Computer Network and Data Communication

UNIT 2: Layered Network Architecture

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Course Outline

2. Layered Network Architecture **[4 Hrs]**

- **2.1.** Introduction to Layered Approach
- **2.2.** Benefits of Layered Model
- **2.3.** OSI Reference Model
- **2.4.** TCP/IP Model
- **2.5.** Network Protocol and TCP/IP Protocol Suite

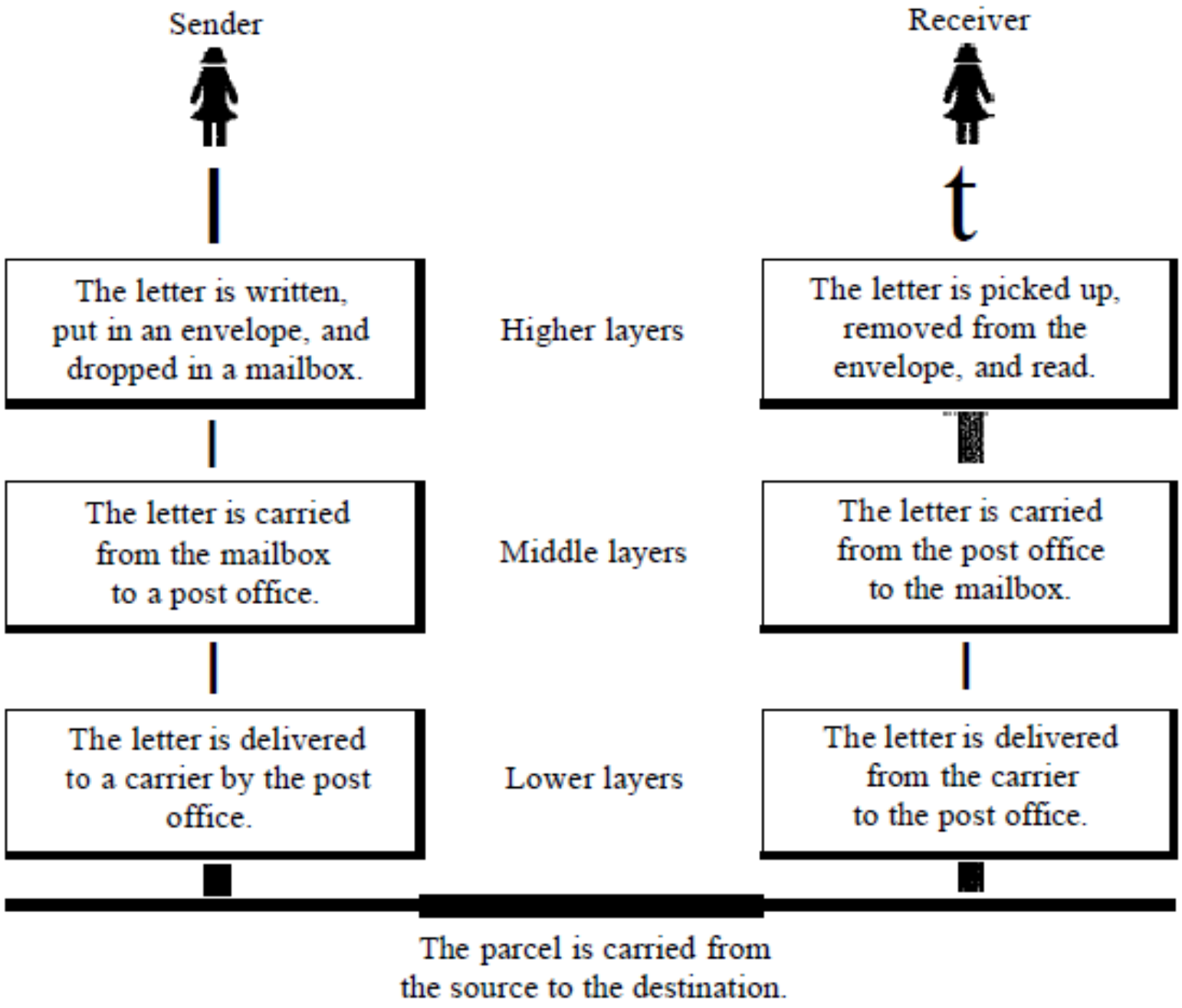
Layered Approach

- conceptual framework used to organize the structure of computer networks and communication protocols

- Divides the complex process of network communication into a series of hierarchical layers, with each layer responsible for specific functions.

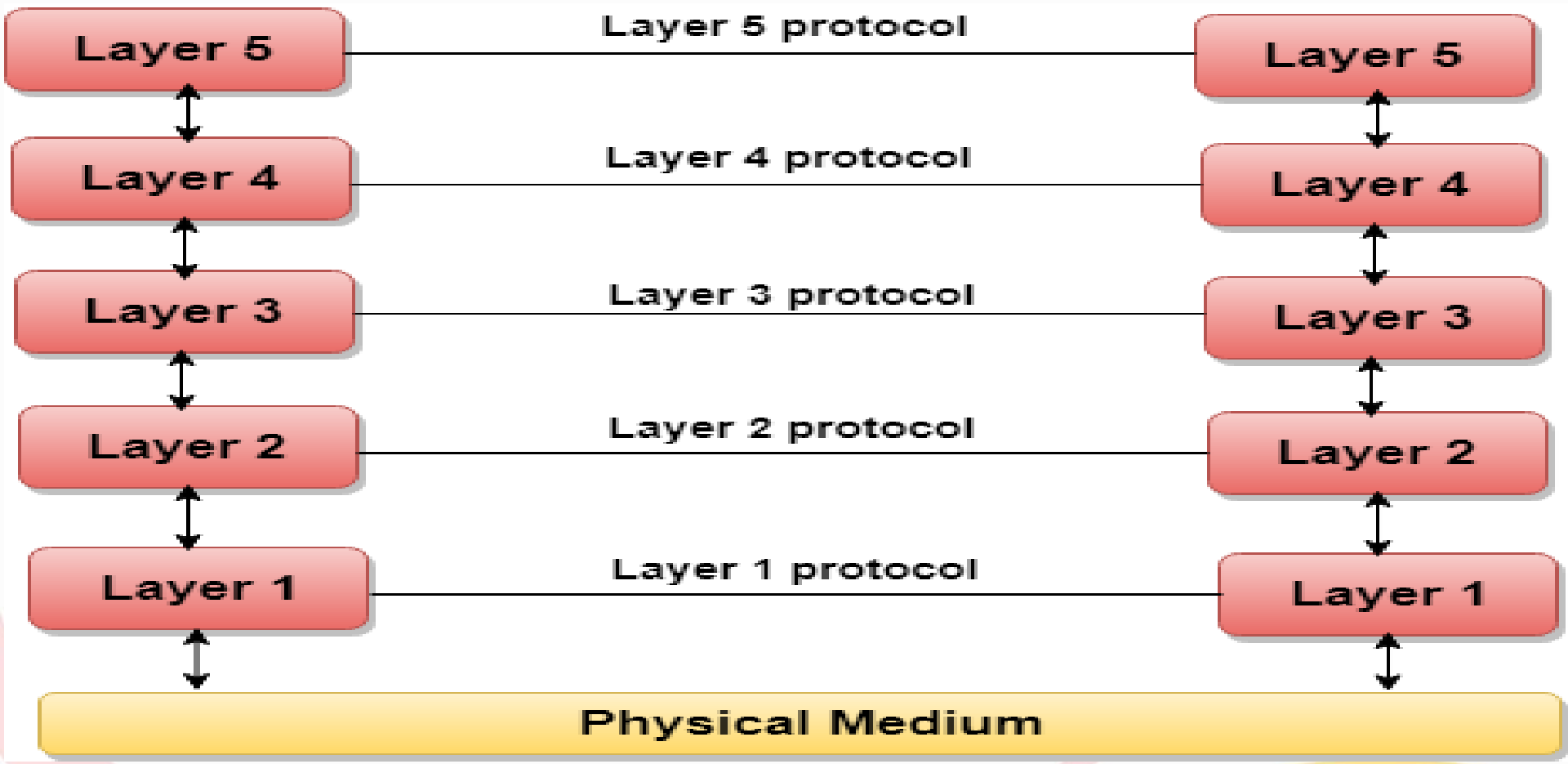
- Main aim of the layered architecture is to divide the design into small pieces.

- The most well-known layered network architecture
  -OSI (Open Systems Interconnection) model,
  - TCP/IP (Transmission Control Protocol/Internet Protocol)



Layered Approach

- Provide the services from lower to higher layer without defining how the services are implemented.
- The basic elements of layered architecture are services, protocols, and interfaces.
  - **Service**: It is a set of actions that a layer provides to the higher layer.
  - **Protocol**: It defines a set of rules that a layer uses to exchange the information with peer entity. These rules mainly concern about both the contents and order of the messages used.
  - **Interface**: It is a way through which the message is transferred from one layer to another layer.



- In case of layered architecture, no data is transferred from layer n of one machine to layer n of another machine. Instead, each layer passes the data to the layer immediately just below it, until the lowest layer is reached.

Benefits of Layered Model

1. Modularity:

- Divide the complex network functions into separate layers.
- Each layer performs a specific set of tasks, making the overall system easier to understand, implement, test, and maintain.
- Modularity allows for independent development and updates to each layer, enabling faster innovation and adaptation to changing requirements.

2. Abstraction:

- Layers in the model provide abstraction by hiding the complexity of lower-level processes from higher-level layers.
- This abstraction allows layers to communicate through well-defined interfaces, shielding upper layers from the details of lower-layer implementations.

Benefits of Layered Model

3. Standardization:

- The layered model facilitates standardization by defining clear boundaries and interfaces between layers.

4.Interoperability:

- By defining standardized interfaces between layers, the layered model promotes interoperability.
- Devices and systems built using the same layer protocols can communicate seamlessly, regardless of their underlying hardware or software implementations

Benefits of Layered Model

5. Scalability:

- The layered model supports scalability by allowing systems to grow and evolve over time.
- New layers can be added or existing layers modified to accommodate changes in requirements

6.Ease of Troubleshooting:

- The layered model simplifies troubleshooting and debugging by localizing problems to specific layers.

Benefits of Layered Model

7. Ease of Implementation:

- Layers in the model can be implemented independently

8.Security:

- The layered model enhances security by enabling the implementation of security mechanisms at multiple layers.

OSI Reference Model

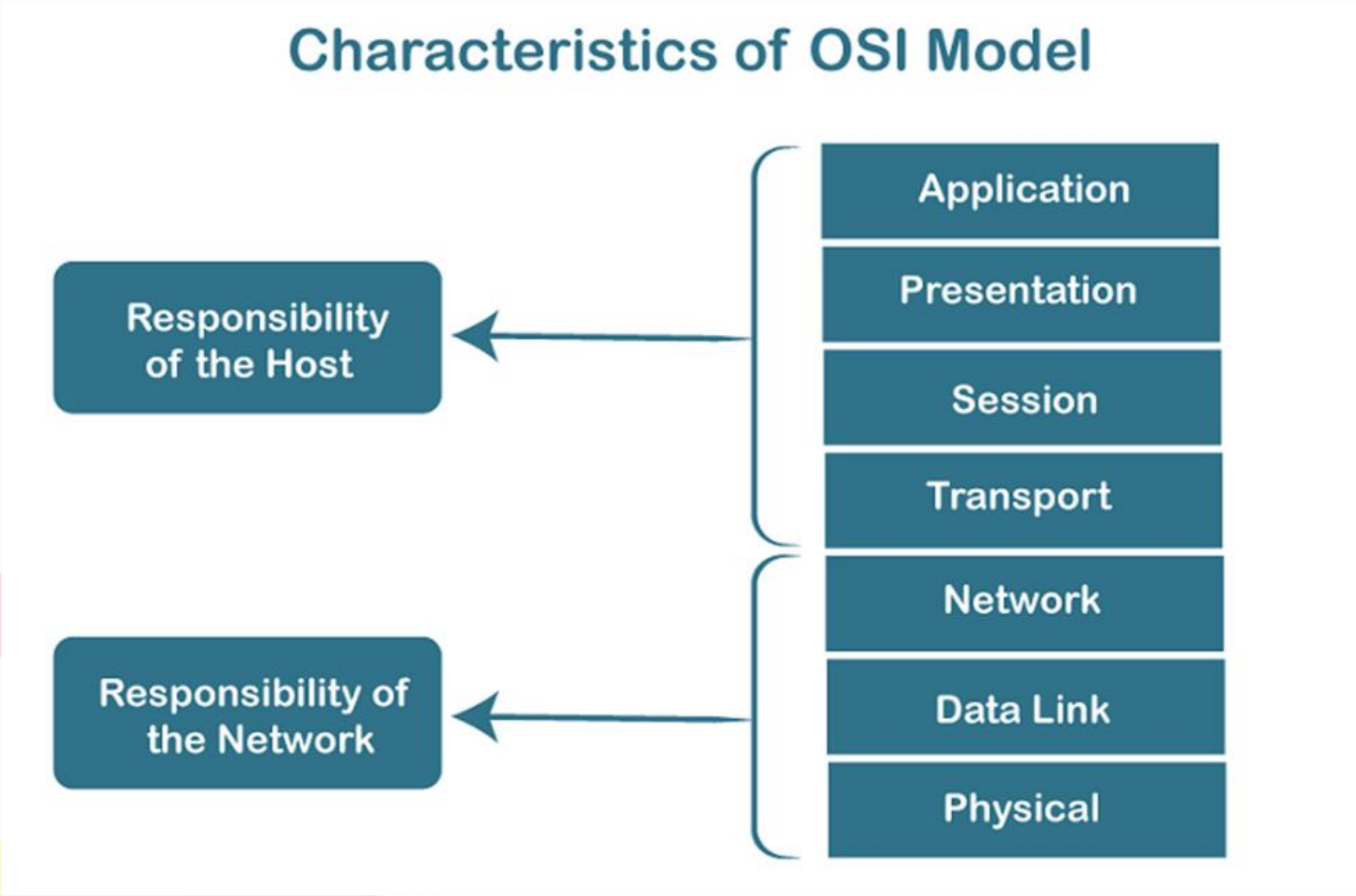
- OSI Open System Interconnection is a reference model that describes how information from a software application in one computer moves through a physical medium to the software application in another computer.
- OSI consists of seven layers, and each layer performs a particular network function.
- OSI model was developed by the International Organization for Standardization (ISO) in 1984
- OSI model divides the whole task into seven smaller and manageable tasks.
- Each layer is assigned a particular task.

OSI Reference Model

- Define rules for:
  - How network devices communicate
  - Methods used to determine when to send data
  - Methods to ensure that data is received correctly
  - How the network is cabled
  - How the network maintains the flow of data
  - How bits of data are represented

- https://www.youtube.com/watch?v=Ca1jnqwqzg0

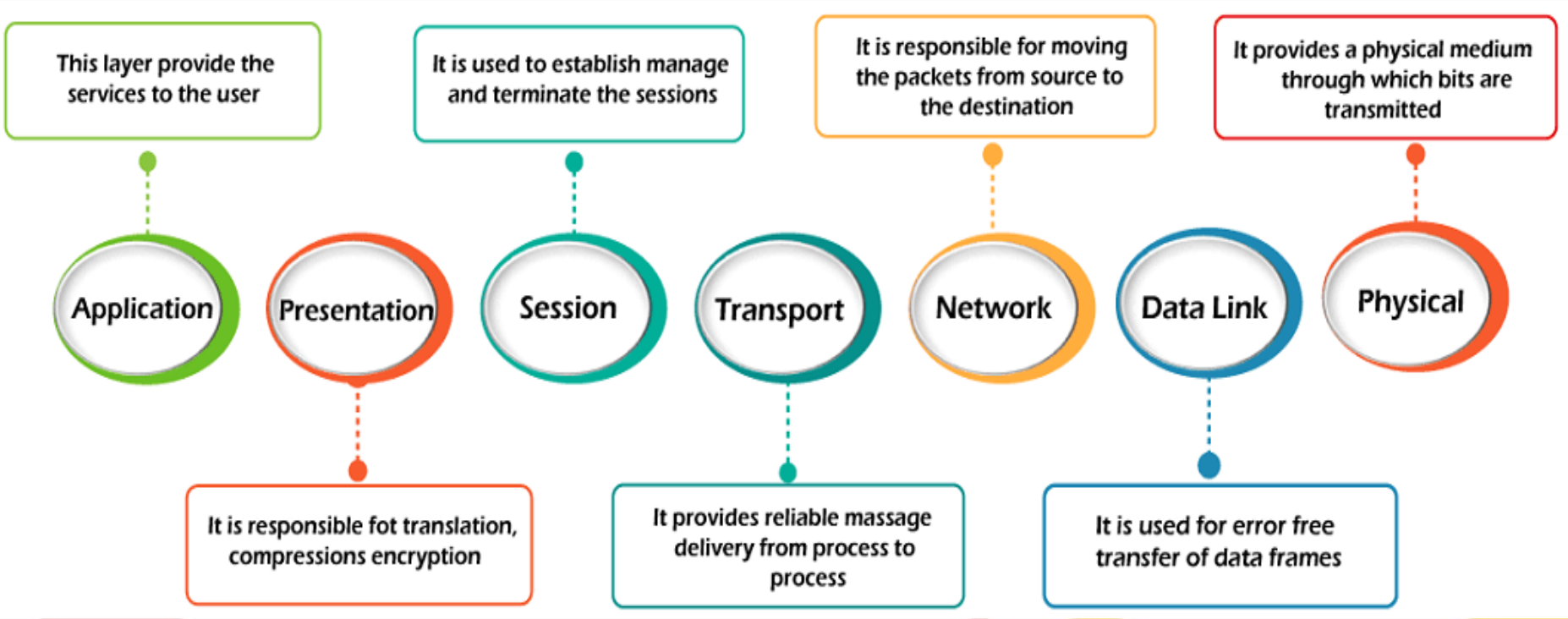
OSI Reference Model



Characteristics of OSI Reference Model

- Layered -Structured Layered Model
- Hierarchical Approach - Lower Layer serves upper Laye
- Abstraction- hide individual layer processes
- Standardization- clear Boundary and interfaces
- Interoperability- Diff h/w and s/w with common protocol can communicate
- Encaspulation- Each layer hide internal details
- Independence- Each Layers are independent
- Ease of Troubleshooting
- Flexibility and Scalability

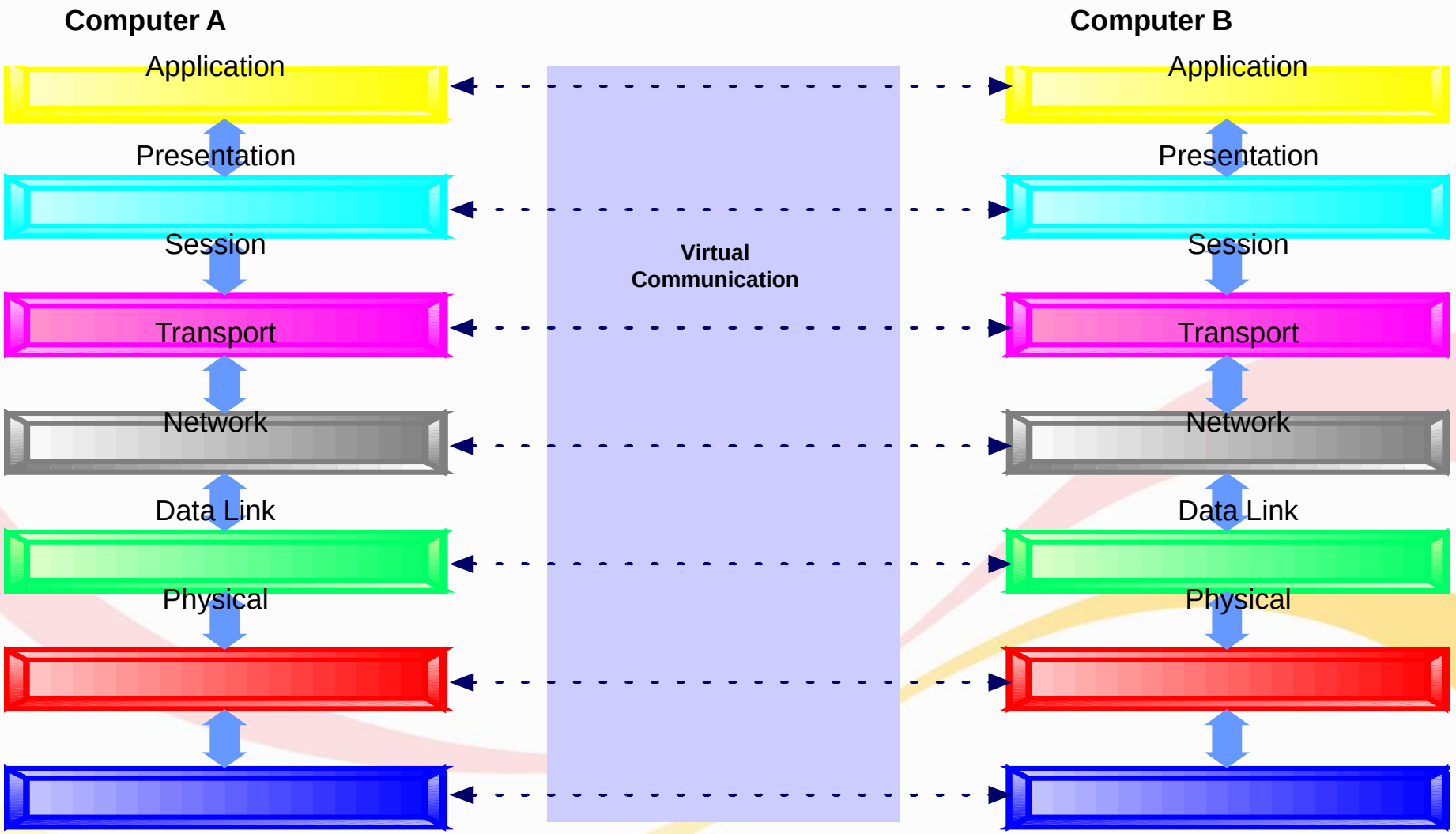
Layers of OSI Model



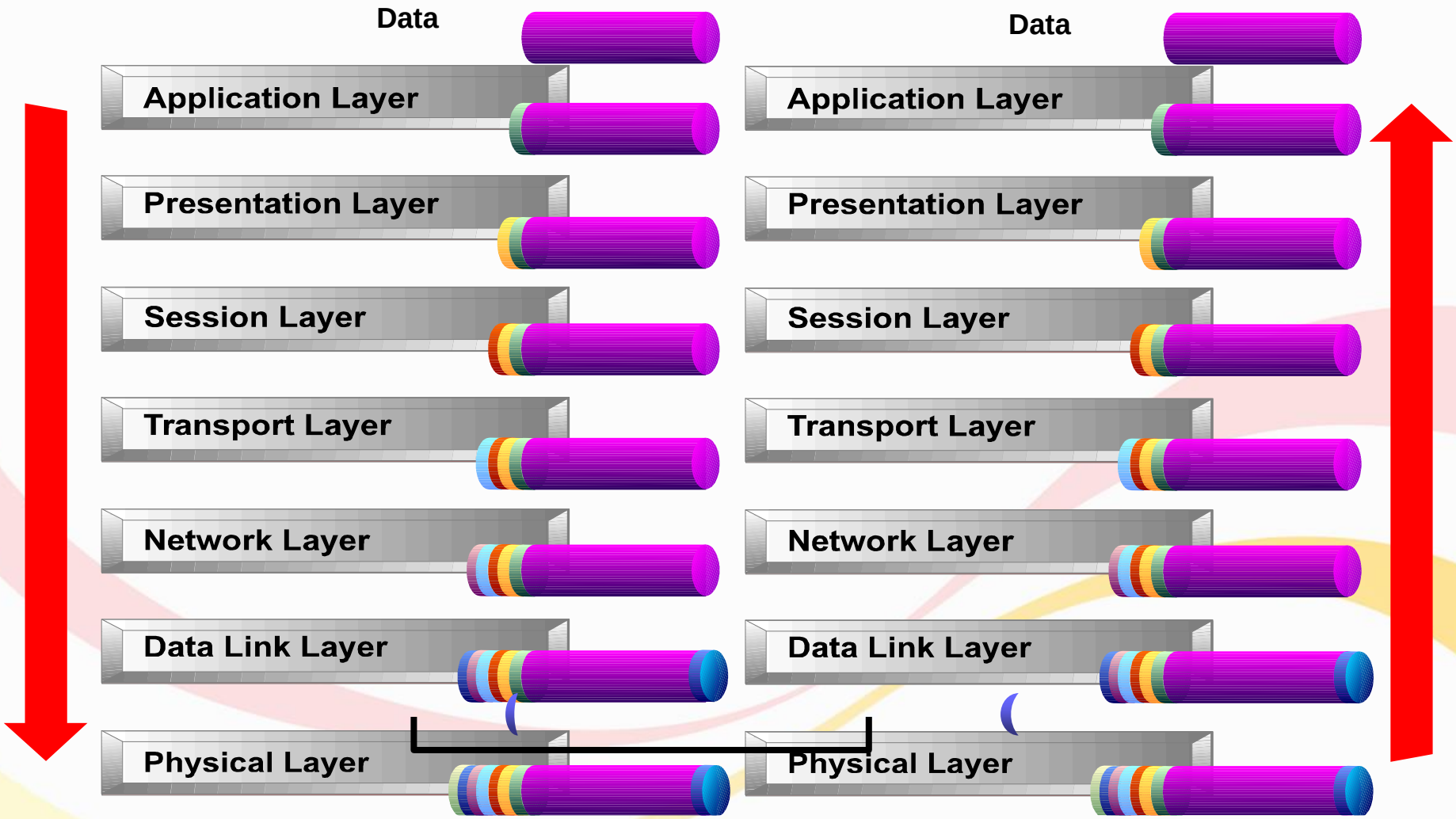
Relationship of OSI Layers

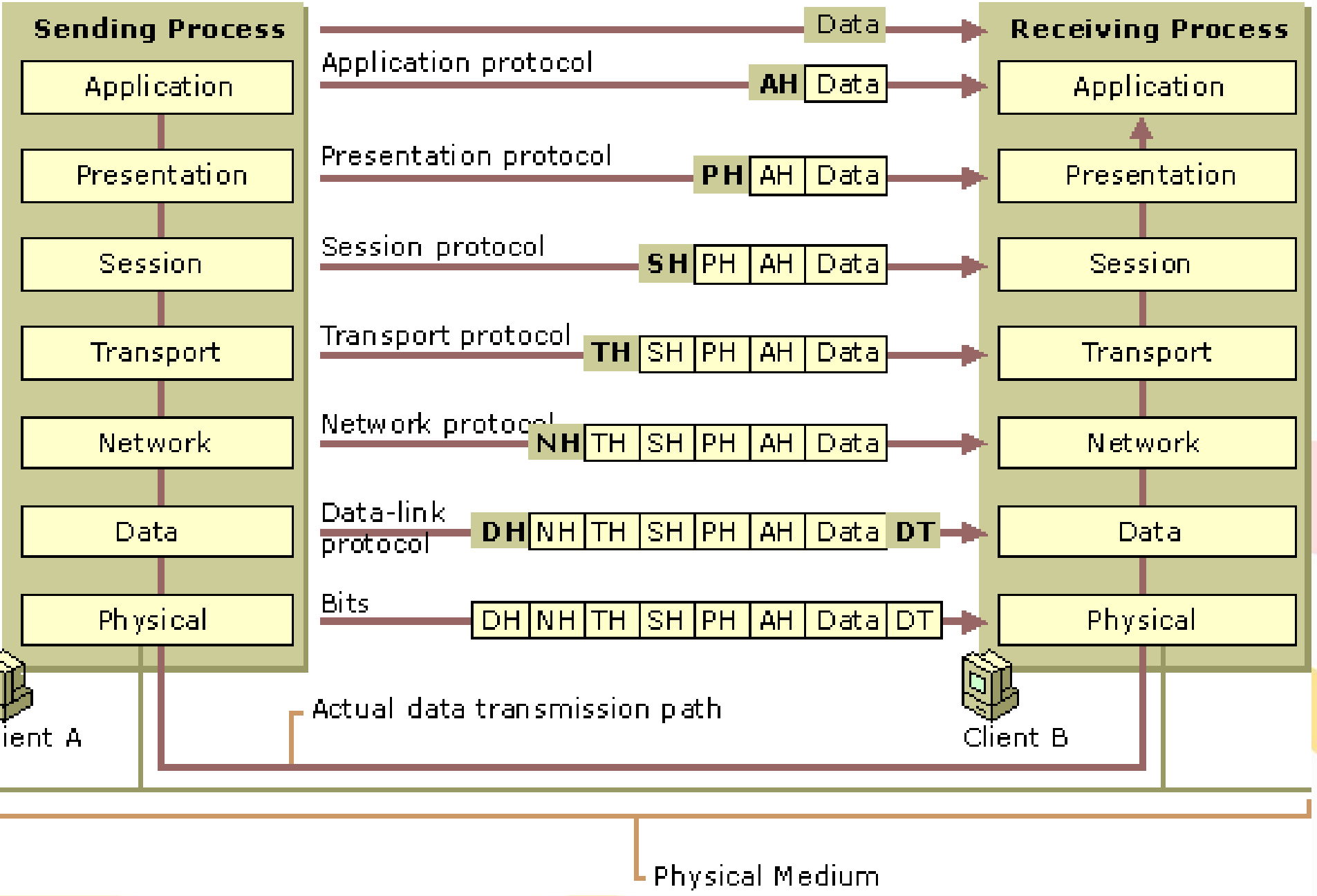
- Each layer of the OSI model must communicate with the layer above and below it
  - For example, the Presentation layer must communicate with the Application layer (one above) and the Session layer (one below)
- As data passes down through the OSI layers, each layer (except Physical) adds some information to the data
- When data reaches the receiving computer, the information added by each layer of the OSI model is read and processed by the corresponding layer on the receiving computer
- This is referred to as peer-layer communications

Relationships among OSI layers

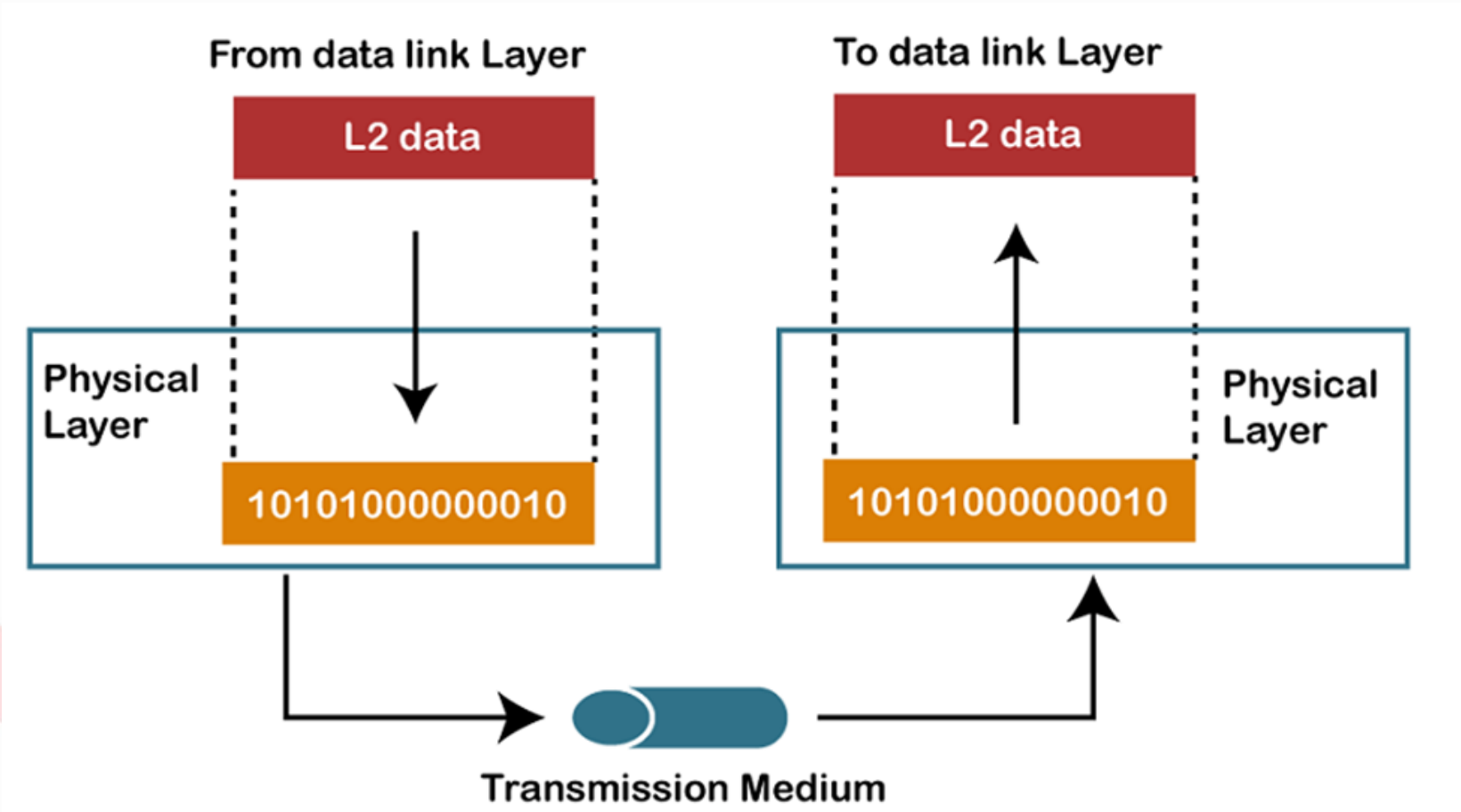


Data Communication between two hosts





Physical Layer

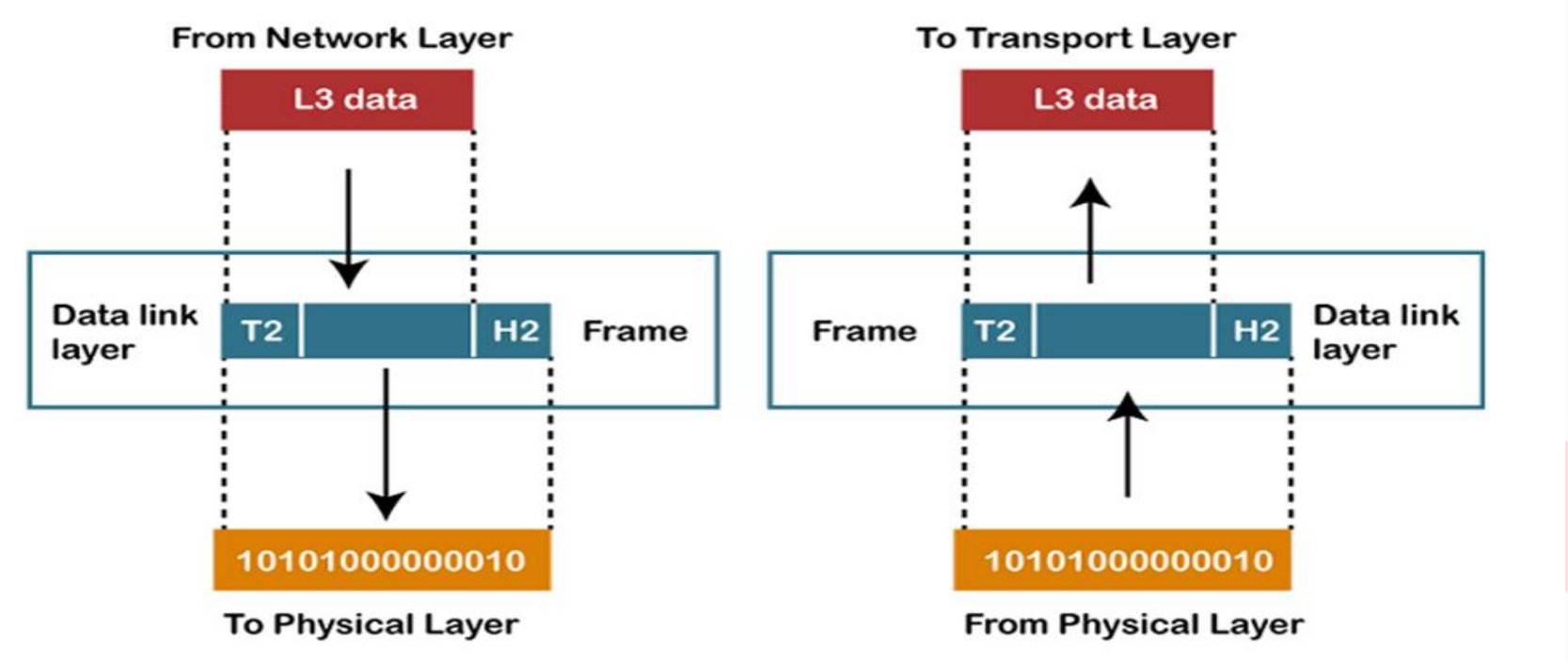


Function of Physical Layer

- **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.

• **Examples:** Ethernet cables, optical fibers, wireless transmission.

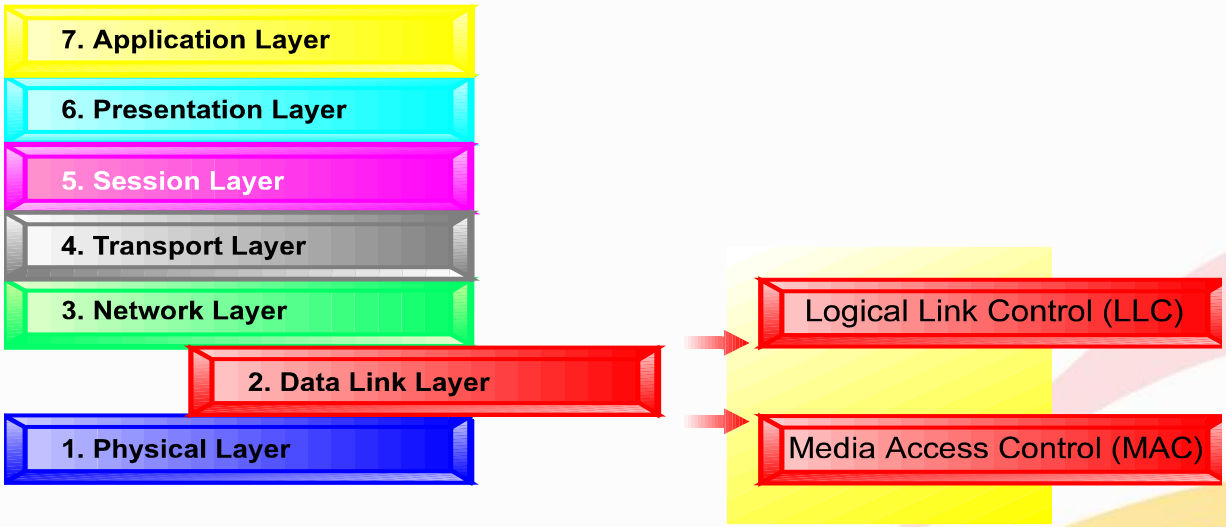
Data Link Layer



- This layer is responsible for the error-free transfer of data frames.
- It provides a reliable and efficient communication
- It is mainly responsible for the unique identification of each device

Data Link Layer {Contd..}

- Consists of two sub layers



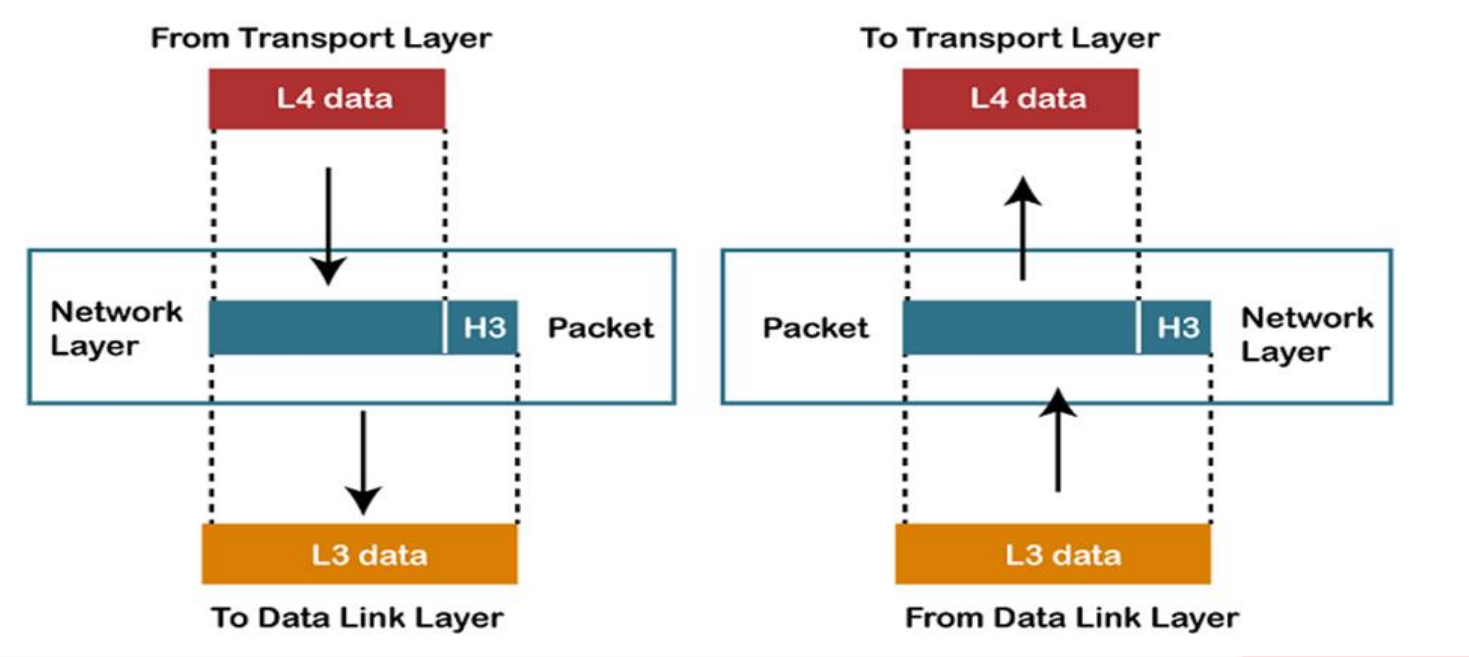
Function of Data Link Layer

- **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:**
  - It ensures that the transmitting station such as a server with higher processing speed does not exceed the receiving station, with lower processing speed.

Function of Data Link Layer

- **Error Control:**
  - Error control is achieved by adding different protocols in Data link layer
  - If any error seems to occurr, 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.
- Examples: Ethernet switches, Wi-Fi access points, MAC addresses.

Network Layer

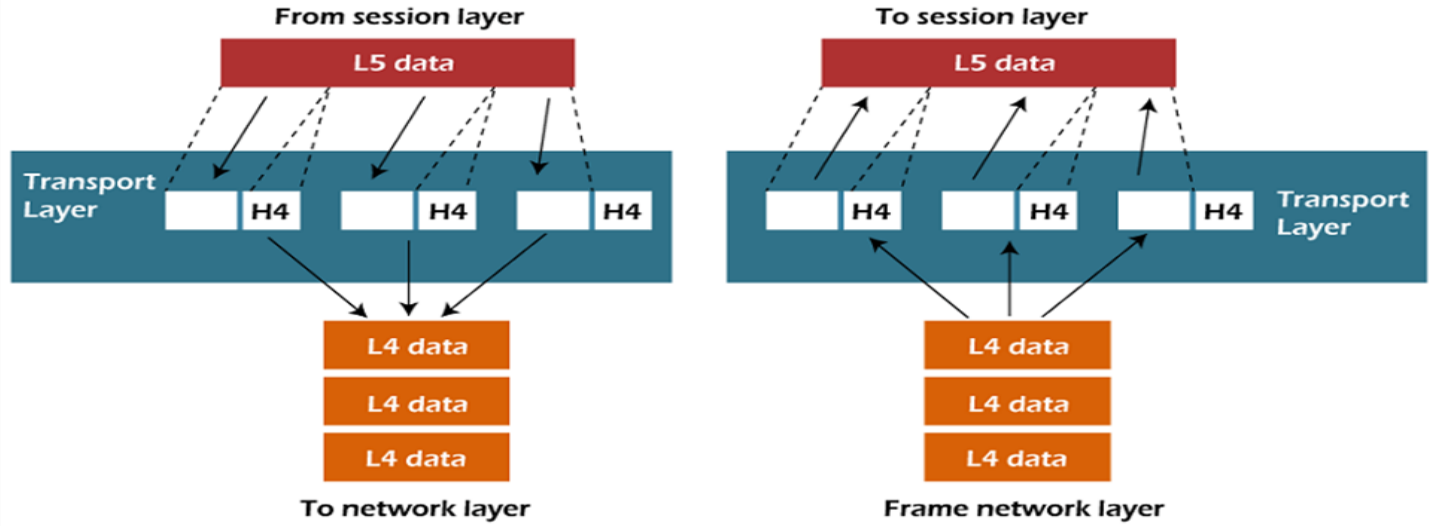


- Manages device addressing, tracks the location of devices on the network.
- Determines the best path to move data from source to the destination
- Routing and forwarding the packets- Routers
- Examples of protocols are IP and Ipv6.

Function of Network Layer

- **Internetworking**: 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.
- Examples: Routers, IP addresses, routing protocols (e.g., OSPF, BGP).

Transport Layer



- The main responsibility of the transport layer is to transfer the data completely.
- Ensures that messages are transmitted in the order in which they are sent and there is no duplication of data.
- 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:**
  - 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.

Functions of Transport Layer:

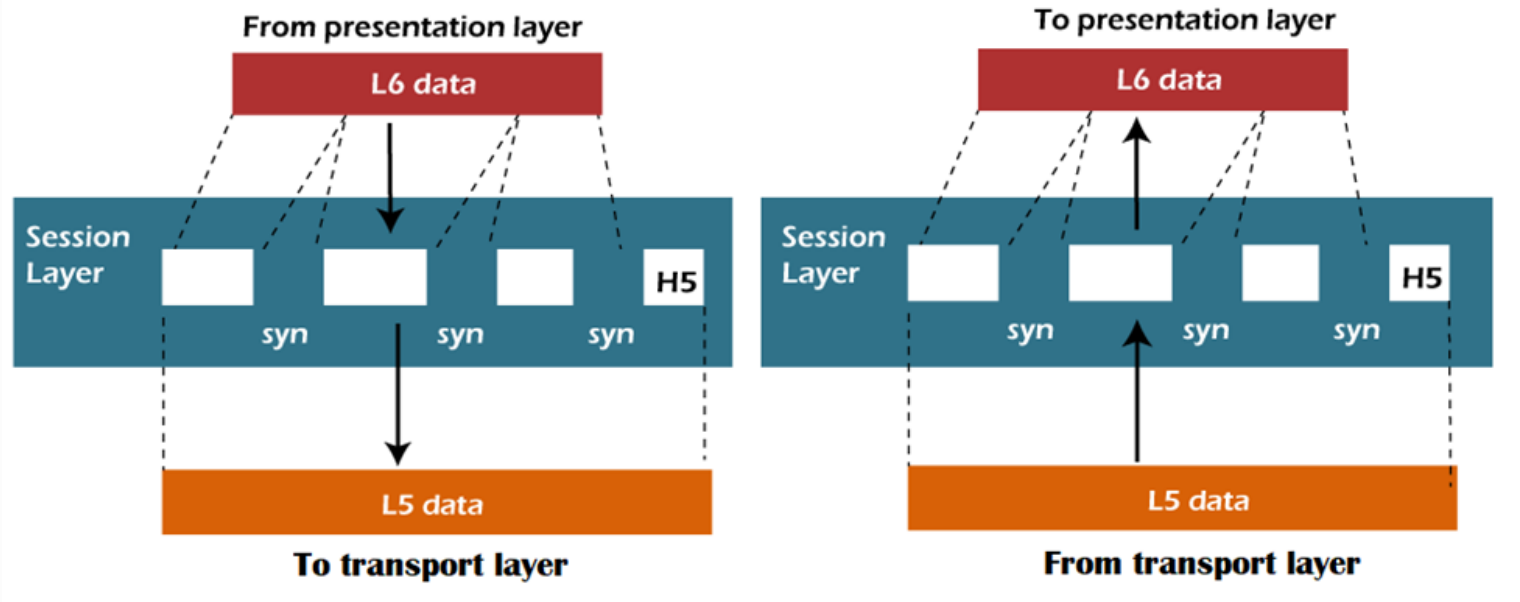
- **Connection control**:
  - Transport layer provides two services **Connection-oriented service and connectionless service.**
  - A connectionless service treats each segment as an individual packet, and they all travel in different routes to reach the destination.
  - A connection-oriented service 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.

Protocols in transport Layer

- TCP and UDP

Will Discuss Later

Session Layer

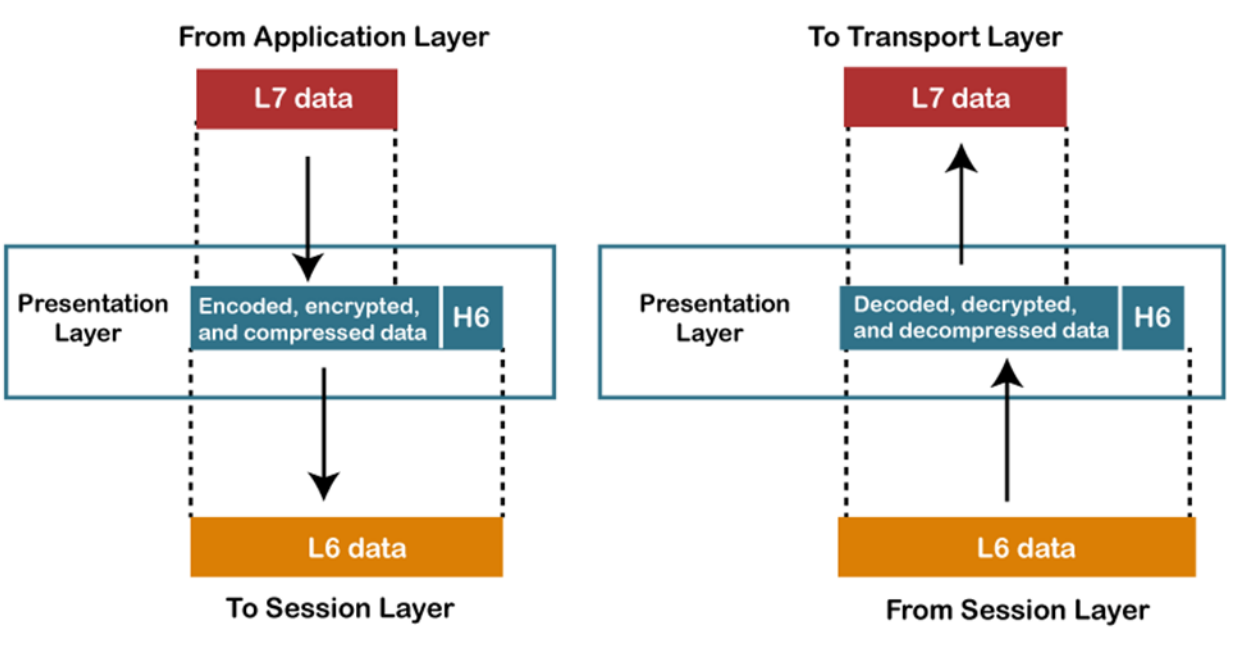


- The Session layer is used to establish, maintain and synchronizes the interaction between communicating devices.

Function of Session Layer

- **Session Establishment:** Establish, maintains and terminates session- Connection between communicating devices
- **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.
- **Authentication**: The process of identification is known as authentication.
- **Authorization**: It grants privileges after authentication of the user.

Presentation Layer

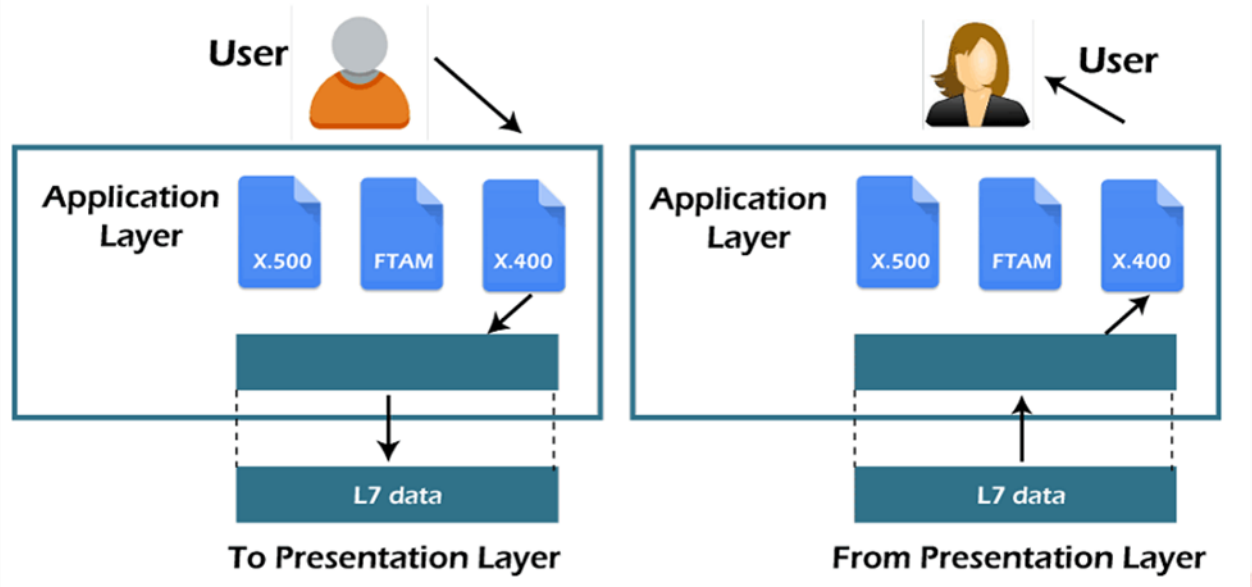


- Presentation layer is mainly concerned with the syntax and semantics of the information exchanged between the two systems.
- It acts as a data translator for a network. It translates data from one form to another.
- converts the data from one presentation format to another format.

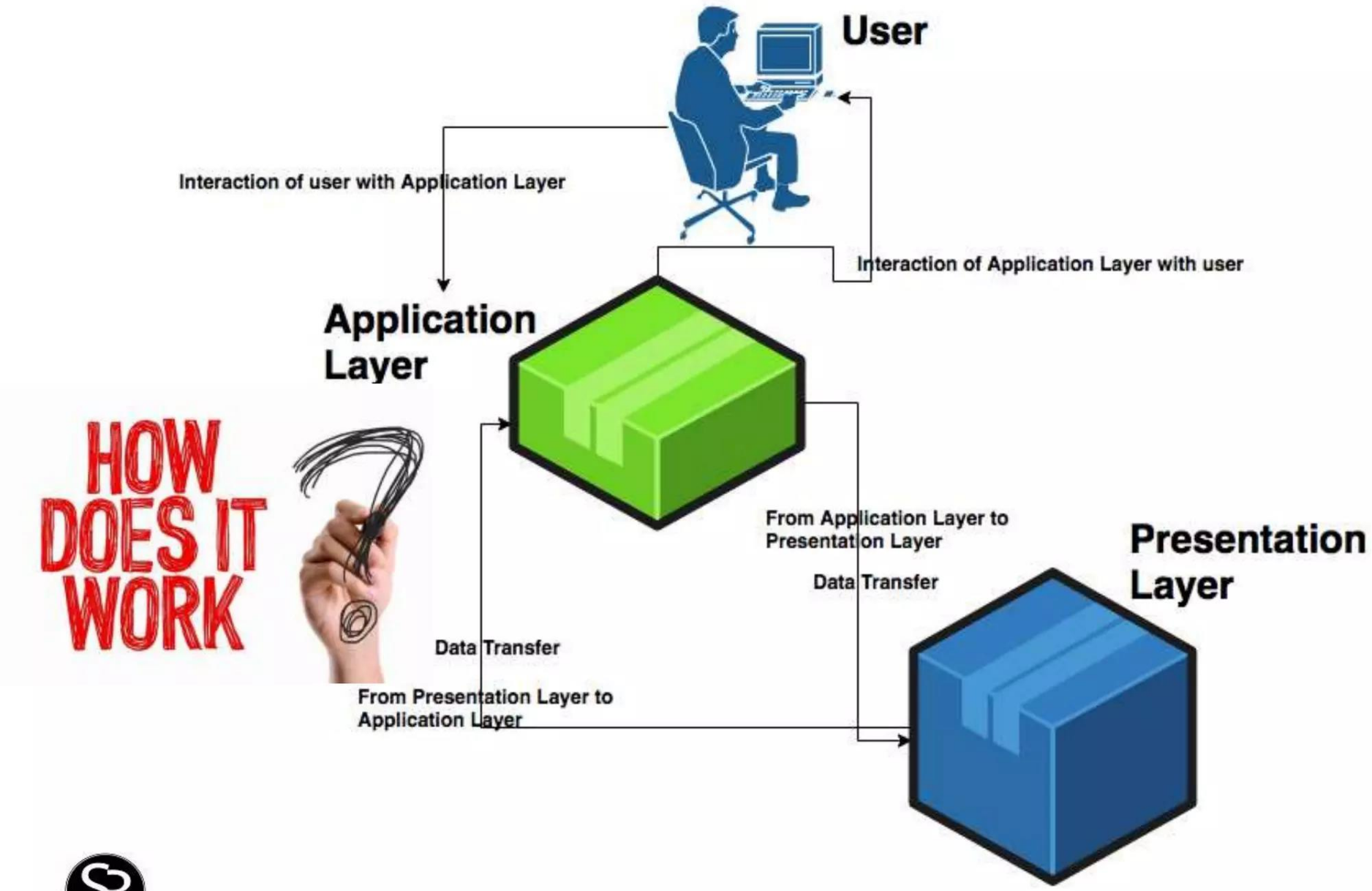
Function of Presentation Layer

- **Translation:** 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.
- This layer provides the network services to the end-users.


User
Interaction of user with Application Layer
Interaction of Application Layer with user
Application Layer
From Application Layer to Presentation Layer
Data Transfer
Presentation Layer
Data Transfer
From Presentation Layer to Application Layer
HOW DOES IT WORK

Function of Application Layer

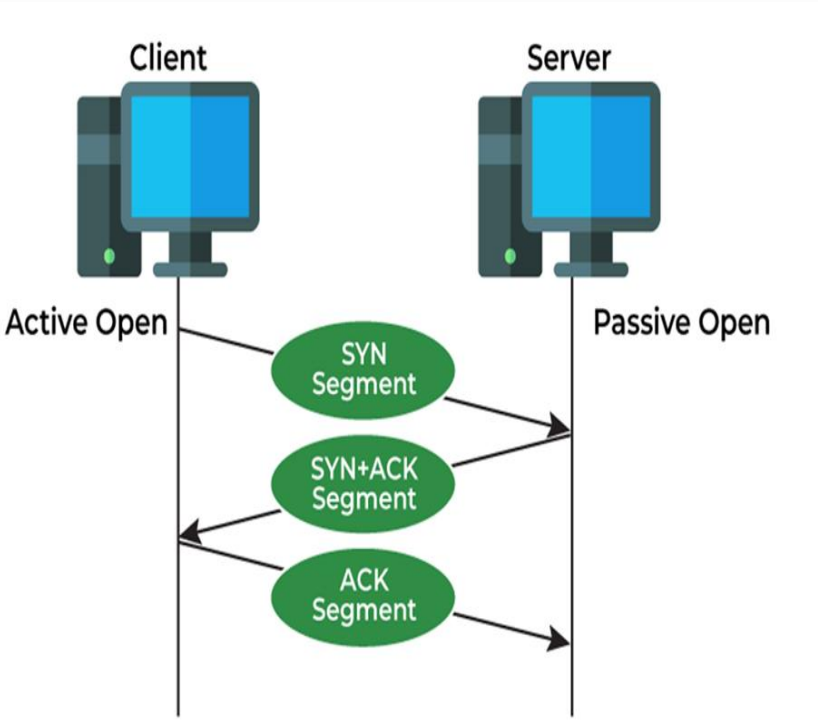
- **File transfer, access, and management (FTAM):** An application layer allows a user to access the files in a remote computer, to retrieve the files from a computer and to manage the files in a remote computer.
- **Mail services**: An application layer provides the facility for email forwarding and storage.
- Remote Host Access
- specifies the availability of resources, i.e., it checks whether adequate network resources are available or not.

TCP vs UDP

- Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) both are protocols of the Transport Layer.
- TCP is a connection-oriented protocol where as UDP is an unreliable and connectionless protocol.

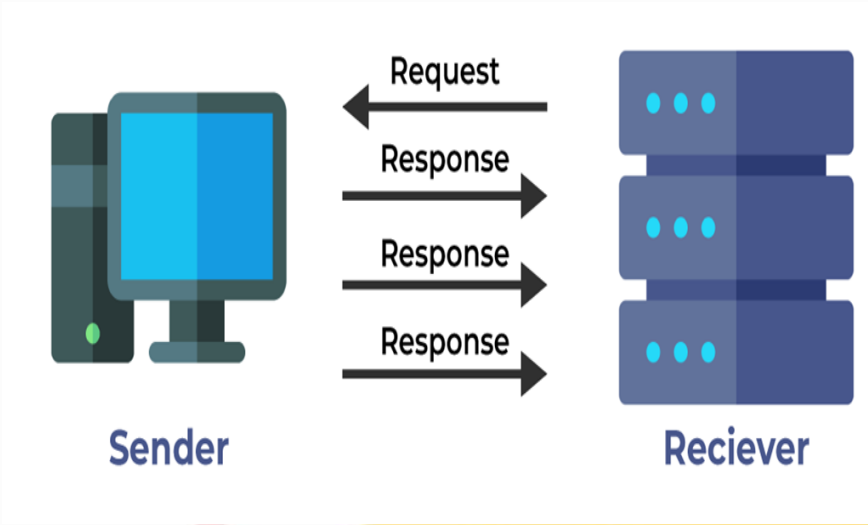
TCP

- connection-oriented protocol for communications that helps in the exchange of messages between different devices over a network
- Establishes connection before data transfer with a three-way handshake process (SYN, SYN-ACK, ACK).



UDP

- UDP is not the connection-oriented protocol.
- There is no overhead for opening a connection, maintaining a connection, or terminating a connection.
- Connectionless. No connection setup required before sending data.



Feature	TCP	UDP
Types of Service	TCP is a connection-oriented protocol..	UDP is not the connection-oriented protocol.
Reliability	Provides reliable, connection-oriented communication.	Provides unreliable, connectionless communication.
Connection Establishment	Establishes connection before data transfer	Connectionless. No connection setup required before sending data.

Feature	TCP	UDP
Flow Control and Congestion Control	Uses flow control and congestion control mechanisms	Does not provide built-in flow control or congestion control.
Error Checking	Provides extensive error checking mechanisms, including checksums and retransmissions, to ensure data integrity.	Has minimal error checking. Includes a checksum for basic error detection, but does not retransmit lost packets.
Order of Delivery	Guarantees the order of delivery for data packets.	Does not guarantee the order of delivery.
Transmission Speed	Slower than UDP.	Offers faster transmission speed compared to TCP.

Feature	TCP	UDP
Usage in Applications	Commonly used for applications where data integrity and reliability are critical, such as downloading files, sending emails, and accessing web pages.	Used in applications that prioritize speed and efficiency, such as streaming media, online gaming, real-time communication, and DNS queries.

Application Layer Protocols:SMTP

- Simple Mail Transfer Protocol - protocol used to organize email.
- With the use of this protocol, data is sent from one email address to another.
- It is accountable for the transmission of email messages over the Internet.
- It is a valid protocol for ensuring the delivery of email messages.
- It also provides security for email transmission by supporting authentication mechanisms.

Application Layer Protocols:HTTP

- Hypertext Transfer Protocol allows users to access Internet data.
- It is accountable for the conversation between the client and the web server.
- When a user requests data, the browser transmits an HTTP request to a server hosting the data.
- The server replies with an HTTP response, which holds the requested data or an error notification if the data is not found or cannot be accessed.

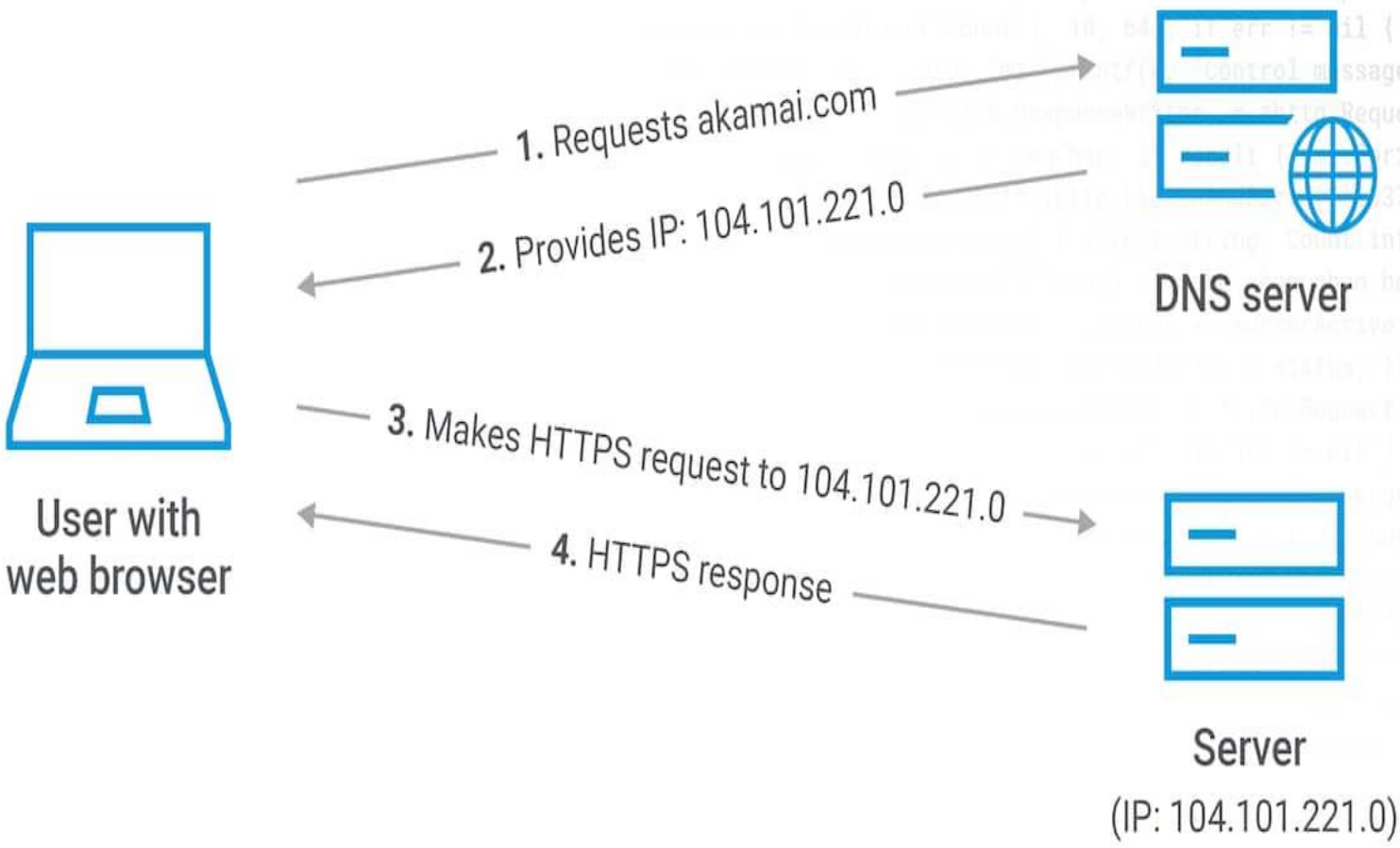
Application Layer Protocols:FTP

- File Transfer Protocol is used to send files between server and client using the internet.
- It uses a client-server model, where the client requests a file, and the server responds with the requested file.

Application Layer Protocols:DNS

- translates human-readable domain names into IP addresses so that web browsers can comprehend what a user desires to access on the Internet.

- **2a03:2880:f103:83:face:b00c:0:25de**
- **31.13.66.35**


1. Requests akamai.com
2. Provides IP: 104.101.221.0
DNS server
3. Makes HTTPS request to 104.101.221.0
4. HTTPS response
User with web browser
Server
(IP: 104.101.221.0)

Application Layer Protocols:TELNET

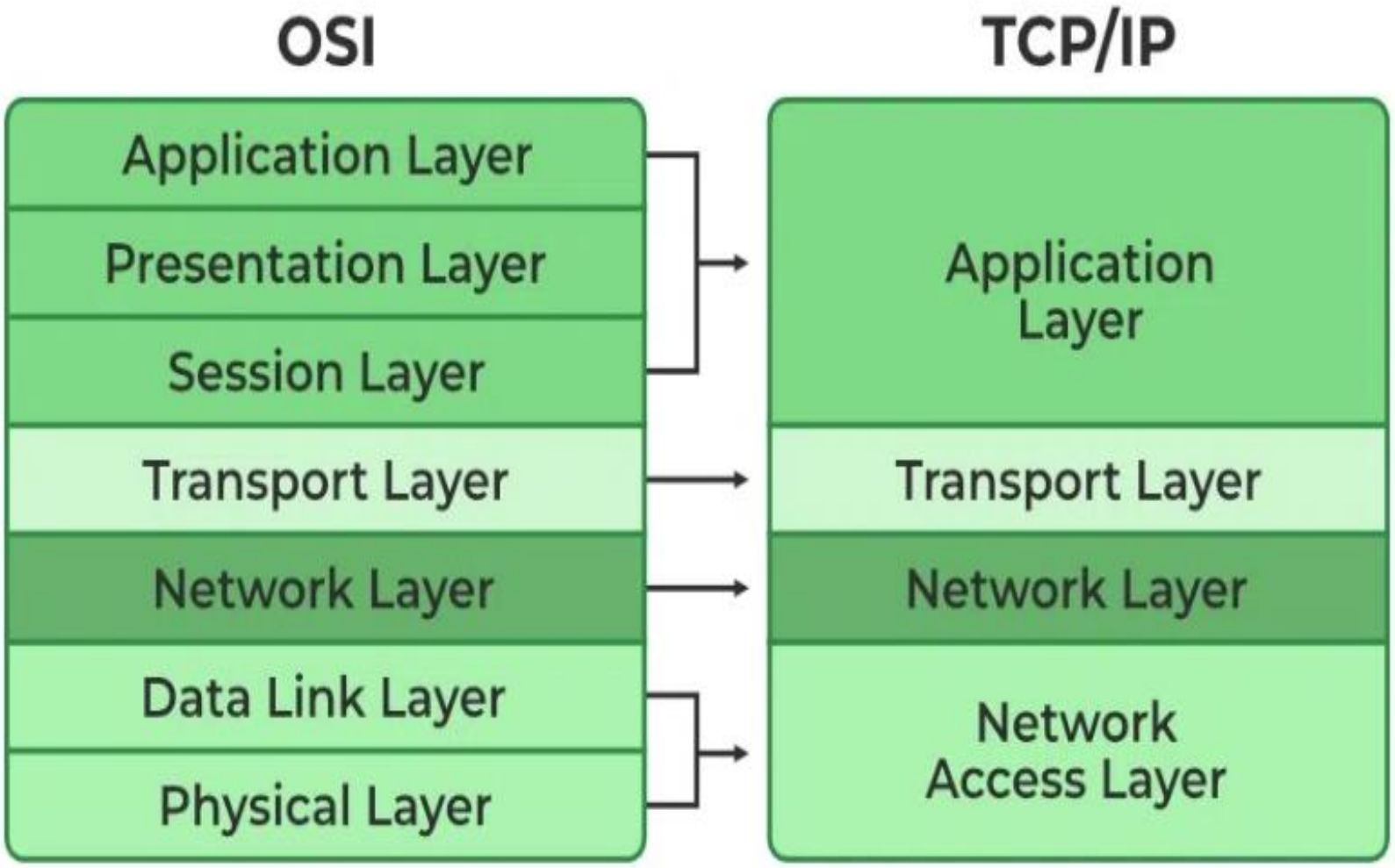
- telecommunication network that delivers remote access to a network appliance.
- **Remote Access Protocol**

TCP/IP

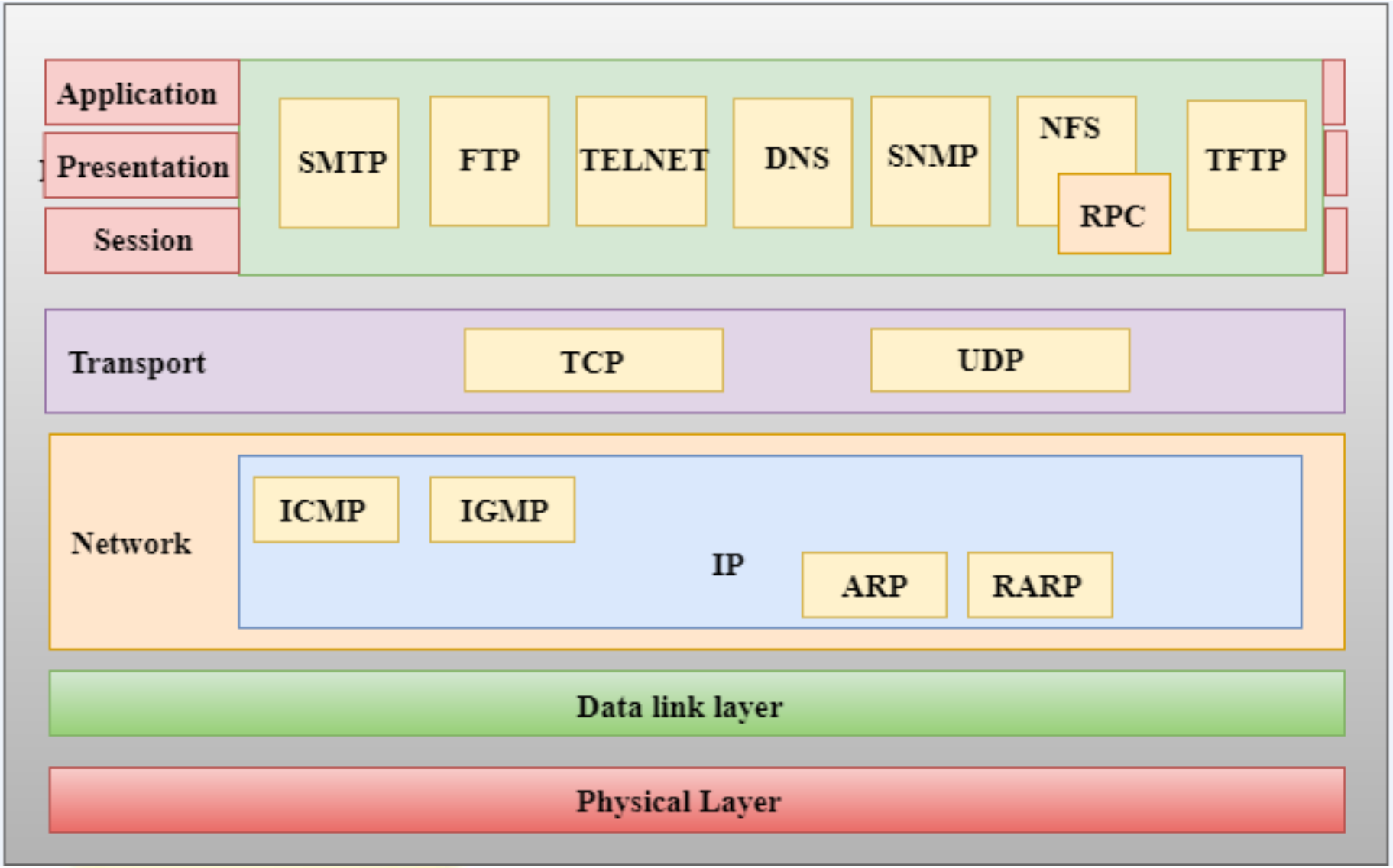
- Transmission Control Protocol/Internet Protocol
- Designed and developed by the Department of Defense (DoD) in the 1960s
- The number of layers is sometimes referred to as five or four.
- **Layers of TCP/IP Model**

1. Application Layer
2. Transport Layer(TCP/UDP)
3. Network/Internet Layer(IP)
4. Data Link Layer
5. Physical Layer

TCP/IP


OSI
TCP/IP
Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer
Application Layer
Transport Layer
Network Layer
Network Access Layer

TCP/IP Layers



Network Access Layer

- lowest layer of the TCP/IP model.
- combination of the Physical layer and Data Link layer
- The Major functions carried out by this layer are
  - transmission of the data
  - defines how the data should be sent physically through the network
  - encapsulating the IP datagram into frames transmitted by the network
  - mapping of IP addresses into physical addresses.
- The protocols used by this layer are ethernet, token ring, FDDI, X.25, frame relay.

Internet Layer

- An internet layer is the second layer of the TCP/IP model.
- also known as the network layer.
- The main responsibility of the internet layer is to send the packets from source to the destination irrespective of the route they take.

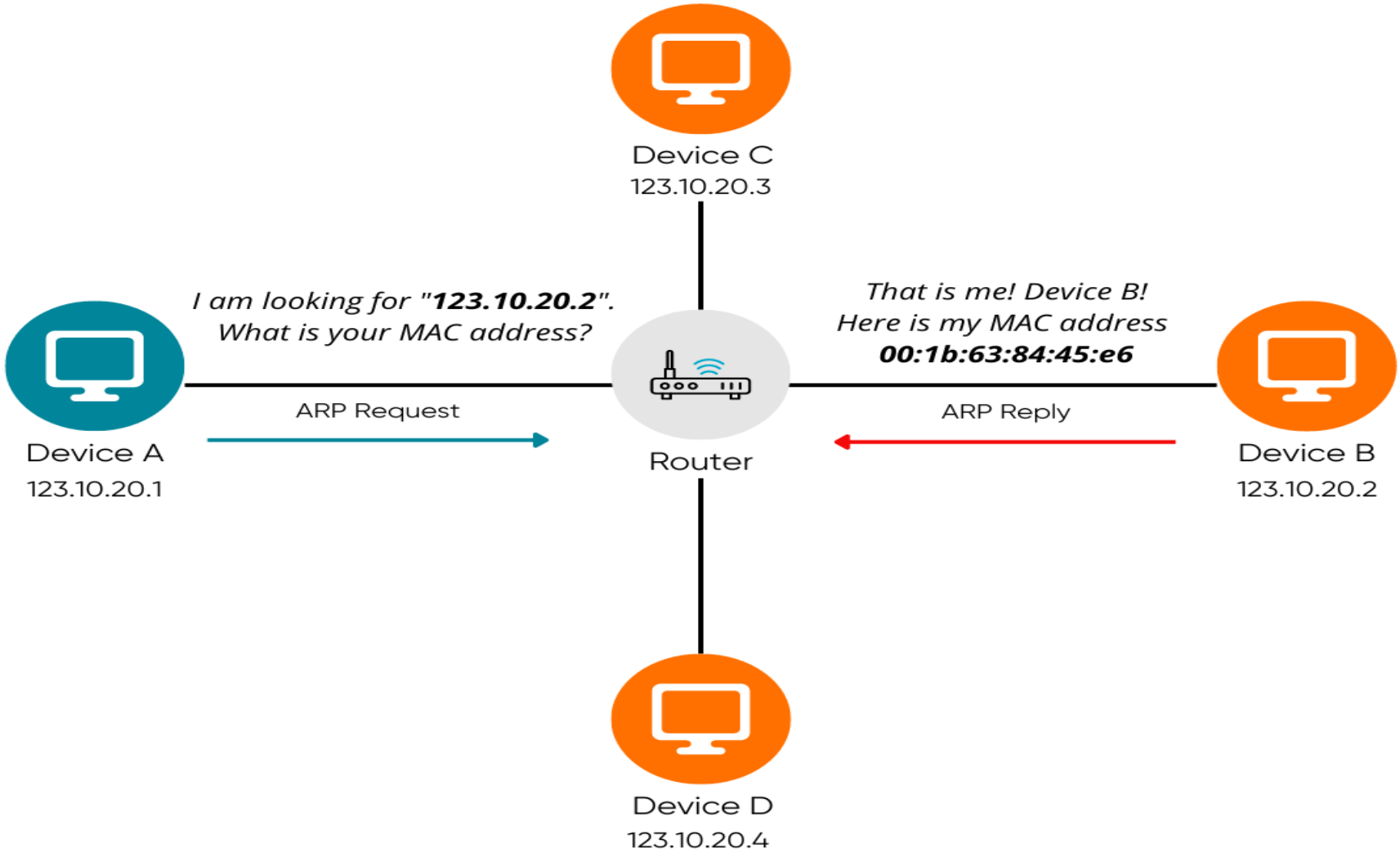
IP Protocol

- Most significant protocol of Internet layer
- Major Responsibilities
  - IP Addressing- Logical Addressing
  - Host to host communication – Find Best Path
  - Data Encapsulation- via IP datagram
  - Fragmentation and Reassembly
    - If Datagram > MTU it Fragments the data
  - Routing

ARP Protocol

- Address Resolution Protocol.
- ARP is a network layer protocol
  - used to find the physical address from the IP address.
- **ARP request**: When a sender wants to know the physical address of the device, it broadcasts the ARP request to the network.
- **ARP reply**: Every device attached to the network will accept the ARP request and process the request, but only recipient recognize the IP address and sends back its physical address in the form of ARP reply. The recipient adds the physical address both to its cache memory and to the datagram header

How Does ARP Work?



ClouDNS

ICMP Protocol

- Internet Control Message Protocol
- A datagram travels from router-to-router until it reaches its destination.
- If a router is unable to route the data because of some unusual conditions such as disabled links, a device is on fire or network congestion, then the ICMP protocol is used to inform the sender that the datagram is undeliverable.
- o The core responsibility of the ICMP protocol is to report the problems

Transport Layer

- The transport layer is responsible for the reliability, flow control, and error control of data which is being sent over the network.
- The two protocols used in the transport layer are User Datagram protocol and Transmission control protocol.

Application Layer

- Topmost Layer of TCP/IP
- Handles function of
  - Session
  - Presentation and
  - Application Layer
- Major Protocols
  - HTTP, SNMP, SMTP, DNS, Telnet, FTP

Tutorial

- Explain Layered Approach in Network Architecture with its significance.
- Explain in detail about OSI Reference Model with major functionality of each layers.
- Differentiate TCP/IP and OSI Reference Model.
- Explain TCP/IP Protocol suite. Differentiate TCP and UDP Protocol.

Review

1. OSI stands for

a) open system interconnection
b) operating system interface
c) optical service implementation
d) none of the mentioned

Review

3. Segmentation and reassembly is the responsibility of

a. 7th Layer
b. 6th Layer
c. 5th Layer
d. 4th layer

Review

7. Which address identifies a process on a host?

a. physical address
b. logical address
c. port address
d. specific address

Review

8. The_____ layer uses data compression yo reduce the number of bits to be transmitted.

a. presentation
b. network
c. data link
d. application

Review

3. Logical Addressing and Routing are functions of which layer?

a) Physical Layer

b) Transport Layer

c) Data Link Layer

d) Network Layer

Review

4. Flow Control and Error Control are functions of which layer?

a) Physical Layer

b) Application Layer

c) Data Link Layer

d) Network Layer

END of UNIT 2

Thank You.