Chapter 1

Introduction

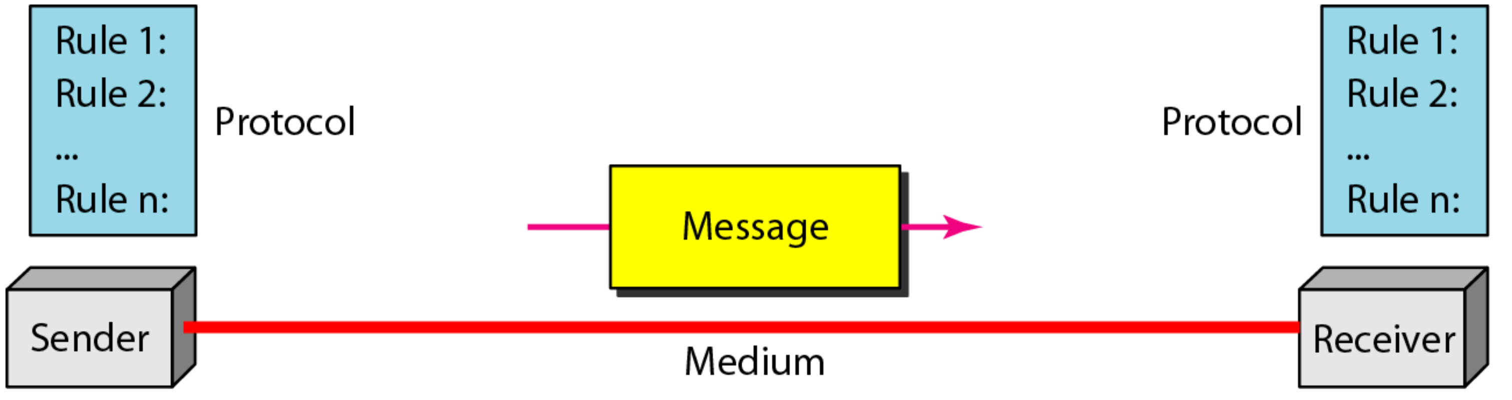
1-1 DATA COMMUNICATIONS

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
Data Representation
Data Flow

Figure 1.1 *Five components of data communication*



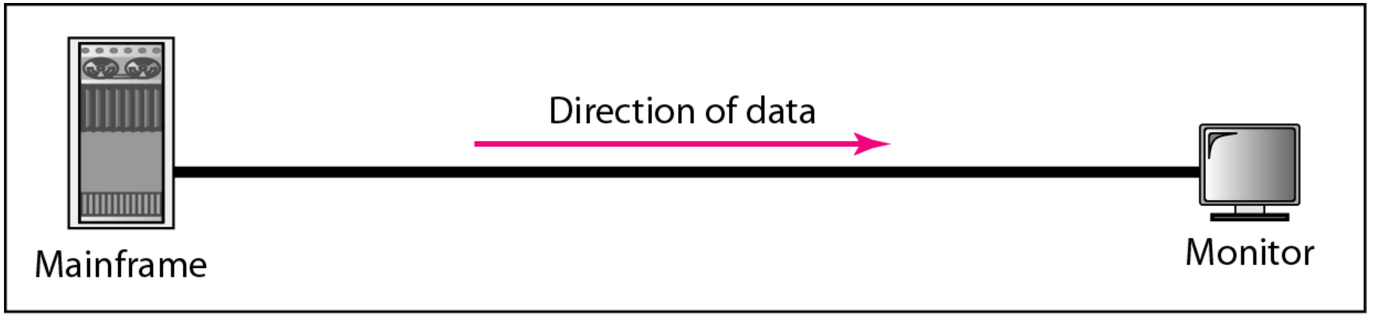
Fundamental Characteristics of Data Communication

- **Delivery**
- **Accuracy**
- **Timeliness**
- **Jitter**

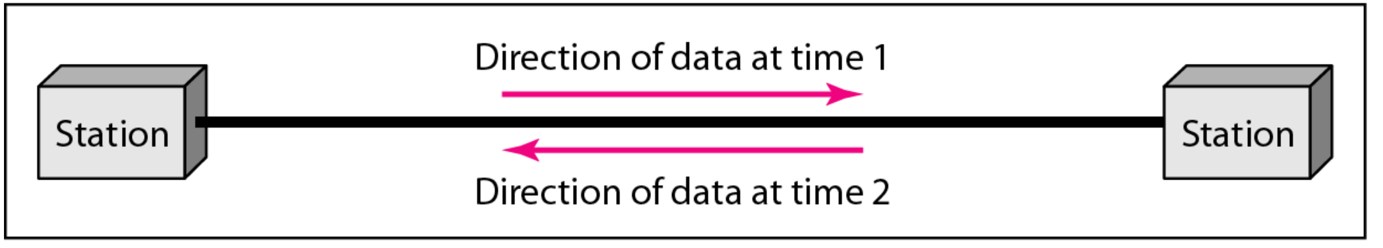
Data Representation:

- **Text, Numbers, Images, Video and Audio**

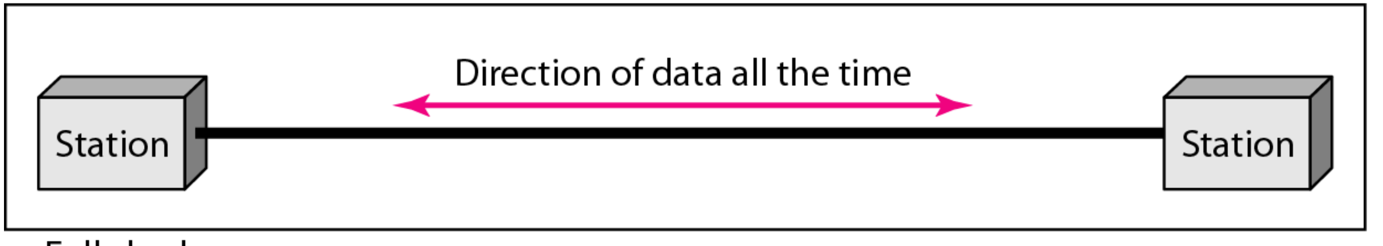
Figure 1.2 *Data flow (simplex, half-duplex, and full-duplex)*



a. Simplex



b. Half-duplex



c. Full-duplex

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.

Topics discussed in this section:

Distributed Processing
Network Criteria
Physical Structures
Network Models
Categories of Networks
Interconnection of Networks: Internetwork

Network Criteria

Performance

- Transit time
- Response time
- Throughput
- Delay

Reliability

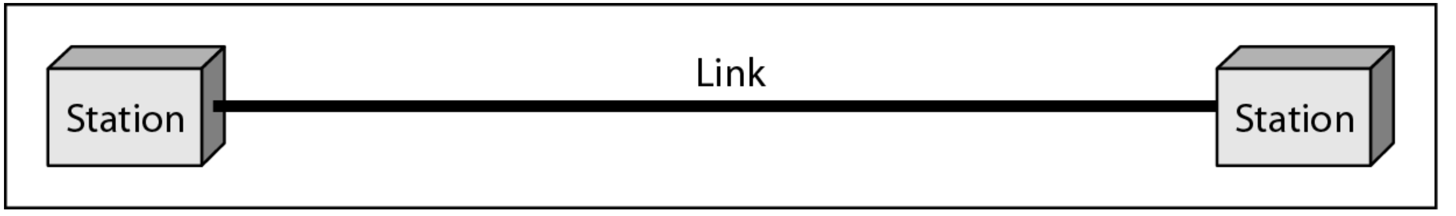
- Accuracy of delivery
- Frequency of failures
- Time to recovery from failures
- Robustness in catastrophe

Security

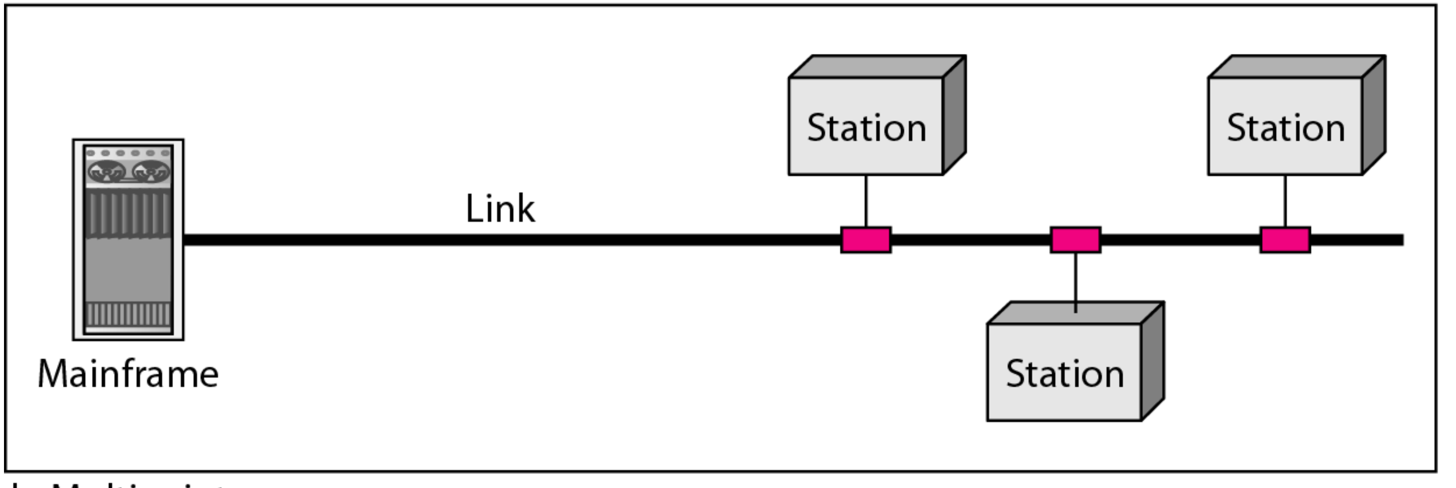
- Protecting from unauthorized access
- Protecting data from damage
- policies and procedures for recovery from breaches and data losses

Physical Structures: Links and Topology

Links:



a. Point-to-point



b. Multipoint

Figure 1.4 *Categories of topology*

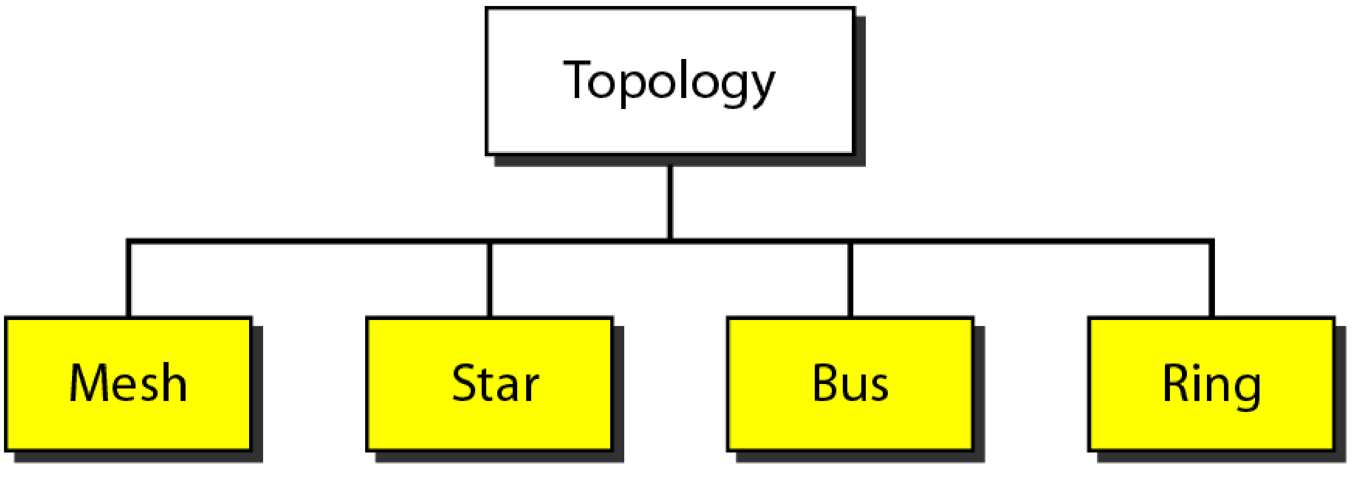


Figure 1.5 *A fully connected mesh topology (five devices)*

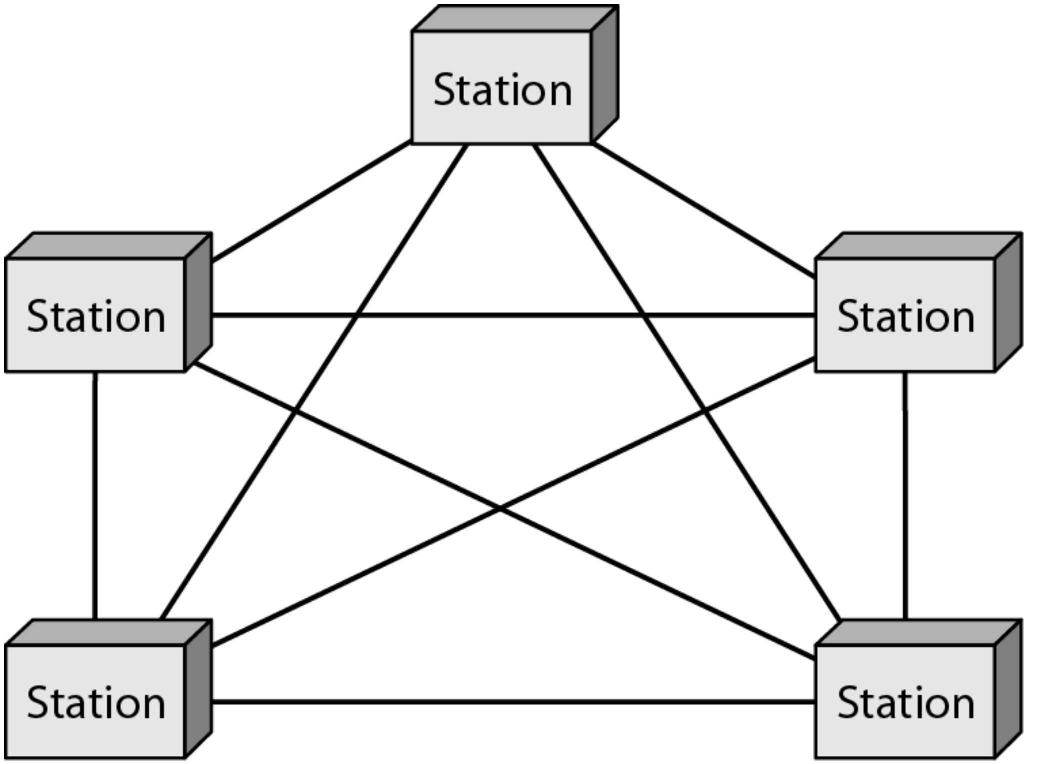


Figure 1.6 *A star topology connecting four stations*

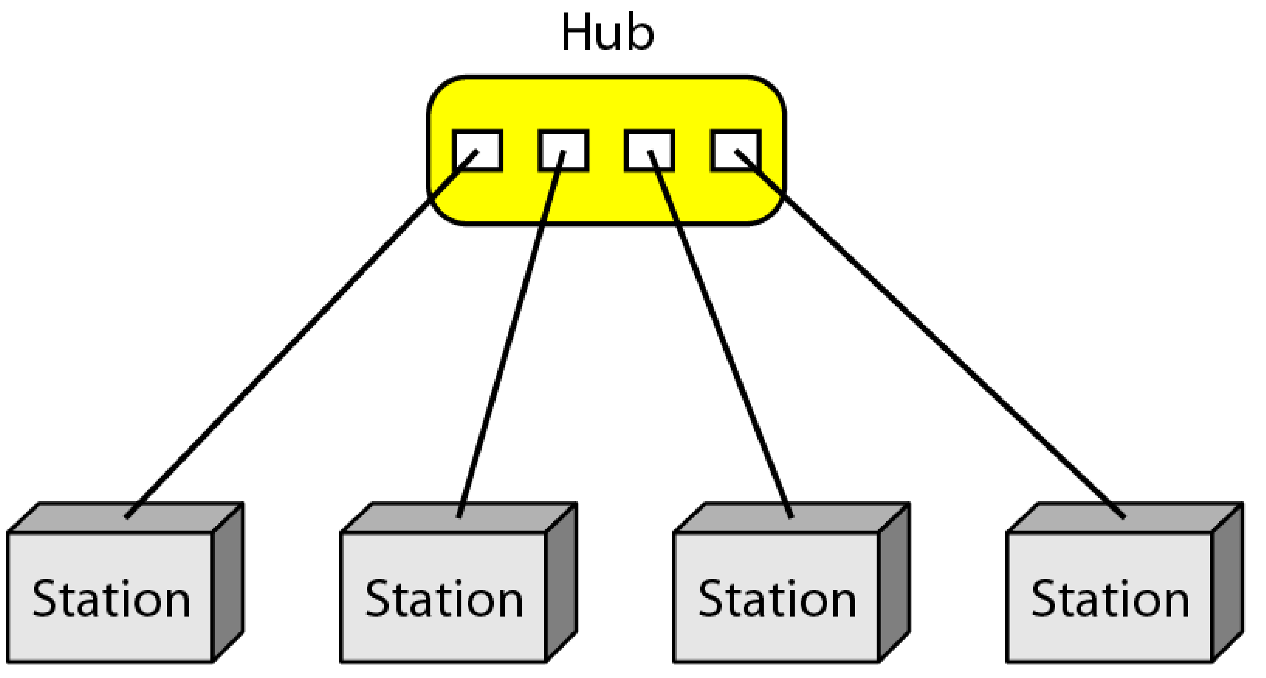


Figure 1.7 *A bus topology connecting three stations*

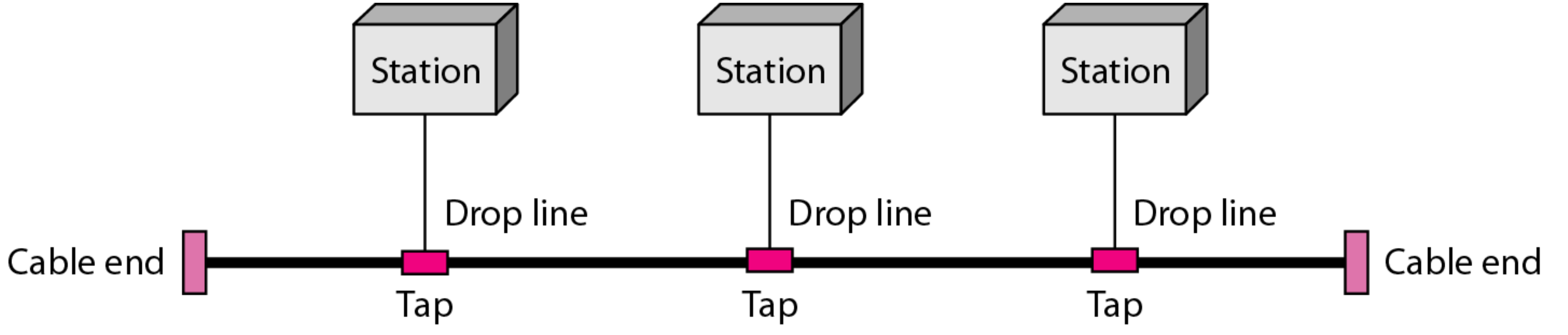


Figure 1.8 *A ring topology connecting six stations*

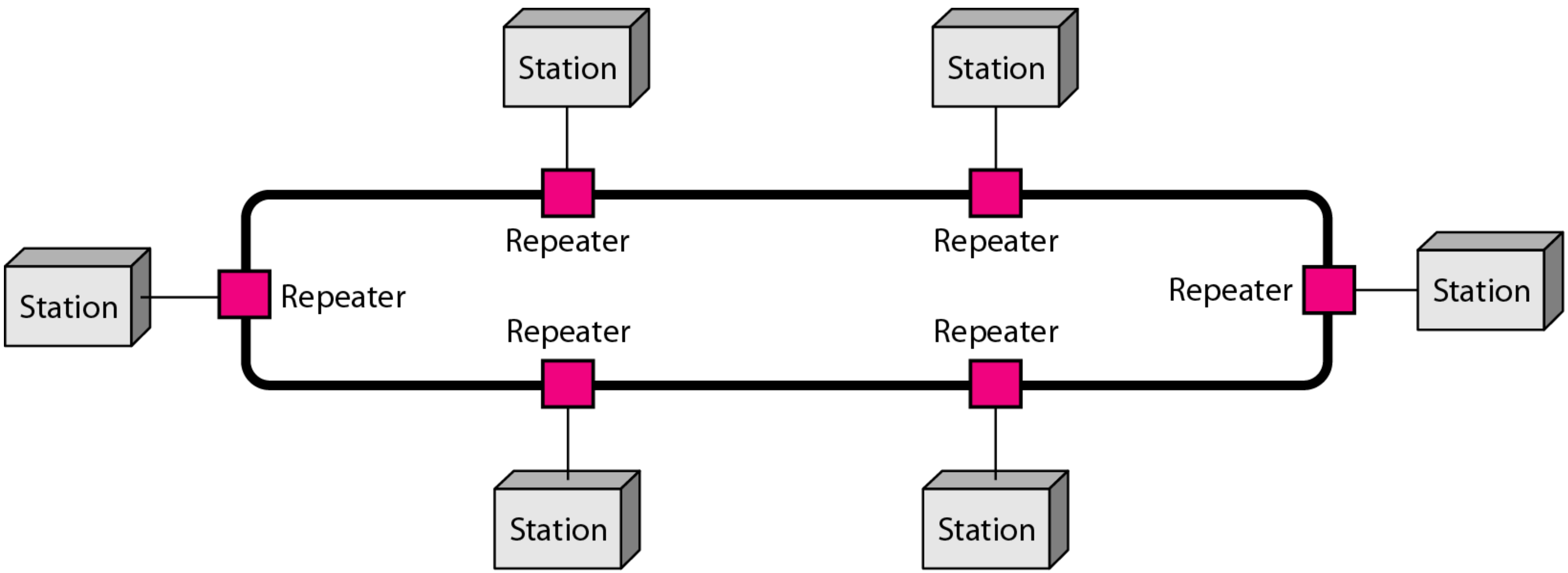


Figure 1.9 *A hybrid topology: a star backbone with three bus networks*

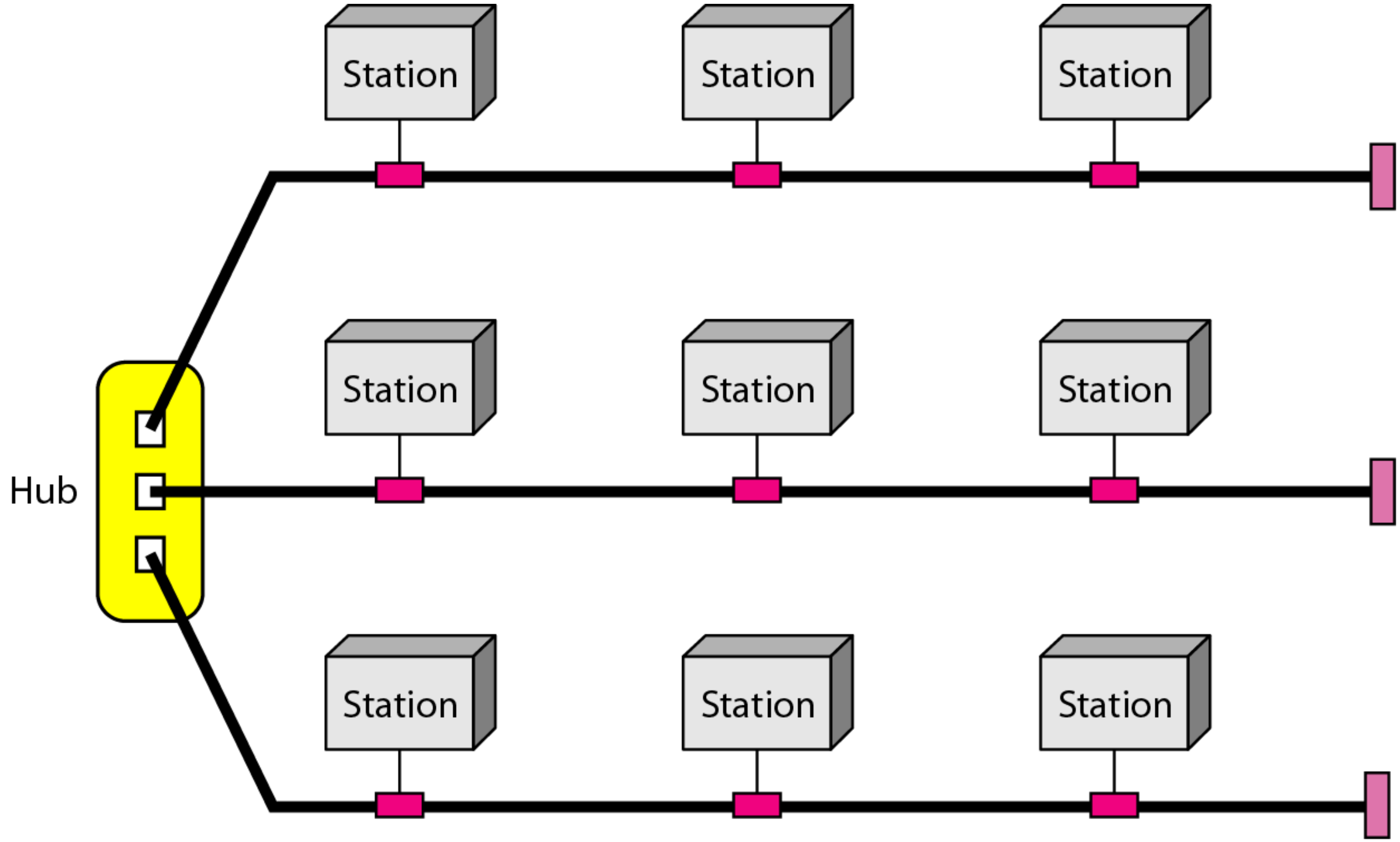


Figure 1.10 *An isolated LAN connecting 12 computers to a hub in a closet*

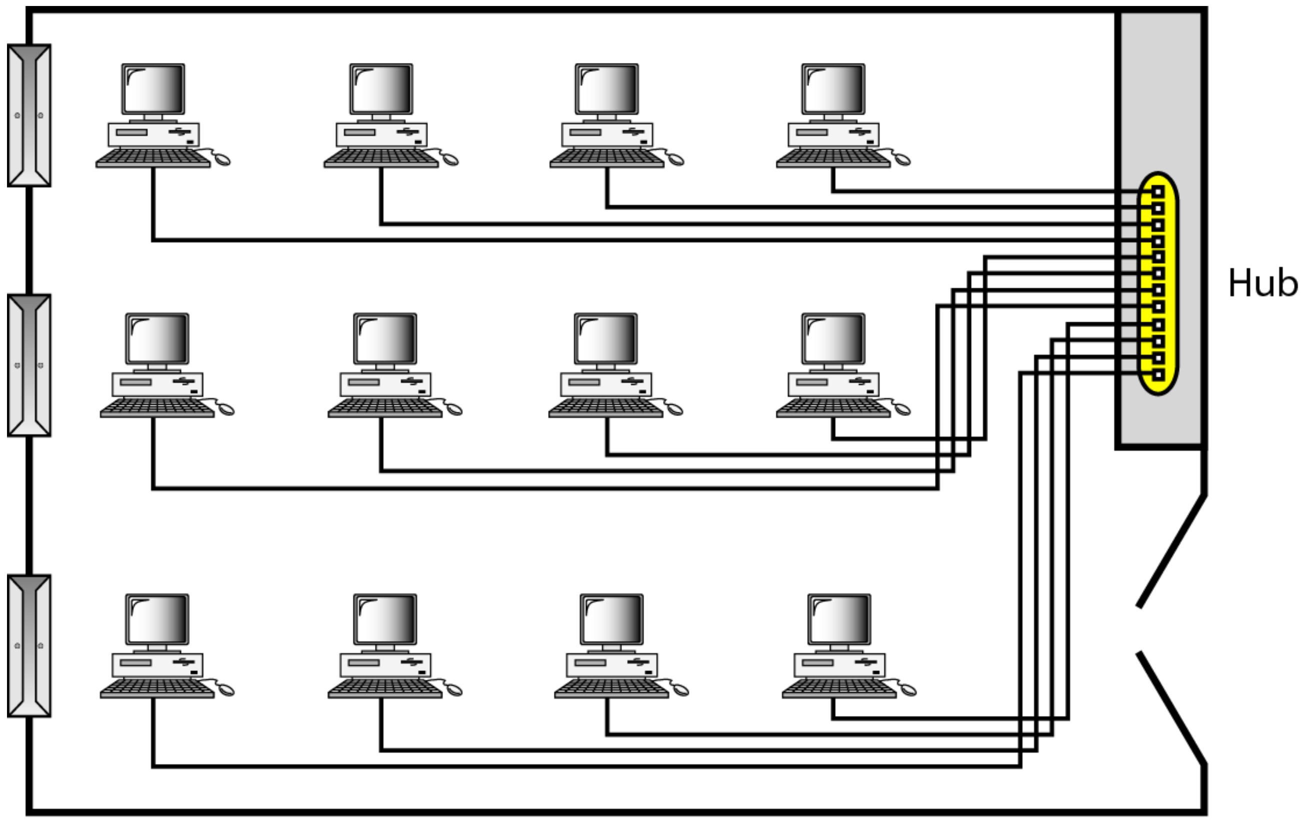
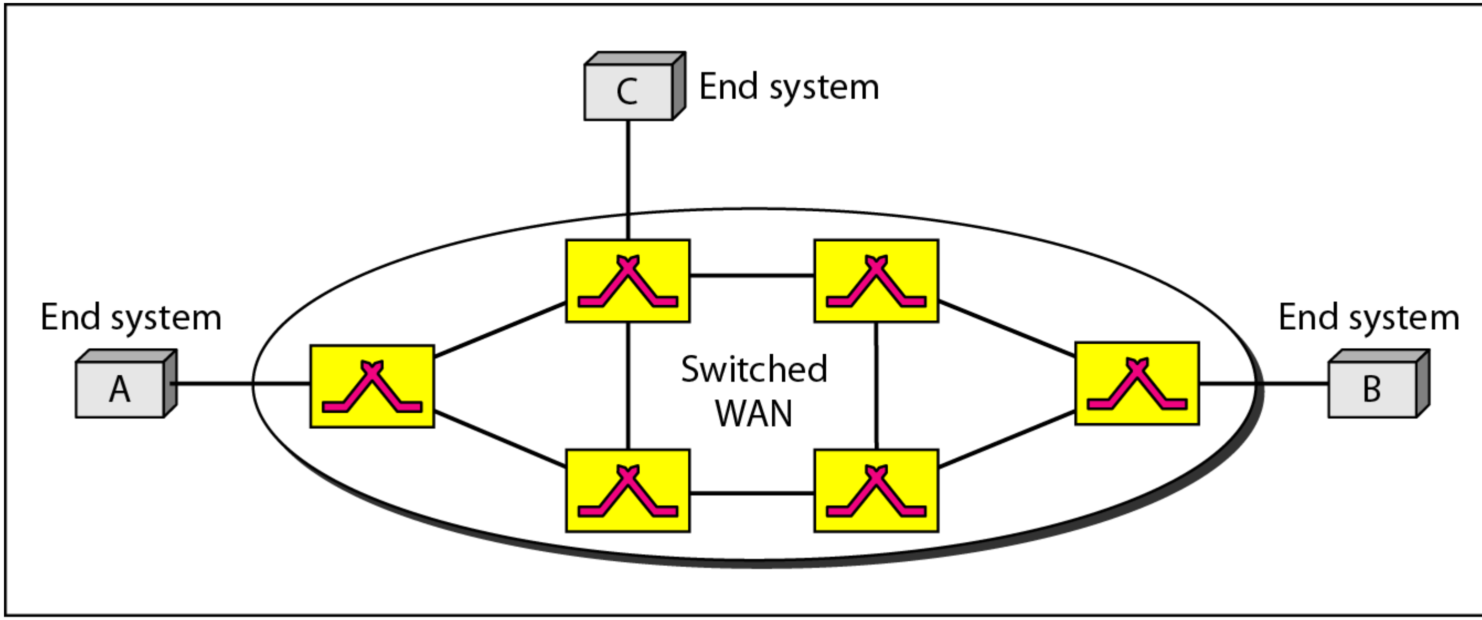
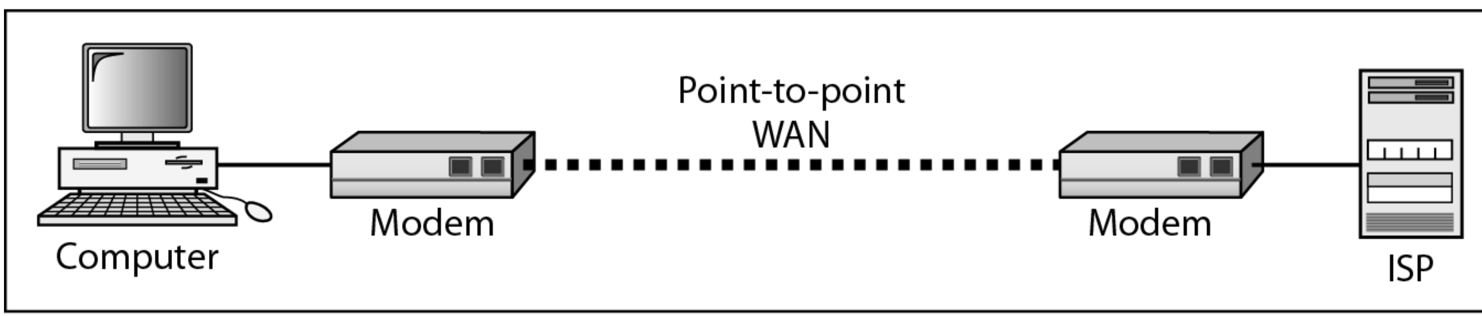


Figure 1.11 *WANs: a switched WAN and a point-to-point WAN*

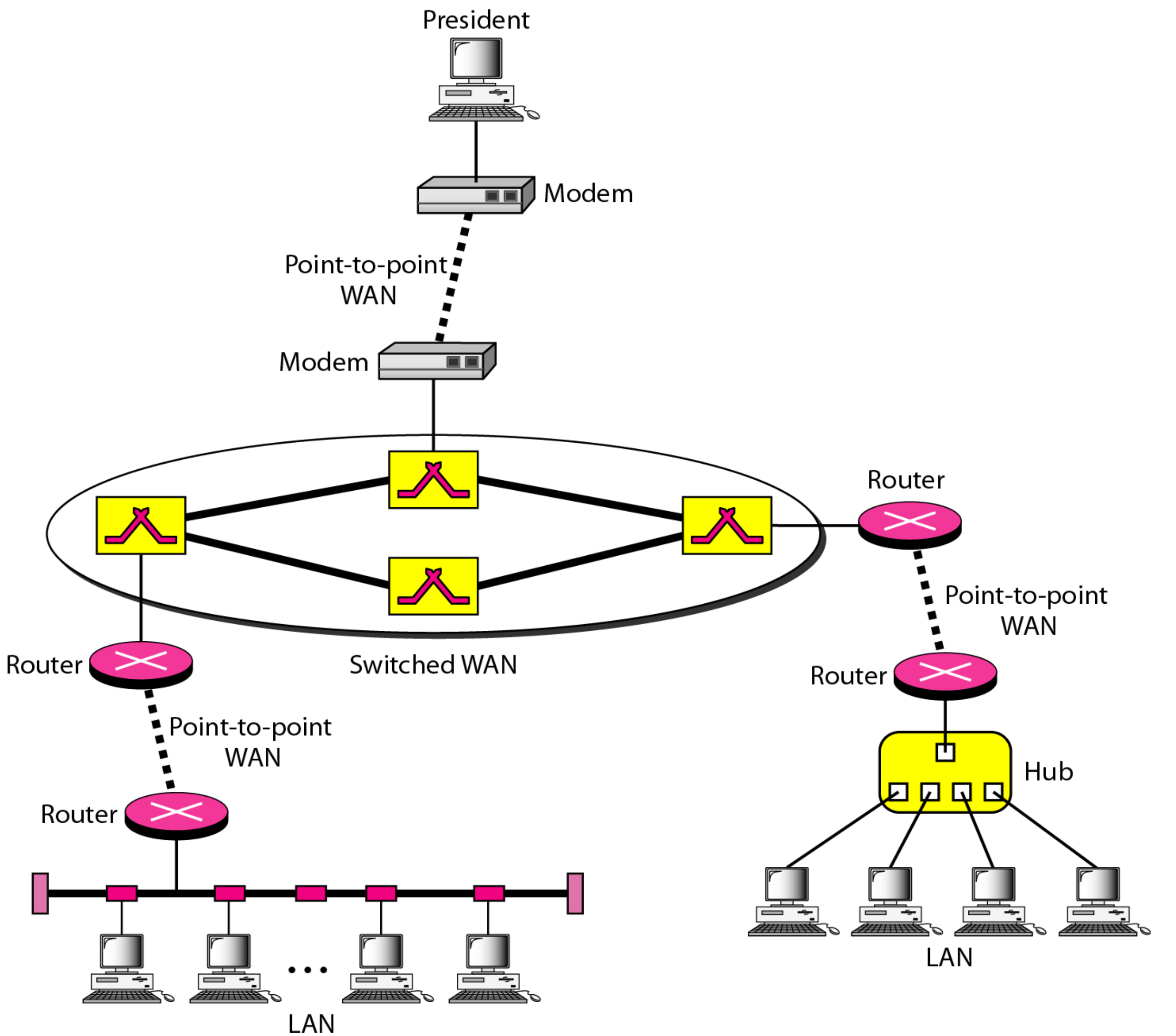


a. Switched WAN



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:

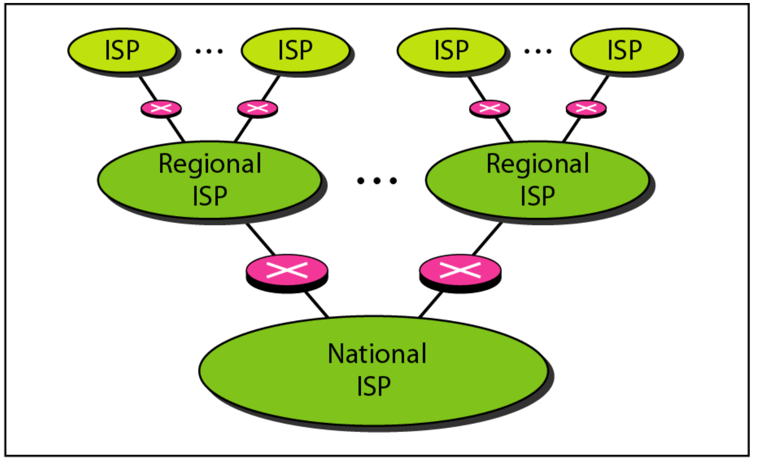
A Brief History
The Internet Today (ISPs)

BRIEF HISTORY

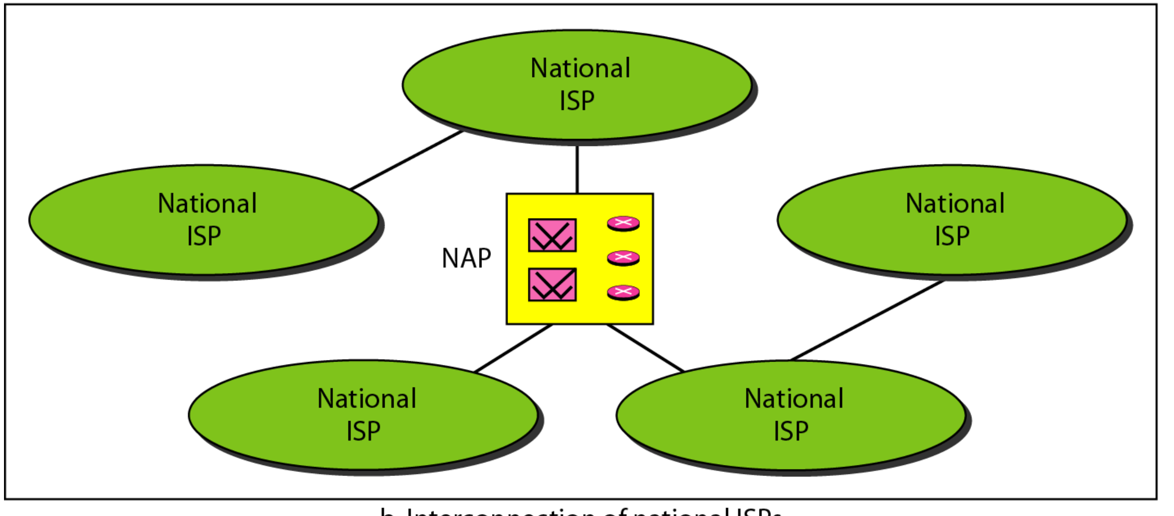
- Mid 1960's : Mainframes

- 1967 : Advanced Research Project Agency (ARPA)
  - 4 nodes: UCLA, UCSB, SRI, UU
  - IMPs: Interface Message Processor
  - NCP: Network Control Protocol
  - Vint Cerf and Bob Kahn
  - TCP: Transmission Control Protocol (Landmark paper in 1973)
  - TCP & IP

Figure 1.13 *Hierarchical organization of the Internet*



a. Structure of a national ISP



b. Interconnection of national ISPs

1-4 PROTOCOLS AND STANDARDS

In this section, we define two widely used terms: protocols and standards. First, we define protocol, which is synonymous with rule. Then we discuss standards, which are agreed-upon rules.

Topics discussed in this section:

Protocols
Standards
Standards Organizations
Internet Standards

PROTOCOLS

- Data Communication Protocol
  - What to communicate
  - How to communicate
  - When to communicate

- Syntax: Structure or Format of the data (specific meaning to the order of the fields)
- Semantics: Interpretation of the fields & Action based on interpretation
- Timing: Controlling the rate of transmission (when to sent and how fast to sent)

INTERNET STANDARDS AND RFCs

- The Internet Society
  - Internet Architecture Group (IAG)
  - Internet Engineering Task Force (IETF)
  - Internet Engineering Steering Group (IESG)

- Request for Comments (RFCs)
  - The actual development of new standards is carried out by working groups charted by IETF Requests for Comments (RFCs)
  - Membership is voluntary
  - The process involved:
  - The working group makes a draft version of the document
  - Places in the "Internet Draft" online directory
  - Kept there for 6 months, and review and comments on the draft are obtained.

Some Example RFCs

- RFC 791: Internet Protocol (IP)
- RFC 792: Internet Control Message Protocol (ICMP)
- RFC 793: Transmission Control Protocol (TCP)
- RFC 959: File Transfer Protocol (FTP)
- RFC 1035: Domain Names, Specification and Implementation (DNS)
- RFC 1058: Routing Information Protocol (RIP)
- RFC 1157: Simple N/W Management Protocol (SNMP)
- RFC 1945: Hyper Text Transfer Protocol (HTTP)
- RFC 1321: The Message Digest Algorithm (MD5)

Chapter 2

Network Models

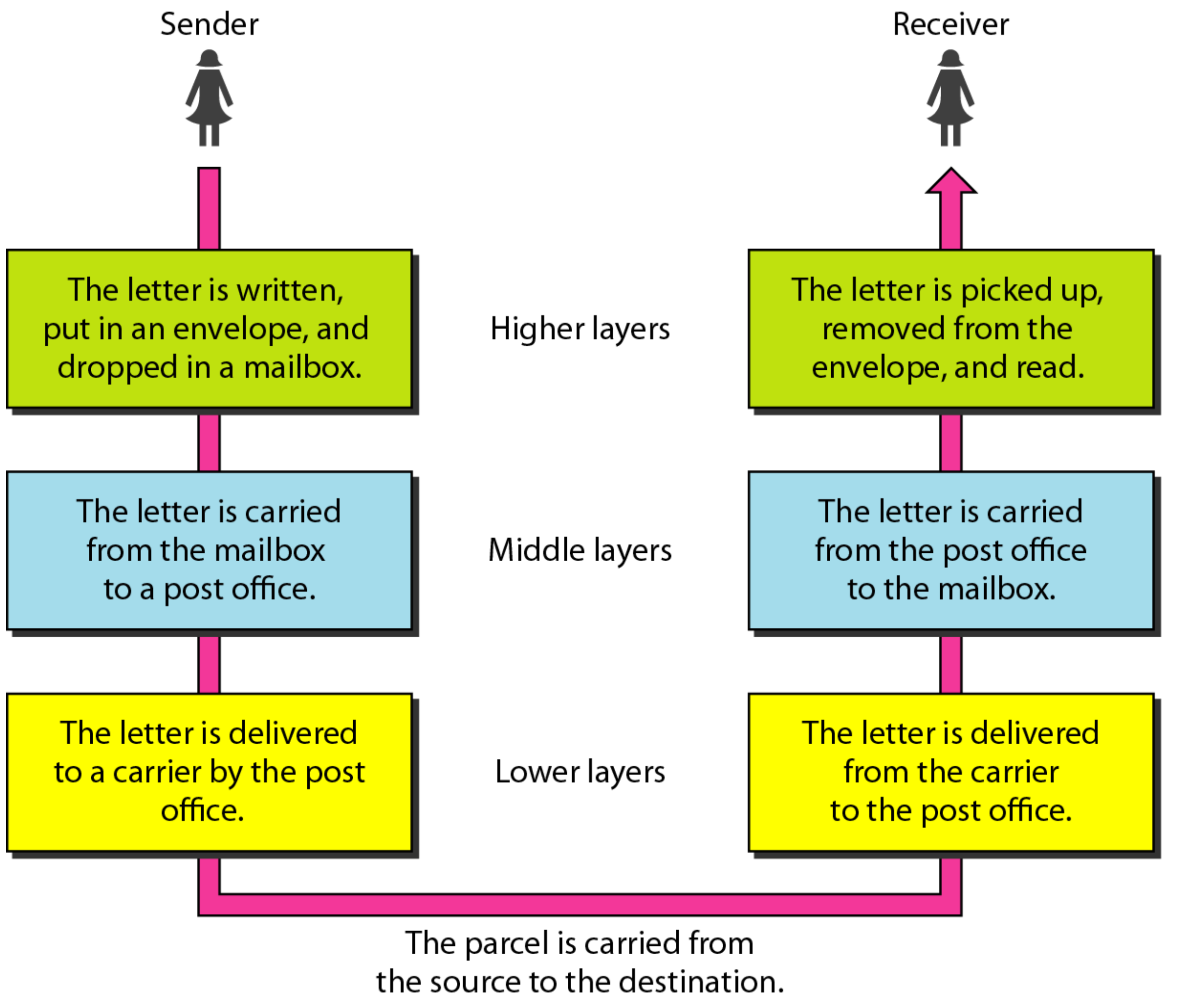
2-1 LAYERED TASKS

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

THE OSI MODEL

ISO is the organization.

OSI is the model.

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.

Figure 2.2 *Seven layers of the OSI model*

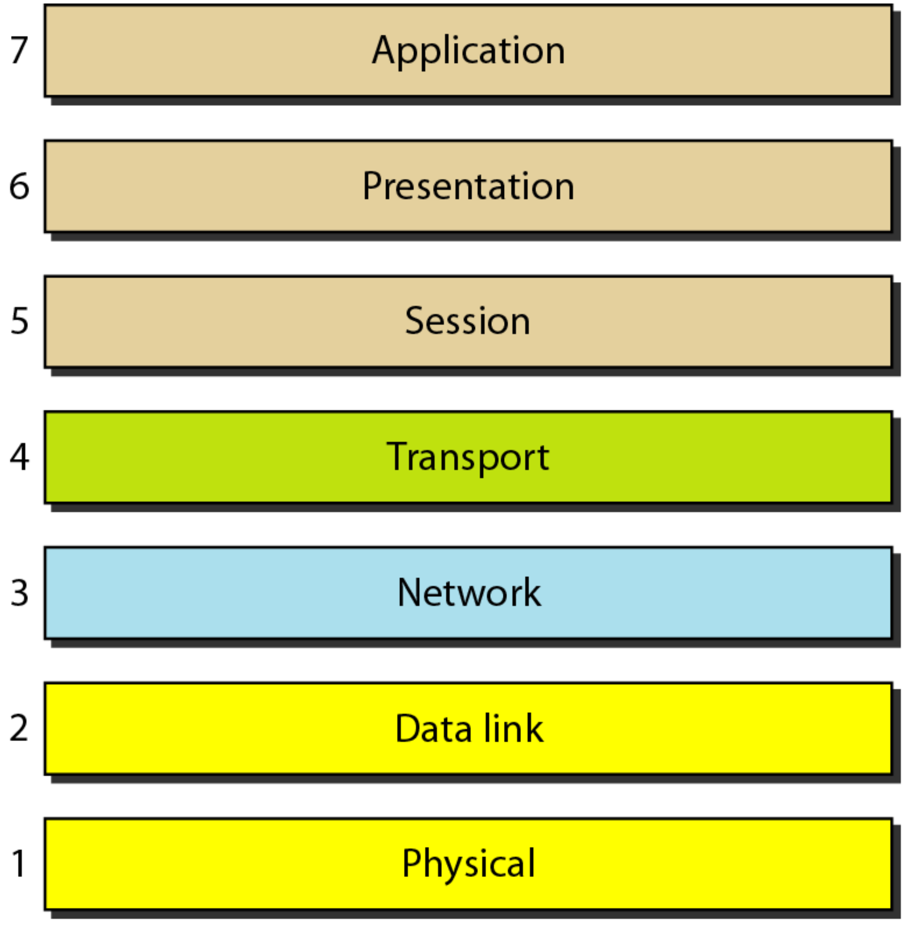


Figure 2.3 *The interaction between layers in the OSI model*

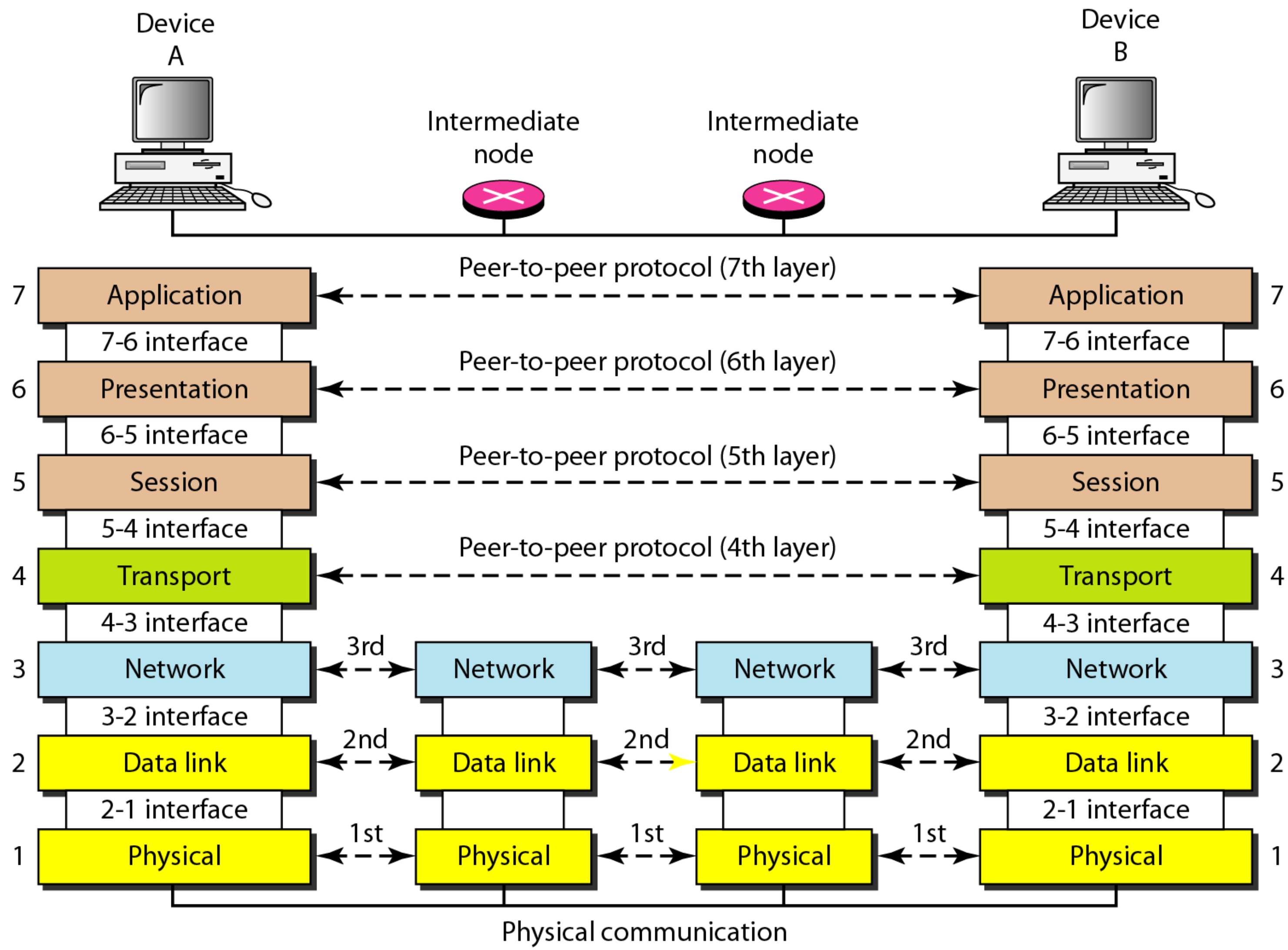
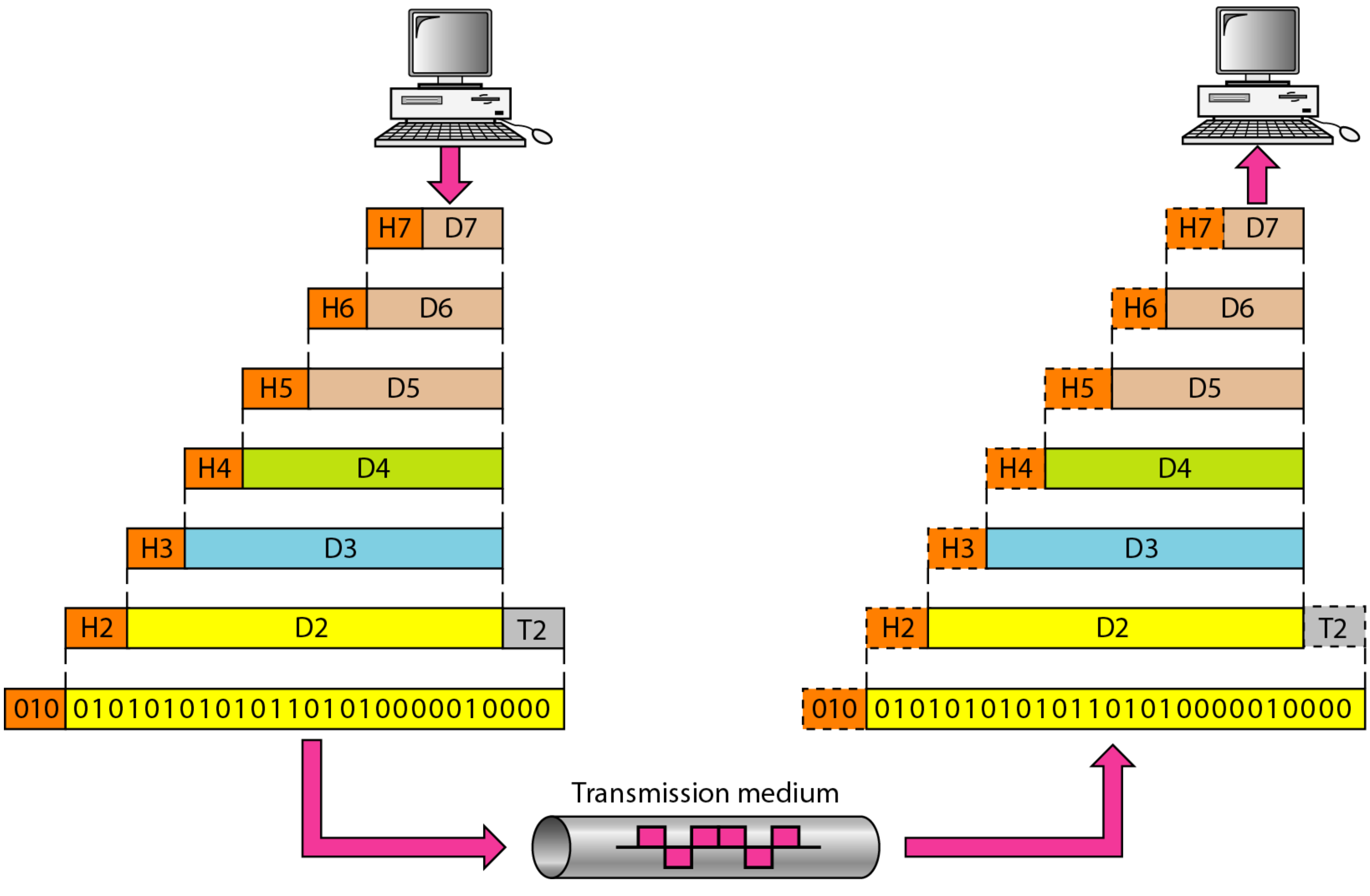


Figure 2.4 *An exchange using the OSI model*



Important Characteristics of OSI Model

- Layered Architectute
- Peer to Peer Processes
- Peer to Peer Protocol
- Interfaces between layers
  - Interface defines the information and services a layer must provide for the layer above it
- Organization of the layers
  - 1,2&3: Network support layers
  - 5,6&7: User support layers
  - 4: Links the lower and upper groups of layers
- Encapsulation
- Interoperability

2-3 LAYERS IN THE OSI MODEL

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

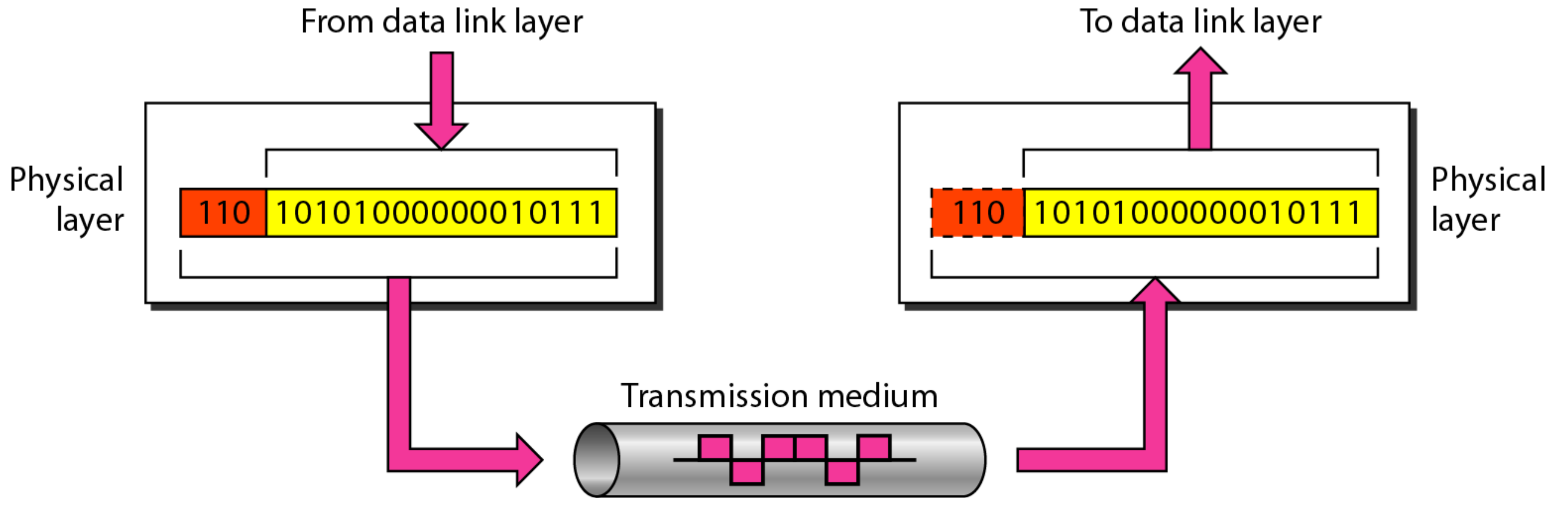
Topics discussed in this section:

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

Physical Layer

- Actual transmission of data (Unreliable)
- Physical characteristics of interfaces and medium
- Representation of bits
- Data rate or Transmission rate
- Synchronization of bits
- Line configuration
- Physical topology
- Transmission mode (simplex/duplex)

Figure 2.5 *Physical layer*



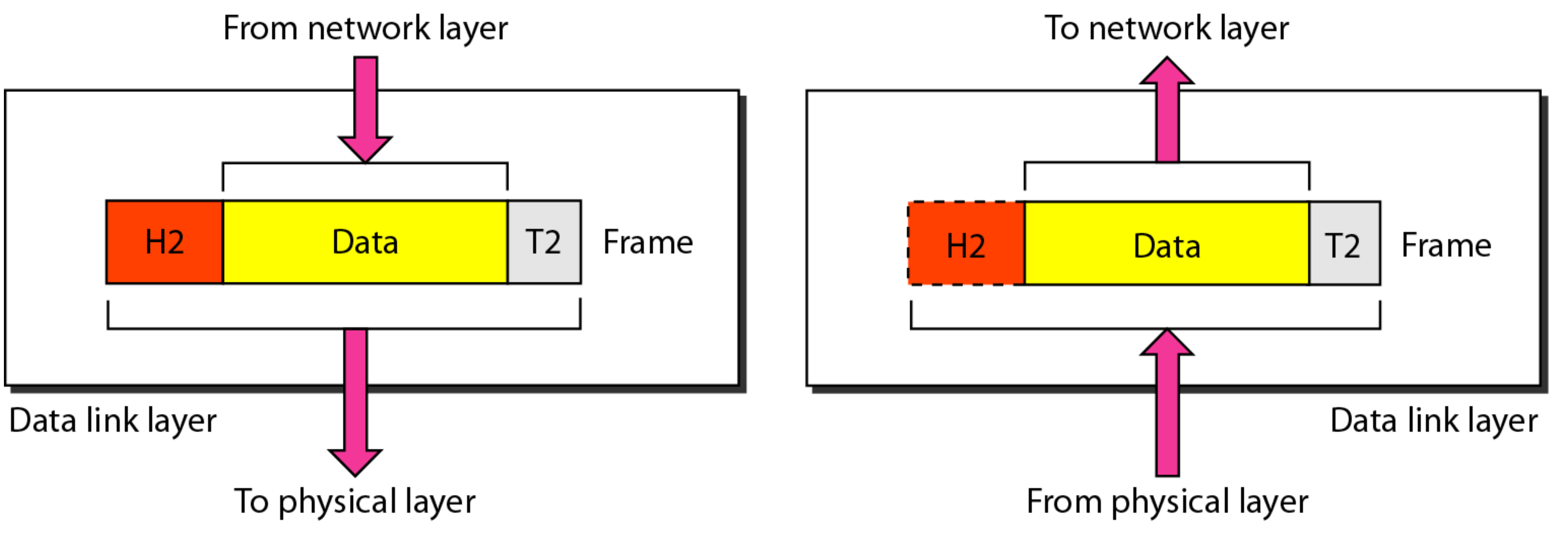
Note

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

Data Link Layer

- Transform unreliable transmission to reliable transmission
- Framing
- Physical addressing
- Flow control
- Error & Duplicate control
- Access control (MAC Layer)

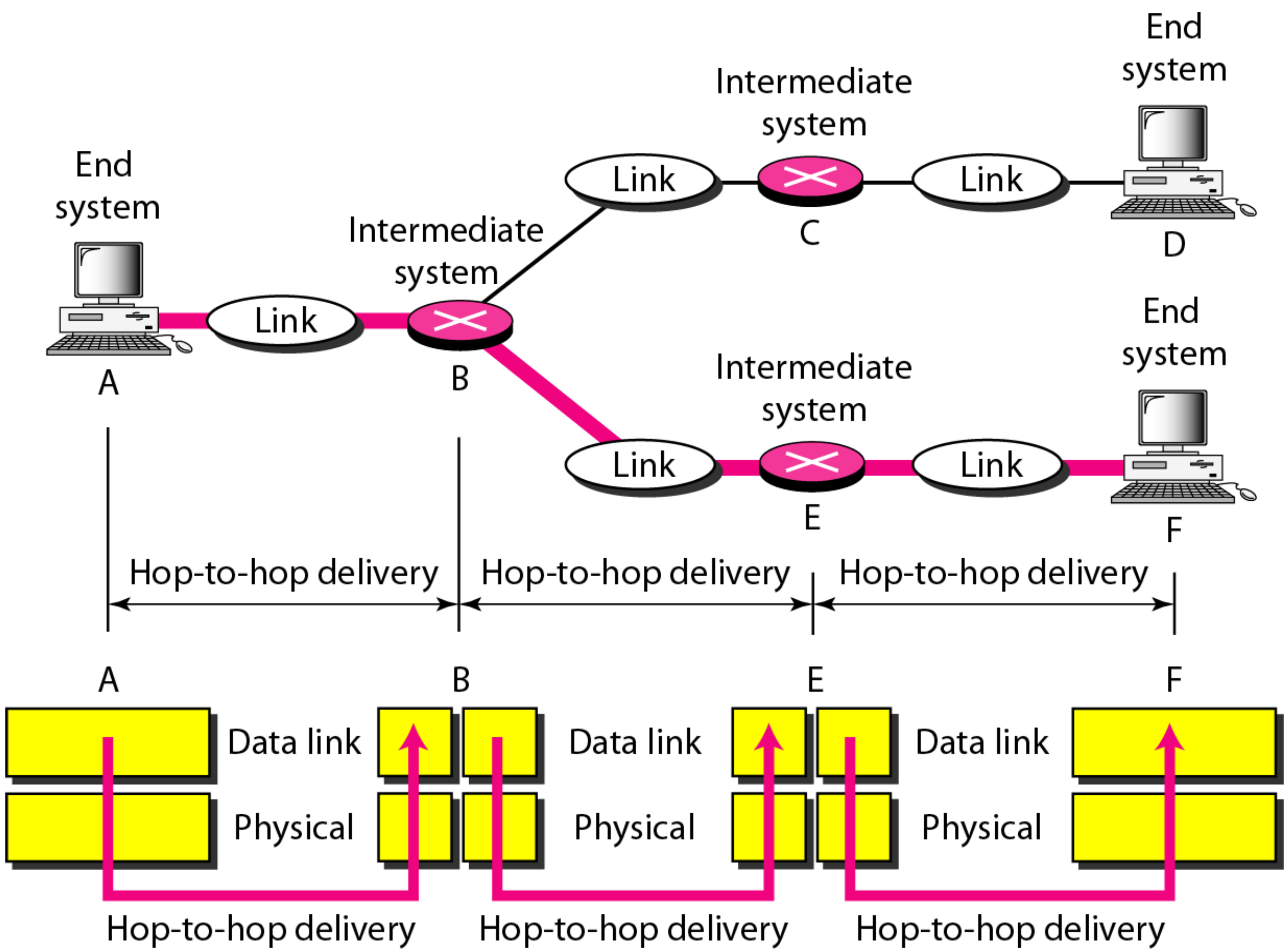
Figure 2.6 *Data link layer*



Note

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

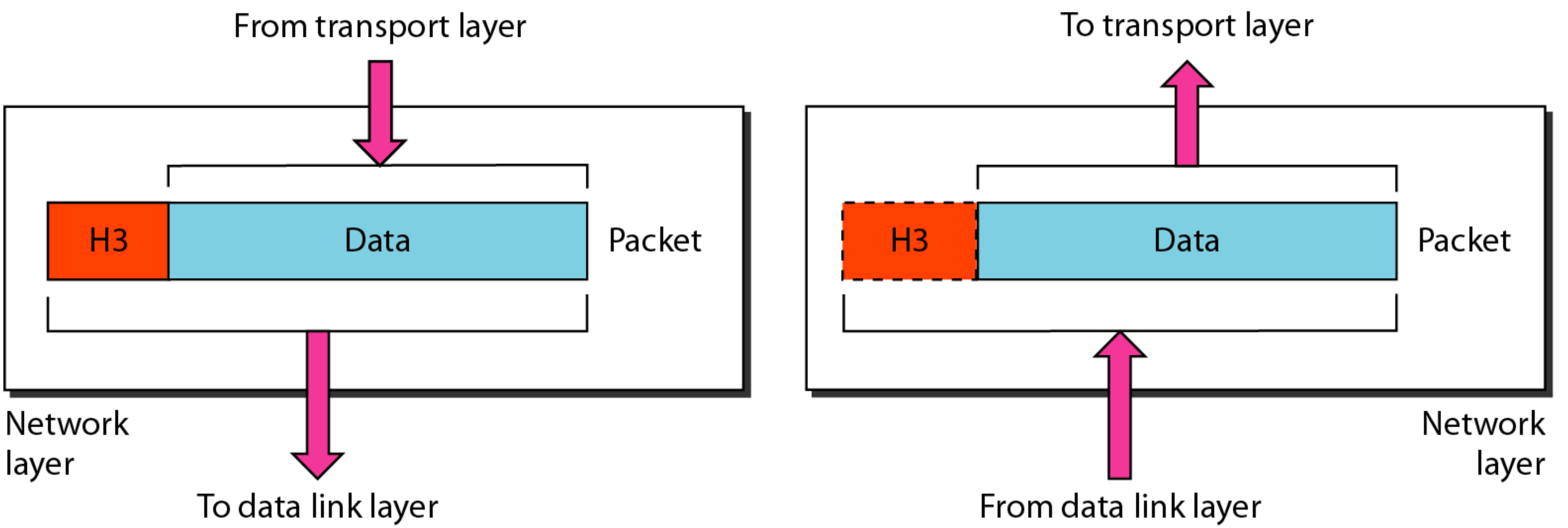
Figure 2.7 *Hop-to-hop delivery*



Network Layer

- Source to destination (end-to-end) delivary
- Logical addressing
- Routing
  - Connectionless vs Connection-oriented
  - Traffic (congestion) control
  - Feedback
  - Protocols: IP, ARP, RARP, ICMP, IGMP

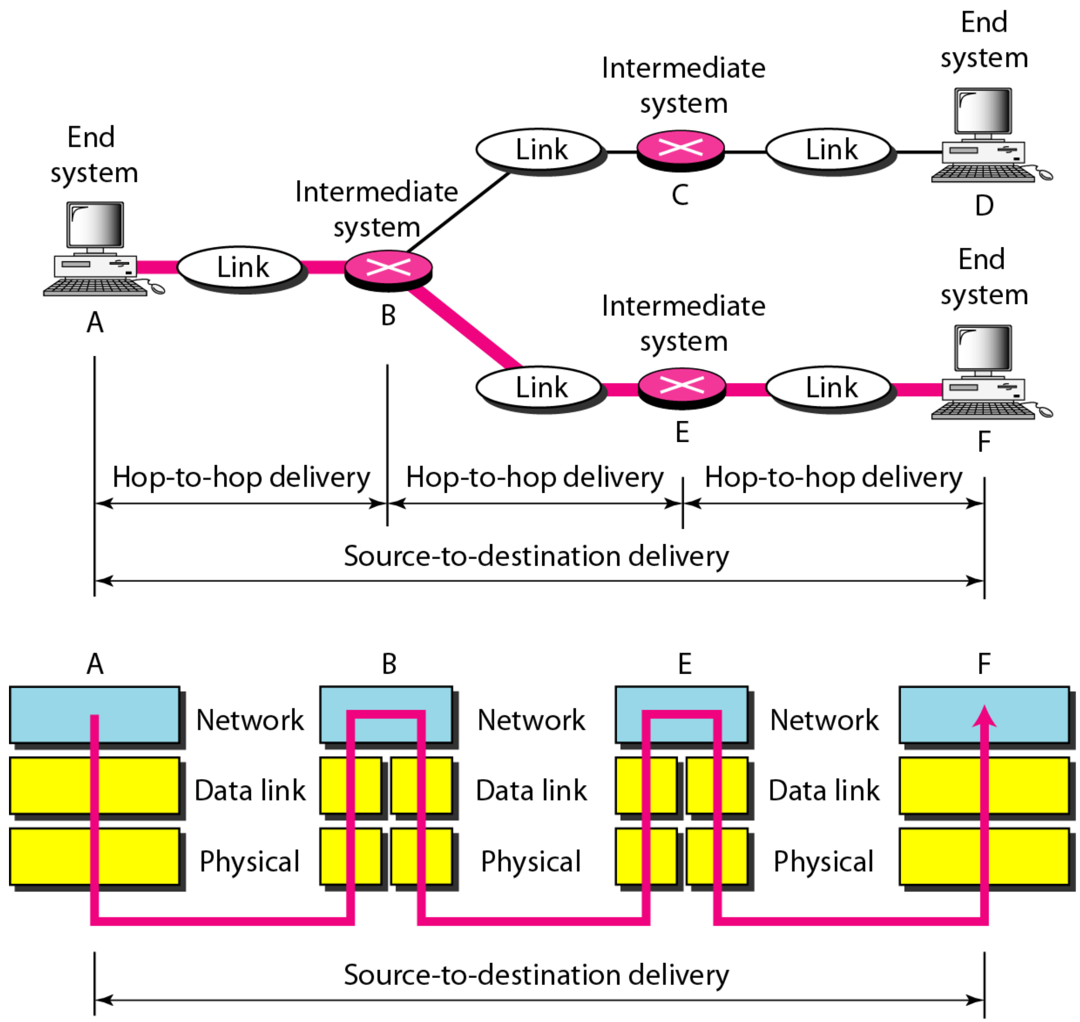
Figure 2.8 *Network layer*



Note

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

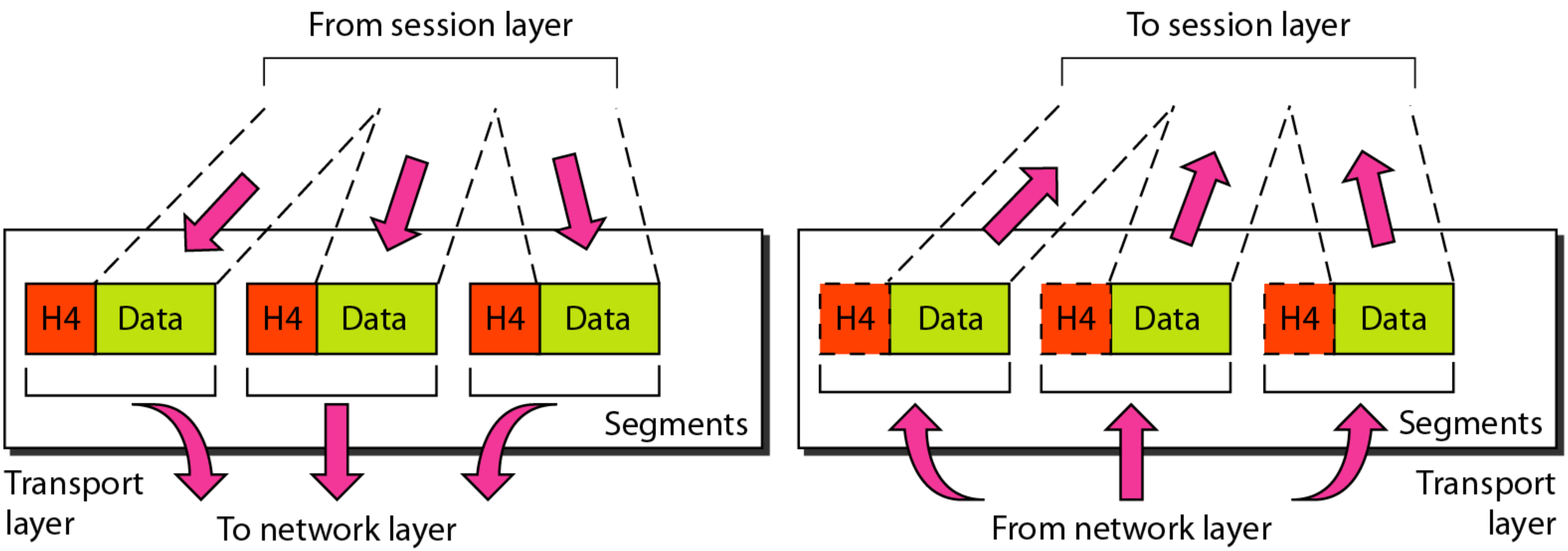
Figure 2.9 *Source-to-destination delivery*



Transport Layer

- Process to process delivery
- Port addressing (Service point addressing)
- Segmentation and reassembly
- Multiplexing/demultiplexing
- Connection control (connectionless/connection-oriented)
- Flow & Congestion control
- Error control

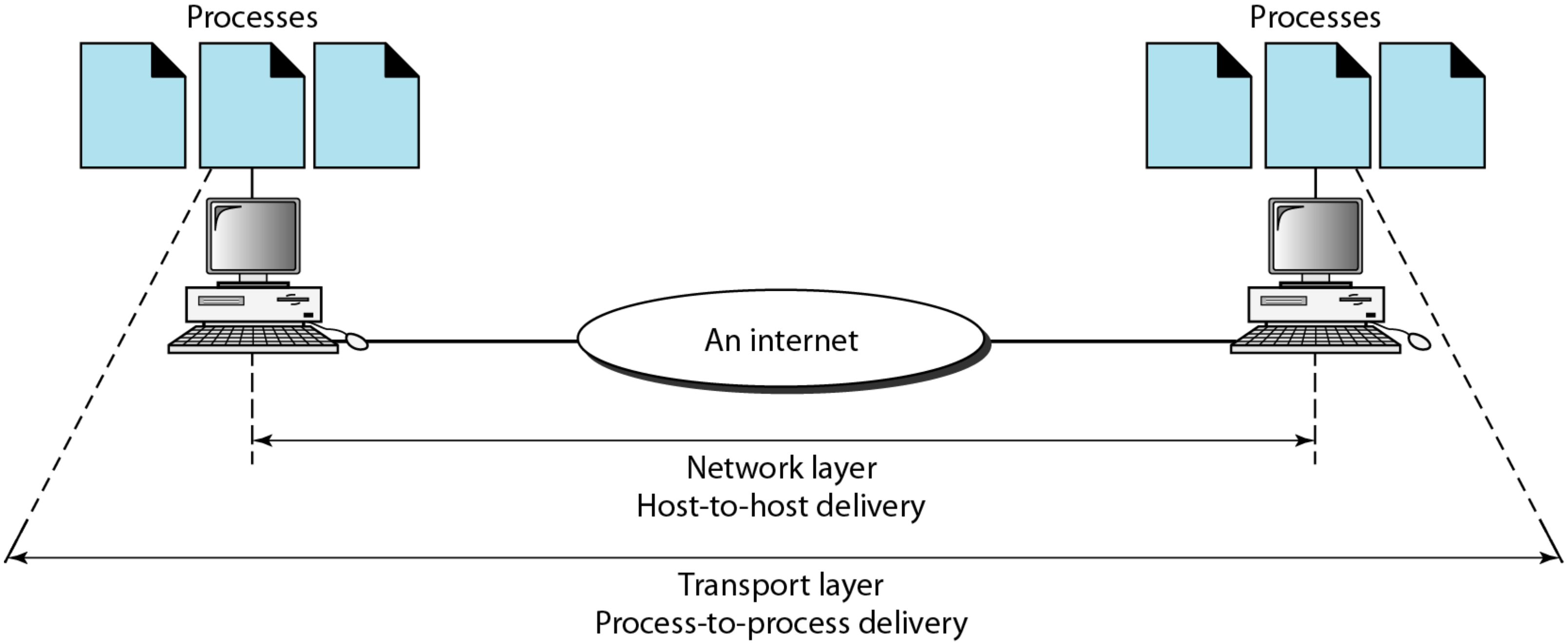
Figure 2.10 *Transport layer*



Note

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

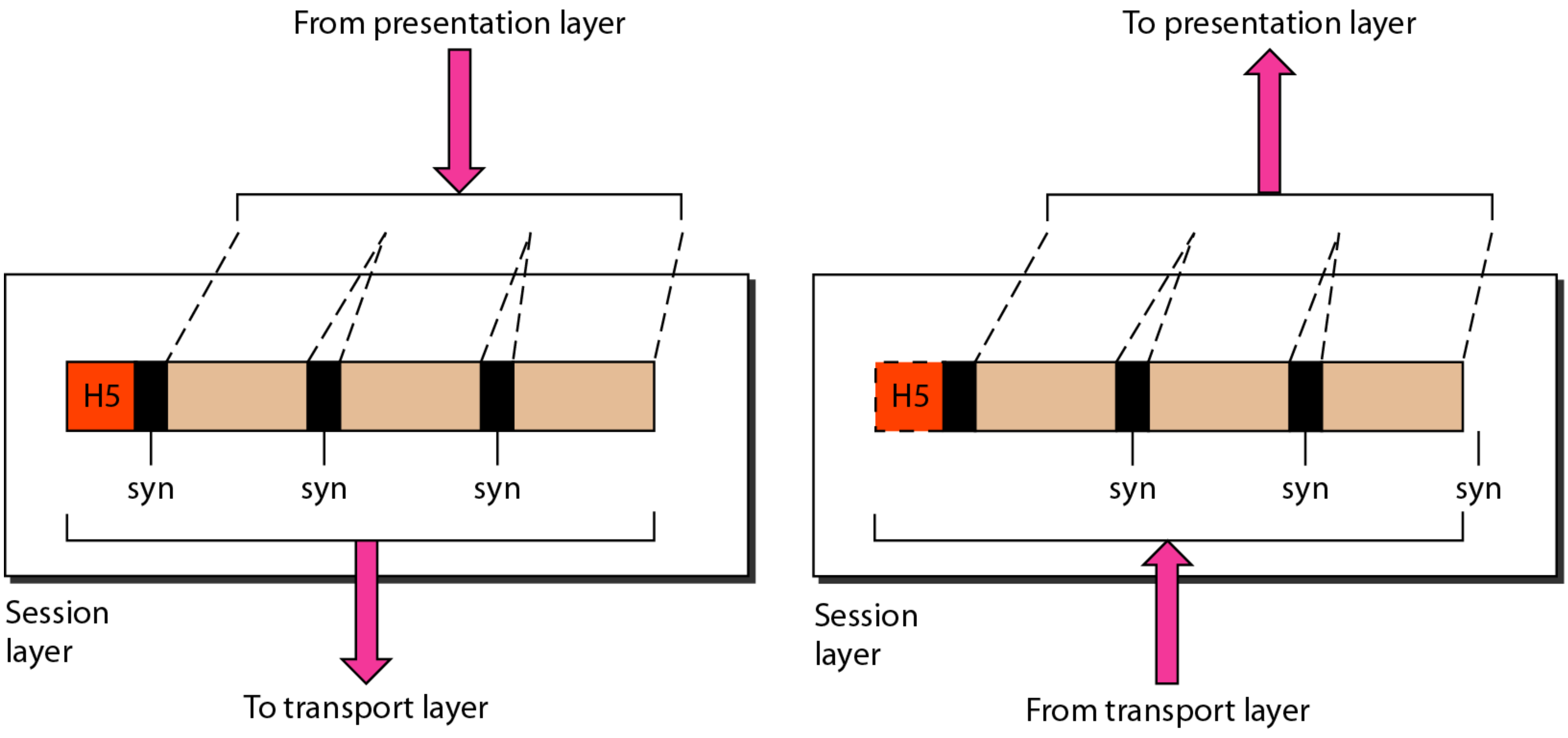
Figure 2.11 *Reliable process-to-process delivery of a message*



Session Layer

- Dialog control (simplex/duplex)
  - Session creation/termination
  - Resource allocation/management
- Synchronization
  - Check points (tracking)
- Access rights associated to the sessions

Figure 2.12 *Session layer*



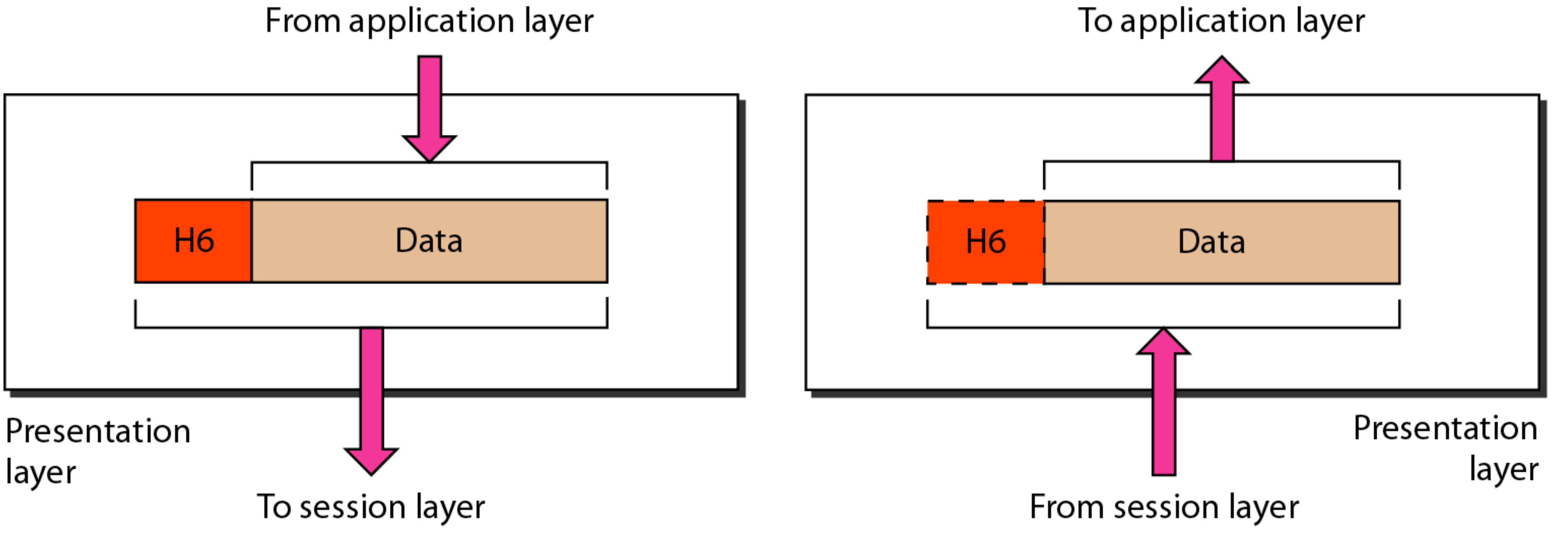
Note

The session layer is responsible for dialog control and synchronization.

Presentation Layer

- Syntax and semantics of the information exchange
- Translation (code conversion)
- Compression
- Encryption

Figure 2.13 *Presentation layer*



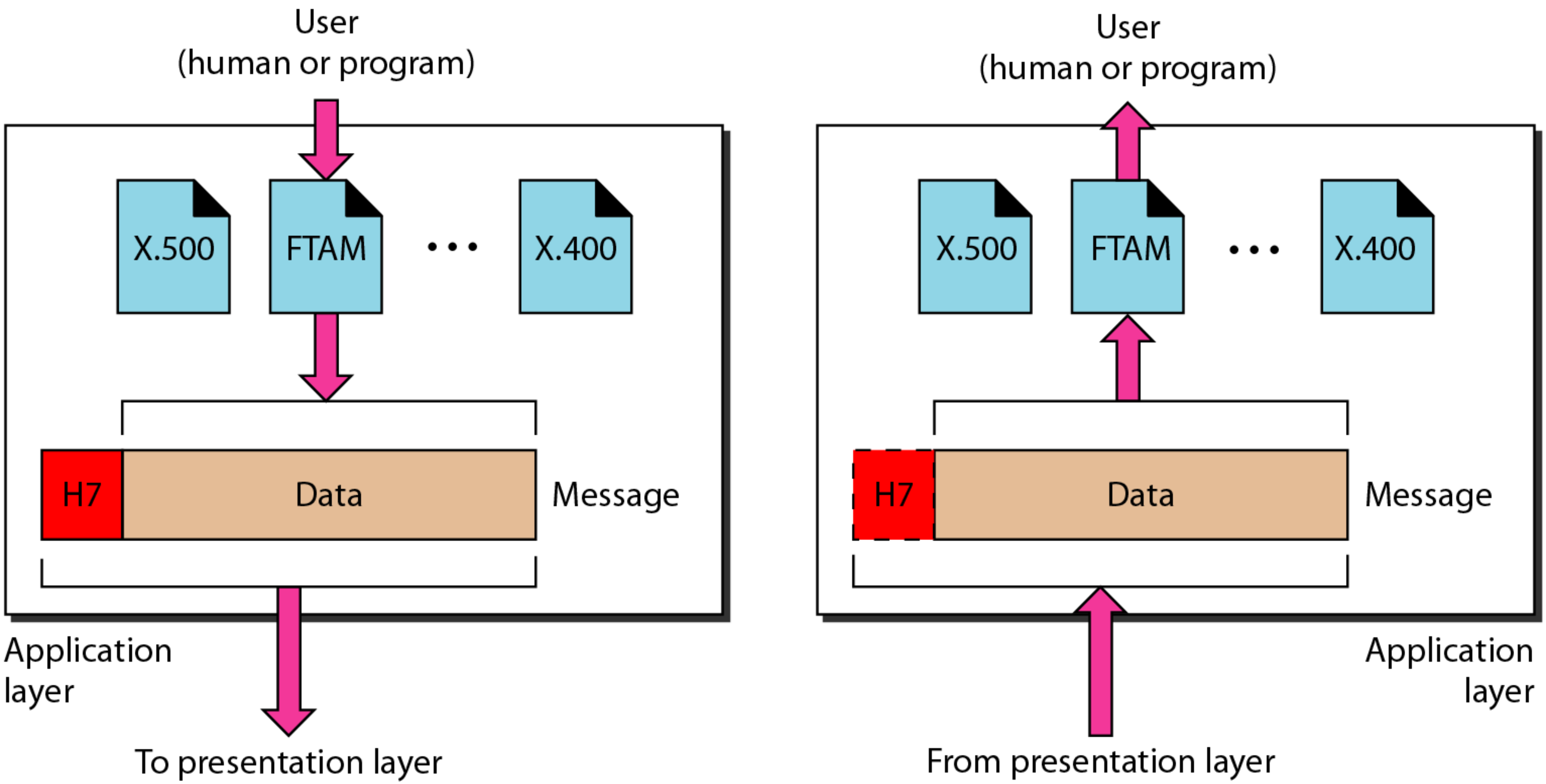
Note

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

Application Layer

- Left over services by the bottom layers
- Task-specific services
- User interface and support for services
  - Email
  - Remote file access and transfer
  - Shared database management
  - WWW

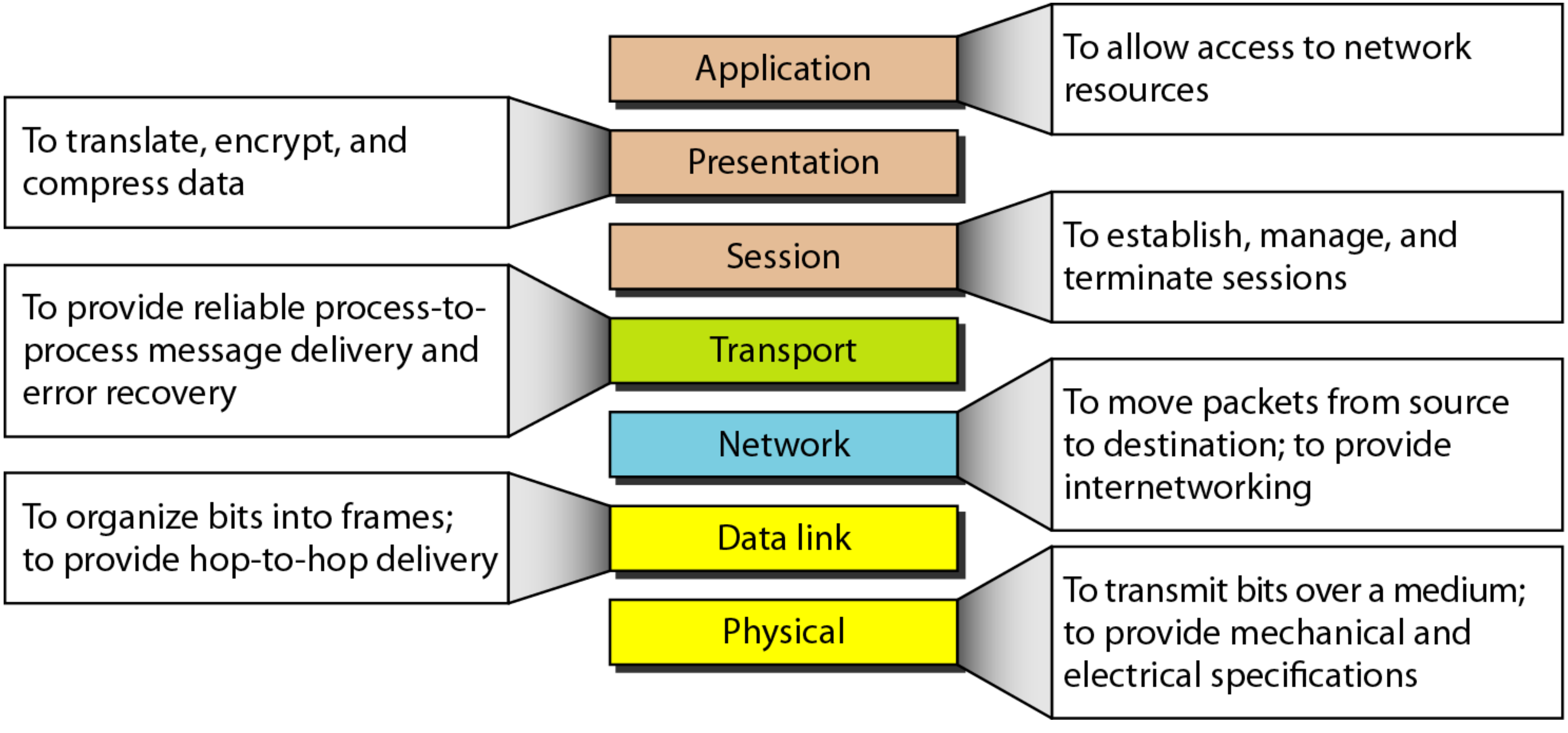
Figure 2.14 *Application layer*



Note

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

Figure 2.15 *Summary of layers*



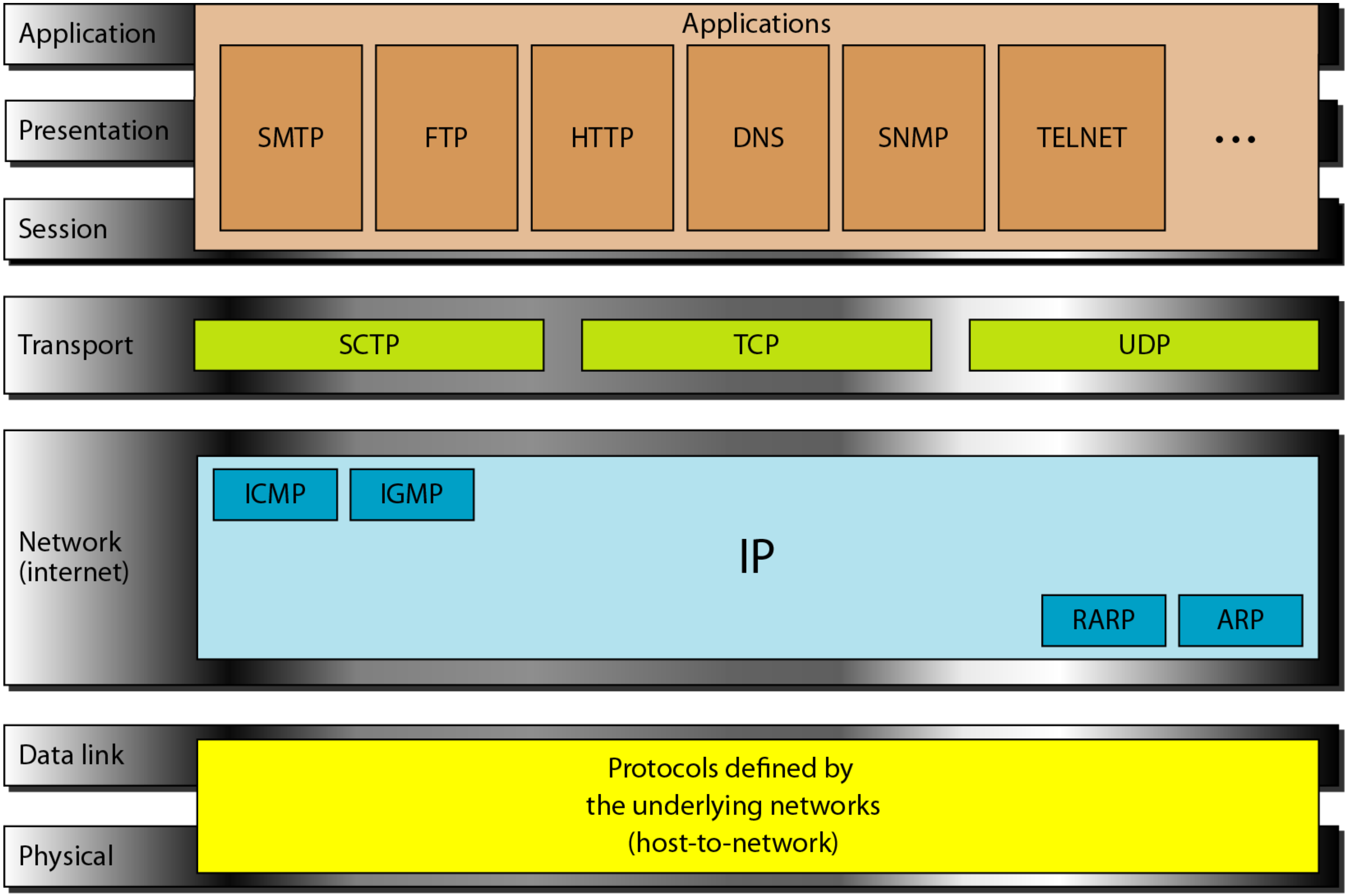
2-4 TCP/IP PROTOCOL SUITE

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*



TCP/IP PROTOCOL SUITE

Physical and Data Link Layers

Network Layer

Internetworking Protocol (IP): Unreliable & Connectionless

Address Resolution Protocol: Logical (IP) to Physical

Reverse Address Resolution Protocol: Physical to Logical

Internet Control Message Protocol: Query & Error reporting messages

Internet Group Message Protocol: Transmission to group of users

Transport Layer

UDP: Simple & Unreliable

TCP: Reliable & Commection-oriented

SCTP: Best features of UDP and TCP

Application Layer

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*

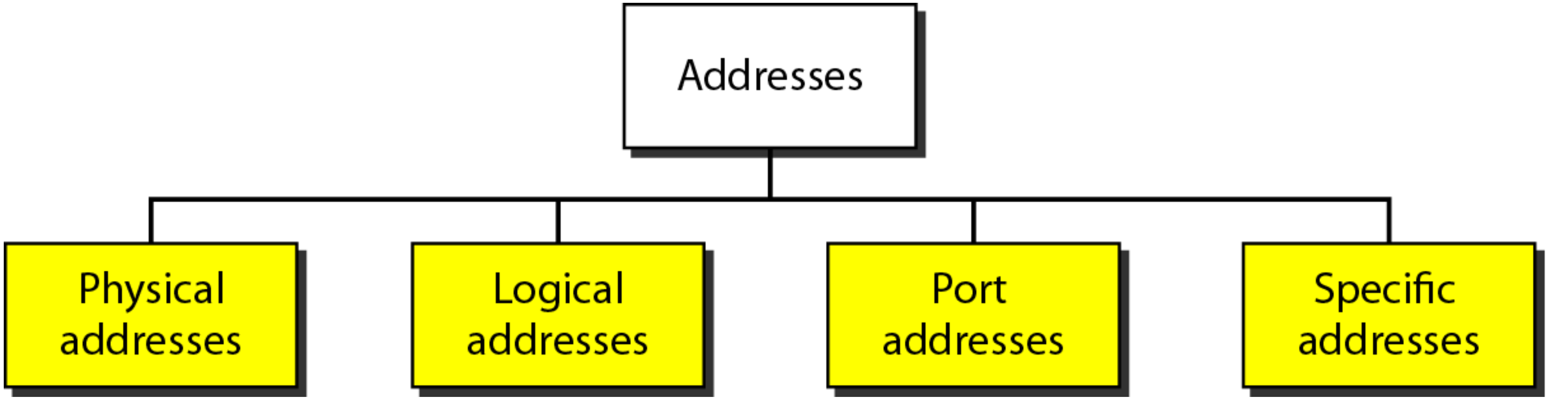
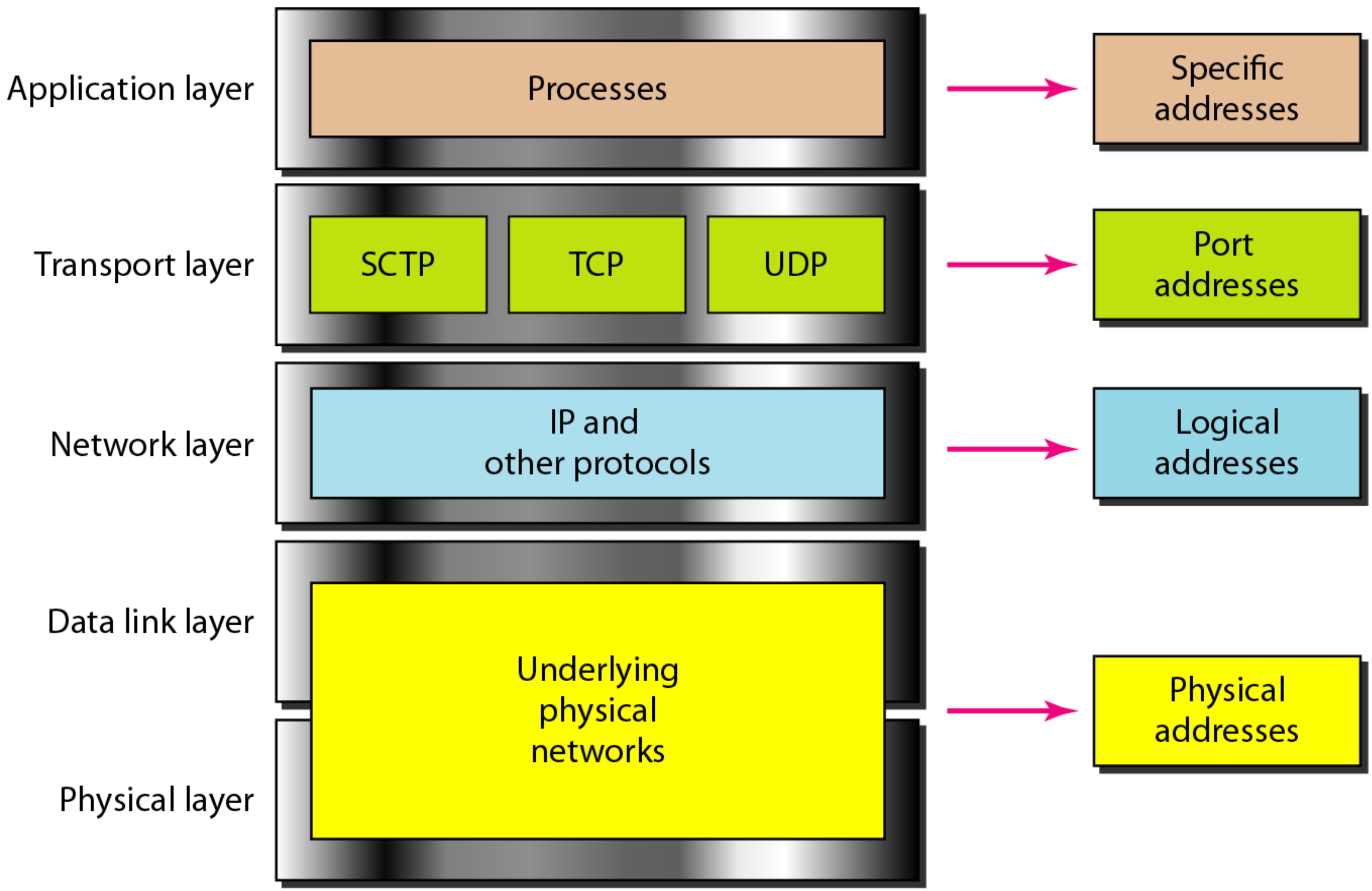


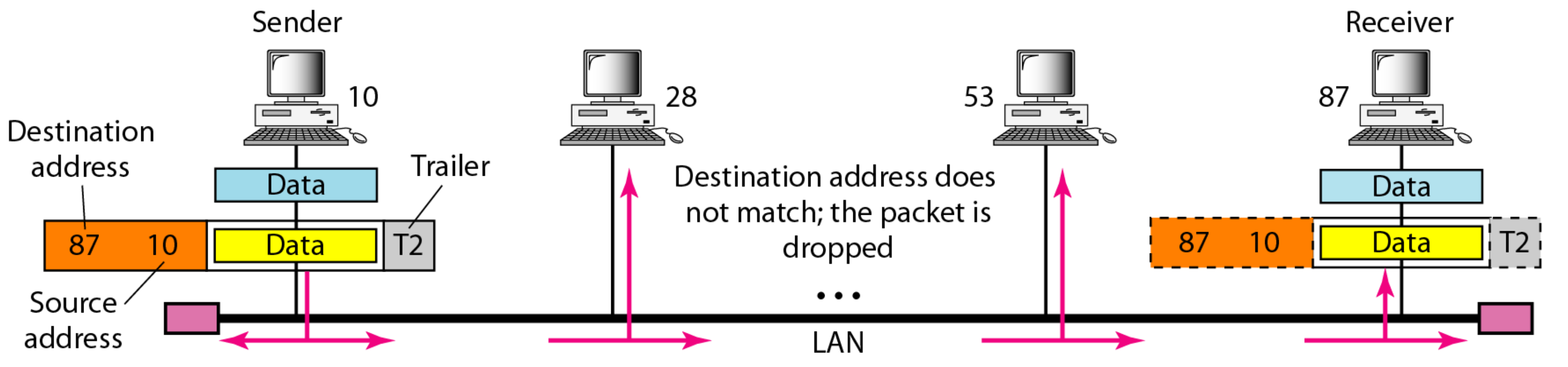
Figure 2.18 *Relationship of layers and addresses in TCP/IP*



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:

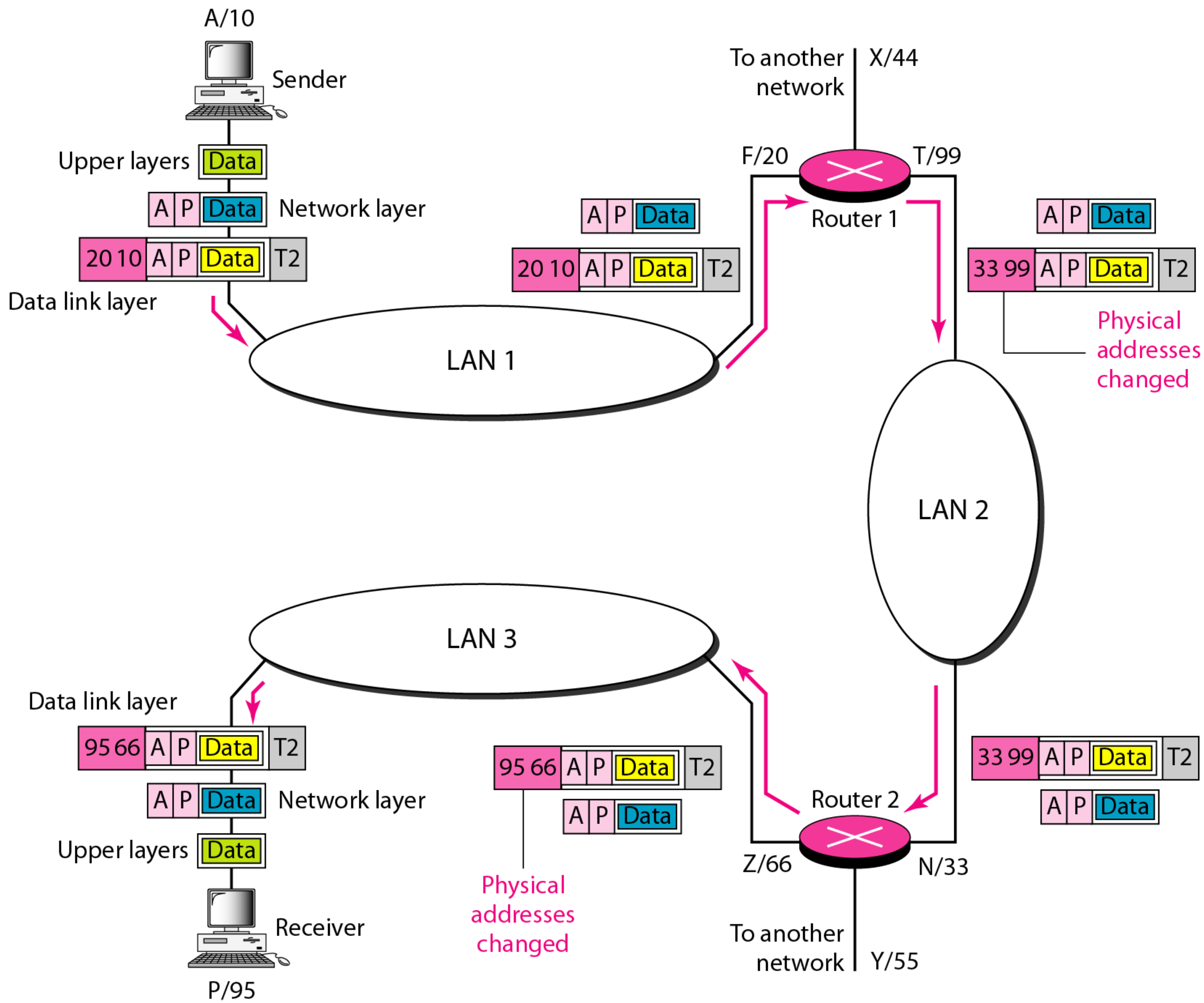
07:01:02:01:2C:4B

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.

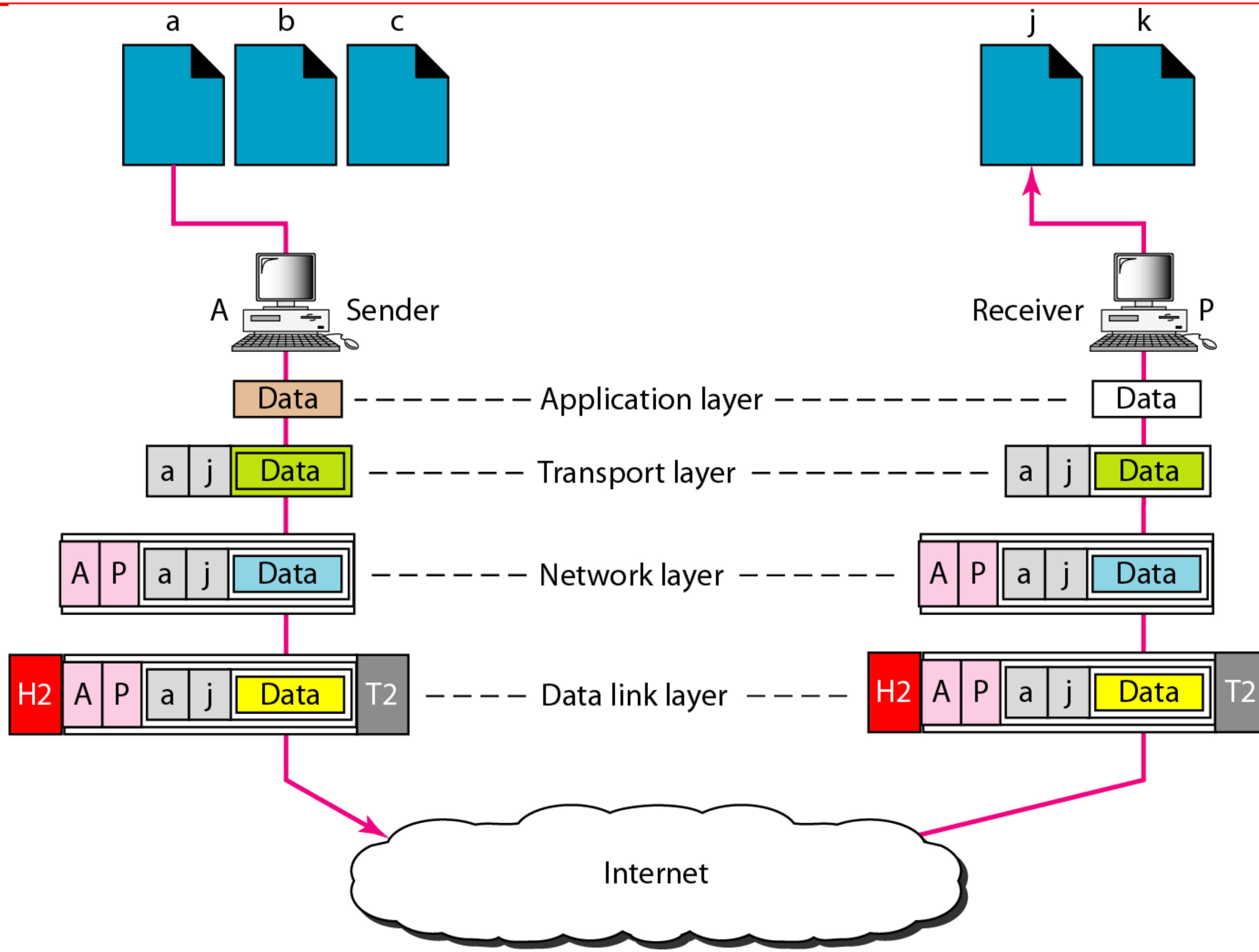
Figure 2.20 *IP addresses*



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.**