Introduction

Computer Network

- A **network** is a collection of **computers**, **servers**, **mainframes**, **network devices**, **peripherals**, or other devices connected to one another to allow the sharing of data.
- An excellent example of a network is the Internet, which connects millions of people all over the world.
- One of the first computer networks to use packet switching, ARPANET was developed in the mid-1960s and is considered to be the direct predecessor of the modern Internet. The first ARPANET message was sent on October 29, 1969.

Uses of Computer Networks

❖ Business Applications

- Many companies have a substantial number of computers. For example, a company may have separate computers to monitor production, keep track of inventories, and do the payroll.
- Initially, each of these computers may have worked in isolation from the others, but at some point, management may have decided to connect them to be able to extract and correlate information about the entire company.

❖ Resource Sharing

- The goal is to make all programs, equipment's (like printers etc.), and especially data, available to anyone on the network without regard to the physical location of the resource and the user.

❖ Server-Client model

- One can imagine a company's information system as consisting of one or more databases and some employees who need to access it remotely. In this model, the data is stored on powerful computers called **Servers**. Often these are centrally housed and maintained by a system administrator. In contrast, the employees have simple machines, called **Clients**, on their desks, using which they access remote data.

❖ Communication Medium

- A computer network can provide a powerful communication medium among employees. Virtually every company that has two or more computers now has e-mail (electronic mail), which employees generally use for a great deal of daily communication.

❖ Home Applications

- Access to remote information
- Person-to-person communication
- Interactive entertainment
- Electronic commerce

❖ eCommerce

- A goal that is starting to become more important in businesses is doing business with consumers over the Internet. Airlines, bookstores and music vendors have discovered that many customers like the convenience of shopping from home. This sector is expected to grow quickly in the future.

The most popular forms are listed in the below figure:

Tag and Full Name	Example
B2C - Business-to-Consumer	Ordering books on-line
B2B - Business-to-Business	Car manufacturer ordering tires from supplier
C2C - Consumer-to-Consumer	Auctioning second-hand products on line
G2C - Government-to-Consumer	Government distributing tax forms electronically
P2P - Peer-to-Peer	File sharing

❖ Mobile Users

- Mobile computers, such as notebook computers and Mobile phones, is one of the fastest-growing segment of the entire computer industry. Although wireless networking and mobile computing are often related, they are not identical, as the below figure shows.

Wireless	Mlobile	Applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in older, unwired buildings
Yes	Yes	Portable office; PDA for store inventory

Network Hardware

There are two types of transmission technology that are in widespread use. They are as follows:

1. **Broadcast links**
   - Broadcast networks have a single communication channel that is shared by all the machines on the network.
   - Short messages, called **packets** in certain contexts, sent by any machine are received by all the others.
   - An address field within the packet specifies the intended recipient.
   - Upon receiving a packet, a machine checks the address field. If the packet is intended for the receiving machine, that machine processes the packet; if the packet is intended for some other machine, it is just ignored.
   - Example:- Calling a students by his/her name in the class.

2. Point-to-point links

- **P**oint-to-point networks consist of many connections between individual pairs of machines.
- To go from the source to the destination, a packet on this type of network may have to first visit one or more intermediate machines. Often multiple routes, of different lengths, are possible, so finding good ones is important in point-to-point networks.
- Point-to-point transmission with one sender and one receiver is sometimes called unicasting.
- An example is a telephone call.

Distance is important as a classification metric because different techniques are used at different scales.

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

There are many types of computer network :

❑ Local Area Networks (LANs)

- The computers are geographically close together (that is, in the same building).
- They are widely used to connect personal computers and workstations in company offices and factories to share resources (e.g., printers) and exchange information.

❑ Wide Area Networks (WANs)

- The computers are farther apart and are connected by telephone lines or radio waves.
- The best-known example of a MAN is the cable television network available in many cities.

❑ Metropolitan Area Networks MANs)

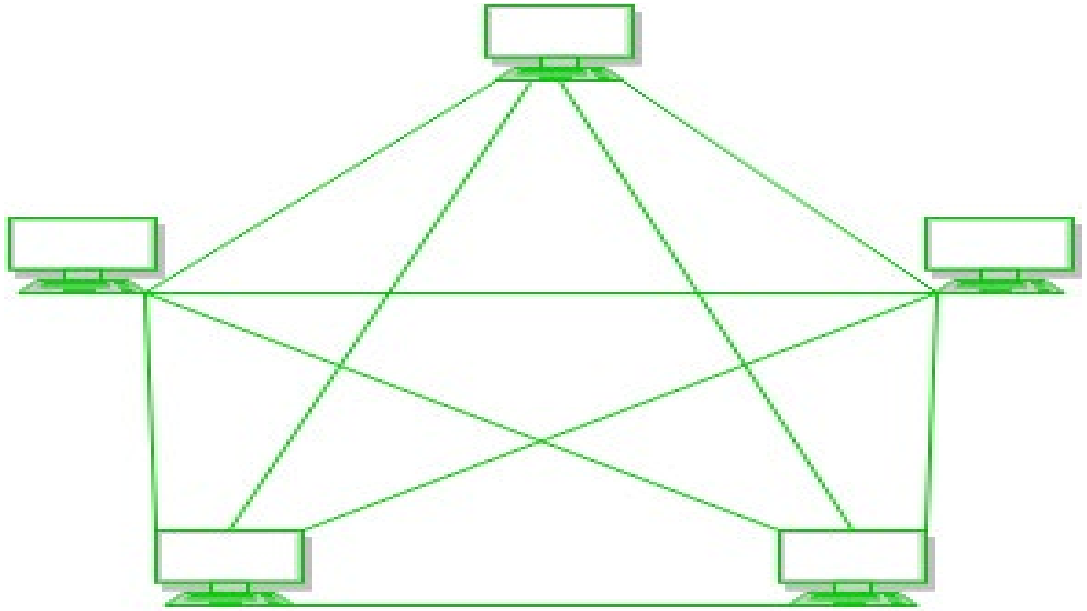
- A data network designed for a town or city.
- Example:- Internet

Types of Network Topology

The arrangement of a network which comprises of nodes and connecting lines via sender and receiver is referred as **network topology**. The various network topologies are :

a) Mesh Topology :

- In mesh topology, every device is connected to another device via particular channel.

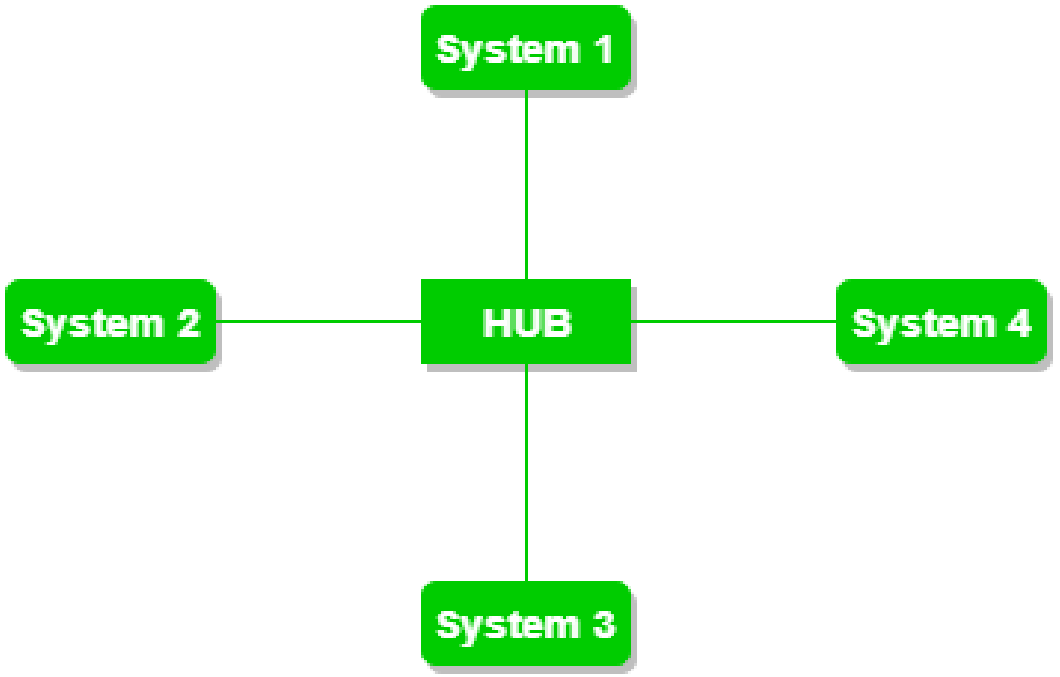


- **Advantages of this topology :**
  - It is robust.
  - Fault is diagnosed easily. Data is reliable because data is transferred among the devices through dedicated channels or links.
  - Provides security and privacy.

- **Problems with this topology :**
  - Installation and configuration is difficult.
  - Cost of cables are high as bulk wiring is required, hence suitable for less number of devices.
  - Cost of maintenance is high.

b) Star Topology

- In star topology, all the devices are connected to a single hub through a cable.
- This hub is the central node and all others nodes are connected to the central node.
- The hub can be passive in nature i.e. not intelligent hub such as broadcasting devices, at the same time the hub can be intelligent known as active hubs.

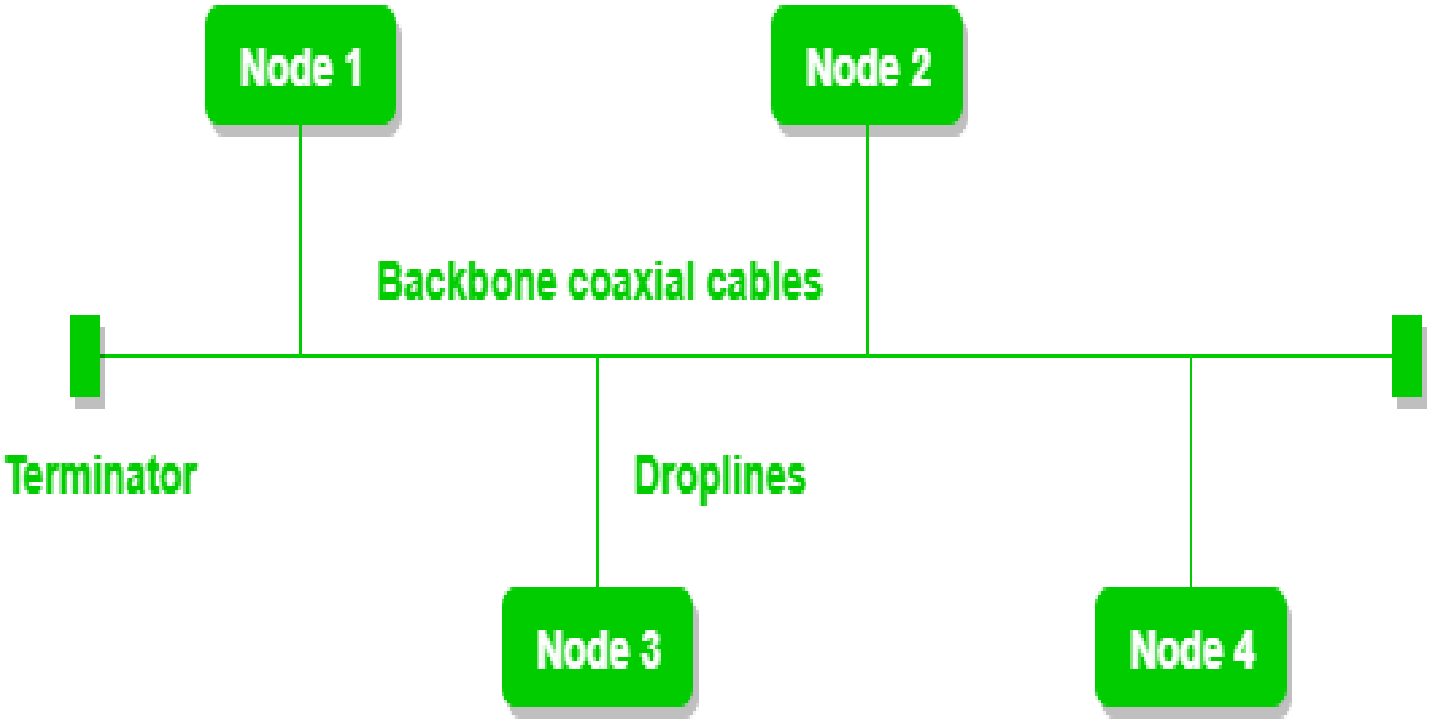


- **Advantages of this topology :**
  - If N devices are connected to each other in star topology, then the number of cables required to connect them is N. So, it is easy to set up.
  - Each device require only 1 port i.e. to connect to the hub.

- **Problems with this topology :**
  - If the concentrator (hub) on which the whole topology relies fails, the whole system will crash down.
  - Cost of installation is high.
  - Performance is based on the single concentrator i.e. hub.

c) Bus Topology

- Bus topology is a network type in which every computer and network device is connected to single cable.
- It transmits the data from one end to another in single direction.
- No bi-directional feature is in bus topology.

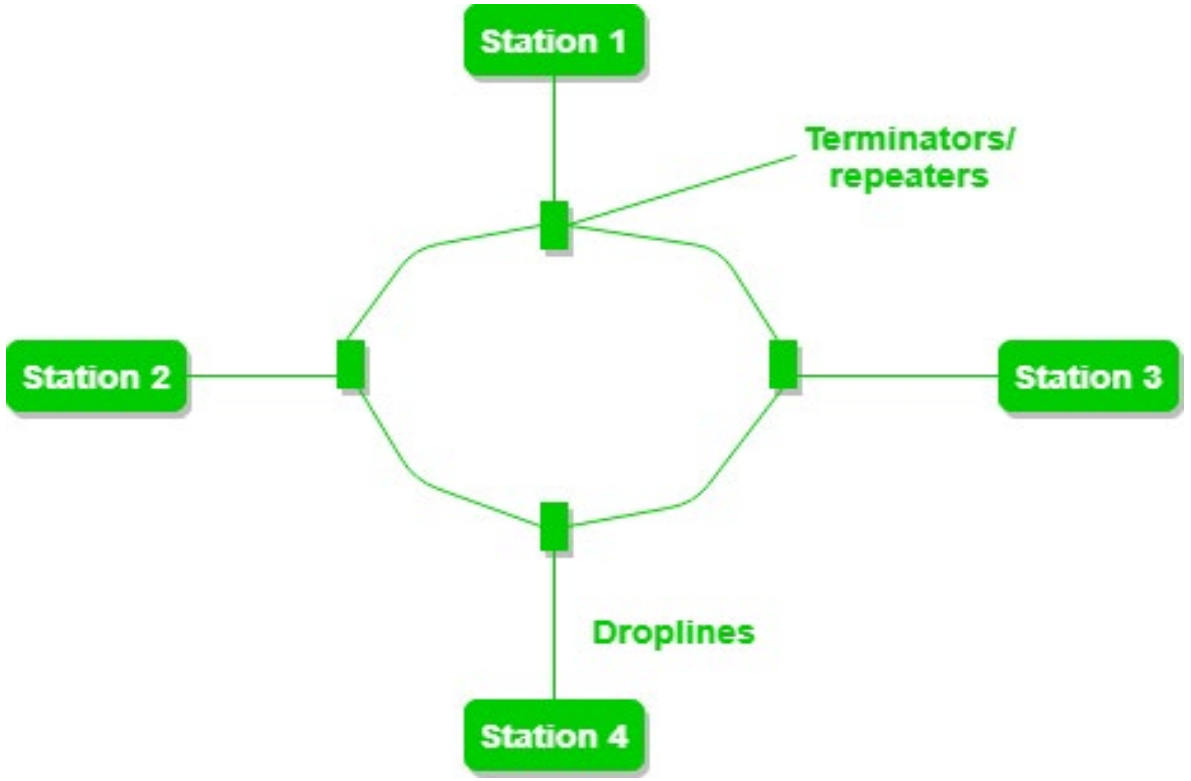


- **Advantages of this topology :**
  - If N devices are connected to each other in bus topology, then the number of cables required to connect them is 1 which is known as backbone cable and N drop lines are required.
  - Cost of the cable is less as compared to other topology, but it is used to built small networks.

- **Problems with this topology :**
  - If the common cable fails, then the whole system will crash down.
  - If the network traffic is heavy, it increases collisions in the network. To avoid this, various protocols are used in MAC layer known as Pure Aloha, Slotted Aloha, CSMA/CD etc.

d) Ring Topology :

- In this topology, it forms a ring connecting a devices with its exactly two neighboring devices.



- The following operations takes place in ring topology are :
  - One station is known as **monitor** station which takes all the responsibility to perform the operations.
  - To transmit the data, station has to hold the token. After the transmission is done, the token is to be released for other stations to use.
  - When no station is transmitting the data, then the token will circulate in the ring.
  - There are two types of token release techniques : **Early token release** releases the token just after the transmitting the data and **Delay token release** releases the token after the acknowledgement is received from the receiver.

- **Advantages of this topology :**
  - The possibility of collision is minimum in this type of topology.
  - Cheap to install and expand.

- **Problems with this topology :**
  - Troubleshooting is difficult in this topology.
  - Addition of stations in between or removal of stations can disturb the whole topology.

e) Hybrid Topology :

- This topology is a collection of two or more topologies which are described above.
- This is a scalable topology which can be expanded easily.
- It is reliable one but at the same it is a costly topology.

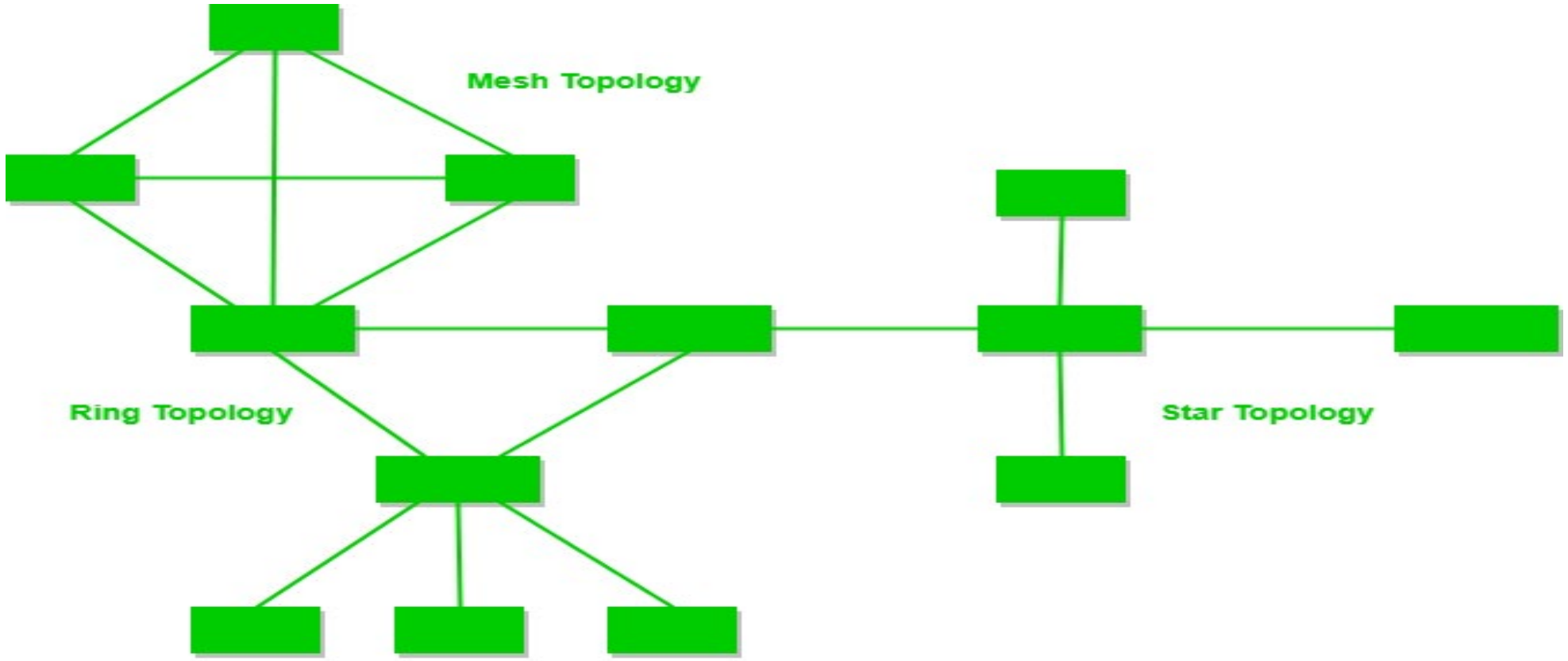


Figure - A Hybrid Topology

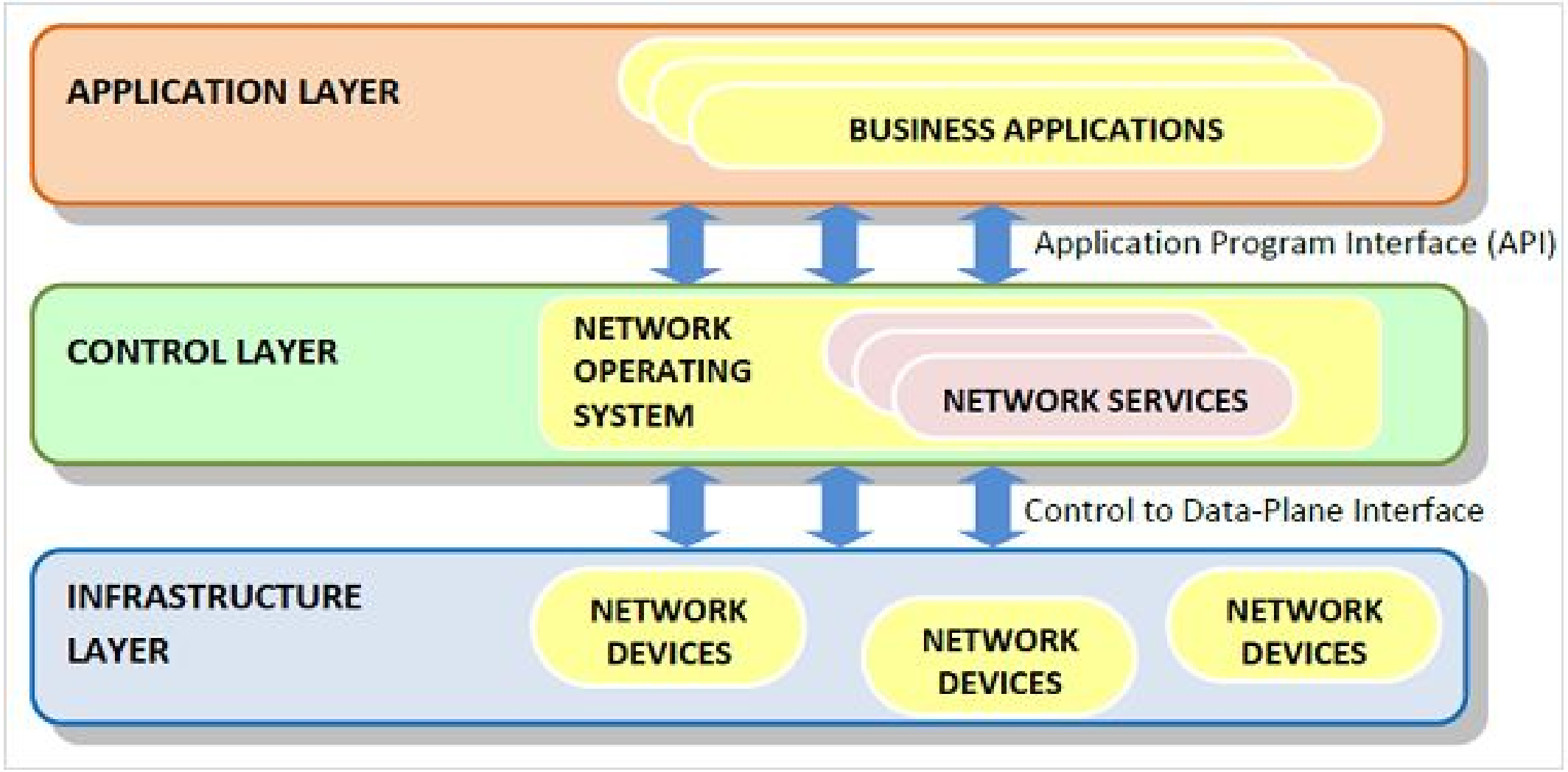
Network Software

- Network software encompasses a broad range of software used for **design**, **implementation**, and **operation** and **monitoring** of computer networks. Traditional networks were hardware based with software embedded. With the advent of **Software – Defined Networking (SDN),** software is separated from the hardware thus making it more adaptable to the ever-changing nature of the computer network.

- **Functions of Network Software**
  - Helps to set up and install computer networks
  - Enables users to have access to network resources in a seamless manner
  - Allows administrations to add or remove users from the network
  - Helps to define locations of data storage and allows users to access that data
  - Helps administrators and security system to protect the network from data breaches, unauthorized access and attacks on a network
  - Enables network virtualizations

SDN Framework

The Software Defined Networking framework has three layers as depicted in the following diagram −



- **APPLICATION LAYER**
  - SDN applications reside in the Application Layer.
  - The applications convey their needs for resources and services to the control layer through APIs.

- **CONTROL LAYER**
  - The Network Control Software, bundled into the Network Operating System, lies in this layer.
  - It provides an abstract view of the underlying network infrastructure.
  - It receives the requirements of the SDN applications and relays them to the network components.

- **INFRASTRUCTURE LAYER**
  - Also called the Data Plane Layer, this layer contains the actual network components.
  - The network devices reside in this layer that shows their network capabilities through the Control to data-Plane Interface.

Reference Models

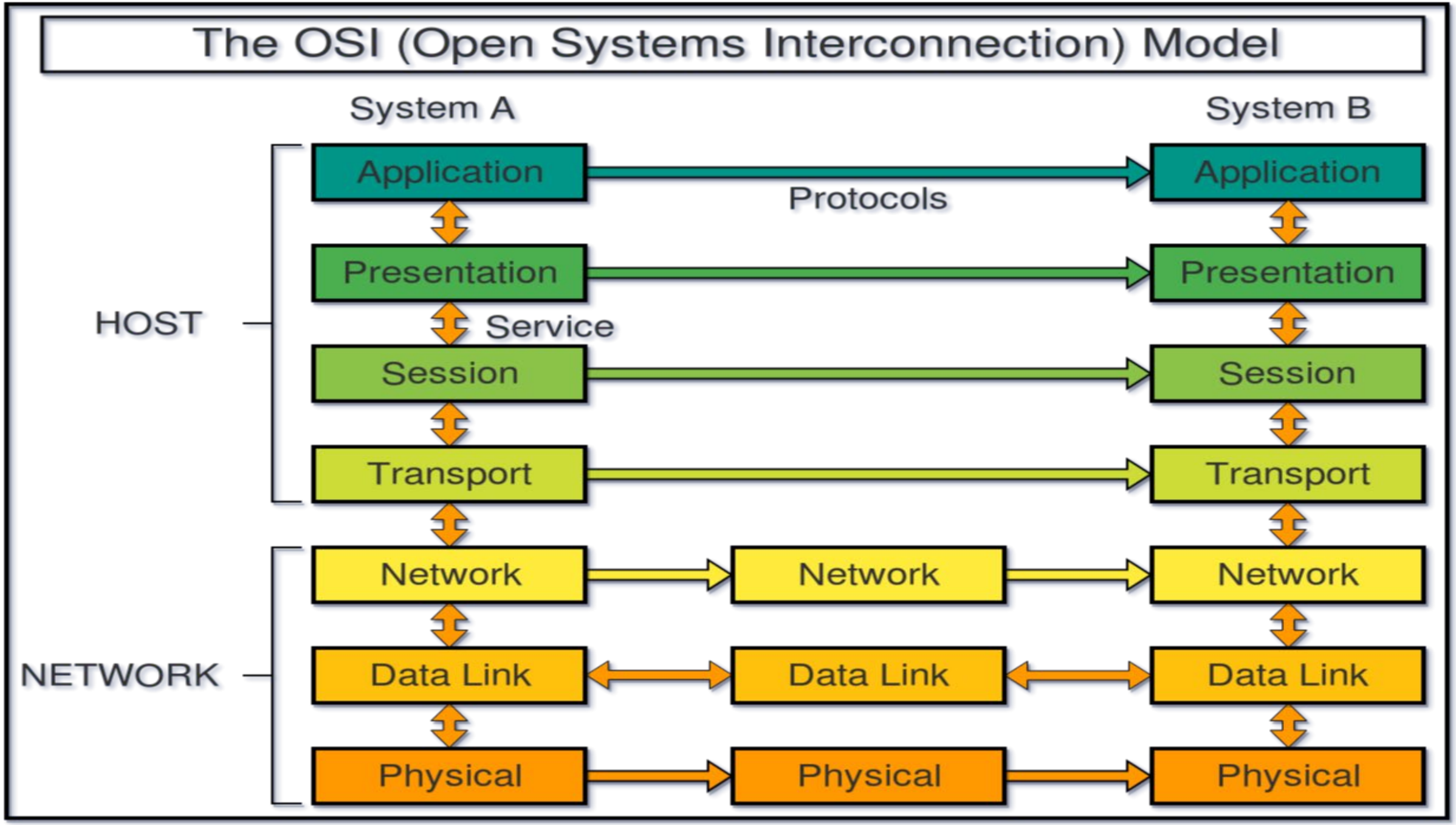
In the next two sections we will discuss two important network architectures,

- The OSI reference model
- The TCP/IP model

❑The OSI Reference Model

- This model is based on a proposal developed by the **International Standards Organization** (**ISO**) as a first step toward **international standardization of the protocols** used in the various layers (Day and Zimmermann, 1983).

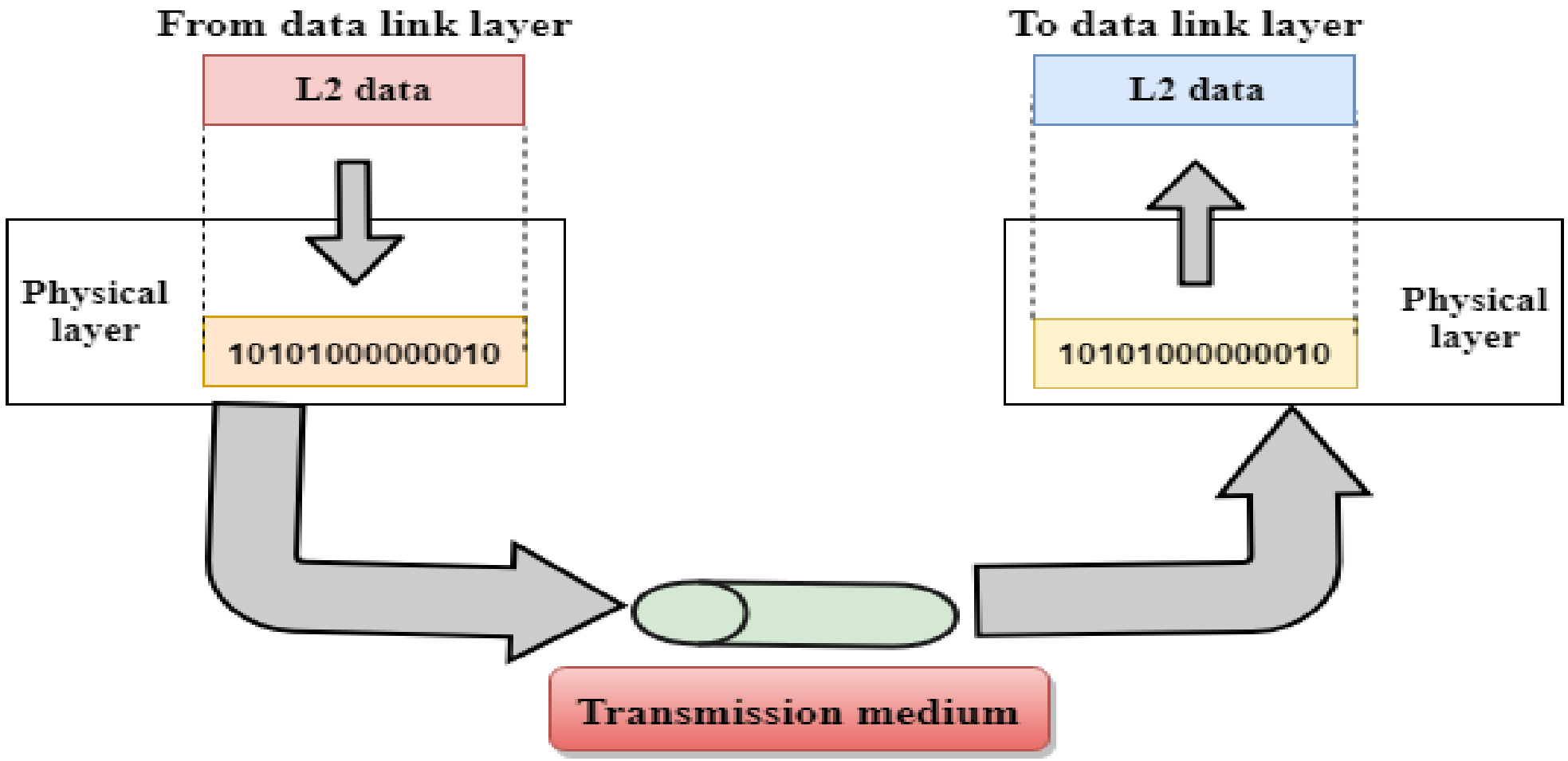
- It was revised in 1995 (Day, 1995). The model is called the **ISO OSI** (**Open Systems Interconnection**) Reference Model because it deals with connecting open systems—that is, systems that are open for communication with other systems. We will just call it the OSI model for short.


The OSI (Open Systems Interconnection) Model
System A
System B
Application
Protocols
Application
Presentation
Presentation
HOST
Service
Session
Session
Transport
Transport
Network
Network
Network
NETWORK
Data Link
Data Link
Data Link
Physical
Physical
Physical

The OSI model has seven layers. The principles that were applied to arrive at the seven layers can be briefly summarized as follows:

- 1. A layer should be created where a different abstraction is needed.
- 2. Each layer should perform a well-defined function.
- 3. The function of each layer should be chosen with an eye toward defining internationally standardized protocols.
- 4. The layer boundaries should be chosen to minimize the information flow across the interfaces.
- 5. The number of layers should be large enough that distinct functions need not be thrown together in the same layer out of necessity and small enough that the architecture does not become unwieldy.

Physical layer

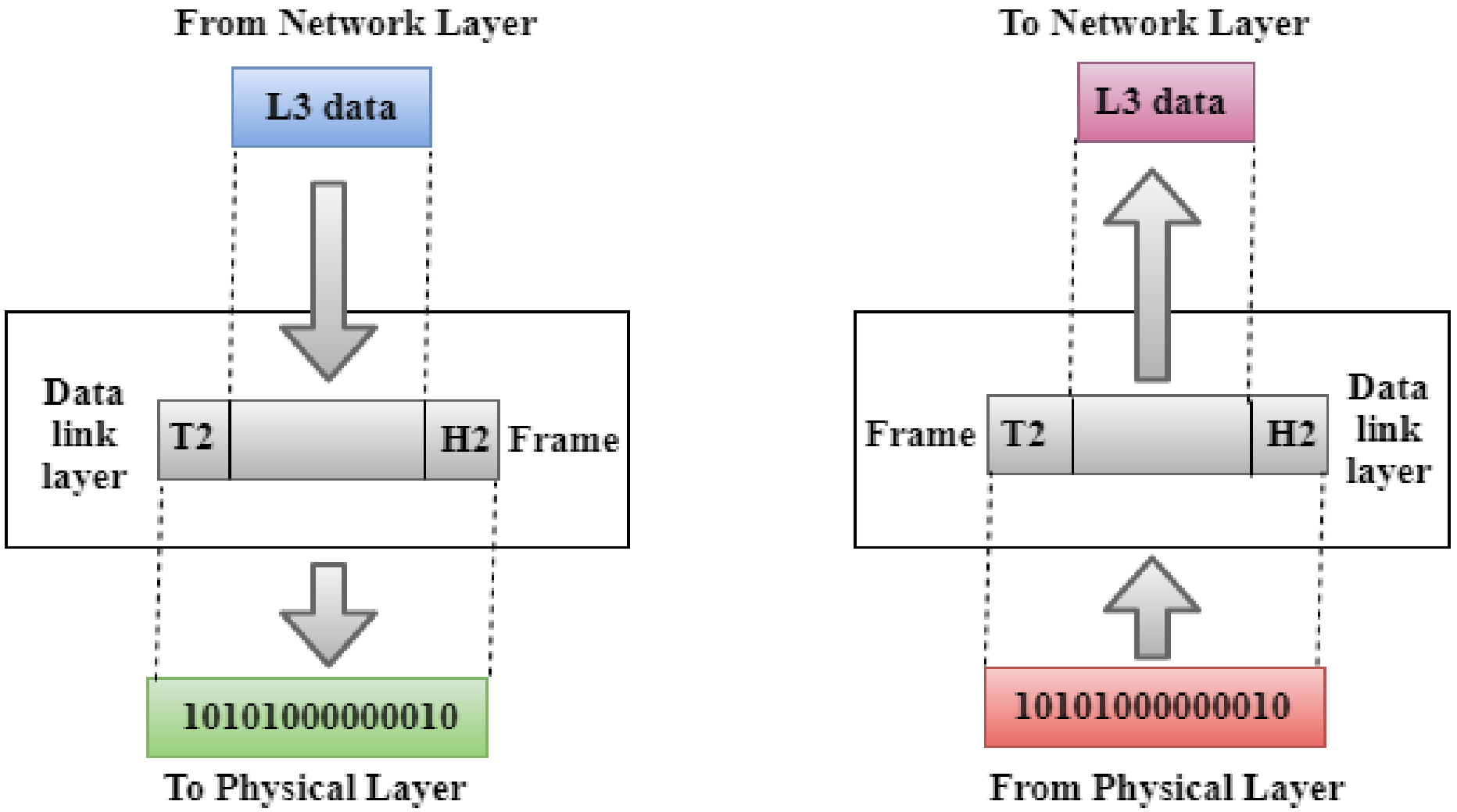


- The main functionality of the physical layer is to **transmit the individual bits from one node to another node.**
- It is the lowest layer of the OSI model.
- It establishes, **maintains and deactivates the physical connection**.
- It specifies the mechanical, electrical and procedural network interface specifications.

❑Functions of a Physical layer:

- **Line Configuration:** It defines the way how two or more devices can be connected physically.
- **Data Transmission:** It defines the transmission mode whether it is simplex, half-duplex or full-duplex mode between the two devices on the network.
- **Topology:** It defines the way how network devices are arranged.
- **Signals:** It determines the type of the signal used for transmitting the information.

Data-Link Layer



- This layer is responsible for the **error-free transfer of data frames.**
- It defines **the format of the data** on the network.
- It provides a **reliable** and **efficient *communication between two or more devices***.
- It is mainly responsible for **the unique identification of each device** that resides on a local network.

❑ Functions of the Data-link layer

- **Framing:** The data link layer translates the physical's raw bit stream into packets known as Frames. The Data link layer adds the header and trailer to the frame. The header which is added to the frame contains the hardware destination and source address.

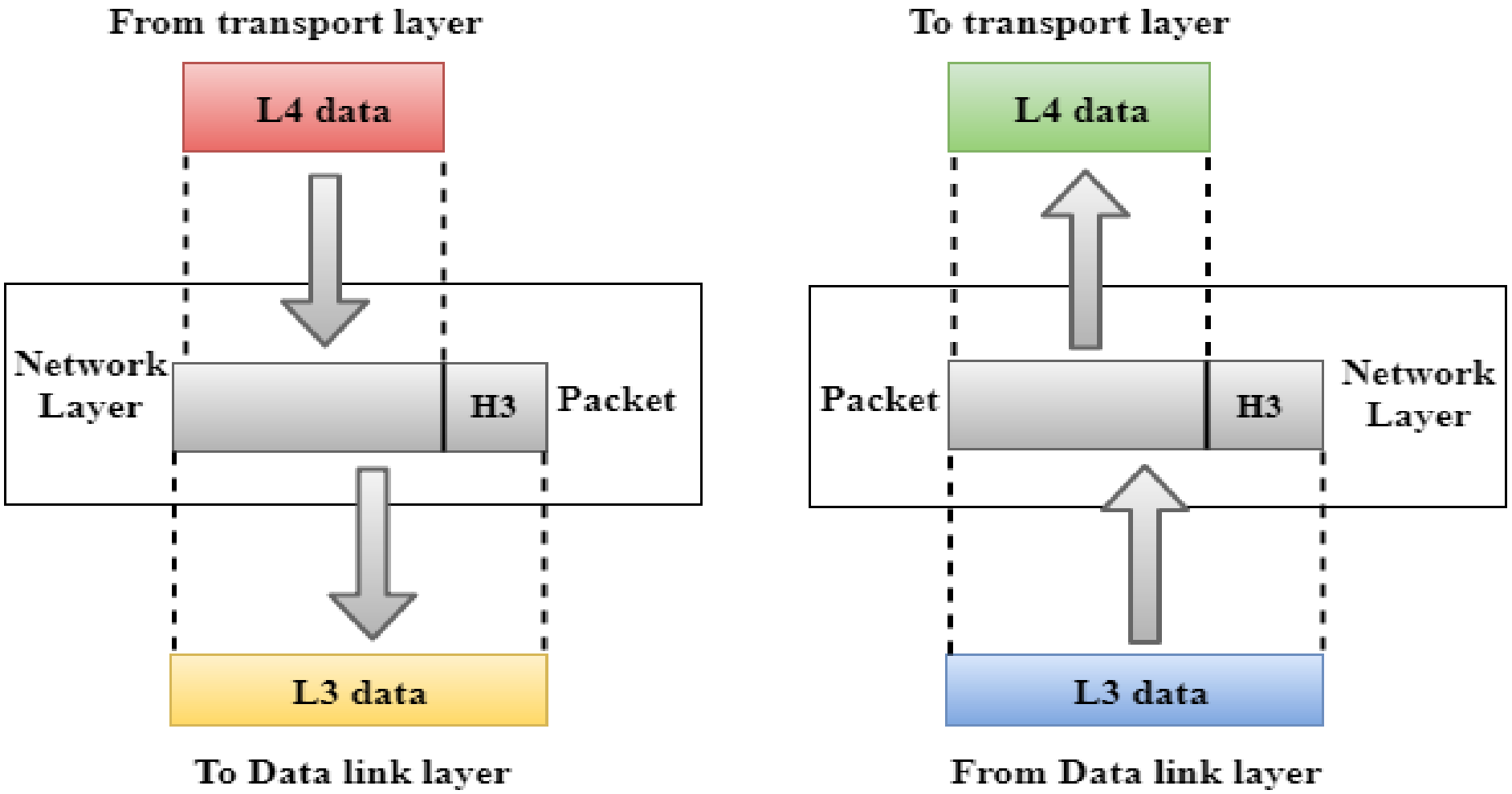
- **Physical Addressing:** The Data link layer adds a header to the frame that contains a destination address. The frame is transmitted to the destination address mentioned in the header.

- **Flow Control:** Flow control is the main functionality of the Data-link layer. It is the technique through which the constant data rate is maintained on both the sides so that no data get corrupted. It ensures that the transmitting station such as a server with higher processing speed does not exceed the receiving station, with lower processing speed.

- **Error Control:** Error control is achieved by adding a calculated value CRC (Cyclic Redundancy Check) that is placed to the Data link layer's trailer which is added to the message frame before it is sent to the physical layer. If any error seems to occur, then the receiver sends the acknowledgment for the retransmission of the corrupted frames.

- **Access Control:** When two or more devices are connected to the same communication channel, then the data link layer protocols are used to determine which device has control over the link at a given time.

Network Layer

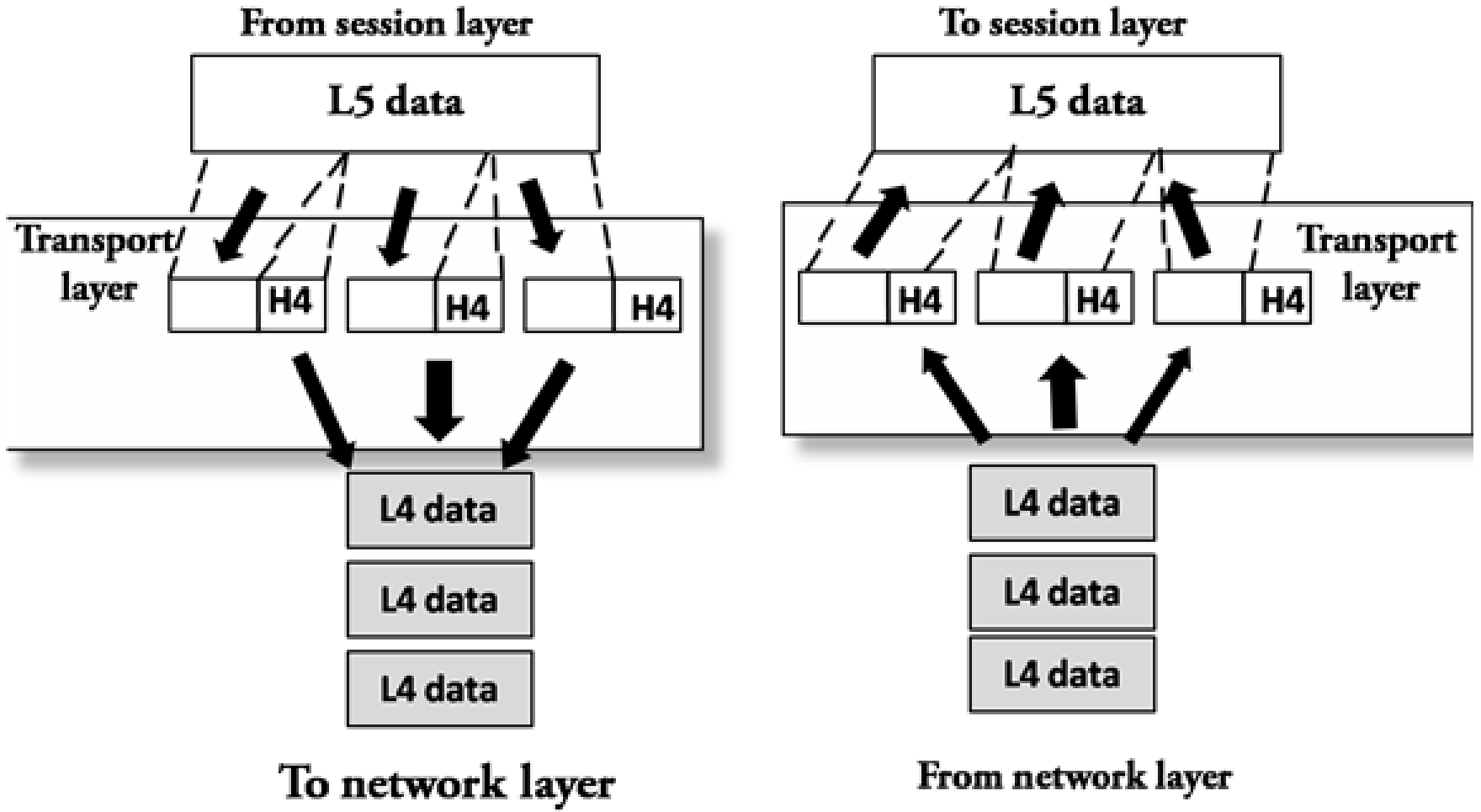


- It is a layer 3 that manages device **addressing**, **tracks the location of devices** on the network.
- It determines the **best path to move data from source to the destination** based on the network conditions, the priority of service, and other factors.
- The **Data link layer is responsible for routing and forwarding the packets.**
- Routers are the layer 3 devices, they are specified in this layer and used to provide the **routing services within an internetwork**.
- The protocols used to route the network traffic are known as Network layer protocols. Examples of protocols are IPv4 and IPv6

❑Functions of Network Layer:

- **Internetworking:** An internetworking is the main responsibility of the network layer. It provides a logical connection between different devices.
- **Addressing:** A Network layer adds the source and destination address to the header of the frame. Addressing is used to identify the device on the internet.
- **Routing:** Routing is the major component of the network layer, and it determines the best optimal path out of the multiple paths from source to the destination.
- **Packetizing:** A Network Layer receives the packets from the upper layer and converts them into packets. This process is known as Packetizing. It is achieved by internet protocol (IP).

Transport Layer

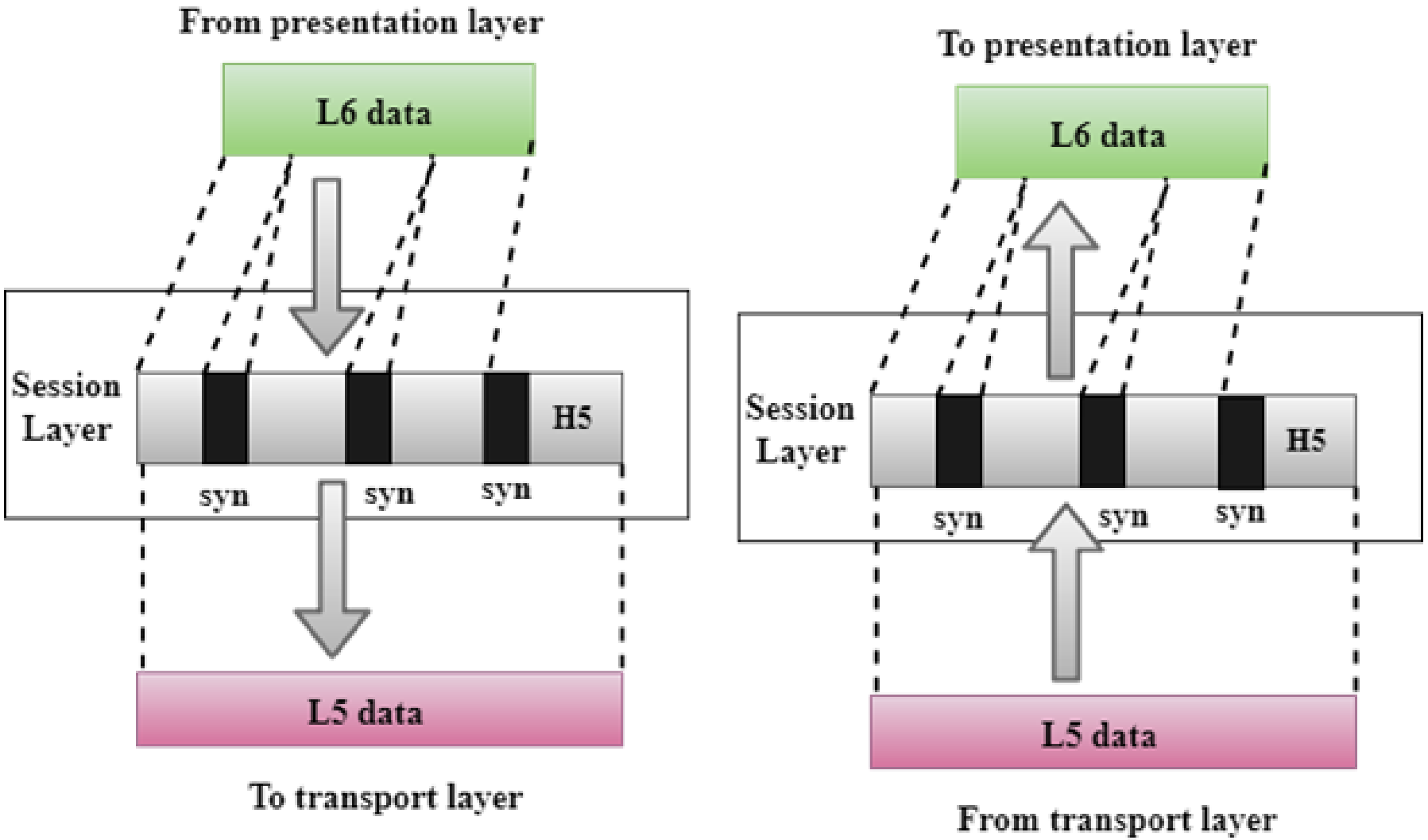


- The Transport layer is a Layer 4 ensures that **messages are transmitted in the order in which they are sent and there is no duplication of data.**
- The main responsibility of the transport layer is **to transfer the data completely**.
- It receives the data from the upper layer and converts them into **smaller units** known as **segments**.
- This layer can be termed as an **end-to-end layer** as it provides a ***point-to-point connection between source and destination to deliver the data reliably.***

❑ Functions of Transport Layer:

- **Service-point addressing:** Computers run several programs simultaneously due to this reason, the transmission of data from source to the destination not only from one computer to another computer but also from one process to another process. The transport layer adds the header that contains the address known as a service-point address or port address. The responsibility of the network layer is to transmit the data from one computer to another computer and the responsibility of the transport layer is to transmit the message to the correct process.
- **Segmentation and reassembly:** When the transport layer receives the message from the upper layer, it divides the message into multiple segments, and each segment is assigned with a sequence number that uniquely identifies each segment. When the message has arrived at the destination, then the transport layer reassembles the message based on their sequence numbers.
- **Connection control:** Transport layer provides two services Connection-oriented service and connectionless service. A connectionless service treats each segment as an individual packet, and they all travel in different routes to reach the destination. A connection-oriented service makes a connection with the transport layer at the destination machine before delivering the packets. In connection-oriented service, all the packets travel in the single route.
- **Flow control:** The transport layer also responsible for flow control but it is performed end-to-end rather than across a single link.
- **Error control:** The transport layer is also responsible for Error control. Error control is performed end-to-end rather than across the single link. The sender transport layer ensures that message reach at the destination without any error.

Session Layer



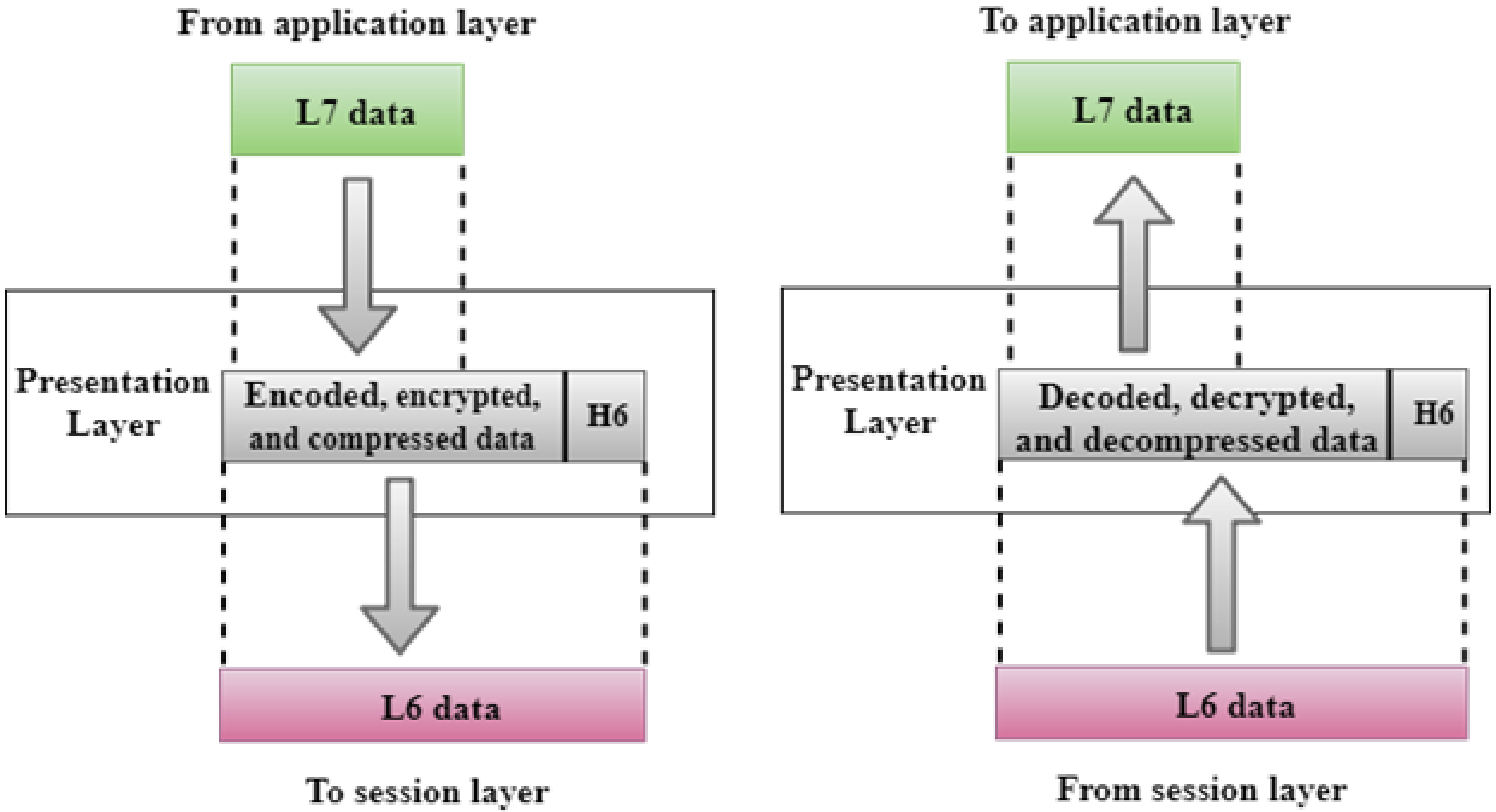
- It is a layer 3 in the OSI model.
- The Session layer is used to **establish**, **maintain** and **synchronizes** the **interaction between communicating devices.**

❑Functions of Session layer:

- **Dialog control:** Session layer acts as a dialog controller that creates a dialog between two processes or we can say that it allows the communication between two processes which can be either half-duplex or full-duplex.

- **Synchronization:** Session layer adds some checkpoints when transmitting the data in a sequence. If some error occurs in the middle of the transmission of data, then the transmission will take place again from the checkpoint. This process is known as Synchronization and recovery.

Presentation Layer

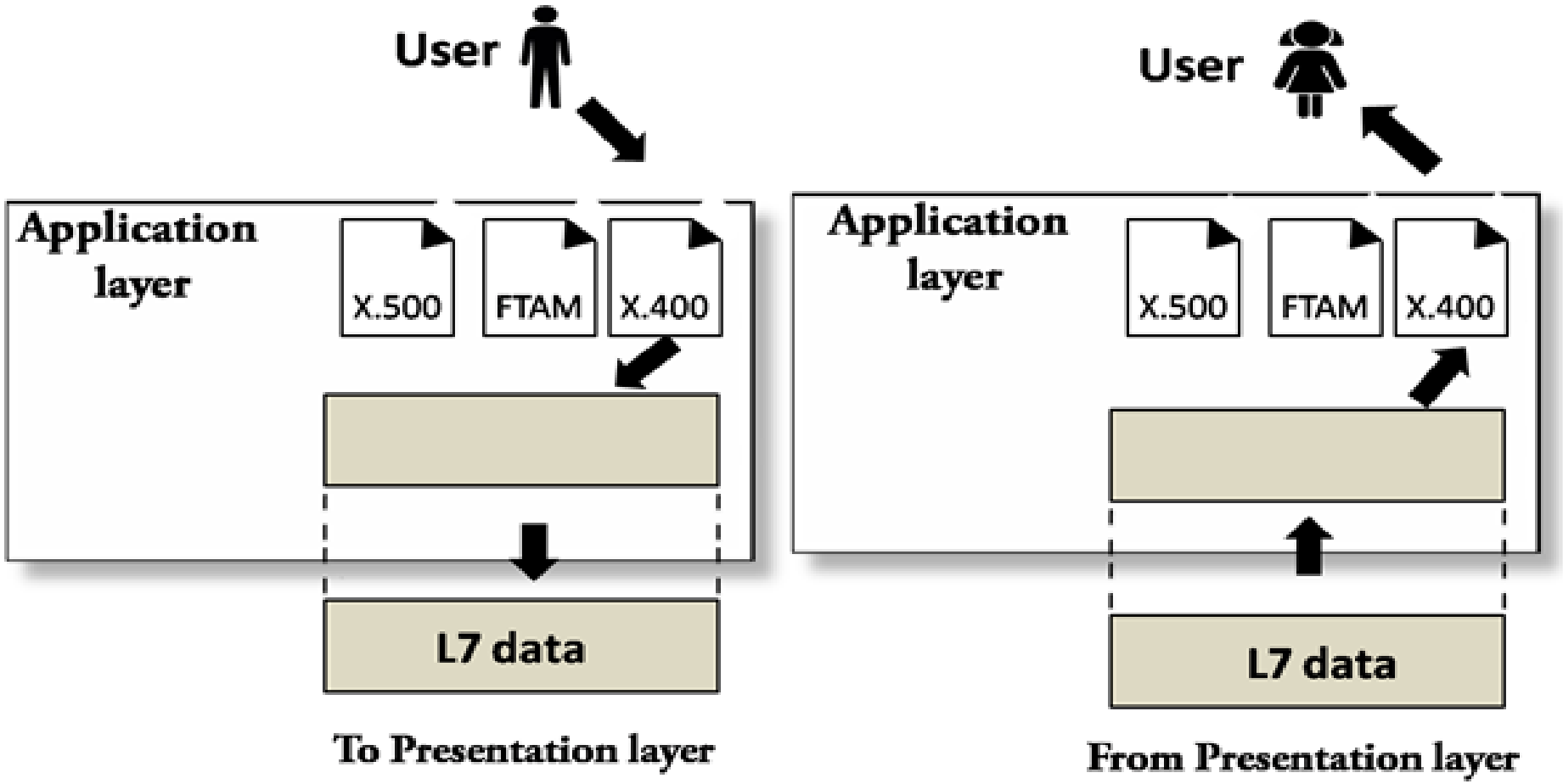


- A Presentation layer is mainly concerned with **the syntax and semantics** of the information exchanged between the two systems.
- It acts as a **data translator for a network**.
- This layer is a part of the operating system that converts the data from one presentation format to another format.
- The Presentation layer is also known as the **syntax layer**.

❑Functions of Presentation layer:

- **Translation:** The processes in two systems exchange the information in the form of character strings, numbers and so on. Different computers use different encoding methods, the presentation layer handles the interoperability between the different encoding methods. It converts the data from sender-dependent format into a common format and changes the common format into receiver-dependent format at the receiving end.
- **Encryption:** Encryption is needed to maintain privacy. Encryption is a process of converting the sender-transmitted information into another form and sends the resulting message over the network.
- **Compression:** Data compression is a process of compressing the data, i.e., it reduces the number of bits to be transmitted. Data compression is very important in multimedia such as text, audio, video.

Application Layer



- An application layer serves as a window for users and application processes to access network service.
- It handles issues such as network transparency, resource allocation, etc.
- An application layer is not an application, but it performs the application layer functions.
- This layer provides the network services to the end-users.

❑Functions of Application layer:

- **File transfer, access, and management (FTAM):** An application layer allows a user to access the files in a remote computer, to retrieve the files from a computer and to manage the files in a remote computer.
- **Mail services:** An application layer provides the facility for email forwarding and storage.
- Directory services: An application provides the distributed database sources and is used to provide that global information about various objects.

Network Standardization

- Many network vendors and suppliers exist, each with its own ideas of how things should be done. Without coordination, there would be complete chaos, and users would get nothing done.
- The only way out is to agree on some network standards.
- Not only do standards allow different computers to communicate, but they also increase the market for products adhering to the standard.
- A larger market leads to mass production, economies of scale in manufacturing, VLSI implementations, and other benefits that decrease price and further increase acceptance.
- In the area of computer network standards, there are several organizations of each type, which are discussed below.

1. Who's Who in the Telecommunications World

- In 1865, representatives from many European governments met to form the predecessor to today's **ITU (International Telecommunication Union).** Its job was standardizing international telecommunications, which in those days meant telegraphy.
- Even then it was clear that if half the countries used
- Morse code and the other half used some other code, there was going to be a problem. When the telephone was put into international service, ITU took over the job of standardizing telephony (pronounced te-LEF-ony) as well. In 1947, ITU became an agency of the United Nations.

❖ITU has three main sectors:

- **1. Radiocommunications Sector (ITU-R)**- concerned with allocating ***radio frequencies worldwide to the competing interest groups.***
- **2. Telecommunications Standardization Sector (ITU-T)-** concerned with ***telephone and data communication systems.***
  - ITU-T has four classes of members:
    1. National governments.
    2. Sector members.
    3. Associate members.
    4. Regulatory agencies.
- **3. Development Sector (ITU-D).**

2. Who's Who in the International Standards World

- International standards are produced and published by **ISO (International Standards Organization**), a voluntary nontreaty organization founded in 1946.
- Its members are the national standards organizations of the 89 member countries. These members include **ANSI (U.S.)**, **BSI (Great Britain), AFNOR (France), DIN (Germany),** and 85 others
- **NIST (National Institute of Standards and Technology)** is part of the U.S. Department of Commerce. It used to be the **National Bureau of Standards**. It issues standards that are mandatory for purchases made by the U.S.Government, except for those of the Department of Defense, which has its own standards.
- Another major player in the standards world is **IEEE (Institute of Electrical and Electronics Engineers)**, the largest professional organization in the world.
- In addition to publishing scores of journals and running hundreds of conferences each year, IEEE has a standardization group that develops standards in the area of electrical engineering and computing.
- IEEE's 802 committee has standardized many kinds of LANs.

Number	Topic
802.1	Overview and architecture of LANs
802.2 ↓	Logical link control
802.3 *	Ethernet
802.4 ↓	Token bus (was briefly used in manufacturing plants)
802.5	Token ring (IBM's entry into the LAN world)
802.6 ↓	Dual queue dual bus (early metropolitan area network)
802.7 ↓	Technical advisory group on broadband technologies
802.8 †	Technical advisory group on fiber optic technologies
802.9 ↓	Isochronous LANs (for real-time applications)
802.10 ↓	Virtual LANs and security
802.11 *	Wireless LANs
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)
802.13	Unlucky number. Nobody wanted it
802.14 ↓	Cable modems (defunct: an industry consortium got there first)
802.15 *	Personal area networks (Bluetooth)
802.16 *	Broadband wireless
802.17	Resilient packet ring

The 802 working groups.

3. Who's Who in the Internet Standards World

- In 1983, the committee **IAB (Internet Activities Board)** and was given a slighter broader mission, namely, to keep the researchers involved with the **ARPANET** and the Internet pointed more-or-less in the same direction.

- The meaning of the acronym "IAB" was later changed to **Internet Architecture Board**.

- By 1989, the Internet had grown so large that this highly informal style no longer worked.

- In the summer of 1989, the IAB was reorganized again. The researchers were moved to the **IRTF (Internet Research Task Force),** which was made subsidiary to IAB, along with the **IETF (Internet Engineering Task Force).**

Metric Units

- It is also worth pointing out that for measuring memory, disk, file, and database sizes, in common industry practice, the units have slightly different meanings.
- There, kilo means 2^10 (1024) rather than 10^3 (1000) because **memories are always a power of two**. Thus, a 1-KB memory contains 1024 bytes, not 1000 bytes.
- Similarly, a 1-MB memory contains 2^20 (1,048,576) bytes, a 1-GB memory contains 2^30 (1,073,741,824) bytes, and a 1-TB database contains 2^40 (1,099,511,627,776) bytes.
- However, a 1-kbps communication line transmits 1000 bits per second and a 10-Mbps LAN runs at 10,000,000 bits/sec because these **speeds are not powers of two**.
- Unfortunately, many people tend to mix up these two systems, especially for disk sizes.