Chapter 6

Computer Networks

OBJECTIVES

After studying this chapter, the student should be able to:

➢ Describe network criteria, physical structures and categories of networks.
➢ Describe the TCP/IP protocol suite as the network model in the Internet.
➢ Define the layers in the TCP/IP protocol suite and their relationship.
➢ Discuss the client-server architecture of the Internet.
➢ Describe the three early applications of the Internet:
➢ Understand the World Wide Web as the most common application of the Internet and its components.
➢ Distinguish between three Internet document types: static, dynamic and active.

6.1

INTRODUCTION

Description

- 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 in the network to another.
  - The software consists of instructions that make the services that we expect from a network possible

Network Criteria

- ☐ **Performance** can be measured in many ways, including transit time and response time.

- ☐ **Reliability** is measured by the frequency of failure, the time it takes to recover from a failure, and the network's robustness in a catastrophe.

- ☐ **Network security** issues include protecting data from unauthorized access, damage and change, and implementing policies and procedures for recovery from breaches and data losses.

Physical structures

☐ **Types of Connection:**

- ■ A network consists of two or more devices connected through **links**.

- ■ A link is a communications pathway that transfers data from one device to another.

- ■ Two possible types: **point-to-point** and **multipoint**.
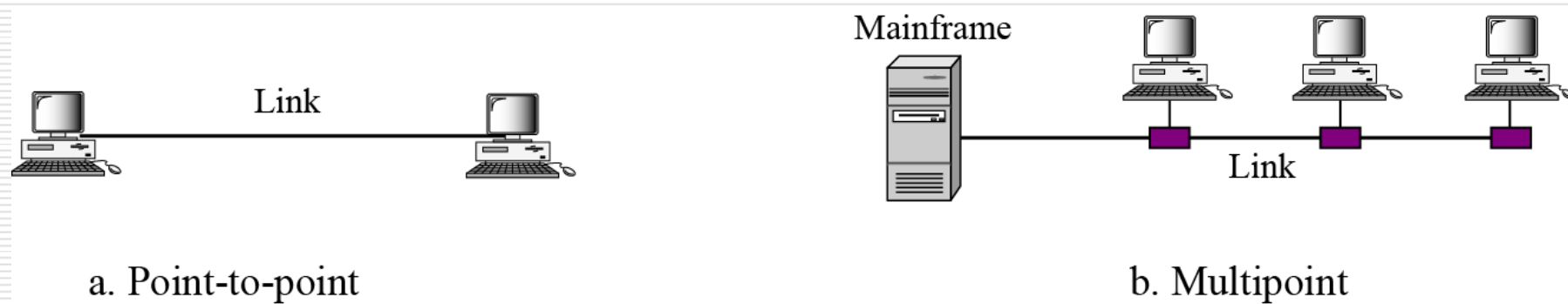
Physical structures

a. Point-to-point

b. Multipoint

Figure 6.1 **Types of connections: point-to-point and multipoint**
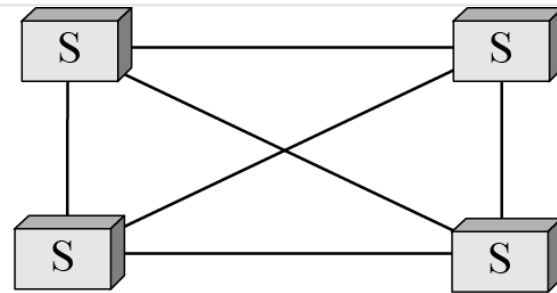
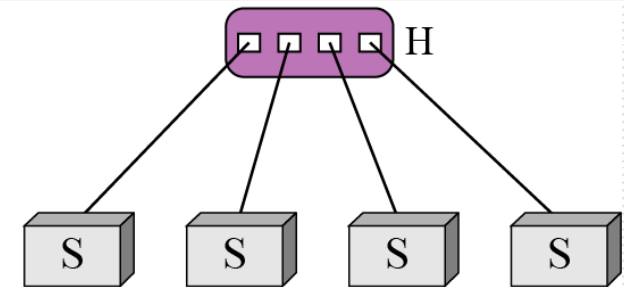# Physical topology

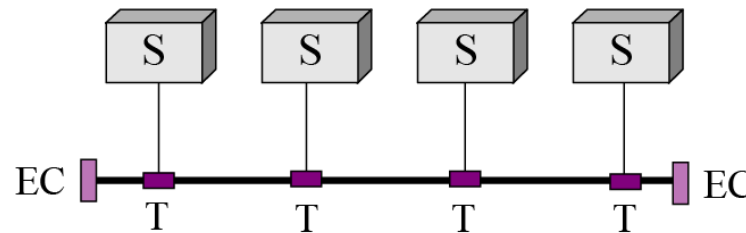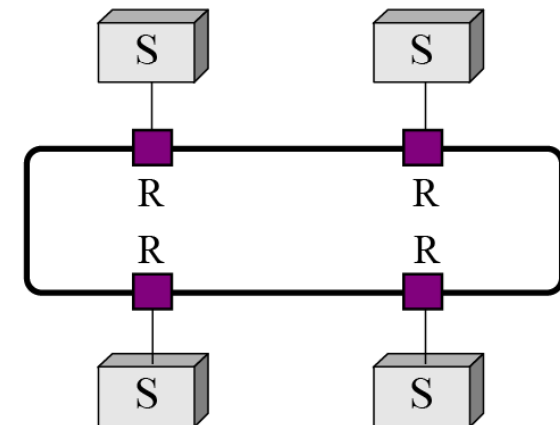Legend:
S: Station
R: Repeater
H: Hub
T: Tap
EC: End Cable

a. Mesh

b. Star

c. Bus

d. Ring

Figure 6.2 **Four physical topologies**

Categories of networks

- Three broad categories
    - **local-area networks (LANs)**
    - **Wide-area networks (WANs)**
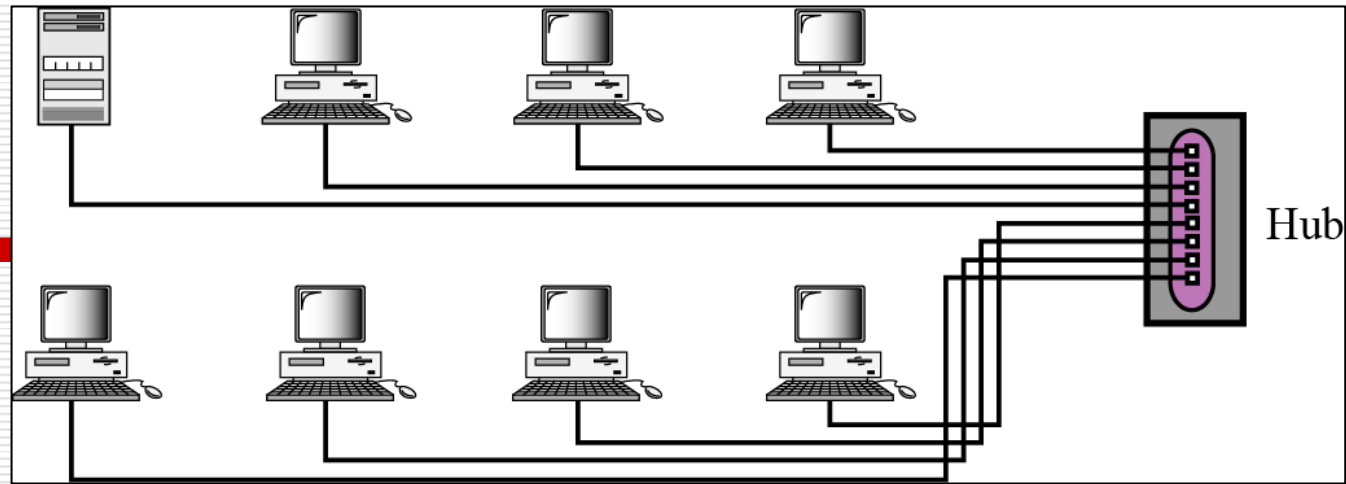   - **Metropolitan area networks (MANs)**.

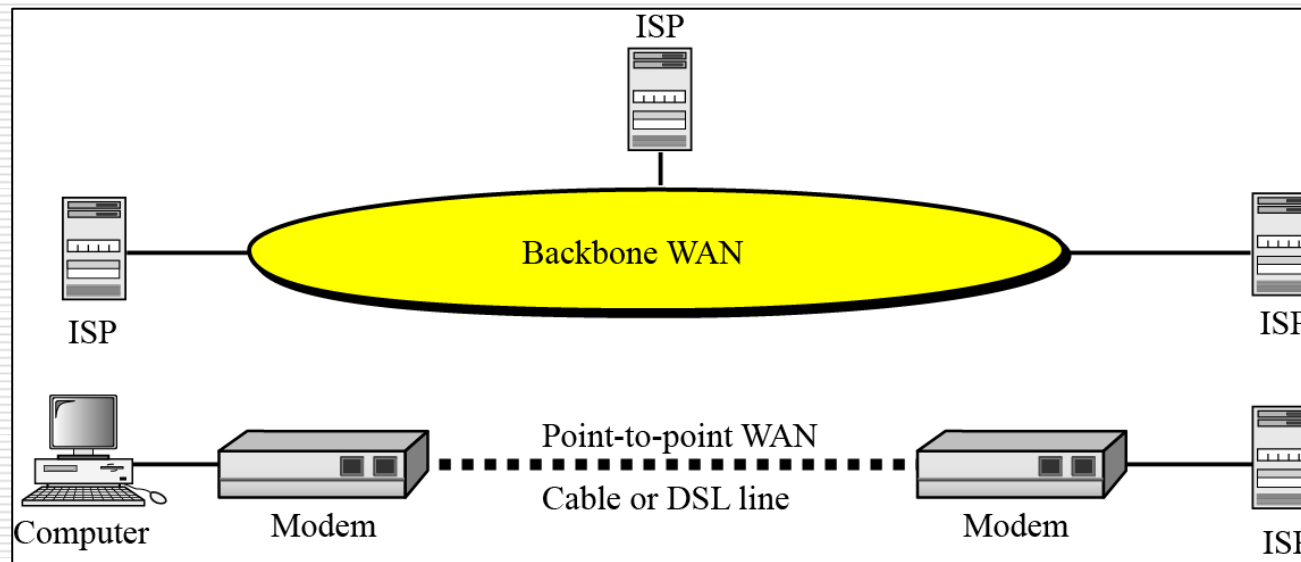**Figure 6.3** **An isolated LAN connecting eight computers to a hub**

Figure 6.4 **A point-to-point WAN and a backbone WAN**

An Internet

☐ Networks are connected to one another.

☐ When two or more networks are connected, they become an **internetwork**, or an **internet** (lowercase "i").
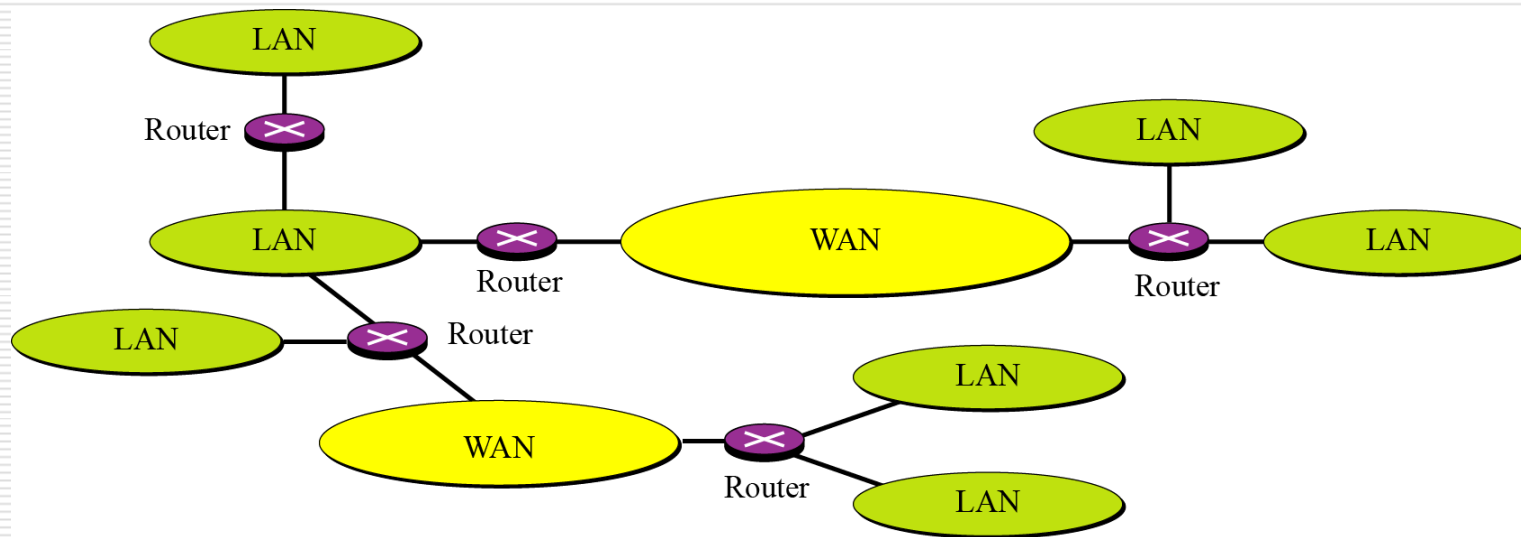

Figure 6.5 **An internet made of WANs, LANs, and routers**

The Internet

- The most notable internet is the **Internet** (uppercase "I"), a collaboration of hundreds of thousands of interconnected networks.

- Private individuals use the Internet. Millions of people are users.

- Most end users who want an Internet connection use the services of **Internet service providers (ISPs)**.
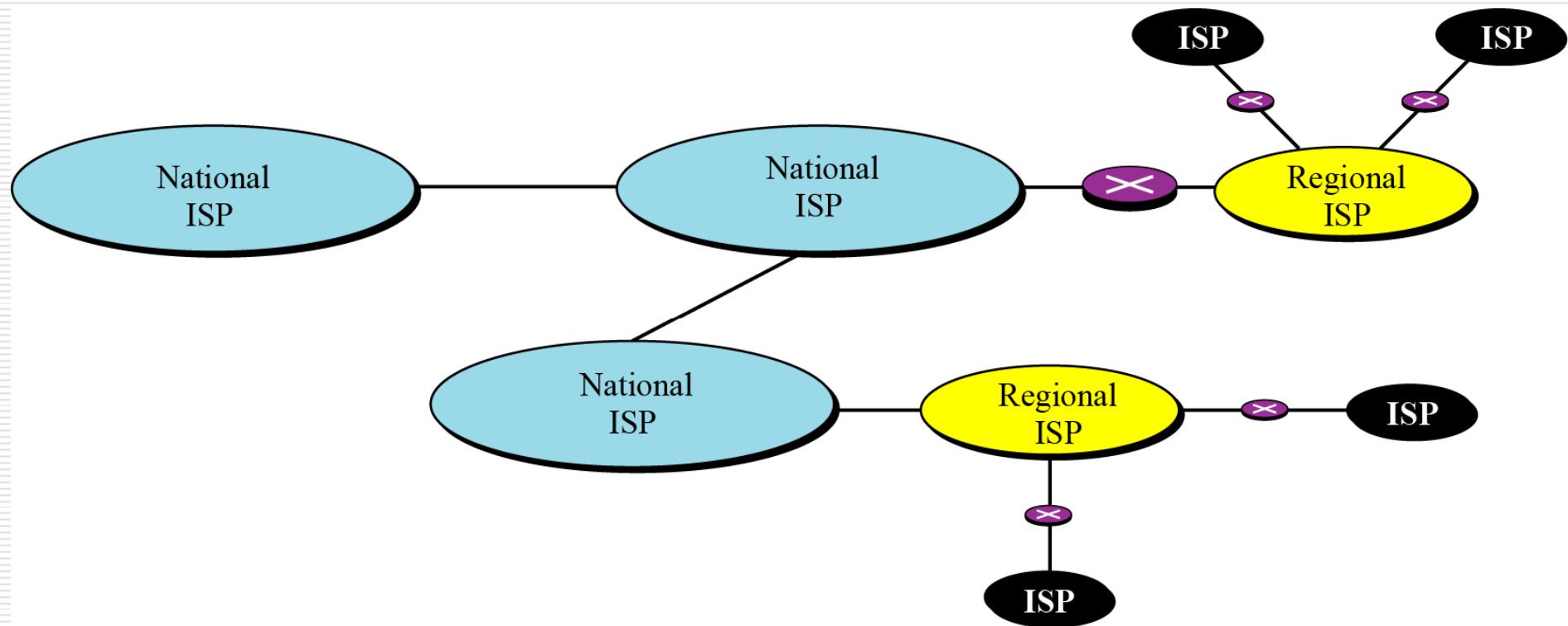
The Internet

Figure 6.6 **Hierarchical organization of the Internet**

6.2

TCP/IP PROTOCOL SUITE

TCP/IP

- ☐ **Protocols (a set of rules on Internet)**
  - ■ These allow different local and wide area networks, using different technologies, to be connected together and carry a message from one point to another.
- ☐ **TCP/IP protocol suite**
  - ■ The set, or suite, of protocols that controls the Internet today
  - ■ The abbreviations (TCP and IP) will become clear as we explain different protocols.

TCP/IP

☐ The original TCP/IP protocol suite was defined as having four layers

☐ The TCP/IP protocol suite today is a five-layer model

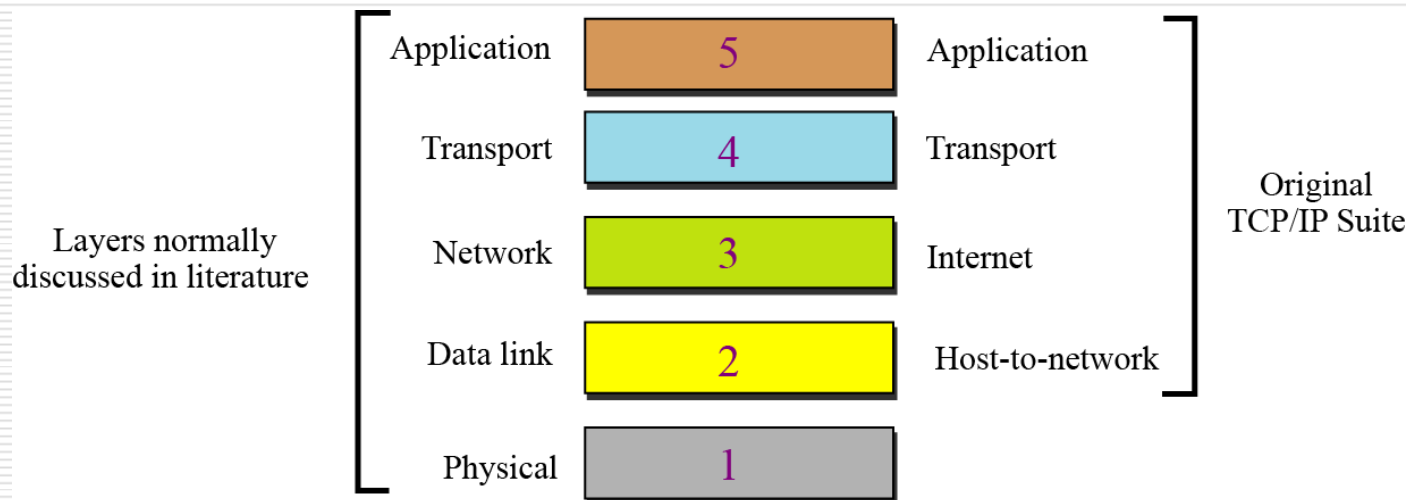| Layers normally discussed in literature		Original TCP/IP Suite
Application	5	Application
Transport	4	Transport
Network	3	Internet
Data link	2	Host-to-network
Physical	1	

Figure 6.7 **The TCP/IP protocol suite**

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TCP/IP

☐ Figure 6.8 shows the layers involved when a message is sent from device A to device B.

■ Routers use only the first three layers.

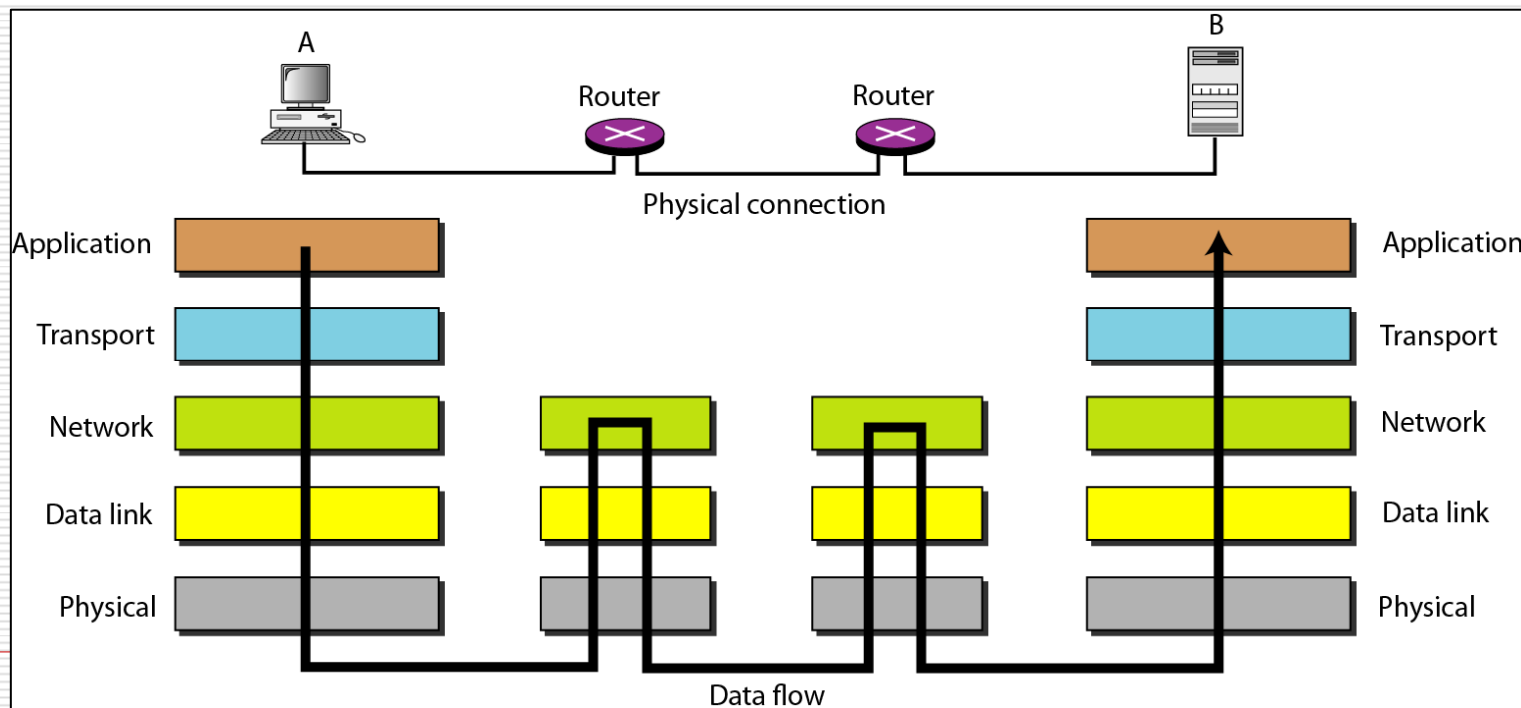**Figure 6.8** **The interaction between layers in the TCP/IP protocol suite**

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6.3

LAYERS

Description

□ This section briefly describes the function of each **layer** in the TCP/IP protocol suite.

□ We show how a message travels through the different layers until it reaches the physical layer and is sent by the transmission media.

Application Layer

☐ The application layer enables a user, whether human or software, to access the network.

- services such as electronic mail, remote file access and transfer, browsing the World Wide Web, and so on.

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

Application Layer

☐ **Client-server architecture**
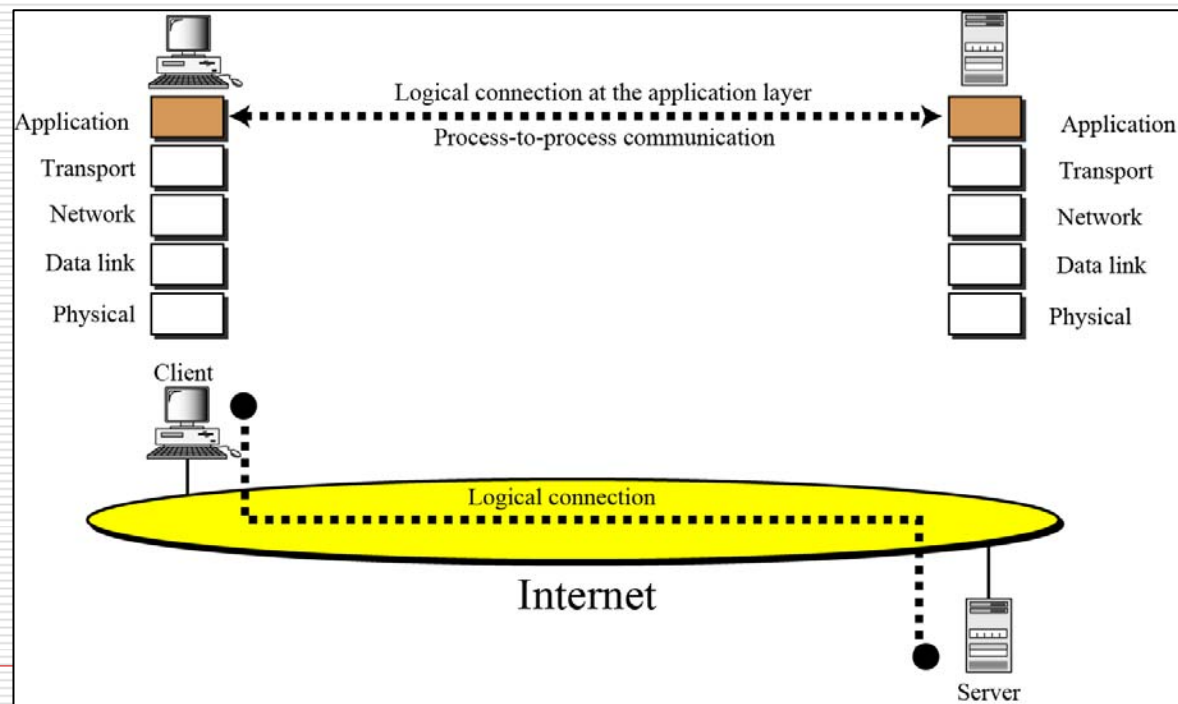- Allow two application programs, running on two remote computers, to communicate with each other

Figure 6.9 Communication at the application layer

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Application Layer

☐ **Application-layer address**
- ■ When a client needs to send a request to a server, it needs the server application-layer address.
- ■ For example, to identify one particular site, the client uses a Uniform Resource Locator (URL).
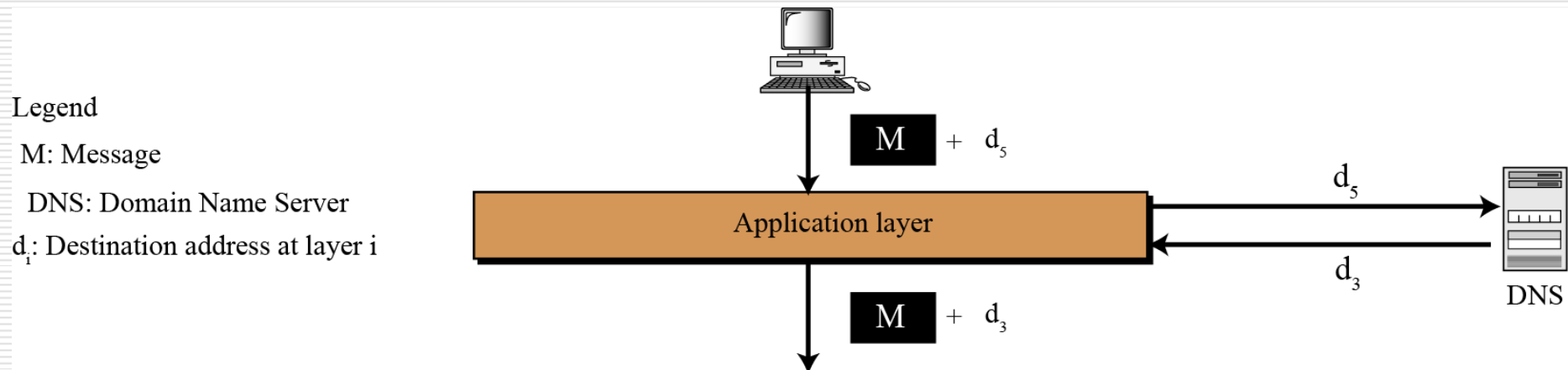
Legend

M: Message

DNS: Domain Name Server

d_i: Destination address at layer i

$M + d_5$

d_5

Application layer

d_3

DNS

$M + d_3$

Figure 6.10 **Addresses at the application layer** 22

Transport layer

- ☐ Logical communication
  - ■ process-to-process delivery of the entire message
- ☐ The two application layers consider the transport layer as the agent that takes responsibility for delivering the messages.

The transport layer is responsible for the logical delivery of a message between client and server processes.
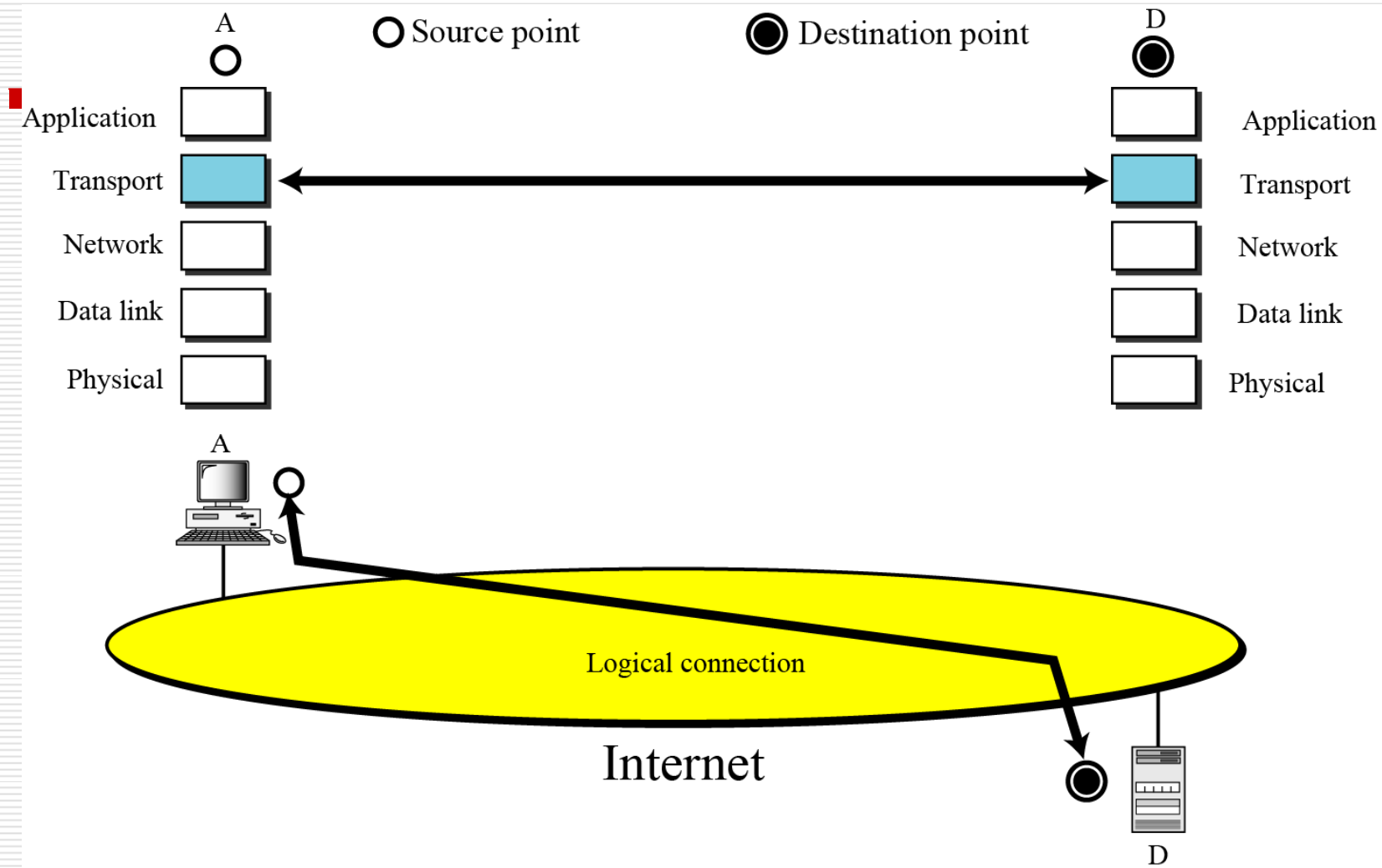
Figure 6.11 Communication at the transport layer

Transport layer

- **Transport-layer addresses (port numbers)**
  - The server computer may be running several processes at the same time.
  - Another address for server process identification, called a port number.
  - When the message arrives at the server, it must be directed to the correct process.

Transport layer

Legend

M: Message

d_i: Destination address at layer i
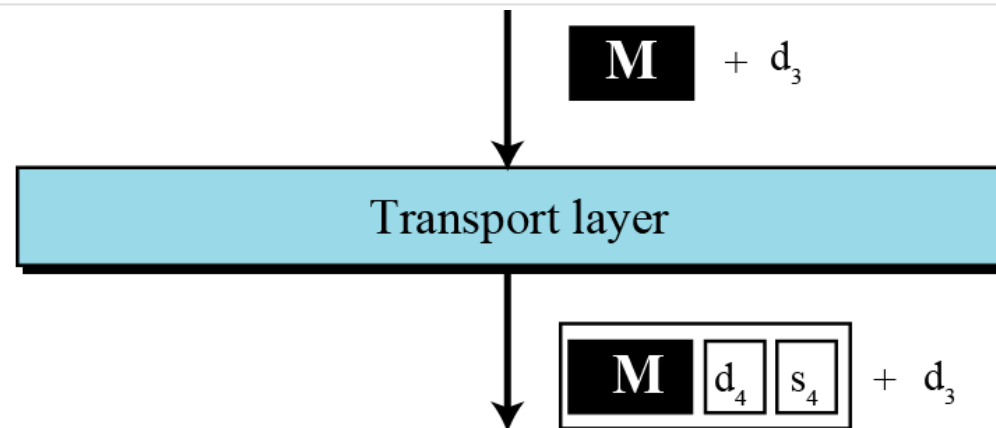
s_i: Source address at layer i

Figure 6.12 **Addresses at the transport layer**

Transport layer

- **Transport-layer protocols**
  - During the life of the TCP/IP protocol suite three transport layer protocols have been designed: **UDP**, **TCP** and **SCTP**.

- **User Datagram Protocol (UDP)**
  - The simplest of all three protocols.
  - UDP does multiplexing and de-multiplexing It also does a type of error control by adding a checksum to the packet.

Transport layer

- **Transmission Control Protocol (TCP)**
  - Support all the duties of a transport layer.
  - It is not as fast and as efficient as UDP.
  - TCP uses sequence numbers, acknowledgment numbers and checksums.
  - It also uses buffers at the sender's site.
  - This combination of provisions provides multiplexing, de-multiplexing, flow control, congestion control and error control.

Transport layer

- **Stream Control Transmission Protocol (SCTP)**
  - A new protocol that is designed for new services expected from the Internet, such as Internet telephony and video streaming.
  - This protocol combines the advantages of both UDP and TCP.
  - Like UDP, it is suitable for real-time transmission of audio and video, but like TCP, it provides error and flow control.

Network layer

- Source-to-destination (computer-to-computer or host-to-host) delivery of a packet, possibly across multiple networks (links).

- Ensure that each packet gets from its point of origin to its final destination.

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

Network layer

☐ **Network-layer addresses**

- The packet traveling from the client to the server and the packet returning from the server need a network-layer address.

- The server address is provided by the server, while the client address is known by the client computer.

Legend

M: Message

d_i: Destination address at layer i

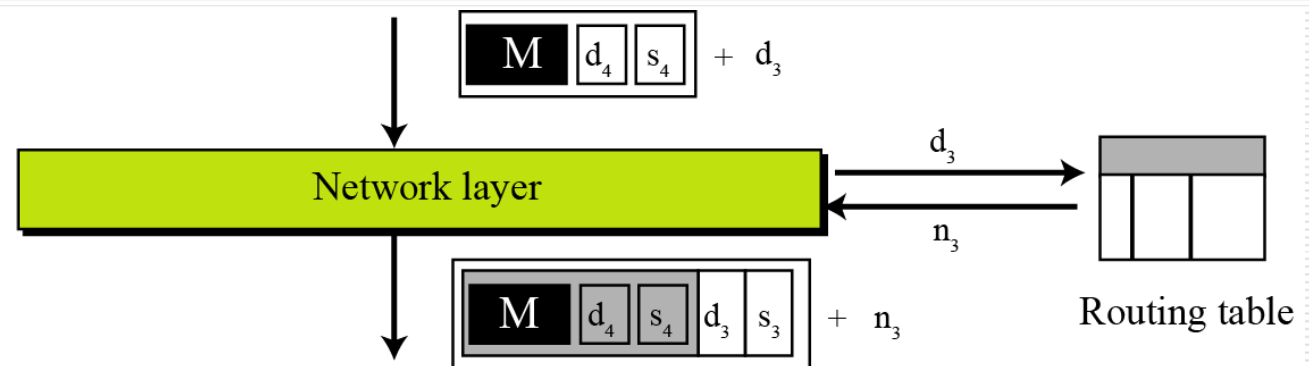s_i: Source address at layer i

n_i: Next-hop address at layer i

Figure 6.13 **Addresses at the network layer**

Network layer

☐ **Routing**

- ■ Routing means determination of the partial or total path of a packet.

- ■ The delivery of a packet from its source to its destination may be a combination of several deliveries: a source-to-router delivery, several router-to-router delivery, and finally a router-to-destination delivery.
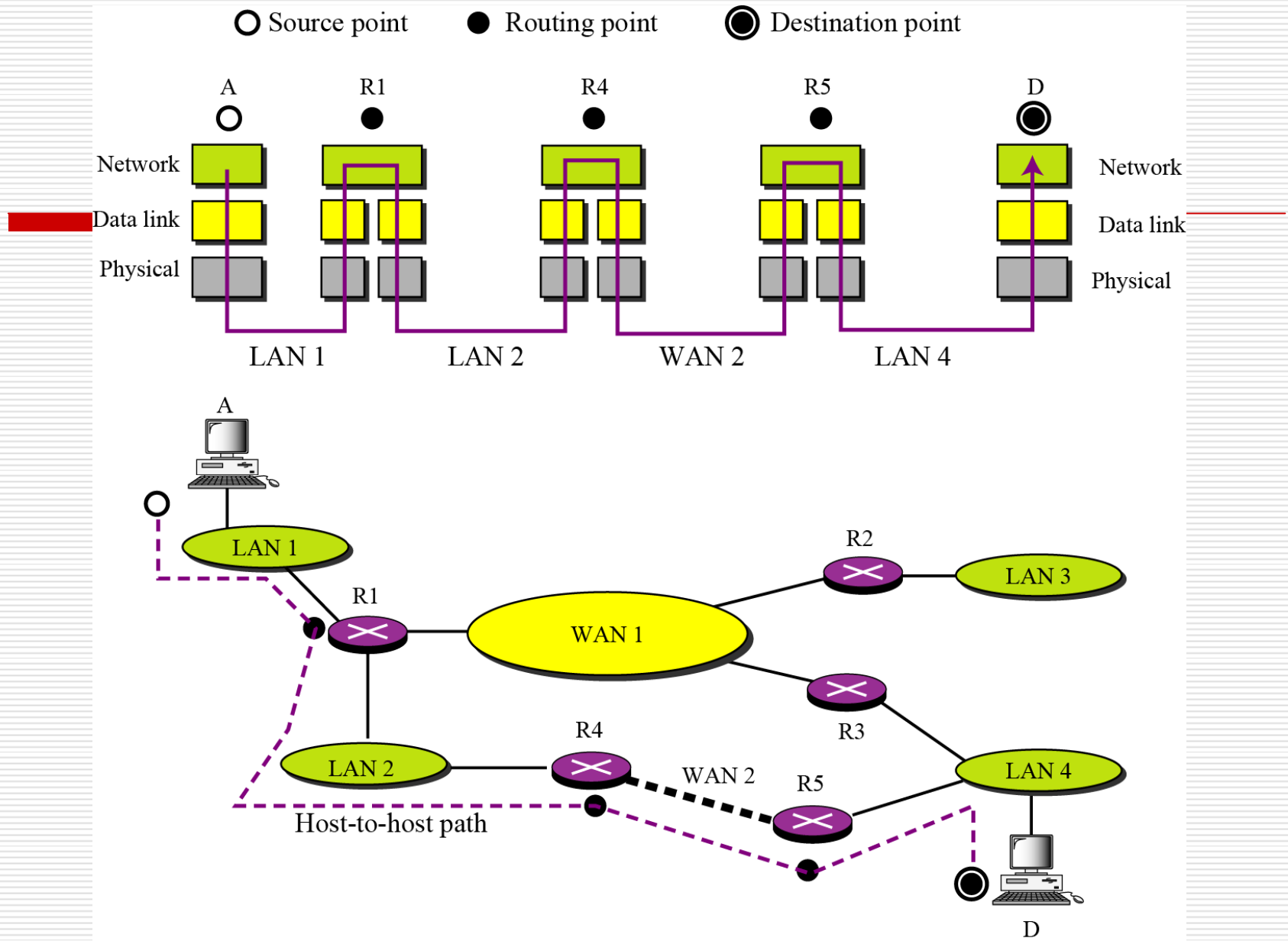
Figure 6.14 Routing at the network layer

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Network layer

□ **Network-layer protocols**

- ■ In the TCP/IP protocol suite, the main protocol at the network layer is **Internet Protocol (IP)**.

- ■ The current version is IPv4 (version 4) although IPv6 (version 6) is also in use, although not ubiquitously.

- ■ IPv4 is responsible for the delivery of a packet from the source to the destination.

- ■ Every computer and router is identified by a 32-bit IP address, which is presented in dotted decimal notation.

Network layer

◻ IPv4 address

- ■ Divide the 32-bit address into four 8-bit sections

- ■ Write each section as a decimal number between 0 and 255 with three dots separating the sections. For example,

00001010 00011001 10101100 00001111

is written as **10.25.172.15**

Dotted-Decimal Notation

Data link layer

- The network layer packet may pass through several routers from its source to its destination.

- Carrying the packet from one node (a computer or a router) to another is the responsibility of the data link layer.

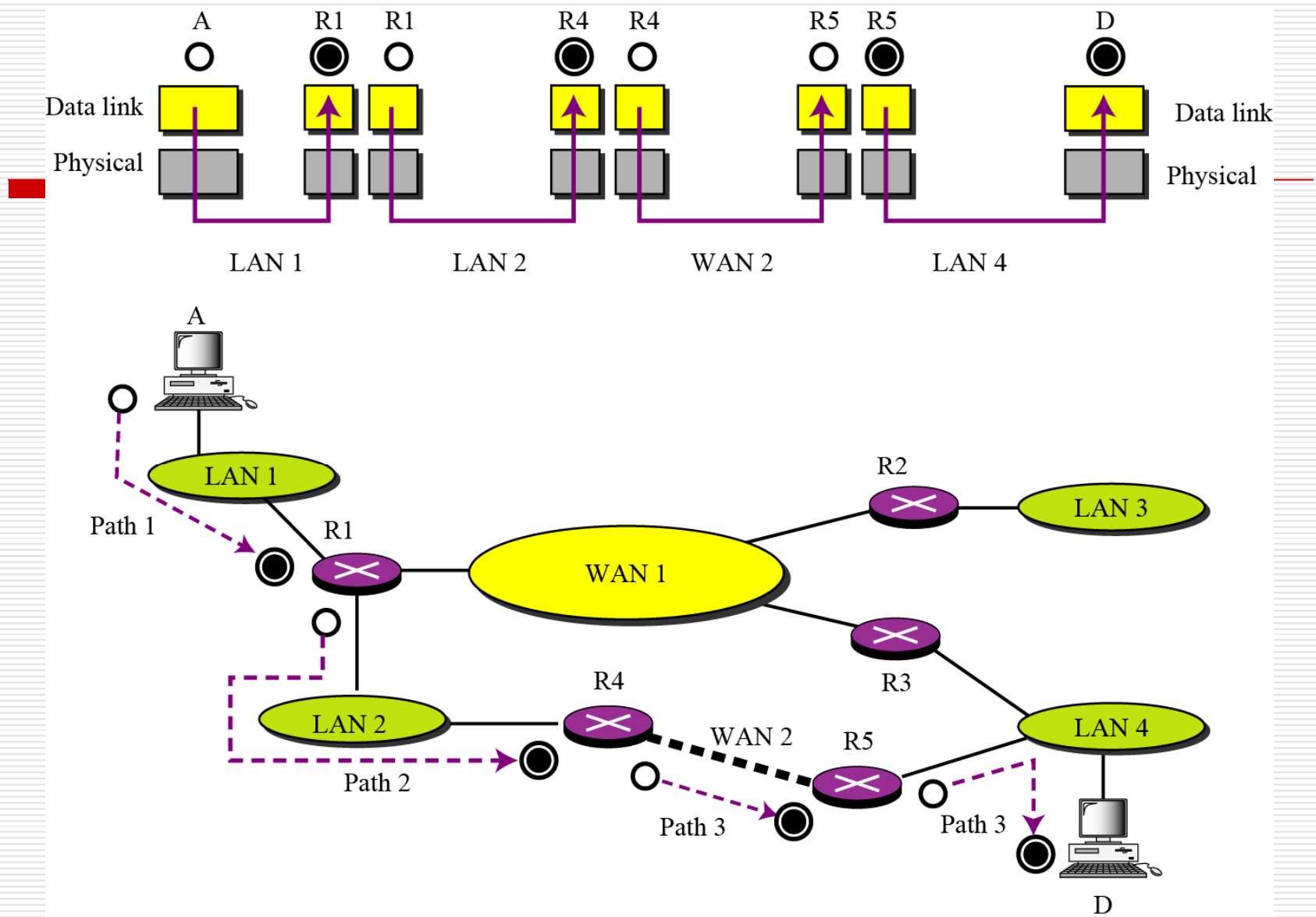**The data link layer is responsible for node-to-node delivery of frames.**

Figure 6.15 **Communication at the data-link layer**

Data link layer

☐ **Data-link layer addresses**

- Question: How computer A knows the data-link layer address of R1, or R1 knows the data-link layer address of R4.

- A device can find the data-link address of another device either **statically** or **dynamically**.
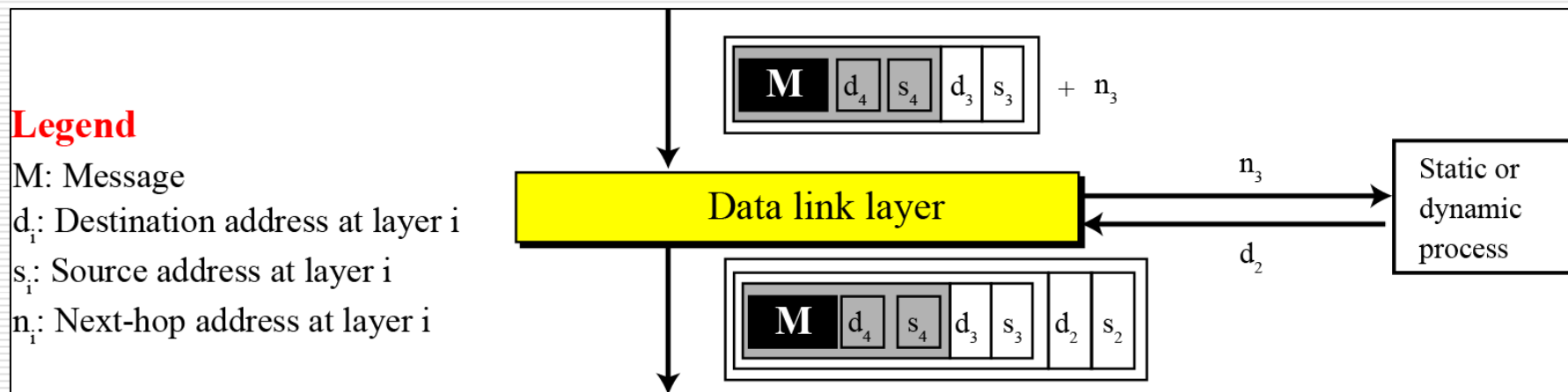

Figure 6.16 **Addresses at the data link layer**

Data link layer

- **Data-link layer addresses**
  - Unlike IP addresses, addresses at the data-link layer cannot be universal.
  - Each data link protocol may have a different address format and size.
  - The Ethernet protocol uses a 48-bit address, which is normally written in hexadecimal format as shown below:

    07:01:02:11:2C:5B

Physical layer

- ☐ Carry a bit stream over a physical medium.
    - ■ The data link layer is responsible for moving a **frame** from one node to another
    - ■ The physical layer is responsible for moving the **individual bits** that make up the frame to the next node.

- ☐ The unit of transfer in the data link layer is a frame, while the unit of transfer in the physical layer is a bit.

The physical layer is responsible for node-to-node delivery of bits

Legend

M: Message

d_i: Destination address at layer i
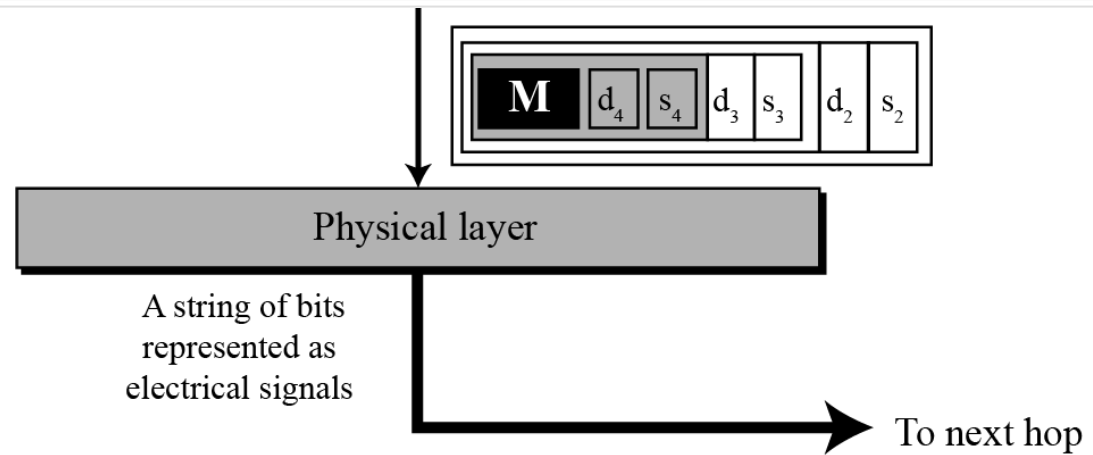
s_i: Source address at layer i

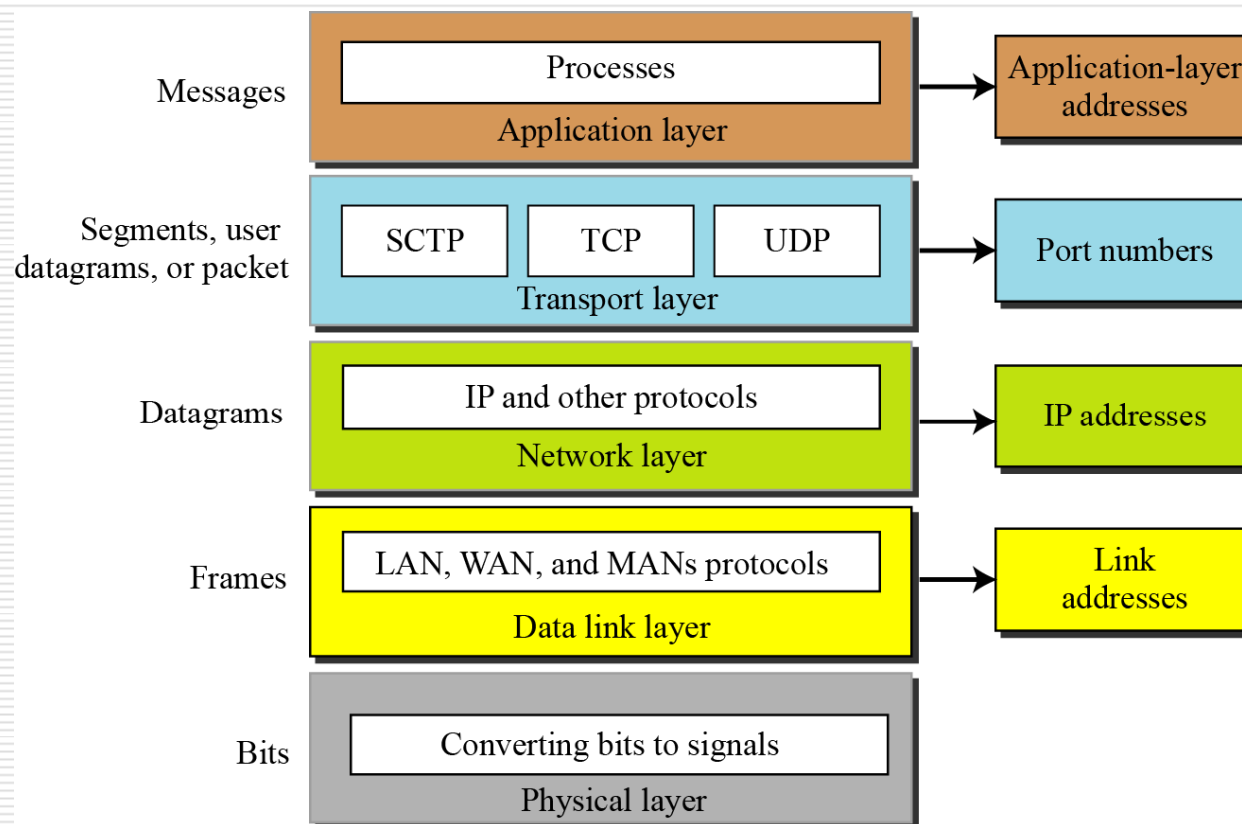**Figure 6.17** **Duty of the physical layer**

Summary of layers

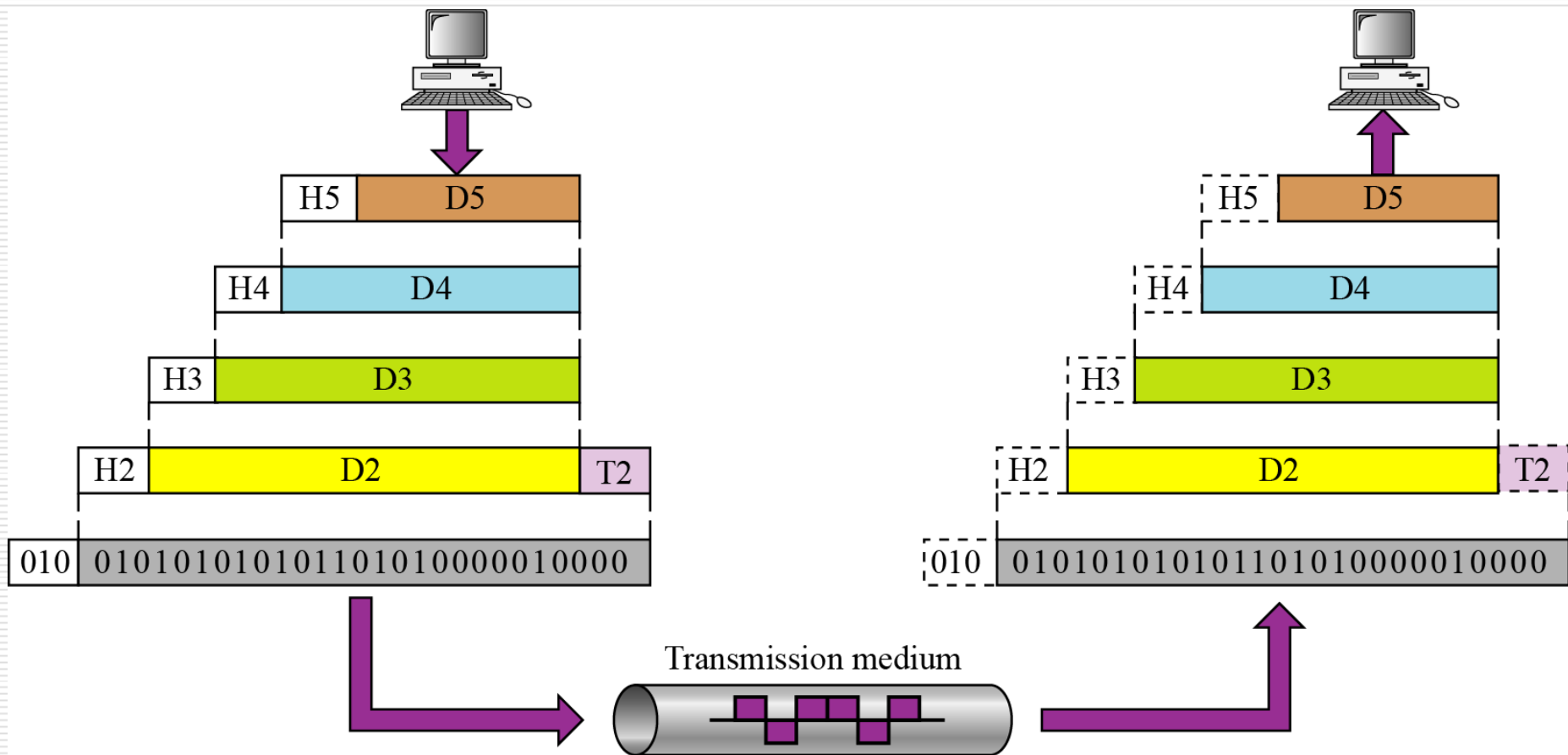**Figure 6.17** **Four levels of addressing in the Internet** 42

Figure 6.19 **An exchange using the TCP/IP model**

6.4

INTERNET APPLICATION

Description

- The main task of the Internet is to provide services for users.
- Among the most popular applications are:
  - **Electronic mail**
  - **Remote login**
  - **File transfer**
  - **World Wide Web (WWW)**
  - **Other Internet applications**

Electronic-mail

- ☐ E-mail is exchange of messages between two entities.

- ☐ Although the sender of the e-mail can be a client program, the receiver cannot be the corresponding server, because that implies that the receiver must let their computer run all the time, as they do not know when an e-mail will arrive.
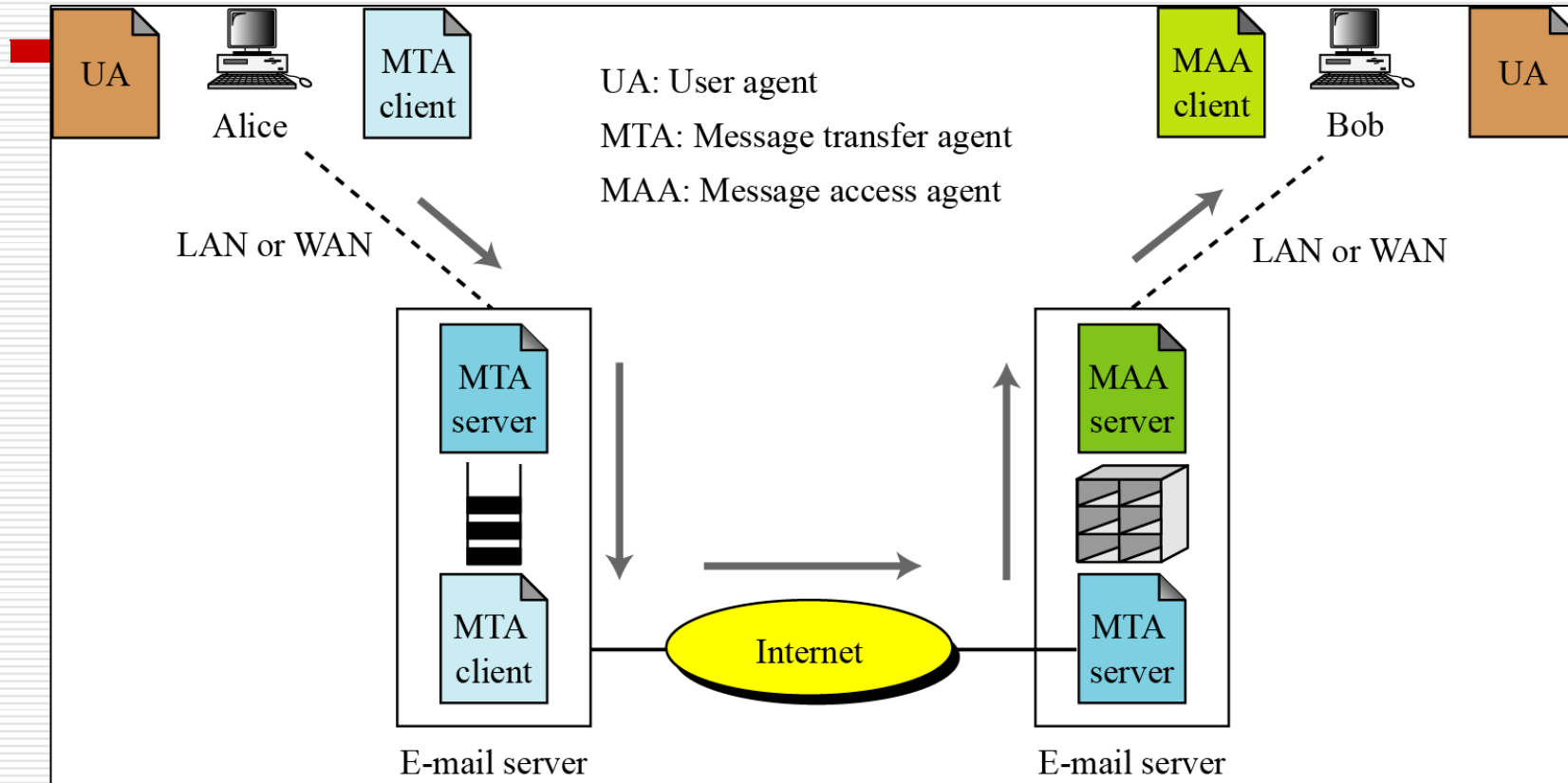
Figure 6.20 E-mail architecture

Electronic-mail

☐ **Mail access protocols**

■ Stored e-mail remains on the mail server until it is retrieved by the recipient through an access protocol.

■ Two e-mail access protocols are in common use: **Post Office Protocol, Version 3 (POP3)** and **Internet Mail Access Protocol (IMAP)**.
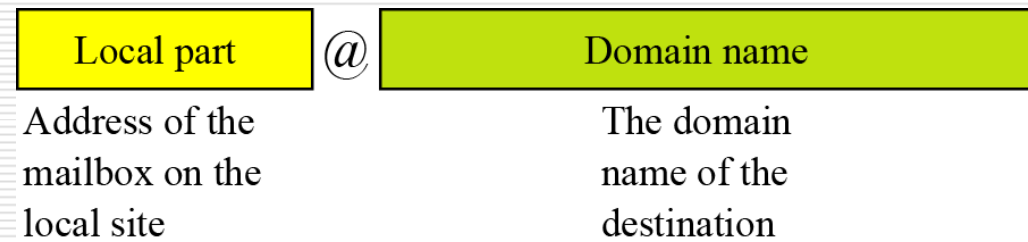
☐ **Addresses**

Local part	@	Domain name
Address of the mailbox on the local site		The domain name of the destination

Figure 6.21 E-mail address

Electronic-mail

☐ **Multi-purpose Internet Mail Extension (MIME)**

- A supplementary protocol that allows non-ASCII data to be sent through SMTP.
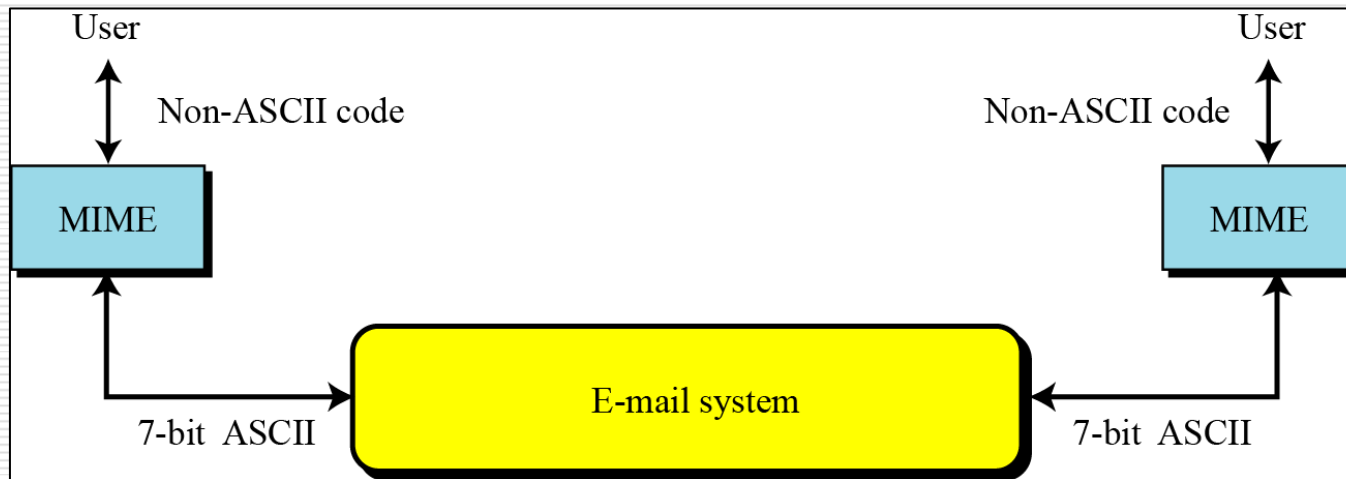
- An extension to SMTP, not an e-mail protocol

Figure 6.22 Multi-purpose Internet Mail Extension (MIME) 49

File Transfer Protocol (FTP)

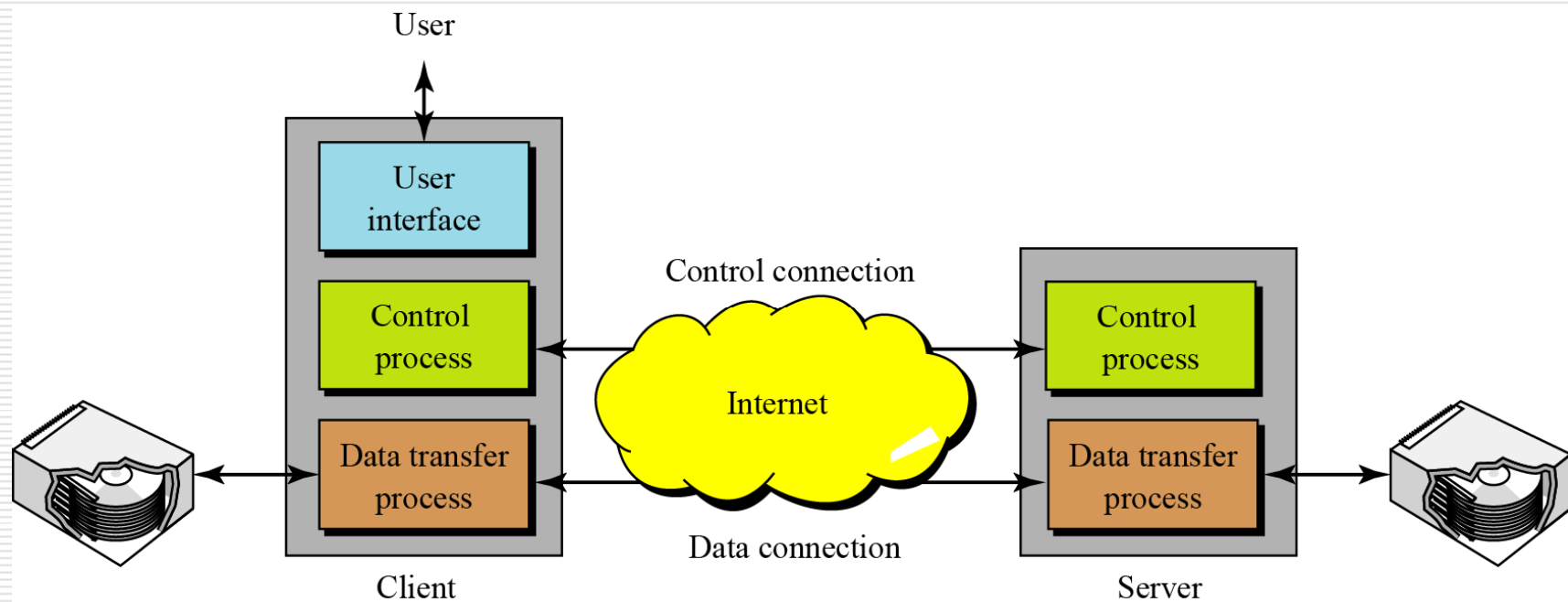The standard mechanism for one of the most common tasks on the INTERNET, copying a file from one computer to another.

Figure 6.23 **File Transfer Protocol (FTP)**

Remote login – TELNET

- ☐ A general-purpose client-server program lets a user access any application program on a remote computer.

- ☐ It allows the user to log onto a remote computer.

- ☐ After logging on, a user can use the services available on the remote computer and transfer the results back to the local computer.
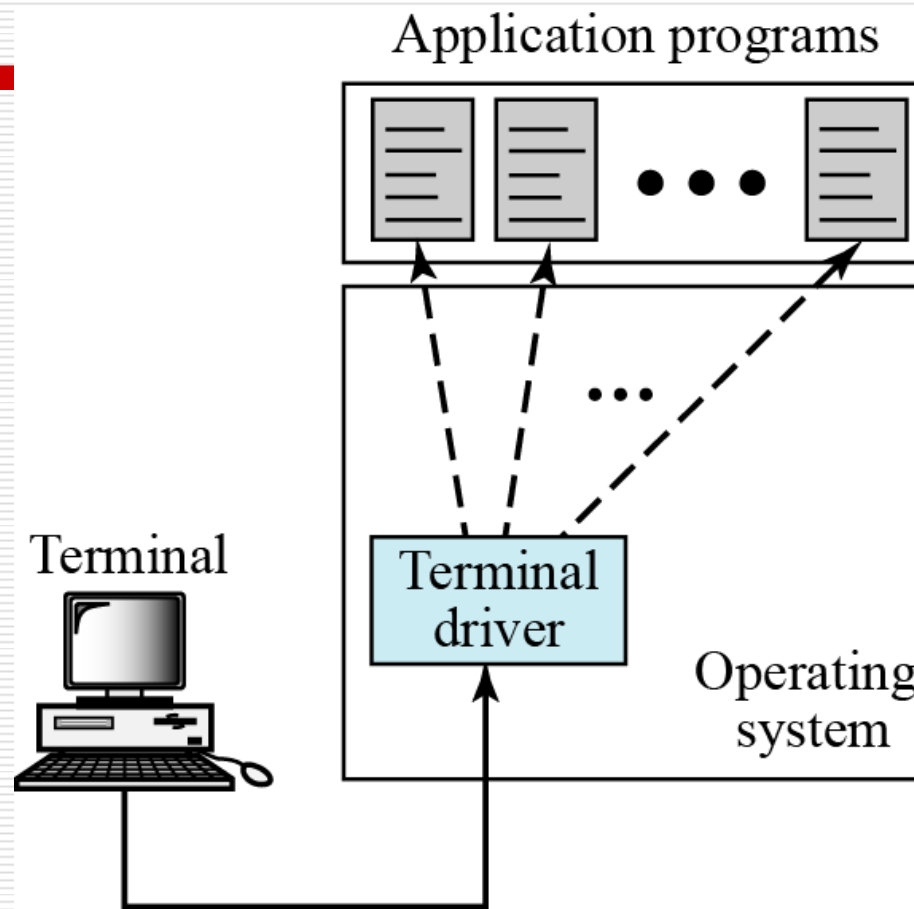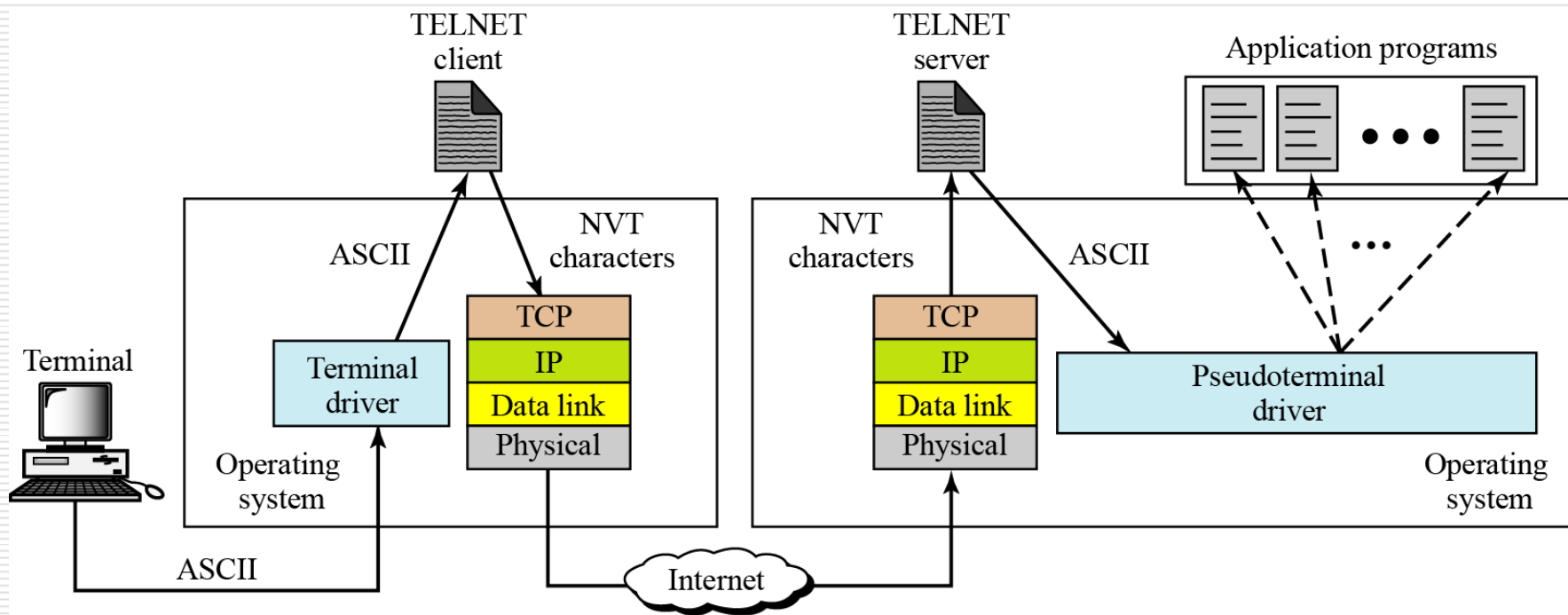
Figure 6.24 Local login

Figure 6.25 Remote login

The World Wide Web (WWW)

- The **WWW**, or just "the Web", is a repository of linked information spread all over the world.

    - Has a unique combination of flexibility, portability and user-friendly features.

    - A distributed client-server service in which a client using a browser can access a service using a server.

    - The service provided is distributed over many locations, called web sites.

WWW

☐ **Hypertext and hypermedia**

- ■ In a hypertext environment, information is stored in a set of documents that are connected together using the concept of links.
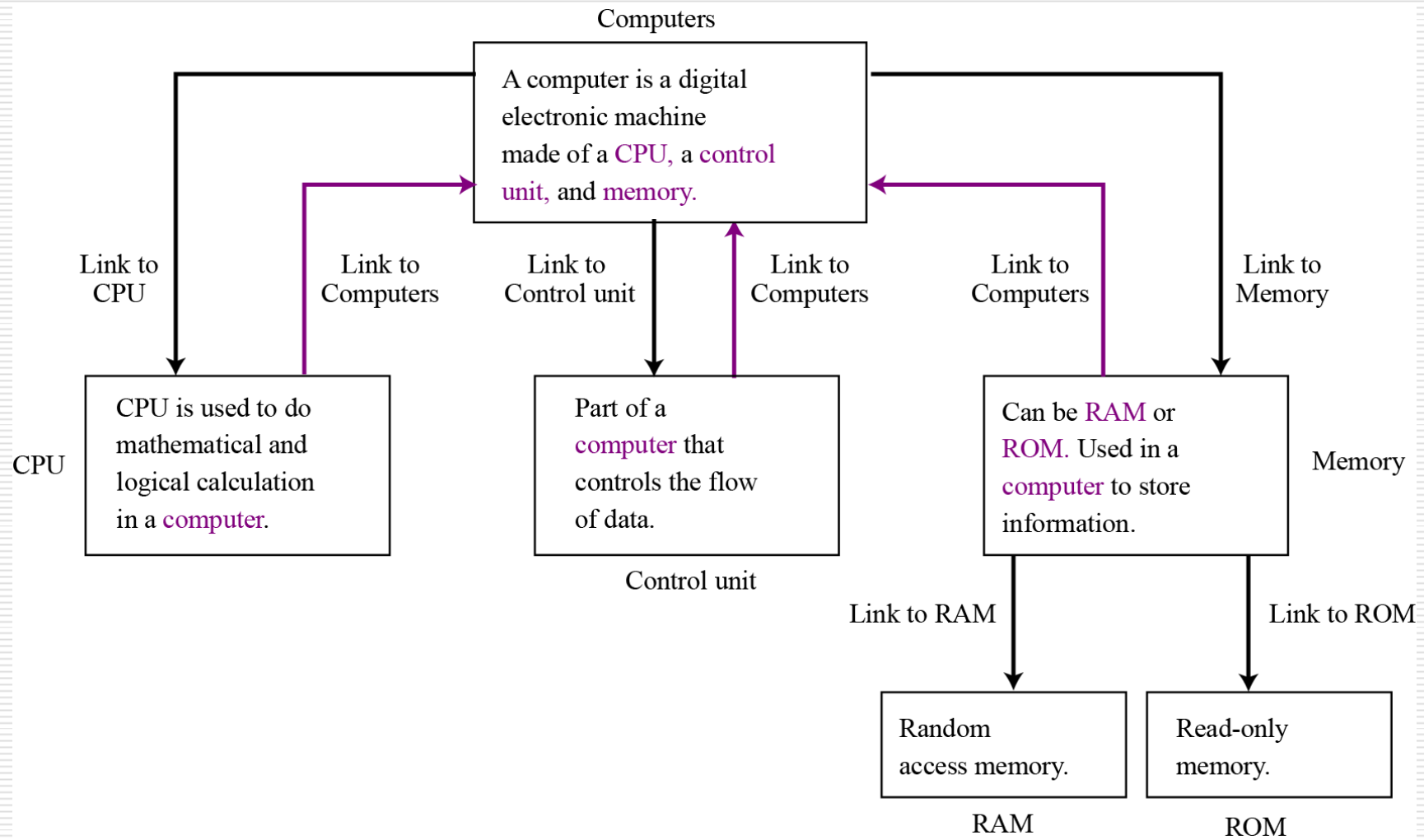
Computers

A computer is a digital electronic machine made of a CPU, a control unit, and memory.

Link to CPU

Link to Computers

Link to Control unit

Link to Computers

Link to Computers

Link to Memory

CPU

CPU is used to do mathematical and logical calculation in a computer.

Part of a computer that controls the flow of data.

Control unit

Can be RAM or ROM. Used in a computer to store information.

Memory

Link to RAM

Link to ROM

Random access memory.

RAM

Read-only memory.

ROM

Figure 6.26 Hypertext

WWW

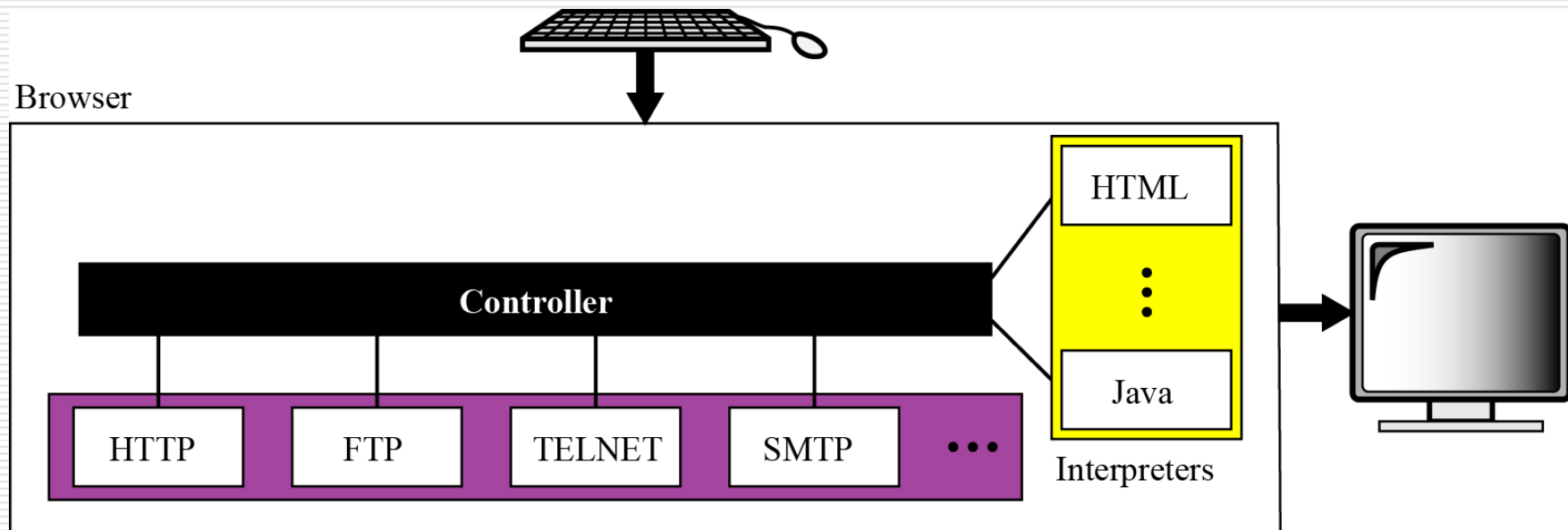☐ Three components: a **browser**, a **web server** and a protocol called **Hypertext Transfer Protocol (HTTP)**.

Figure 6.27 **Browser structure**

WWW

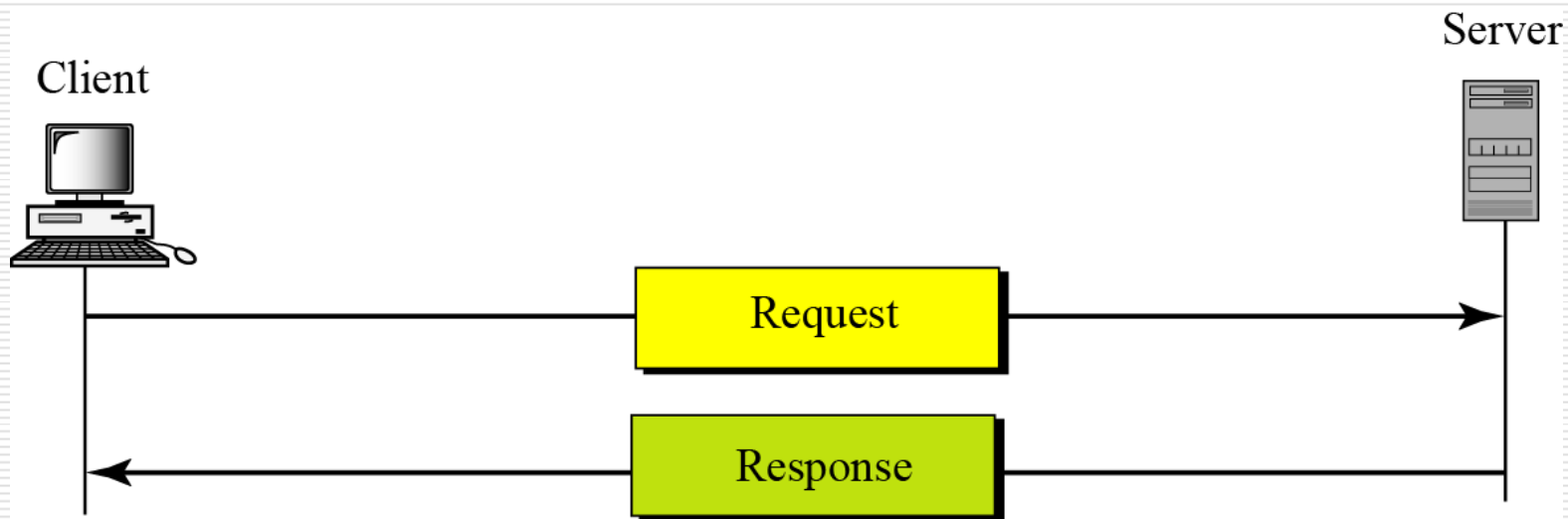☐ **Hypertext Transfer Protocol (HTTP)** is a protocol used mainly to access data on the World Wide Web.

Figure 6.28 HTTP transaction

WWW

- □ **The uniform resource locator (URL)**
  - To facilitate the access of documents distributed throughout the world, HTTP uses the concept of locators.
  - A standard for specifying any kind of information on the Internet.

| Method | :// | Host | : | Port | / | Path |

URL: Uniform Resource Locator

Figure 6.29 URL structure

WWW

- ☐ **Static documents**
  - The documents on the WWW can be grouped into three broad categories: static, dynamic and active.
  - This categorization is based on the time at which the contents of the document are determined.
  - Static documents are fixed-content documents that are created and stored on a server.

A language for creating Web pages.

```
<HTML>

<HEAD>
        <TITLE>  Small College  </TITLE>
</HEAD>

<BODY>
   <H1>  President: Eve Jones  </H1>
   <H1>  Vice President: Adam Brown  </H1>
   <H2>  Department: Math and Science  </H2>
  <H3>  Courses </H3>

    <LI>  CS0 </LI>
    <LI>  CS1 </LI>
    <LI>  CS2 </LI>


  <H2>  Department: Business  </H2>
  <H3>  Courses </H3>

     <LI>  Introduction to Business </LI>
     <LI>  Business Law </LI>
     <LI>  Business Mathematics </LI>

</BODY>

</HTML>
```

HTML document

Small College

President: Eve Jones

 Vice President: Adam Brown

 Department: Math and Science

Courses:

1. CS0
2. CS1
3. CS2

 Department: Business

Courses:

 1. Introduction to Business

 2. Business Law

 3. Business Mathematics

Result

Figure 6.30 HTML example

WWW

☐ **Extensible Markup Language (XML)**
is a language in which tags can be
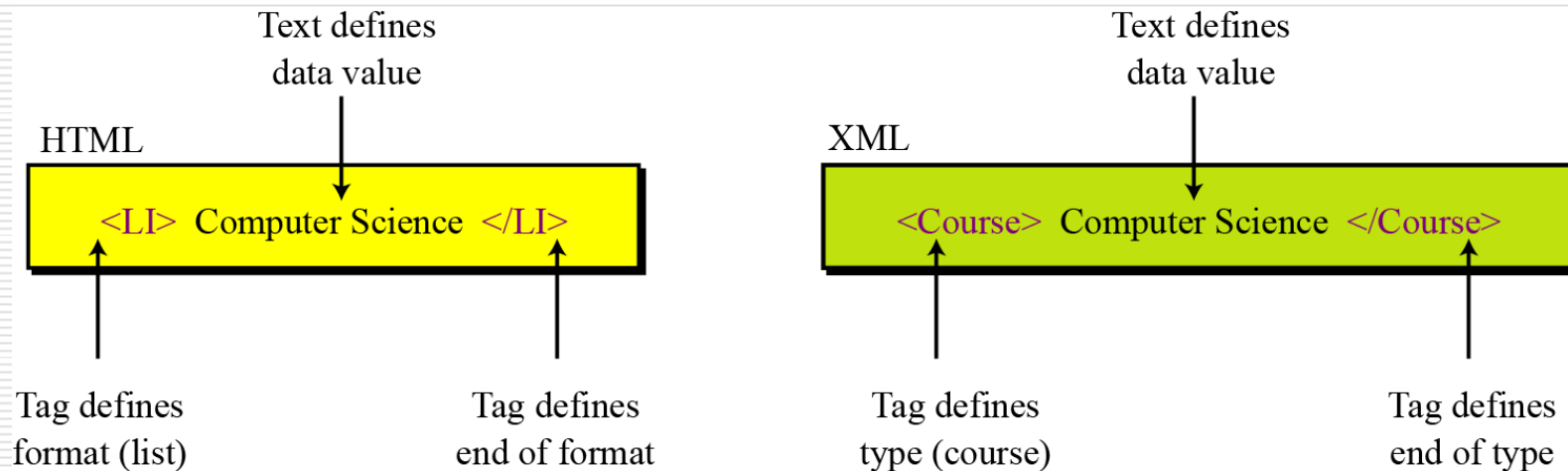used to define the content (type) of
the text between two tags.

Text defines
data value

HTML

<LI> Computer Science </LI>

Tag defines
format (list)

Tag defines
end of format

Text defines
data value

XML

<Course> Computer Science </Course>

Tag defines
type (course)

Tag defines
end of type

Figure 6.31 **Comparing HTML and XML**

WWW

- **Dynamic documents**
  - A dynamic document is created by a Web server whenever a browser requests the document.
  - When a request arrives, the Web server runs an application program that creates the dynamic document.
  - The server returns the output of the program as a response to the browser.

WWW

- ☐ **Active documents**
    - ■ Run a program or a script at the client site.
    - ■ For example, a program that creates animated graphics on the screen, or a program that interacts with the user.
    - ■ When a browser requests an active document, the server sends a copy of the document or a script. The document is then run under the control of the client's browser.

Other Internet applications

- During the last decade other applications have been developed on the Internet.
  - **Videoconferencing**
  - **Group discussion Listservs**
  - **Chat**

Videoconferencing

□ Eliminate the cost of traveling, and save time and energy, by providing communication between two or more groups of participants or a set of individual participants.
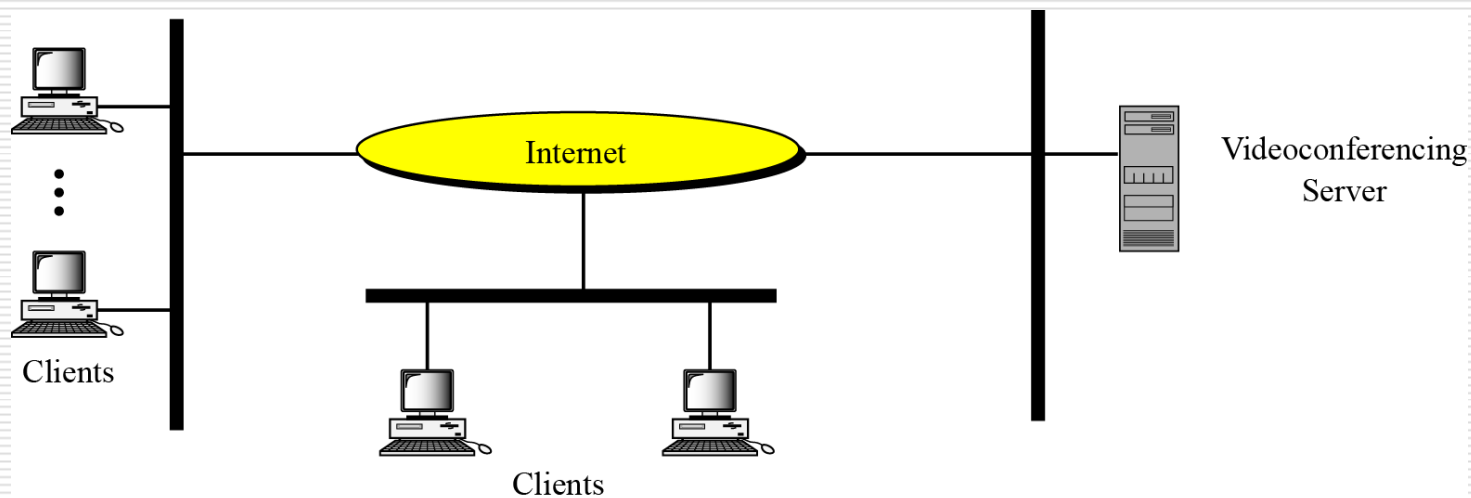

Figure 6.32 **Videoconferencing**

Group discussion Listservs

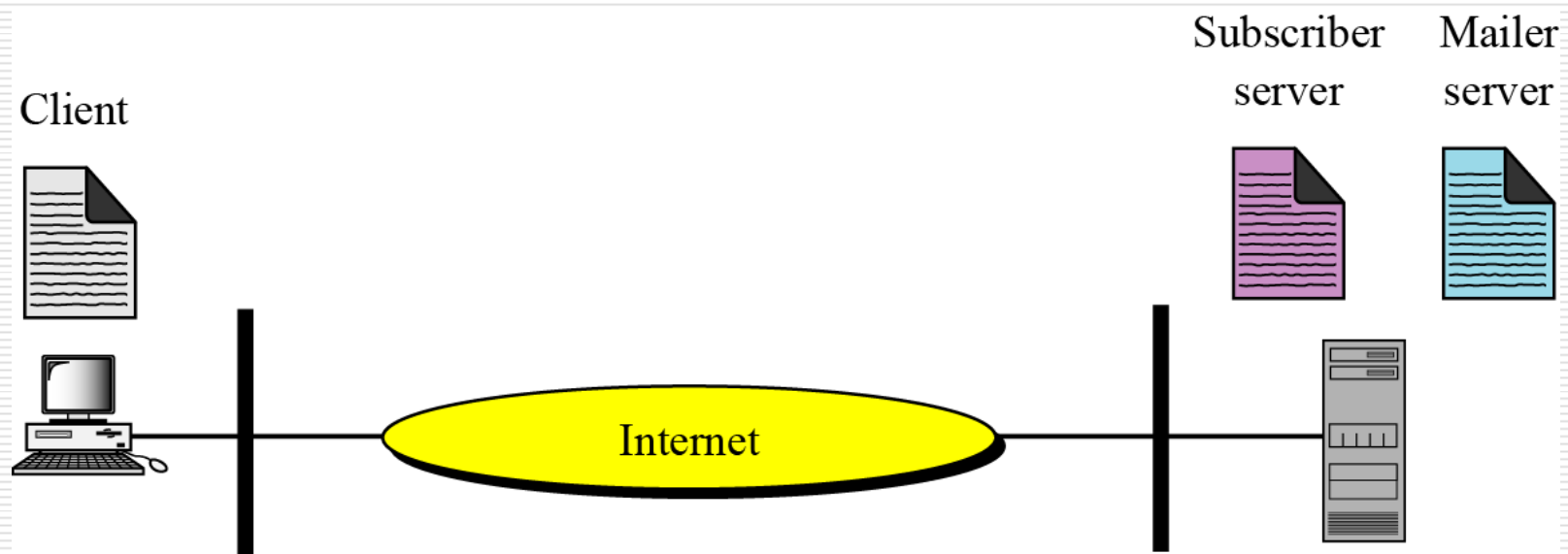☐ Allow a group of users to discuss a common topic of interest.

Figure 6.33 **Listserv organization**

Chat

☐ This is a real-time application like videoconferencing, in which two or more parties are involved in an exchange of text and optionally audio and video.

☐ The two parties can send text to each other, talk to each other (the same way as they might talk on the phone), and even see each other with suitable cameras.