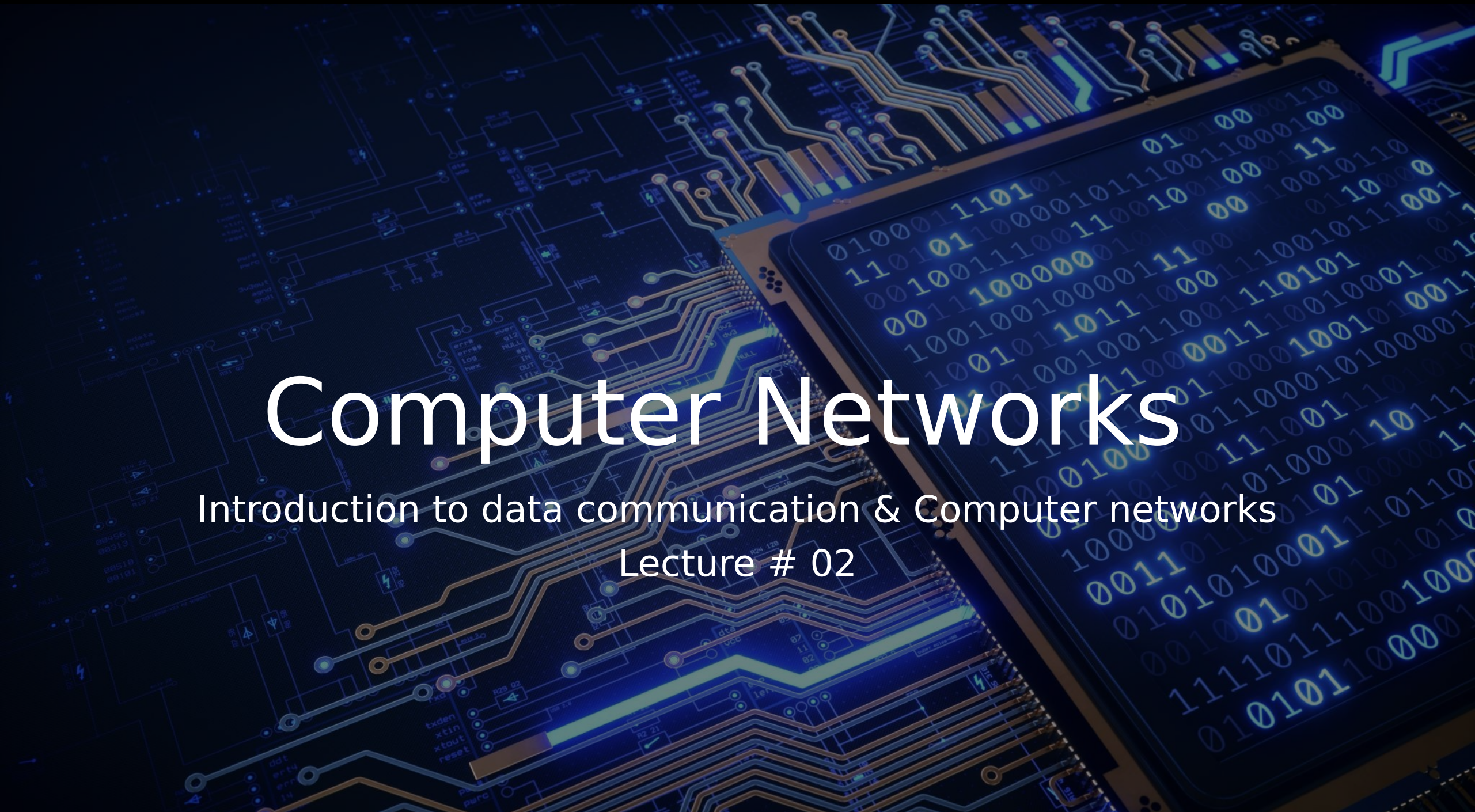


Computer Networks

Introduction to data communication & Computer networks

Lecture # 02

Services

- Internet is an infrastructure that provides services to applications
- Examples:
  - electronic mail, Web surfing, social networks, instant messaging, Voiceover-IP (VoIP), video streaming, distributed games, peer-to-peer (P2P) file sharing, television over the Internet, remote login, and much, much more.
- Called distributed applications, since they involve multiple end systems that exchange data with each other.
- Applications run on the end systems and not on the switches.

- Application Programming Interface APIs

CASE HISTORY

A DIZZYING ARRAY OF INTERNET END SYSTEMS

Not too long ago, the end-system devices connected to the Internet were primarily traditional computers such as desktop machines and powerful servers. Beginning in the late 1990s and continuing today, a wide range of interesting devices are being connected to the Internet, leveraging their ability to send and receive digital data. Given the Internet's ubiquity, its well-defined (standardized) protocols, and the availability of Internet-ready commodity hardware, it's natural to use Internet technology to network these devices together and to Internet-connected servers.

Many of these devices are based in the home—video game consoles (e.g., Microsoft's Xbox), Internet-ready televisions, digital picture frames that download and display digital pictures, washing machines, refrigerators, and even a toaster that downloads meteorological information and burns an image of the day's forecast (e.g., mixed clouds and sun) on your morning toast [BBC 2001]. IP-enabled phones with GPS capabilities put location-dependent services (maps, information about nearby services or people) at your fingertips. Networked sensors embedded into the physical environment allow monitoring of buildings, bridges, seismic activity, wildlife habitats, river estuaries, and the weather. Biomedical devices can be embedded and networked in a body-area network. With so many diverse devices being networked together, the Internet is indeed becoming an "Internet of things" [ITU 2005b].

Network Edge

- Hosts/ End Nodes
- Client-Servers/ Peers
- Access Network
  - the network that physically connects an end system to the first router (also known as the “edge router”) on a path from the end system to any other distant end system.

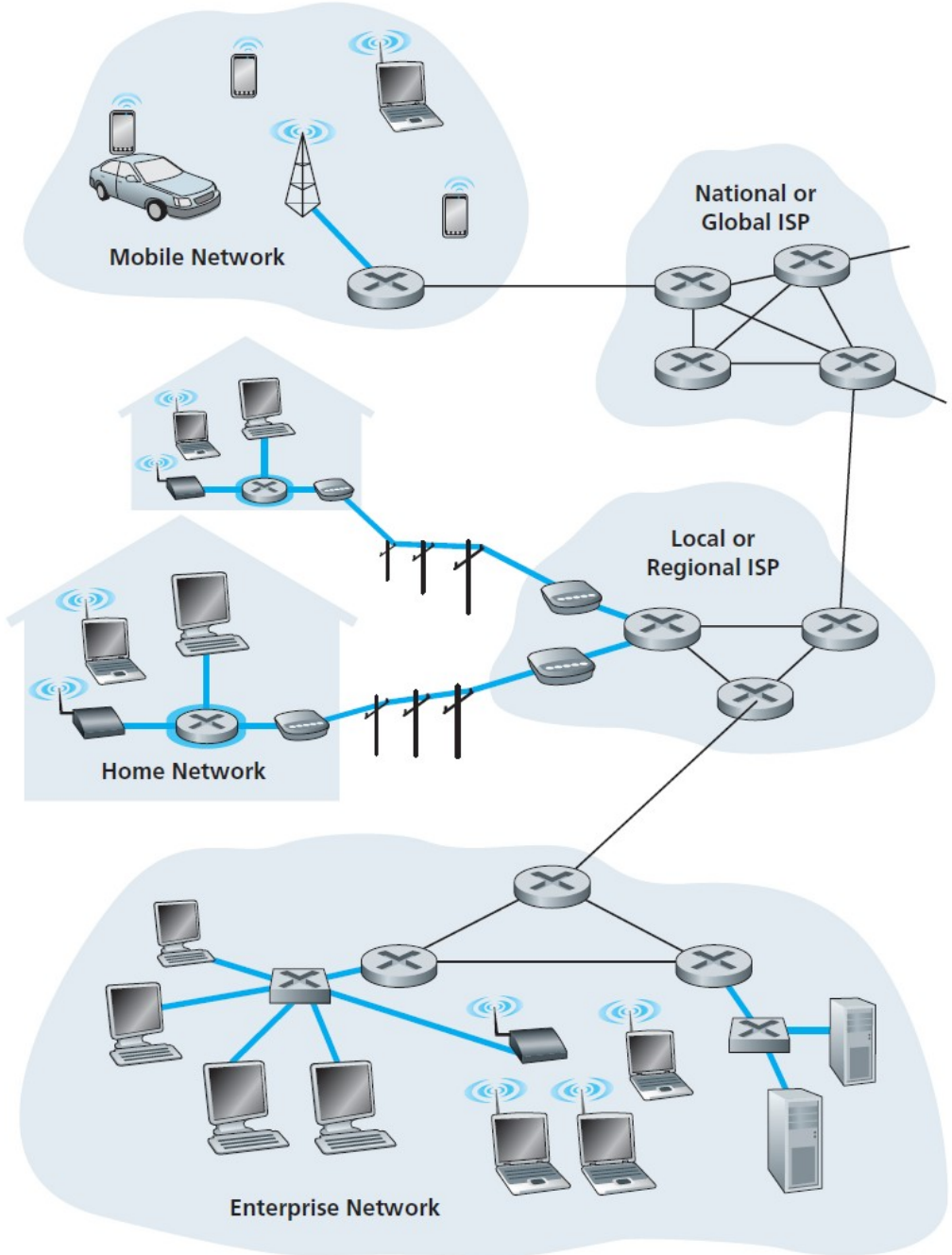


Figure 1.4 ♦ Access networks

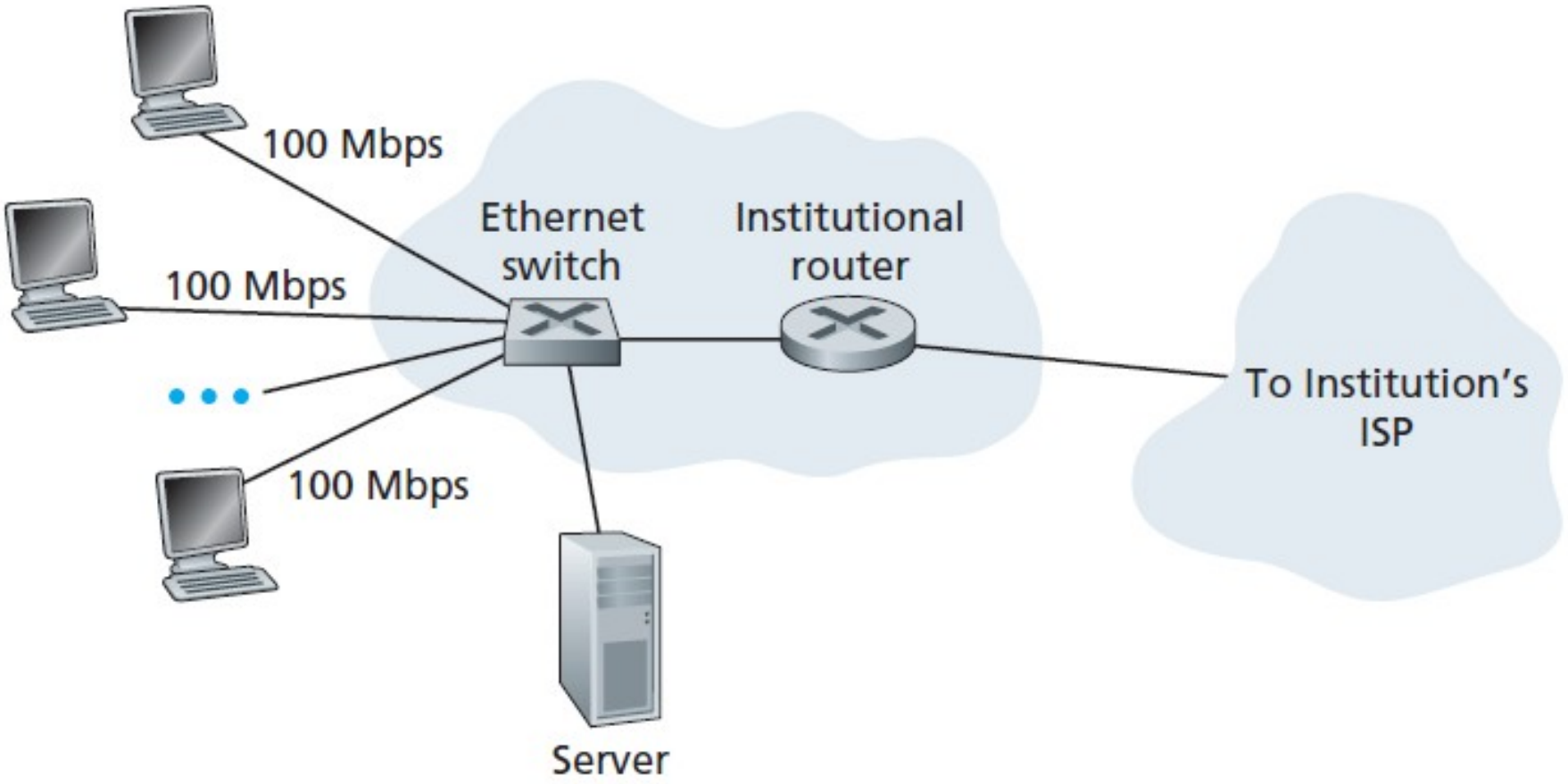


Figure 1.8 ♦ Ethernet Internet access

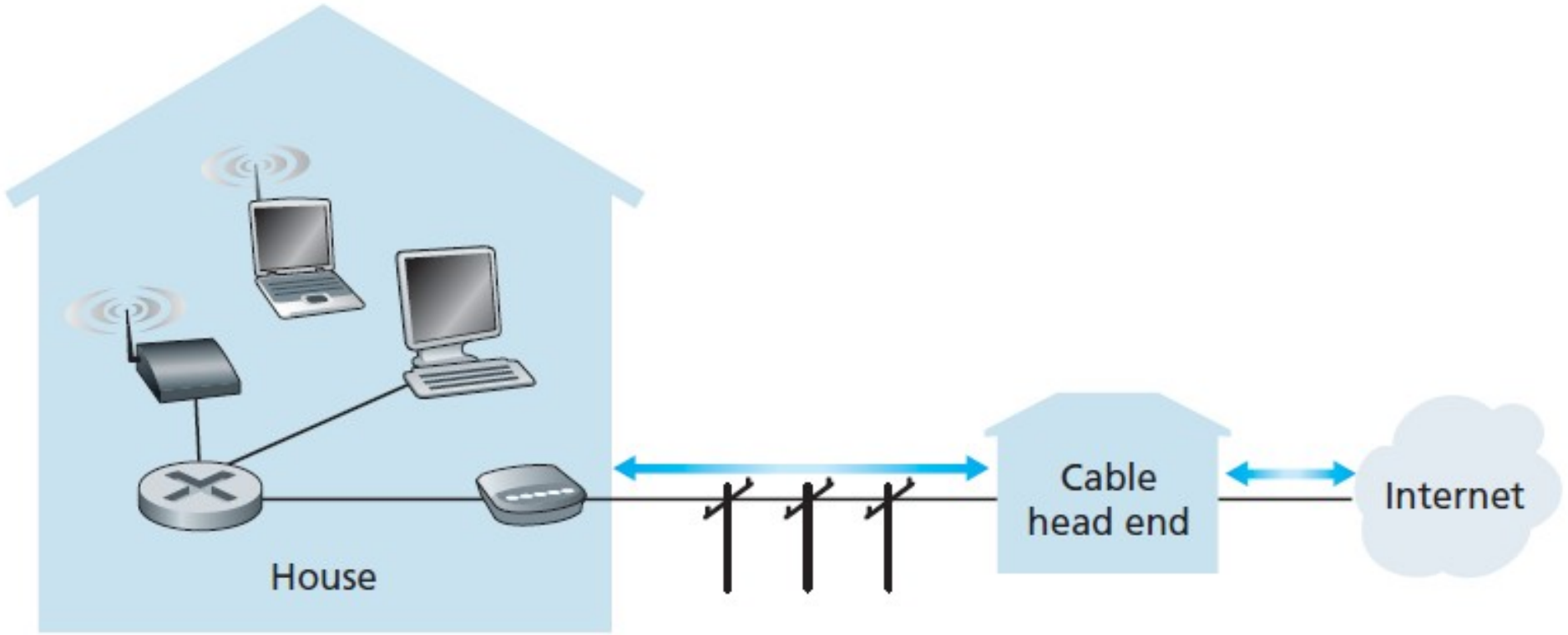


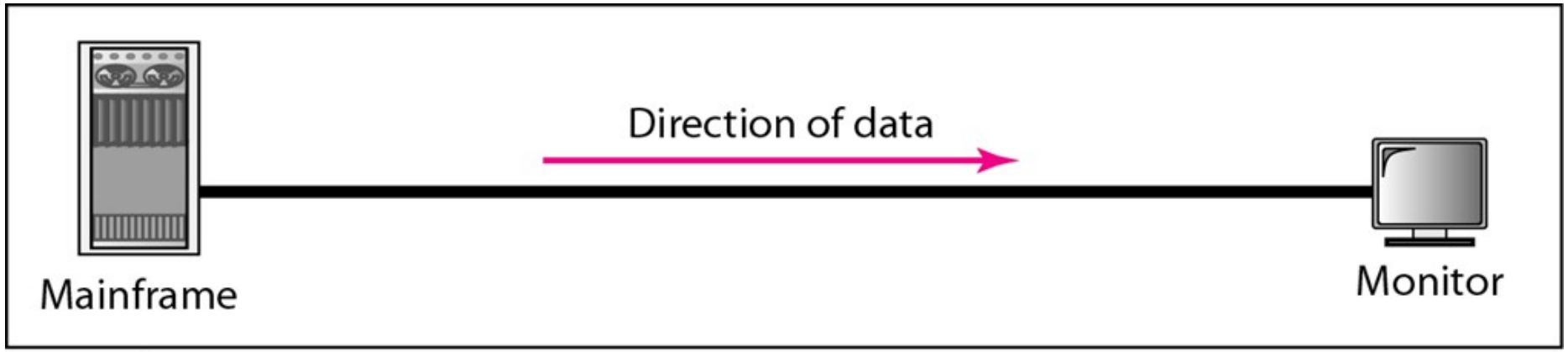
Figure 1.9 ♦ A typical home network

Wide-Area Wireless Access

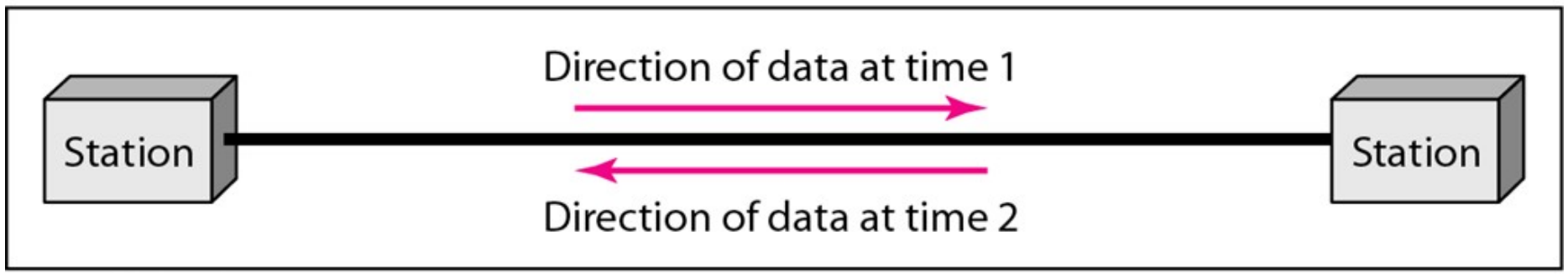
- Mobile Networks
- 3G, 4G, 5G, LTE

Types of Communication or Connections
Directions of Data Flow

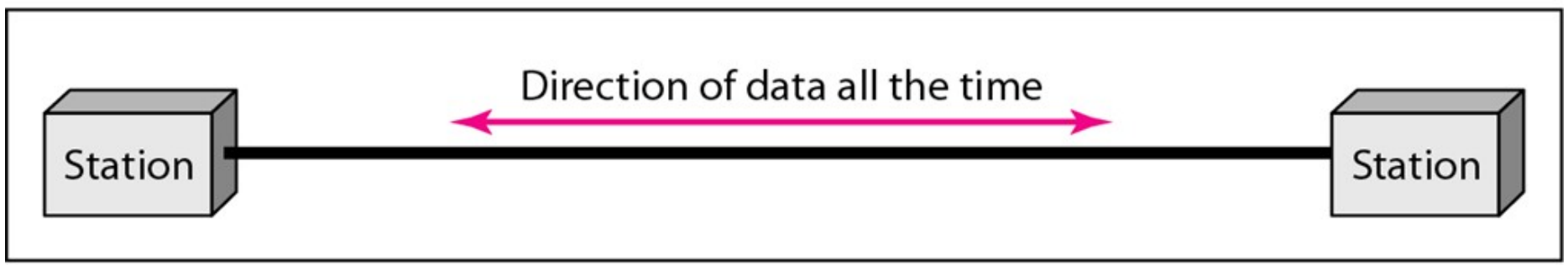
- Communication modes could be:
  - Simplex
    - One Way (Uni directional) only
    - One device is sender and other is receiver
    - Monitor, Speakers, Bluetooth devices etc
    - Is Keyboard Simplex?
  - Half Duplex
    - Bi-directional
    - Only One device can send at a time and other will receive
    - Traditional Wireless Sets
  - Full Duplex
    - Bi-Directional
    - Both Devices can send/Receive simultaneously
    - Telephone Network



a. Simplex



b. Half-duplex



c. Full-duplex

Networks

A **network** is a set of devices (often referred to as nodes) connected by communication links.

A **node** can be a computer, printer, or any other device capable of sending and/or receiving data generated by other nodes on the network.

A **link** can be a cable, air, optical fiber, or any medium which can transport a signal carrying information.

- Network Criteria
- Physical Structures
- Categories of Networks

Network Criteria

Performance

- Depends on Network Elements
- Measured in terms of Delay and Throughput

Reliability

- Failure rate of network components
- Measured in terms of availability/robustness

Security

- Data protection against corruption/loss of data due to:
  - Errors
  - Malicious users

Physical Structure

Type of Connection

- Point to Point -single transmitter and receiver
- Multipoint -multiple recipients of single transmission

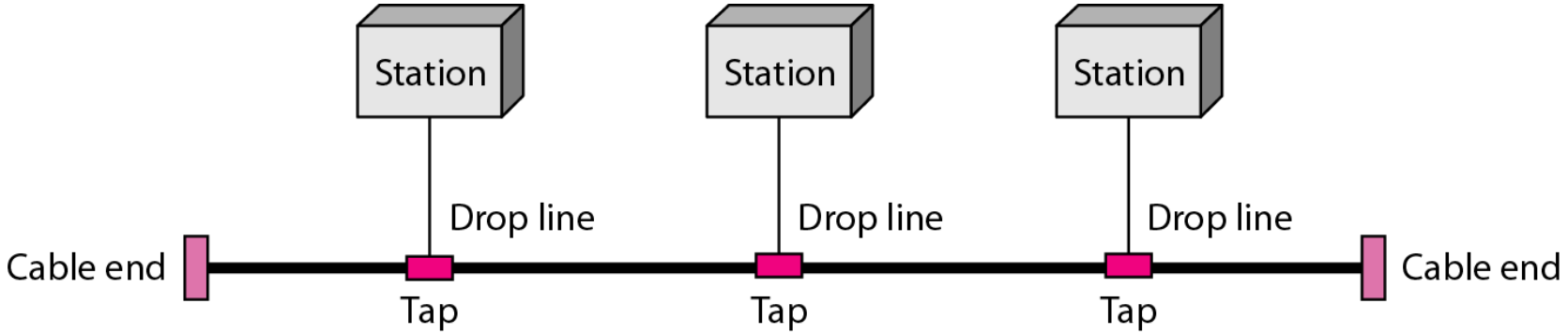
Physical Topology

- Connection of devices
- Type of transmission -unicast, mulitcast, broadcast

Physical Topology

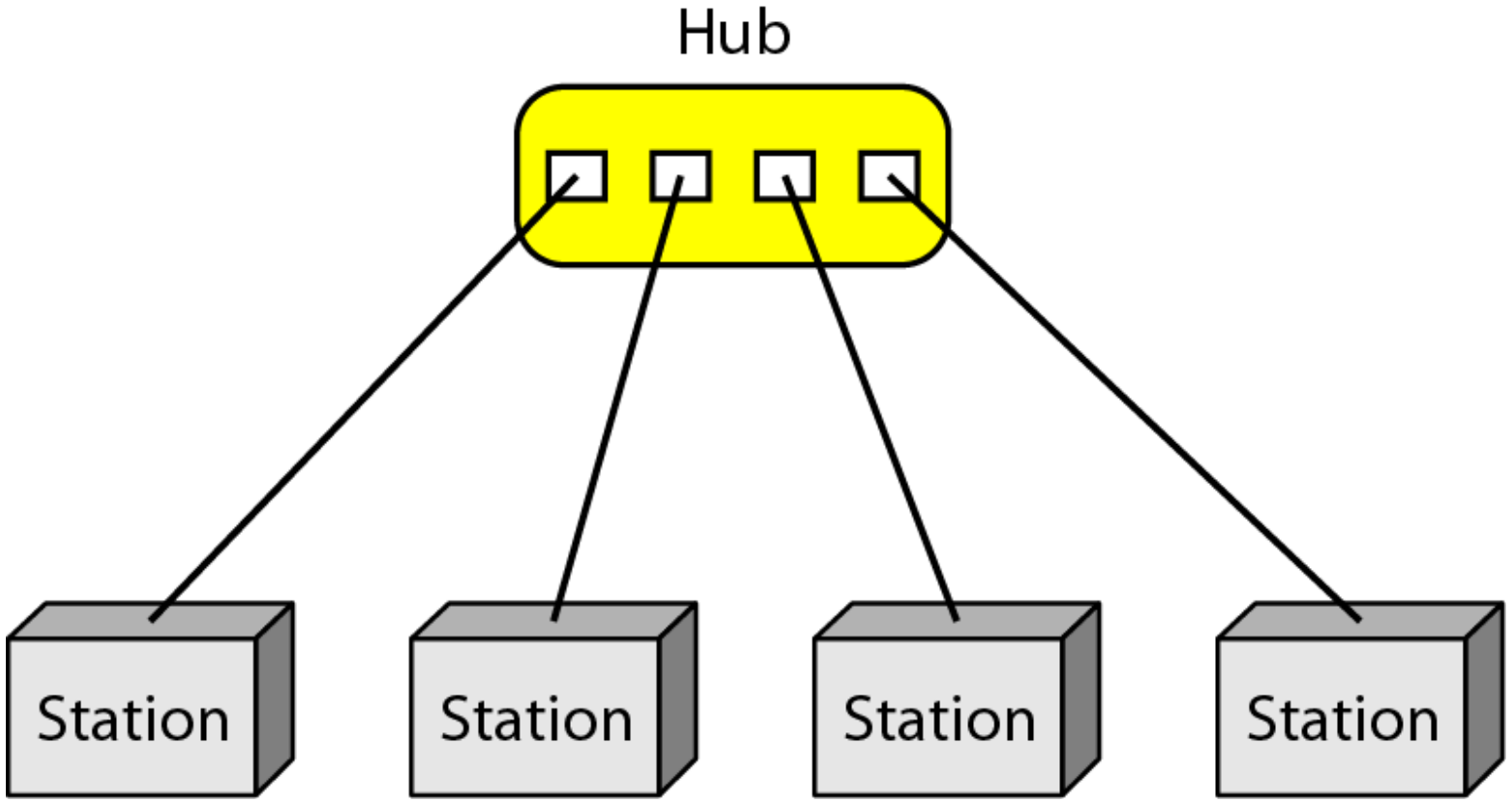
- Topology dictates that how nodes are physically connected in a network
- Geometric representation of relationship of all the links and linking devices
- Four basic topologies:
  - Mesh
  - Star
  - Bus
  - Ring

Topology: Bus



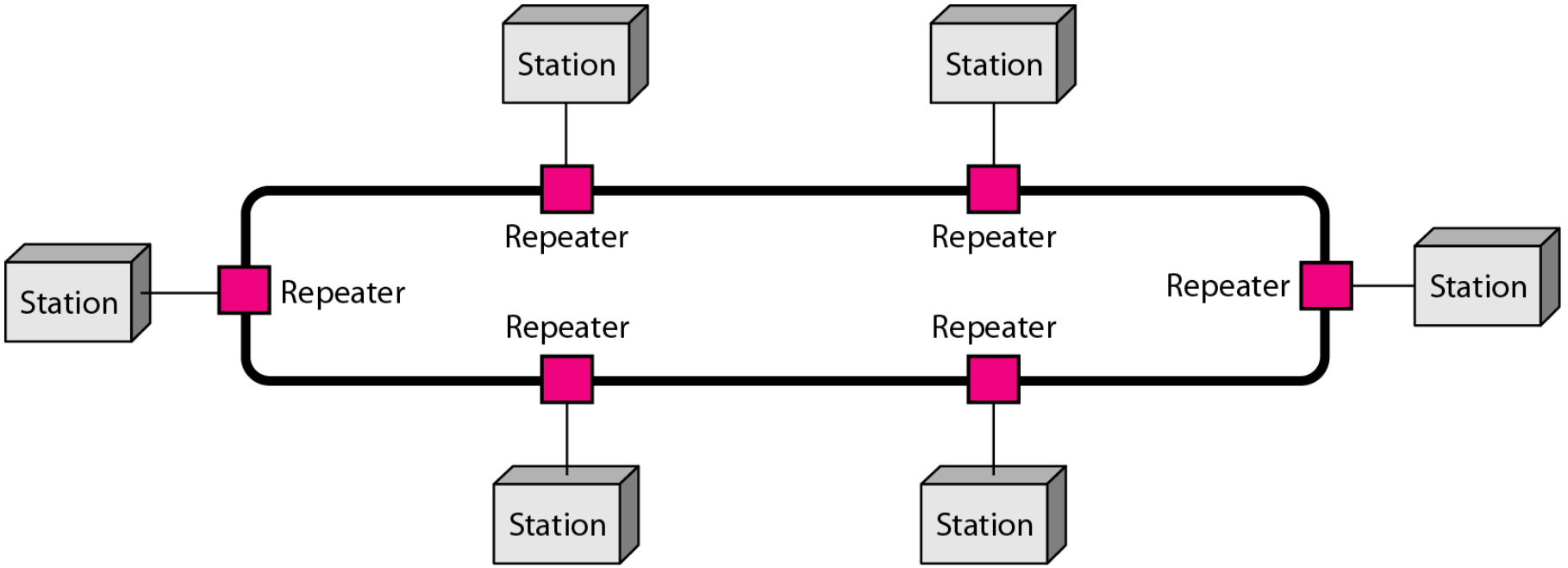
A Bus Topology connecting three stations

Topology: Star



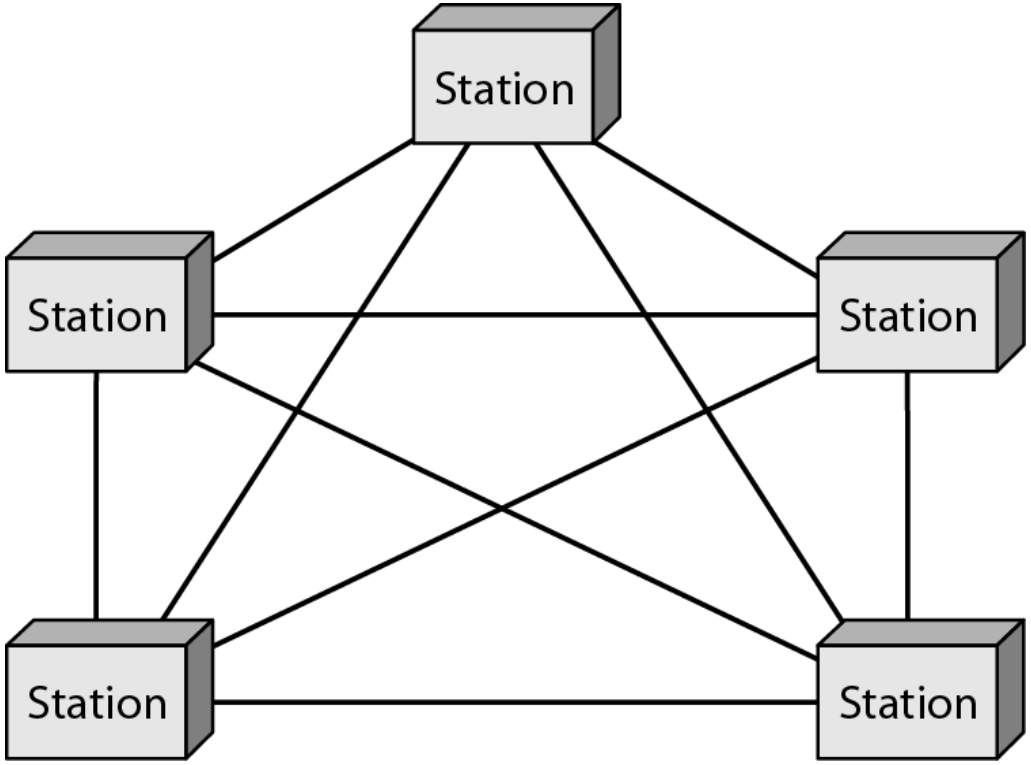
A star topology connecting four stations through a central device (hub)

Topology: Ring



A Ring Topology connecting six stations

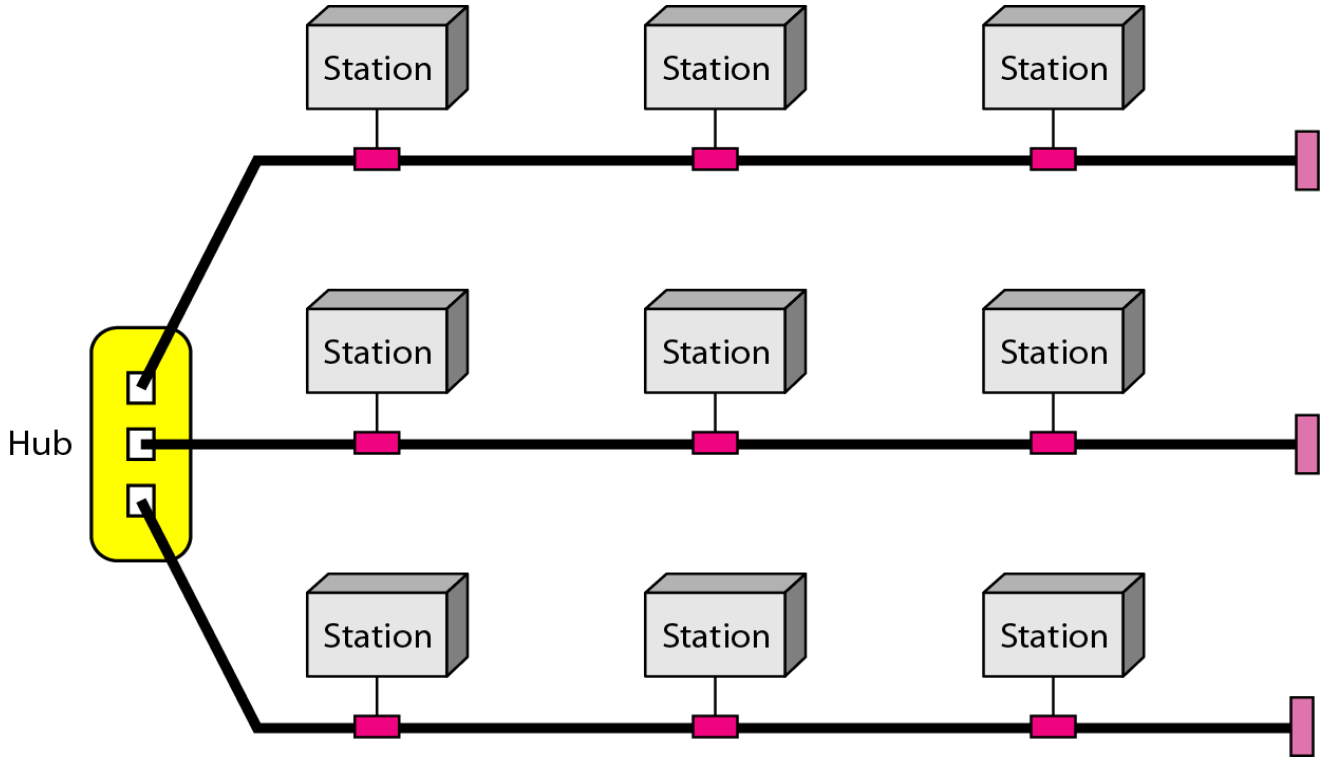
Topology: Fully Connected Mesh



All the stations have a P-to-P link with all other stations in the network

Hybrid Topology

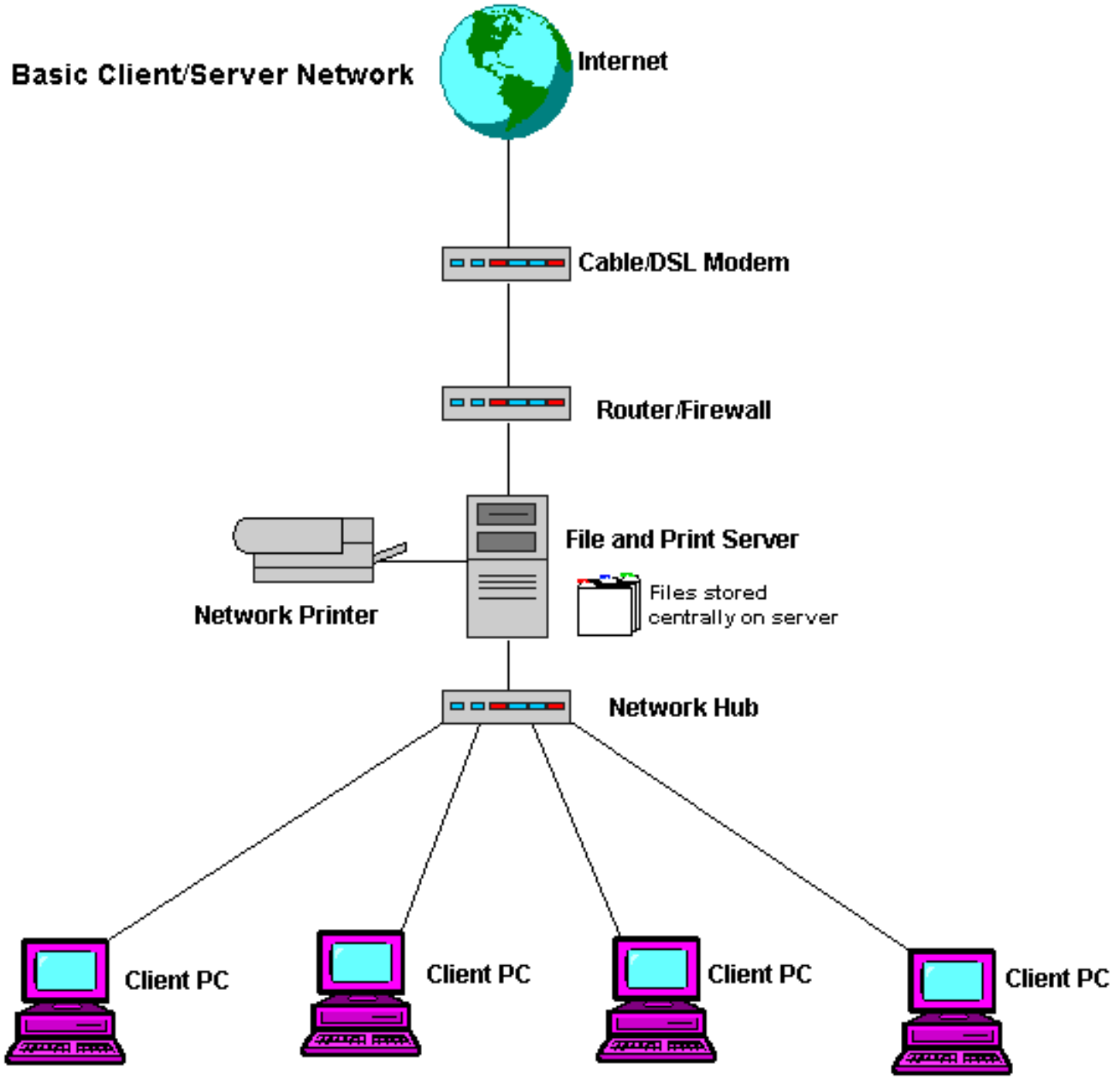
- Topology that is constituted by integrating more than one topology



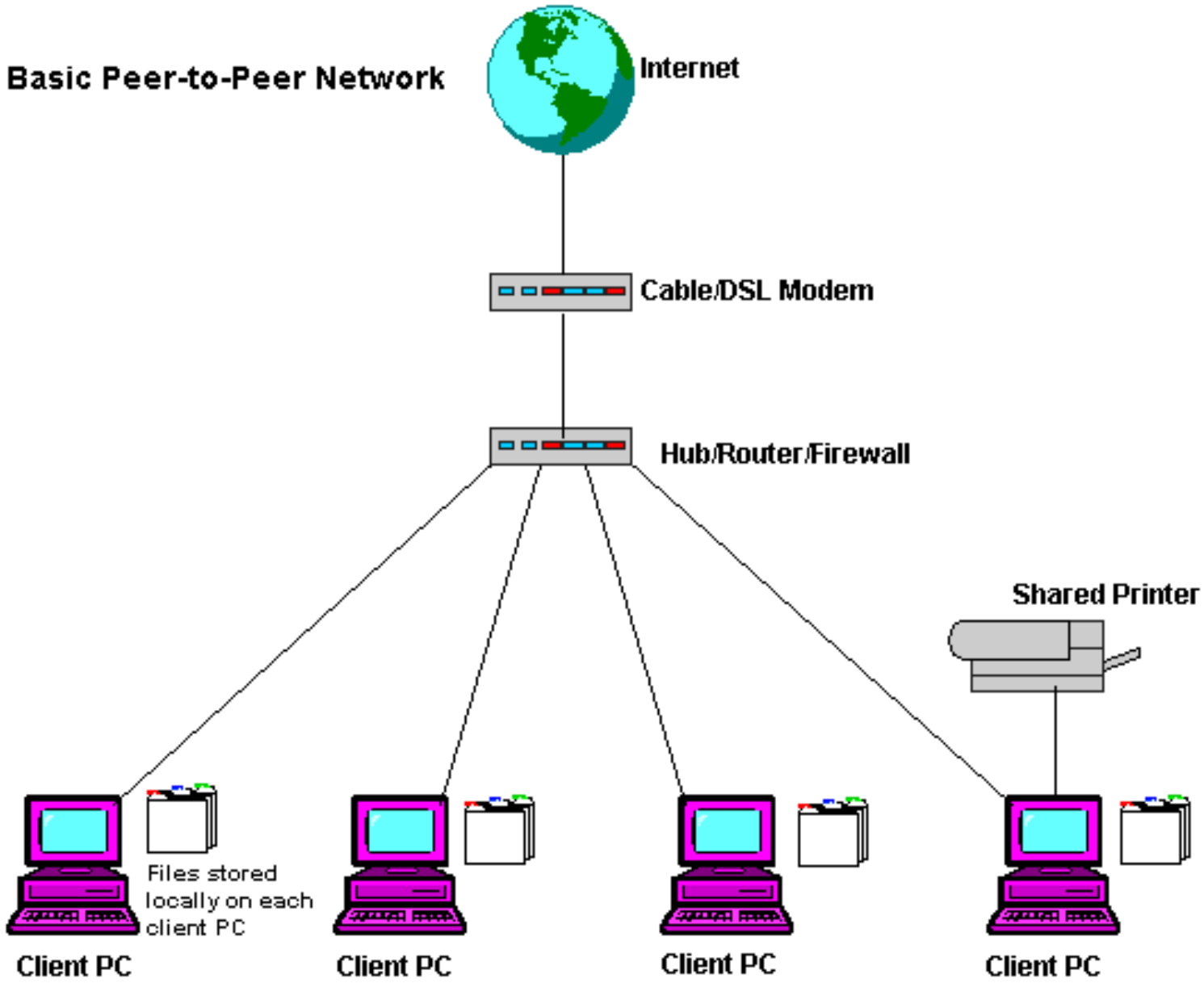
Types of Networks

- Client Server Networks
- Peer To Peer Networks

Client Server Implementation



Peer-to-Peer Networks



Reading Assignment

- Discuss Client/Server and Peer-to-Peer networks with examples. State usage, advantages, disadvantages of each.
- Some types of networks have been discussed like LAN and WAN. You are required to learn about other network configurations including:
  - WAN (Wide Area Network)
  - LAN (Local Area Network)
  - WLAN (Wireless Local Area Network)
  - MAN (Metropolitan Area Network)
  - SAN (Storage Area Network)
  - CAN (Campus/Controlled/Cluster Area Network)
  - PAN (Personal Area Network)

- ***Note: All reading assignments are part of exam***

Network Model

A network is a combination of hardware and software that sends data from one location to another.

The hardware consists of the physical equipment that carries signals from one point of the network to another.

The software consists of instruction sets that make possible the services that we expect from a network.

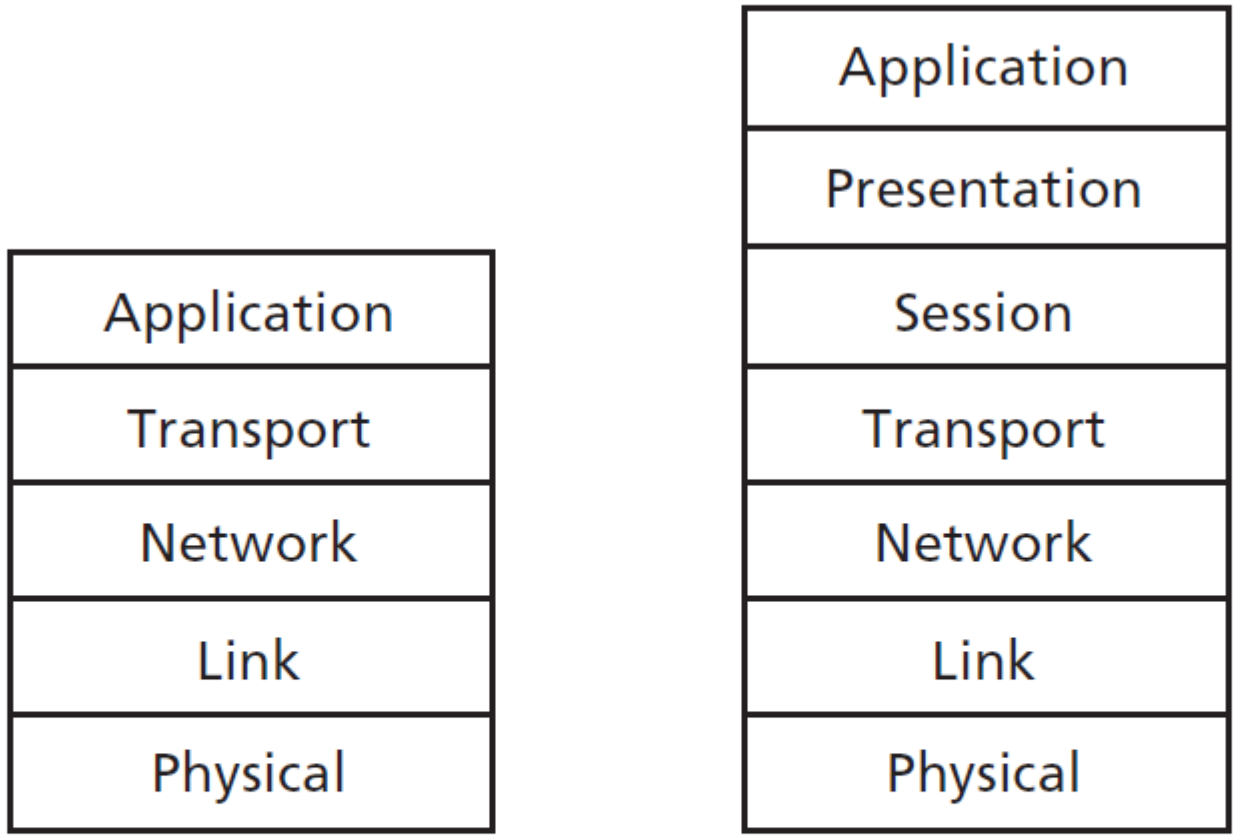
Network Models

OSI Model(Open Systems Interconnection) :

- 7 Layers
- Ideal model
- provide reference to guide vendors and developers.

TCP/IP Model (Transmission Control Protocol/ Internet Protocol)

- 4 Layers, 5 Layer
- Older than OSI Model
- Implemented in most internet standards
- TCP/ IP protocol suite

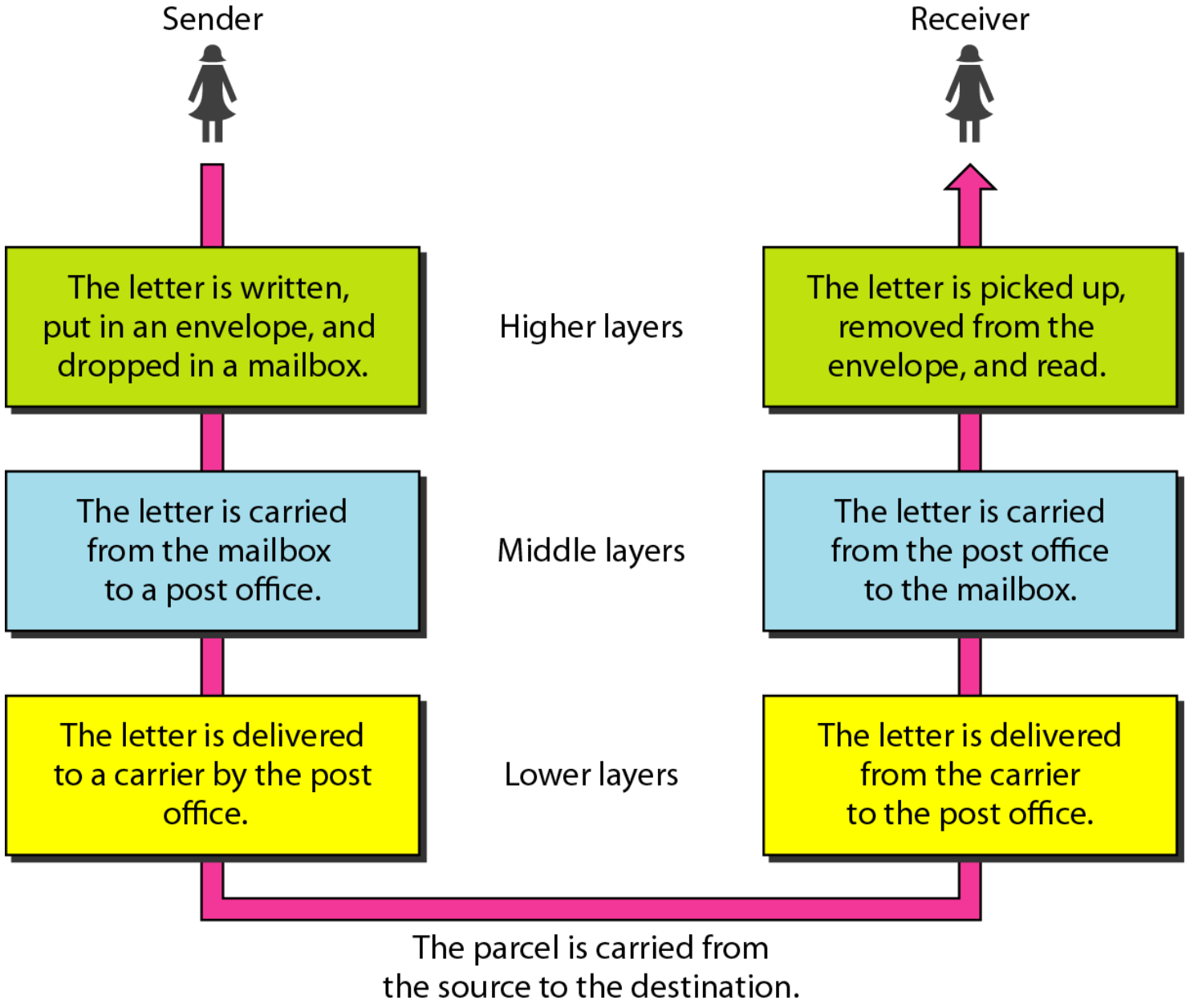


a. Five-layer Internet protocol stack

b. Seven-layer ISO OSI reference model

Figure 1.23 ♦ The Internet protocol stack (a) and OSI reference model (b)

Layered Tasks



OSI Model

In1970s, the International Standards Organization (ISO) introduced an ISO standard Open Systems Interconnection OSI model.

An open system is a set of protocols that allows any two different systems to communicate regardless of their underlying architecture.

The purpose of the OSI model is to show how to facilitate communication between different systems without requiring changes to the logic of the underlying hardware and software.

The OSI model is not a protocol; it is a model for understanding and designing a network architecture that is flexible, robust, and interoperable.

Layered framework for the design of network systems that allows communication between all types of computer systems.

Seven separate but related layers,

Each layers defines a part of the process of moving information across a network.

An understanding of the fundamentals of the OSI model provides a solid basis for exploring data communications.

- Layered Architecture
- Peer to Peer Processes
- Interfaces between Layers
- Encapsulation

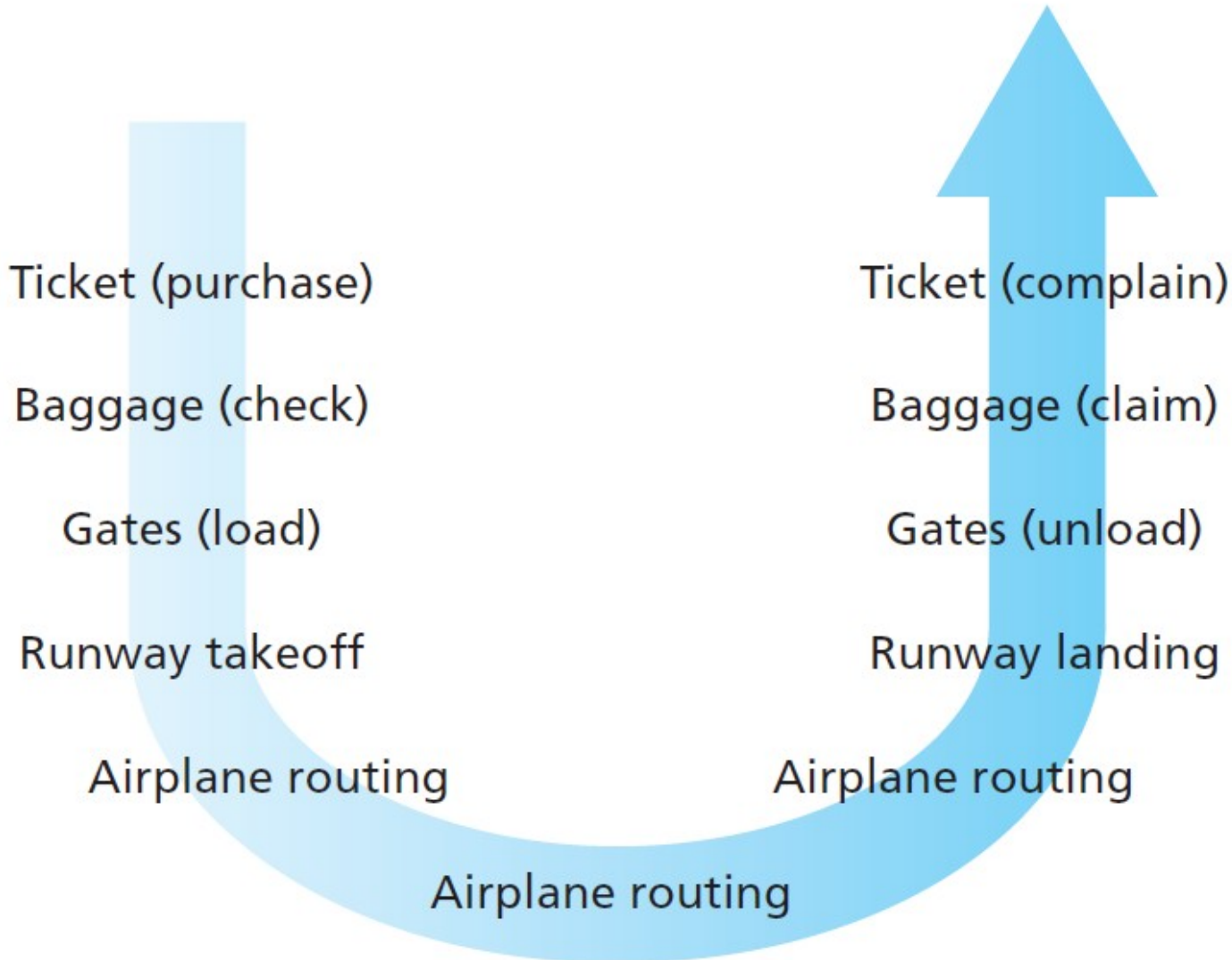
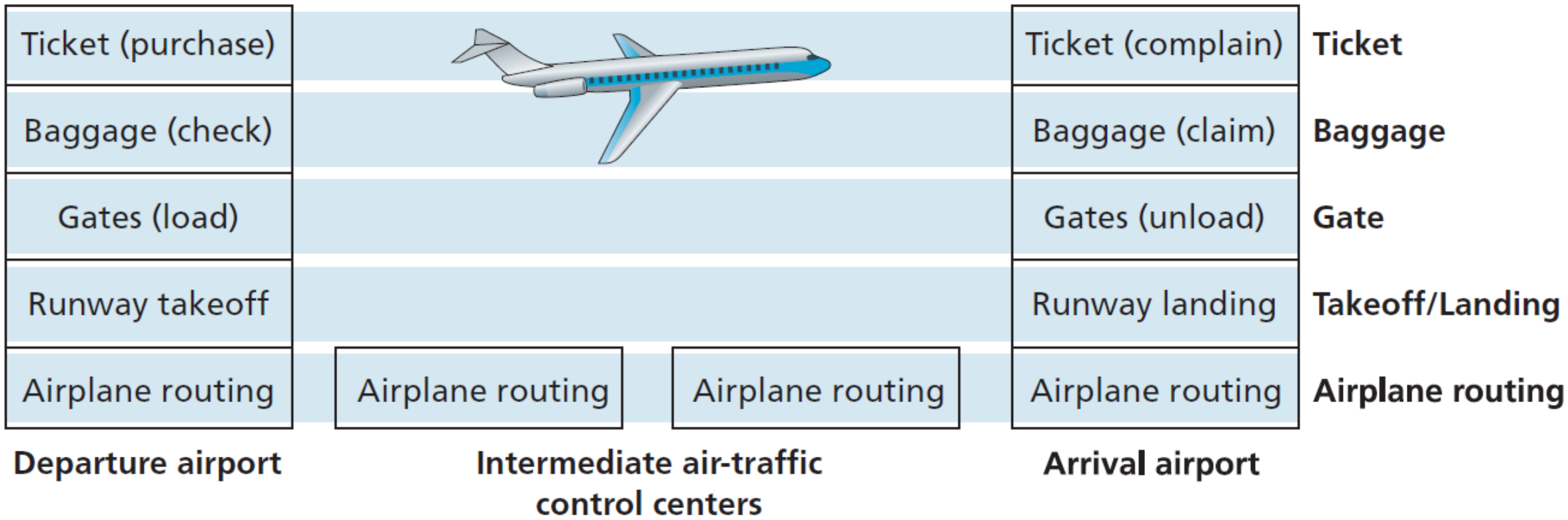


Figure 1.21 ♦ Taking an airplane trip: actions


Ticket (purchase)
Baggage (check)
Gates (load)
Runway takeoff
Airplane routing
Airplane routing
Airplane routing
Ticket (complain)
Baggage (claim)
Gates (unload)
Runway landing
Airplane routing
Ticket
Baggage
Gate
Takeoff/Landing
Airplane routing
Departure airport
Intermediate air-traffic control centers
Arrival airport

Layered Architecture

The OSI model is composed of seven ordered layers: physical (layer 1), data link (layer 2), network (layer 3), transport (layer 4), session (layer 5), presentation (layer 6), and application (layer 7).

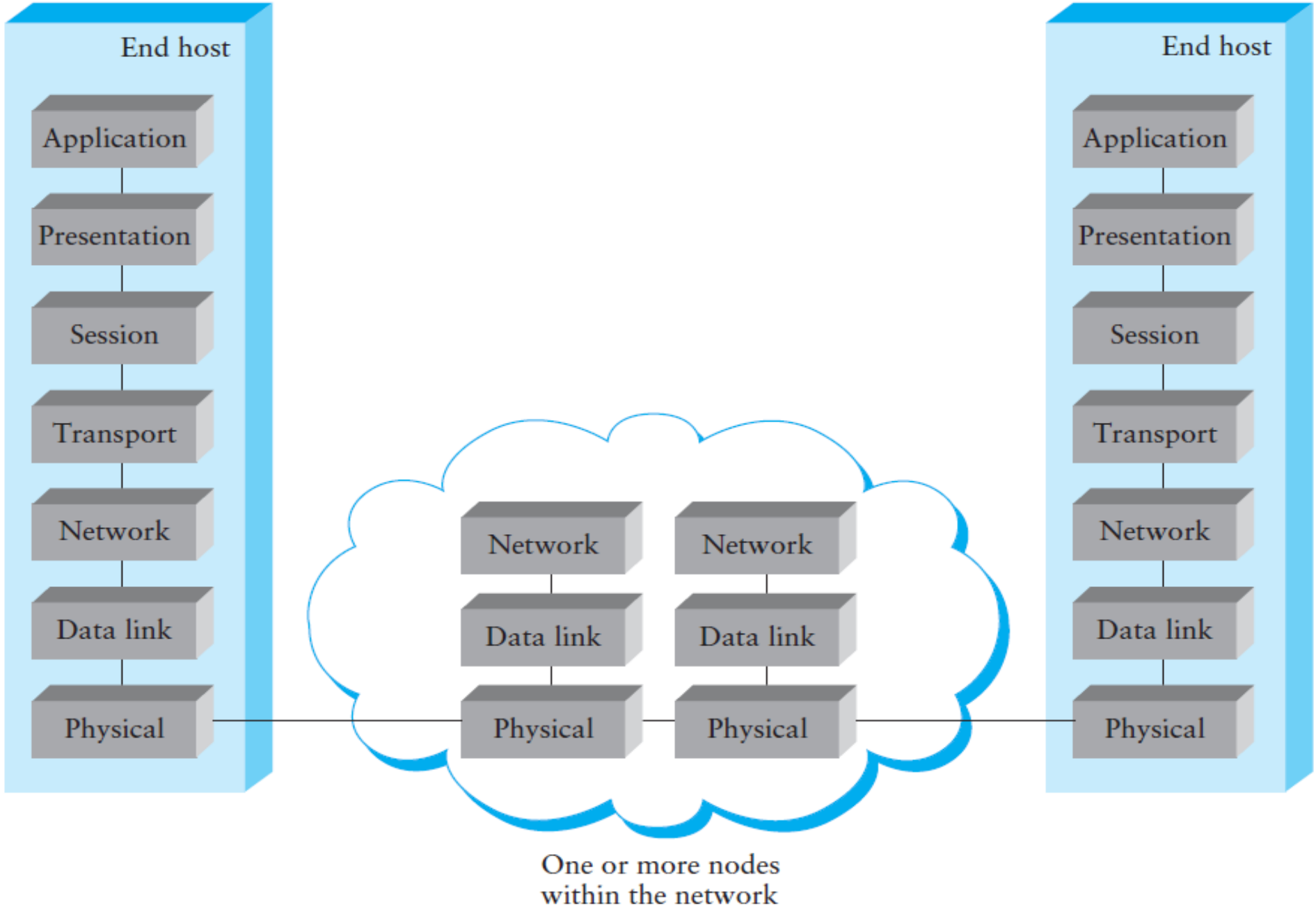
As the message travels from A to B, it may pass through many intermediate nodes.

These intermediate nodes usually involve only the first three layers of the OSI model.

Each layer defines a family of functions distinct from those of the other layers.

Within a single machine, each layer calls upon the services of the layer just below it.

This communication is governed by an agreed-upon series of rules and conventions called protocols.


End host
Application
Presentation
Session
Transport
Network
Data link
Physical
Network
Data link
Physical
Network
Data link
Physical
End host
Application
Presentation
Session
Transport
Network
Data link
Physical
One or more nodes
within the network

7 Layers of the OSI Model

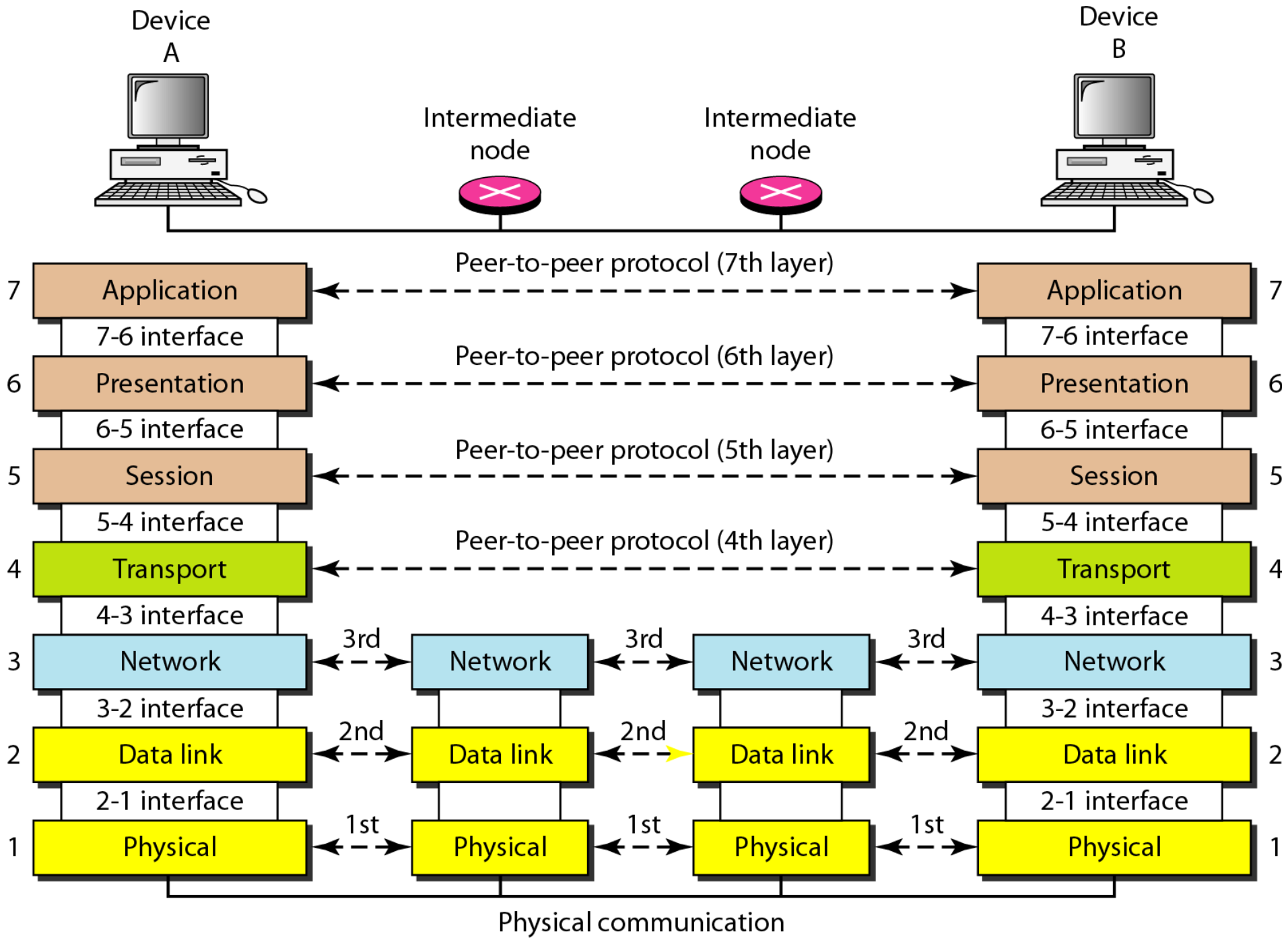
Layer	Responsible For:
7.) Application	Provides Services to User Apps
6.) Presentation	Data Representation
5.) Session	Communication Between Hosts
4.) Transport	Flow Ctrl, Error Detection/Correction
3.) Network	End to End Delivery, Logical Addr
2.) Data Link	Media Access Ctrl, Physical Addr
1.) Physical	Medium, Interfaces, Puts Bits on Med.

Examples

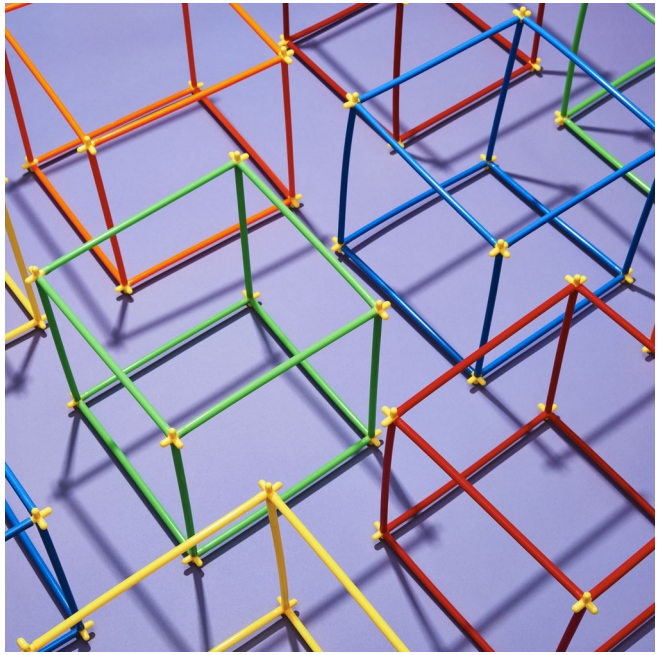
Layer	Example
7.) Application	HTTP, FTP, SMTP
6.) Presentation	ASCII, JPEG, PGP
5.) Session	BOOTP, NetBIOS, DHCP, DNS
4.) Transport	TCP, UDP, SPX
3.) Network	IP, IPX, ICMP
2.) Data Link	Ethernet, Token Ring, Frame Relay
1.) Physical	Bits, Interfaces, Hubs

Peer to Peer Processes

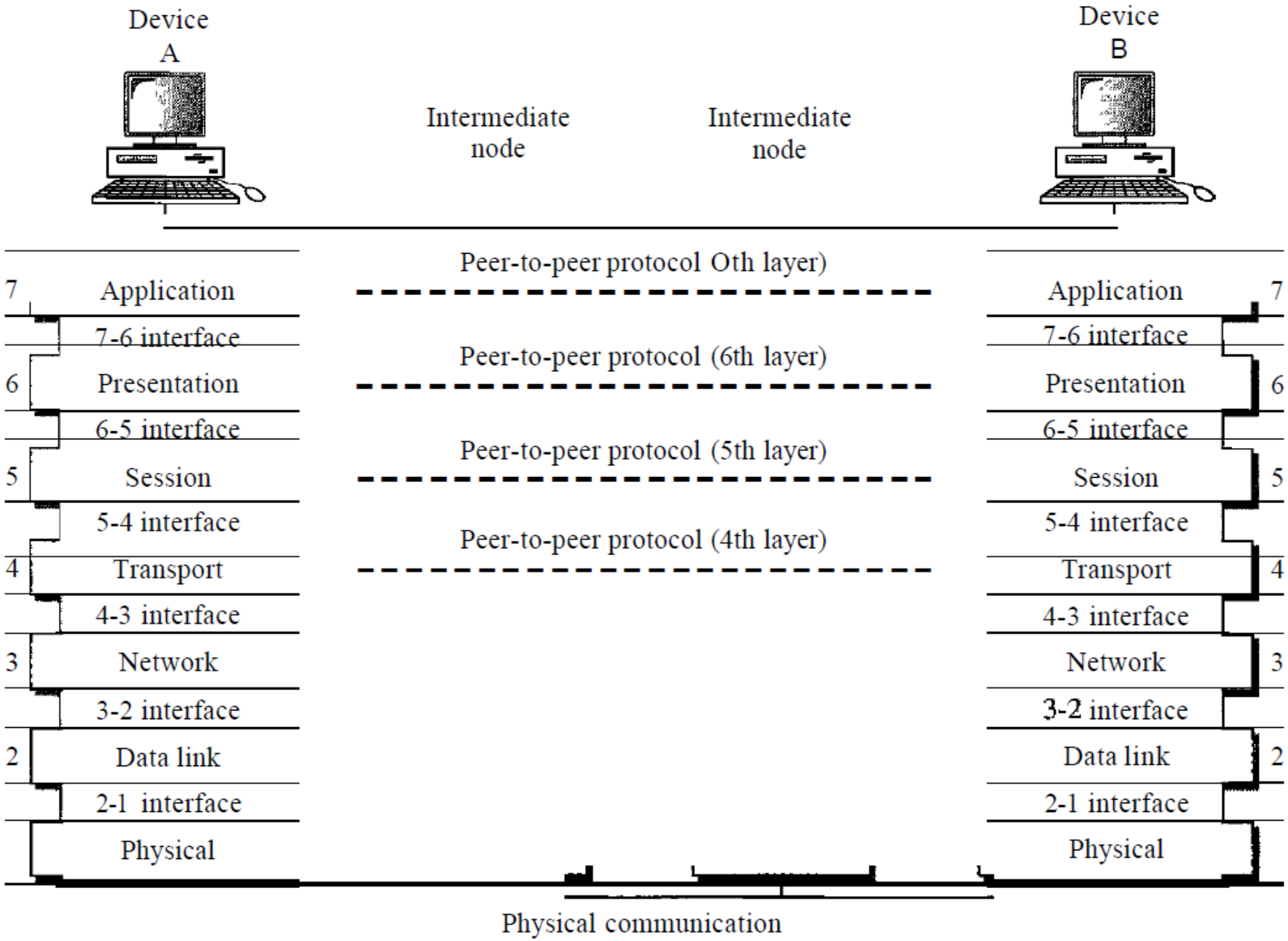
- The processes on each machine that communicate at a given layer are called peer-to-peer processes.
- Communication between machines is therefore a peer-to-peer process using the protocols appropriate to a given layer.
- Each layer in the sending device adds its own information to the message it receives from the layer just above it and passes the whole package to the layer just below it.


Device A
Device B
Intermediate node
Intermediate node
Peer-to-peer protocol (7th layer)
Peer-to-peer protocol (6th layer)
Peer-to-peer protocol (5th layer)
Peer-to-peer protocol (4th layer)
7
Application
7-6 interface
6
Presentation
6-5 interface
5
Session
5-4 interface
4
Transport
4-3 interface
3
Network
3-2 interface
2
Data link
2-1 interface
1
Physical
3rd
2nd
1st
Physical communication

Interfaces between the Layers

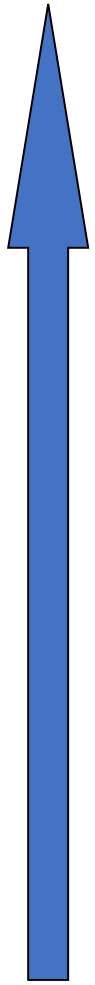


- The passing of the data and network information down through the layers of the sending device and back up through the layers of the receiving device is made possible
- Interface between each pair of adjacent layers.
- Defines the information and services a layer must provide for the layer above it.
- Well-defined interfaces and layer functions provide modularity to a network.
- As long as a layer provides the expected services to the layer above it, the specific implementation of its functions can be modified or replaced without requiring

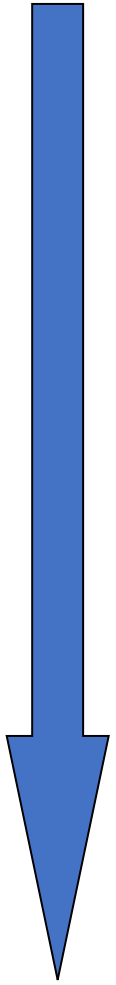

Device A
Device B
Intermediate node
Intermediate node
Peer-to-peer protocol Oth layer)
Peer-to-peer protocol (6th layer)
Peer-to-peer protocol (5th layer)
Peer-to-peer protocol (4th layer)
7 Application
7-6 interface
6 Presentation
6-5 interface
5 Session
5-4 interface
4 Transport
4-3 interface
3 Network
3-2 interface
2 Data link
2-1 interface
Physical
Application 7
7-6 interface
Presentation 6
6-5 interface
Session 5
5-4 interface
Transport 4
4-3 interface
Network 3
3-2 interface
Data link 2
2-1 interface
Physical
Physical communication

PDU’s And the OSI Model

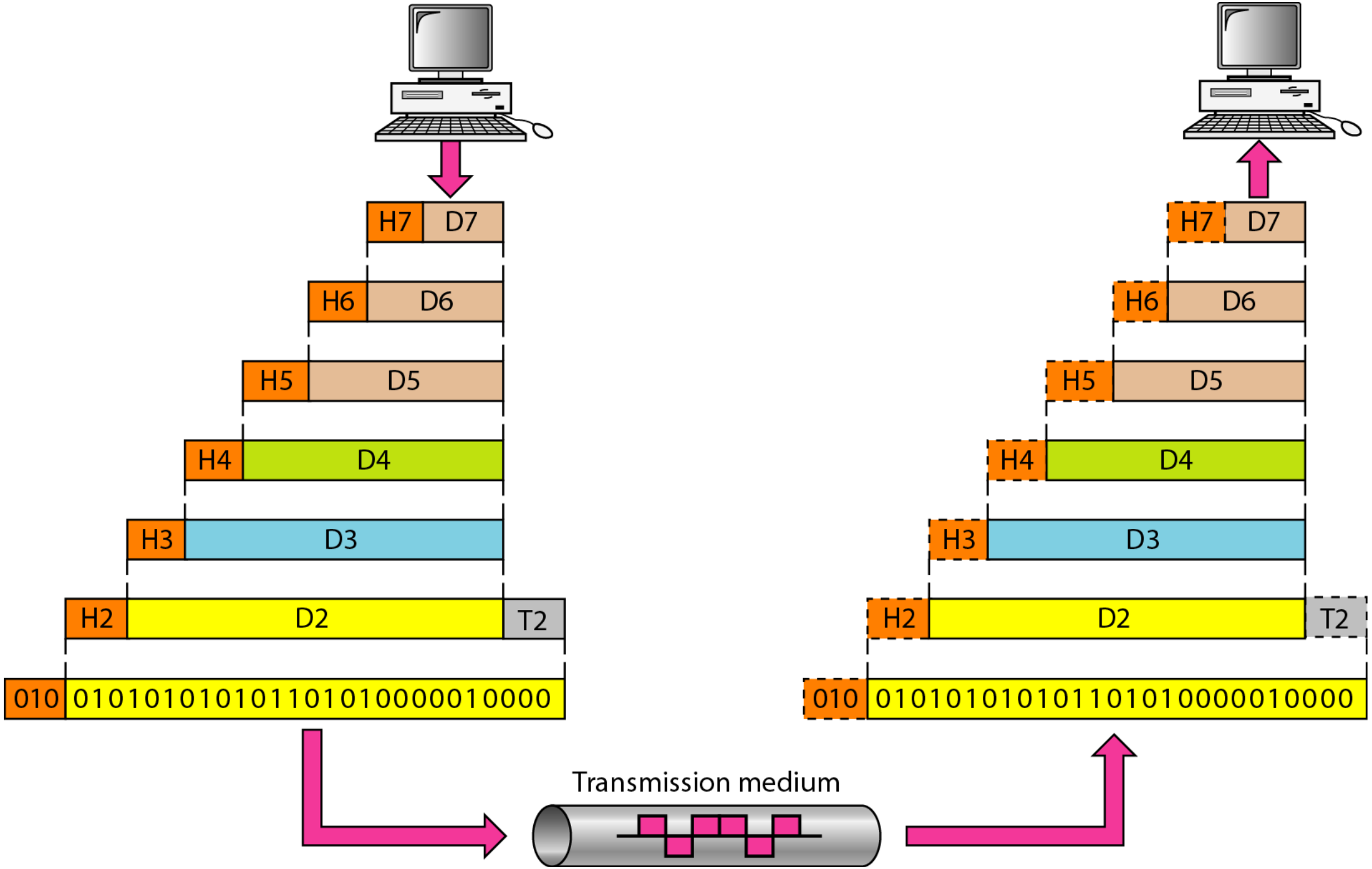
Decapsulation



Layer	PDU Name
7.) Application	Data
6.) Presentation	Data
5.) Session	Data
4.) Transport	Segment
3.) Network	Packet
2.) Data Link	Frame
1.) Physical	Bits



Encapsulation


H7
D7
H6
D6
H5
D5
H4
D4
H3
D3
H2
D2
T2
010
0101010101011010100000010000
Transmission medium
H7
D7
H6
D6
H5
D5
H4
D4
H3
D3
H2
D2
T2
010
0101010101011010100000010000

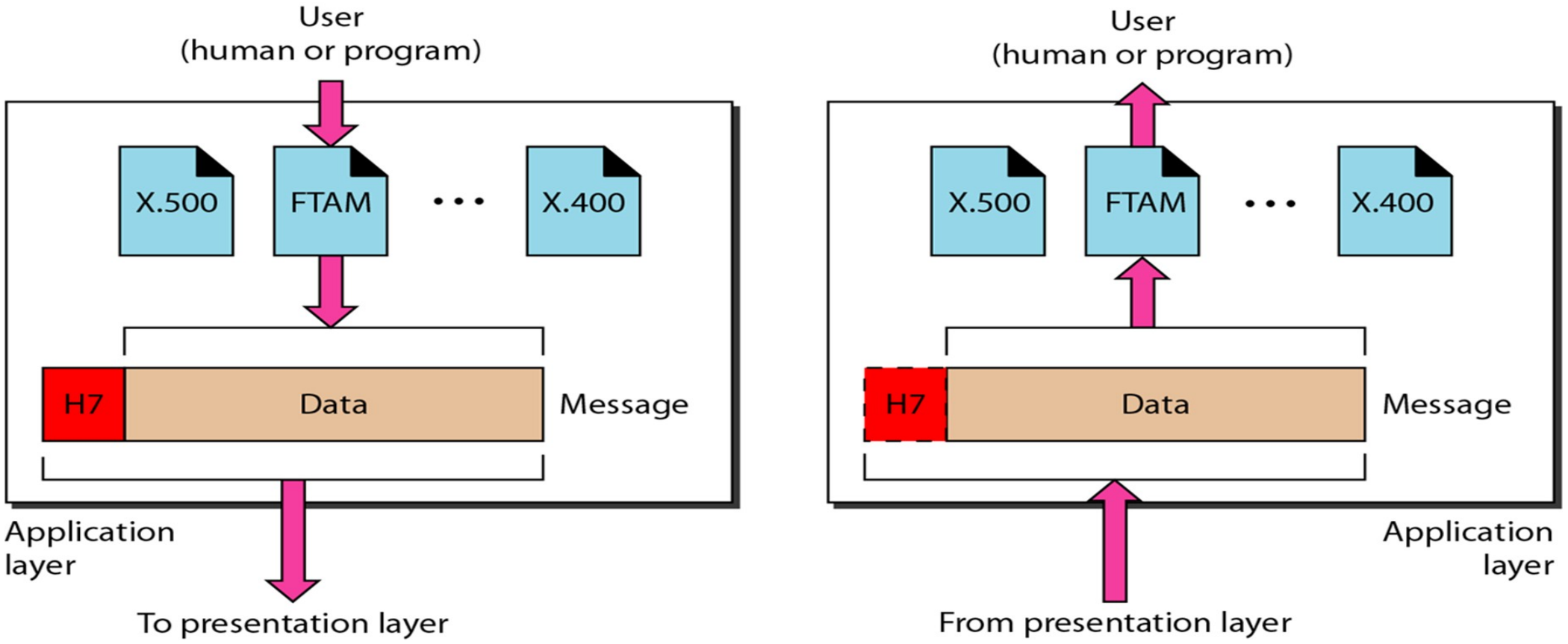
Layer 7 – Application Layer

- The application layer enables the user, whether human or software, to access the network.
- It provides user interfaces and support for services such as electronic mail, remote file access and transfer, shared database management, and other types of distributed information services.
- The application layer is responsible for providing services to the user.

- **Network virtual terminal:** A network virtual terminal is a software version of a physical terminal, and it allows a user to log on to a remote host. To do so, the application creates a software emulation of a terminal at the remote host. The user's computer talks to the software terminal which, in turn, talks to the host, and vice versa. The remote host believes it is communicating with one of its own terminals and allows the user to log on.
- **File transfer, access, and management:** This application allows a user to access files in a remote host (to make changes or read data), to retrieve files from a remote computer for use in the local computer, and to manage or control files in a remote computer locally.
- **Mail services:** This application provides the basis for e-mail forwarding and storage.
- **Directory services:** This application provides distributed database sources and access for global information about various objects and services.

Layer 6 – Presentation Layer

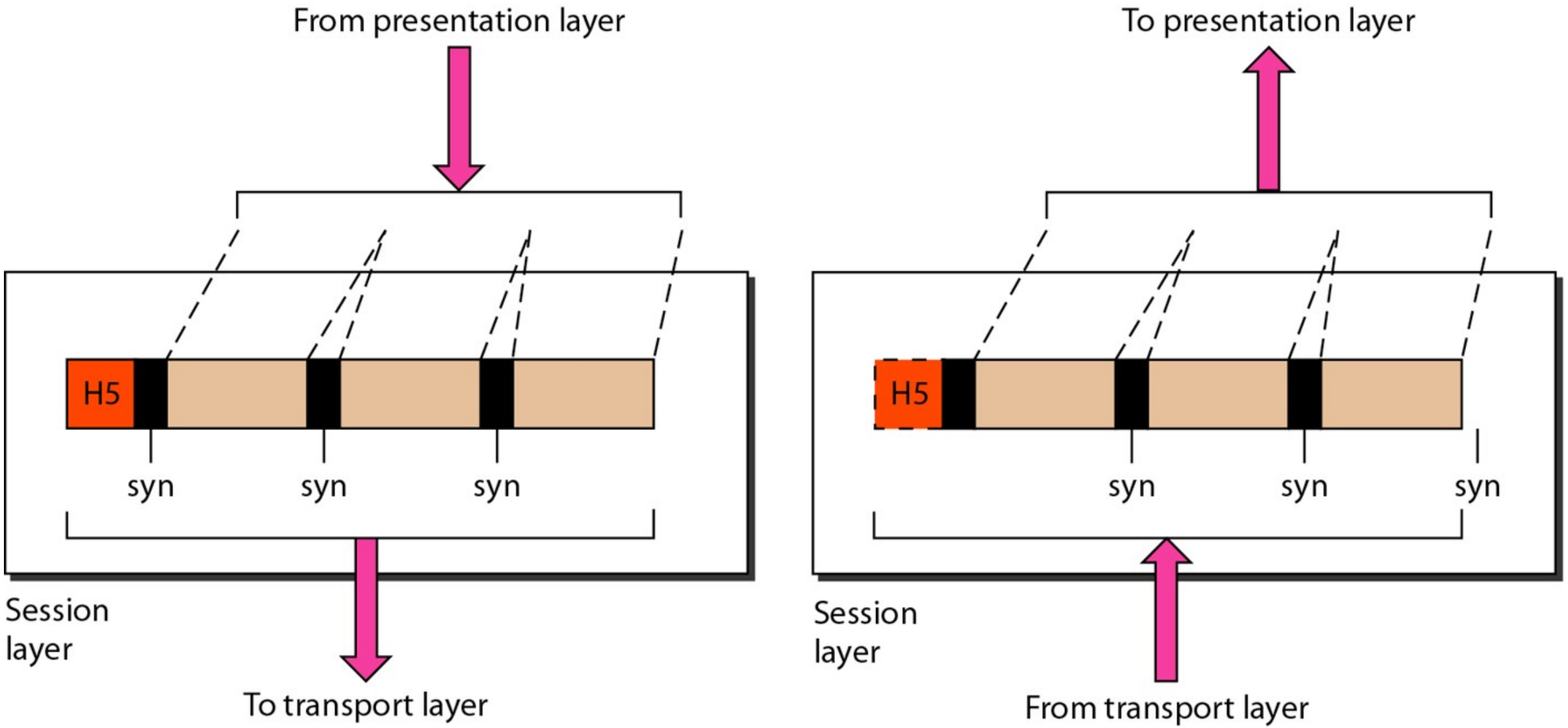
- The presentation layer is concerned with the syntax and semantics of the information exchanged between two systems.



- **Translation:** Because different computers use different encoding systems, the presentation layer is responsible for interoperability between these different encoding methods. The presentation layer at the sender changes the information from its sender-dependent format into a common format. The presentation layer at the receiving machine changes the common format into its receiver-dependent format.
- **Encryption:** To carry sensitive information, a system must be able to ensure privacy. Encryption means that the sender transforms the original information to another form and sends the resulting message out over the network. Decryption reverses the original process to transform the message back to its original form.
- **Compression:** Data compression reduces the number of bits contained in the information. Data compression becomes particularly important in the transmission of multimedia such as text, audio, and video.

Layer 5 – Session Layer

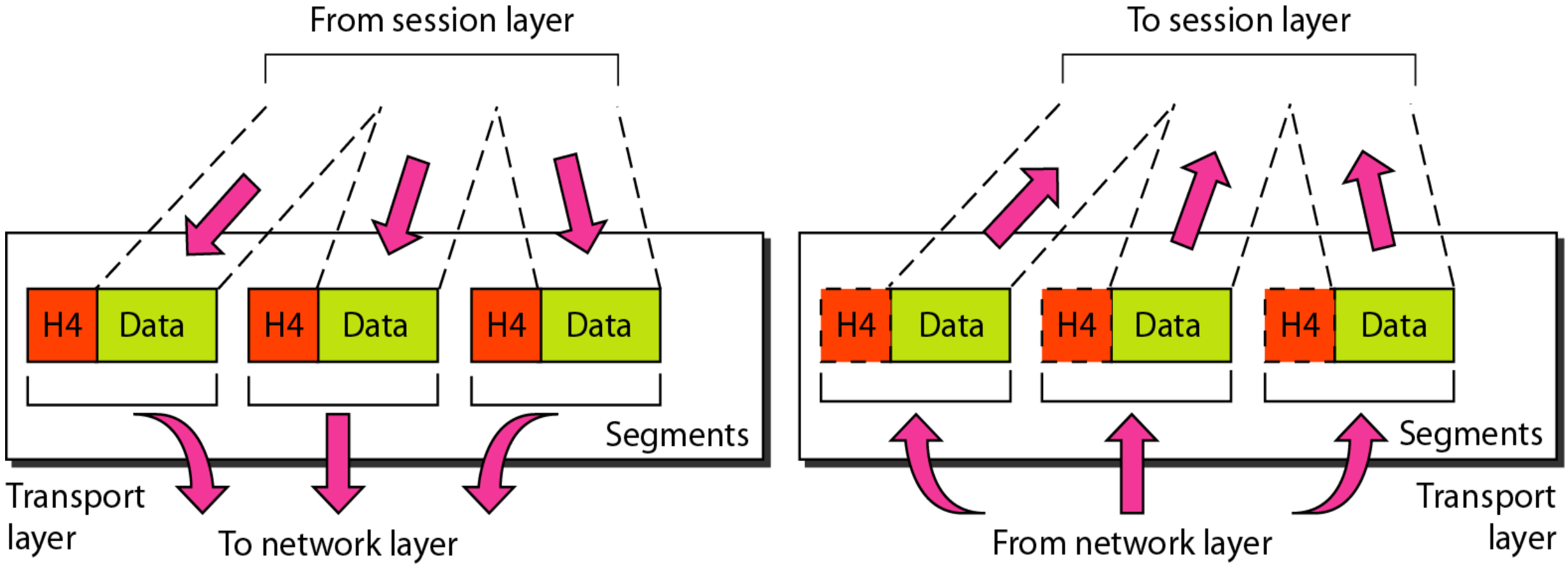
- The session layer is responsible for dialog control and synchronization.
- The session layer is the network *dialog controller.*
- It establishes, maintains, and synchronizes the interaction among communicating systems.


From presentation layer
H5
syn
syn
syn
Session
layer
To transport layer
To presentation layer
H5
syn
syn
syn
Session
layer
From transport layer

- **Dialog control:** The session layer allows two systems to enter into a dialog. It allows the communication between two processes to take place in either half-duplex (one way at a time) or full-duplex (two ways at a time) mode.
- **Synchronization:** The session layer allows a process to add checkpoints, or synchronization points, to a stream of data. For example, if a system is sending a file of 2000 pages, it is advisable to insert checkpoints after every 100 pages to ensure that each 100-page unit is received and acknowledged independently. In this case, if a crash happens during the transmission of page 523, the only pages that need to be resent after system recovery are pages 501 to 523. Pages previous to 501 need not be resent.

Layer 4 – Transport Layer

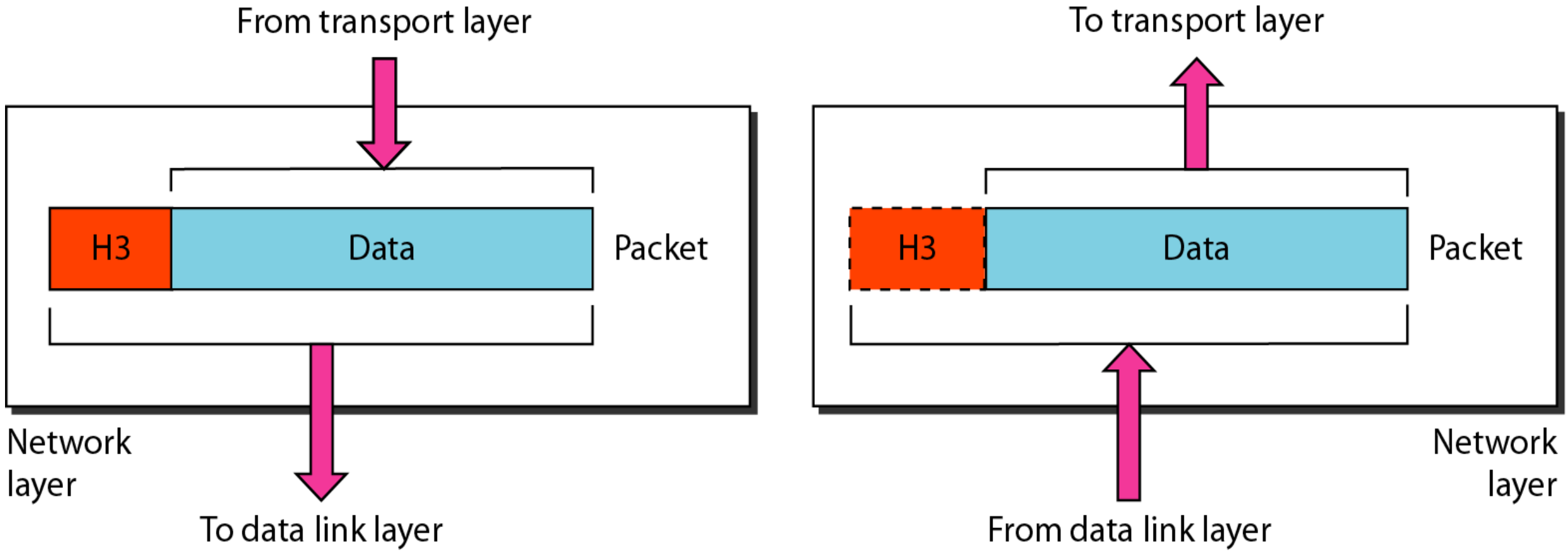
- The transport layer is responsible for process-to-process delivery of the entire message.
- A process is an application program running on a host.
- Whereas the network layer oversees source-to-destination delivery of individual packets, it does not recognize any relationship between those packets. It treats each one independently, as though each piece belonged to a separate message, whether or not it does.
- The transport layer, on the other hand, ensures that the whole message arrives intact and in order, overseeing both error control and flow control at the source-to-destination level.


From session layer
H4
Data
H4
Data
H4
Data
Segments
Transport layer
To network layer
To session layer
H4
Data
H4
Data
H4
Data
Segments
From network layer
Transport layer

- **Service-point addressing:** Source-to-destination delivery means delivery not only from one computer to the next but also from a specific process (running program) on one computer to a specific process (running program) on the other. The transport layer header must therefore include a type of address called a ***service-point address*** (or port address). The network layer gets each packet to the correct computer; the transport layer gets the entire message to the correct process on that computer.
- **Segmentation and reassembly:** A message is divided into transmittable segments, with each segment containing a sequence number. These numbers enable the transport layer to reassemble the message correctly upon arriving at the destination and to identify and replace packets that were lost in transmission.
- **Connection control:** The transport layer can be either connectionless(UDP) or connection oriented(TCP).
- **Flow control:** Like the data link layer, the transport layer is responsible for flow control. However, flow control at this layer is performed end to end rather than across a single link.
- **Error control:** Like the data link layer, the transport layer is responsible for error control. However, error control at this layer is performed process-to-process rather than across a single link. Error correction is usually achieved through retransmission.

Layer 3 – Network Layer

- The network layer is responsible for the delivery of individual packets from the source host to the destination host.
- If two systems are connected to the same link, there is usually no need for a network layer. However, if the two systems are attached to different networks (links) with connecting devices between the networks (links), there is often a need for the network layer to accomplish source-to-destination delivery.

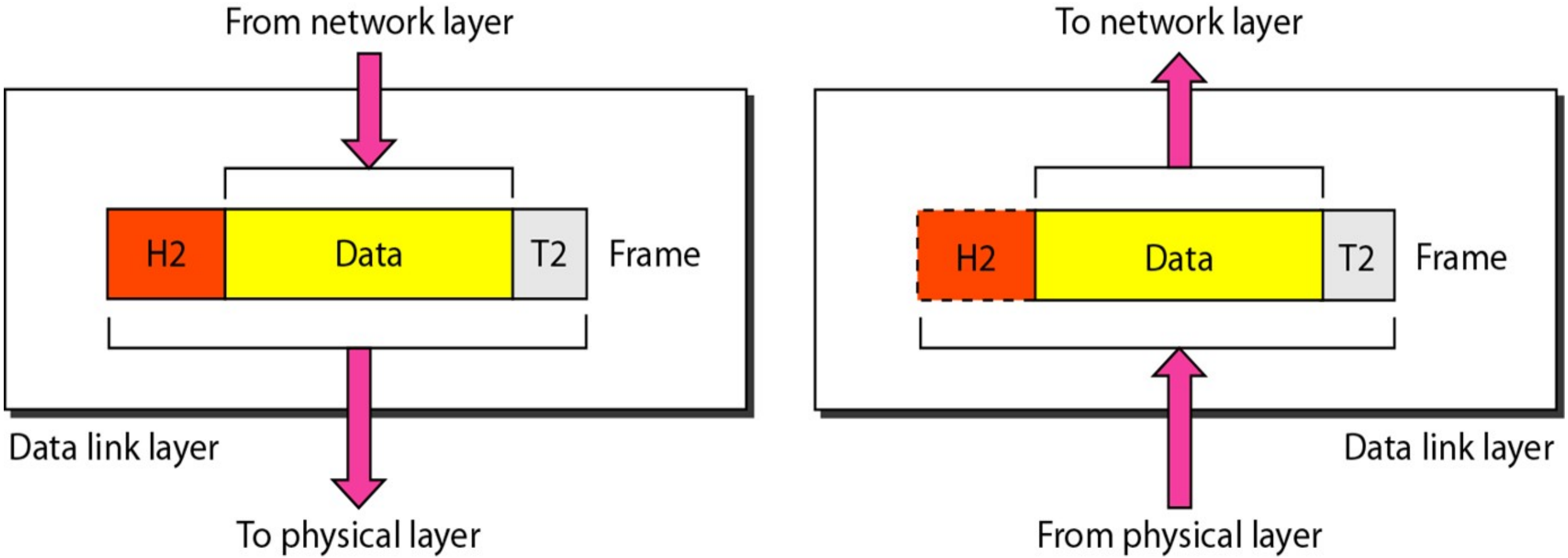

From transport layer
H3
Data
Packet
Network layer
To data link layer
To transport layer
H3
Data
Packet
Network layer
From data link layer

- The network Layer controls the operation of the subnet. The main aim of this layer is to deliver packets from source to destination across multiple links (networks). If two computers (system) are connected on the same link, then there is no need for a network layer. It routes the signal through different channels to the other end and acts as a network controller.
- It also divides the outgoing messages into packets and to assemble incoming packets into messages for higher levels.
- In broadcast networks, the routing problem is simple, so the network layer is often thin or even non-existent.

1. It translates logical network address into physical address. Concerned with circuit, message or packet switching.
2. Routers and gateways operate in the network layer. Mechanism is provided by Network Layer for routing the packets to final destination.
3. Connection services are provided including network layer flow control, network layer error control and packet sequence control.
4. Breaks larger packets into small packets.

Layer 2 – Data Link Layer

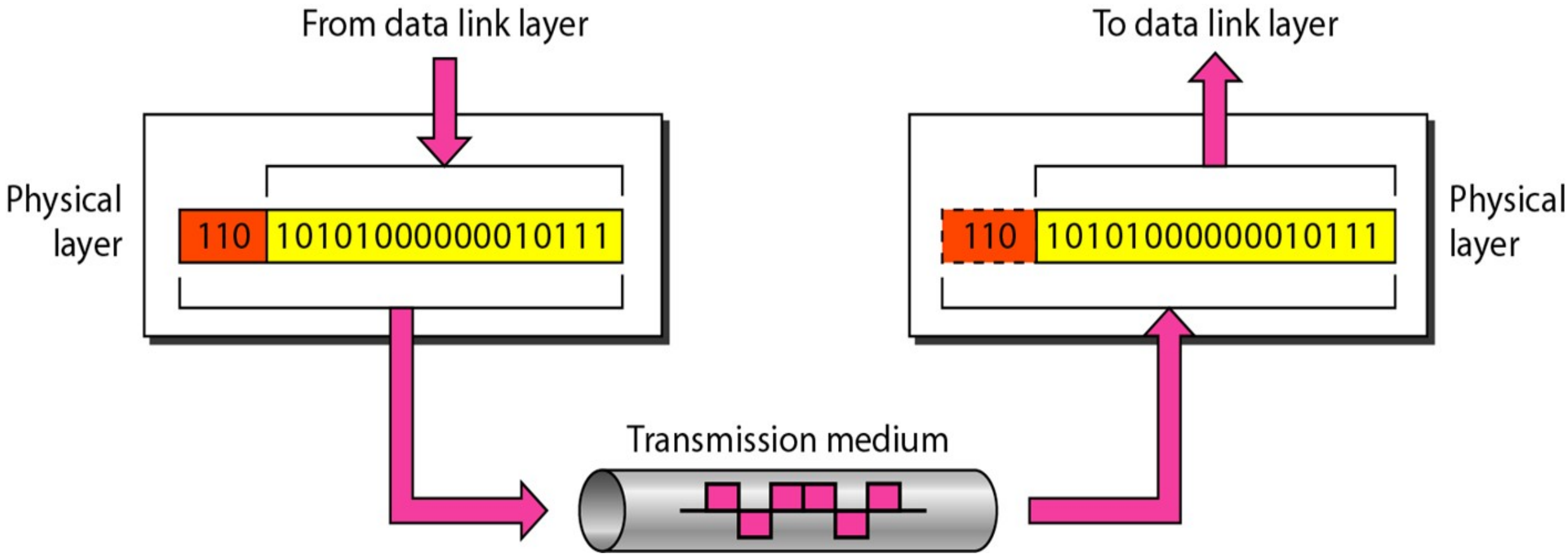
- The data link layer transforms the physical layer, a raw transmission facility, to a reliable link.
- It makes the physical layer appear error free to the upper layer (network layer).
- The data link layer is responsible for moving frames from one hop (node) to the next.


From network layer
H2
Data
T2
Frame
Data link layer
To physical layer
To network layer
H2
Data
T2
Frame
Data link layer
From physical layer

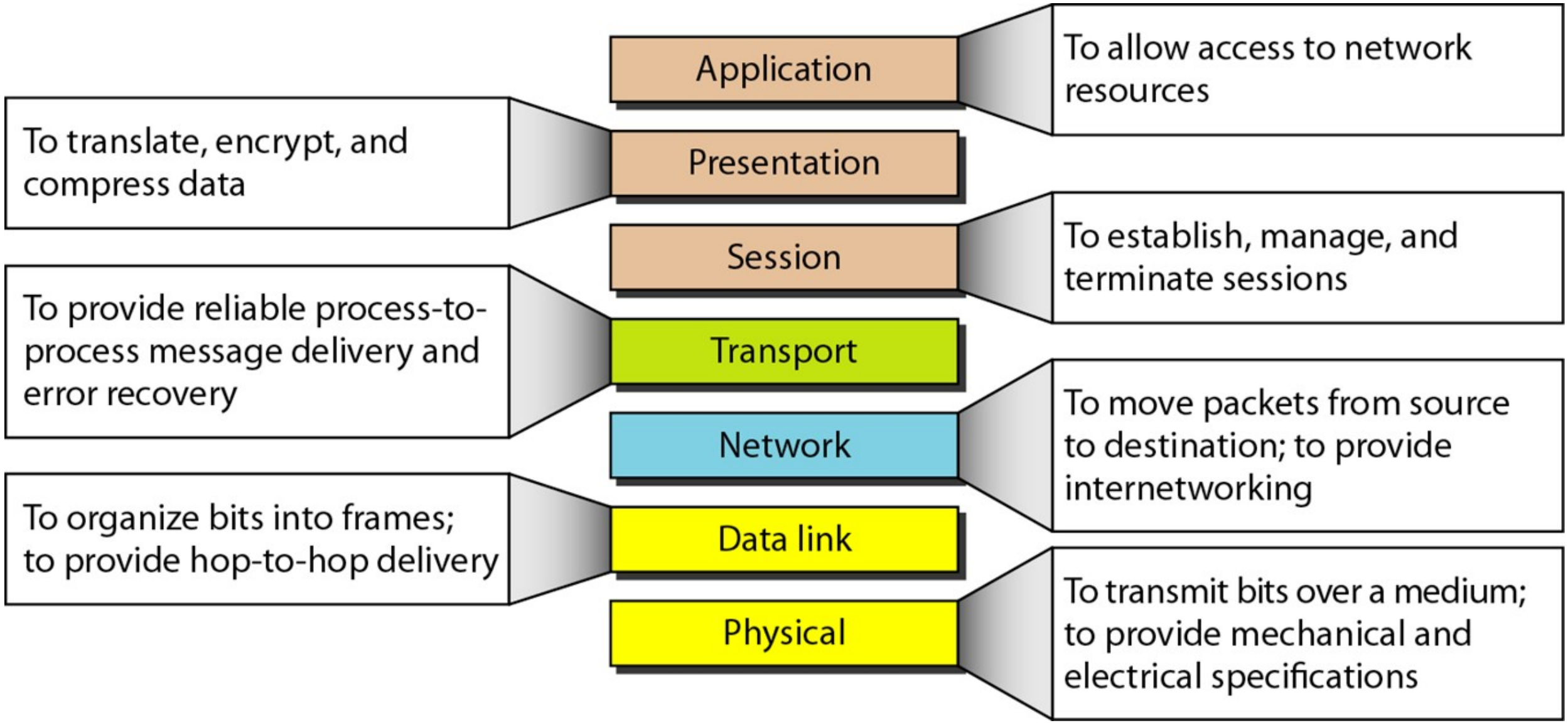
- **Framing:** Divides the stream of bits received from the network layer into manageable data units called frames.
- **Physical addressing:** If frames are to be distributed to different systems on the network, the data link layer adds a header to the frame to define the sender and/or receiver of the frame. If the frame is intended for a system outside the sender’s network, the receiver address is the address of the device that connects the network to the next one.
- **Flow control:** If the rate at which the data are absorbed by the receiver is less than the rate at which data are produced in the sender, the data link layer imposes a flow control mechanism to avoid overwhelming the receiver.
- **Error control:** Adds reliability to the physical layer by adding mechanisms to detect and retransmit damaged or lost frames. Uses a mechanism to recognize duplicate frames. Error control is normally achieved through a trailer added to the end of the frame.
- **Access control:** When two or more devices are connected to the same link, data link layer protocols are necessary to determine which device has control over the link at any given time.

Layer 1 – Physical Layer

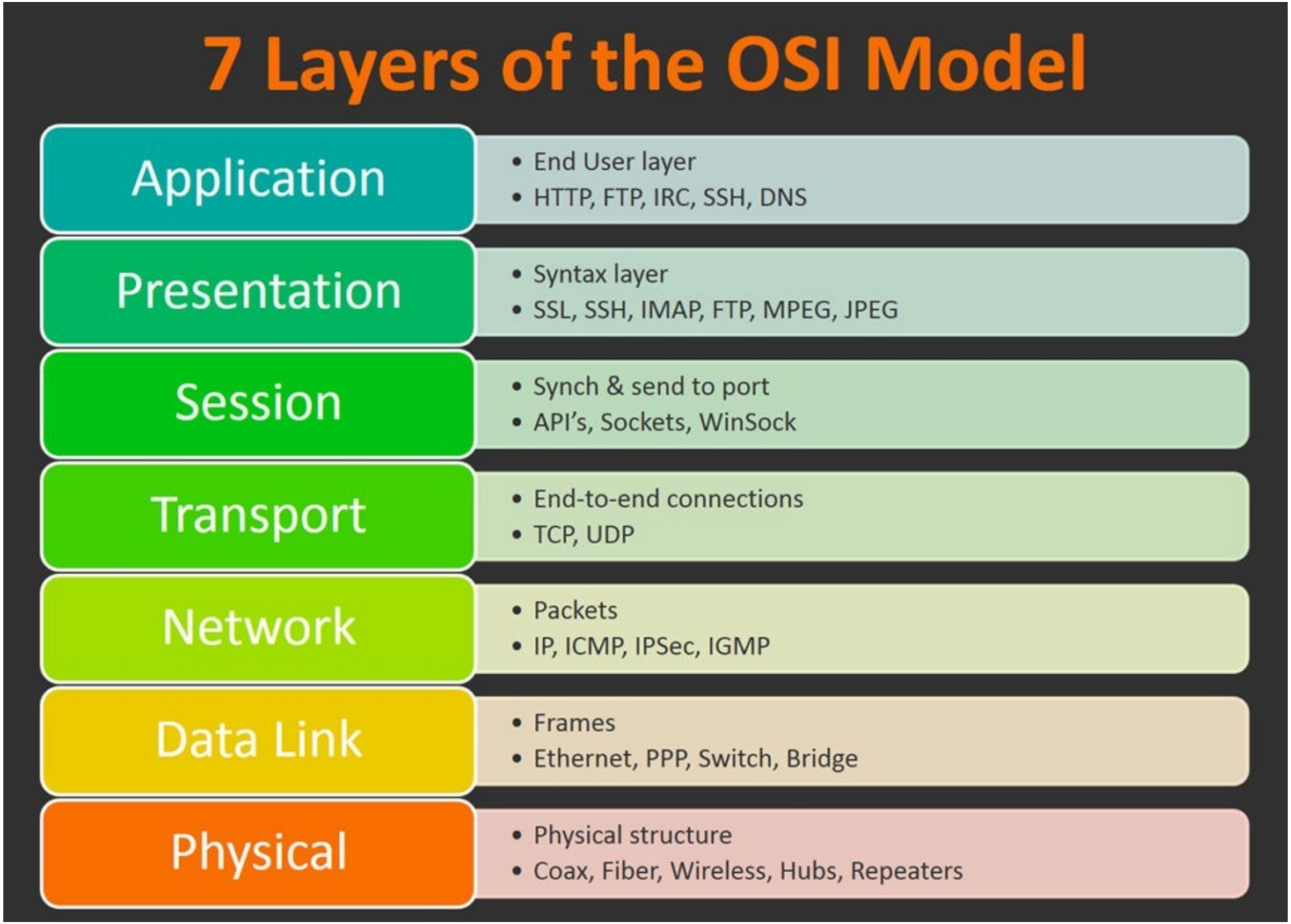
- Coordinates the functions required to carry a bit stream over a physical medium.
- Deals with the mechanical and electrical specifications of the interface and transmission medium.
- Also defines the procedures and functions that physical devices and interfaces have to perform for transmission to occur.
- Provides services to the upper layer(data link layer).
- The physical layer is responsible for movements of individual bits from one hop (node) to the next.


From data link layer
To data link layer
Physical layer
110
1010100000010111
110
1010100000010111
Physical layer
Transmission medium

- **Physical characteristics of interfaces and medium**: Interface between the devices and the transmission medium. It also defines the type of transmission medium.
- **Representation of bits**: The physical layer data consists of a stream of bits sequence of (0s or 1s) with no interpretation. To be transmitted, bits must be encoded into signals--electrical or optical. Defines the type of encoding.
- **Data rate:** The transmission rate-the number of bits sent each second.
- **Synchronization of bits:** The sender and receiver not only must use the same bit rate but also must be synchronized at the bit level. In other words, the sender and the receiver clocks must be synchronized.
- **Line configuration:** concerned with the connection of devices to the media (point-to-point, multipoint).
- **Physical topology:** The physical topology defines how devices are connected to make a network. mesh topology, a star topology , a ring topology, a bus topology or a hybrid topology.
- **Transmission mode:** The physical layer also defines the direction of transmission between two devices: simplex, half-duplex, or full-duplex.

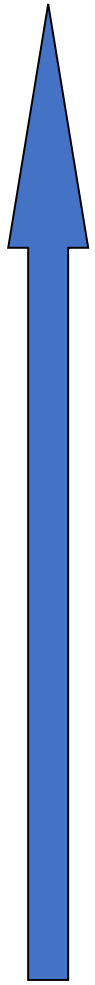

Application
To allow access to network resources
Presentation
To translate, encrypt, and compress data
Session
To establish, manage, and terminate sessions
Transport
To provide reliable process-to-process message delivery and error recovery
Network
To move packets from source to destination; to provide internetworking
Data link
To organize bits into frames; to provide hop-to-hop delivery
Physical
To transmit bits over a medium; to provide mechanical and electrical specifications

7 Layers of the OSI Model

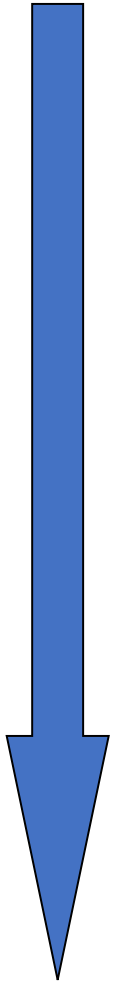


PDU’s And the OSI Model

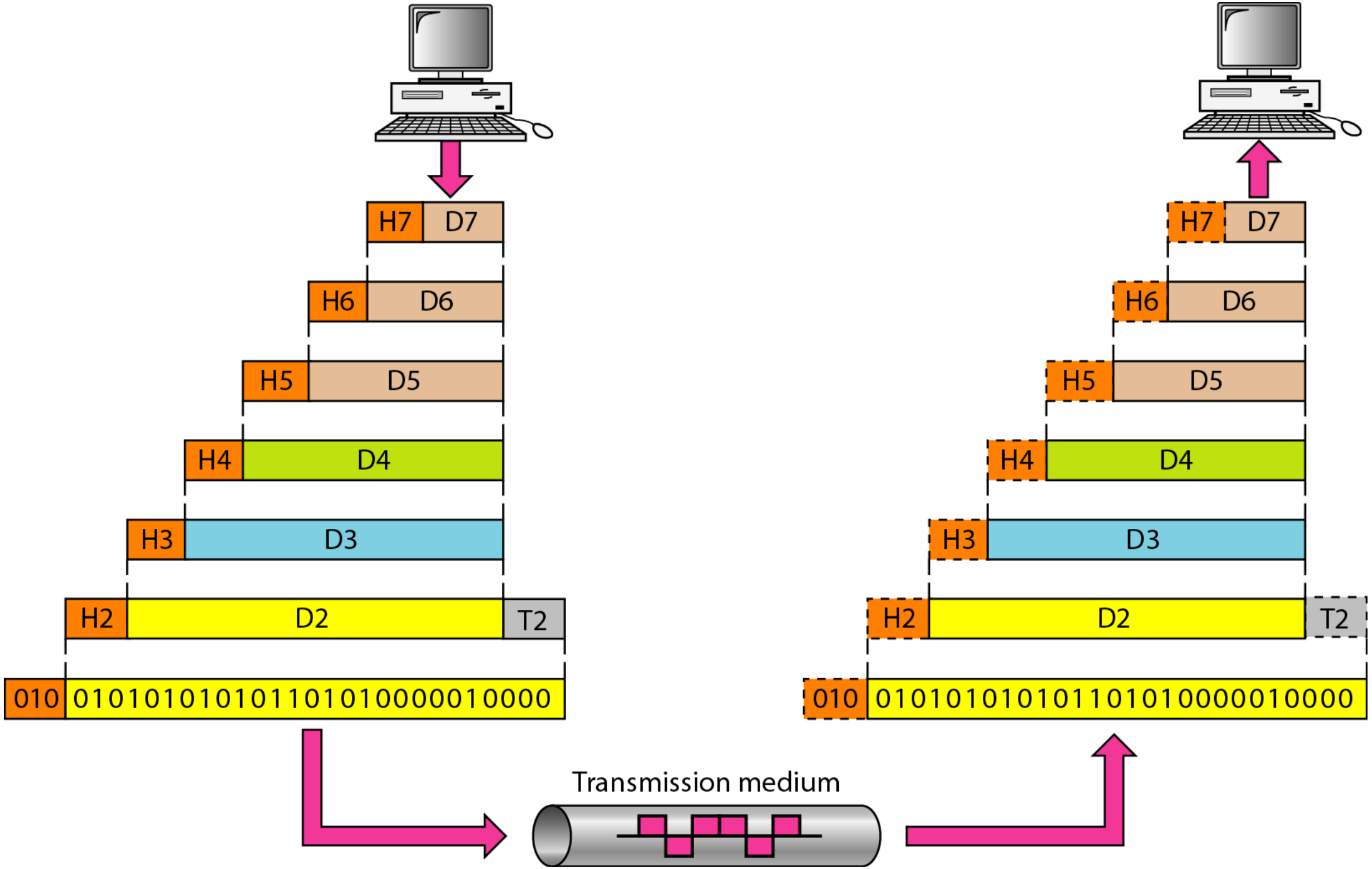
Decapsulation



Layer	PDU Name
7.) Application	Data
6.) Presentation	Data
5.) Session	Data
4.) Transport	Segment
3.) Network	Packet
2.) Data Link	Frame
1.) Physical	Bits

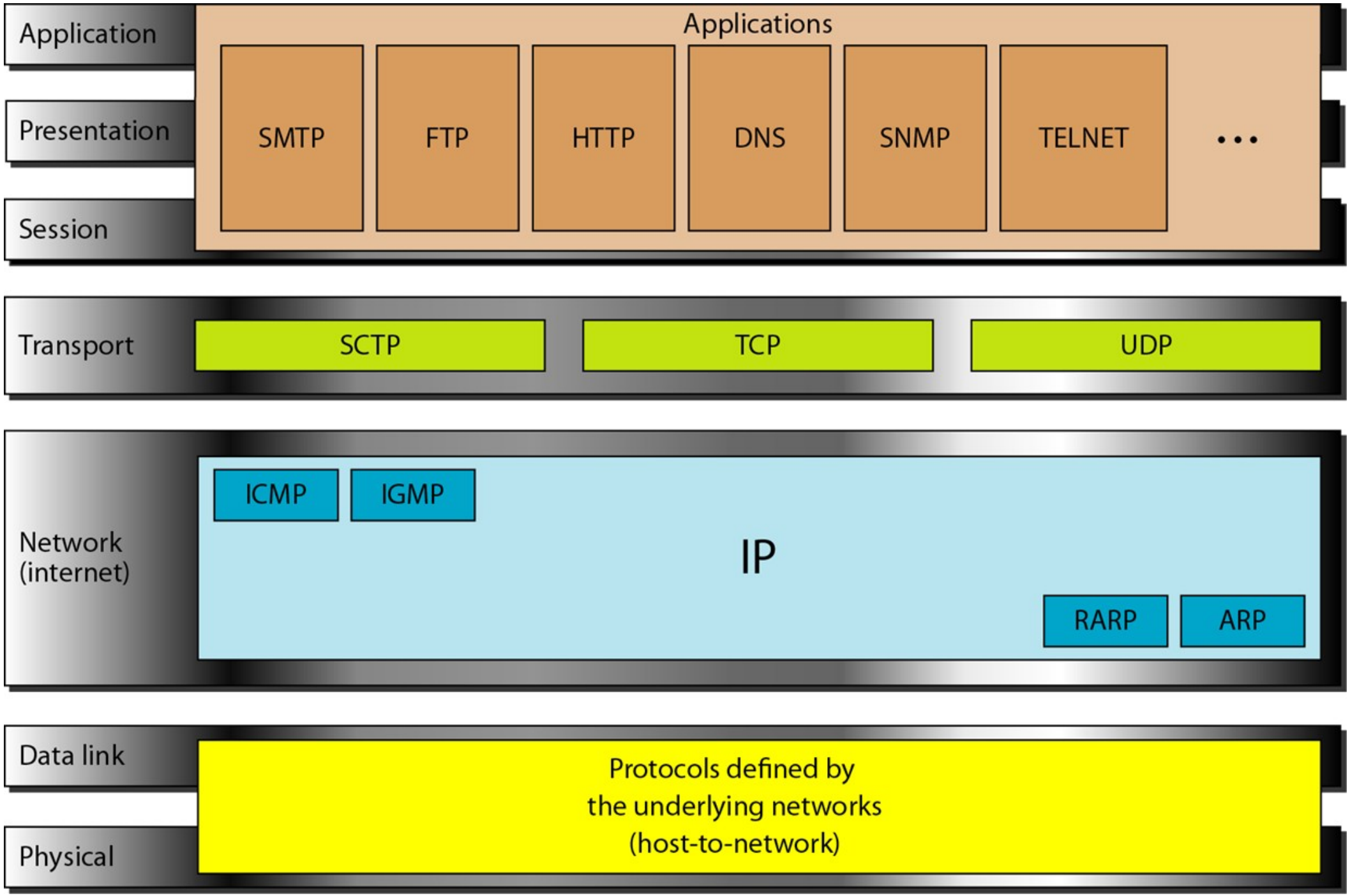


Encapsulation


H7
D7
H6
D6
H5
D5
H4
D4
H3
D3
H2
D2
T2
010
0101010101011010100000010000
Transmission medium
H7
D7
H6
D6
H5
D5
H4
D4
H3
D3
H2
D2
T2
010
0101010101011010100000010000

TCP/IP Protocol Suite

- The layers in the TCP/IP protocol suite do not exactly match those in the OSI model.
- The original TCP/IP protocol suite was defined as having four layers: host-to-network, internet, transport, and application.
- However, when TCP/IP is compared to OSI, we can say that the TCP/IP protocol suite is made of five layers:
  - physical,
  - data link,
  - network,
  - transport, and
  - application.


Application
Presentation
Session
Applications
SMTP
FTP
HTTP
DNS
SNMP
TELNET
• • •
Transport
SCTP
TCP
UDP
Network
(internet)
ICMP
IGMP
IP
RARP
ARP
Data link
Physical
Protocols defined by
the underlying networks
(host-to-network)

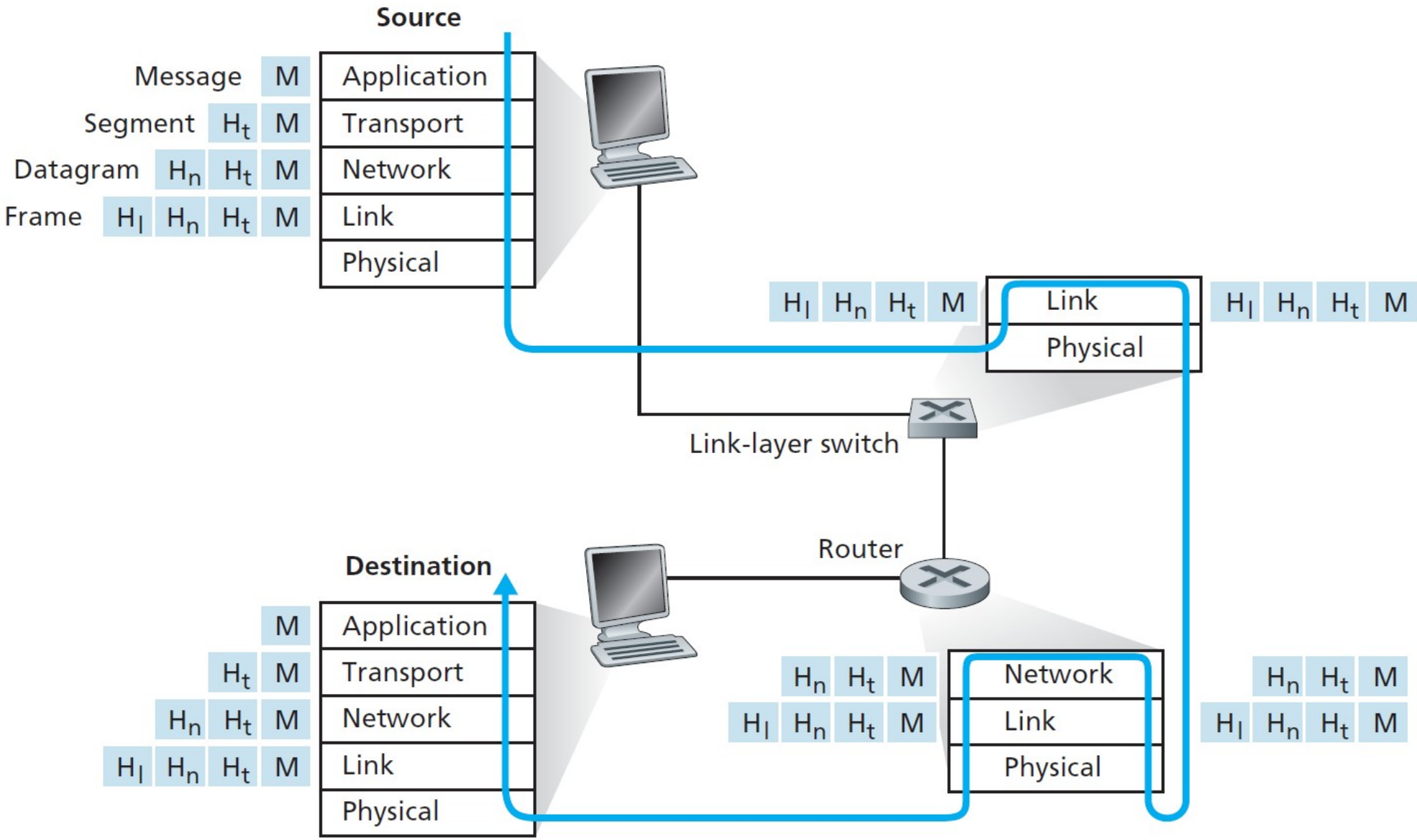
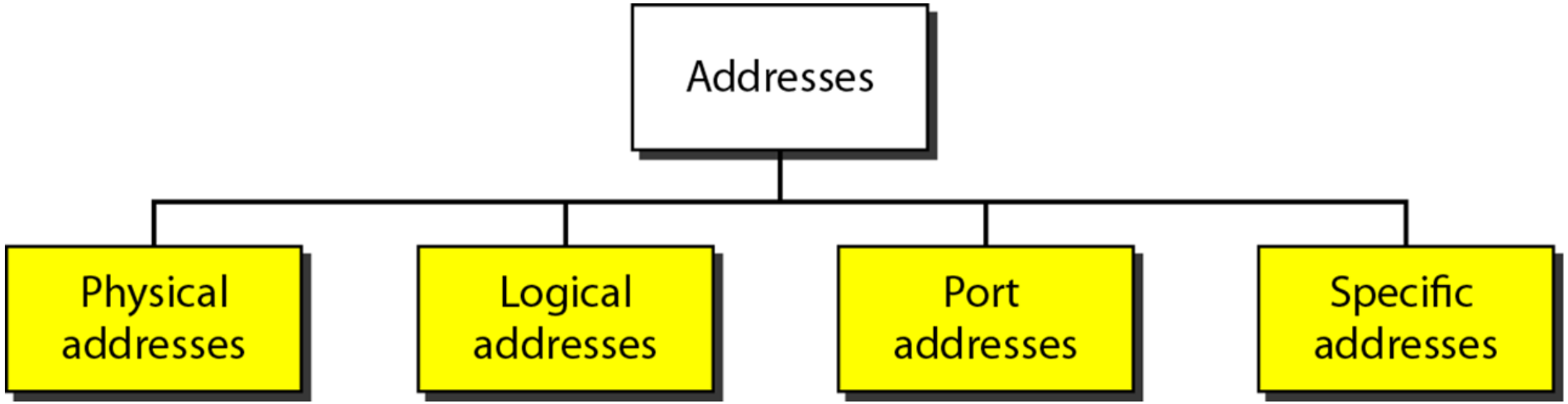
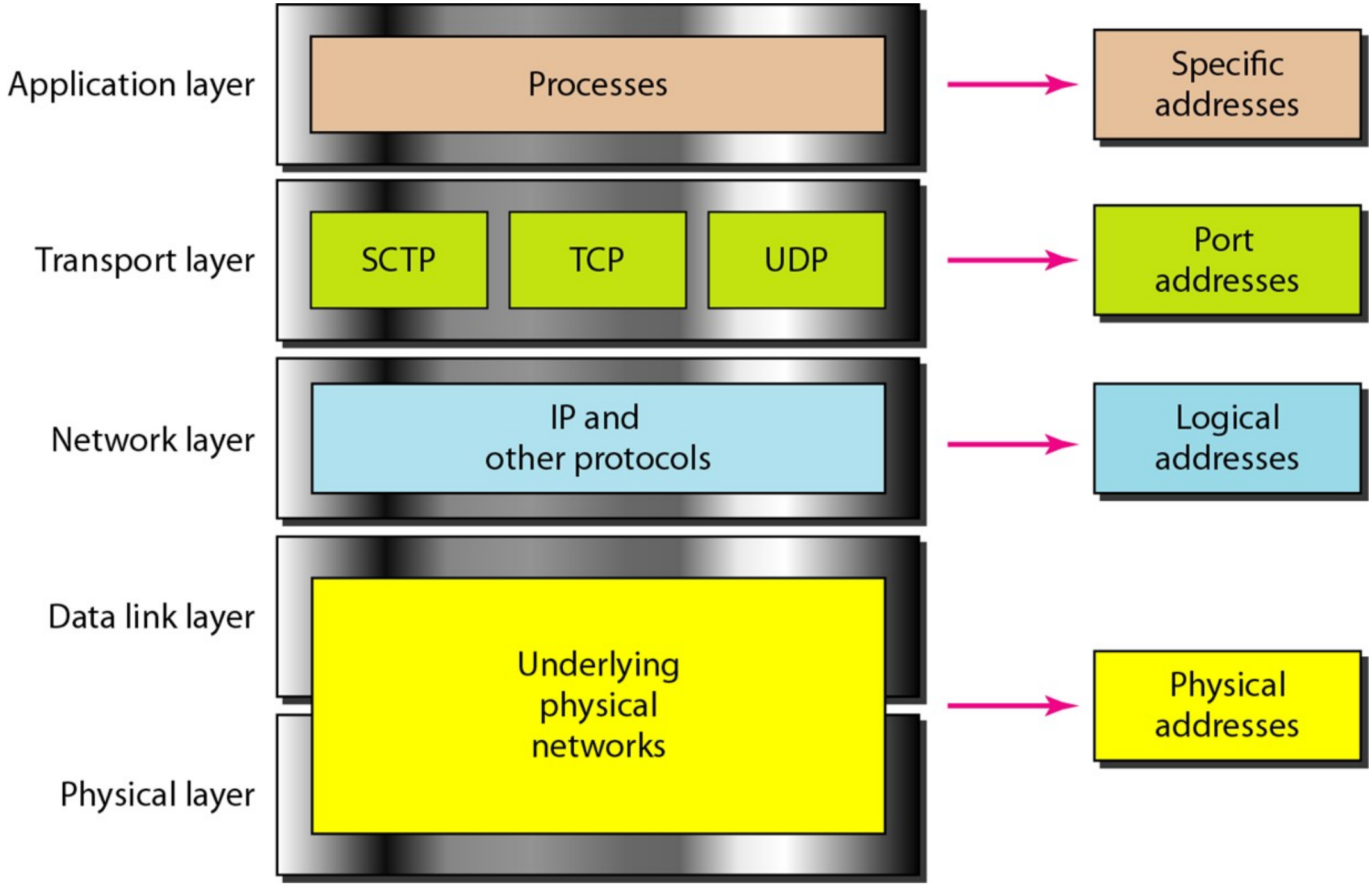


Figure 1.24 ♦ Hosts, routers, and link-layer switches; each contains a different set of layers, reflecting their differences in functionality

Addressing

- Four levels of addresses are used in an internet employing the *TCP/IP* protocols:
  - physical (link) addresses,
  - logical (IP) addresses,
  - port addresses, and
  - specific addresses




Application layer
Processes
Specific addresses
Transport layer
SCTP
TCP
UDP
Port addresses
Network layer
IP and other protocols
Logical addresses
Data link layer
Underlying physical networks
Physical addresses
Physical layer

Reading Assignment

- Comparison between OSI and TCP/IP model.
- Addresses and its types.
- Different Addresses for different applications and networks.
- Cmd-> ipconfig/all

References

- https://www.computernetworkingnotes.com/networking-tutorials/network-cable-types-and-specifications.html
- Data Communication and Computer Networks by Behrouz A Forouzan.pdf
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- https://www.academia.edu/37562829/INTRODUCTION_TO_COMPUTER_NETWORKS
- https://www.studytonight.com/computer-networks/osi-model-network-layer#:~:text=Network%20Layer%20%2D%20OSI%20Model,across%20multiple%20links%20(networks).&text=It%20routes%20the%20signal%20through,acts%20as%20a%20network%20controller