
# Advanced Networking and Cybersecurity

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Data Communications and Networking Fourth Edition

Forouzan

# Chapter 1

# Introduction

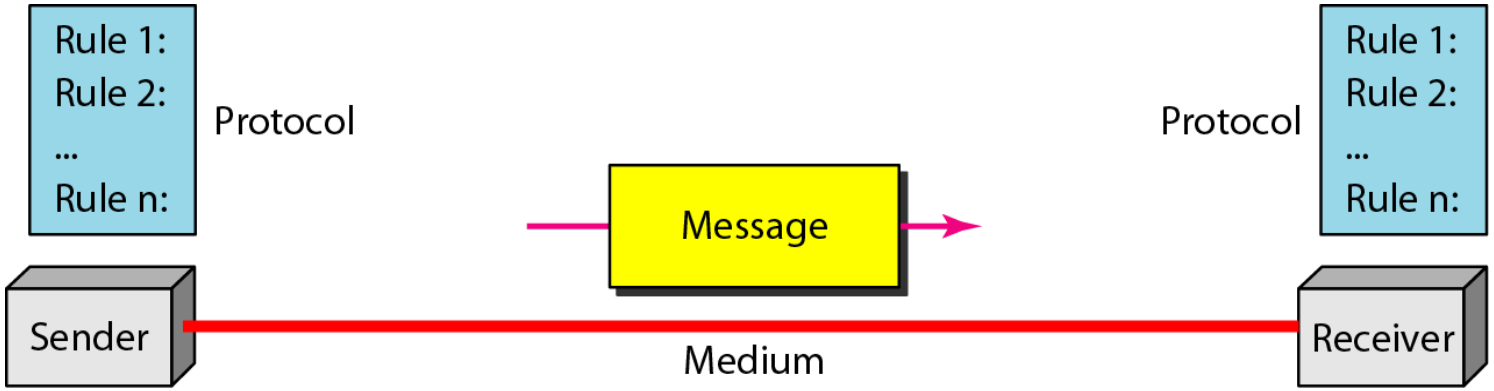
# 1-1 DATA COMMUNICATIONS

***The term telecommunication means communication at a distance. The word data refers to information presented in whatever form is agreed upon by the parties creating and using the data. Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable.***

***Topics discussed in this section:***

- **Components of a data communications system**
- **Data Flow**

## Figure 1.1 *Components of a data communication system*



# 1-2 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.***

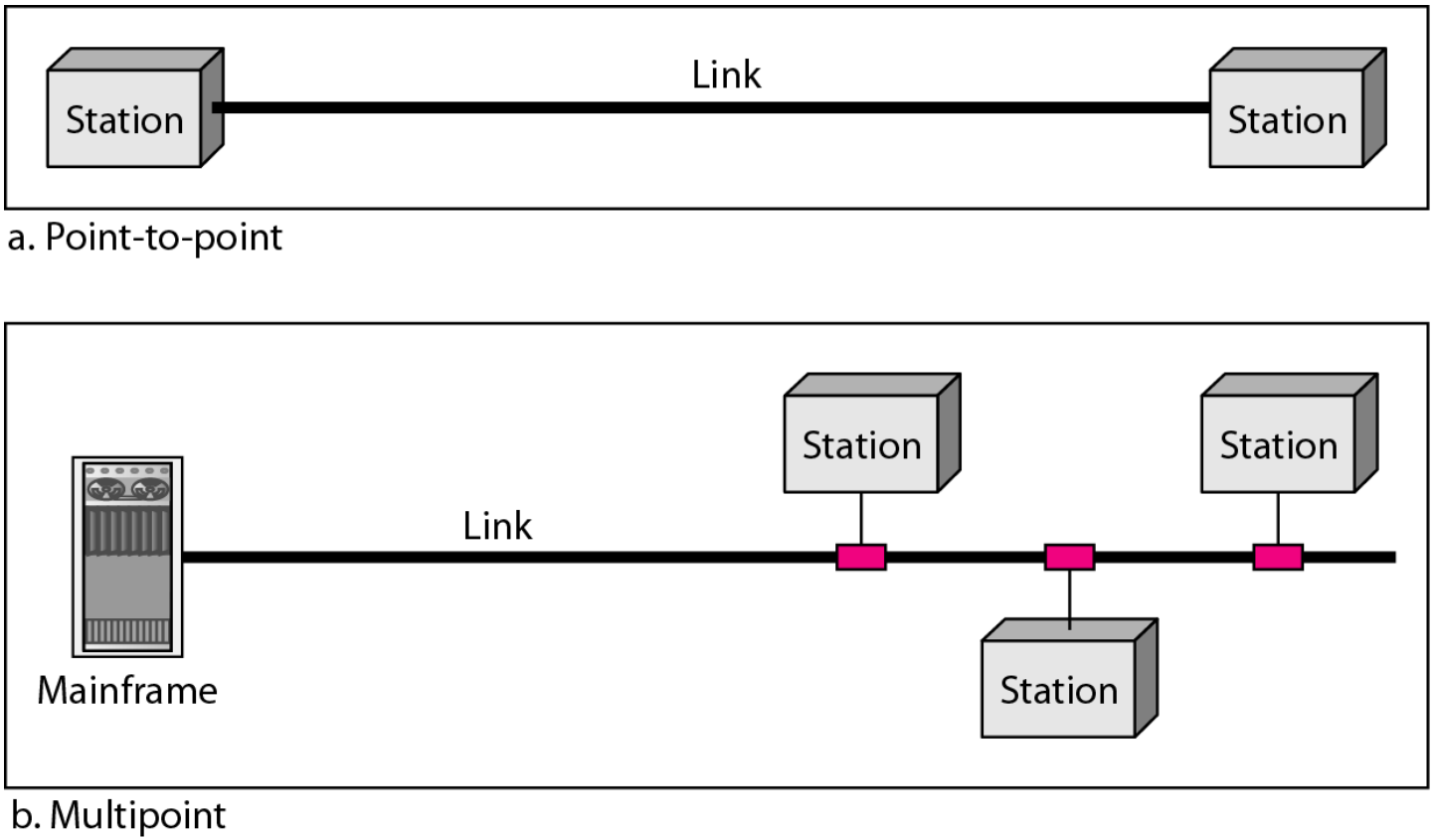
***Topics discussed in this section:***

- **Network Criteria**
- **Physical Structures**
- **Categories of Networks**

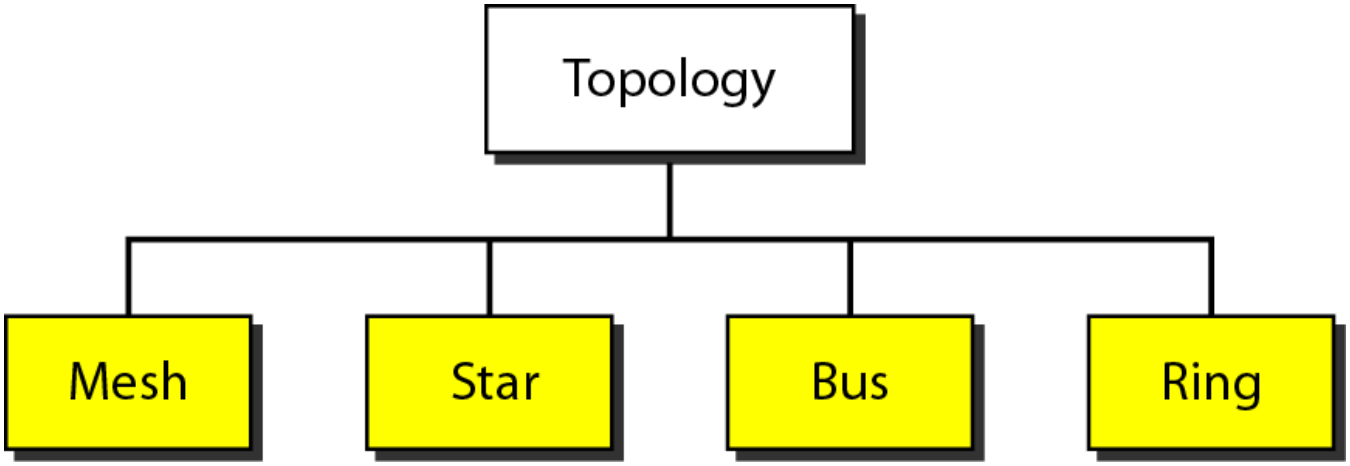
# Physical Structures

- 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

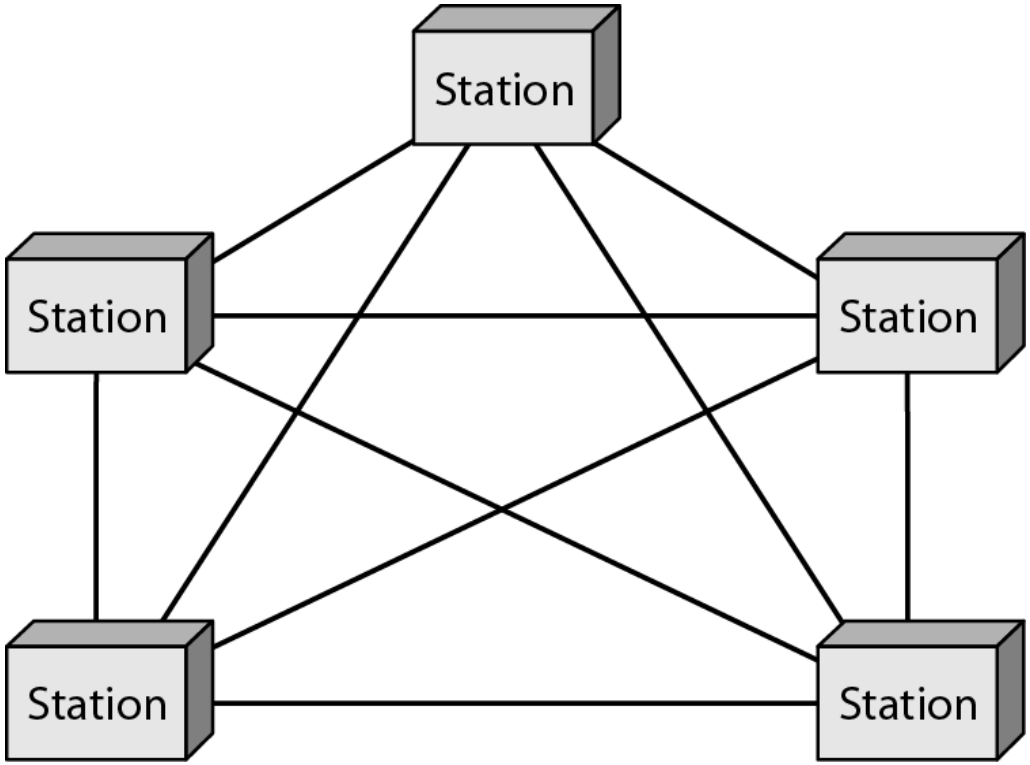
## Figure 1.3 *Types of connections: point-to-point and multipoint*



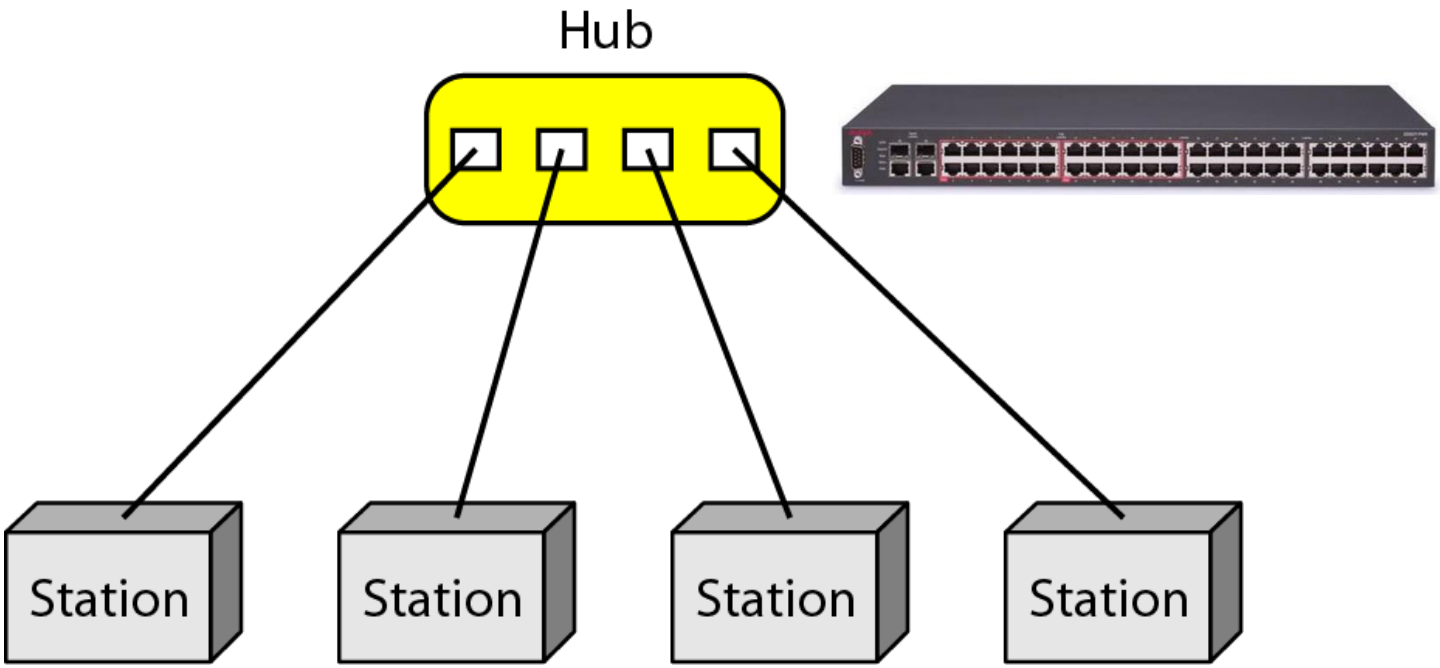
## Figure 1.4 *Categories of topology*



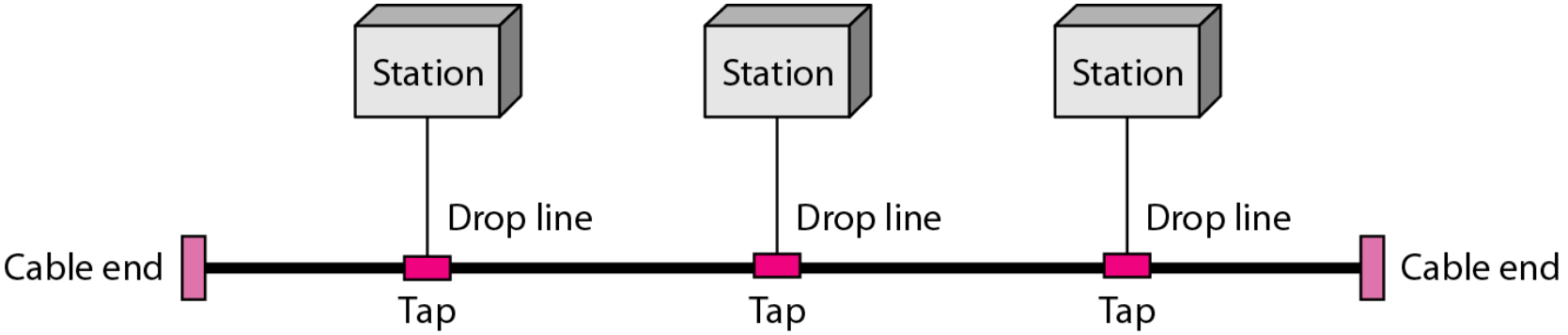
## Figure 1.5 *A fully connected mesh topology (five devices)*

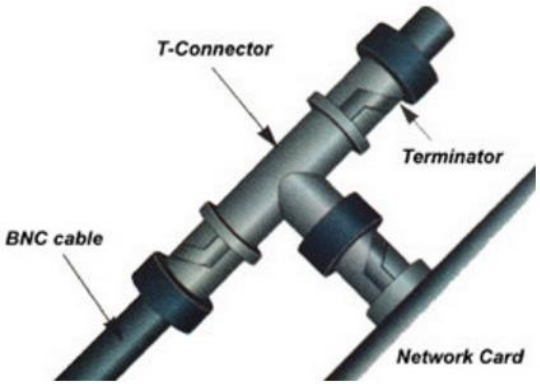


## Figure 1.6 *A star topology connecting four stations*

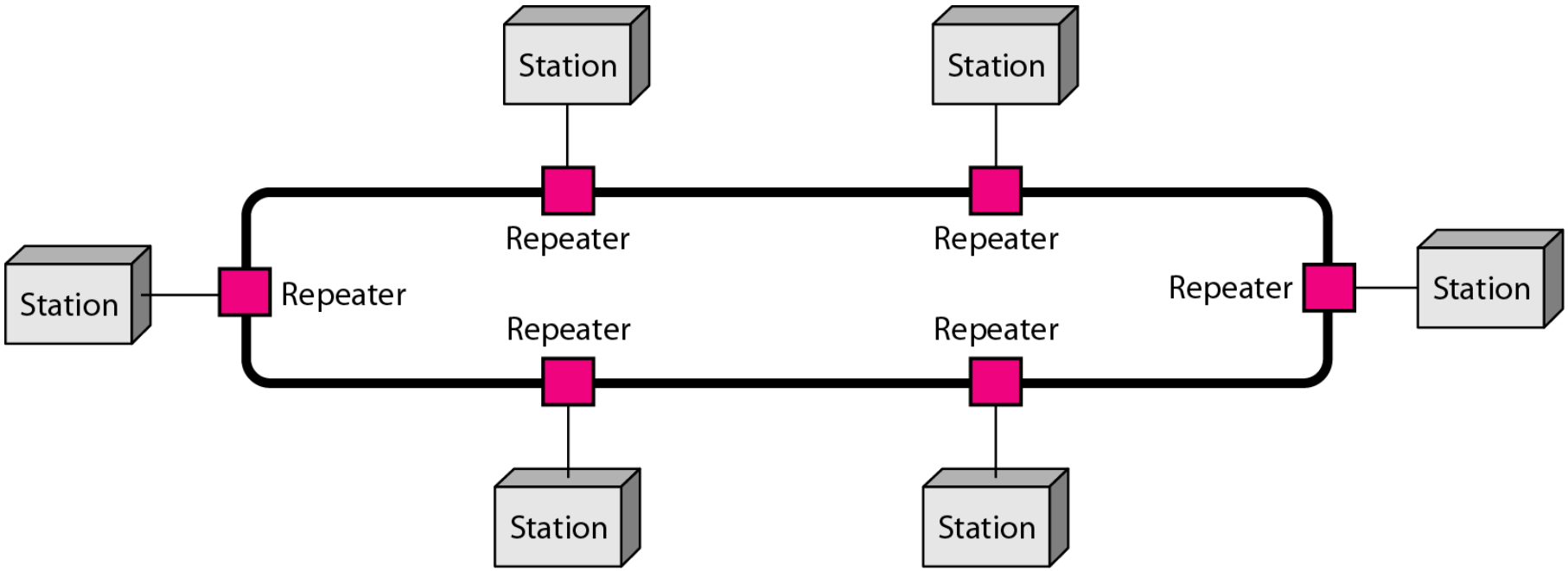


## Figure 1.7 *A bus topology connecting three stations*




## Figure 1.8 *A ring topology connecting six stations*



Physically, a token ring network is wired as a star, with 'MAUs' in the center, 'arms' out to each station, and the loop going out-and-back through each

100 Mbit/s IBM Token Ring Management Adapter with Wake On LAN.
UTP (RJ45) and STP (IBM Data Connector) interfaces are present.

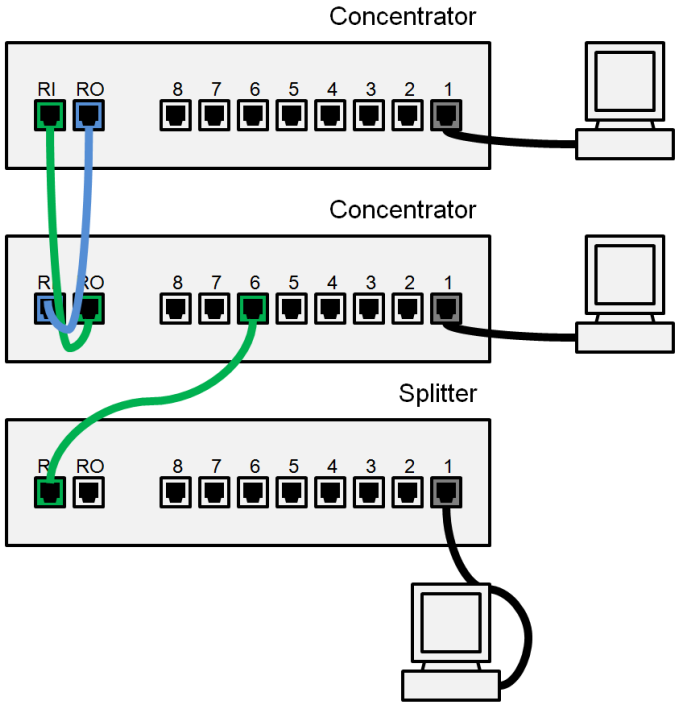
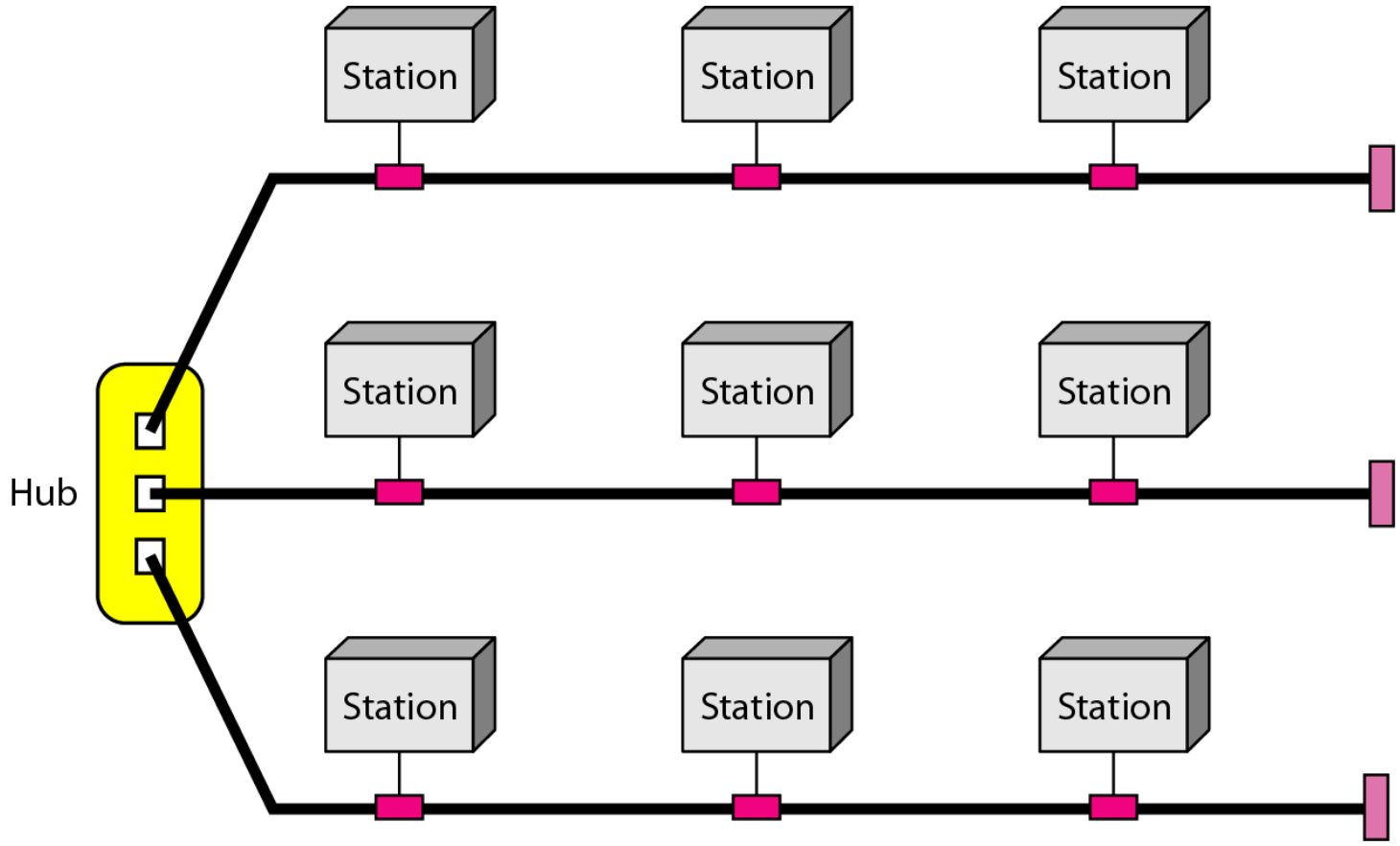


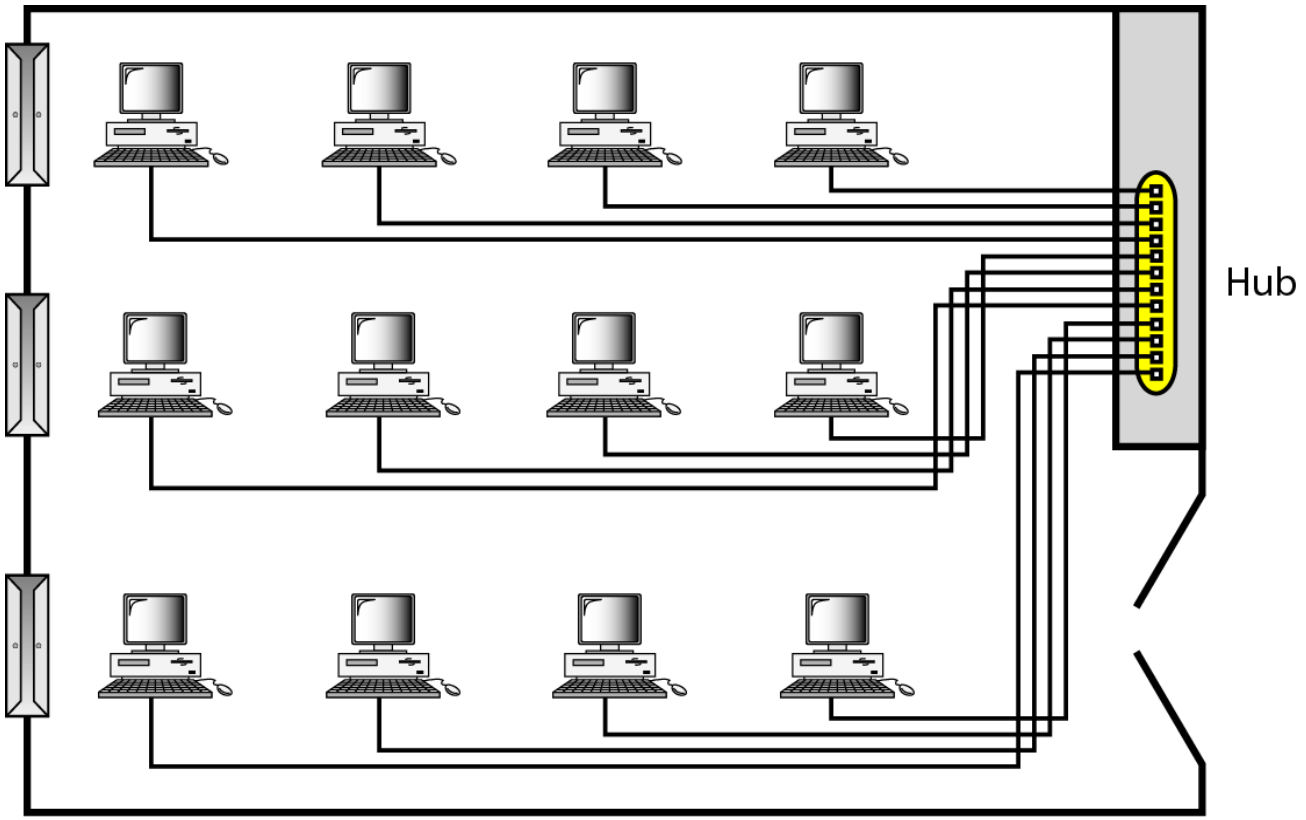
**Figure 1.9** *A hybrid topology: a star backbone with three bus networks*



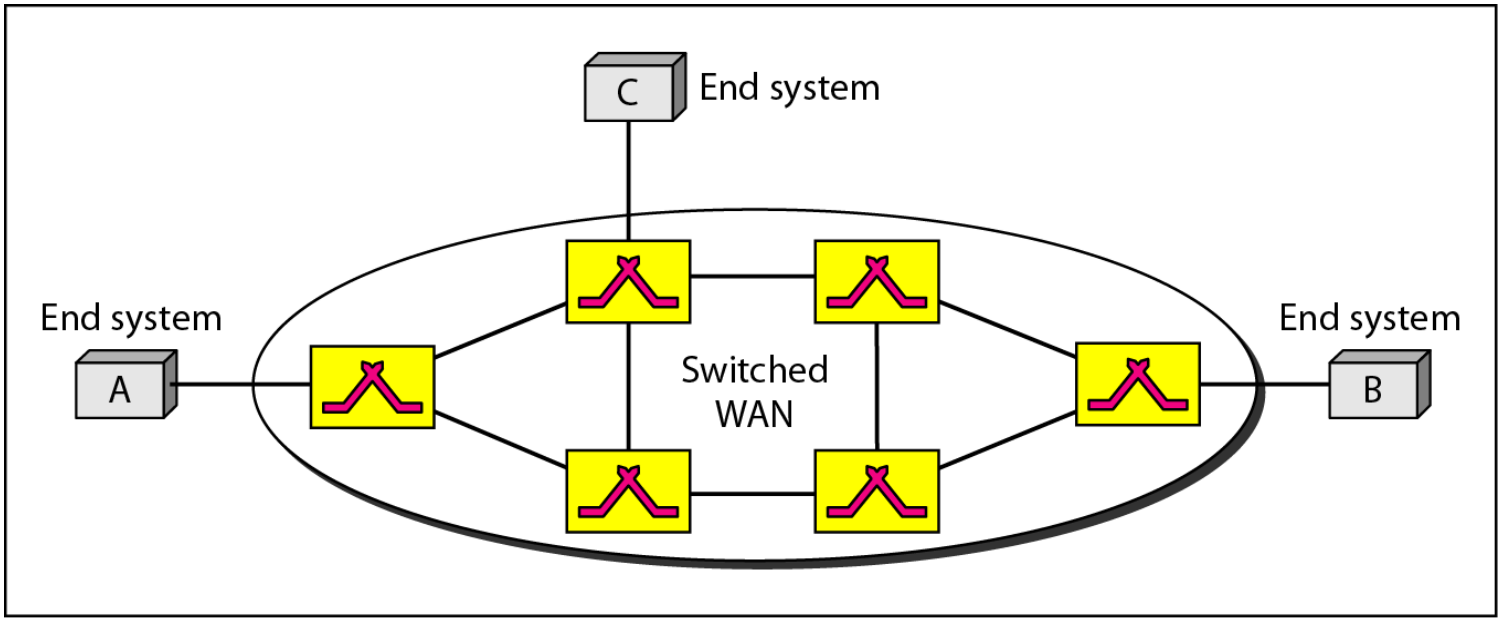
# Categories of Networks

- Local Area Networks (LANs)
  - Short distances
  - Designed to provide local interconnectivity
- Wide Area Networks (WANs)
  - Long distances
  - Provide connectivity over large areas
- Metropolitan Area Networks (MANs)
  - Provide connectivity over areas such as a city, a campus

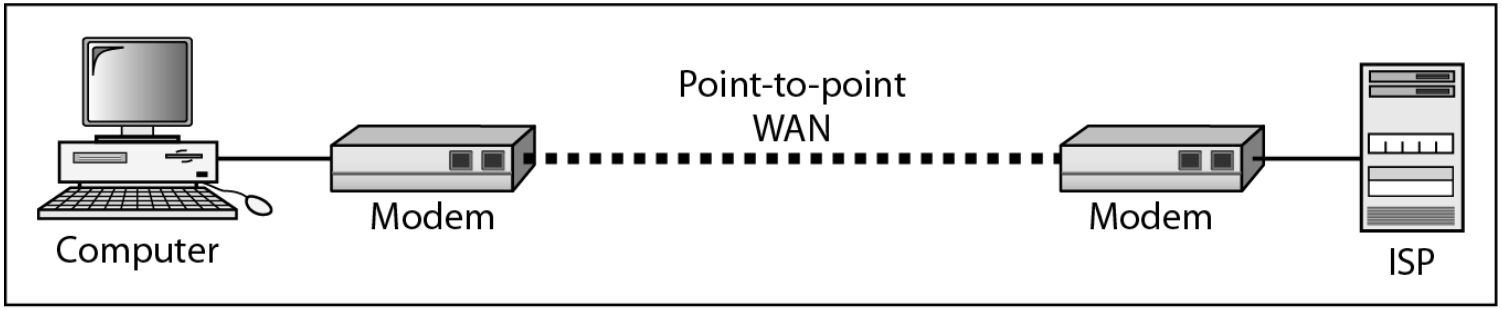
## Figure 1.10 *An isolated LAN connecting 12 computers to a hub in a closet*



## Figure 1.11 *WANs: a switched WAN and a point-to-point WAN*

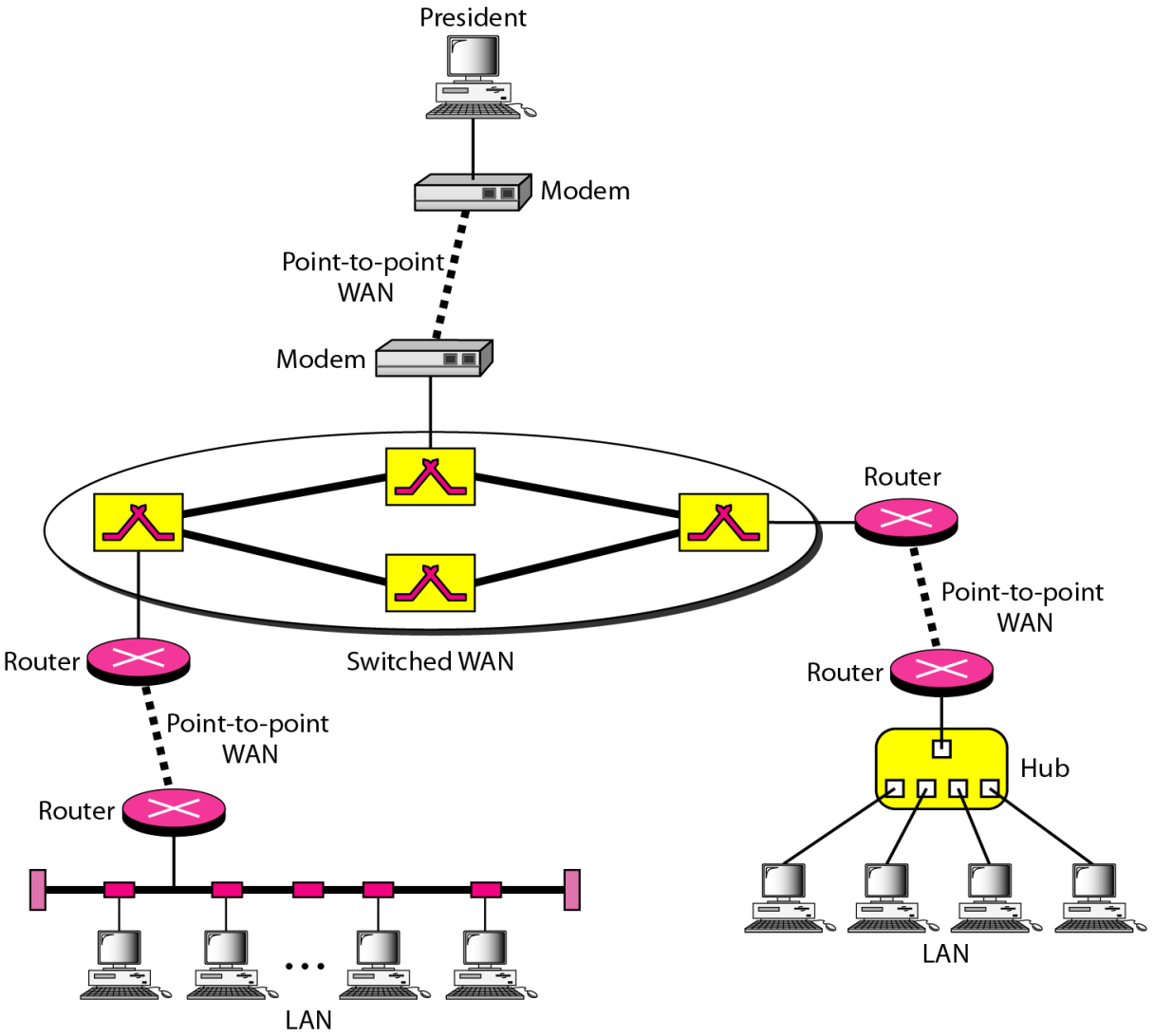



a. Switched WAN




b. Point-to-point WAN

# Figure 1.12 *A heterogeneous network made of four WANs and two LANs*



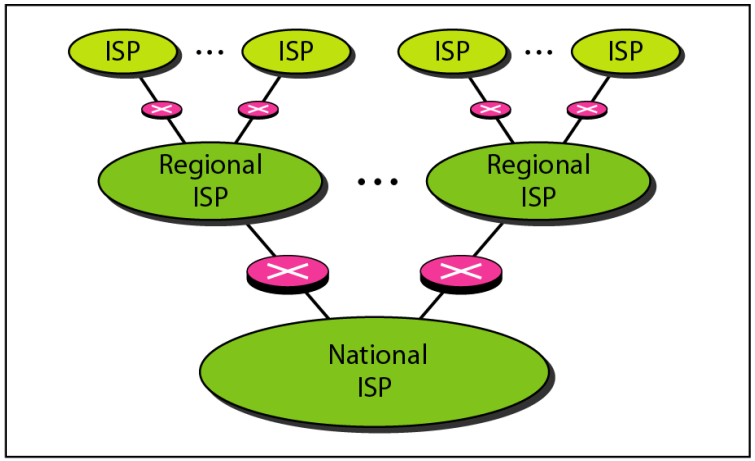
# 1-3 THE INTERNET

***The Internet has revolutionized many aspects of our daily lives. It has affected the way we do business as well as the way we spend our leisure time. The Internet is a communication system that has brought a wealth of information to our fingertips and organized it for our use.***

***Topics discussed in this section:***

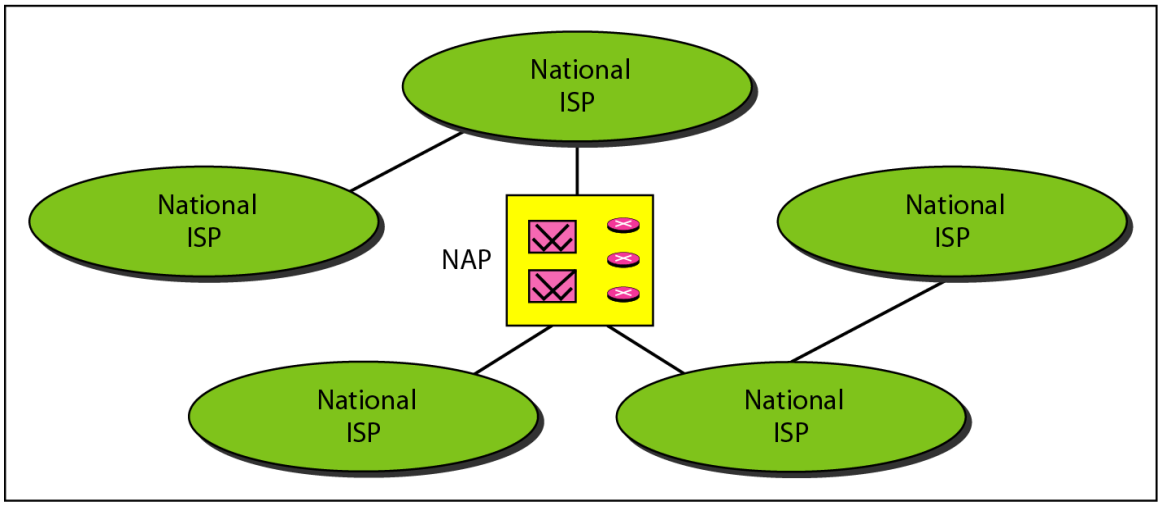
**Organization of the Internet**
**Internet Service Providers (ISPs)**

# Figure 1.13 *Hierarchical organization of the Internet*




a. Structure of a national ISP

NAP:Network Access Provider
ISP : Internet Service Provider




b. Interconnection of national ISPs

# Internet vs internet

- **i**nternet : two or more networks which are interconnected (can communicate with each other)
- **I**nternet : the network of networks all across the globe, as we see today

# 1-4 PROTOCOLS and STANDARDS

***A protocol is synonymous with rule. It consists of a set of rules that govern data communications. It determines what is communicated, how it is communicated and when it is communicated. The key elements of a protocol are syntax, semantics and timing***

***Standards is a set of agreed upon rules***

***Topics discussed in this section:***

- **Syntax : structure/format of a data group /message**
- **Semantics : meaning of each element of a message**
- **Timing : when data shall be sent and how fast**

# Elements of a Protocol

- Syntax
  - Structure or format of the data
  - Indicates how to read the bits - field delineation
- Semantics
  - Interprets the meaning of the bits
  - Knows which fields define what action
- Timing
  - When data should be sent and
  - What Speed at which data should be sent or speed at which it is being received.

# Standards and standards producing bodies

- USA
  - ANSI, EIA, IEEE,
- Europe
  - ETSI
- Japan
  - ARIB
- International
  - ITU, ISO, 3GPP, etc.

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# Chapter 2

# Network Models

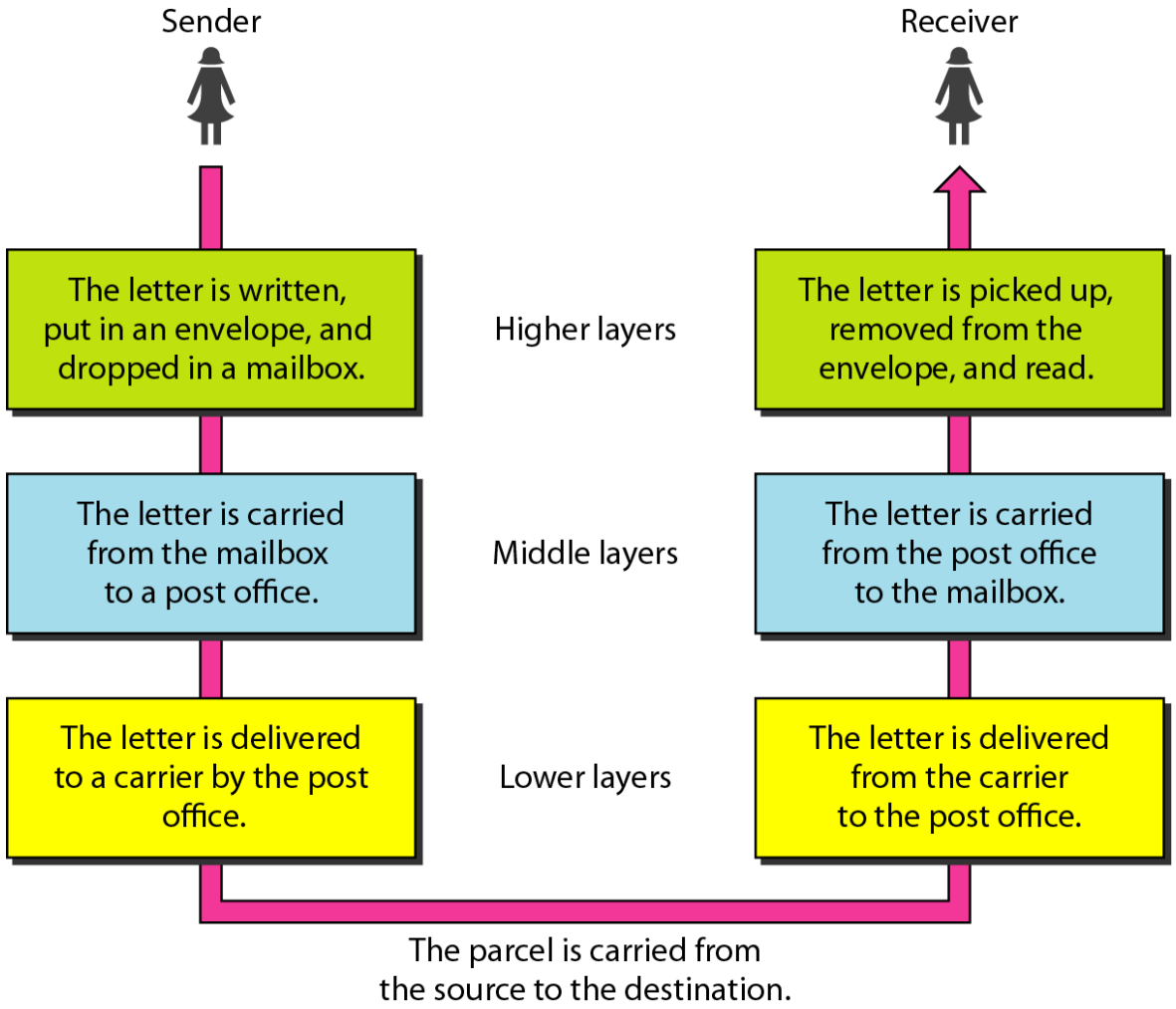
# 2-1 LAYERED TASKS

***We use the concept of layers in our daily life. As an example, let us consider two friends who communicate through postal mail. The process of sending a letter to a friend would be complex if there were no services available from the post office.***

***Topics discussed in this section:***

**Sender, Receiver, and Carrier**
**Hierarchy**

# Figure 2.1 Tasks involved in sending a letter



# 2-2 THE OSI MODEL

***Established in 1947, the International Standards Organization (ISO) is a multinational body dedicated to worldwide agreement on international standards. An ISO standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model. It was first introduced in the late 1970s.***

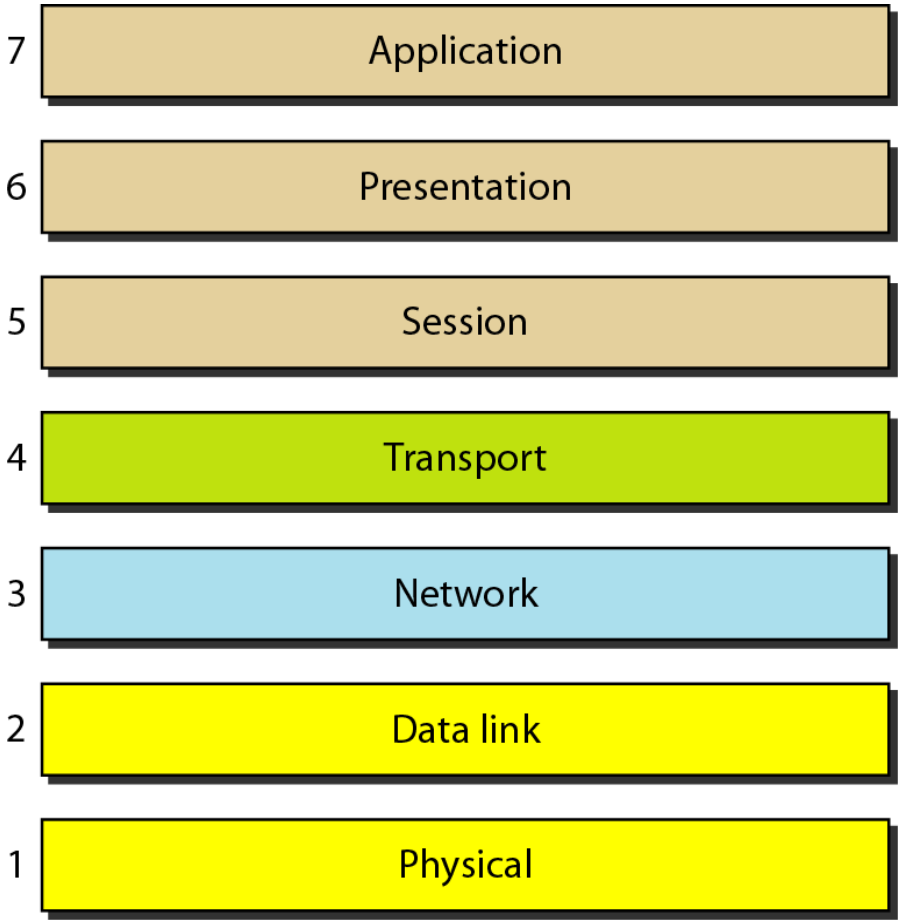
***Topics discussed in this section:***

**Layered Architecture**
**Peer-to-Peer Processes**
**Encapsulation**

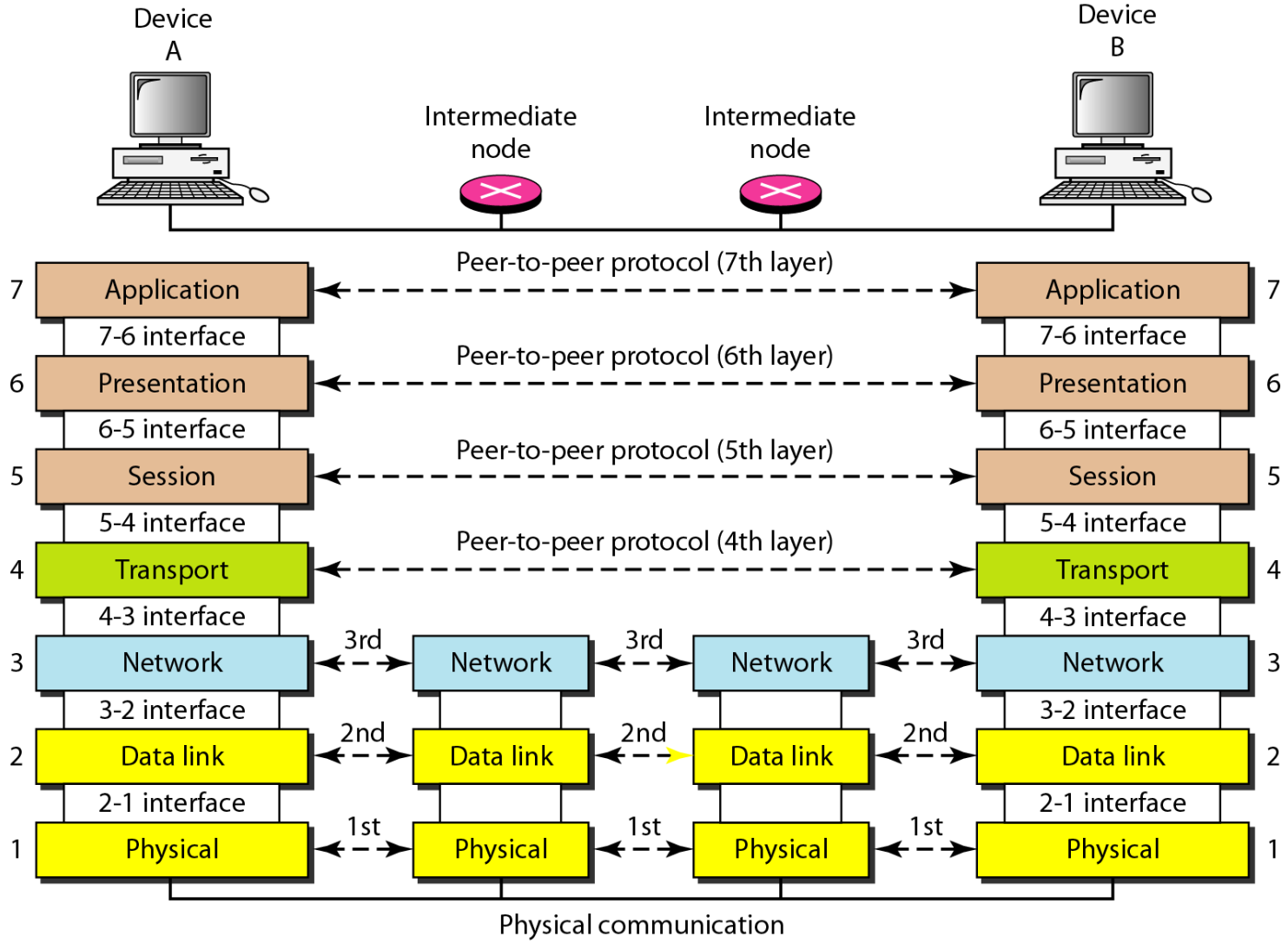
*Note*

**ISO is the organization.**
**OSI is the model.**

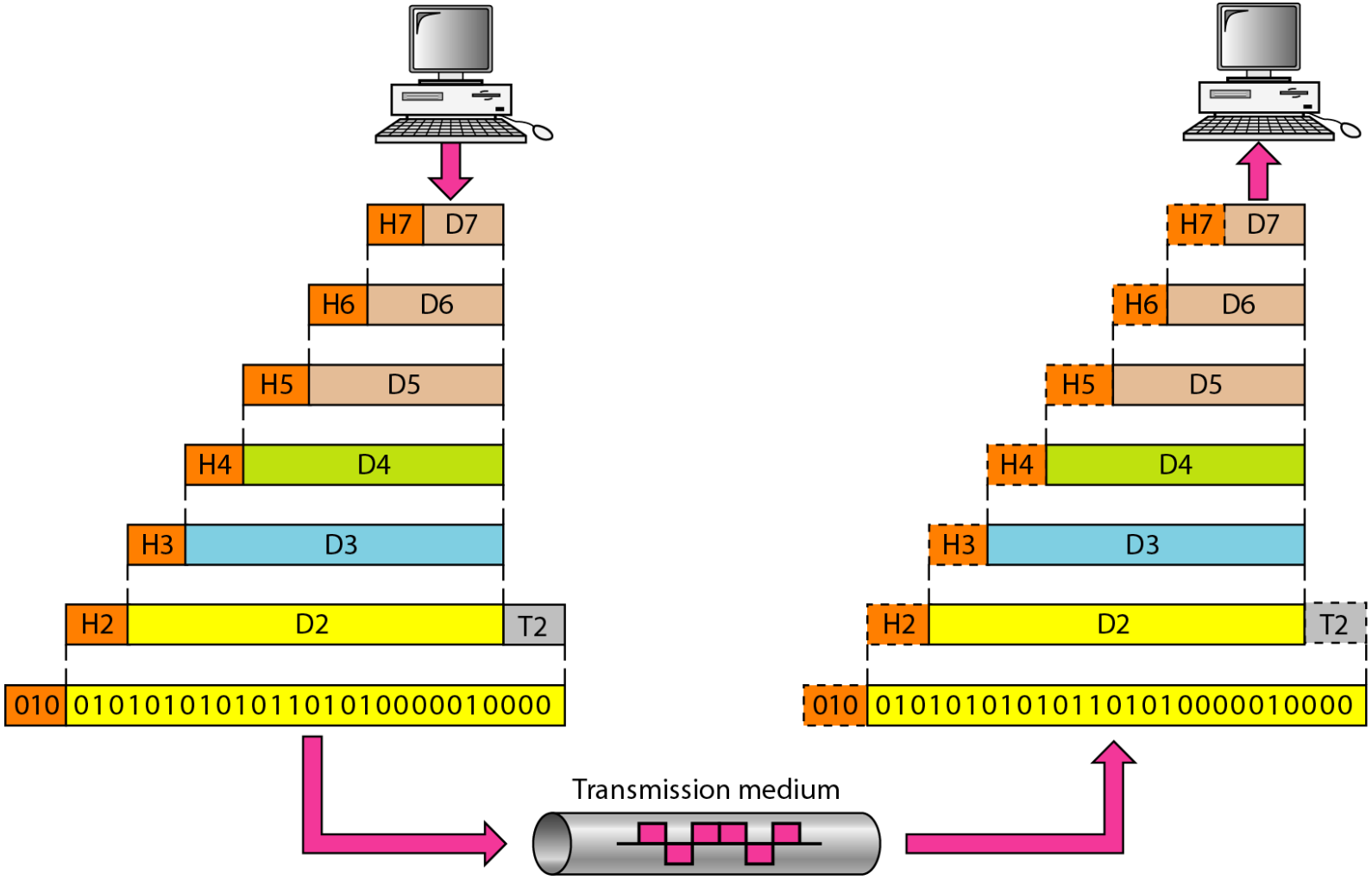
## Figure 2.2 *Seven layers of the OSI model*



## Figure 2.3 *The interaction between layers in the OSI model*



## Figure 2.4 *An exchange using the OSI model*



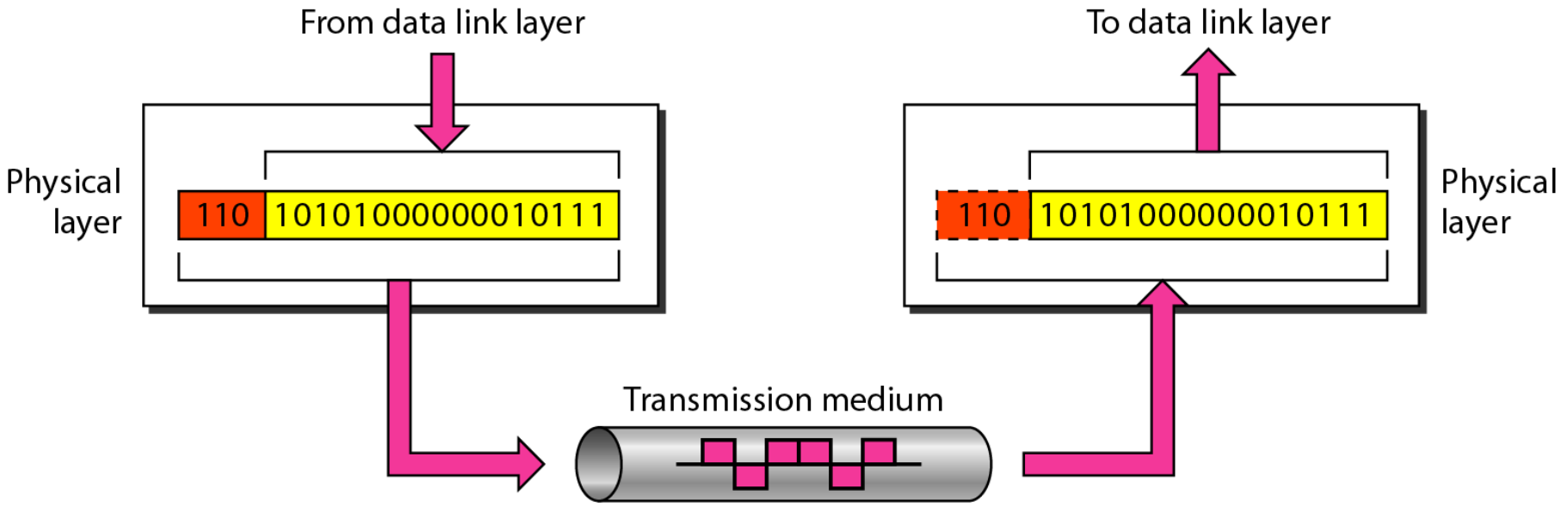
# 2-3 LAYERS IN THE OSI MODEL

***In this section we briefly describe the functions of each layer in the OSI model.***

***Topics discussed in this section:***

**Physical Layer**
**Data Link Layer**
**Network Layer**
**Transport Layer**
**Session Layer**
**Presentation Layer**
**Application Layer**

## Figure 2.5 *Physical layer*

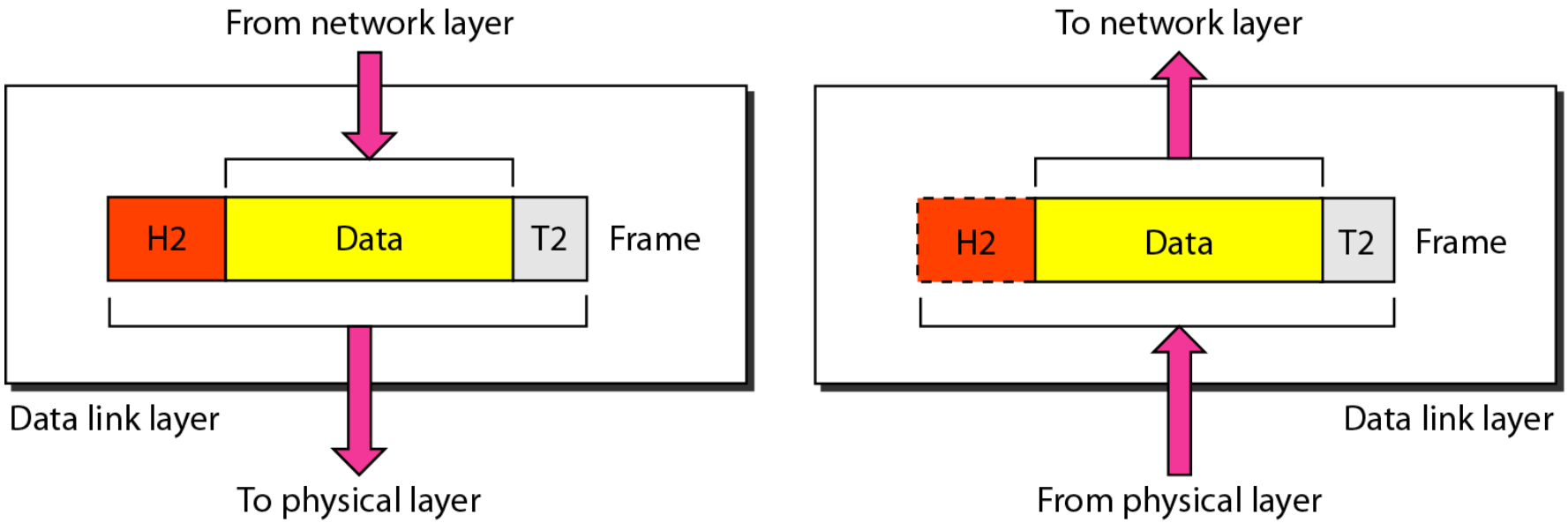


*Note*

**The physical layer is responsible for movements of individual bits from one hop (node) to the next.**

Interface between device and the transmission medium
Data rate
Sychronization
Line configuration (one-to-one, one-to-many, etc)
Physical network topology
Transmission mode

## Figure 2.6 *Data link layer*

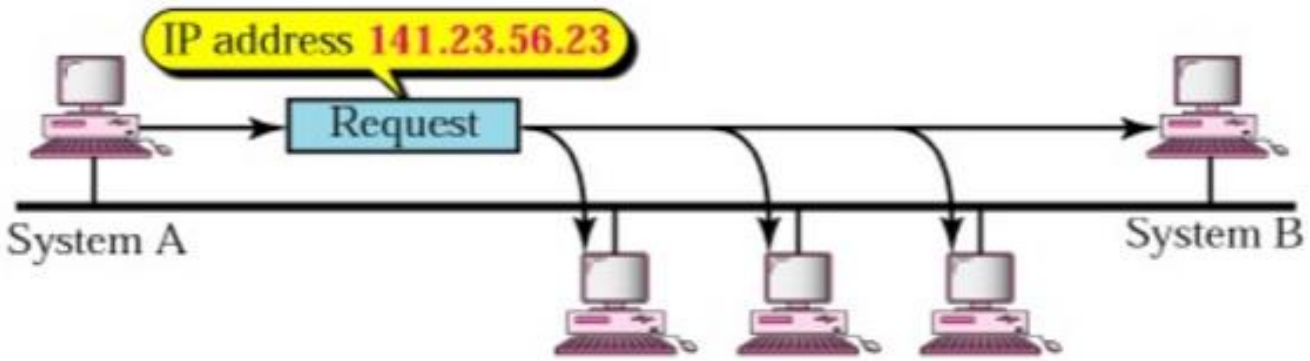


*Note*

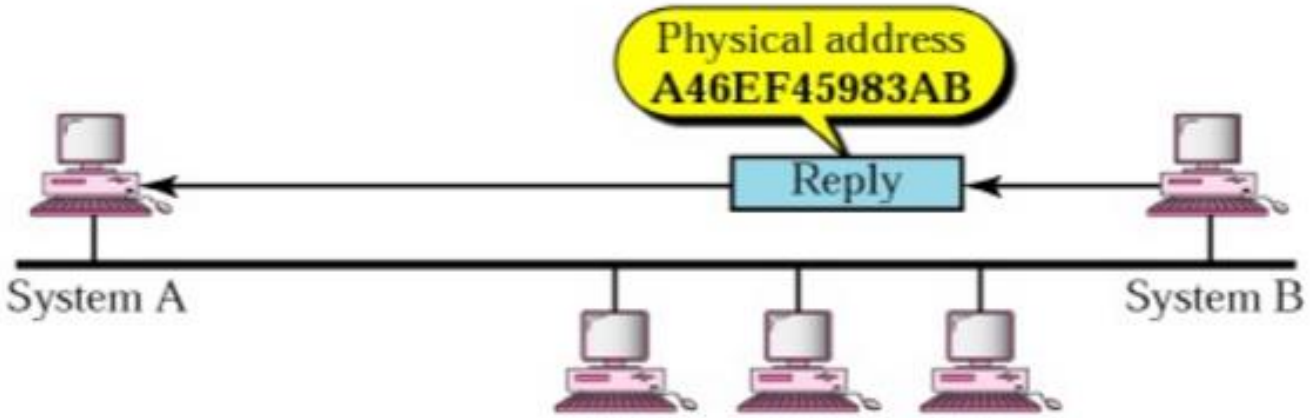
**The data link layer is responsible for moving frames from one hop (node) to the next.**

Physical layer addressing
Framing
Flow control
Error control
Access control
Responsible for hop-by-hop delivery

# ARP PROTOCOL

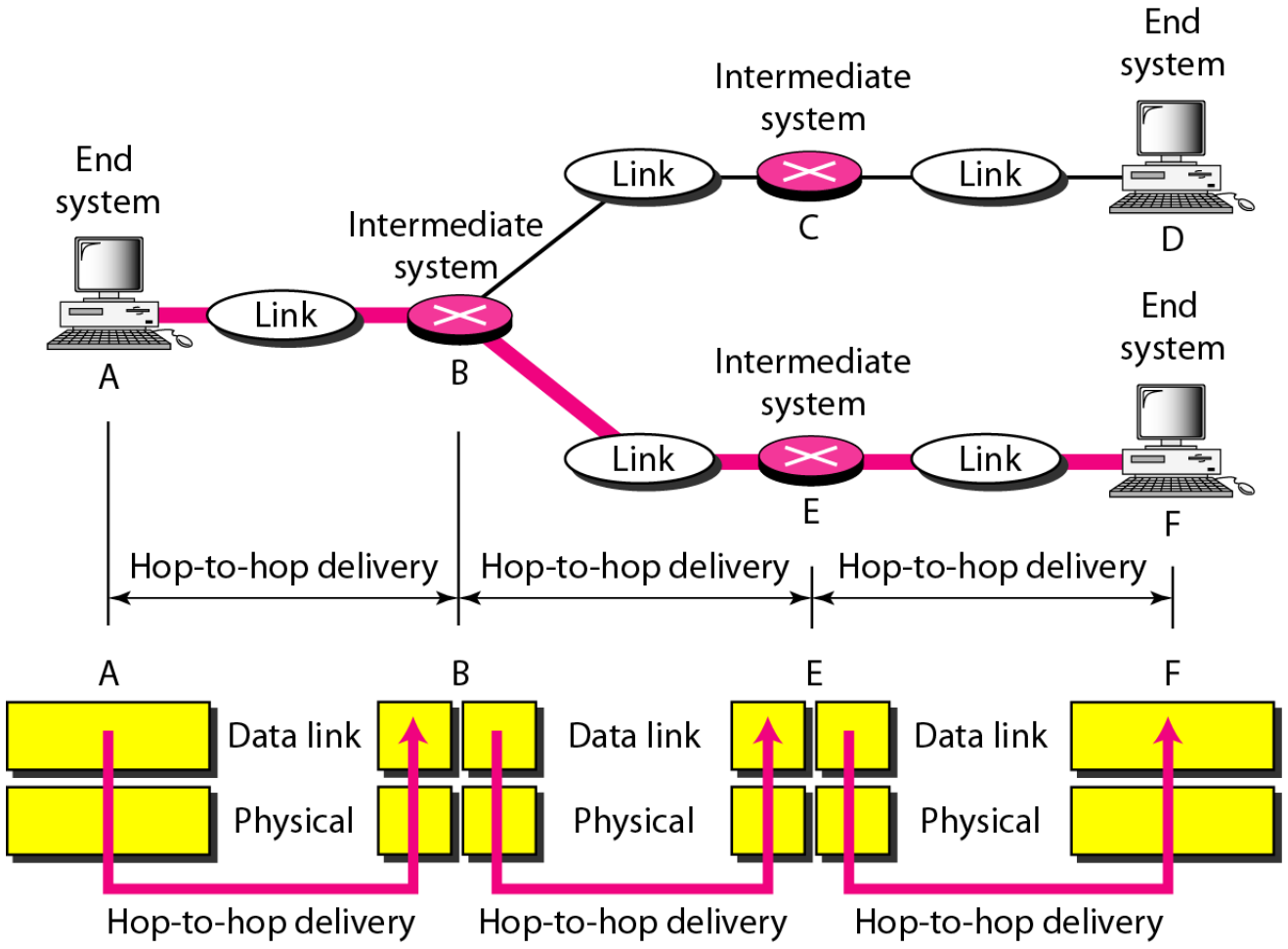



a. ARP request is broadcast

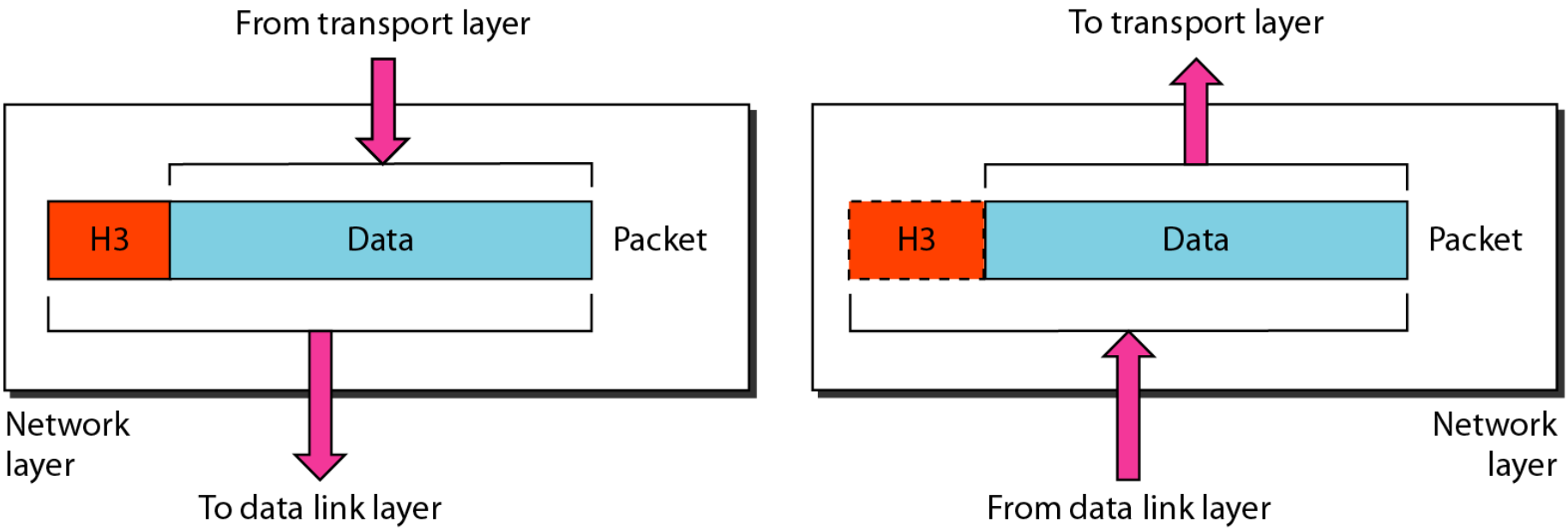



b. ARP reply is unicast

# Figure 2.7 *Hop-to-hop delivery*



## Figure 2.8 *Network layer*



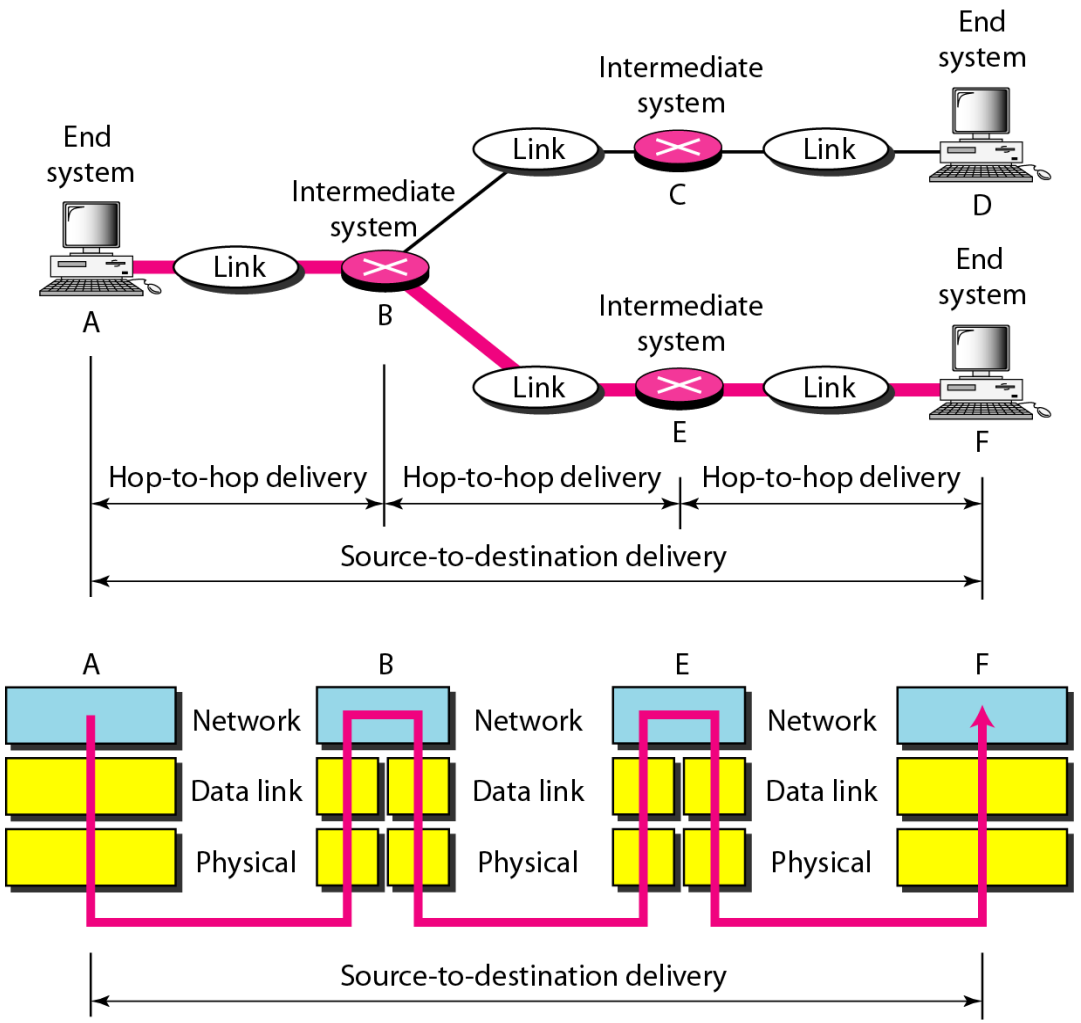
*Note*

**The network layer is responsible for the delivery of individual packets from the source host to the destination host.**

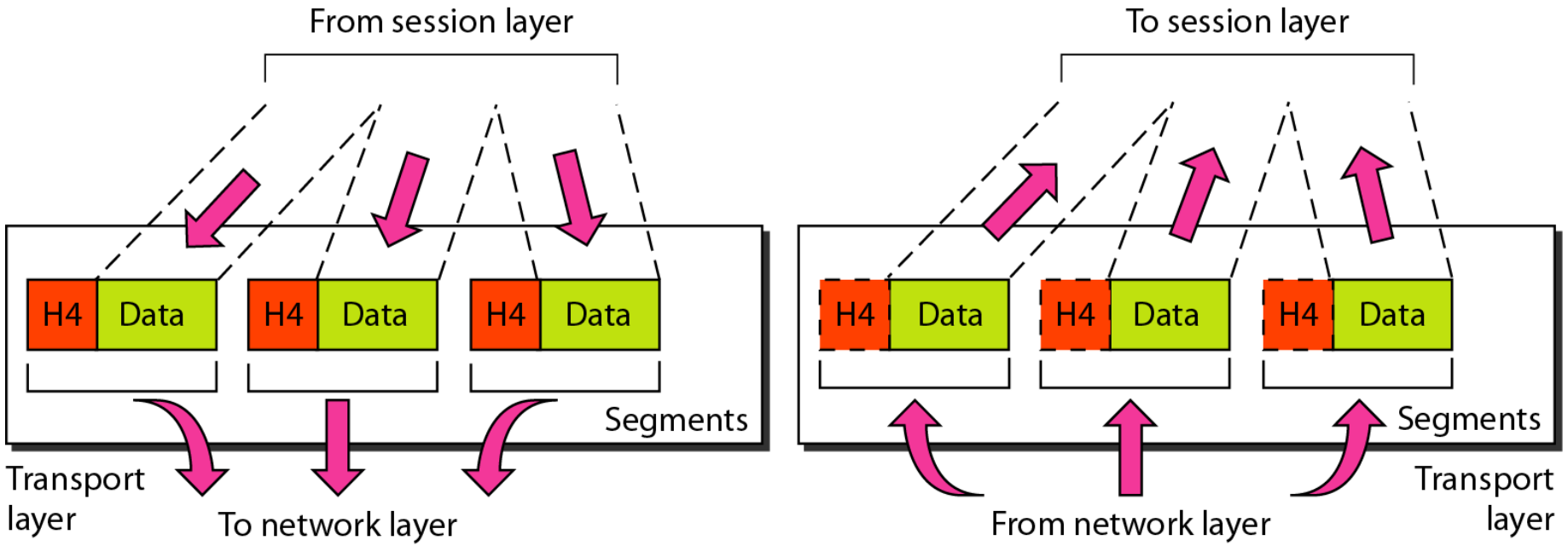
Logical addressing

Routing

# Figure 2.9 *Source-to-destination delivery*



## Figure 2.10 *Transport layer*

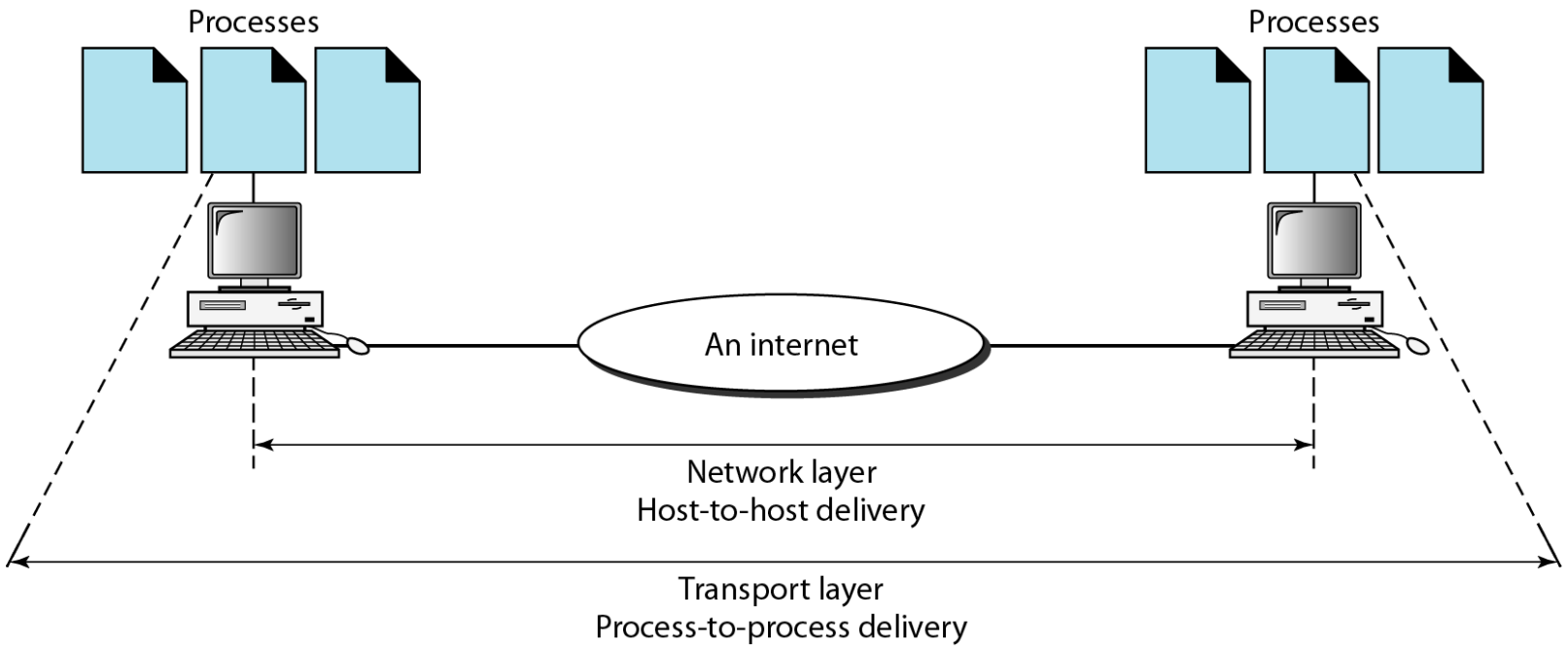


*Note*

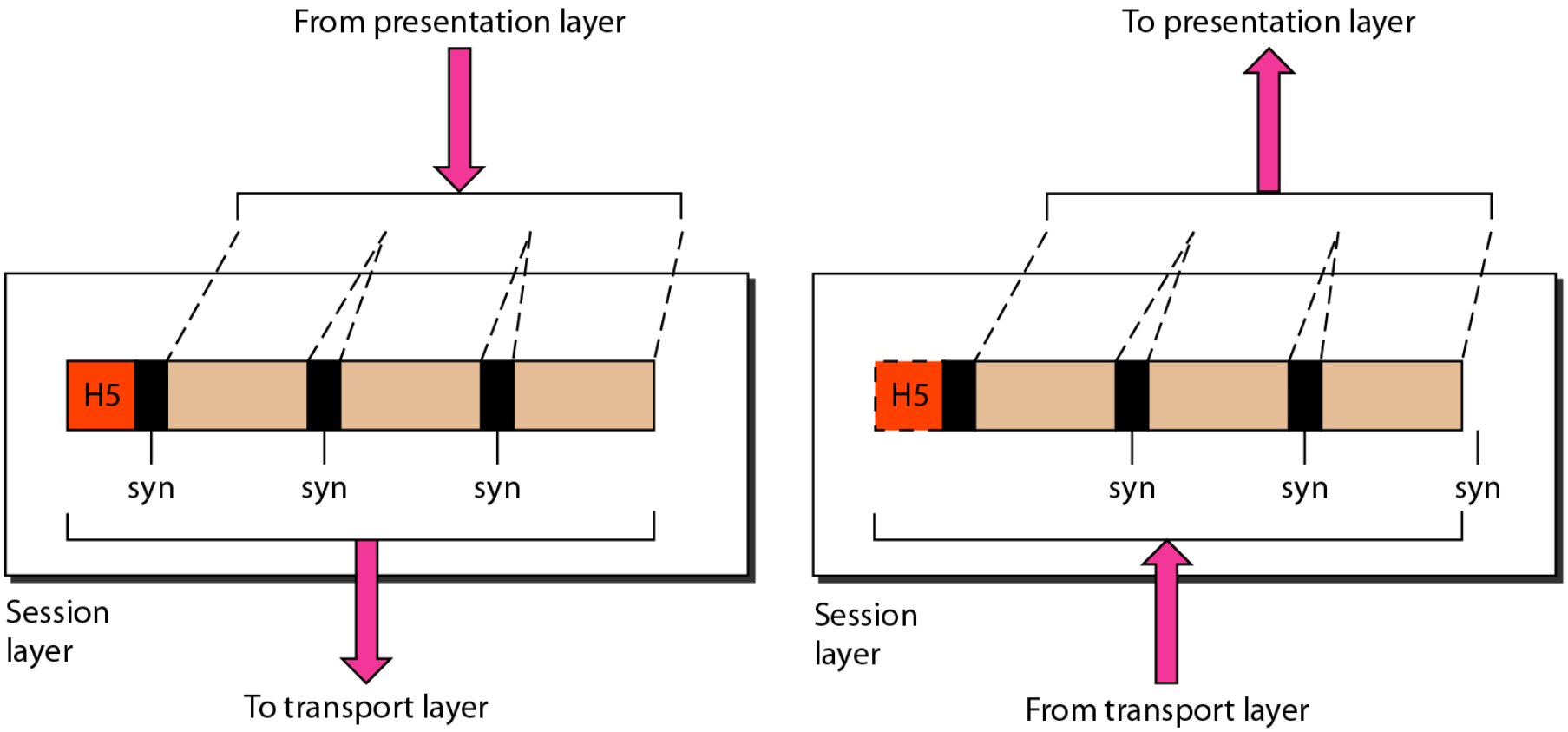
**The transport layer is responsible for the delivery of a message from one process to another.**

Service point addressing
Segmentation and reassembly
Connection control
Flow control (end to end)
Error control

## Figure 2.11 *Reliable process-to-process delivery of a message*



## Figure 2.12 *Session layer*

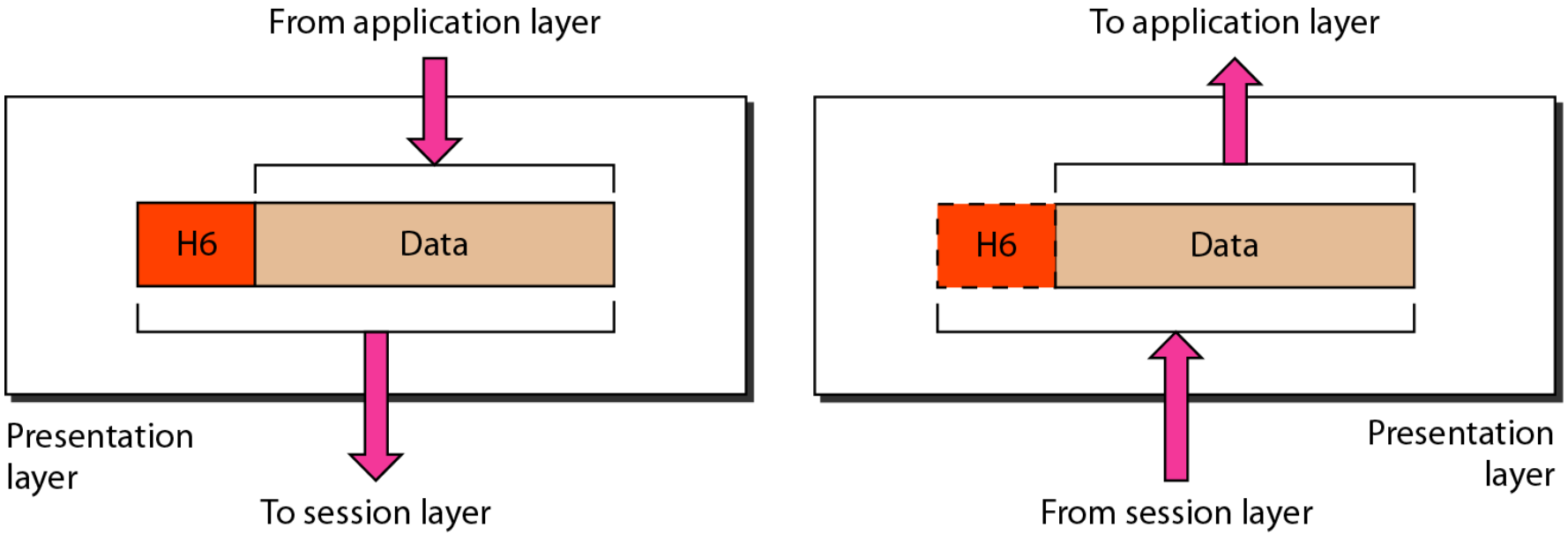


***Note***

**The session layer is responsible for dialog control and synchronization.**

Dialog control
Synchronization (e.g. facilitates resume of broken download)

## Figure 2.13 *Presentation layer*

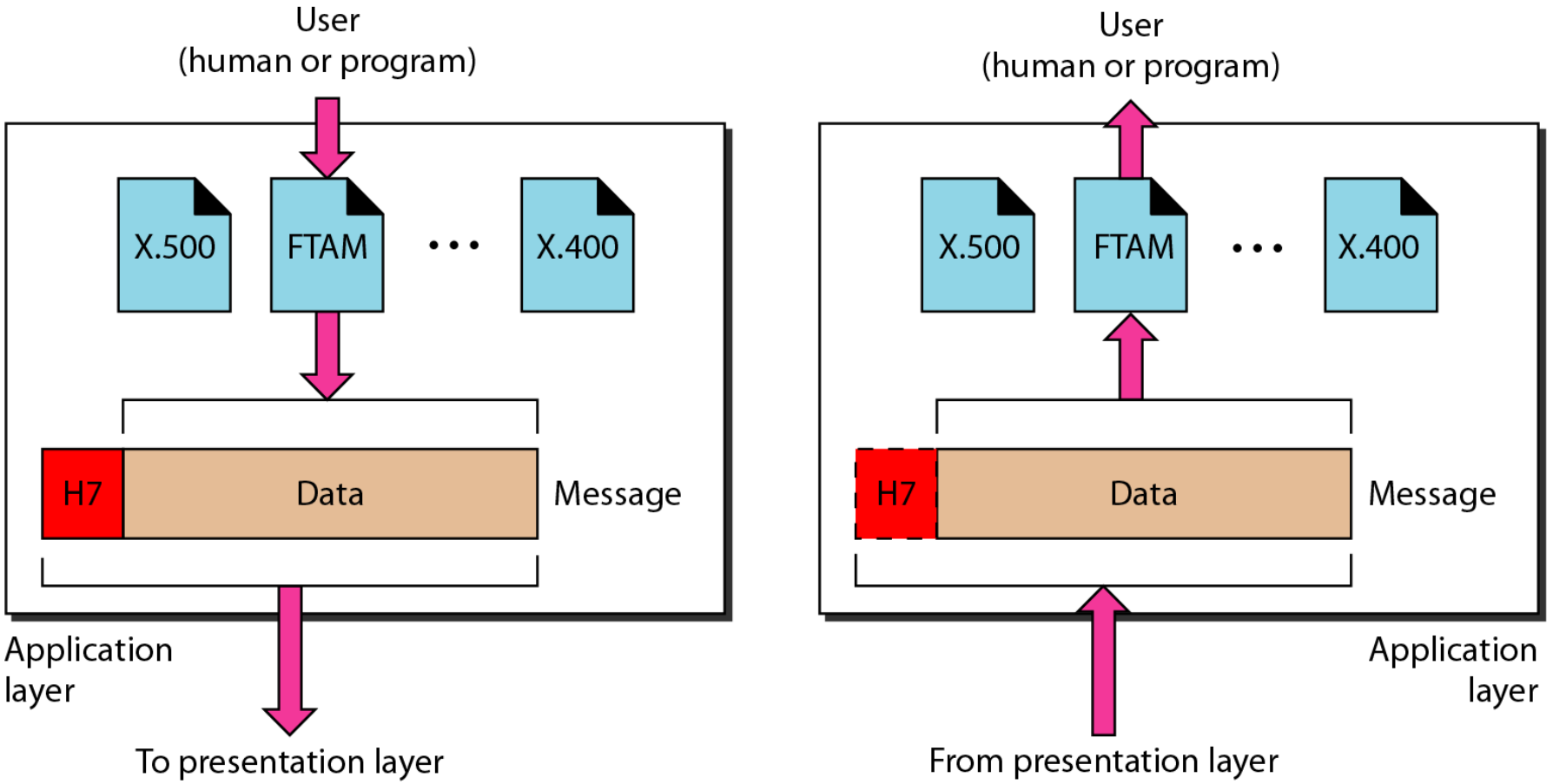


*Note*

**The presentation layer is responsible for translation, compression, and encryption.**

Translation
Compression
Encryption

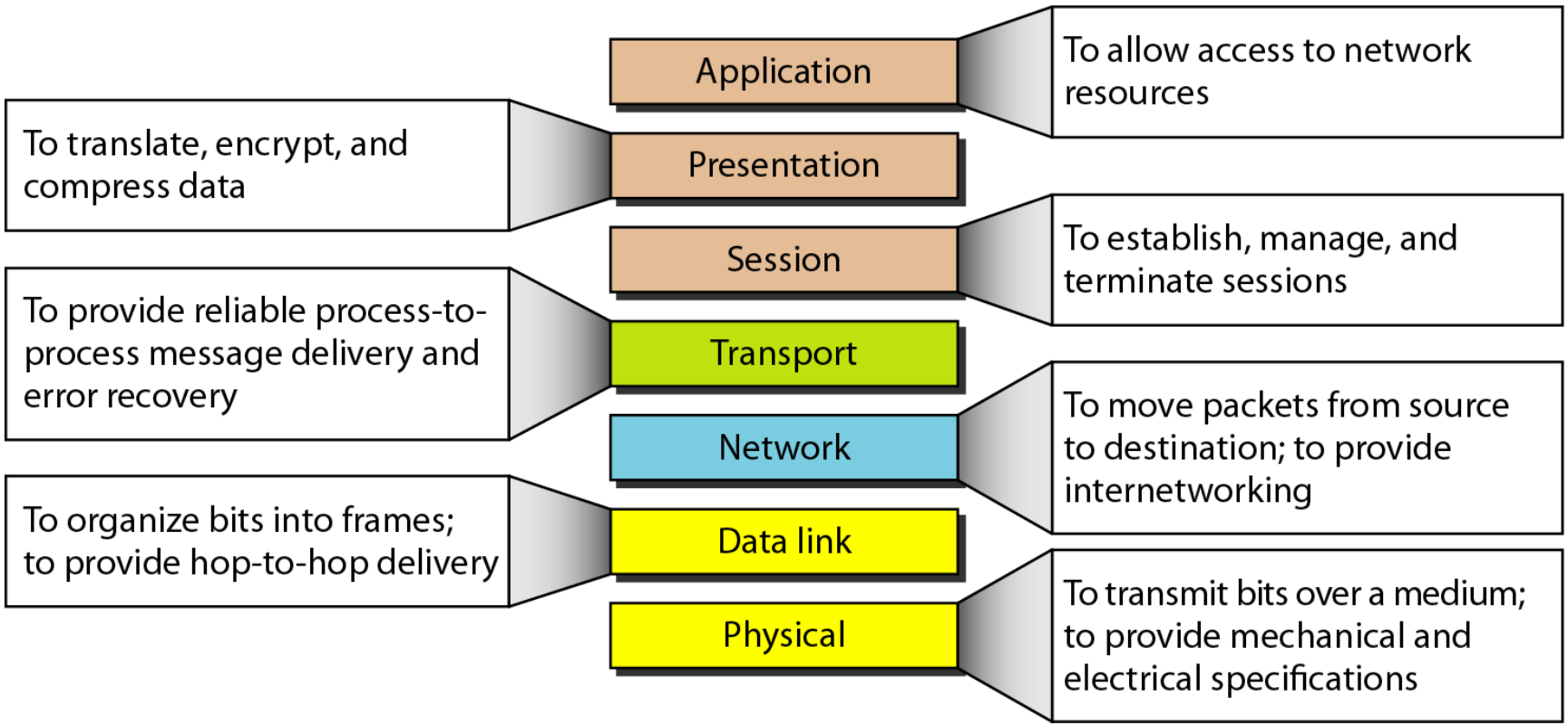
## Figure 2.14 *Application layer*



*Note*

**The application layer is responsible for providing services to the user.**

## Figure 2.15 *Summary of layers*



# TCP, UDP and SCTP Comparison

| Attribute | TCP | UDP | SCTP |
|---|---|---|---|
| **Reliability** | Reliable | Unreliable | Reliable |
| **Connection Management** | Connection-orientated | Connectionless | Connection-orientated |
| **Transmission** | Byte-orientated | Message-orientated | Message-orientated |
| **Flow Control** | Yes | No | Yes |
| **Congestion Control** | Yes | No | Yes |
| **Fault Tolerance** | No | No | Yes |
| **Data Delivery** | Strictly Ordered | Unordered | Partially Ordered |
| **Security** | Yes | Yes | Improved |

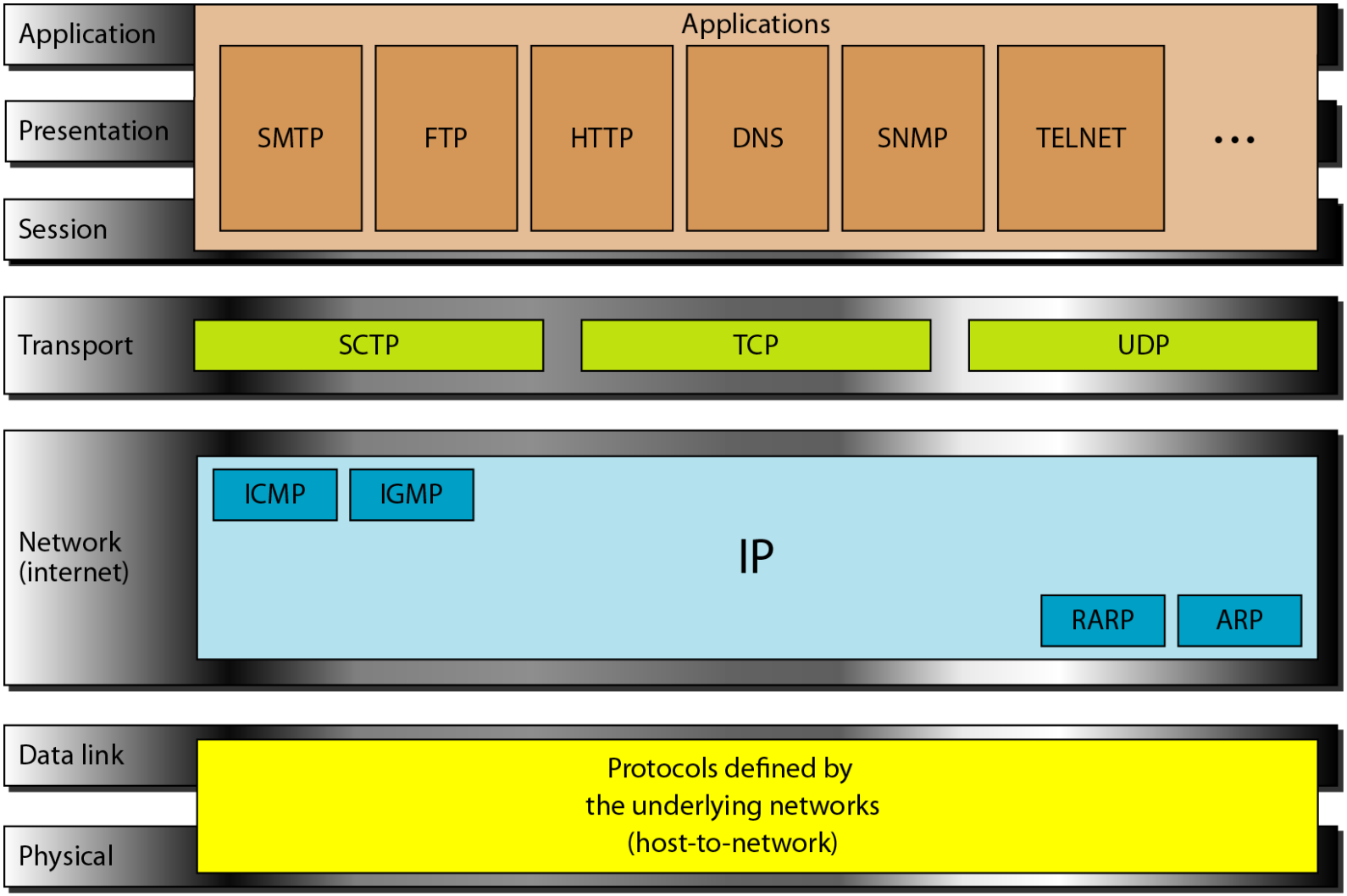
# 2-4 TCP/IP PROTOCOL SUITE

***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.***

***Topics discussed in this section:***

**Physical and Data Link Layers**
**Network Layer**
**Transport Layer**
**Application Layer**

# Figure 2.16 *TCP/IP and OSI model*



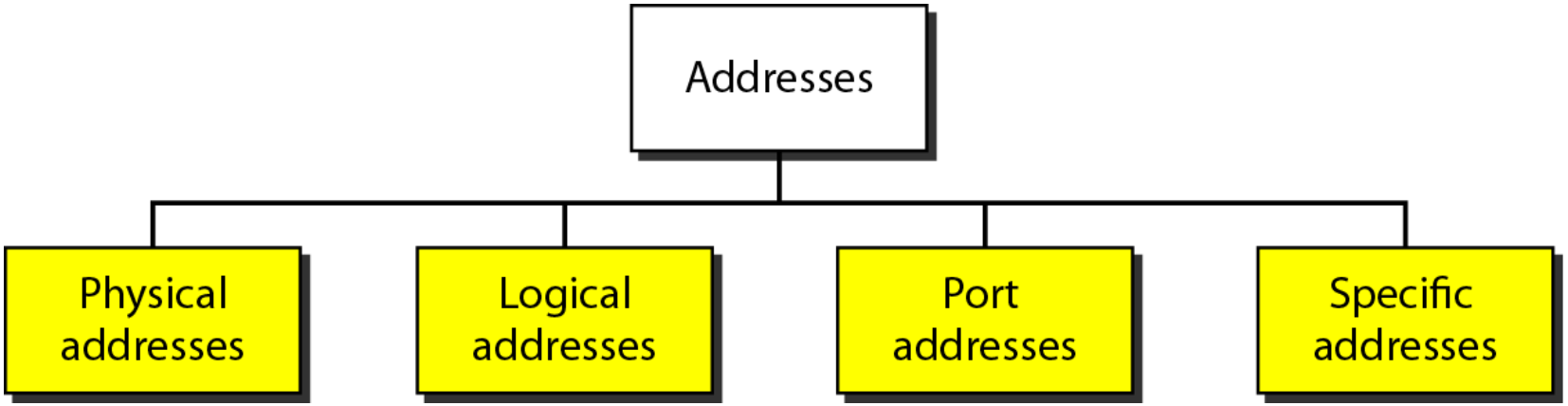
# 2-5 ADDRESSING

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

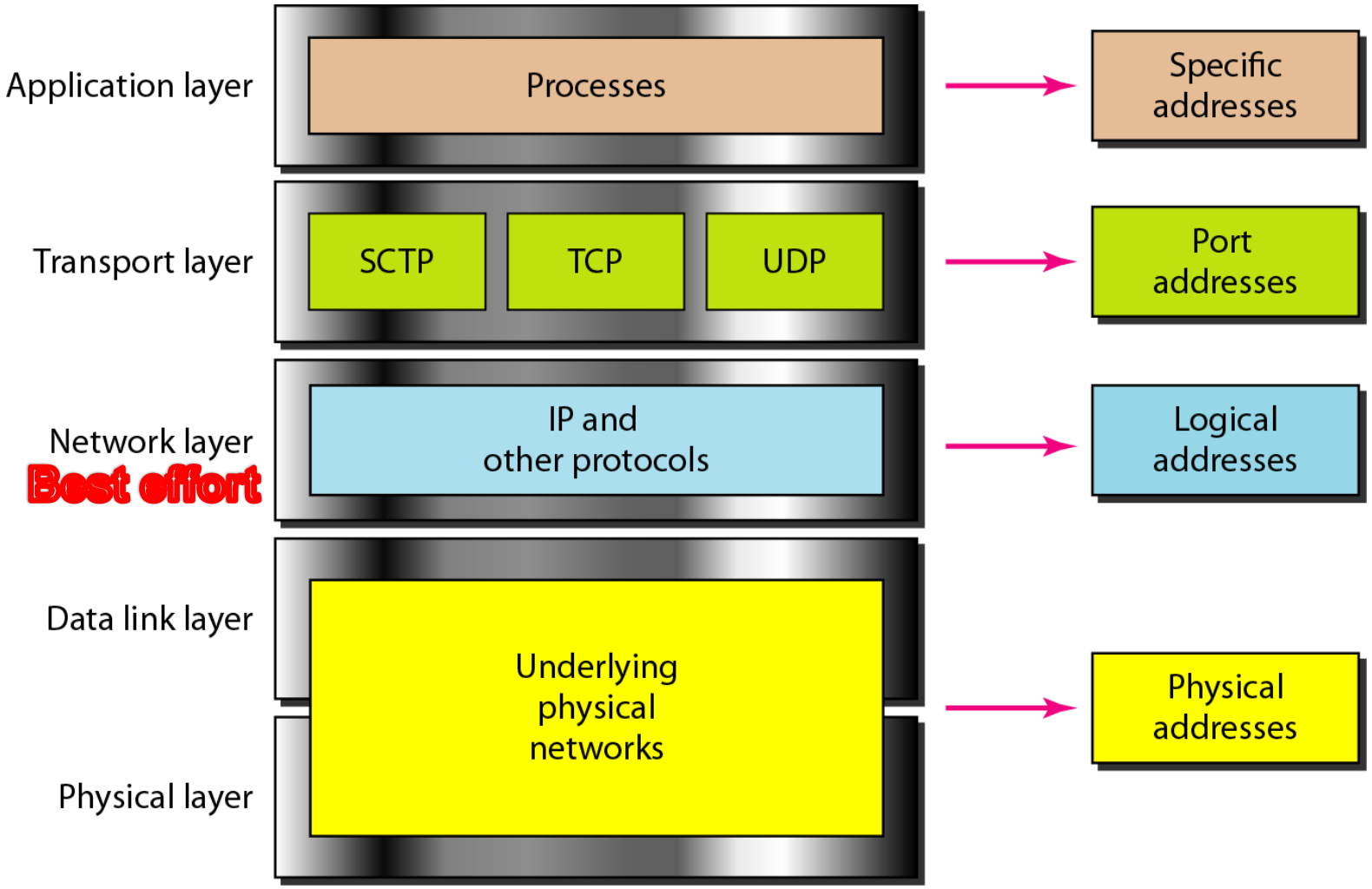
***Topics discussed in this section:***

**Physical Addresses**
**Logical Addresses**
**Port Addresses**
**Specific Addresses**

## Figure 2.17 *Addresses in TCP/IP*



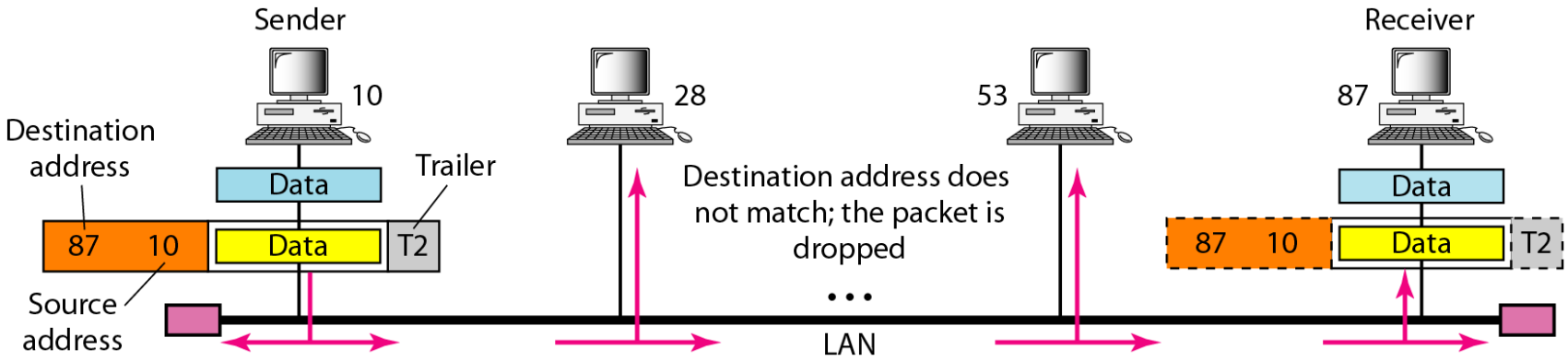
## Figure 2.18 *Relationship of layers and addresses in TCP/IP*



# *Example 2.1*

***In Figure 2.19 a node with physical address 10 sends a frame to a node with physical address 87. The two nodes are connected by a link (bus topology LAN). As the figure shows, the computer with physical address 10 is the sender, and the computer with physical address 87 is the receiver.***

# Figure 2.19 *Physical addresses*



# *Example 2.2*

***As we will see in Chapter 13, most local-area networks use a 48-bit (6-byte) physical address written as 12 hexadecimal digits; every byte (2 hexadecimal digits) is separated by a colon, as shown below:***

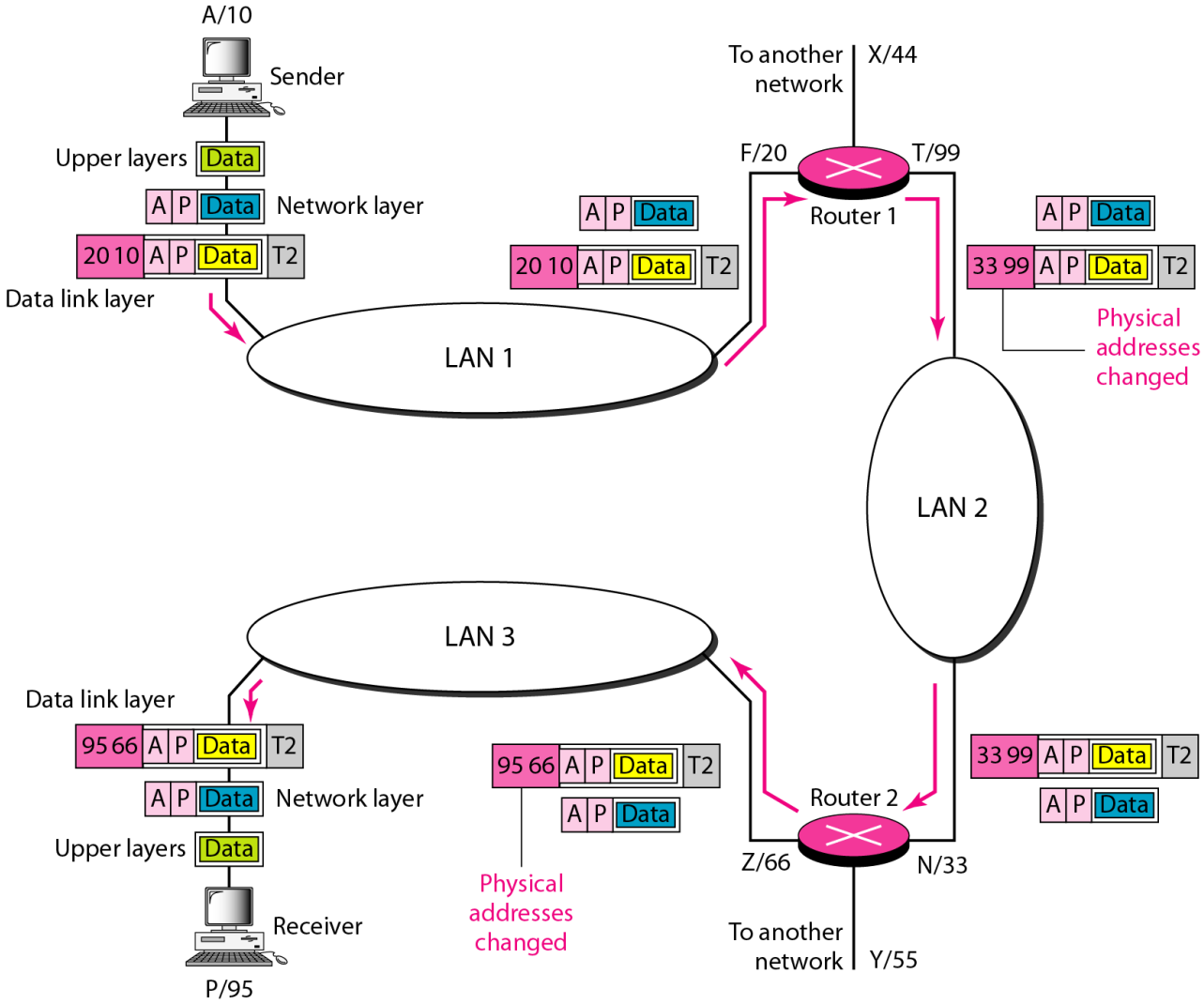
**07:01:02:01:2C:4B**

**A 6-byte (12 hexadecimal digits) physical address.**

# *Example 2.3*

***Figure 2.20 shows a part of an internet with two routers connecting three LANs. Each device (computer or router) has a pair of addresses (logical and physical) for each connection. In this case, each computer is connected to only one link and therefore has only one pair of addresses. Each router, however, is connected to three networks (only two are shown in the figure). So each router has three pairs of addresses, one for each connection.***

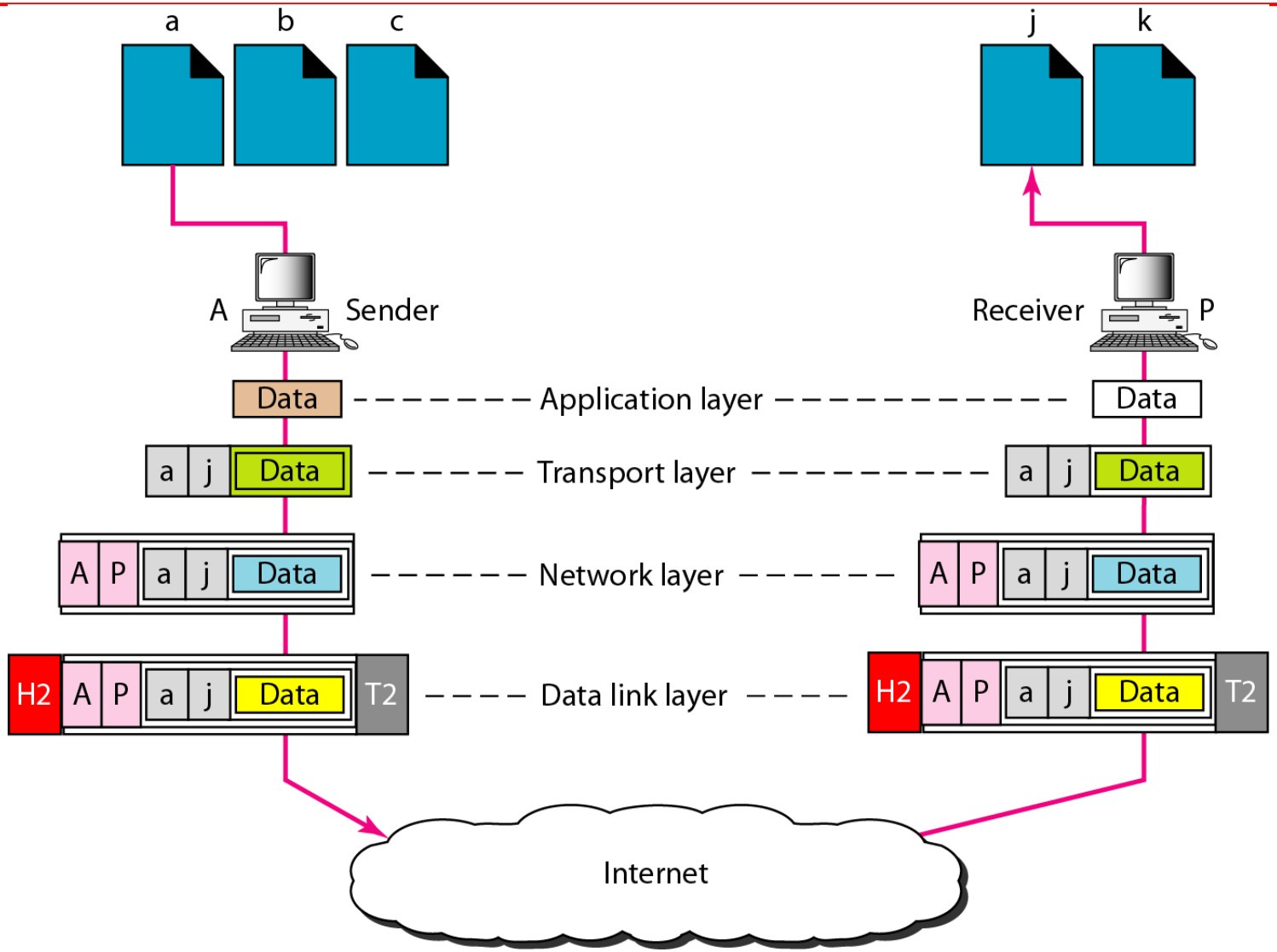
# Figure 2.20 *IP addresses*



# Example 2.4

*Figure 2.21 shows two computers communicating via the Internet. The sending computer is running three processes at this time with port addresses a, b, and c. The receiving computer is running two processes at this time with port addresses j and k. Process a in the sending computer needs to communicate with process j in the receiving computer. Note that although physical addresses change from hop to hop, logical and port addresses remain the same from the source to destination.*

## Figure 2.21 *Port addresses*



*Note*

**The physical addresses will change from hop to hop, but the logical addresses usually remain the same.**

# *Example 2.5*

***As we will see in Chapter 23, a port address is a 16-bit address represented by one decimal number as shown.***

**753**

**A 16-bit port address represented as one single number.**

*Note*

**The physical addresses change from hop to hop, but the logical and port addresses usually remain the same.**