

Computer Networks

Lecture 04

Data encapsulation

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Lecture

04

LEARNING OUTCOMES

- Understand the types of network models.
- Understand the function of each layer in OSI model.
- Differentiate between OSI model and TCP/IP (Internet) model.
- Define data encapsulation.
- Understand how encapsulation takes place.
- Understand how frames switching from source to destination.
- Understand circuit switching.
- Understand packet switching.
- Recognize the difference between circuit and packet switching.
- Understand Internet structure.

What is Network models?

The Network Models are references models for [how applications can communicate over a network](#). There are two common network models, [OSI seven-layer model](#) and [TCP/IP model](#).

OSI Seven-Layer Model:

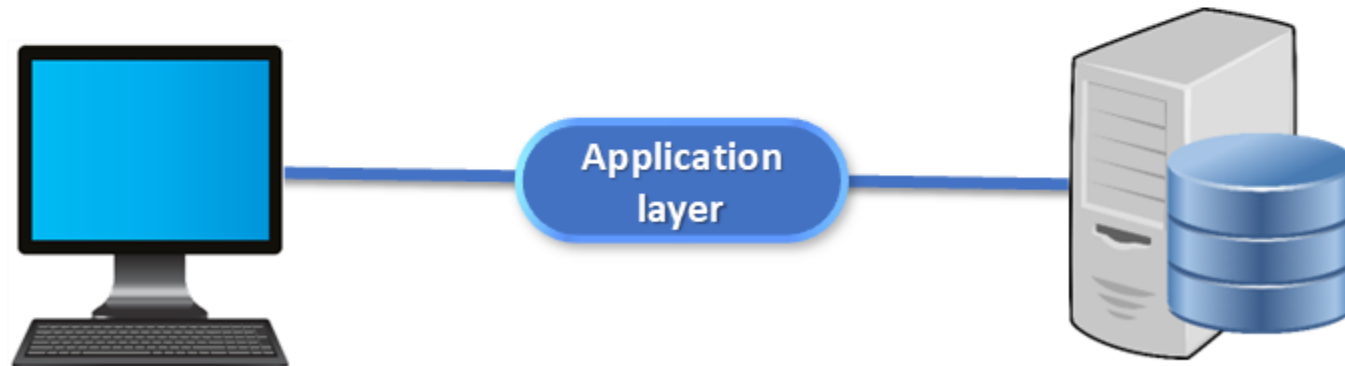
Each layer in the [Open Systems Interconnection model \(OSI\) seven-layer model](#) defines an important function in computer networking, and the protocols that operate at that layer offer solutions to those functions. Discussing the network model starting from layer 7 to layer 1 is called "Top-down approach".

<i>Layer 7</i>	Application
<i>Layer 6</i>	Presentation
<i>Layer 5</i>	Session
<i>Layer 4</i>	Transport
<i>Layer 3</i>	Network
<i>Layer 2</i>	Data Link
<i>Layer 1</i>	Physical

Application Layer

The application layer is the top-most layer in the OSI Model and is used for establishing process-to-process communication and user services in a network. It's **the interface between user applications and the underlying network**.

It's a layer that involves human interaction with applications and software to connect users together across the network.



Application

Presentation

Session

Transport

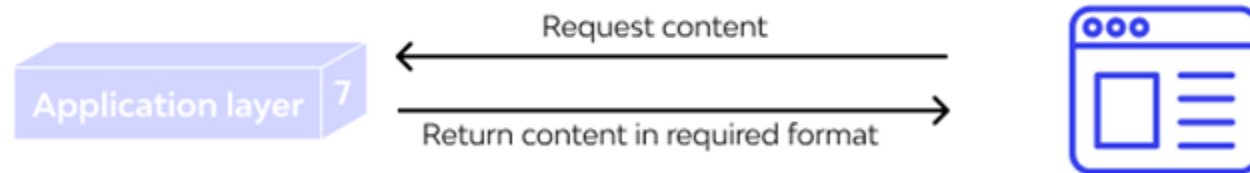
Network

Data-Link

Physical

The application layer is the medium through which the users can communicate with each other, a set of protocols are required to establish such communications.

For example; Opening a web page requires HTTP or HTTPS protocols. Similarly, sending and receiving emails need POP3 or IMAP, and SMTP.



Application

Presentation

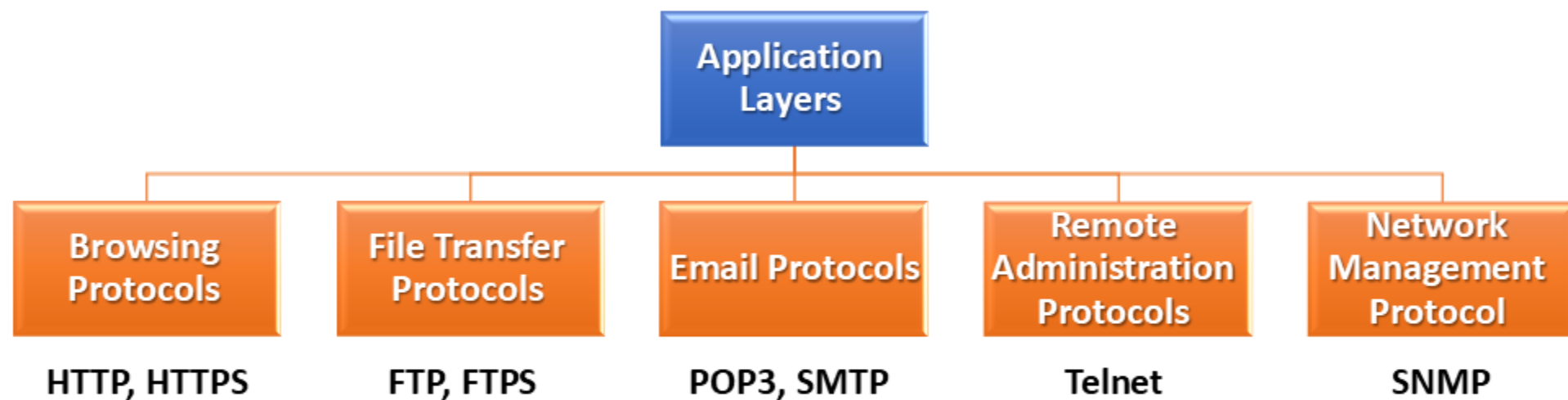
Session

Transport

Network

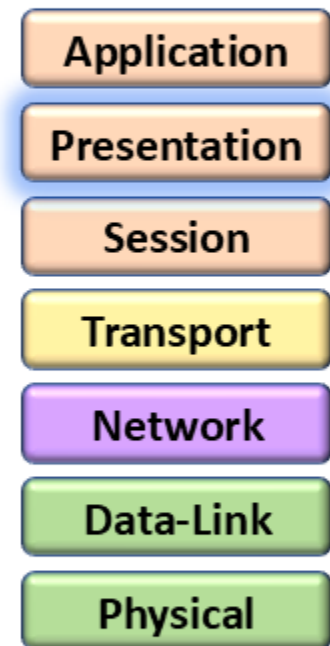
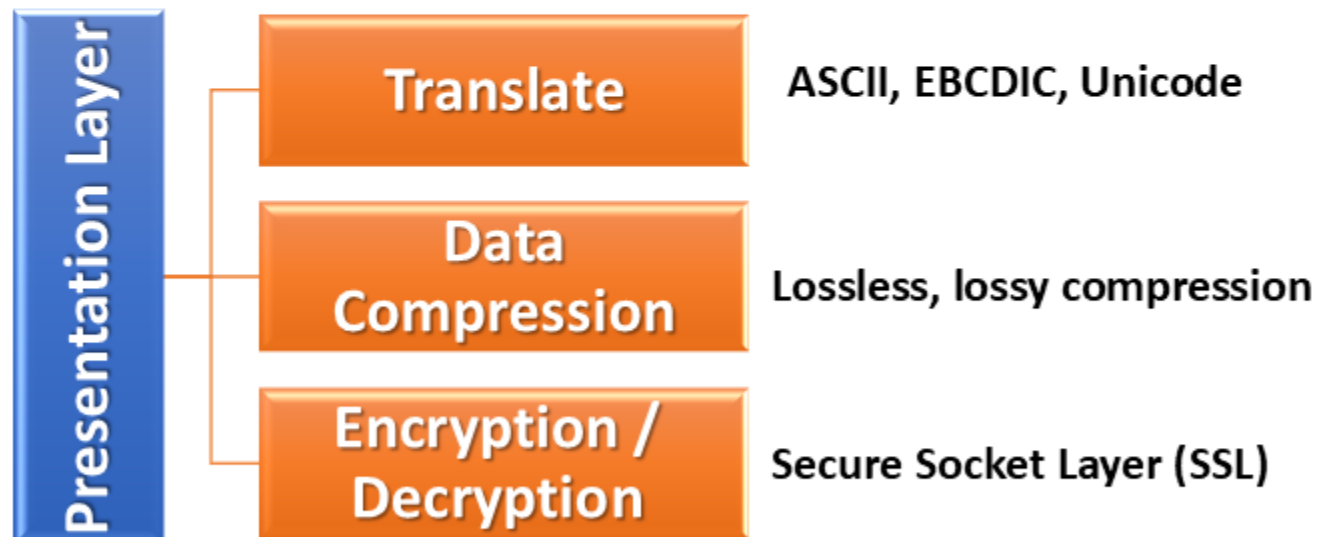
Data-Link

Physical



Presentation Layer

The presentation layer is the 6th layer in the OSI Model and is used for translating, compressing, and encoding data before transmission.



Translation; Before being transmitted, the data remains in the form of characters and numbers. This data must be changed to bitstreams before transmission.

Data compression; reducing the number of bits requiring transmission, which improves the data throughput.

Data Encryption and Decryption; Encryption is needed for security purposes when sending data across networks. An encryption algorithm is used during transmission, while a decryption algorithm is used at the receiving node.

Application

Presentation

Session

Transport

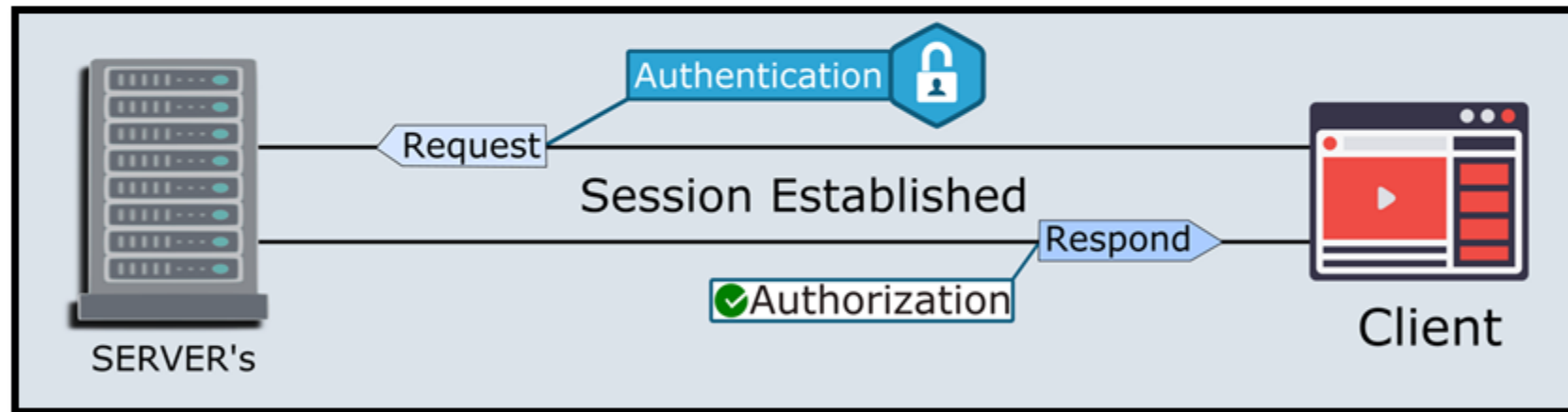
Network

Data-Link

Physical

Session Layer

The session layer is responsible for establishing, managing, authenticating, and terminating communicative sessions.



Application

Presentation

Session

Transport

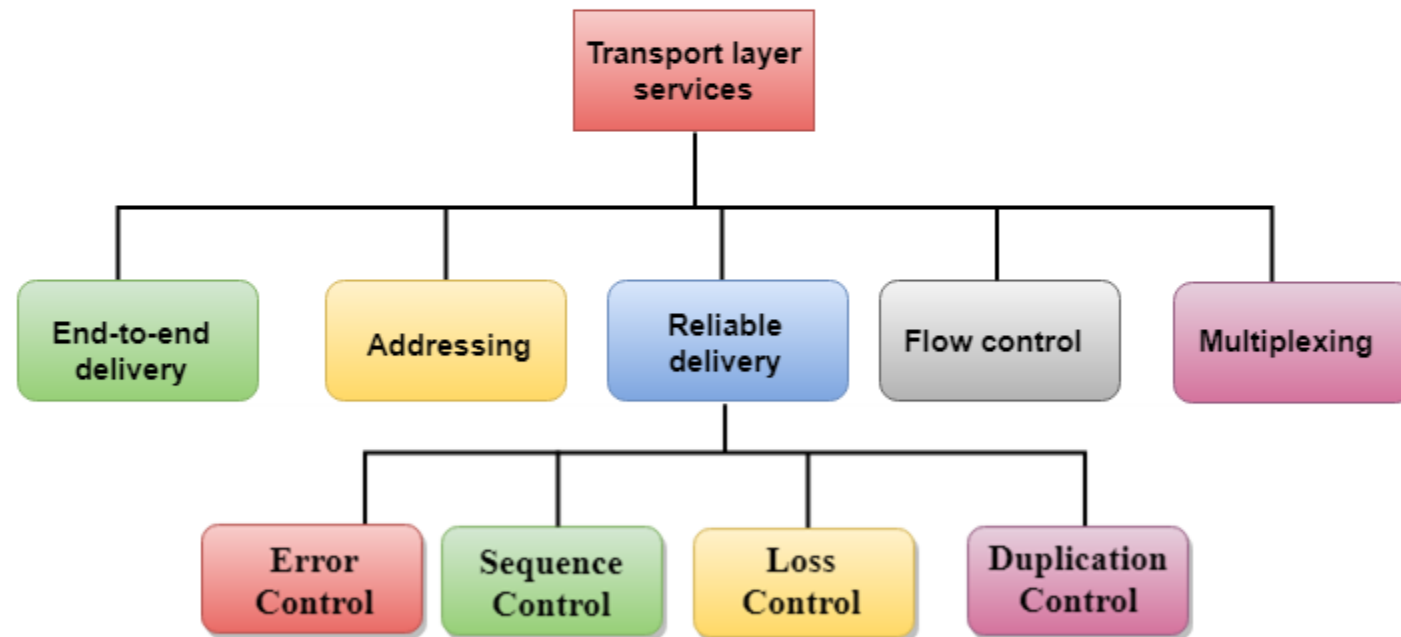
Network

Data-Link

Physical

Transport Layer:

The transport layer provides reliable process-to-process message delivery and error recovery.



Application

Presentation

Session

Transport

Network

Data-Link

Physical

Transport
Layer

Connection Oriented Transmission (TCP)



Ensure that all data are received correctly

UDP (connectionless)



It does not matter if all data is received correctly

Connectionless Transmission (UCP)

End-to-End Delivery

Application

Presentation

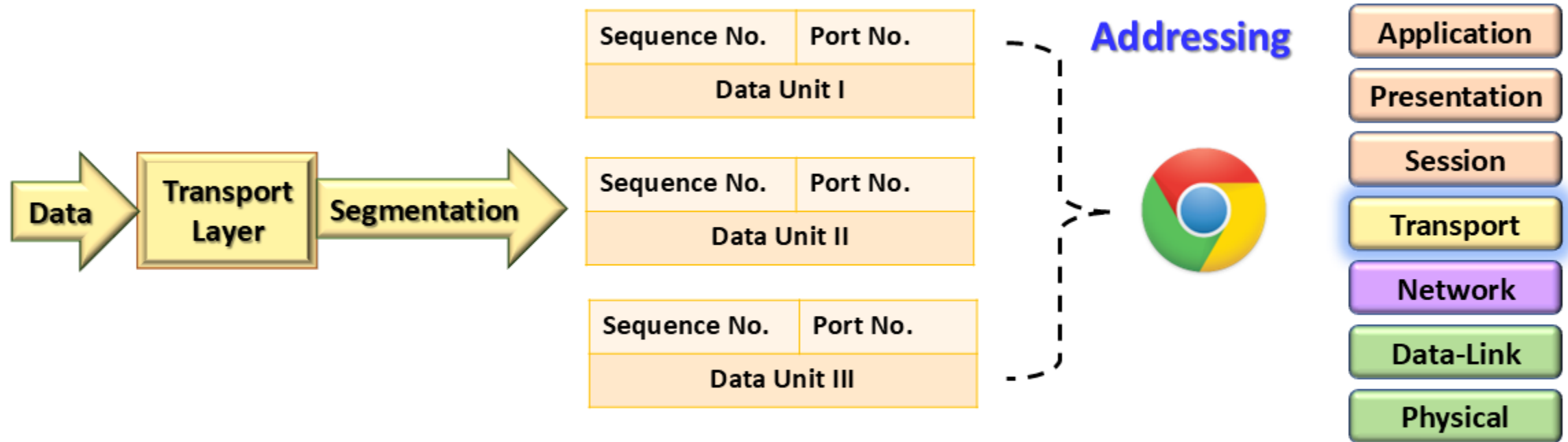
Session

Transport

Network

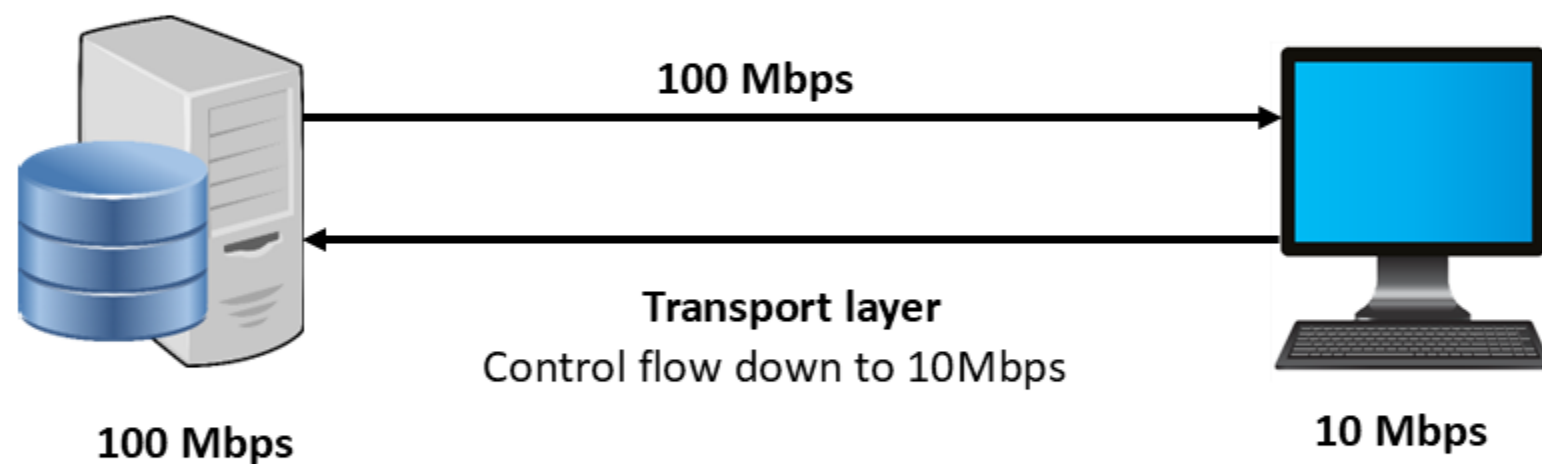
Data-Link

Physical



The **transport layer** breaks up the data into chunks called **segments** (depending on the specific transport protocol used) and gives each segment a **sequence number**.

By reading the sequencing numbers, the receiving system knows both the total number of segments and how to put them back together.



Flow Control

Application

Presentation

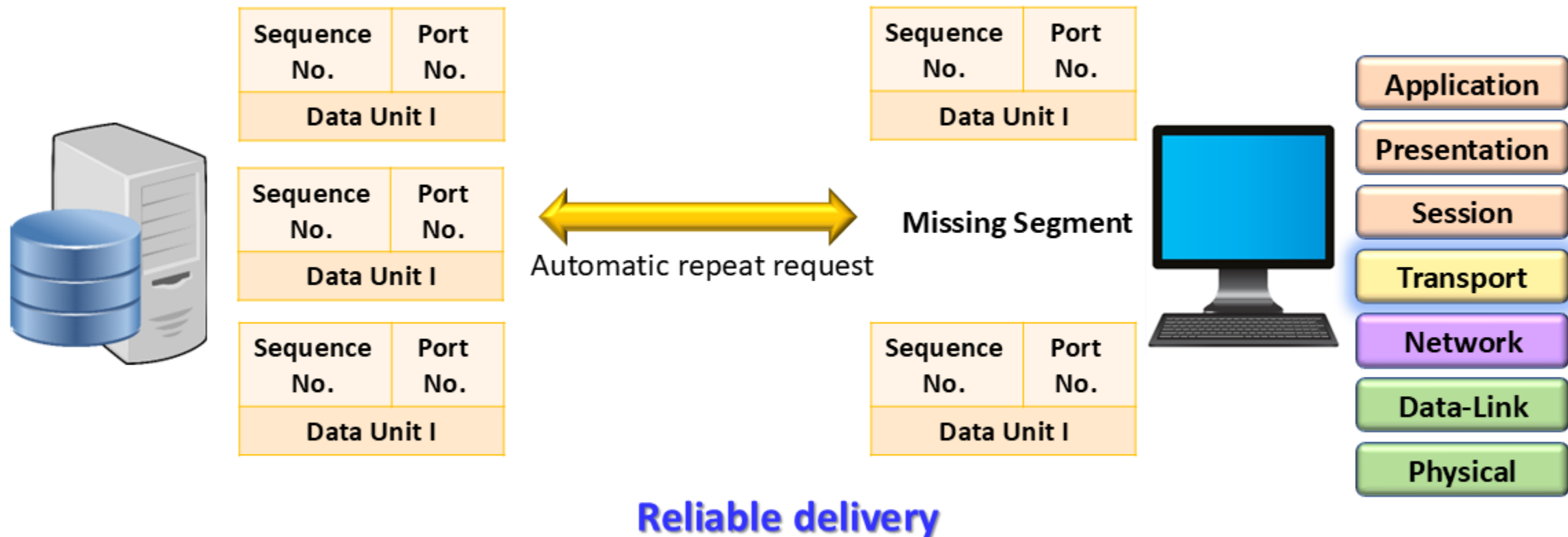
Session

Transport

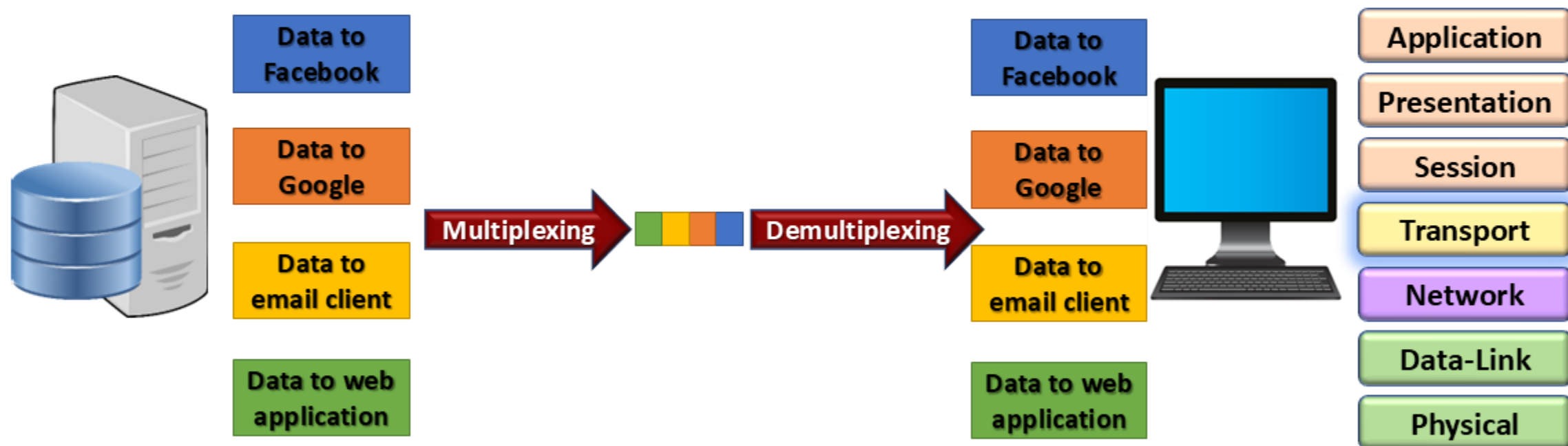
Network

Data-Link

Physical



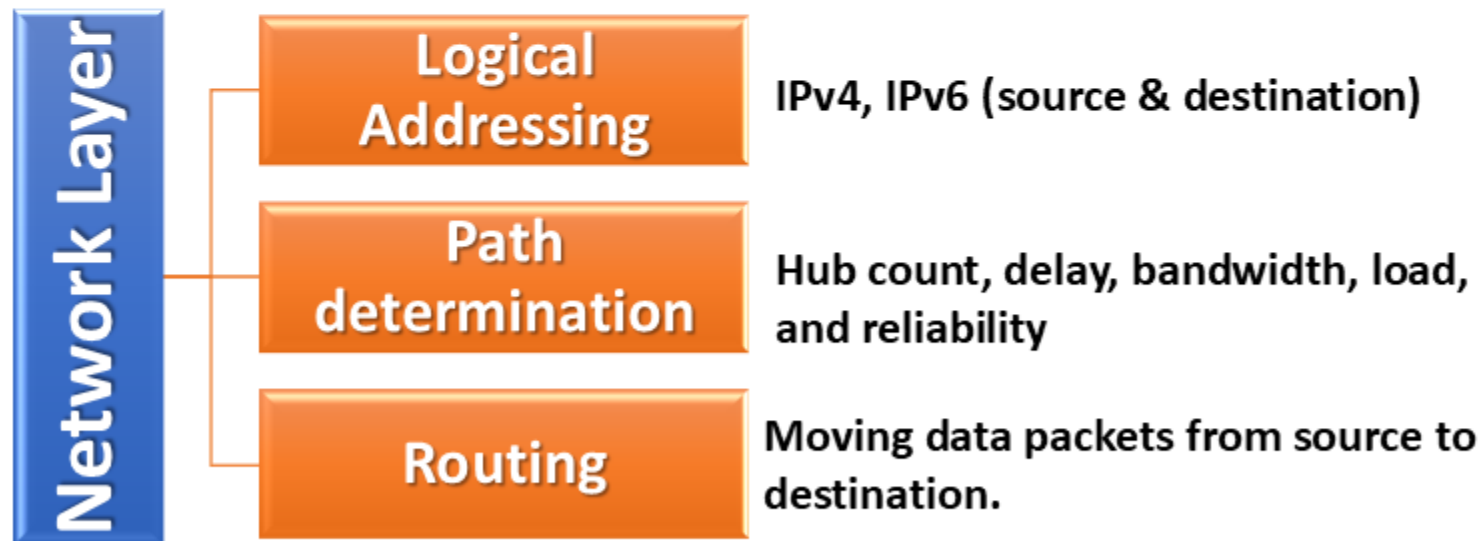
Multiplexing at the Transport Layer, the data is collected from various application processes. These segments contain the source port number, destination port number, header files, and data.



Multiplexing - Demultiplexing

Network Layer:

The network layer performs logical addressing. The network layer divides the segments received from the transport layer into packets and adding a header to the packet which includes the logical addresses (IP Addresses) of both the sender and the receiver.



Application

Presentation

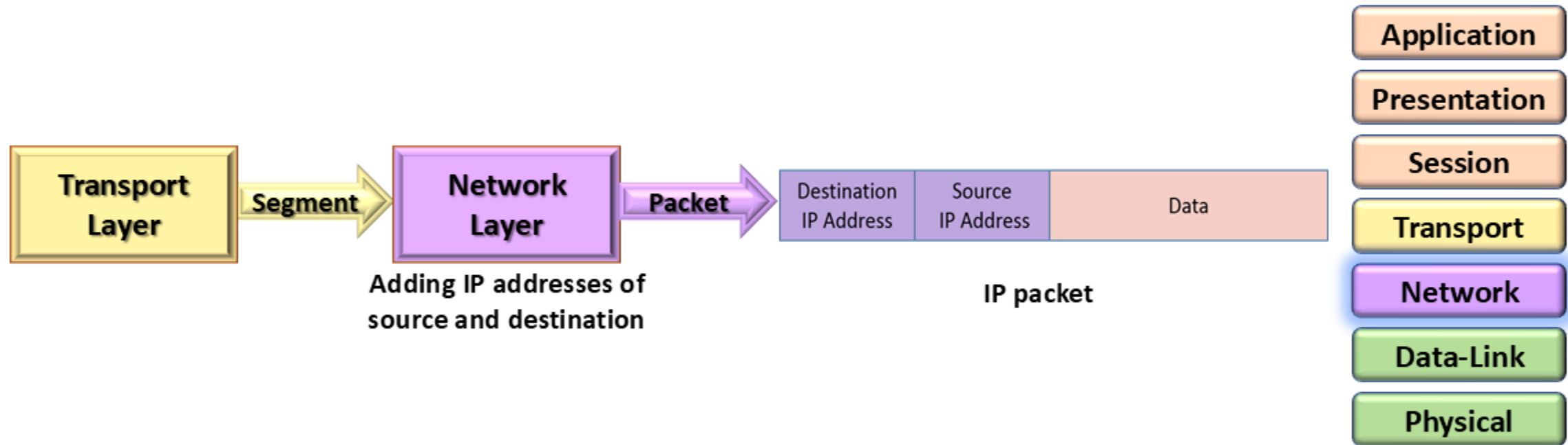
Session

Transport

Network

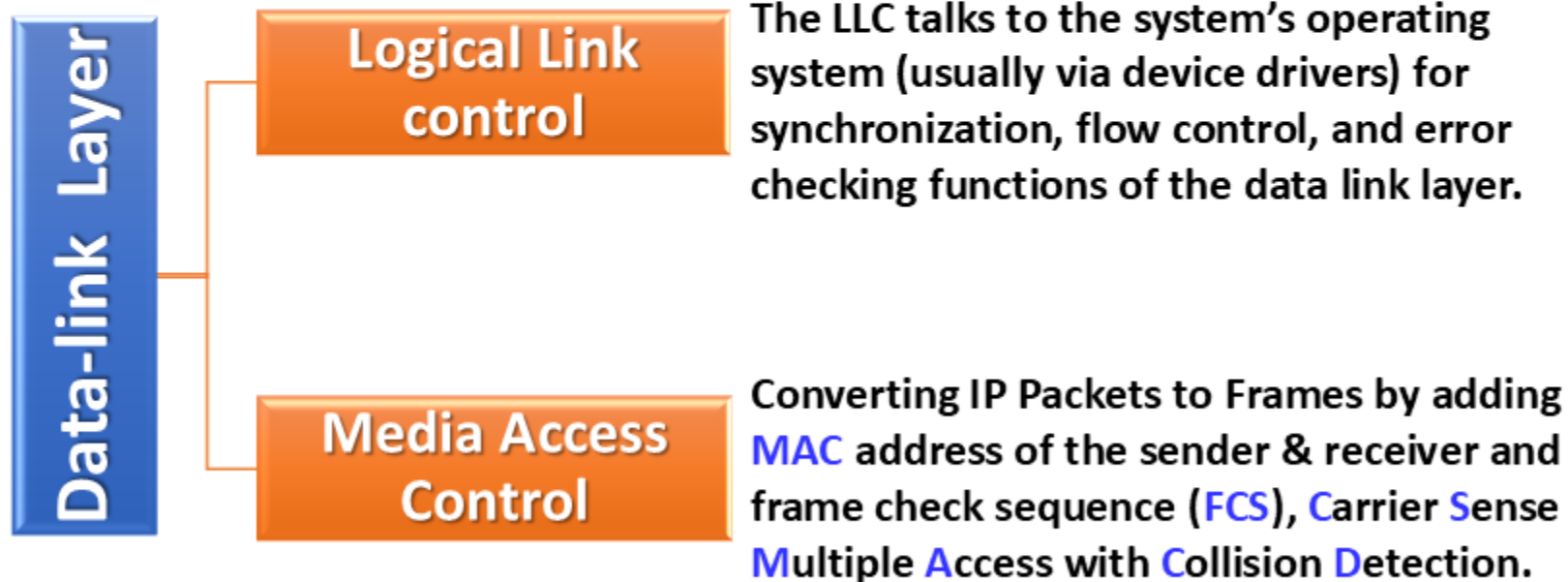
Data-Link

Physical



Data-Link Layer:

The data link layer ensures that all packets of information are passed on free of errors. It makes sure the appropriate physical protocol is assigned to the data.



Application

Presentation

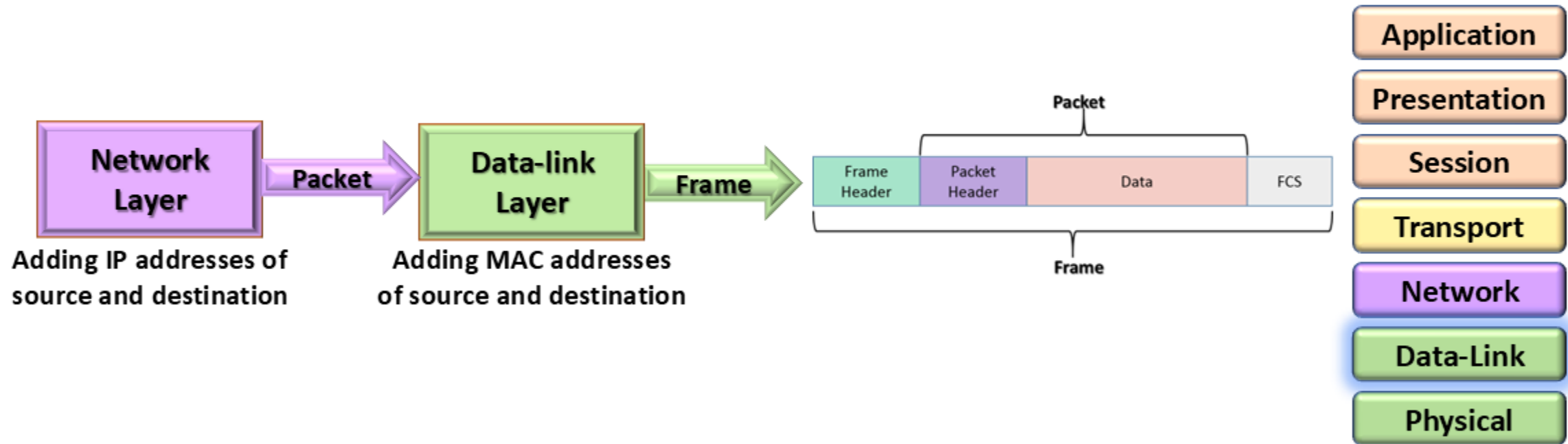
Session

Transport

Network

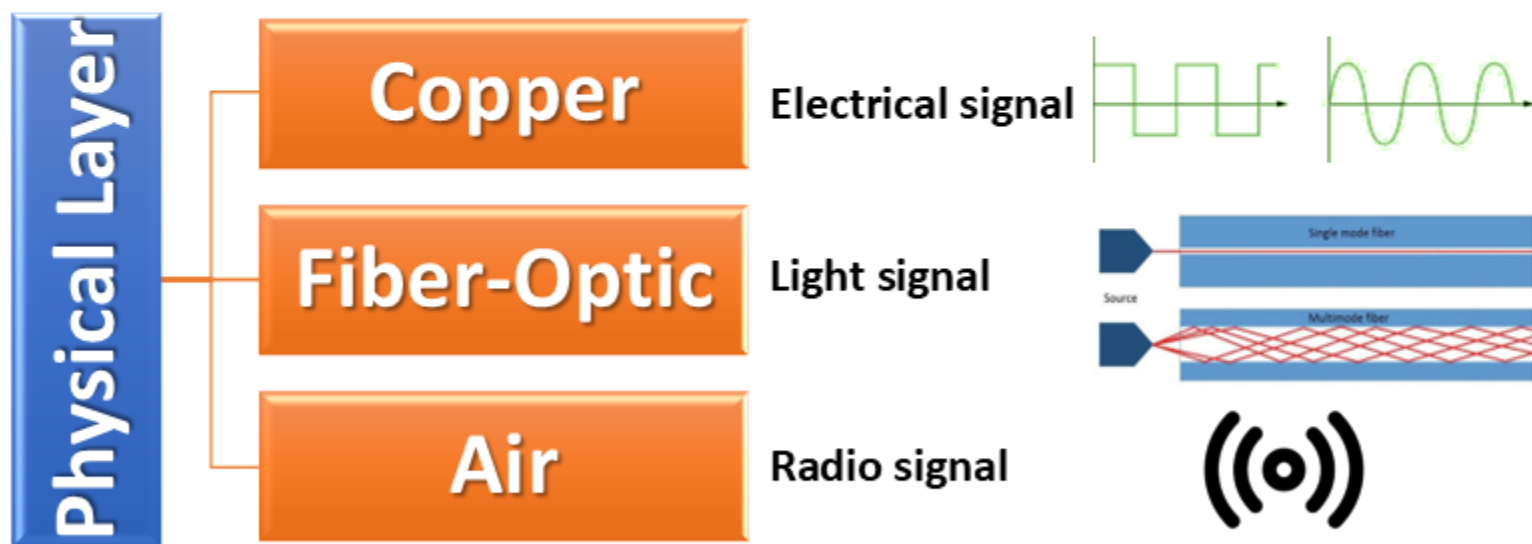
Data-Link

Physical



Physical Layer:

The physical layer performs encoding and decoding of bits into physical signals then transmit signals over physical media between devices.



Application

Presentation

Session

Transport

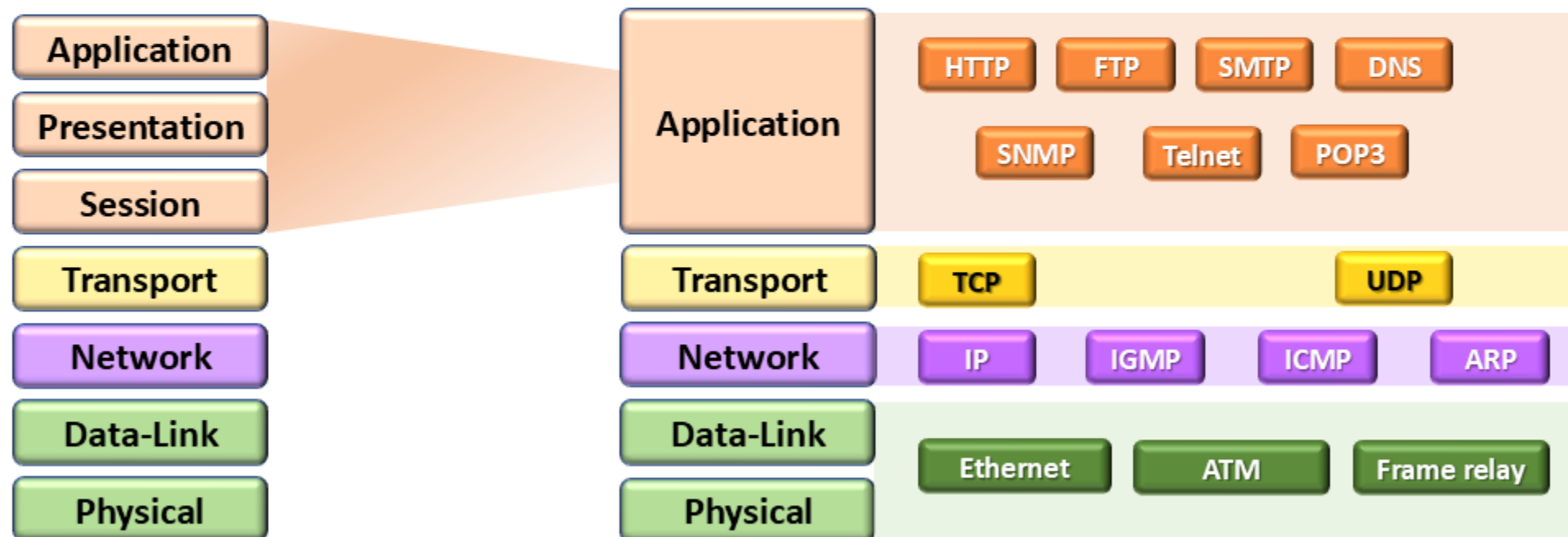
Network

Data-Link

Physical

Internet (TCP/IP) Model:

It is a compact design of OSI model consists of five layers where the 5th , 6th , and 7th layers of OSI model represented by application layer in TCP/IP model.

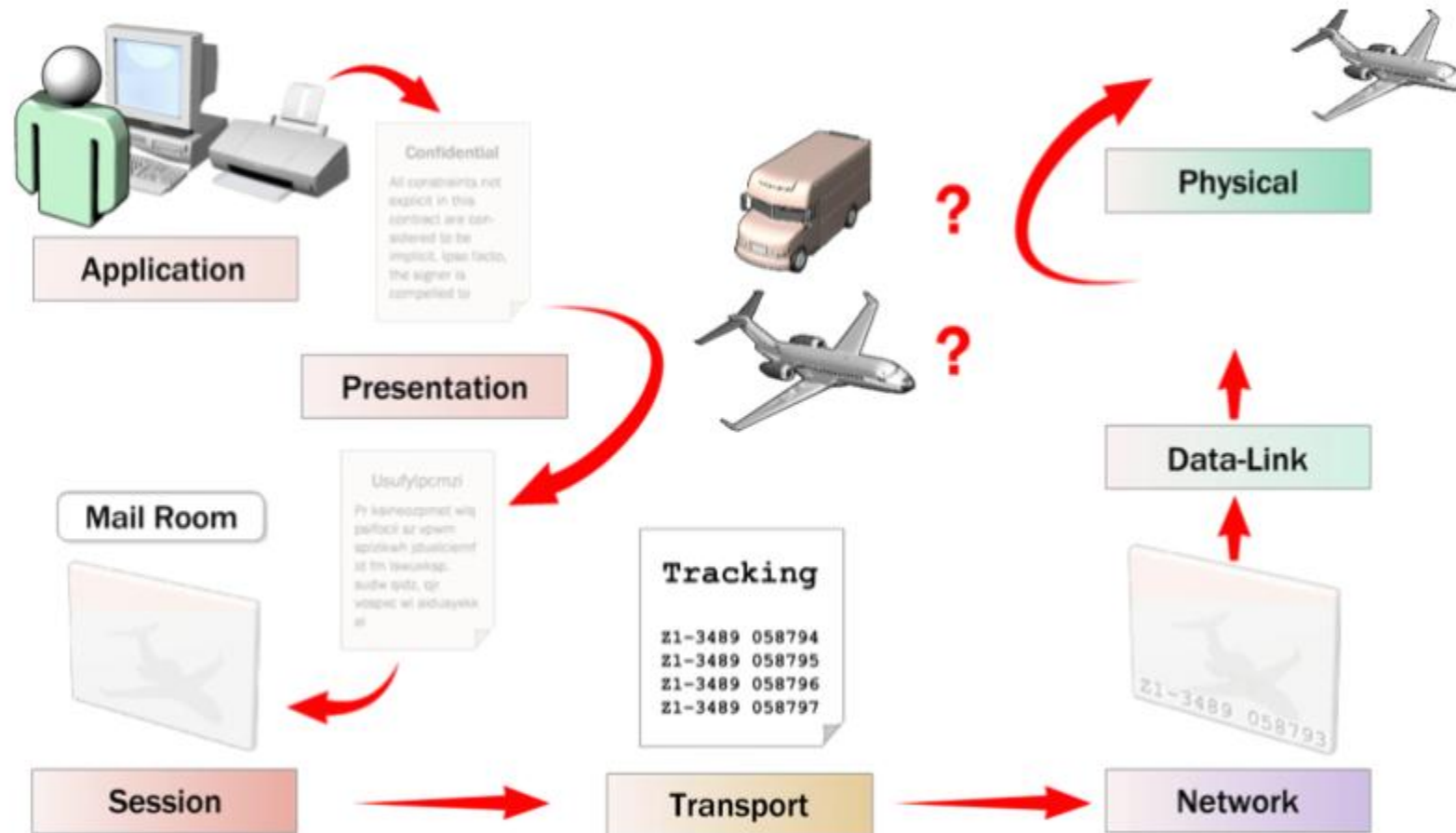


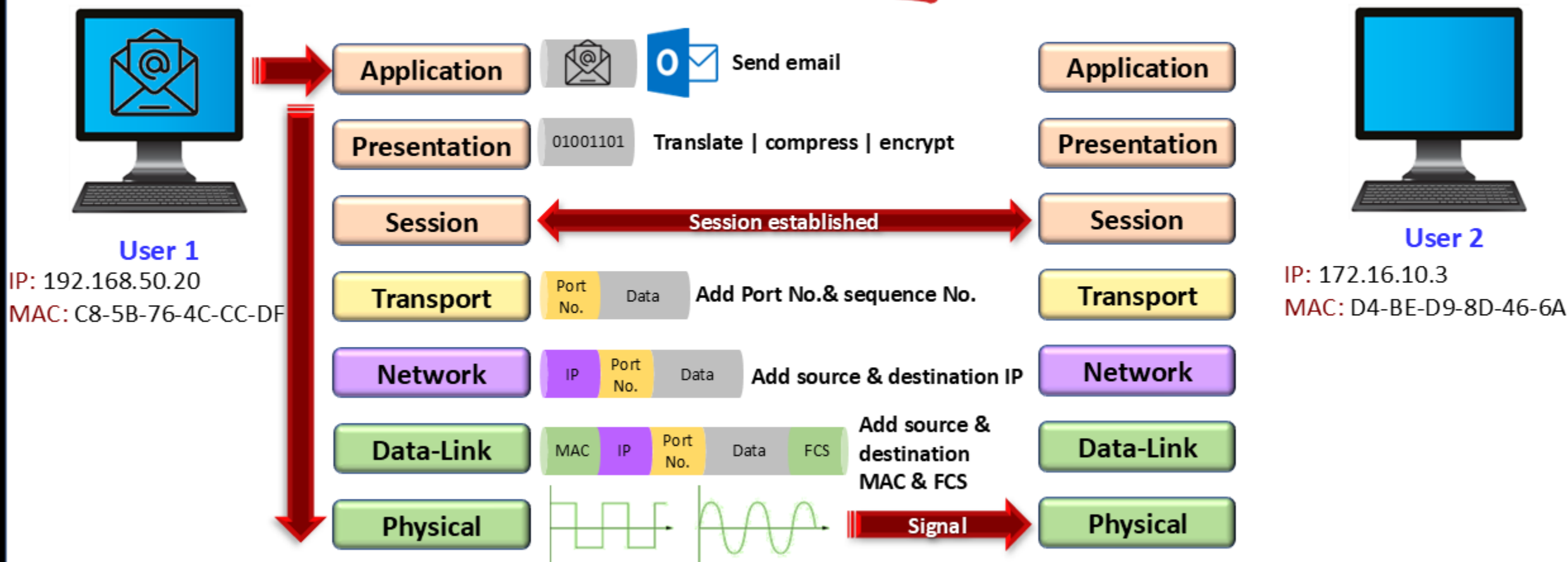
What is encapsulation and de-encapsulation?

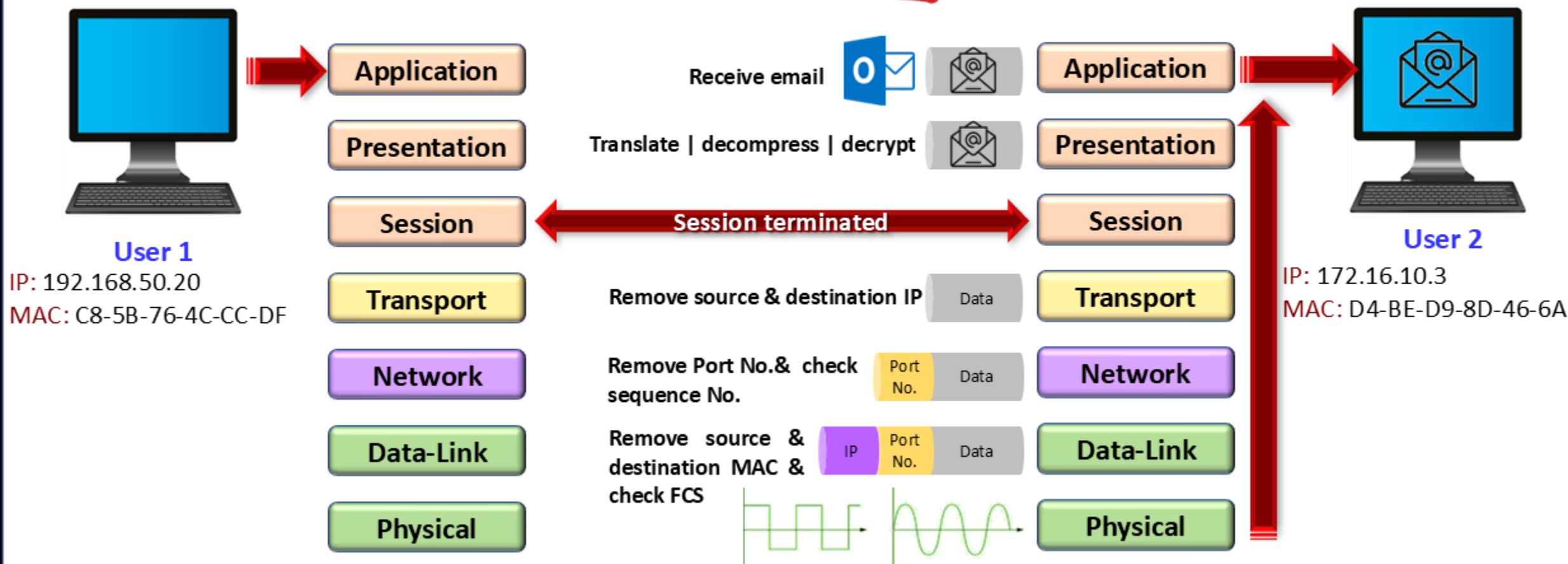
Encapsulation is how network protocols work together in layers by dividing data into definite packets and attaching extra information that adds more features to each packet in order to transmit data through the network. It takes place on the sender's side.

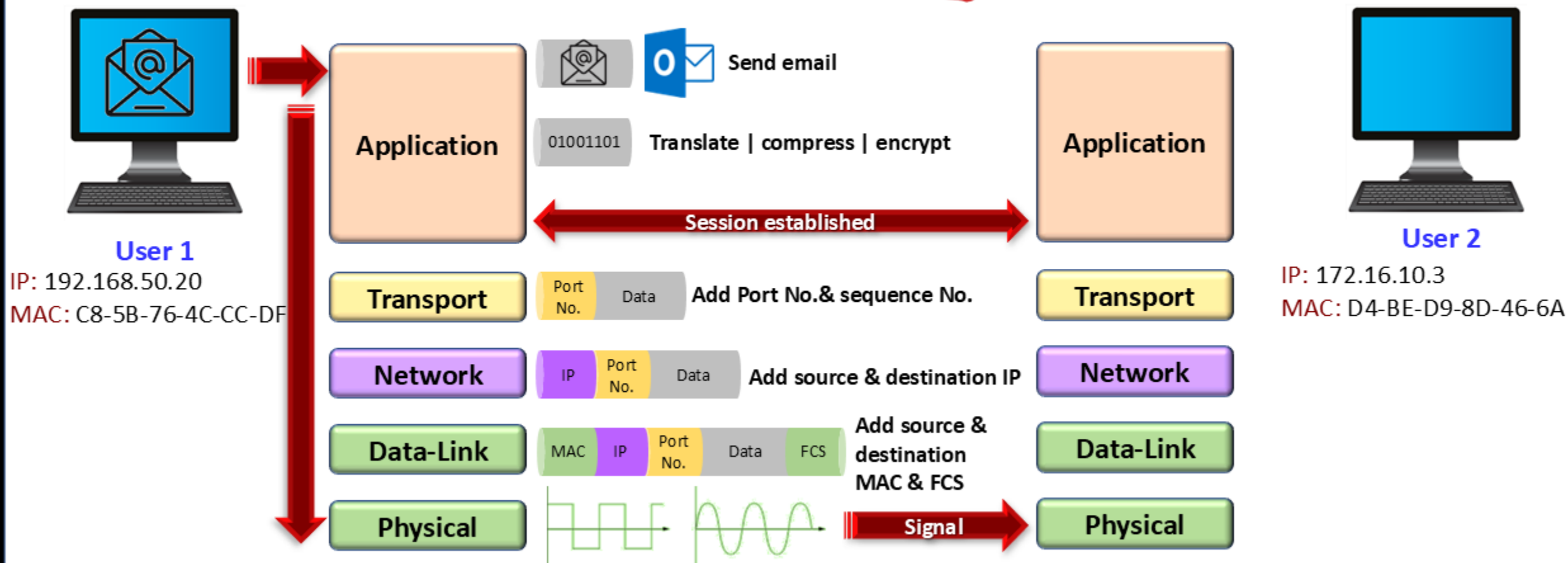
De-encapsulation occurs at the receiver's side, where attached information from the received data is removed to obtain the original data (the reverse of encapsulated).

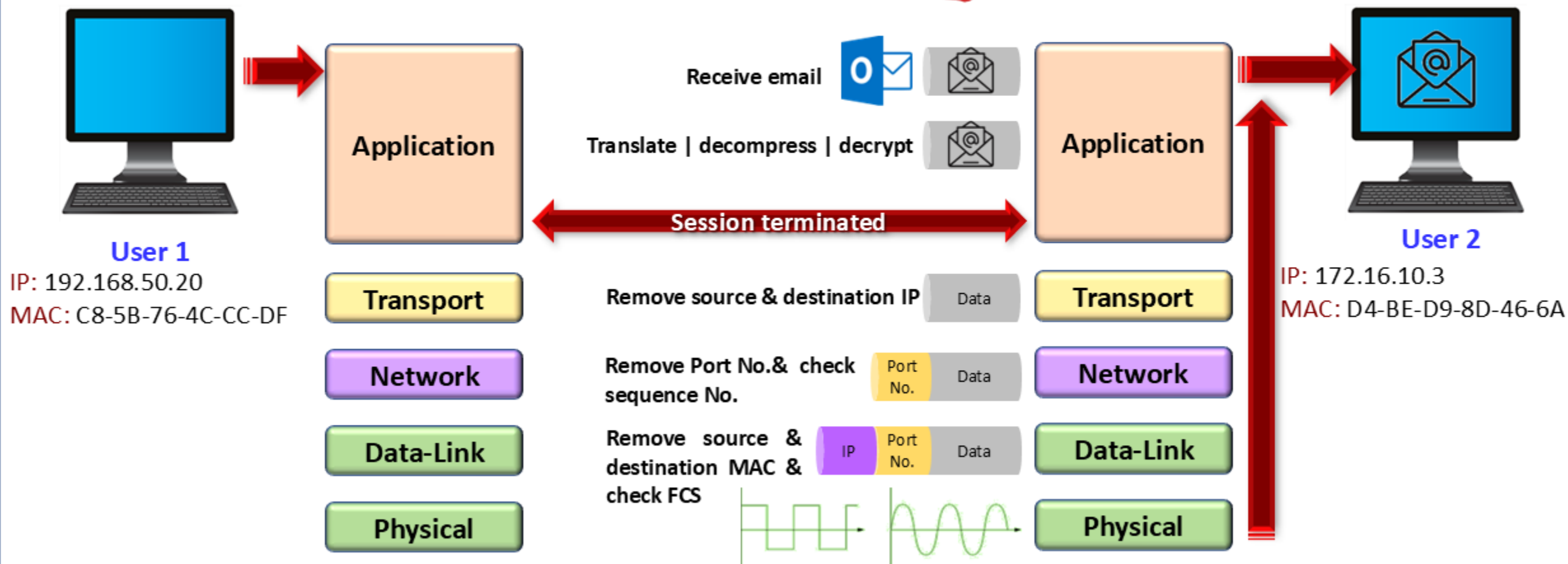
Data Encapsulation



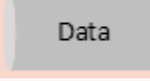
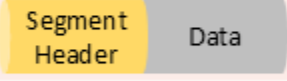
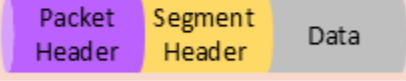
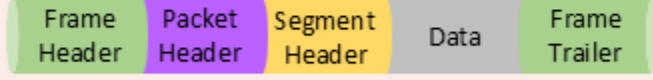
OSI model encapsulation

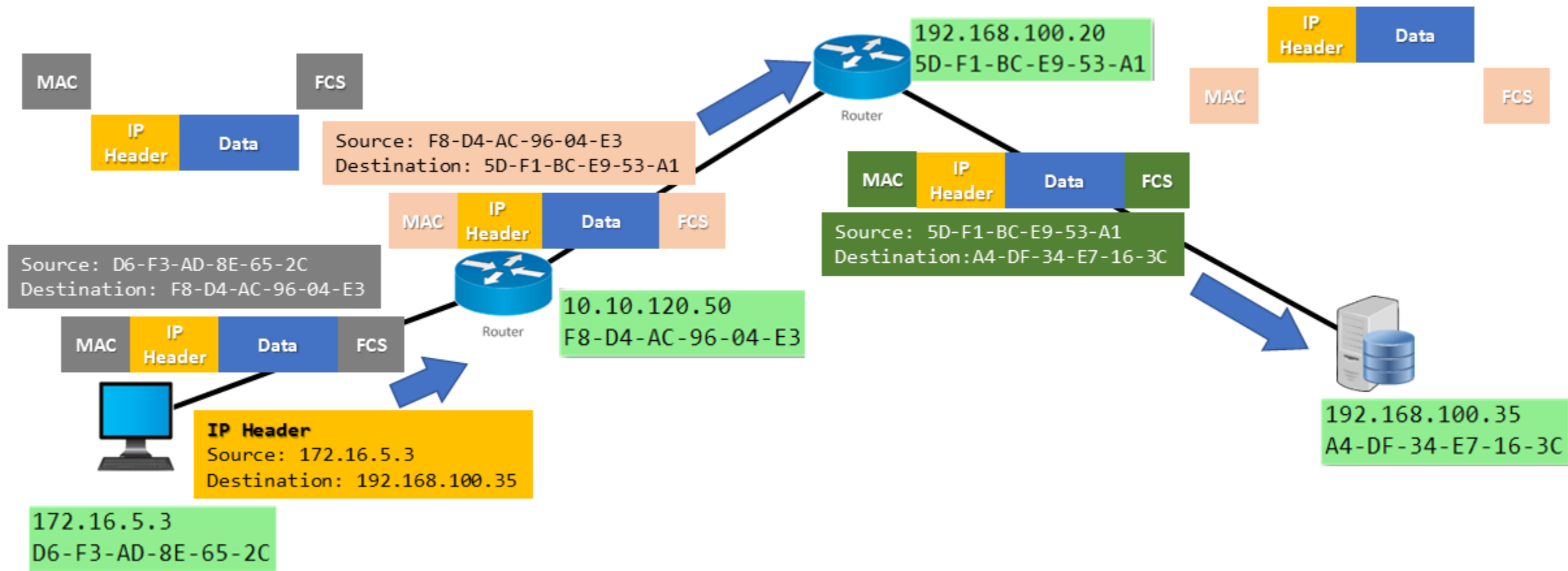
OSI model encapsulation

Internet model encapsulation

Internet model encapsulation

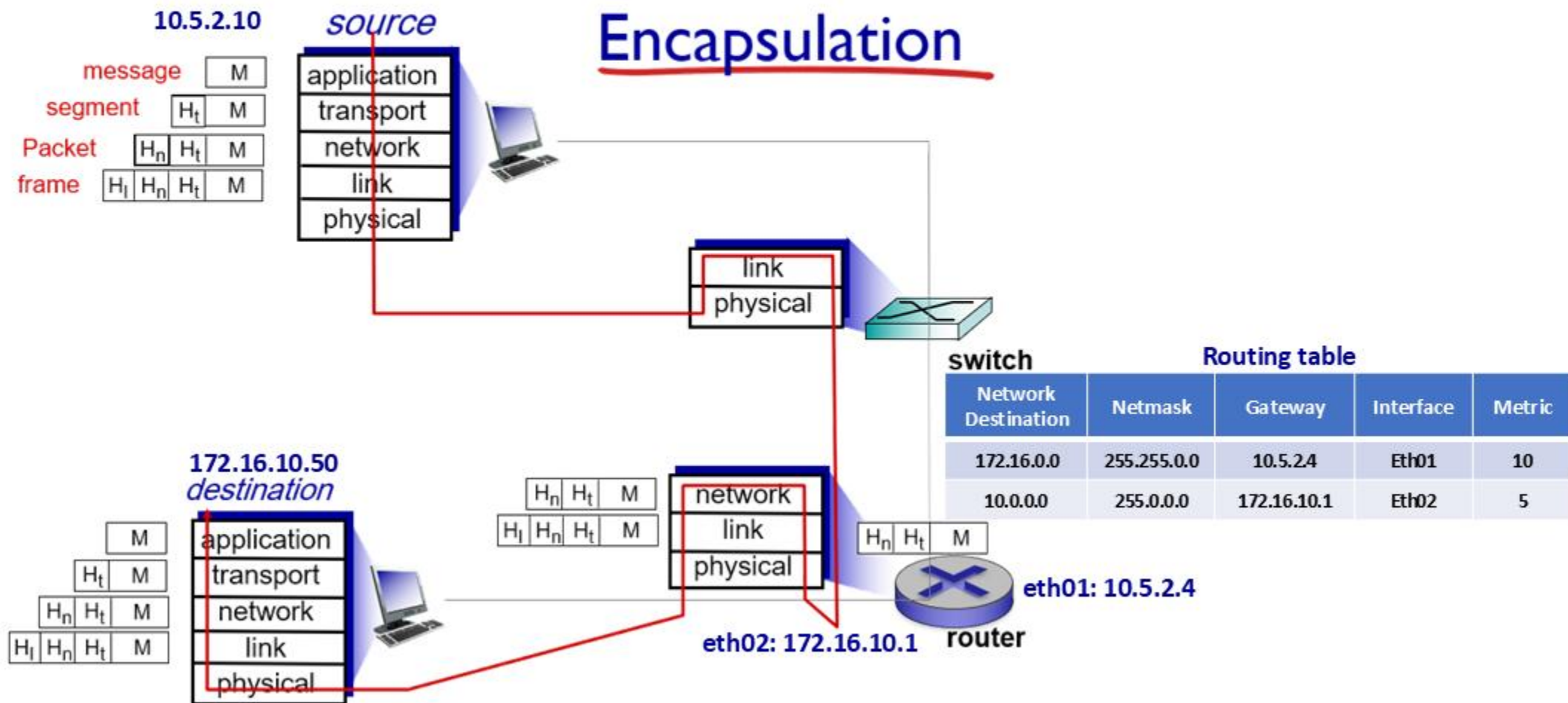
Encapsulation De-encapsulation process OSI / Internet models

OSI Model	Internet (TCP/IP) model	Encapsulation term	Encapsulation De-encapsulation
Application	Application	Data	
Presentation		Data	
Session		Data	
Transport	Transport	Segment	
Network	Network	Packet	
Data-Link	Data-Link	Frame / Datagram	
Physical	Physical	Signal (bits in a wire)	



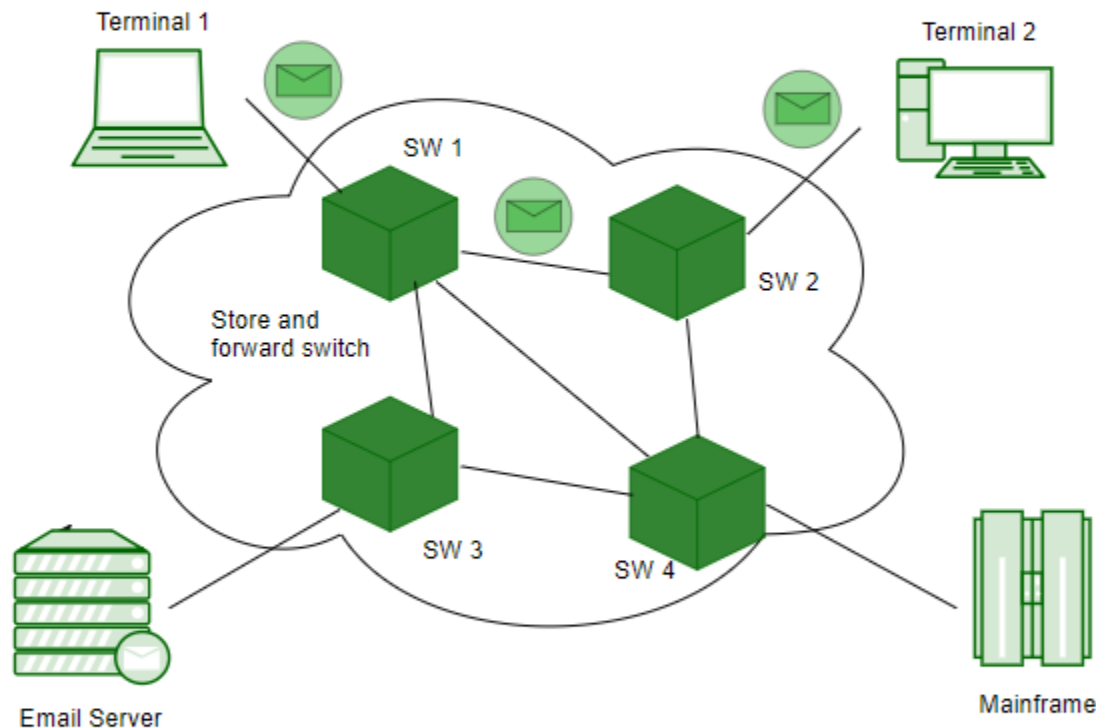
Frame switching from source to destination

Data Encapsulation



Network switching:

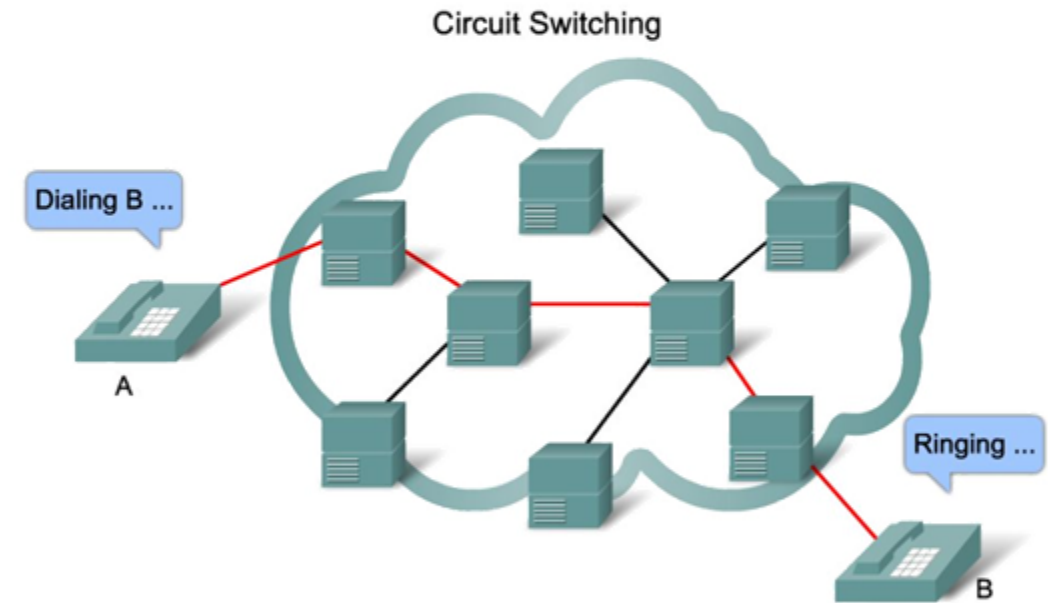
It is the process of channeling data received from any number of input ports to another designated port that will transmit the data to its desired destination. The device through which the input data passes is called a switch. Data entering a port is referred to as ingress, while data leaving the port is referred to as egress. The switch represents the medium through which the data is routed to its destination.



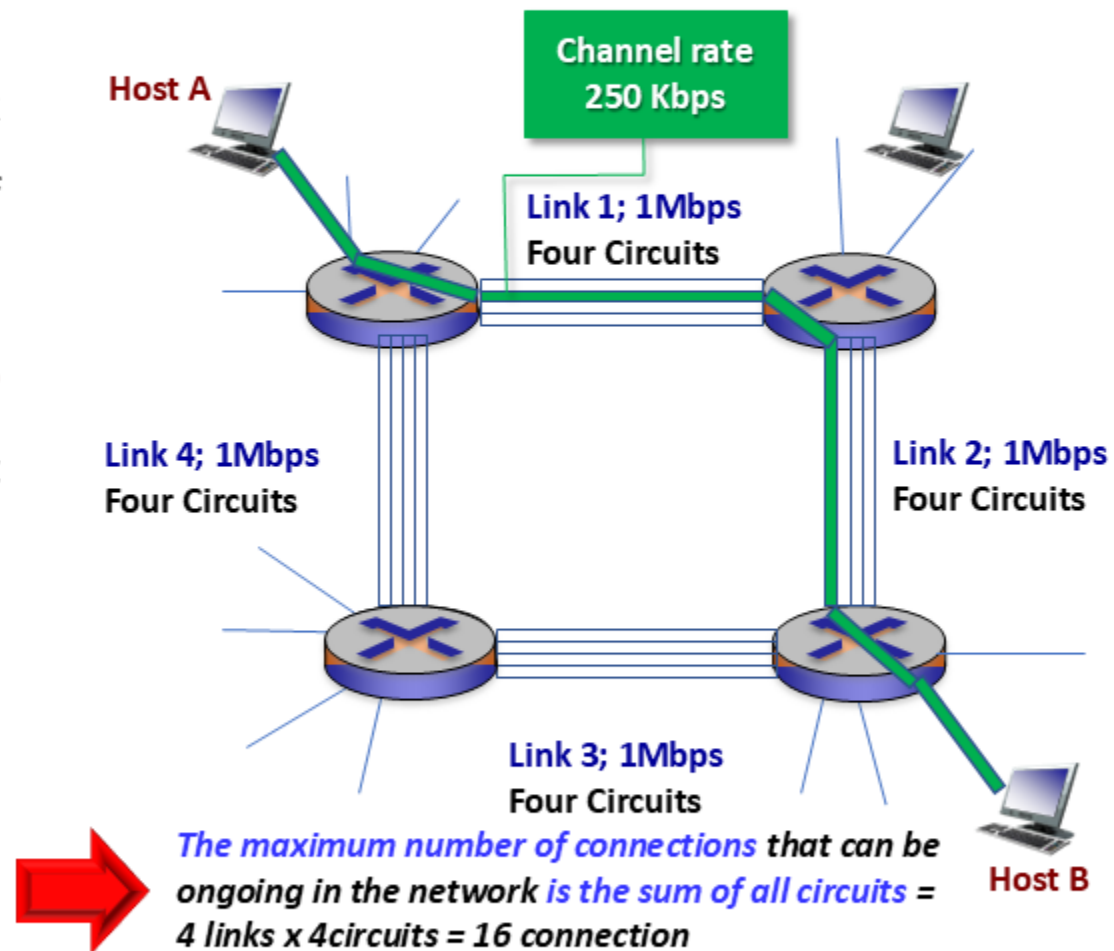
Circuit switching:

The establishment of a **dedicated communication path** between the two nodes, within a physical network. This path (circuit) is established and maintained for the duration of the session.

No matter the length of the communication session, the circuit will remain, and the data paths maintained. The circuit is only terminated when the session ends. The session consists of three phases: circuit establishment, data transfer, and circuit termination/disconnect.

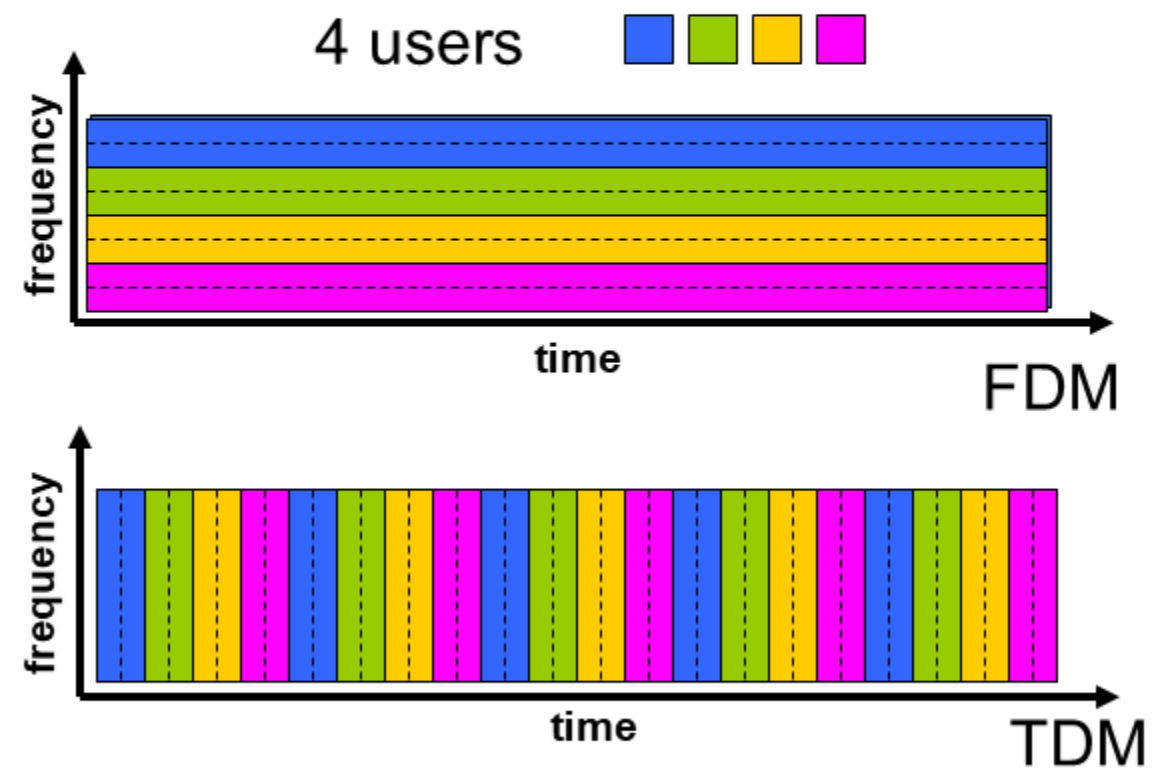


- In the right diagram; the network consists of four links each link consists of four circuit (channel) and has a transmission rate of 1 Mbps then each circuit has a transmission rate of 250 Kbps.
- Host A established connection with Host B through *circuit two in link one and circuit four in link two*, the combination of circuit two and circuit four is called "socket".
- The socket is a dedicated resource, it is not sharing as long as the connection between Host A and Host B continues, even if the socket segment is Idle. The circuits are created with either FDM or TDM.



Circuit switching: FDM versus TDM

- **Frequency Division Multiplexing (FDM)** is used when multiple data signals are combined for simultaneous transmission via a shared communication medium. It is a technique by which the total bandwidth is divided into a series of non-overlapping frequency sub-bands, where each sub-band carry different signal.
- **Time-division multiplexing (TDM)** is a method of transmitting and receiving independent signals over a common signal path by means of synchronized switches at each end of the transmission line. TDM is used for long-distance communication links and bears heavy data traffic loads from end user.

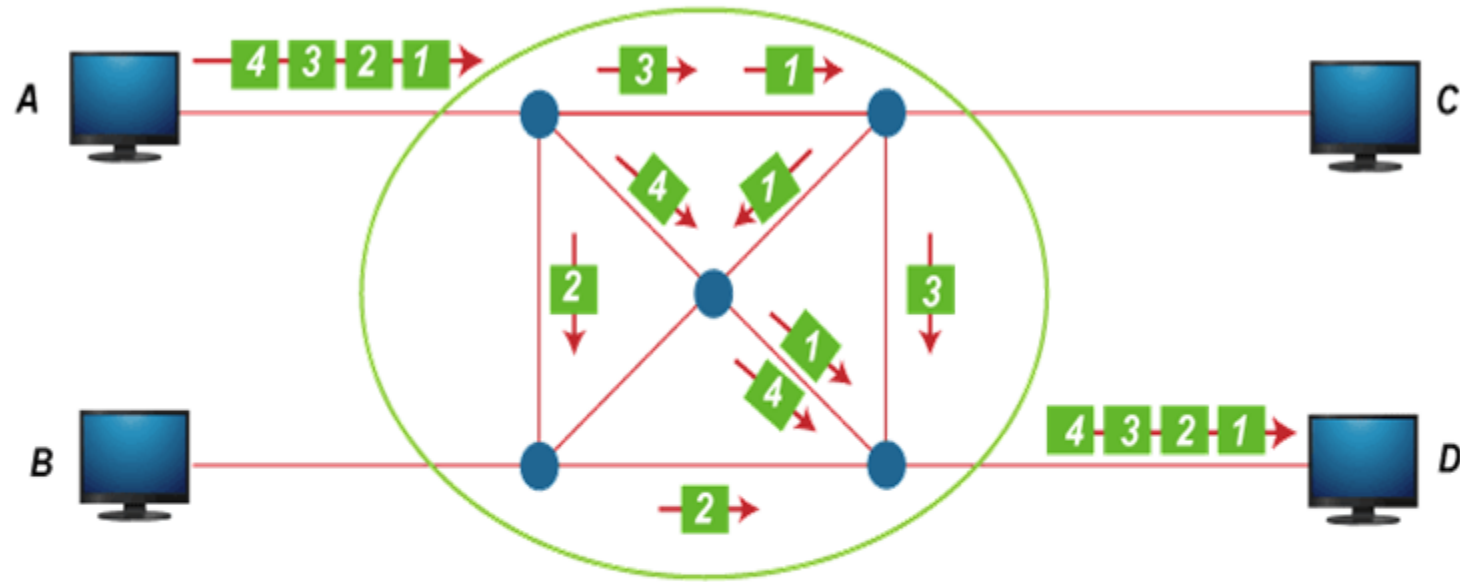


Advantages of circuit switching:

- A committed transmission channel is established between the computers which give a guaranteed data rate.
- There is no delay in data flow because of the dedicated transmission path.

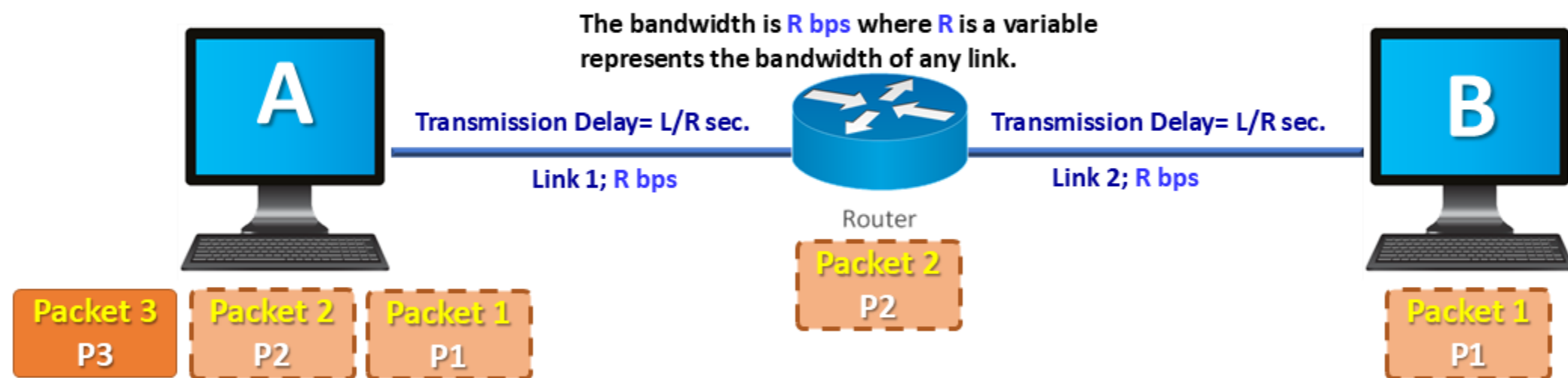
Disadvantages of circuit switching:

- It takes a long time to establish a connection.
- More bandwidth is required in setting up dedicated channels.
- It cannot be used to transmit any other data even if the channel is free as the connection is dedicated to circuit switching.

**Packet switching:**

Packet switching is defined as the process of breaking down messages into small components, called packets, each packet then independently navigates its way using the information, through the network to its destination (Switching information (source and destination) is then included in the header information of the packet). Because the messages transmitted are smaller packets, there is less demand for resources on intermediate network devices.

Packet Switching uses **Store and Forward** technique while switching the packets; while forwarding the packet each hop first stores that packet then forward.



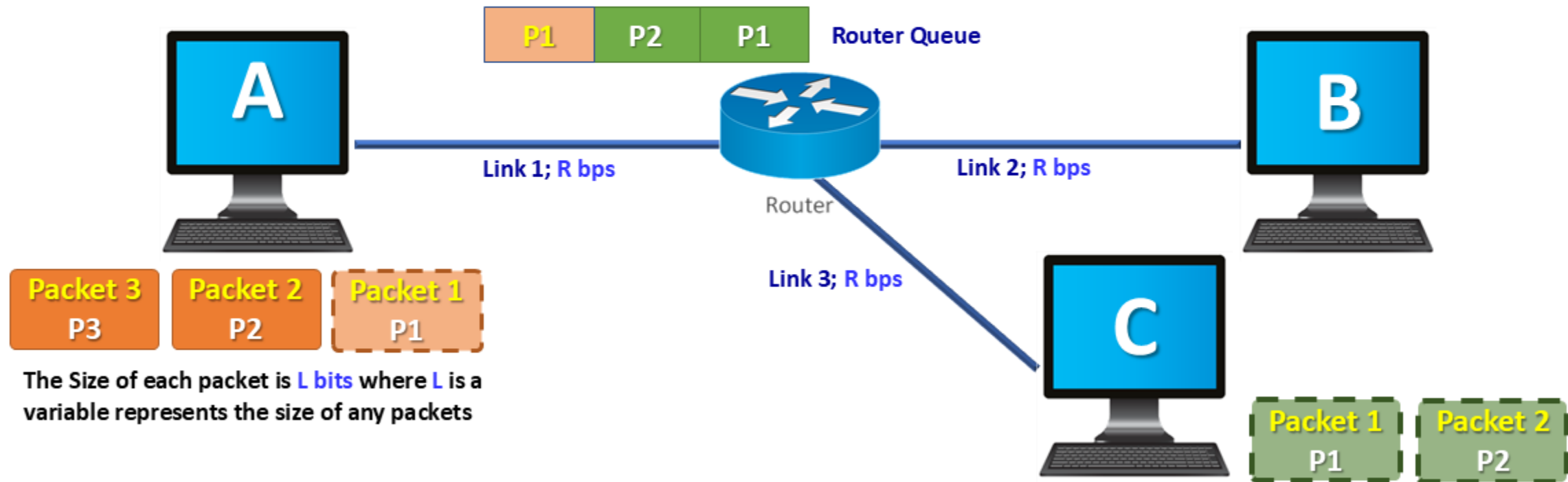
The Size of each packet is L bits where L is a variable represents the size of any packets

$$\text{Transmission Delay} = [N + (P-1) L / R]$$

where L is the size of packets, N is the number of links, P is the number of packets, and R is the bandwidth.

Packet Switching suffer from other delays such as propagation, queuing, and processing delays.

$$(\text{Latency} = T_{\text{Propagation}} + T_{\text{transmission}} + T_{\text{queuing}} + T_{\text{processing}})$$



Advantages of Packet switching:

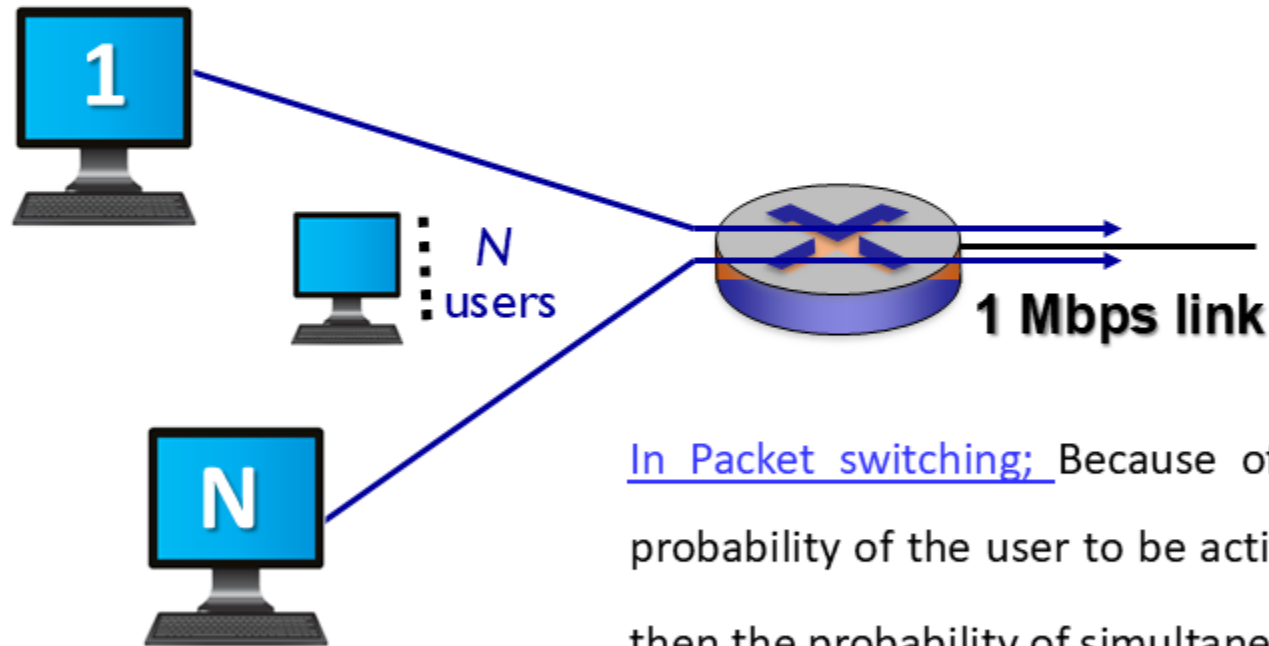
- More efficient in terms of bandwidth, since the concept of reserving circuit is not there.
- More reliable as a destination can detect the missing packet.
- More fault tolerant because packets may follow a different path in case any link is down, Unlike Circuit Switching.
- Cost-effective and comparatively cheaper to implement.

Disadvantages of Packet switching:

- Complexity is more at each node because of the facility to follow multiple paths.
- Transmission delay is more because of rerouting.
- Packet Switching is beneficial only for small messages, but for large messages Circuit Switching is better.

Circuit versus Packet switching

- Packet switching is more efficient than Circuit switching



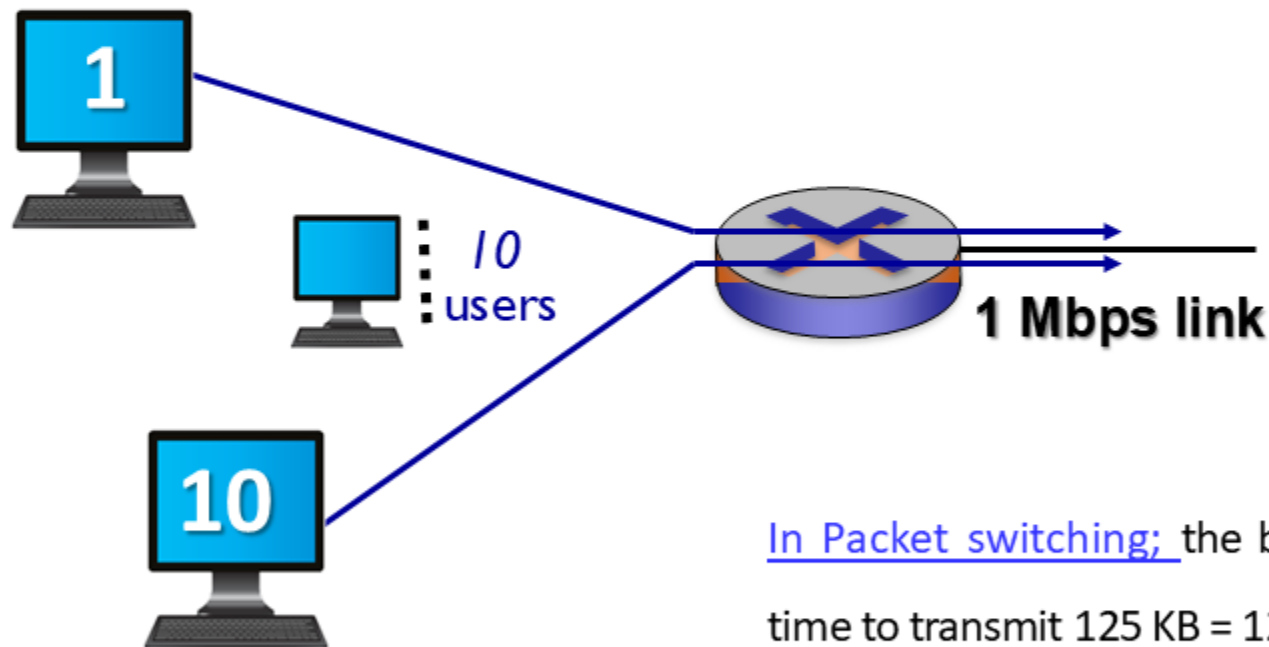
No. of active users are 10% of all users and transmit data at 100 Kbps.

In circuit switching; the bandwidth will distribute for each user. No. of users that can be supported = $1 \text{ Mbps} / 100 \text{ Kbps} = 10$ users at the same time can use the bandwidth in circuit switching.

In Packet switching; Because of each user can be active 10% of the time, then the probability of the user to be active = $p[\text{one user be active}] = 0.1$. If the no. of users (n) = 35, then the probability of simultaneous 10 active users = $\sum_{x=0}^{10} \binom{n}{x} P^x (1 - P)^{n-x} = 0.9996$
Thus, the probability of having 11 or more simultaneous active users = $1 - 0.9996 = 0.0004$

Circuit versus Packet switching

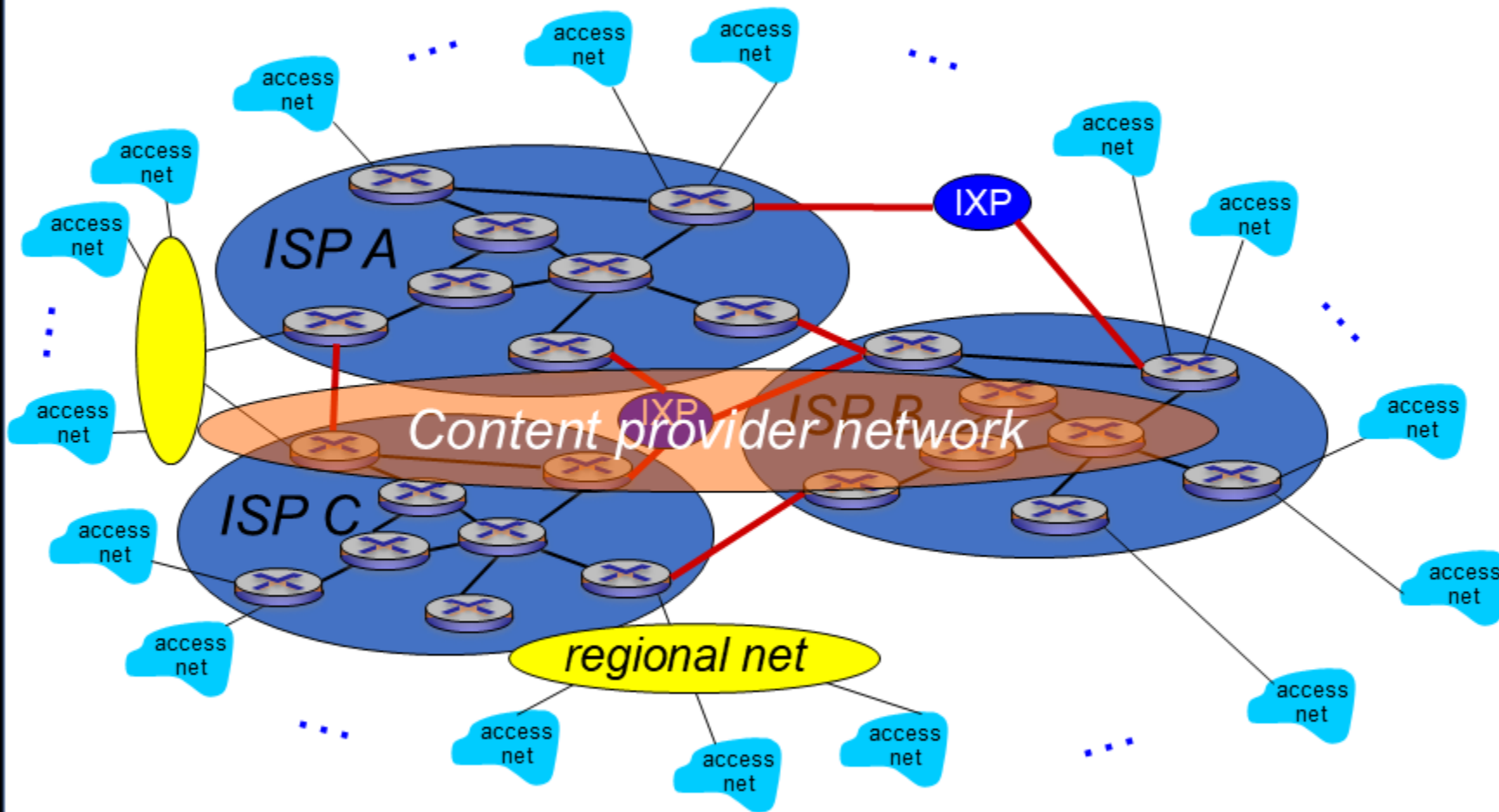
- Packet switching offers better sharing of link's transmission capacity.



Only ONE user is active

In circuit switching; the bandwidth will distribute for each user. Thus, each user can have bandwidth of 100 Kbps. Using TDM, the total time to transmit 125 KB = $125 \text{ KB} / 100 \text{ Kbps} = 1000000 \text{ bits} / 100000 \text{ bps} = \mathbf{10 \text{ Sec.}}$

In Packet switching; the bandwidth will be dedicated for active user. Thus, the total time to transmit 125 KB = $125 \text{ KB} / 1 \text{ Mbps} = 1000000 \text{ bits} / 1000000 \text{ bps} = \mathbf{1 \text{ Sec.}}$



The subnets (which contain home users and enterprises etc.) connected to the local ISP through what is called *Point of presence* (the equipment like DSLAM which present in telephone central). The local ISP connected to the regional ISP which connected to other Global ISP through *Internet exchange point (IXP)*.

Content provider networks (e.g., Google, Microsoft) may run their own network, to bring services, content close to end users.

