Chapter 1: Introduction

Data and Signal

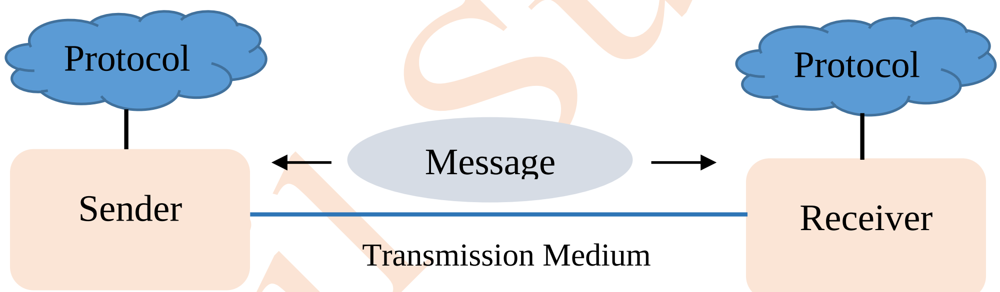
Data is a collection of raw facts, figures, or information that can be processed or transmitted. Data can be any text, image, audio, video, or multimedia files.

Communication is an act of sending and receiving data.

Thus, data communication refers to the exchange of data between two or more networked or connected devices via some transmission media.

Components of Data Communication

Data Communication has five components as shown in figure below.



Message is a data or information that need to be send. Information may be text, number, image, audio or video.

Sender is a device that sends the message. It may be computer, workstation or telephone.

Receiver is a device that receives the message. It may be computer, workstation or telephone.

Transmission medium is the path or channel through which the message travels from sender to receiver.

Protocol is a set of rules and guidelines that defines how data is transmitted and received.

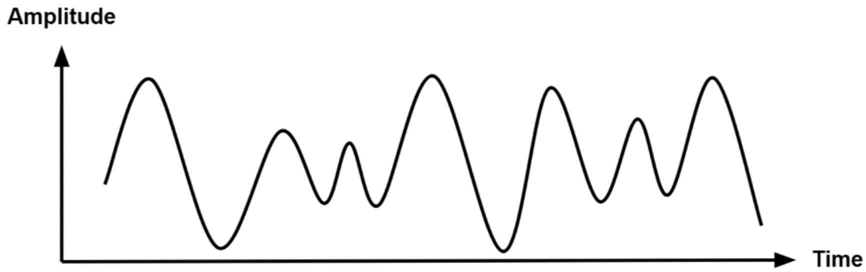
Digital and Analog Signal

Signal: A physical quantity that has the capability to transmit information from one point to another is called a signal. It is a function of one or more independent variables.

Analog Signal

An **analog signal** is a continuous signal that represents physical measurements. It varies smoothly over time and can take any value within a given range**.**

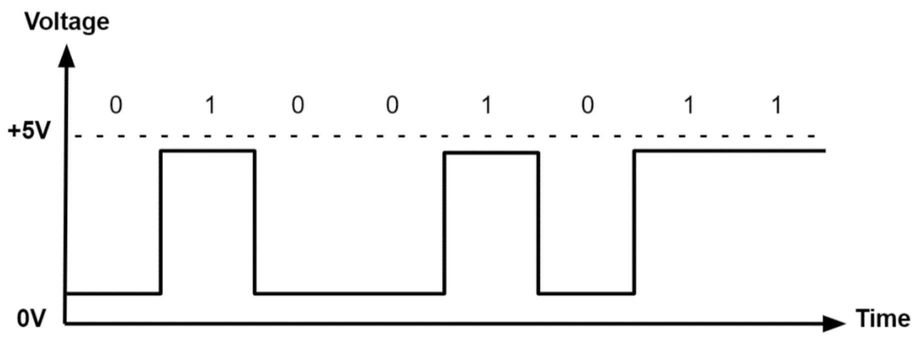
Examples: Human voice in air, Temperature sensor output



Digital Signal

A digital signal is a type of electronic signal that has a finite set of discrete values representing information.

Examples: Computer data, Data transmitted over internet



1. **Advantages of digital system over analog system**

   a. Due to better noise immunity, a digital system is more reliable than analog system.
   b. Programmability
   c. Ease of storage

d. Digital systems can use powerful processors, algorithms, and software to perform complex tasks quickly and accurately.
e. Digital systems can easily connect with computers and other digital devices for automation, analysis, and smart functionalities.

2. Block diagram of analog communication system

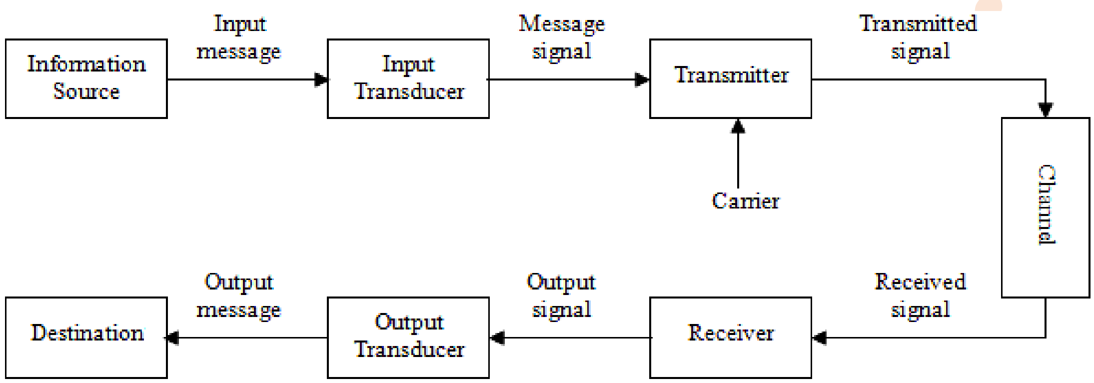


Figure: Block diagram of analog communication system

3. Block diagram of digital communication system

****Do yourself**

Data Representation

Computer and communication systems deal with various types of data such as text, numbers, images, audio, and video.

Text includes combinations of alphabets in lower case (a, b, …) as well as upper case (A, B,…) In a text, every character is assigned a distinct code, like ASCII code. Example: “A” = 65 = 1000001

Numbers include a combination of digits from 0 to 9. It is stored as a pattern of bits. Number are not represented by ASCII. The 0s and 1s are used to represent digital data.

Images are made of pixels. It is digitally stored in the computer. After an image is divided into pixels, each pixel is assigned a bit pattern. Size of image is dependent on its resolution. Consider a simple black and white image. If 1 is black (or on) and 0 is white (or off), then a simple black and white picture can be created using binary. Images can be in the format of jpeg, png, gif etc.

Audio signal is a representation of sound or music which can be recorded and broadcasted. It is continuous but not discrete.

Video is a combination of images and audio. Frames per second (FPS) are used to show movement.

Types or Modes of Data Communication/ Data Flow

Data communication happens in the form of signals between two or more computing devices or nodes. The transfer of data happens over a point-to-point or multipoint communication channel. Data communication between different devices is broadly categorized into 3 types: Simplex communication, Half-duplex communication, and Full-duplex communication.

Simplex Communication

It is a one-way or unidirectional communication between two devices in which one device is sender and other one is receiver. It is like a one-way street where vehicles can move in only one direction. Examples: entering data using keyboard, TV broadcast etc.

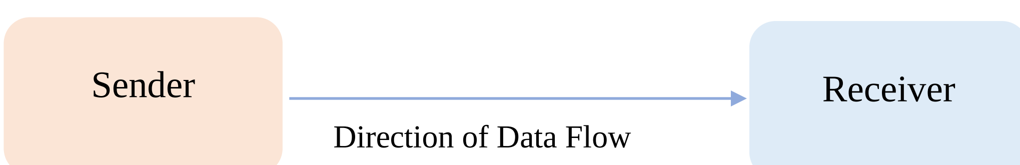


Figure: Simplex mode of data communication

Half-duplex Communication

It is two way or bidirectional communication between two devices in which both the devices can send and receive data or control signals in both directions, but not at the same time. While one device is sending data, the other one will receive and vice-versa. It is like sharing a one-way narrow bridge among vehicles moving in both directions.

Example: Walkie-talkie

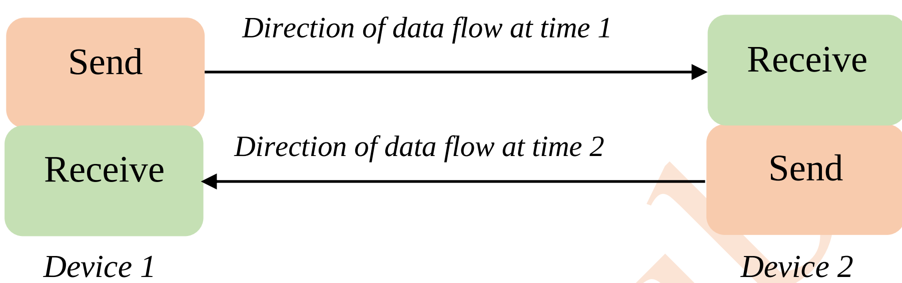


Figure: Half-duplex mode of data communication

Full-duplex Communication

It is two way or bidirectional communication in which both devices can send and receive data simultaneously. This can be done either by using two physically separate simplex lines - one for sending and other for receiving, or the capacity of the single channel is shared between the signals travelling in different directions.

Example: Mobile phone communication

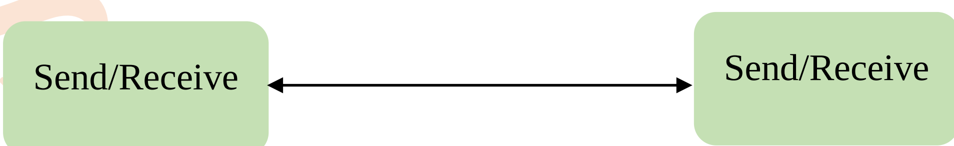


Figure: Full-duplex mode of data communication

Data Communication Characteristics

The effectiveness of data communication system depends on the following four fundamental characteristics.

a. **Delivery**

   The data should be delivered to the correct destination

b. **Accuracy**

   The data should be delivered accurately and without any error.

c. **Timeless**

   The data should be delivered on time. Late delivery of data is useless in real-time system (video calling, live games).

d. **Jitter**

   Jitter refers to variations in packet arrival time. It is the uneven delay in the delivery of audio or video packets.

A Communication Model

The fundamental purpose of a communication system is the exchange of data between two parties. A simple model of communication is illustrated in figure below.

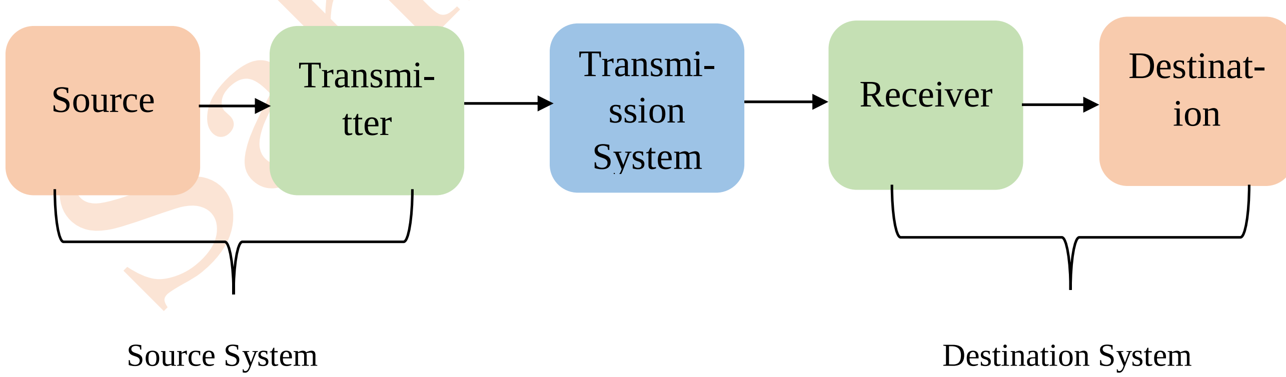


Figure: General block diagram of communication model

Source: This device generates the data to be transmitted. Examples are telephones and personal computers.

Transmitter: A transmitter typically does not send data in its original forms as generated by the source system. Instead, it transforms and encodes the data into electromagnetic signals that are suitable for transmission through a communication system.

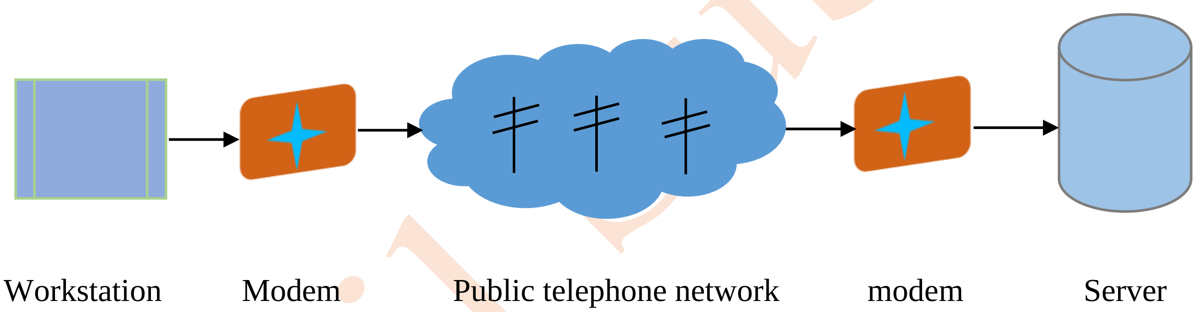
Transmission System: This can be a transmission line or a complex network connecting source and destination.

Receiver: The receiver accepts the signal from the transmission system and converts it into a form that can be handled by the destination device

Destination: It takes the incoming data from the receiver.

Example of communication model

This example presents communication between a workstation and a server over a public telephone network.



Workstation is the source or sender. It is typically a computer or terminal where data is created. **Modem** stands for modulator-demodulator. Modem at workstation side converts digital signals from the workstation into analog signals suitable for transmission over network.

Public telephone network acts as the transmission medium. It is a network of wired or wireless systems used to carry the signal over long distances. It introduces possible noise or interference during transmission. **Modem** at server side performs demodulation. It converts the received analog signal back to digital form. This allows the server to understand the original message. **Server** acts as the destination. It processes, stores, or responds to the data received. It might be a file server, mail server, mail server, or a web server depending on the application.

A Data Communication Model

Below block diagram provides a new perspective on the communication model. Let's detail the figure using electronic mail as an example.

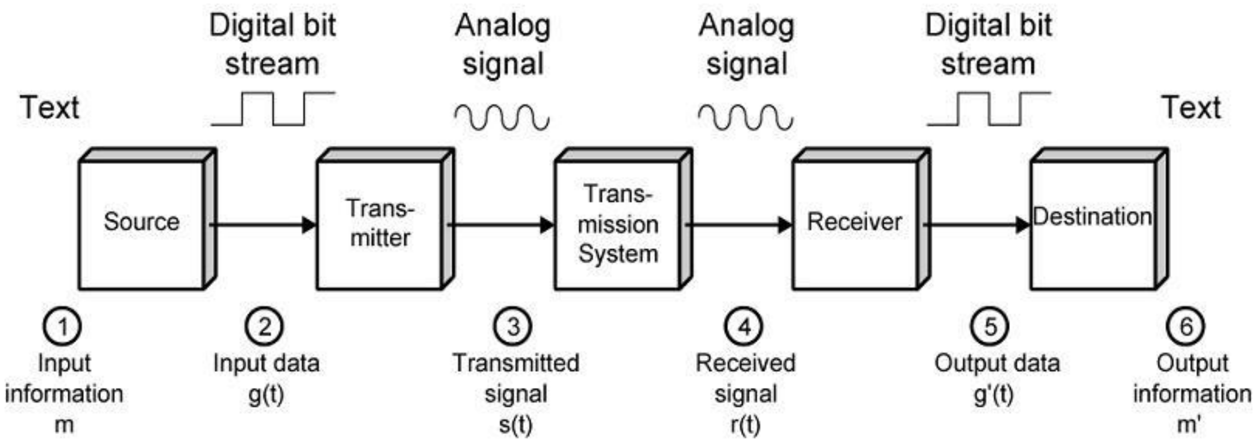


Figure: Simplified Data Communication Model

**Explain in detail (Ref: William Stallings)

Networks

A network is a collection of connected devices (like computers, phones, printers, etc.) linked to exchange data or resources. These devices can communicate through wired or wireless connections. The goal of a network is to enable communication and sharing.

Computer Network is a type of network where two or more computers are connected to share files, data, internet access, etc.

Local Area Network (LAN)

A Local Area Network is a type of network designed to connect devices within a limited geographical area, such as a single office, building, or campus. Due to its confined scope, a LAN is typically restricted in size. LANs generally offer data transfer speeds ranging from 10 Mbps to 100 Mbps, although modern LANs can achieve significantly higher speeds. Commonly implemented network topologies in LANs include bus, ring, and star configurations.

A home Wi-Fi network serves as a LAN, connecting various devices such as computers, smartphones, and smart TVs. LANs offer the advantage of high-speed, localized communication between devices without the need of route data through the internet. This setup functions as a private, interconnected environment that enhances both productivity and convenience.

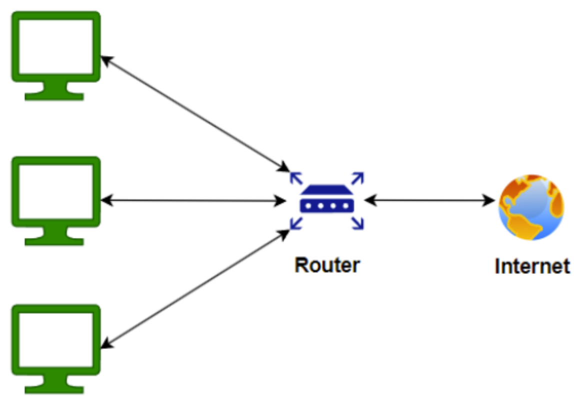


Figure: Local Area Network

A router functions as the central point through which most LANs connect to the Internet. In residential settings, a single router is typically sufficient to manage the network. However, in larger LAN environments, additional devices such as network switches are often employed to optimize the efficient transmission of data packets across multiple devices.

LANs typically connect devices using Ethernet, Wi-Fi, or a combination of both technologies. Ethernet provides a wired connection and operates at the physical and data link layers of the OSI model, enabling reliable and high-speed communication. Wi-Fi, on the other hand, is a wireless communication protocol that allows devices to connect to the LAN without physical cables, offering greater flexibility and mobility.

Wide Area Network (WAN)

A WAN is a type of computer network that spans a large geographical area, typically connecting multiple LANs. WANs are commonly established using leased telecommunication lines, where routers at each end link the respective LANs, enabling seamless communication and data exchange across distant locations.

Example: The bank connects its ATMs located in different cities through the network

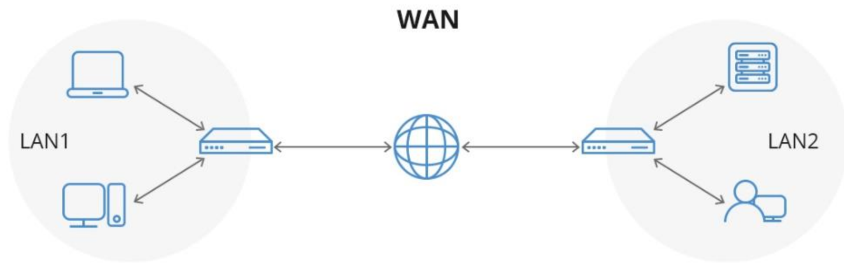


Figure: Wide Area Network

Types of WAN

1. **Switched WANs**

   Switched WANs utilize shared communication infrastructure to enable data transmission across multiple locations. In this type of network, data is segmented into packets, which are routed over common network resources based on their respective destination addresses. Switched WANs rely on switching devices, such as routers and network switches, to dynamically determine the optimal path for each packet to reach its destination. These networks typically use packet-switching technologies and protocols such as Frame Relay, X.25, and Asynchronous Transfer Mode (ATM) to manage data flow efficiently.

   Example: Using a telephone network or packet-switched network to send data from Office A to Office B only when required.

2. **Point-to-Point WANs**

   Point-to-Point WANs create a dedicated, direct communication between two defined locations. This type of WAN provides a private and exclusive communication link between the endpoints, ensuring consistent and secure data transfer.

Advantages of WAN

a. Wide geographical reach
b. Resource sharing
c. Centralized management
d. Increased productivity
e. Scalability

Disadvantages of WAN

a. High costs
b. Security concerns
c. Limited bandwidth
d. Reliability concerns

The OSI Model

The Open Systems Interconnection (OSI) reference model was developed by the International Organization for Standardization (ISO) as a model to provide a standard framework or guideline for understanding and designing how different networking systems communicate with each other. The OSI Model consists of 7 layers and each layer has specific functions and responsibilities.

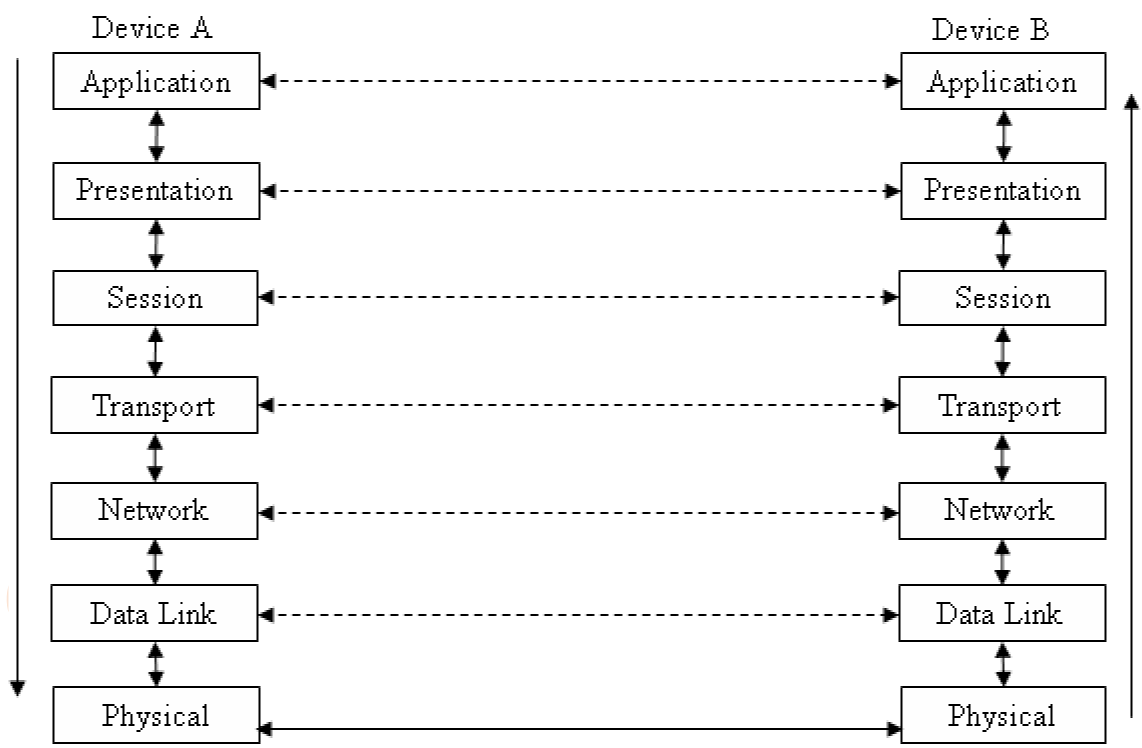


Figure: The OSI reference Model

(All People Seems To Need Data Processing)

Application Layer

The Application Layer is the highest layer in the OSI model and is responsible for managing network communication at the user level. It serves as the interface between end-user applications and the underlying network services, enabling users to send and receive data. It manages the protocols required by the application to present the data to the user. This layer supports various network services such as file transfer, email, and other application-based communications. Key functionalities of the application layer include resource sharing, remote file access, and network management.

Examples of protocols operating at the application layer include Hypertext Transfer Protocol (HTTP) for web browsing, File Transfer Protocol (FTP) for file transfer, Simple Mail Transfer Protocol (SMTP) for email services, and Domain Name System (DNS) for resolving domain names to IP addresses. These protocols ensure that user applications can effectively communicate with each other and with servers over a network.

Presentation Layer

The Presentation Layer, positioned as the 6th layer in the Open Systems Interconnection (OSI) model, is often referred to as the Translation Layer due to its key role in translating data formats. It acts as an intermediary between the Application Layer and the lower layers, ensuring that data is appropriately formatted, encoded, or decoded before transmission across the network. This layer is primarily responsible for defining and managing data representation, including tasks such as data formatting, compression, and encryption. It ensures that the data sent by the application layer of one system can be properly interpreted by the application layer of another. For this reason, it is also known as the Syntax Layer, as it ensures the correct structure and syntax of the data during both transmission and reception.

<u>Functions of Presentation Layer</u>

a. Data Translation

   Converts data into a standardized format (eg. ASCII to EBCDIC and EBCDIC to ASCII)

b. Data Compression and decompression

   Compresses data to reduce its size before transmission to optimize bandwidth and speed. **Decompresses** the data back to its original form at the receiver's end.

c. Data encryption and decryption

Encrypts data before sending it across the network for security and **Decrypts** received data so it becomes readable again.

d. Syntax and data structure management
Ensures that data structures (like numbers, text, images, etc.) are in a format that both sender and receiver understand.

Session Layer

The Session Layer, positioned as the fifth layer in the OSI (Open Systems Interconnection) model, is responsible for managing communication sessions between networked devices. It plays a key role in initiating, maintaining, and terminating dialogues between applications on separate systems. It establishes, manages, and terminates the connections between the local and remote applications.

Functions of Session Layer

a. Session establishment, maintenance, and termination

- **Establishes** a communication session between two systems.
- **Maintains** the session while data is being transferred.
- **Terminates** the session when the communication is complete.

Analogy: Like starting a phone call (session starts), talking (session ongoing), and hanging up (session ends).

b. Communication synchronization

It maintains reliable communication by inserting synchronization points and checkpoints within the data stream, allowing for consistent data transfer and recovery in case of interruptions.

Example:

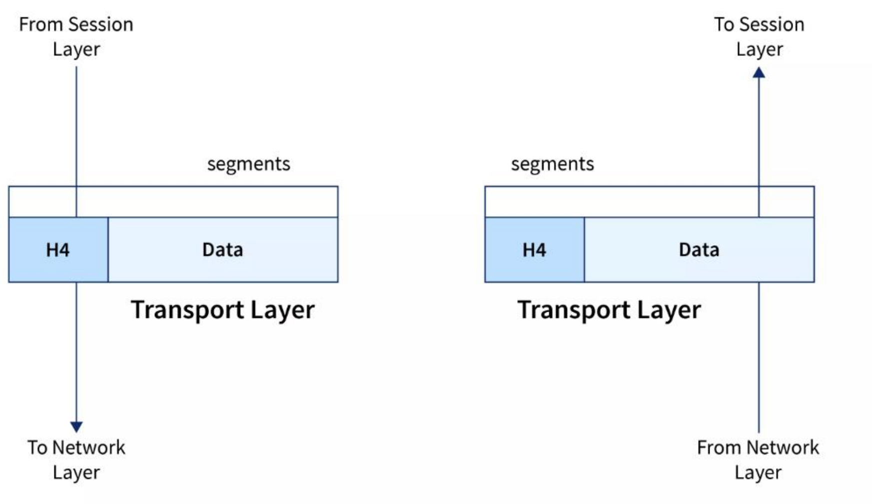
During a large file download, if the connection drops at 75%, the session layer uses the last checkpoint to resume the transfer from 75% instead of starting over from the beginning.

c. Dialog Management

This function determines the flow of communication between two devices, specifying which party can transmit data at a given time. In half-duplex mode, a token-based mechanism is often used, where only the device holding the token can send data. In contrast, full-duplex mode allows both parties to transmit data simultaneously.

Transport Layer

The Transport Layer, positioned as the fourth layer in the OSI model, is responsible for ensuring end-to-end (process-to-process) delivery of data. Its primary objective is to preserve the correct sequence of data, ensuring that information arrives at the destination in the same order in which it was transmitted. This layer supports two types of communication services: connection-oriented and connectionless transmission (TCP and UDP).



<u>Functions of Transport Layer</u>

a. Maintains Data Order

   It ensures that data packets are delivered to the receiving application in the exact sequence in which they were sent.

b. Segmentation

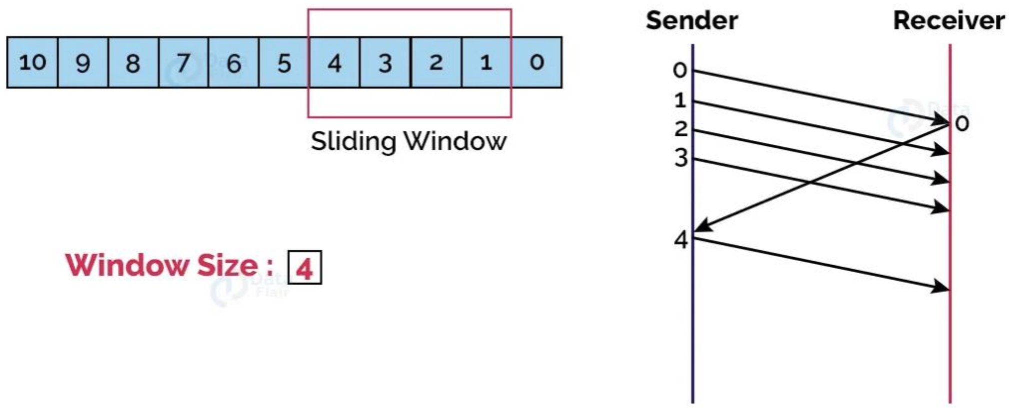
   Data received from the upper layers is divided into smaller units called segments, which are easier to manage and transmit over the network.

c. Port Addressing

   The transport layer assigns a port number to each segment by adding it to the header. This enables the data to be directed to the correct application process at the destination.

d. Flow Control

If the sender transmits data faster than the receiver can process it, data loss or congestion might occur. To avoid this, the transport layer uses mechanisms like the sliding window protocol**.**

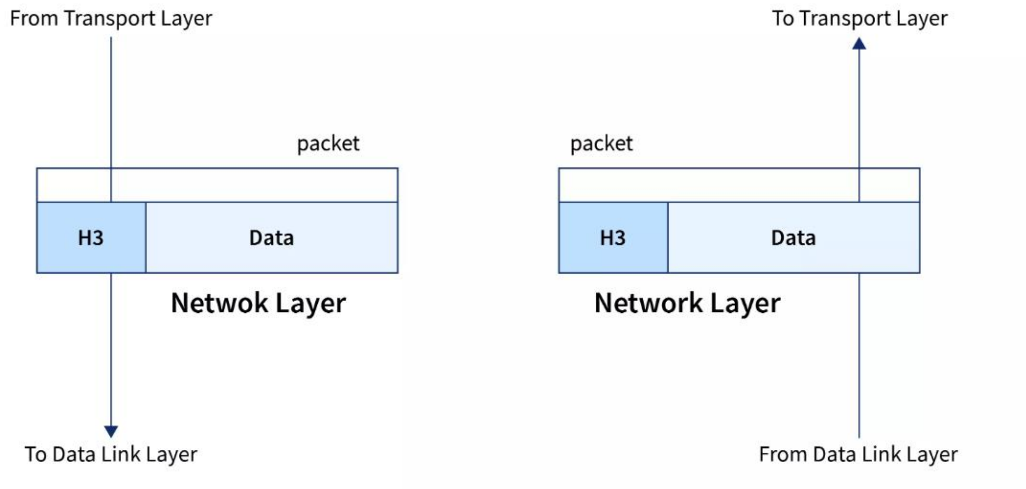


Network Layer

The Network Layer, the third layer of the OSI model, facilitates communication between hosts across different networks. It receives data from the transport layer and organizes it into units called **packets** for transmission.

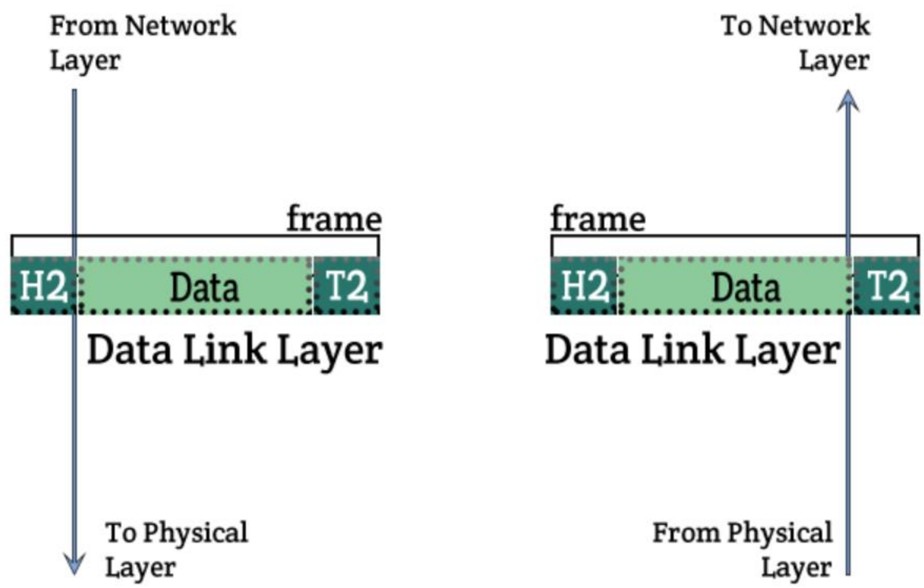
<u>Logical Addressing:</u> The network layer adds the logical address i.e. IP address (Internet Protocol address) if the packet crosses the network boundary. It helps in the proper identification of devices on the network. Hence, the network layer adds the source and destination address to the header of the packet.

<u>Routing:</u> Routing simply means determining the best (optimal) path out of multiple paths from the source to the destination. So the network layer must choose the best routing path for the data to travel.



Data Link Layer

The Data Link Layer is responsible for ensuring the error-free transmission of data frames over the physical layer. It can uniquely identify each device on a local network through its MAC address. When a packet arrives within the network, the Data Link Layer delivers it to the correct host using this MAC address.



Frame Header: It contains the source and the destination addresses of the frame and the control bytes.
Trailer: It contains the error detection and error correction bits. It is also called a Frame Check Sequence (FCS).

Physical Layer

The Physical Layer is the lowest layer of the OSI reference model and is responsible for establishing the actual physical connection between network devices. It deals with the transmission of bitstreams over a physical medium, representing data in the form of binary bits (0s and 1s). The Data Link Layer passes data frames to the Physical Layer, which then converts the frames into electrical, optical, or radio signals representing binary data. These signals are subsequently transmitted through the appropriate wired or wireless communication medium. It states the data transmission rate, i.e., number of bits transmitted per second; and the duration of a bit, i.e., how long a bit stays. Physical layer specifies how the different, devices/nodes are arranged in a network i.e. bus topology, star topology, or mesh topology.