a narrowband channel.

Broad band Transmission

We utilise modulation in broadband transmission, which means we convert the signal to an analog signal before transferring it. The digital signal is first transformed to an analog signal because we have a bandpass channel, we cannot send this signal straight over the available channel. For example, consider a bandpass channel with lower and higher frequencies of 50Hz and 80Hz, and the signal to be sent has a frequency of 10Hz. The analog signal is modulated with a carrier frequency in order to pass through the bandpass channel. For example, suppose an analog signal (10Hz) is modulated by a carrier frequency of 50Hz, resulting in a signal with a frequency of 60Hz that may pass through our bandpass channel. At the other end, the signal is demodulated and turned back into a digital signal, as shown in Figure 16:

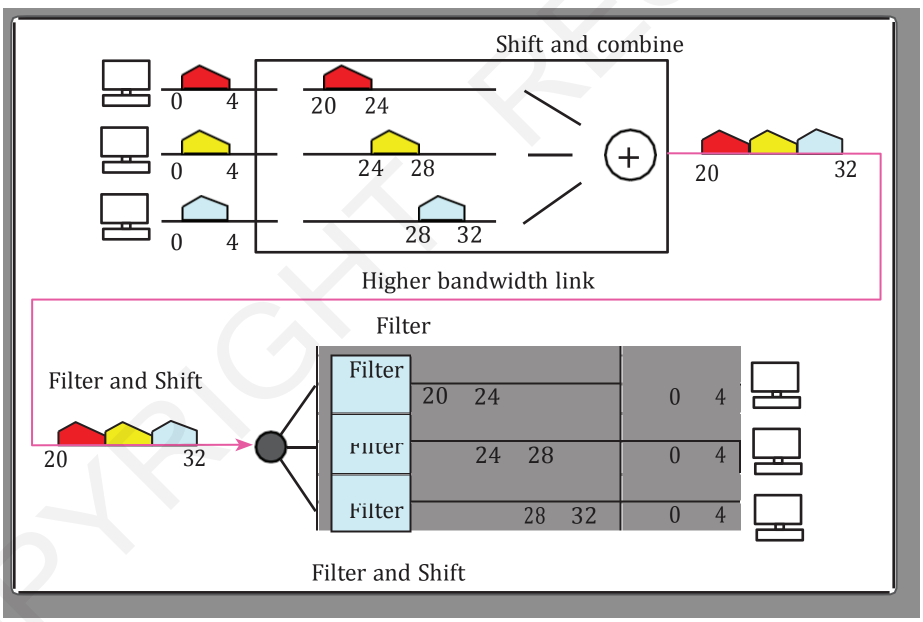


Figure 16: Broadband Transmission Involving Modulation & Demodulation

3.5 TRANSMISSION IMPAIRMENT

The original signals at the source are altered at the destination after passing through certain transmission media. This indicates that there is a problem with the signal. Signal degradation is caused by three factors: attenuation, distortion, and noise.

3.5.1 Attenuation

Attenuation is defined as a loss of energy. When a signal is sent from source to destination over a communication channel or medium, it loses part of its energy due to the resistance of the medium and some of the electrical energy in the signal is transformed to heat. As a result of this attenuation, the signal gets degraded. Amplifiers are used to enhance signals and reduce signal attenuation. The decibel (dB) is a unit used to express the relative intensity of two signals or one signal at two distinct locations. When a signal is attenuated, the decibel is negative; when a signal is amplified, the decibel is positive.

$$dB = 10\log_{10}\frac{S_p}{S_q}$$

Variables S_p and S_q are the powers of a signal at points p and q, respectively. Figure 17 shows the attenuation of signals:

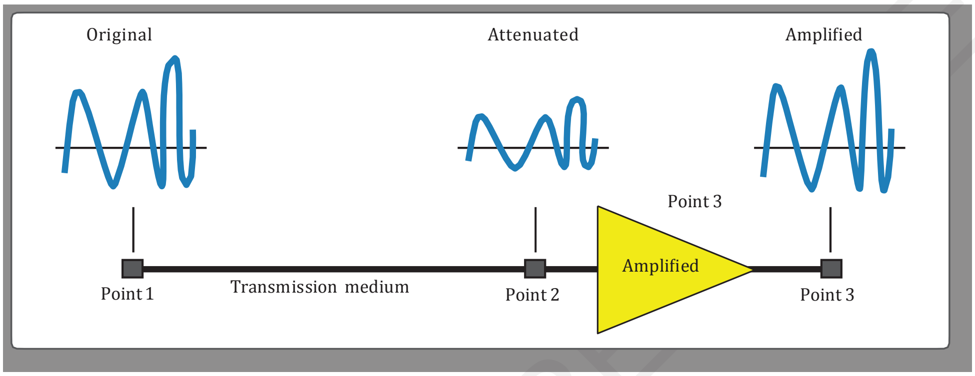


Figure 17: Signal Attenuation

3.5.2 Distortion

Signal distortion occurs when a signal alters its original form or shape while travelling from its source to its final destination. In the case of a composite signal, each sine wave has its own propagation speed across the communication channel as well as its own delay in reaching the destination. As a result, the delay of distinct sine waves varies, implying that signal components at the receiver have phases that differ from those at the sender. As a result, the final destination changes the form of the composite signal. Figure 18 shows the distortion of signals:

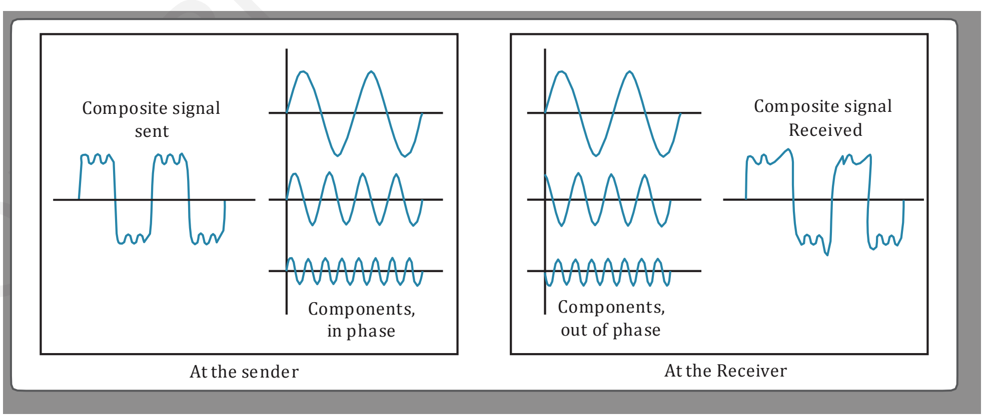


Figure 18: Signal Distortion

3.5.3 Noise

Noise is an undesirable signal that is present in all recorded signals. As a result, it is another cause of impairment. Noises such as thermal noise, generated noise, crosstalk, and impulsive noise can all damage the original signal. The random movement of electrons in a wire generates an additional signal known as thermal noise. Noises that are induced are produced by sources such as motors and appliances. The effect of the transmitting antenna on the receiving antenna is referred to as crosstalk. Impulse noise is a signal with a high energy in a short period of time that originates from sources such as power lines, lightning, and so on.

Now the signal to noise ratio is defined as follows:

$$SNR = \text{Average Signal Power} / \text{Average Noise Power}$$

SNR can be described in decibel units as follows:

$$SNR_{dB} = 10\log_{10}SNR$$

Figure 19 shows the noise in signals:

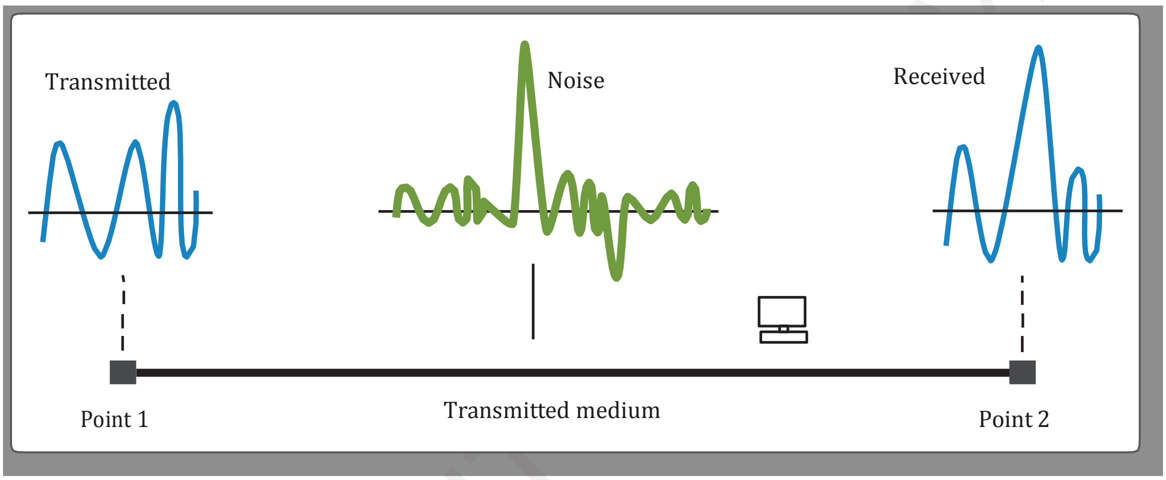


Figure 19: Noise in signals

3.6 DATA RATE LIMITS

In data communication, data rate refers to how quickly data may be transferred across a channel in bits per second. The data rate is now determined by three factors:

1. The bandwidth
2. The level of the signals
3. The quality of the channel

According to Nyquist, in the situation of a noiseless channel, the theoretical maximum bit rate may be determined using the following formula:

$$\text{Bit rate} = 2 \times B \times \log_2 N$$

Here, B is the bandwidth of the channel, N is the number of signal levels and the bit rate is calculated in bits per second.

However, in the case of our real-world data exchanges, a noiseless channel is not achievable. In 1944, Claude Shannon devised a method to compute the theoretical maximum data rate for a noisy channel. The Shannon capacity is the name given to this formula.

$$\text{Capacity} = B \times \log_2 (1+SNR)$$

Here, B is the bandwidth of the channel, SNR is the signal to noise ratio and capacity is the bit rate of the channel in bits per second.

3.7 PERFORMANCE

How good is the network's performance? This is an essential topic in networking. We talk about quality of service, which is an overall assessment of network performance.

3.7.1 Bandwidth

The part of the electromagnetic spectrum occupied by the signal is described as its bandwidth. It is also the frequency range across which a signal is conveyed. The bandwidth of various sorts of transmissions varies. For example, a voice signal, a music signal, and so on.

Analog and digital signal bandwidths are calculated differently; analog signal bandwidth is measured in terms of frequency (hz), whereas digital signal bandwidth is measured in terms of bit rate (bits per second, bps). The bandwidth of the signal differs from the bandwidth of the medium/channel.

Bandwidth of a Channel

A channel is the medium via which the information-carrying signal will be transmitted. The bandwidth of the channel is the analog signal's frequency range that the channel can convey. In terms of digitalsignals, channel bandwidth is the highest bit rate supported by the channel. Specifically, it is the maximum quantity of data that a channel can convey per second.

The medium's bandwidth should always be larger than the bandwidth of the signal to be sent; otherwise, the transmitted signal will be attenuated, distorted, or both, resulting in information loss. The channel bandwidth controls whether an analog or digital signal will be delivered.

3.7.2 Throughput

The throughput is the quantity of data that can be transmitted across a communication connection in bits per second. As a result, it differs from bandwidth, which provides the entire capacity of a channel in the case of data transmission in bits per second. In general, throughput is always smaller than the bandwidth of a communication connection.

3.7.3 Latency (Delay)

The length of time necessary to reach a whole message entirely at the destination -from the moment the first bit is transmitted to the source- is referred to as latency or delay. The delay is determined using the formula below:

Latency = Propagation Time + Transmission Time + Queuing Time + Processing Delay

The following is the description of the different elements of a latency formula:

- Propagation Time: The amount of time necessary for a bit to get from the source to the destination is referred to as propagation time. Divide the distance by the propagation speed to get the propagation time.

Propagation Time = Distance / Propagation Speed

The propagation speed of electromagnetic signals is determined by two factors: the communication medium and the signal frequency.

- Transmission Time: The time it takes for a full message to reach the receiver from the sender is referred to as the transmission time in data communications. In other words, the transmission time is the period between the first bit leaving the sender and the final bit arriving at the recipient of a message. The transmission time of a message is determined by the message's size and the channel's bandwidth.

Transmission Time = Message Size / Bandwidth

- Queuing Time: The queue time is the amount of time it takes for each intermediate or end device to hold the message before processing it. The waiting time varies according on the level of strain on the communication network. An intermediate or end device, such as a router, processes the messages one by one in some sequence. If there are a lot of messages, each one will have to wait. As a result, as the network traffic grows, so does the queuing time.

3.7.4 Bandwidth-Delay Product

The bandwidth-delay product, which is very significant in data transmission, is the product of the two. The bandwidth-delay product specifies the number of bits that may be sent across the channel. Note that, the bandwidth-delay product specifies the maximum number of bits that may be sent across the channel. Figure 20 shows the bandwidth-delay product:

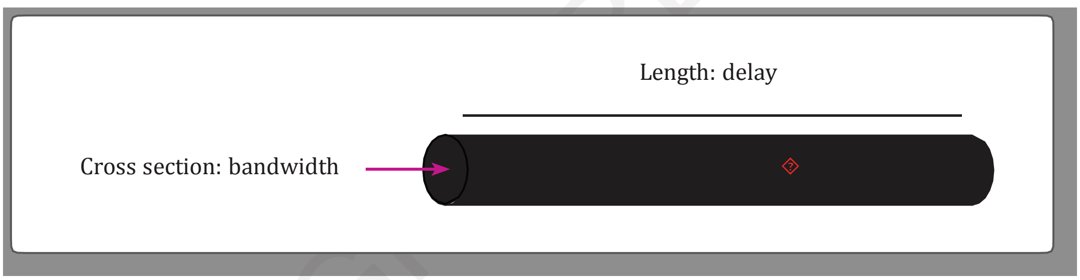


Figure 20: Bandwidth-Delay Product

3.7.5 Jitter

Jitter is defined as a change in the latency between received packets. This continuous stream can become lumpy or the latency between each packet might fluctuate instead of being constant due to network congestion, incorrect queuing, or configuration problems.

3.8 CONCLUSION

- The physical layer is the sole layer of the OSI network architecture that deals with the physical connection of two separate stations.
- It is made up of various networking gear, transmission medium, and computer network transmission methods.
- Analog is the inverse of digital. The original meaning of analog was anything that is comparable to another; the two are said to be analogous.

- The term "digital" refers to electrical equipment that creates, stores, and analyses data in two states: positive and negative.
- Analog data is data that is physically represented. Analog data is used by all analog devices.
- Digital data is data that represents different types of data via the use of specialised machine language systems that may be understood by various technologies.
- Digital data is used by all digital devices.
- Periodic analog signals may be divided into two types: simple and composite.
- A sine wave is a basic periodic analog signal that cannot be broken into smaller signals.
- According to Fourier analysis, any composite signal is a mixture of simple sine waves with varying frequencies, amplitudes, and phases.
- A periodic composite signal is a collection of discrete-frequency signals, whereas a nonperiodic composite signal is a mixture of sine waves with continuous frequencies.
- A sine wave is a basic periodic analog signal that cannot be broken into smaller signals.
- A sine wave is characterized by three parameters:
  - Peak Amplitude
  - Frequency
  - Phase
- Peak amplitude is a signal's amplitude is the absolute magnitude of its intensity at time t.
- The number of cycles completed by the wave in one second is referred to as its frequency.
- The phase of a waveform specifies its location with respect to time (specifically relative to time 0).
- The wavelength of a signal is defined as the connection between frequency (or period) and wave propagation speed across a medium.
- The time-domain graphic depicts variations in signal amplitude over time. It represents the time and amplitude relationship of a signal.
- The frequency-domain graphic displays the signal frequency as well as the peak amplitude.
- A composite signal is made up of two or more basic sine waves that have distinct frequencies, phases, and amplitudes.
- Composite signals can be either periodic or asynchronous.
- A periodic composite signal can be decomposed into a succession of discrete frequency signals.
- The bandwidth of a composite signal is the range of frequencies present in it.
- A digital signal can also be used to explain information.
- Bit rate is the amount of data sent in one second.
- A digital signal's bit length is the distance one bit occupies on the transmission media, which may be determined using the following equations.
- A digital signal can be sent in two different ways:
- Baseband Transmission
- Broad band Transmission

- Attenuation is defined as a loss of energy. When a signal is sent from source to destination over a communication channel or medium, it loses part of its energy due to the resistance of the medium, and some of the electrical energy in the signal is transformed to heat.
- Signal distortion occurs when a signal alters its original form or shape while travelling from its source to its final destination.
- Noise is an undesirable signal that is present in all recorded signals. As a result, it is another cause of impairment.
- The part of the electromagnetic spectrum occupied by the signal is described as its bandwidth.
- A channel is the medium via which the information-carrying signal will be transmitted.
- The throughput is the quantity of data that can be transmitted across a communication connection in bits per second.
- The length of time necessary to reach a whole message entirely at the destination from the moment the first bit is transmitted to the source is referred to as latency or delay.
- The amount of time necessary for a bit to get from the source to the destination is referred to as propagation time.
- The time it takes for a full message to arrive reach the receiver from the sender is referred to as the transmission time in data communications.
- The queue time is the amount of time it takes for each intermediate or end device to hold the message before processing it.
- The bandwidth-delay product, which is very significant in data transmission, is the product of the two.
- Jitter is defined as a change in the latency between received packets.

3.9 GLOSSARY

- Bandwidth: The difference between a composite signal's highest and lowest frequencies. It also determines a line's or network's information-carrying capacity.
- Physical Layer: The mechanical and electrical requirements of the medium are handled by the first layer of the Internet model.
- Analog data: It refers to a data that is physically represented.
- Digital data: IT refers to a data that represents different types of data via the use of specialised machine language systems that may be understood by various technologies.
- Sine wave: It is a basic periodic analog signal that cannot be broken into smaller signals.
- Peak amplitude: It is a signal's amplitude is the absolute magnitude of its intensity at time t.
- Composite signal: A signal that is made up of two or more basic sine waves that have distinct frequencies, phases, and amplitudes.
- Jitter: It is defined as a change in the latency between received packets.
- Optical Fiber: A light beam is carried by a tiny thread of glass or other transparent material.
- Packet Switching: A packet-switched network is used to transmit data.

3.10 SELF-ASSESSMENT QUESTIONS

A. Essay Type Questions

1. The physical layer is the sole layer of the OSI network architecture that deals with the physical connection of two separate stations. Discuss.
2. List down the different between analog signal and digital signal.
3. A sine wave is a basic periodic analog signal that cannot be broken into smaller signals. Discuss the parameter of a sine wave.
4. A digital signal can be sent in two different ways. Discuss.
5. Signal degradation is caused by three factors: attenuation, distortion, and noise. Discuss the concept of distortion in detail.

3.11 ANSWERS AND HINTS FOR SELF-ASSESSMENT QUESTIONS

A. Hints for Essay Type Questions

1. This layer specifies the hardware, cabling, wiring, frequencies, and pulses required to represent binary signals, among other things. It is made up of various networking gear, transmission medium, and computer network transmission methods. Refer to Section Introduction
2. An analog signal is a continuously varying electromagnetic wave in which the time varying characteristic of the signal is a representation of some other time varying quantity that depending on spectrum, may be carried via a number of mediums. Refer to Section Analog and Digital
3. A sine wave is defined by three parameters, namely, peak amplitude, frequency, and phase. The description of the parameters is as follows:
   - Peak amplitude: A signal's amplitude is the absolute magnitude of its intensity at time 't'. A signal's peak amplitude is the absolute magnitude of its maximum intensity. A signal's amplitude is proportional to the energy carried by the signal.

   Refer to Section Periodic Analog Signals
4. A digital signal can be sent in two different ways:
   - Baseband transmission
   - Broadband transmission

   Refer to Section Digital Signals
5. Signal distortion occurs when a signal alters its original form or shape while travelling from its source to its final destination. In the case of a composite signal, each sine wave has its own propagation speed across the communication channel as well as its own delay in reaching the destination. Refer to Section Transmission Impairment

2.12 POST-UNIT READING MATERIAL

- https://www.google.co.in/books/edition/Fundamentals_of_Data_Communication_Netwo/MRREDwAAQBAJ?hl=en&gbpv=1&dq=data+and+communication+network&printsec=frontcover

- https://www.google.co.in/books/edition/Data_Communications_and_Networking/bwUNZ vJbE eQC?hl= en&gbpv=1 &dq=data+communication+forouzan+5th+edition+ppt&printsec=frontcover

2.13 TOPICS FOR DISCUSSION FORUMS

- Discuss with your classmates about the concept of analog and digital signals. Also, do the online research on the Fourier analysis.

UNIT
04

Digital Transmission

Names of Sub-Units

The Concept of Digital to Digital, Analog to Digital Conversion, Basic Conversion Problems, Unipolar, Polar, and Multilevel, Transmission Modes and PCM, DM, Parallel, and Serial Structure.

Overview

This unit begins by discussing about the concept of digital to digital conversion. Next, the unit discusses the analog to digital conversion and basic conversion problems in unipolar, polar and multilevel conversions. Further the unit explains the Transmission modes and PCM, DM, parallel. Towards the end, the unit discusses the serial structure.

Learning Objectives

In this unit, you will learn to:

- Discuss the concept of digital to digital conversion
- Explain the concept of analog to digital conversion
- Describe the basic conversion problems in unipolar, polar and multilevel
- Explain the significance of transmission modes
- Discuss the serial structure of digital conversion

Learning Outcomes

At the end of this unit, you would:

- ⌘ Evaluate the concept of digital to digital conversion
- ⌘ Assess the concept of analog to digital conversion
- ⌘ Evaluate the importance of basic conversion problems in unipolar, polar and multilevel
- ⌘ Determine the significance of transmission modes
- ⌘ Explore the serial structure of digital conversion

4.1 INTRODUCTION

Data may be represented in two ways: Analog and digital. The information was stored in a digital format by the computers. As a result, the data must be translated to digital format before being used by a computer.

4.2 DIGITAL-TO-DIGITAL CONVERSION

The representation of digital information by a digital signal is known as digital-to-digital encoding. The process of converting binary 1s and 0s created by a computer into a series of voltage pulses that can be transmitted across a wire is known as digital-to-digital encoding.

4.2.1 Line Coding Schemes

Line coding schemes identifies the relationship among the binary information in a data bit stream and the square-wave power deviations on the wire that signify this information electrically. For example, Integrated Services Digital Network (ISDN) technology usage some different line coding schemes.

It is the conversion of digital data to a digital signal. In other terms, it is the process of transforming binary data (a sequence of bits) into a digital signal (a series of discrete, discontinuous voltage pulses). The categorization of line coding schemes is shown in the Figure 1:

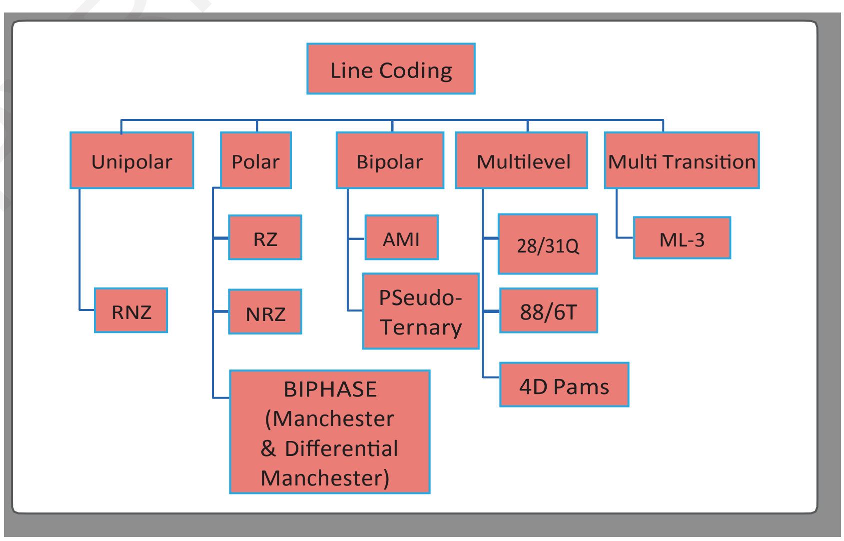


Figure 1: Classification of Line Coding Schemes

4.2.2 Unipolar

The voltage pulses are sent through a medium connection such as wire or cable in a digital transmission system. One voltage level represents 0 in most kinds of encoding, whereas another voltage level represents 1. Each pulse's polarity decides whether it is positive or negative. Because it only employs one polarity, this form of encoding is known as Unipolar encoding. The polarity is allocated to the 1 binary state in Unipolar encoding. 1s are represented as positive numbers, whereas 0s are represented as zero numbers. In Unipolar encoding, a '1' represents a high voltage and a '0' represents a zero value. Unipolar encoding is easier to implement and less costly. Unipolar encoding has two drawbacks that make it less appealing:

- DC Component
- Synchronization

4.2.3 Polar

Polar encoding is a type of encoding that employs two voltage levels, one positive and the other negative.

The average voltage level is lowered by employing two voltage levels, and the DC component issue of the unipolar encoding technique is addressed. The classification of polar encoding is shown in Figure 2:

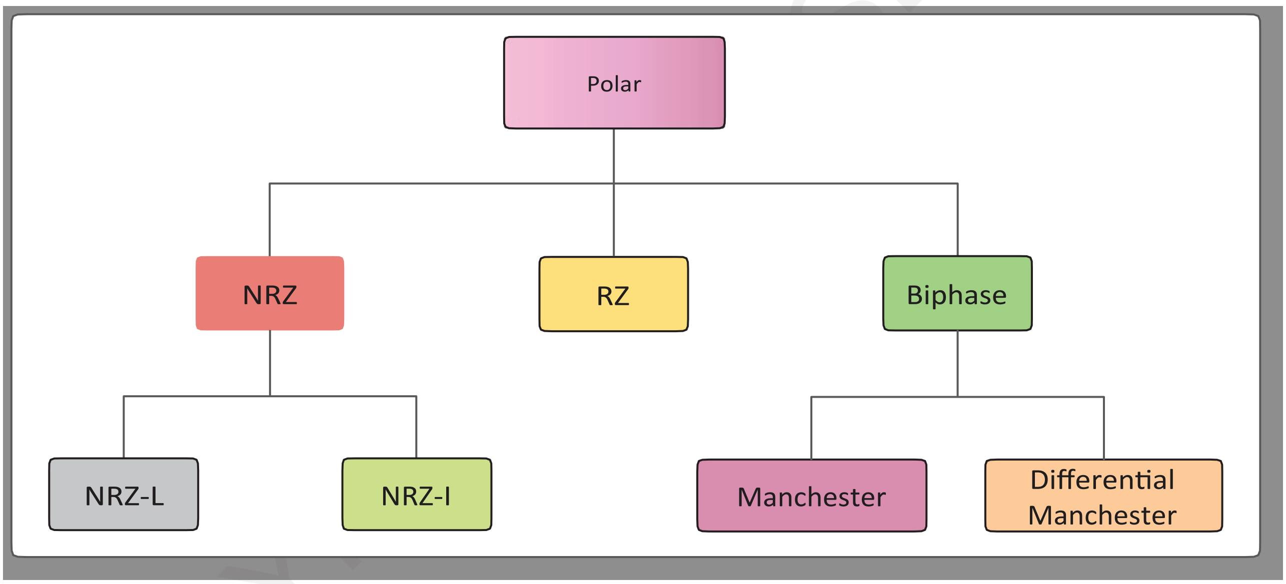


Figure 2: Classification of Polar encoding

NRZ

A NRZ stands for (non-return-to-zero) denotes to a procedure of digital transmission in which the binary states low and high is denoted by numerals 0 and 1 are transmitted by definite constant DC(direct-current) voltage s.

The following are the two most prevalent NRZ methods are as follows:

- NRZ-L: The level of the signal in NRZ-L encoding is determined by the type of bit it encodes. The voltages of a bit are positive or negative depending on whether it is 0 or 1. As a result, we may say that the signal's level is determined by the bit's state.
- NRZ-I: NRZ-I is a voltage level inversion that represents one bit. A transition between positive and negative voltage represents one bit in the NRZ-I encoding method. In this system, a 0 bit indicates no change, and a 1 bit indicates a voltage level change.

RZ

Return to zero is abbreviated RZ. To establish synchronisation, there must be a signal change for each bit. However, we need three values: Positive, negative, and zero, in order to change with each bit. Positive voltage equals 1, negative voltage equals 0, and zero voltage equals none in the RZ encoding method.

The signal in the RZ scheme returns to zero halfway through each period. Positive-to-zero represents 1 bit in the RZ scheme, while negative-to-zero represents 0 bit. RZ's disadvantage is that it makes two signal modifications in order to encode one bit with higher bandwidth.

Biphase

Biphase encoding is a type of encoding in which the signal changes in the middle of a bit interval but does not return to zero.

Biphase encoding can be accomplished in two ways:

- Manchester: It modifies the signal in the midst of the bit interval but does not reset the bit interval to zero. A negative-to-positive transition represents binary 1 in Manchester encoding, while a positive-to-negative transition represents binary 0. Manchester has the same amount of synchronisation as the RZ system, but with two amplitude levels.
- Differential Manchester: The signal is changed in the midst of the bit interval for synchronisation, but the bit is determined by the presence or absence of the transition at the beginning of the interval. Binary 0 is represented by a transition, while binary 1 is represented by the absence of a transition. Two signal changes equal 0 in the Manchester Encoding method, while one signal change equals 1.

4.2.4 Bipolar

Positive, negative, and zero voltage levels are represented using the bipolar encoding method. Binary 0 is represented by zero level, while binary 1 is represented by alternating positive and negative voltages in the Bipolar encoding method. If positive amplitude is represented by the first 1 bit, then the negative voltage is represented by the second 1 bit, positive amplitude is represented by the third 1 bit, and so on. Even if the 1bits are not consecutive, this alternation can occur. The 0 sign represents zero voltage, whereas the 1 symbol alternates between +V and -V in Bipolar Alternate Mark Inversion (AMI). The inverse of AMI is pseudoternary. The levels of positive, negative, and zero voltage are represented by bipolar encoding is shown in Figure 3:

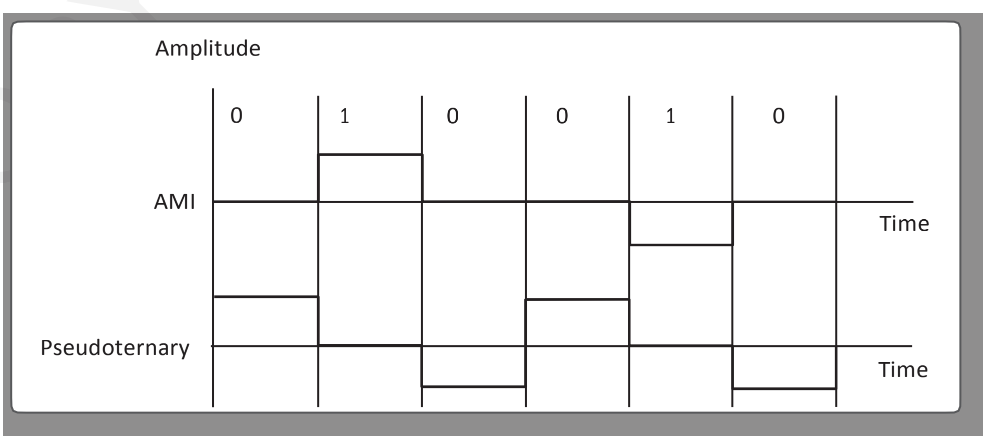


Figure 3: Representation of voltage levels using bipolar encoding.

4.2.5 Multilevel

The term 'multilevel' refers to an ordered or nested data structure, frequently subjects within organizational groups, but the nesting might also contain the constant measures within subjects, or respondents within clusters, as in cluster sample. The expression of multilevel model is used as a general term for all models for nested data. A multilevel encoding has several properties is describes as:

- To raise the bit rate, the amount of data bits per symbol is increased.
- There are two sorts of data components: A 1 and a 0. They may be put into a pattern of n elements to generate two m symbols.
- We can build L n signal elements using L signal levels and n signal elements. The following scenarios are possible:
  - With 2^m symbols and Ln signals, if $2^m > L^n$, the data items cannot be represented because there are insufficient signals.
  - We have an accurate mapping of one symbol on one signal if $2^m = L^n$.
- We have more signals than symbols if $2^{m<} L^n$, and we may pick the signals that are more distinct to represent the symbols, resulting in greater noise immunity and error detection since some signals are invalid.
- mBnL schemes are the name given to these sorts of coding. A pattern of m data elements is encoded as a pattern of n signal elements in mBnL schemes, in which $2^m <= L^n$. 2B1Q (two binary, one quaternary) is used. It employs 2-bit data patterns and encodes each 2-bit pattern as a single signal element in a four-level signal. The multilevel coding of 2B1Q is shown in Figure 4:

	Positive Level	Negative level
Next Level	Next Level	Next Level
00	+1	-1
01	+3	-3
10	-1	+1
11	-3	+3

Transition Table

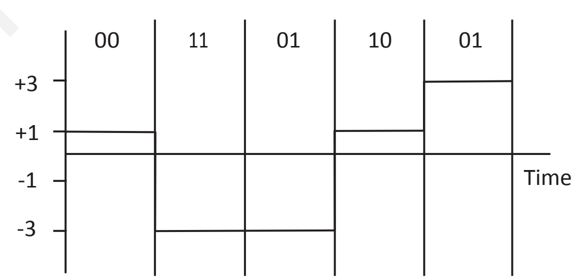


Figure 4: Multilevel Coding Scheme: 2B1Q

8B6T is a hexadecimal number that (eight binary, six ternary). Here, an 8-bit pattern is encoded as a pattern of six signal elements, with the signal having three levels. m = 8; n = 6; T = 3 in this case. As a result, we can have 2^8 =256 data patterns and 3^6 =478 signal patterns.

An example of multilevel coding schemes of 8B6T is shown in Figure 5:

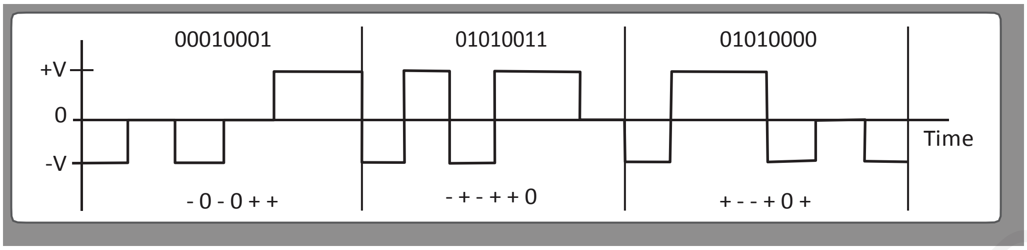


Figure 5: Multilevel coding scheme: 8B6T

The 4 data line made possible by the 5-level pulse amplitude modulation which is known as (4D-PAM5) block-encoding scheme. PAM is a system that encodes message information in the amplitude of a sequence of signal pulses. It has five levels provide it 625 code points. Data is delivered across four channels at the same time, which is referred to as 4D.It has five different voltage levels are -2, -1, 0, 1, and 2.

4.2.6 Multitransitional

- Transitions are forced due to synchronisation constraints. This might result in very high bandwidth needs since there are more transitions than bits (for example, a mid-bit transition with inversion).
- Differential codes can be constructed at the bit level, causing transitions at bit boundaries. As a result, the bandwidth need is the same as the bit rate.
- Due to repeated patterns resulting in a periodic signal, the bandwidth need may potentially be lower in some cases.

MLT-3 uses three levels (+v, 0, and -V) and three transition rules to shift between them, with the same signal rate as NRZ-I.

- There is no transition if the next bit is 0.
- The next level is 0 if the next bit is 1 and the current level is not 0.
- The next level is the inverse of the last non-zero level if the next bit is 1 and the current level is 0.

4.2.7 Block Coding Schemes (4B/5B)

4B/5B encoding is a form of 'Block coding'. This process is a set of bits rather than outputting a signal for each single bit (as in Manchester encoding). A set of 4 bits is encoded therefore an additional 5th bit is added. As the input data is occupied 4-bits at a time, there are 2^4, or 16 different bit patterns. The following points refer to the functions of block coding are as follows:

- Block coding provides redundancy to line coding, allowing for mistake detection.
- Block coding converts an m-bit block into an n-bit block, where n is more than m.
- The mB/nB encoding technique is also known as block coding.
- Parity bits or check bits are the extra bits appended to the initial m bits.

An example of block coding schemes is shown in Figure 6:

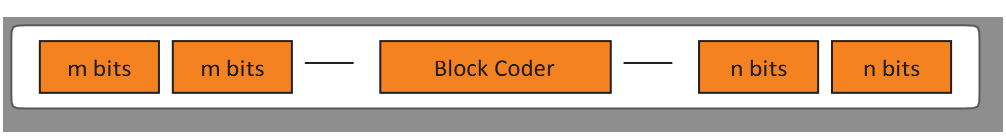


Figure 6: Block Coding

A 4-bit code is transformed to a 5-bit code in this example.

4.3 ANALOG-TO-DIGITAL CONVERSION

Analog-to-digital conversion is the process of digitalizing an analog signal. If a human delivers a voice as an analog signal, we must digitalize the signal to make it less susceptible to noise. It necessitates a decrease in the number of values in an analog message in order to represent them in a digital stream. The information contained in a continuous waveform is transformed into digital pulses during analog-to-digital conversion.

4.3.1 Pulse Code Modulation (PCM)

It is the process of converting an analog signal to a digital signal. The signal-to-noise ratio in PCM is good or reasonable. Pulse Code Modulation requires a large transmitter bandwidth for transmission. The PCM method is divided into three parts: Transmission at the provision end, regeneration along the transmission path, and reception at the receiving end.

4.3.2 Delta Modulation (DM)

Delta modulation is a signal conversion method that converts analog to digital and digital to analog signals. To get a high signal-to-noise ratio, delta modulation is used. To digitally transmit an analog signal, it employs a one-bit PCM coding. Instead of transmitting a coded representation of a sample, delta modulation sends only one bit, which simply signals whether the sample is larger or less than the preceding sample. Differential Pulse Code Modulation of this form is the best or simplest. When compared to the Pulse Code Modulation method, the Delta Modulation signal is smaller.

The next bit in digital data is 1 if the signal is strong; otherwise, it is 0.

4.4 TRANSMISSION MODES

Data is sent across the internet between two digital devices. In the form of bits, a network. The transmission mode is the mode in which data is sent the information. It's possible that the transmission medium is capable of transmitting a single bit per unit of time or several bits per unit of time. Serial transmission is used when a single bit is delivered in a unit of time, while Parallel transmission is used when several bits are sent in a unit of time.

4.4.1 Parallel Transmission

It entails sending N bits across N distinct channels at the same time. When compared to serial transmission, parallel transmission improves transmission speed by a factor of N. The cost of parallel transmission is high since N channels must be employed; therefore it is only suitable for short-distance communication. The communication between the CPU and the projector is an example of parallel transmission.

4.4.2 Serial Transmission

Serial transmission is a process of transmitting a single that sends information of one bit at a time above a single data channel. Data is transferred serially via Serial Transmission, as the name implies, bit by bit, one bit at a time. A single channel is necessary since just one bit must be sent per unit of time. Serial transmission is usually used to join data communications equipment.

4.4.3 Types of Serial Transmission

There are a variety of options based on the timing of data transfer. As stated below, there are two forms of serial transmission is as follows:

Asynchronous Transmission

The following points describes asynchronous transmission is as follows:

- The transmitter and receiver work together in asynchronous serial transmission. And aren't in tune with each other.
- The data is transmitted in 8-bit chunks, or bytes.
- At any time, the sender can begin data transfer, without notifying the recipient
- To prevent the recipient from being confused while receiving the information, before and after each operation, start and stop bits are added. 8-bit group (as displayed below)
- The start and stop bits are represented by 0 and 1, respectively.
- Although the transmitter and receiver may not be synchronised as shown above, they must be synchronised at the bit level, that is, the duration of one bit must be the same for both sender and receiver for correct data transfer.
- There may be pauses in the data transfer, indicating that the sender is not transmitting any data. Consider a user who types at varying speeds, with no data being sent from the keyboard to the CPU at periods.

The asynchronous serial transmission is shown in Figure 7:

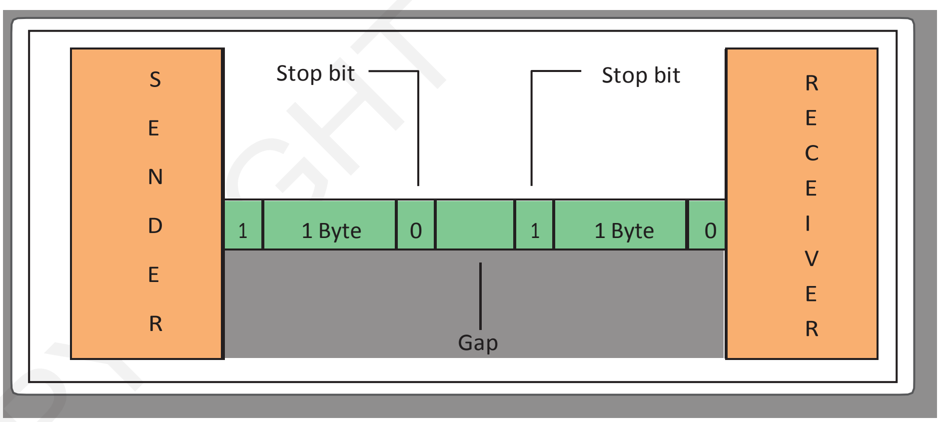


Figure 7: Asynchronous Serial Transmission

Synchronous Transmission

The following points describe about the synchronous transmission:

- The transmitter and receiver are well synced in Synchronous Serial Transmission.
- There is no start or stop bits utilised.
- Instead, a standard master clock is utilised as a point of reference.
- The transmitter merely sends a stream of data bits to the receiver in groups of eight bits, with no start or stop bits.

- Once the bits have been received, it is the receiver's job to recombine them into 8-bit units.
- When no data is being transferred, the sender places a sequence of 0s and 1s on the transmission media to indicate IDLE.

The synchronous serial transmission is shown in Figure 8:

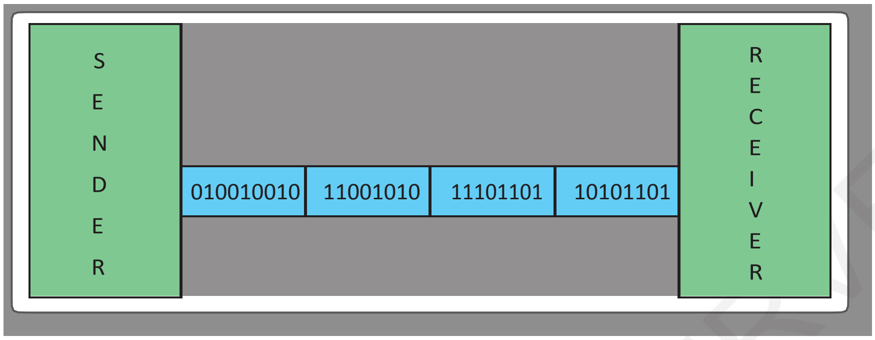


Figure 8: Synchronous Serial Transmission

4.5 CONCLUSION

- Analog-to-digital conversion is the process of digitalizing an analog signal.
- The process of converting binary 1s and 0s created by a computer into a series of voltage pulses is known as digital-to-digital encoding.
- Line coding is the process of transforming binary data (a sequence of bits) into a digital signal.
- Polar encoding is a type of encoding that employs two voltage levels, one positive and the other negative.
- The signal in the RZ scheme returns to zero halfway through each period.
- Pulse code modulation is the process of converting an analog signal to a digital signal.
- The transmission mode is the mode in which data is sent the information.
- Analog-to-digital conversion is the process of digitalizing an analog signal.

4.6 GLOSSARY

- Transmission: A device that sits between a power supply and a specific application in order to adjust one to the other.
- Synchronous: Occurs simultaneously.
- Asynchronous: This does not occur at the same moment.
- Modulation: The process of encoding information from a message source in a fashion that can be sent is known as modulation.
- Polar encoding: It is a type of encoding that employs two voltage levels, one positive and the other negative.
- Pulse Code Modulation (PCM): It is the process of converting an analog signal to a digital signal.
- Analog-to-digital conversion: It is the process of digitalizing an analog signal.

4.7 SELF-ASSESSMENT QUESTIONS

A. Essay Type Questions

1. The process of converting binary 1s and 0s created by a computer into a series of voltage pulses. Explain the concept of digital-to-digital conversion.
2. Positive, negative, and zero voltage levels are represented using the bipolar encoding method. What is a bipolar conversion?
3. It is the process of converting an analog signal to a digital signal. The signal-to-noise ratio in PCM is good or reasonable. Describe the significance of pulse code modulation (PCM).
4. Data is sent across the internet between two digital devices. In the form of bits, a network. Determine the types of transmission mode.
5. It is the process of transforming binary data (a sequence of bits) into a digital signal (a series of discrete, discontinuous voltage pulses). Explain the classification of line coding schemes.

4.8 ANSWERS AND HINTS FOR SELF-ASSESSMENT QUESTIONS

A. Hints for Essay Type Questions

1. The representation of digital information by a digital signal is known as digital-to-digital encoding. The process of converting binary 1s and 0s created by a computer into a series of voltage pulses that can be transmitted across a wire is known as digital-to-digital encoding. Refer to Section Digital-to-Digital Conversion
2. Positive, negative, and zero voltage levels are represented using the bipolar encoding method. Binary 0 is represented by zero level, while binary 1 is represented by alternating positive and negative voltage in the Bipolar encoding method. Refer to Section Digital-to-Digital Conversion
3. It is the process of converting an analog signal to a digital signal. The signal-to-noise ratio in PCM is good or reasonable. Pulse Code Modulation requires a large transmitter bandwidth for transmission. The PCM method is divided into three parts: Transmission at the provision end, regeneration along the transmission path, and reception at the receiving end. Refer to Section Analog-to-Digital Conversion
4. Data is sent across the internet between two digital devices. In the form of bits, a network. The transmission mode is the mode in which data is sent the information. It's possible that the transmission medium is capable of transmitting a single bit per unit of time or several bits per unit of time. Refer to Section Transmission Modes
5. It is the conversion of digital data to a digital signal. In other terms, it is the process of transforming binary data (a sequence of bits) into a digital signal (a series of discrete, discontinuous voltage pulses). Refer to Section Digital-to-Digital Conversion

4.9 POST-UNIT READING MATERIAL

- https://www.tutorialspoint.com/data_communication_computer_network/index.htm
- https://www.smartzworld.com/notes/data-communication-and-computer-networks-pdf-notes-dccn/

4.10 TOPICS FOR DISCUSSION FORUMS

- Discuss with your friends and classmates about the concept of digital transmission and the different types of transmission modes. Also, discuss about the basic conversion problems and how they can relate to our real life, discuss its real world examples.

UNIT

05

Analog Transmission

Names of Sub-Units

Introduction to Conversion, the Concept of Conversion, Amplitude, Frequency and Phase Basic Conversion Problems, Modulation, Shift Keying and Concepts, Definition, Goals, and Structure.

Overview

This unit begins by discussing about the concept of conversion. Next, the unit discusses the concept of amplitude, frequency and phase basic conversion problems. Further the unit explains the modulations, shift keying and its concepts. Towards the end, the unit discusses the definition, goals and structure of conversion.

Learning Objectives

In this unit, you will learn to:

- Discuss the concept of conversion
- Explain the concept of amplitude, frequency and phase basic conversion problems
- Describe the concepts of modulation and shift keying
- Explain the significance of conversion
- Discuss about the goals and structure of conversion

Learning Outcomes

At the end of this unit, you would:

⌘ Evaluate the concept of conversion

⌘ Assess the concept of amplitude, frequency and phase basic conversion problems

⌘ Evaluate the importance of modulations, shift keying and its concepts

⌘ Determine the significance of conversion

⌘ Explore the goals and structure of conversion

5.1 INTRODUCTION

To send digital or analog data via an analog medium, it must first be transformed into analog signals. According to data formatting, there are two possibilities are as follows:

- Bandpass: Filters are employed in real-world settings to filter and pass frequencies of interest. A bandpass is a range of frequencies that can pass through the filter.
- Low-pass: A low-pass filter is one that allows low-frequency signals to pass through.

Digital-to-analog conversion occurs when digital data is transformed into a bandpass analog signal. Analog-to-analog conversion occurs when a low-pass analog signal is transformed into a bandpass analog signal.

5.2 DIGITAL-TO-ANALOG CONVERSION

The process of altering one of the properties of an analog signal based on information in digital data is known as digital-to-analog conversion. The diagram below depicts the relationship between digital data, the digital-to-analog modulation process, and the resulting analog signal. The process of digital-to-analog conversion is shown in Figure 1:

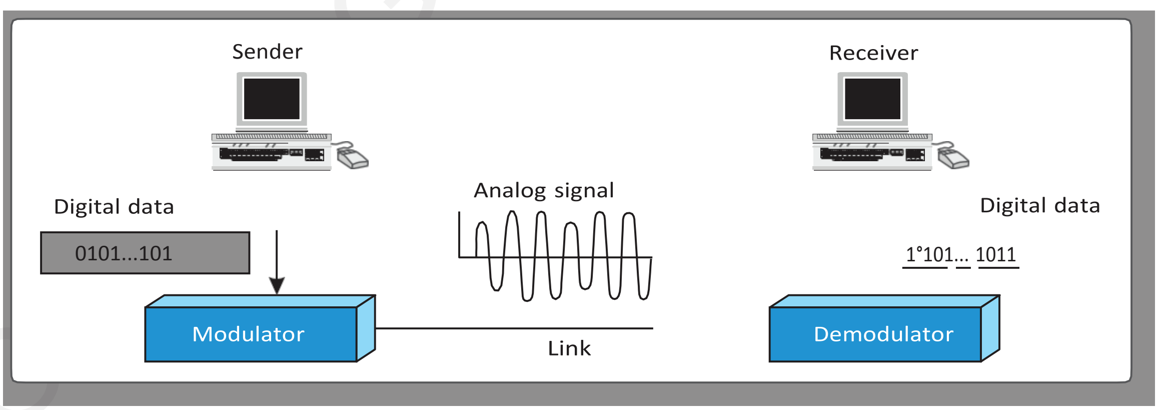


Figure 1: Digital-To-Analog Conversion

A sine wave has three properties: Amplitude, frequency, and phase. When we change any of these properties, we generate a new form of the wave. So, by modifying one aspect of a basic electric signal, we may utilize it to represent digital data. Any of the three properties can be changed in this manner, resulting in at least three techniques for converting digital data into an analog signal: Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), and Phase Shift Keying (PSK). In addition, quadrature amplitude modulation is a fourth (and superior) method that combines altering both the amplitude and phase (QAM).

QAM is the most efficient of these alternatives and is the most widely employed method today. The three properties using for converting digital data into an analog signal is shown in Figure 2:

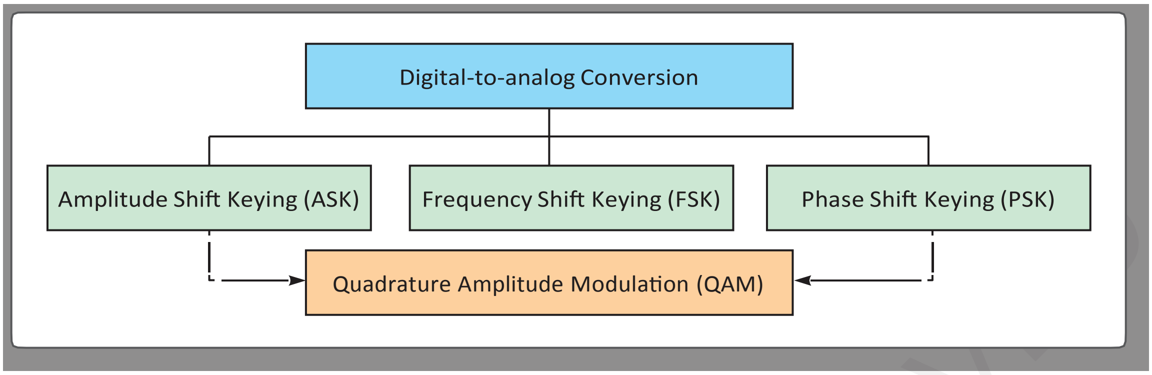


Figure 2: Conversion of Digital Data into an Analog Signal

The following points describes the aspects of digital-to-analog conversion is as follows:

Before delving into particular techniques of digital-to-analog modulation, two fundamental concerns must be addressed: Bit and baud rates, as well as the carrier signal.

- Data Element versus Signal Element: A data element is defined as the smallest piece of information that may be transmitted, the bit. We also defined a signal element as the smallest constant unit of a signal. We shall observe that the nature of the signal element differs slightly in analog transmission.
- Data Rate versus Signal Rate: As with digital transmission, we may determine the data rate (bit rate) and the signal rate (baud rate). They have a good relationship.

$$S = N/r \text{ baud}$$

Where N is the data rate (bps) and r denotes the number of data elements carried by a single signal element. In analog transmission, the value of r is r =log2 L, where L represents the type of signal element, not the level.

- Carrier Signal: In analog transmission, the transmitting equipment generates a high-frequency signal that serves as the information signal's foundation. The carrier signal or carrier frequency is the name given to this basic signal. The receiving device is tuned to the frequency of the carrier signal that the sender anticipates. The carrier signal is then altered by digital information by altering one or more of its properties (amplitude, frequency, or phase). This type of change is known as modulation (shift keying).

Note: The number of bits per second is referred to as the bit rate. The number of signal elements per second is referred to as the baud rate. The baud rate is less than or equal to the bit rate in analog digital data transfer.

5.2.1 Amplitude Shift Keying

To generate signal elements, the amplitude of the carrier signal is changed in amplitude shift keying. Both frequency and phase stay unchanged in this case. The following are the two types of ASK. It is commonly done using only two levels of signal components and is known as binary amplitude shift keying or on-off keying. In this case, the peak amplitude of one signal level is 0 and the peak amplitude of the other is the same as the amplitude of the carrier signal.

How amplitude of carrier signal is changed in amplitude shift keying? Is shown in Figure 3:

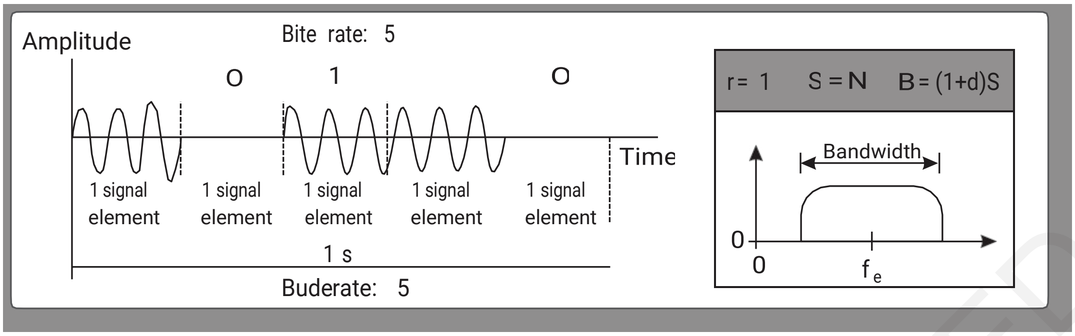


Figure 3: Conversion of Amplitude Carrier Signal into Amplitude Shift Keying (ASK)

There are two types of amplitude shift keying are as follows:

- Bandwidth of ASK: The bandwidth B of ASK is proportional to the signal rate S.

$$B = (1+d)\,S$$

  "d" is due to modulation and filtering, lies between 0 and 1.

- Multilevel ASK: We can have a multilevel ASK with more than two levels. The signal can have 4, 8, 16, or more various amplitudes, and the data can be modulated with 2, 3, 4, or more bits at a time. r = 2, r = 3, r = 4, and so on in these instances. Although this is not done with pure ASK, it is done using QAM.

5.2.2 Frequency Shift Keying

In the instance of frequency shift keying, the carrier signal's frequency is altered to represent signal components. In this case, the modulated signal's frequency remains constant for the length of one signal element and changes for the following signal element if the data element changes. Peak amplitude and phase, on the other hand, stay constant for all signal components. In Binary Frequency Shift Keying (BFSK), two carrier frequencies are considered and more than two carrier frequencies are used in Multilevel Frequency Shift Keying (MFSK) are as follows:

- Binary FSK (BFSK): Consider two carrier frequencies while thinking about binary FSK (or BFSK). We have chosen two carrier frequencies, f_1 and f_2, in Figure. If the data element is 0, we utilize the first carrier; if the data element is 1, we use the second. However, keep in mind that this is a fictitious example used solely for illustration reasons. Normally the carrier frequencies are very high, and the difference between them is very small. An example of binary frequency shift keying is shown in Figure 4:

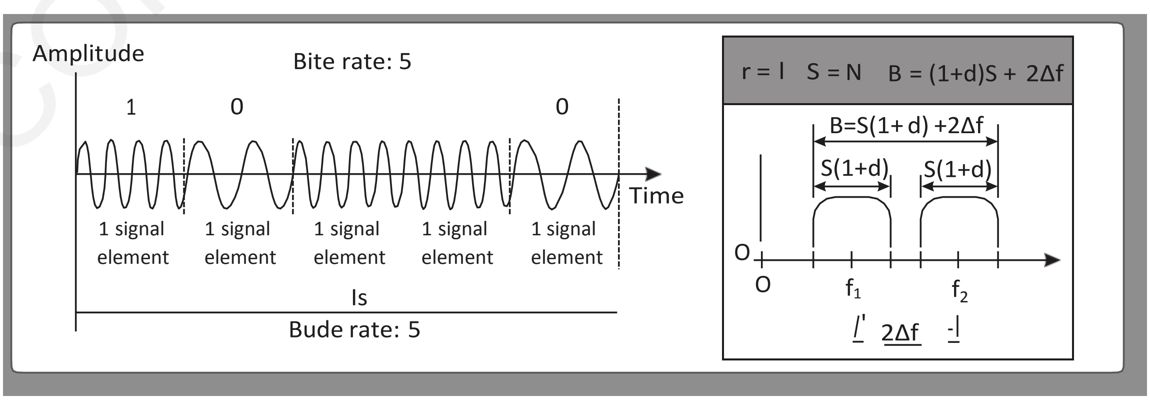


Figure 4: Binary Frequency Shift Keying

- Bandwidth of FSK: If the difference between the two frequencies (f1 and f2) is 2Df, then the required bandwidth B will be:

$$B = (1+d) \times S + 2Df$$

- Multilevel FSK: With the FSK technique, multilevel modulation (MFSK) is fairly uncommon. We have the option of using more than two frequencies. For example, we can communicate two bits at a time using four distinct frequencies, f1, f2, f3, and f4. To send 3 bits at a time, we can use eight frequencies. And so on. However, we need to remember that the frequencies need to be 2Df apart. For the proper operation of the modulator and demodulator, it can be shown that the minimum value of 2Df needs to be S. We can show that the bandwidth with d = 0 is:

$$B = (l+d) \times S + (L-1)2Df \Rightarrow B = L \times S$$

5.2.3 Phase Shift Keying

The phase of the carrier is changed in phase shift keying to represent two or more distinct signal components. As the phase changes, the peak amplitude and frequency stay constant. PSK is now more prevalent than ASK or FSK. However, we will see that QAM, which combines ASK and PSK, is the dominant method of digital-to-analog modulation. The method of phase shift keying are as follows:

- Binary PSK (BPSK): Binary PSK is the simplest PSK, with only two signal components, one with a phase of 0° and the other with a phase of 180°. In Figure depicts a conceptual representation of PSK. Binary PSK is the same as binary ASK, but it has one major *advantage, i.e.,* it is less sensitive to noise. The amplitude of the signal is the condition for bit detection in ASK; the phase is the criterion in PSK. Noise may alter the amplitude more easily than it can alter the phase. To put it another way, PSK is less sensitive to noise than ASK. PSK is preferable to FSK because it eliminates the requirement for two carrier signals. An example of binary phase shift keying is shown in Figure 5:

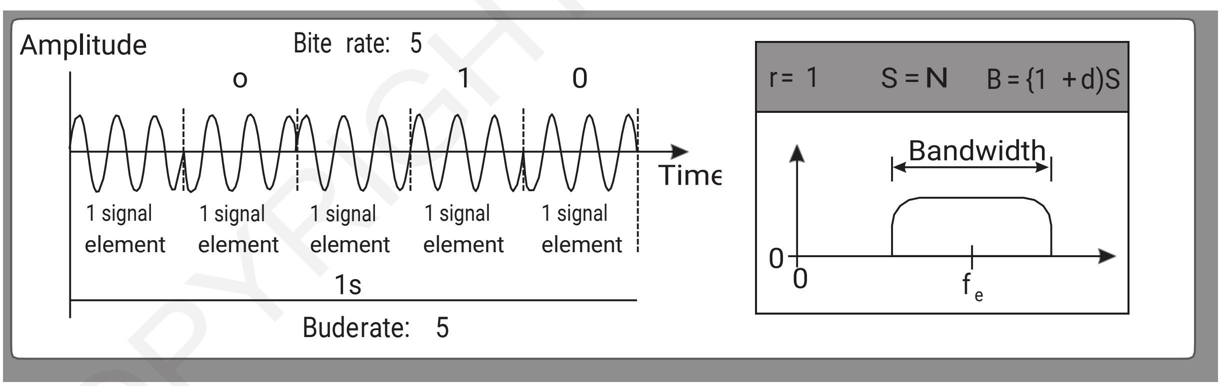


Figure 5: Binary Phase Shift Keying

- Bandwidth: The bandwidth for BPSK is also included in the figure. The bandwidth is the same as in binary ASK, but less than in BFSK. There is no wasted bandwidth in the separation of two carrier signals.

5.2.4 Quadrature Amplitude Modulation

PSK is restricted by the equipment's capacity to detect minor changes in phase. This factor restricts its maximum bit rate. So far, we've only changed one of the three properties of a sine wave at a time; what if we change two? What about combining ASK with PSK? The principle underlying quadrature amplitude modulation is the use of two carriers, one in-phase and the other quadrature, with differing amplitude levels for each carrier (QAM).

Note: Quadrature amplitude modulation is a combination of ASK and PSK

QAM has a plethora of potential variants. Some of these schemes are seen in the figure. Part A depicts the most basic 4-QAM method (four distinct signal element types) that uses a unipolar NRZ signal to modulate each carrier. This is the same process as in ASK (OOK). Part B displays another 4-QAM with polar NRZ, although this is identical to QPSK. Part C depicts another QAM-4 in which we modulated each of the two carriers with a signal with two positive values. Finally, Part D depicts a 16-QAM signal constellation with eight levels, four positive and four negative. An example of quadrature amplitude modulation is shown in Figure 6:

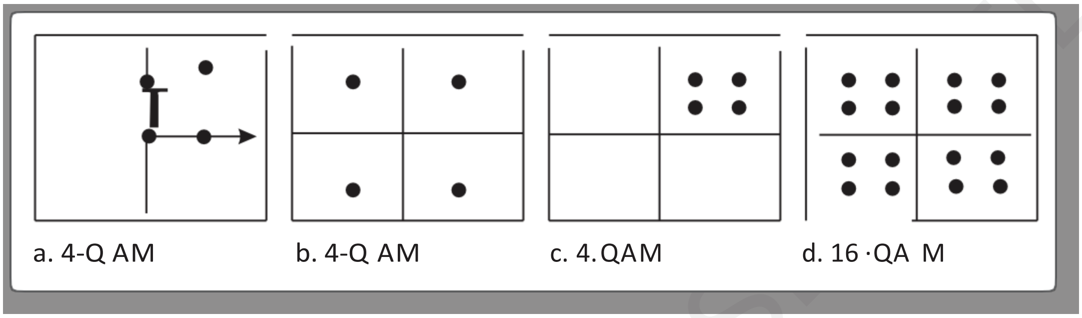


Figure 6: Quadrature Amplitude Modulation

The minimum bandwidth required for QAM transmission is the same as that required for ASK and PSK transmission. QAM has the same advantages as PSK over ASK.

5.3 ANALOG-TO-ANALOG CONVERSION

The encoding of analog information by an analog signal is known as analog-to-analog conversion or analog modulation. One could wonder why we would need to modify an analog signal that is already analog. Modulation is required if the medium is bandpass in nature or if we only have access to a bandpass channel. Radio is one example. Each radio station is given a limited bandwidth by the government. Each station's analog transmission is a low-pass signal in the same frequency band. To listen to various stations, the low-pass signals must be adjusted to a different range.

There are three methods for converting analog to analog: Amplitude Modulation (AM), Frequency Modulation (FM), and Phase Modulation (PM). The classification of analog-to-analog conversion is shown in Figure 7:

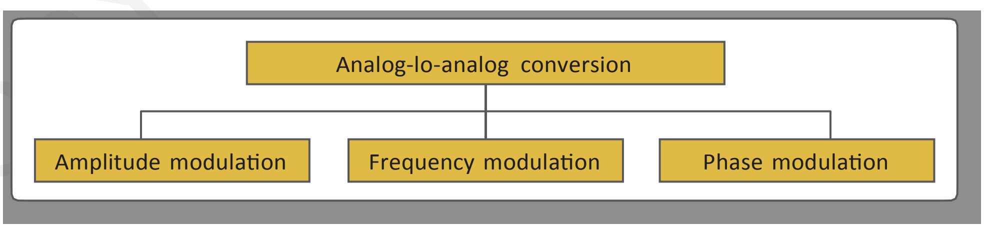


Figure 7: Types of Analog-to-Analog Conversion

5.3.1 Amplitude Modulation

The carrier signal in AM transmission is modulated such that its amplitude fluctuates with the changing amplitudes of the modulating signal. The carrier's frequency and phase stay constant. Only the amplitude varies in response to changes in the information. The diagram below depicts how this notion works. The modulating signal is the carrier's envelope. Because the amplitude of the carrier signal must be altered in response to the amplitude of the modulating signal, AM is often accomplished using a simple multiplier. An example of amplitude modulation is shown in Figure 8:

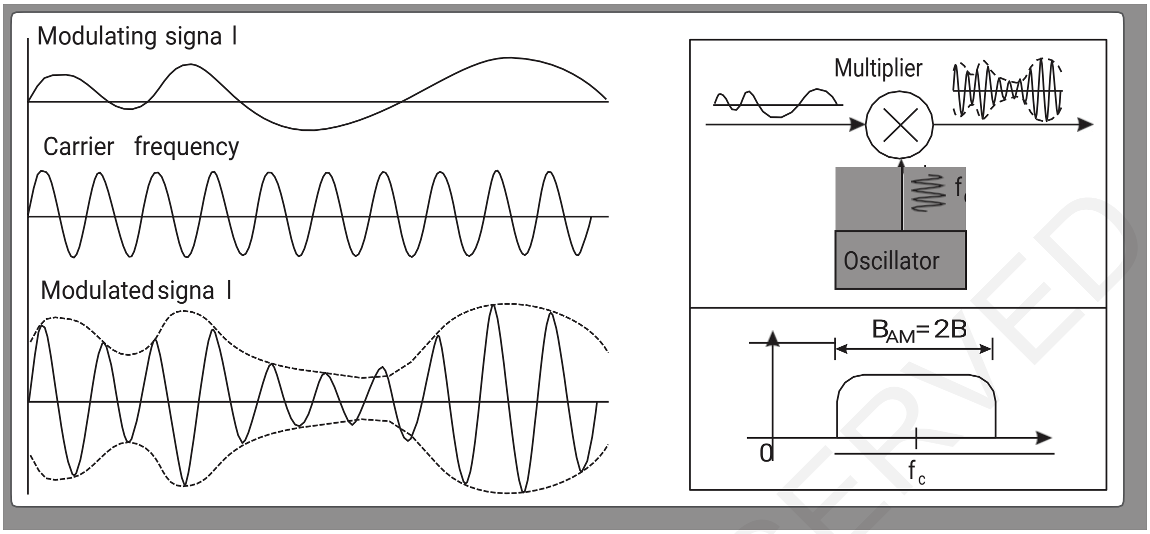


Figure 8: Amplitude Modulation

The total bandwidth required for AM can be determined from the bandwidth of the audio signal:

$$B_{AM} = 2B.$$

5.3.2 Frequency Modulation

The frequency of the carrier signal is modulated in FM transmission to follow the changing voltage level (amplitude) of the modulating signal. The carrier signal's peak amplitude and phase stay constant, but when the amplitude of the information signal varies, so does the carrier's frequency.

The frequency modulation depicts the relationships between the modulating signal, the carrier signal, and the resulting FM signal. FM is often accomplished using a voltage-controlled oscillator, similar to FSK. The frequency of the oscillator varies with the input voltage, which is the modulating signal's amplitude. An example of frequency modulation is shown in Figure 9:

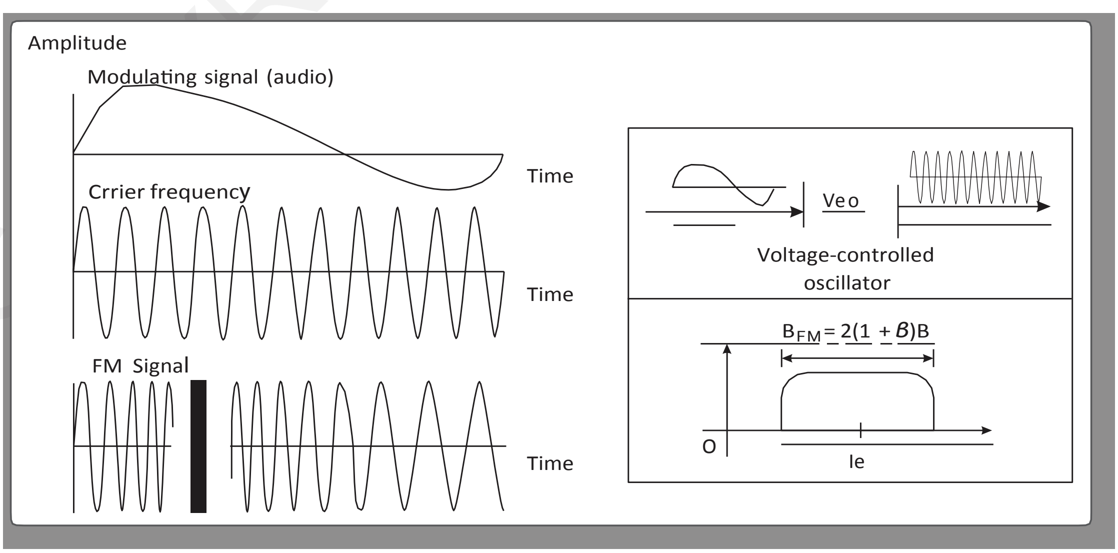


Figure 9: Frequency Modulation

The total bandwidth required for FM can be determined from the bandwidth of the audio signal:

$$B_{FM} = 2\,(1 + \beta)\,B.$$

5.3.3 Phase Modulation

The phase of the carrier signal is modulated in PM transmission to follow the changing voltage level (amplitude) of the modulating signal. The carrier signal's peak amplitude and frequency stay constant, but when the amplitude of the information signal varies, so does the carrier's phase. It is mathematically shown that PM is the same as FM with one exception. In FM, the immediate change in carrier frequency is proportional to the modulating signal's amplitude; in PM, the instantaneous change in carrier frequency is proportional to the modulating signal's derivative of its amplitude. The phase modulation depicts the relationships between the modulating signal, the carrier signal, and the resulting PM signal. An example of phase modulation is shown in Figure 10:

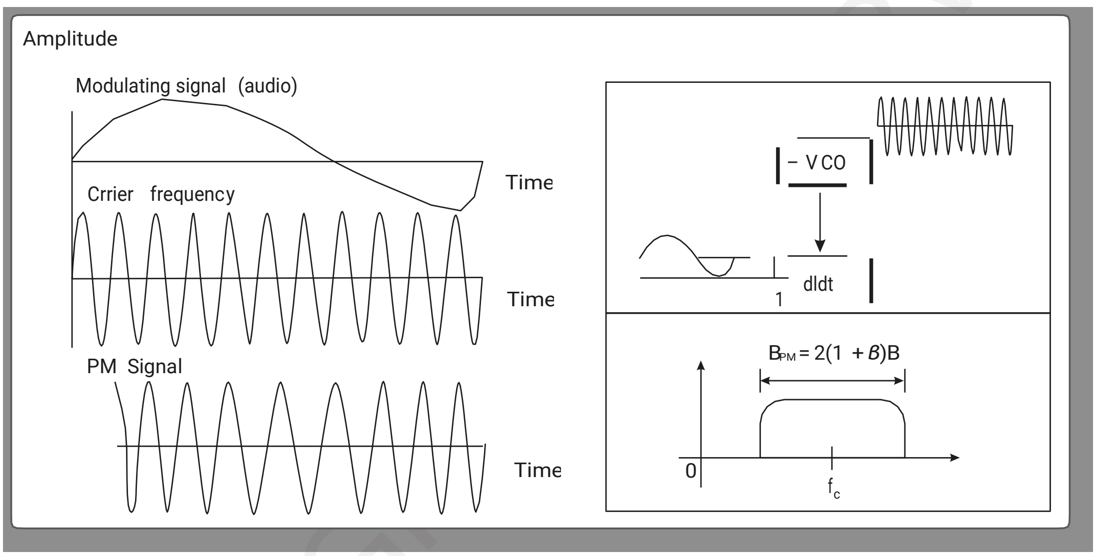


Figure 10: Phase Modulation

PM is often accomplished using a voltage-controlled oscillator and a derivative, as shown in Figure. The frequency of the oscillator varies with the derivative of the input voltage, which represents the modulating signal's amplitude. The total bandwidth required for the PM can be determined from the bandwidth and maximum amplitude of the modulating signal:

$$B_{PM} = 2(1 + \beta)\,B.$$

5.4 CONCLUSION

- The process of altering one of the properties of an analog signal based on information in digital data is known as digital-to-analog conversion.
- To generate signal elements, the amplitude of the carrier signal is changed in amplitude shift keying.
- In Binary Frequency Shift Keying (BFSK), two carrier frequencies are considered and more than two carrier frequencies.
- Frequency shift keying, the carrier signal's frequency is altered to represent signal components.
- The phase of the carrier is changed in phase shift keying to represent two or more distinct signal components.

- The encoding of analog information by an analog signal is known as analog-to-analog conversion or analog modulation.
- The carrier signal in AM transmission is modulated such that its amplitude fluctuates with the changing amplitudes of the modulating signal.
- The frequency of the carrier signal is modulated in FM transmission to follow the changing voltage level (amplitude) of the modulating signal.
- The phase of the carrier signal is modulated in PM transmission to follow the changing voltage level (amplitude) of the modulating signal.

5.5 GLOSSARY

- Amplitude Modulation (AM): It is used to modulate carrier signal such that its amplitude fluctuates with the changing amplitudes.
- Amplitude Shift Keying (ASK): The amplitude of the carrier signal is changed in amplitude shift keying.
- Frequency Modulation (PM): The frequency of the carrier signal is modulated in FM transmission to follow the changing voltage level.
- Frequency Shift Keying (FSK): In the frequency shift keying the carrier signal's frequency is altered to represent signal components.
- Phase Modulation (PM): The phase of the carrier signal is modulated in PM transmission to follow the changing voltage level.
- Phase Shift Keying (PSK): The phase of the carrier is changed in phase shift keying to represent two or more distinct signal components.
- Quadrature Amplitude Modulation (QAM): The quadrature amplitude modulation is a combination of ASK and PSK.
- Analog-to-analog conversion: The encoding of analog information by an analog signal is known as analog-to-analog conversion.
- Digital-to-analog conversion: The process of altering one of the properties of an analog signal based on information in digital data is known as digital-to-analog conversion.

5.6 SELF-ASSESSMENT QUESTIONS

A. Essay Type Questions

1. The process of altering one of the properties of an analog signal based on information in digital data which depicts the relationship between digital. What is a digital-to-analog conversion?
2. To generate signal elements, the amplitude of the carrier signal is changed in amplitude shift keying. Both frequency and phase stay unchanged in this case. Explain the importance of amplitude shift keying.
3. It is the process of encoding of analog information by an analog signal. Determine the concept of analog-to-analog conversion.
4. The phase of the carrier signal is modulated in PM transmission to follow the changing voltage level (amplitude) of the modulating signal. Explain the significance of phase modulation.

5. Before delving into particular techniques of digital-to-analog modulation, two fundamental concerns must be addressed: Bit and baud rates, as well as the carrier signal. Describe the different aspects of digital-to-analog conversion.

5.7 ANSWERS AND HINTS FOR SELF-ASSESSMENT QUESTIONS

A. Hints for Essay Type Questions

1. The process of altering one of the properties of an analog signal based on information in digital data is known as digital-to-analog conversion. The diagram below depicts the relationship between digital data, the digital-to-analog modulation process, and the resulting analog signal.

   Refer to Section Digital-To-Analog Conversion

2. To generate signal elements, the amplitude of the carrier signal is changed in amplitude shift keying. Both frequency and phase stay unchanged in this case. The following are the two types of ASK.It is commonly done using only two levels of signal components and is known as binary amplitude shift keying or on-off keying.

   Refer to Section Digital-To-Analog Conversion

3. The encoding of analog information by an analog signal is known as analog-to-analog conversion or analog modulation. One could wonder why we would need to modify an analog signal that is already analog.

   Refer to Section Analog-To-Analog Conversion

4. The phase of the carrier signal is modulated in PM transmission to follow the changing voltage level (amplitude) of the modulating signal. The carrier signal's peak amplitude and frequency stay constant, but when the amplitude of the information signal varies, so does the carrier's phase. It is mathematically shown that PM is the same as FM with one exception.

   Refer to Section Analog-To-Analog Conversion

5. Before delving into particular techniques of digital-to-analog modulation, two fundamental concerns must be addressed: Bit and baud rates, as well as the carrier signal.

   Refer to Section Digital-To-Analog Conversion

5.8 POST-UNIT READING MATERIAL

- https://www.academia.edu/36978407/Data_Communication_Lecture_Notes
- http://web.cse.ohio-state.edu/~athreya.14/cse3461-5461/Cse3461.B.Introduction.08-28-2012.pdf

5.9 TOPICS FOR DISCUSSION FORUMS

- Discuss with your friends and classmates about the concept of conversion in amplitude, frequencies. Also, discuss about importance of modulations and shift keying and the real world example of conversion and its goals, structure.

UNIT

06

Bandwidth Utilization

Names of Sub-Units

Introduction to Bandwidth, The Concept of Switching, Transmission Medium, Basic Switching Problems, Multiplexing, Spread Spectrum, and Transmission Media, Guided and Unguided Media, Definition, Goals, Structure and How to Implement it.

Overview

This unit begins by discussing about the concept of switching and bandwidth. Next, the unit discusses the basic switching problems and transmission medium like multiplexing, spread spectrum and transmission media. Further the unit explains the guided and unguided media. Towards the end, the unit discusses the definition of switching, its goals and structure and how to implement it.

Learning Objectives

In this unit, you will learn to:

- Discuss the concept of switching and bandwidth
- Explain the concept of basic switching problems and transmission medium
- Describe the guided and unguided media
- Explain the significance of guided and unguided transmission media
- Discuss the goals and structure of switching and how to implement it

Learning Outcomes

At the end of this unit, you would:

- ⌘ Evaluate the concept of switching and bandwidth
- ⌘ Assess the concept of transmission medium and basic switching problems
- ⌘ Evaluate the importance of guided and unguided transmission media
- ⌘ Determine the significance of goals and structure of switching
- ⌘ Explore the implementation of switching

6.1 INTRODUCTION

Understanding the medium via which data flows, as well as the possible mediums and their kinds, is important in Data Communication networking. This unit provides a detailed overview of the many forms of data communication transmission medium. Switching is a general term for constructing a network path for point-to-point communication. It entails nodes in the network using their direct communication connections to connect to other nodes in order to piecewise build a route. Each node can switch to a neighbouring node to extend the path even farther until it is completed.

6.2 BANDWIDTH

The maximum ability of a wired or wireless communications link to transfer data via a network connection in a given length of time is measured in bandwidth. The number of bits, kilobits, megabits, or gigabits that can be sent in one second is commonly used to describe bandwidth. Bandwidth is a term used interchangeably with capacity to indicate the rate at which data is transferred. A widespread misunderstanding is that bandwidth is a measure of network speed.

6.3 SPEED VS BANDWIDTH

The words bandwidth and speed are sometimes confused; however this is incorrect. The source of the misunderstanding might be partly attributable to marketing by the Internet Service Providers (ISPs) that confuse the two by alluding to higher speeds when they really imply bandwidth. In essence, speed relates to the rate at which data can be transferred, whereas bandwidth refers to the amount of data that can be transmitted at that pace. To return to the water metaphor, speed refers to the amount of water that can be pushed through a pipe in a given amount of time; bandwidth refers to the amount of water that can be transported through the pipe in a given amount of time.

6.4 MULTIPLEXING

Multiplexing is a collection of techniques for sending many signals across a single data channel at the same time. In a multiplexed system, lines share one link's bandwidth. Following are the three types of multiplexing techniques:

- Frequency-division multiplexing
- Wavelength-division multiplexing
- Time-division multiplexing

6.4.1 Frequency-Division Multiplexing

A number of signals are broadcast at the same time, with each source transferring its signals in the frequency range allocated to it. To avoid over-lapping, there is an appropriate frequency gap between the two neighbouring signals. The likelihood of a collision is reduced since the signals are transmitted at the assigned frequencies. The frequency spectrum is split into numerous logical channels, each of which gives each user the impression of having their own bandwidth. A number of signals are delivered at the same time, with each signal receiving its own frequency band or channel. It is used in radio and television broadcasting. Guard bands are used to avoid interference between two consecutive channels.

6.4.2 Wavelength-Division Multiplexing

WDM (Wavelength Division Multiplexing) is a technique that allows various data streams with different frequencies to be transmitted over a single optical fibre network, increasing bandwidth. At WDM wavelengths, signals are independent of one another. All protocols must be followed. All speeds are available.

6.4.3 Time-Division Multiplexing

This occurs when the media's data transmission rate is higher than the source, and each signal is given a specific length of time. Due to the tiny size of these slots, all transmissions seem to be in parallel. In frequency division multiplexing, all signals operate at the same time with various frequencies, whereas in time division multiplexing, all signals operate at separate times with the same frequency.

6.5 SPREAD SPECTRUM

The term "spread spectrum" denotes to the extension of signal bandwidth, by numerous orders of magnitude in some cases, which arises when a key is involved to the communication channel. The following points describe more about the spread spectrum is as follows:

- Spread Spectrum is a type of data transmission in which the data sequence takes up more bandwidth than is required to deliver it.
- The signal is effectively mapped to a higher-dimensional signal space.
- A spreading sequence is used to disperse the signal before transmission. The receiver retrieves the signal using the same procedure.
- Spread Spectrum is particularly effective against fixed energy interference (intentional or unintentional).
- Wireless and GPS applications are the most common commercial uses.

6.5.1 Frequency Hopping Spread Spectrum (FHSS)

FHSS (frequency hopping spread spectrum) is a way of sending radio signals that involves moving carriers over many channels in a pseudorandom pattern that is known to both the sender and the receiver. In the 2.4 GHz band, frequency hopping spread spectrum is described as a set of 79 frequencies spanning from 2.402 GHz to 2.480 GHz. Every frequency is GFSK modulated, with a 1MHz channel width and 1 Mbps and 2 Mbps speeds, respectively.

An example of frequency hopping spread spectrum (FHSS) is shown in Figure 1:

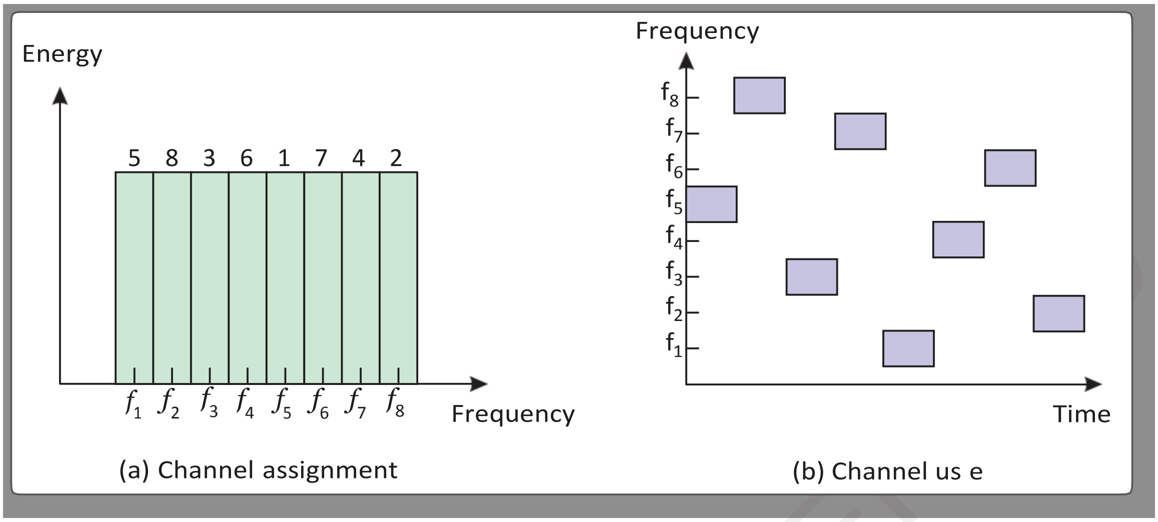


Figure 1: Frequency Hopping Spread Spectrum (FHSS)

6.5.2 Direct Sequence Spread Spectrum

In local area wireless network transmissions, direct sequence spread spectrum (DSSS) is a transmission method. A data signal is coupled with a high data rate bit sequence at the transmitting station in this technique, which splits user data depending on a spreading ratio. Resistance to jamming, sharing single channels among numerous users, reduced background noise, and relative timing between transmitter and receiver are all advantages of utilising DSSS. Direct sequence code division multiple access is another name for this concept. An example of direct sequence spread spectrum is shown in Figure 2:

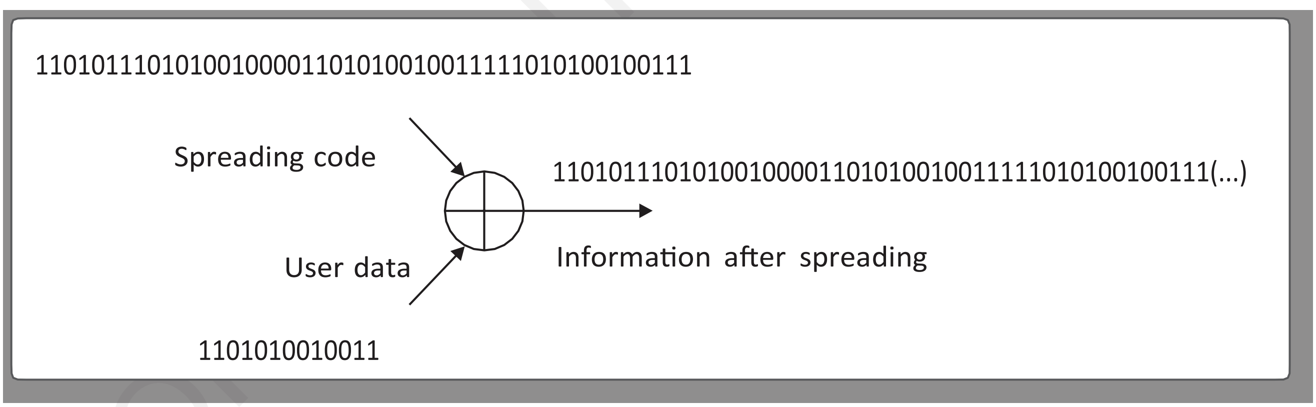


Figure 2: Direct Sequence Spread Spectrum

6.6 TRANSMISSION MEDIA

A transmission medium, in data communication terms, is the physical path between the transmitter and the receiver, or the channel via which data is transmitted from one location to another. The following types of transmission media can be generally classified in to two ways are as follows:

- Guided transmission media
- Unguided transmission media

6.6.1 Guided Media

Bounded media or wired media are other terms for guided transmission media. They are made up of cables or wires that transfer data. They're termed guided because they create a physical link between the transmitter and recipient devices. The physical constraints of these media limit the signal that can flow through them. The most popular guided media are as follows:

- Twisted pair cable
- Coaxial cable
- Fiber optics

Twisted-Pair Cable

Two plastic-insulated copper wires are twisted together to produce a single medium in a twisted pair cable. Only one of these two wires transmits real signal, while the other serves as a ground reference. Noise (electro-magnetic interference) and crosstalk can be reduced by twisting wires together.

The twisted wire pair in STP cables is wrapped with metal foil. As a result, it is less sensitive to noise and crosstalk. An example of twisted-pair cable is shown in Figure 3:

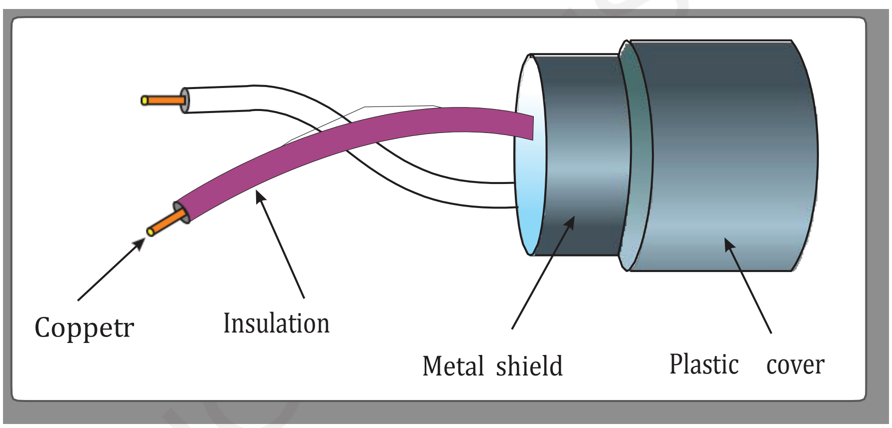


Figure 3: Twisted-Pair Cable

UTP is divided into seven groups, each with its own set of applications. Cat-5, Cat-5e, and Cat-6 cables are often used in computer networks. RJ45 connectors are used to connect UTP wires. RJ45 connectors connects UTP wires is shown in Figure 4:

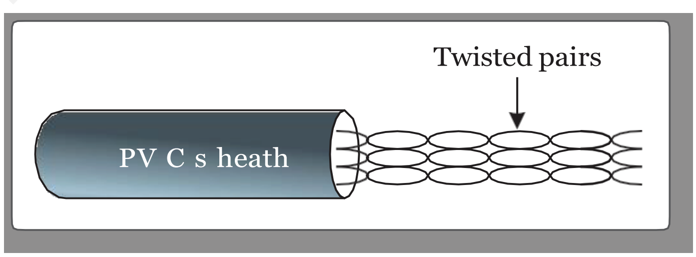


Figure 4: RJ45 connectors are used to connect UTP wires

Coaxial Cable

Copper wires are used in coaxial cable. The core wire is constructed of solid conductor and is located in the middle. The core is encased in an insulating sheath. The second wire is wrapped around the sheath and is also coated in an insulating sheath. All of this is covered by a plastic cover. An example of coaxial cable is shown in Figure 5:

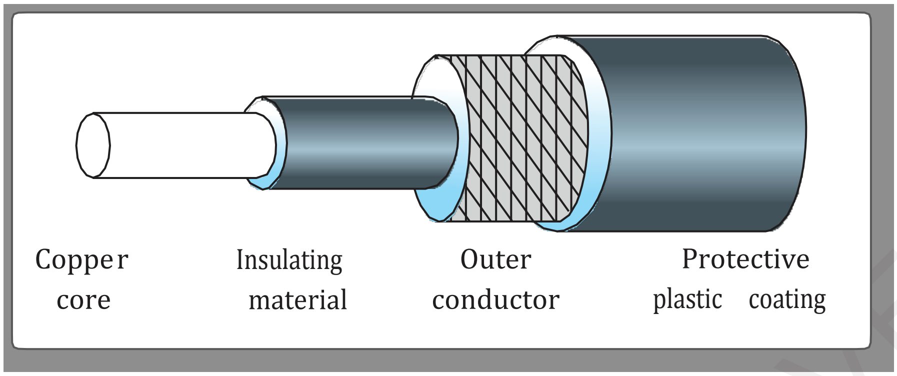


Figure 5: Coaxial Cable

The wrapped structure provides a good shield against noise and cross talk, and the coax cable is capable of carrying higher frequency signals than twisted pair cable. Coaxial connections may deliver up to 450 mbps of bandwidth. RG-59 (Cable TV), RG-58 (Thin Ethernet), and RG-11 are the three types of coax cables (Thick Ethernet). Radio Government is abbreviated as RG. The BNC connection and BNC-T are used to connect the cables. The wire is terminated at the far ends using a BNC terminator.

Fiber-Optic Cable

Fiber Optics is based on light's characteristics. When a light beam strikes a crucial angle, it refracts at a 90-degree angle. Fiber optics have made use of this feature. Fiber optic cable has a core made of high-quality glass or plastic. Light is emitted from one end, passes through it, and is detected and converted to electric data at the other end by a light detector. Fiber Optics is the fastest way of transmission. It is available in two modes: Single mode fibre and multimode fibre. A single mode fibre can only transport one ray of light, but a multimode fibre can carry many beams. An example of fiber-optic cable is shown in Figure 6:

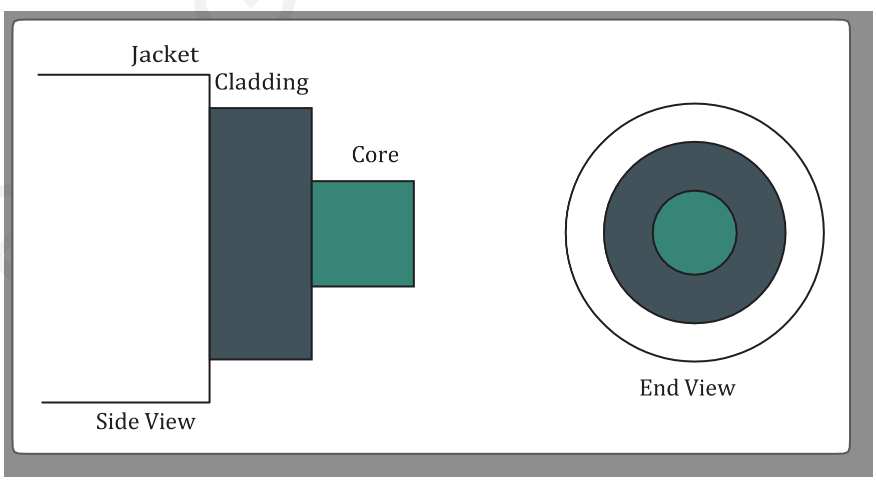


Figure 6: Fiber-Optic Cable

Fiber Optic is available in both unidirectional and bidirectional configurations. Special connectors are used to connect and access fibre optic cables. Subscriber Channel (SC), Straight Tip (ST), or MT-RJ are examples of these.

6.6.2 Unguided Media

Wireless media refers to unguided transmission media. They transmit data in the form of electromagnetic waves, which do not require the use of wires. Geographic borders define the scope of these media. Wireless communications is the term used to describe this form of communication. Unguided signals can travel in three ways are as follows:

- Ground propagation
- Sky propagation
- Line of sight propagation

The most commonly used unguided transmissions are as follows:

- Radio transmission
- Microwave transmission
- Infrared transmission

Radio Waves

These are simple to make and can pierce through walls. It is not necessary to align the transmitting and receiving antennas. 3KHz – 1GHz is the frequency range. Radio waves are used to transmit information via AM and FM radios, as well as cordless phones.

Radio waves are further classified in to two ways are as follows:

- Terrestrial
- Satellite

Microwaves

It's a line-of-sight transmission, which means the transmitting and receiving antennas must be perfectly aligned. The height of the antenna is directly proportionate to the distance reached by the transmission. 1GHz to 300GHz is the frequency range. Mobile phone communication and television distribution are two of the most common uses for these.

Infrared

Infrared rays are utilised for communication across short distances. They are unable to pass through barriers. Interference between systems is avoided as a result of this. 300GHz – 400THz is the frequency range. It's found in TV remotes, wireless mice, keyboards, printers, and other devices.

6.7 SWITCHING

Switching is the process of forwarding packets from one port to another that leads to the destination. When data enters a port, it is referred to as ingress, and when data leaves a port, it is referred to as egress. Switches and nodes can be found in a communication system to link the systems for one-to-one communication, a switching mechanism is used.

6.7.1 Circuit-Switched Networks

The type of switching utilised to provide a dedicated communication route between the transmitter and the receiver is known as circuit switching. The physical link that is created between the sender and the receiver is established. A well-known example of circuit switching is the analog telephone network. This form of switching has a set bandwidth.

The advantages of circuit-switched networks are as follows:

- The bandwidth available is limited.
- When a dedicated communication channel is employed, the quality of communication improves.
- The data transmission rate is predetermined.
- There is no time spent waiting when switching.
- When the conversation is extended and constant, it is preferable.

The disadvantages of circuit-switched networks are as follows:

- In the circuit-switched networks dedicated channels are used, additional bandwidth is required.
- The resources are not being used to their maximum potential.
- The usage of a dedicated channel makes the transmission of additional data impossible.
- The time it takes for two stations to create a physical link is excessive.
- A circuit-switched networks requires each link a dedicated route, circuit switching is costly.
- The connection between the sender and the receiver will be maintained until the user disconnects it. This will continue even if no data transfer is going to take place.

6.7.2 Packet Switching

Packet switching is described as a connectionless network in which communications are split and put together into packets. Each packet is routed separately from the source to the destination. The payload carries the real data in these packets. When the packet arrives at the destination, it is the destination's job to arrange the packets in the correct sequence.

The advantages of packet switching are as follows:

- The packets are delivered to the destination as soon as they are available; thus there is no delay in delivery.
- There is no need for a lot of storage space because the data is sent to the destination as soon as it is received.
- Failure of the connections does not prevent data delivery since packets may be routed via alternate channels.
- While transferring packets, several users might share the same channel.
- Because many sources can transport packets from the same source connection, bandwidth consumption is better when packet switching is used.

The disadvantages of packet switching are as follows:

- Packet switching has a high installation cost.
- When complex protocols are employed, the delivery of these packets becomes simple.
- Packet switching cannot be used for high-quality voice conversations since there is too much latency in this form of connection.
- Information loss and transmission delays may occur as a result of connectivity problems.

6.8 CONCLUSION

- The use of available bandwidth to achieve specified goals is known as bandwidth utilization.
- Multiplexing is a collection of techniques that allows many signals to be sent over a single data connection at the same time.
- WDM is a technique for combining optical signals that uses analogue multiplexing.
- TDM (Time Division Multiplexing) is a digital method that allows several connections to share a link's high capacity.
- Spread Spectrum is a type of data transmission in which the data sequence takes up more bandwidth than is required to deliver it.
- FHSS (frequency hopping spread spectrum) is a way of sending radio signals that involves moving carriers over many channels in a pseudorandom pattern.
- Bounded media or wired media are other terms for guided transmission media.
- Wireless media refers to unguided transmission media. They transmit data in the form of electromagnetic waves.
- Packet switching is described as a connectionless network in which communications are split and put together into packets.

6.9 GLOSSARY

- Multiplexing: The multiplexing is a technology that allows numerous communication signals to be combined in order.
- Direct Sequence Spread Spectrum (DSSS): A direct sequence spread spectrum (DSSS) is a transmission method in a local area wireless network transmissions.
- Frequency Hopping Spread Spectrum (FSSS): Frequency-hopping spread spectrum (FHSS) is a way of delivering radio signals that involves quickly shifting the carrier frequency.
- Switching: It is a process of forwarding packets from one port to another that leads to the destination.
- Circuit-switched: The circuit switching is a telecommunications' network implementation approach.
- Packet-switched: It is a way of arranging data that is delivered across a digital network.
- Unguided Media: An unguided media is a wireless media that transmit data in the form of electromagnetic wave.
- Guided Media: A guided media is a bounded or wired media which is made up of cables or wires that transfer data.

6.10 SELF-ASSESSMENT QUESTIONS

A. Essay Type Questions

1. The maximum ability of a wired or wireless communications link to transfer data via a network connection in a given length of time is measured in bandwidth. What is a bandwidth?
2. It is a collection of techniques for sending many signals across a single data channel at the same time. Describe multiplexing and its types.

3. It denotes to the extension of signal bandwidth, by numerous orders of magnitude. Explain the spread spectrum and its types.
4. The physical path between the transmitter and the receiver, or the channel via which data is transmitted from one location to another. Elaborate the importance of guided and unguided transmission media.
5. It is a process of forwarding packets from one port to another that leads to the destination. Determine the significance of switching.

6.11 ANSWERS AND HINTS FOR SELF-ASSESSMENT QUESTIONS

A. Hints for Essay Type Questions

1. The maximum ability of a wired or wireless communications link to transfer data via a network connection in a given length of time is measured in bandwidth. The number of bits, kilobits, megabits, or gigabits that can be sent in one second is commonly used to describe bandwidth. Refer to Section Bandwidth
2. Multiplexing is a collection of techniques for sending many signals across a single data channel at the same time. In a multiplexed system, lines share one link's bandwidth. Following are the three types of multiplexing techniques are as follows: Frequency-Division Multiplexing, Wavelength-division multiplexing, Time-division multiplexing. Refer to Section Multiplexing
3. The term "spread spectrum" denotes to the extension of signal bandwidth, by numerous orders of magnitude in some cases, which arises when a key is involved to the communication channel. Refer to Section Spread Spectrum
4. A transmission medium, in data communication terms, is the physical path between the transmitter and the receiver, or the channel via which data is transmitted from one location to another. The following types of transmission media can be generally classified are as follows:
    - Guided Transmission Media
    - Unguided Transmission Media

    Refer to Section Transmission Media
5. Switching is the process of forwarding packets from one port to another that leads to the destination. When data enters a port, it is referred to as ingress, and when data leaves a port, it is referred to as ingress. Switches and nodes can be found in a communication system to link the systems for one-to-one communication, a switching mechanism is used. Refer to Section Switching

6.12 POST-UNIT READING MATERIAL

- https://www.sciencedirect.com/topics/computer-science/bandwidth-utilization
- https://www.smartzworld.com/notes/data-communication-and-computer-networks-pdf-notes-dccn/

6.13 TOPICS FOR DISCUSSION FORUMS

- Discuss with your friends and classmates about the concept of switching and bandwidth. Also, discuss on the transmission medium and how they affect the real world.