

# Chapter 7: Computer Networks, the Internet, and the World Wide Web

Invitation to Computer Science,  
C++ Version, Fourth Edition

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# Objectives

In this chapter, you will learn about

- Basic networking concepts
- Communication protocols
- Network services and benefits
- A brief history of the Internet and the World Wide Web

# Introduction

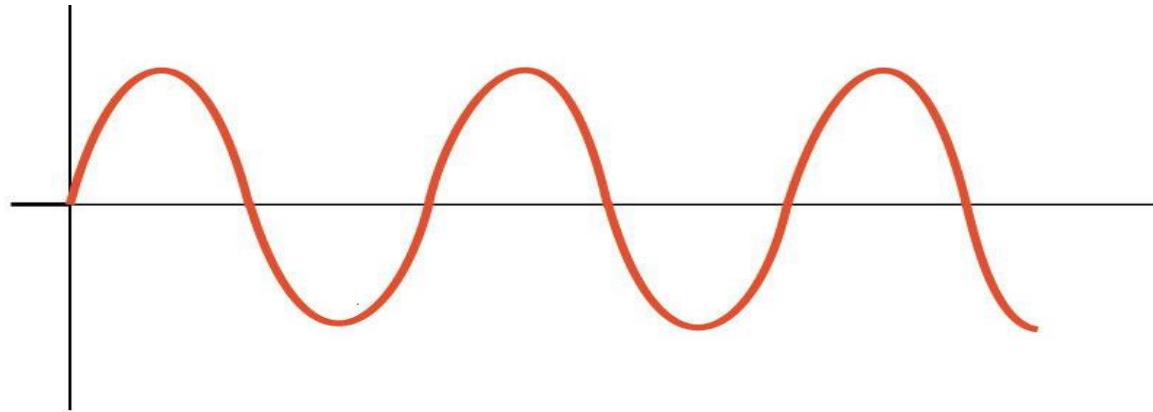
- Computer network
  - Computers connected together
  - Purpose: Exchanging resources and information
  - Just about any kind of information can be sent
    - Examples: Television and radio signals, voice, graphics, handwriting, photographs, movies

# Basic Networking Concepts

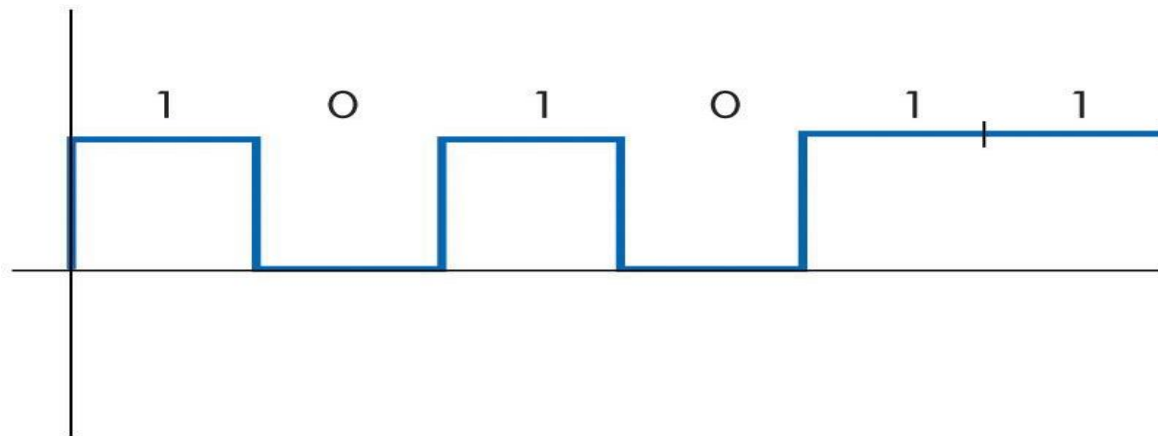
- Computer network
  - Set of independent computer systems connected by telecommunication links
  - Purpose: Sharing information and resources
- Nodes, hosts, or end systems
  - Individual computers on a network

# Communication Links

- Switched, dial-up telephone line
  - A circuit is temporarily established between the caller and callee
  - Analog medium
  - Requires modem at both ends to transmit information produced by a computer
    - Computer produces digital information



(a) Analog Representation



(b) Digital Representation

Figure 7.1 Two Forms of Information Representation

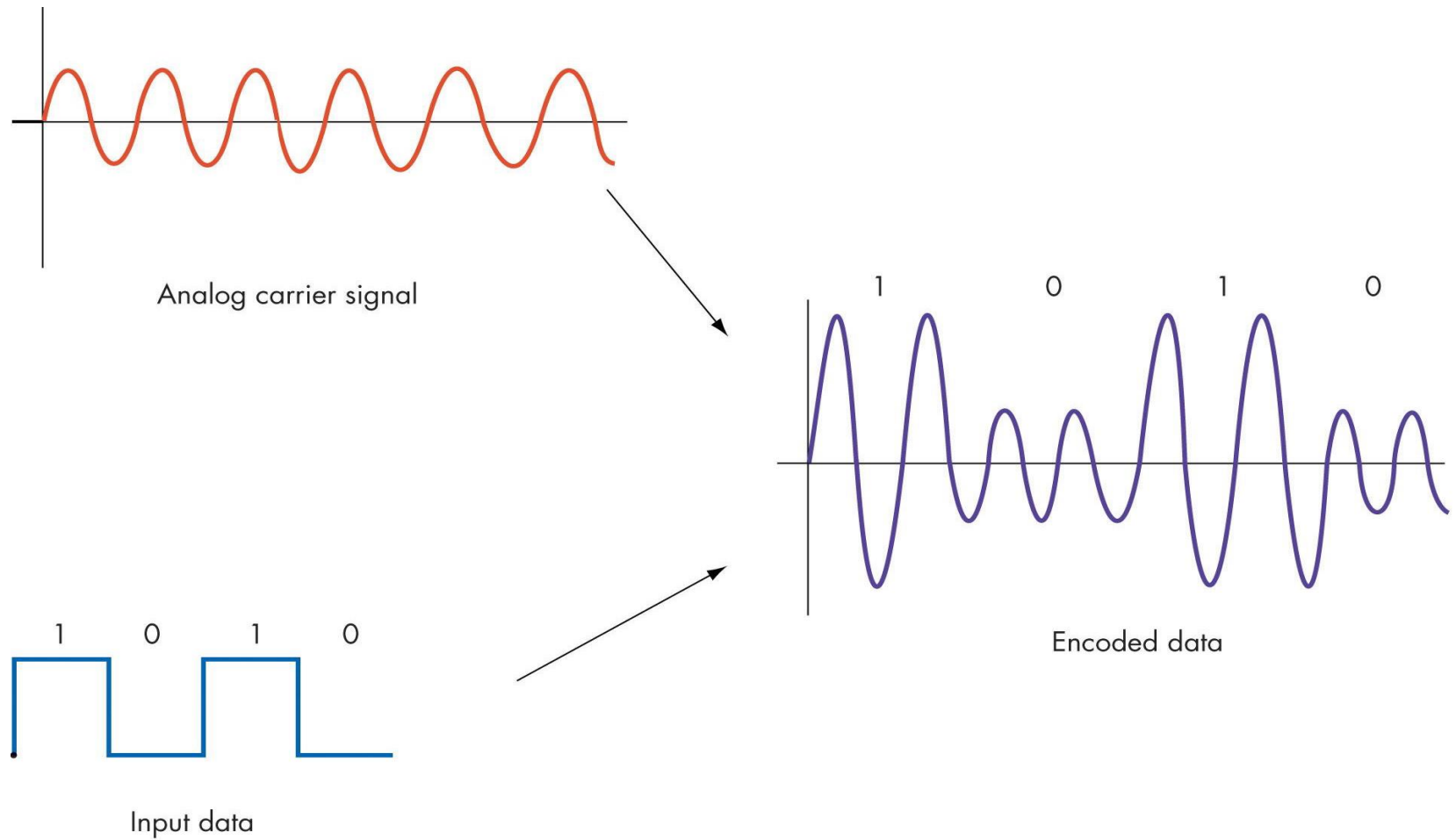


Figure 7.2  
Modulation of a Carrier to Encode Binary Information

# Communication Links (continued)

- Dial-up phone links

- Transmission rate: 56,000 bps (56 Kbps)

- Broadband

- Transmission rate: Exceeding 256,000 bps (256 Kbps)



# Communication Links (continued)

- Options for broadband communications
  - Home use
    - Digital subscriber line (DSL)
    - Cable modem
  - Commercial and office environment
    - Ethernet
    - Fast Ethernet
    - Gigabit Ethernet

LINE TYPE	SPEED	TIME TO TRANSMIT 8 MILLION BITS (ONE COMPRESSED IMAGE)
Dial-up phone line	56 Kbps	2.4 minutes
DSL line, cable modem	2 Mbps	4 seconds
Ethernet	10 Mbps	0.8 second
Fast Ethernet	100 Mbps	0.08 second
Gigabit Ethernet	1 Gbps	0.008 second

Figure 7.3

## Transmission Time of an Image at Different Transmission Speeds

# Communication Links (continued)

- Wireless data communication
  - Uses radio, microwave, and infrared signals
  - Enables “mobile computing”
  - Types of wireless data communication
    - Wireless local access network
    - Wireless wide-area access network

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# Local Area Networks

- Local area network (LAN)
  - Connects hardware devices that are in close proximity
  - The owner of the devices is also the owner of the means of communications
  - Common wired LAN topologies
    - Bus
    - Ring
    - Star

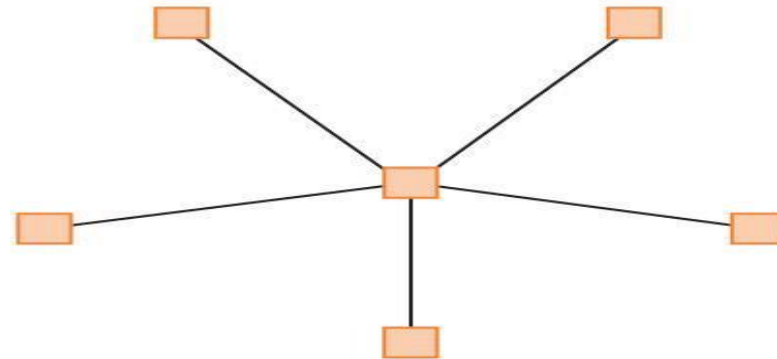
Figure 7.4  
Some Common  
LAN Topologies



(a) Bus



(b) Ring



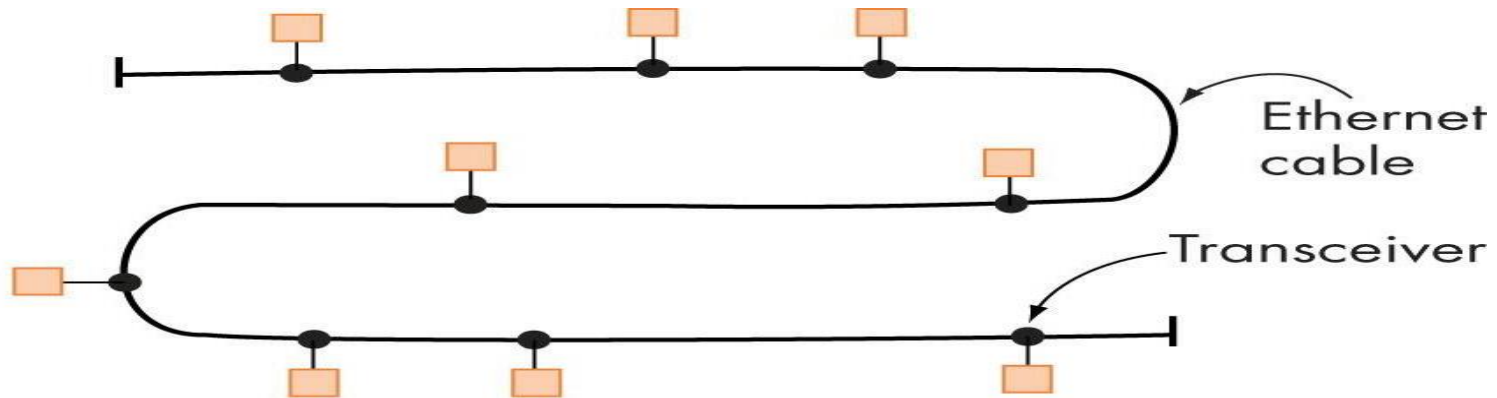
(c) Star

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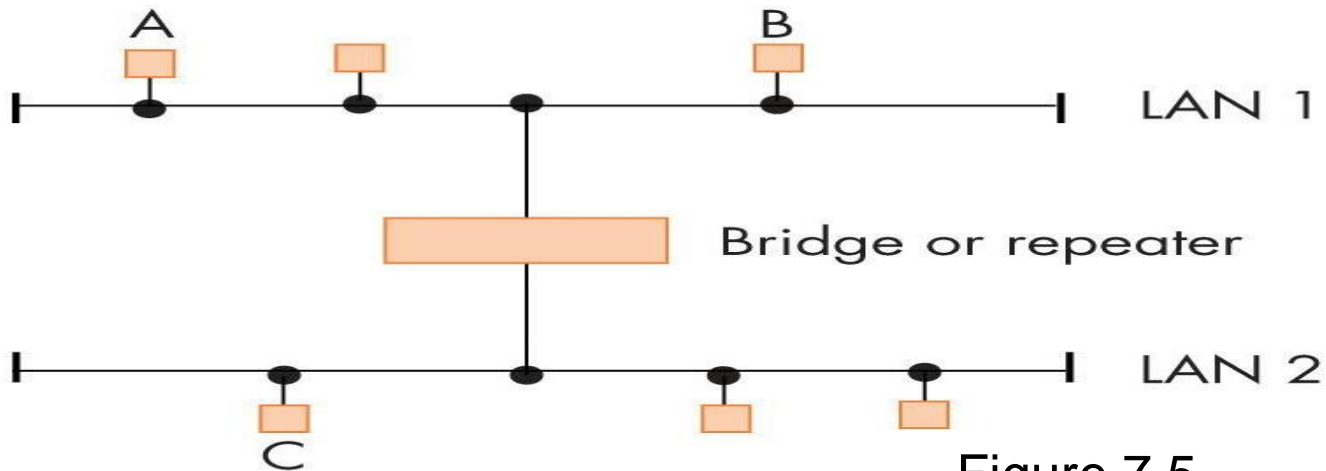
# Local Area Networks (continued)

- Ethernet

- Most widely used LAN technology
- Uses the bus topology
- Two ways to construct an Ethernet LAN
  - Shared cable
  - Hubs: The most widely used technology



(a) Single Cable Configuration



(b) Multiple Cable Configuration

Figure 7.5  
An Ethernet LAN Implemented  
Using Shared Cables

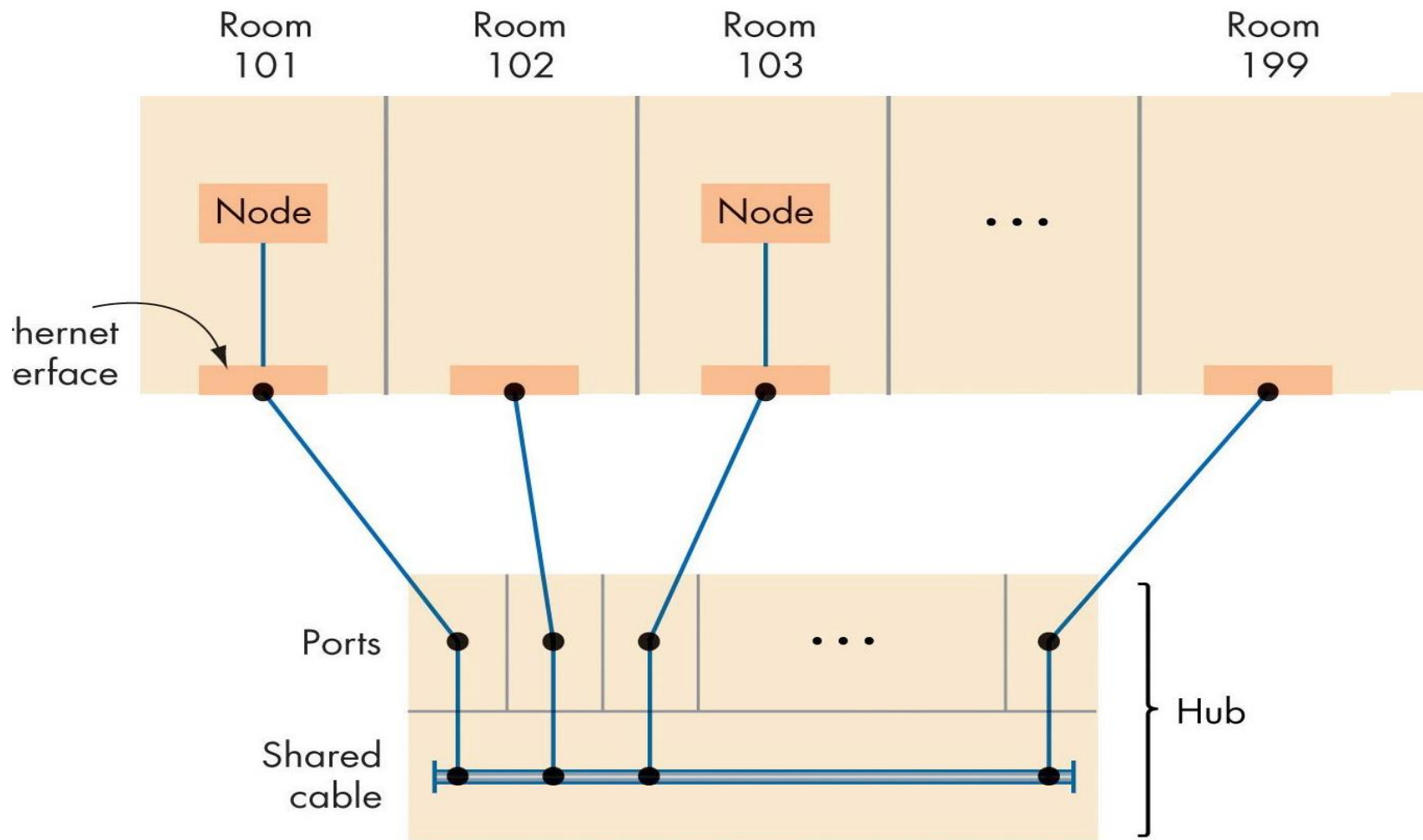


Figure 7.6  
An Ethernet LAN Implemented Using a Hub



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# Wide Area Networks

- Wide area networks (WANs)
  - Connect devices that are across town, across the country, or across the ocean
  - Users must purchase telecommunications services from an external provider
  - Dedicated point-to-point lines
  - Most use a store-and-forward, packet-switched technology to deliver messages

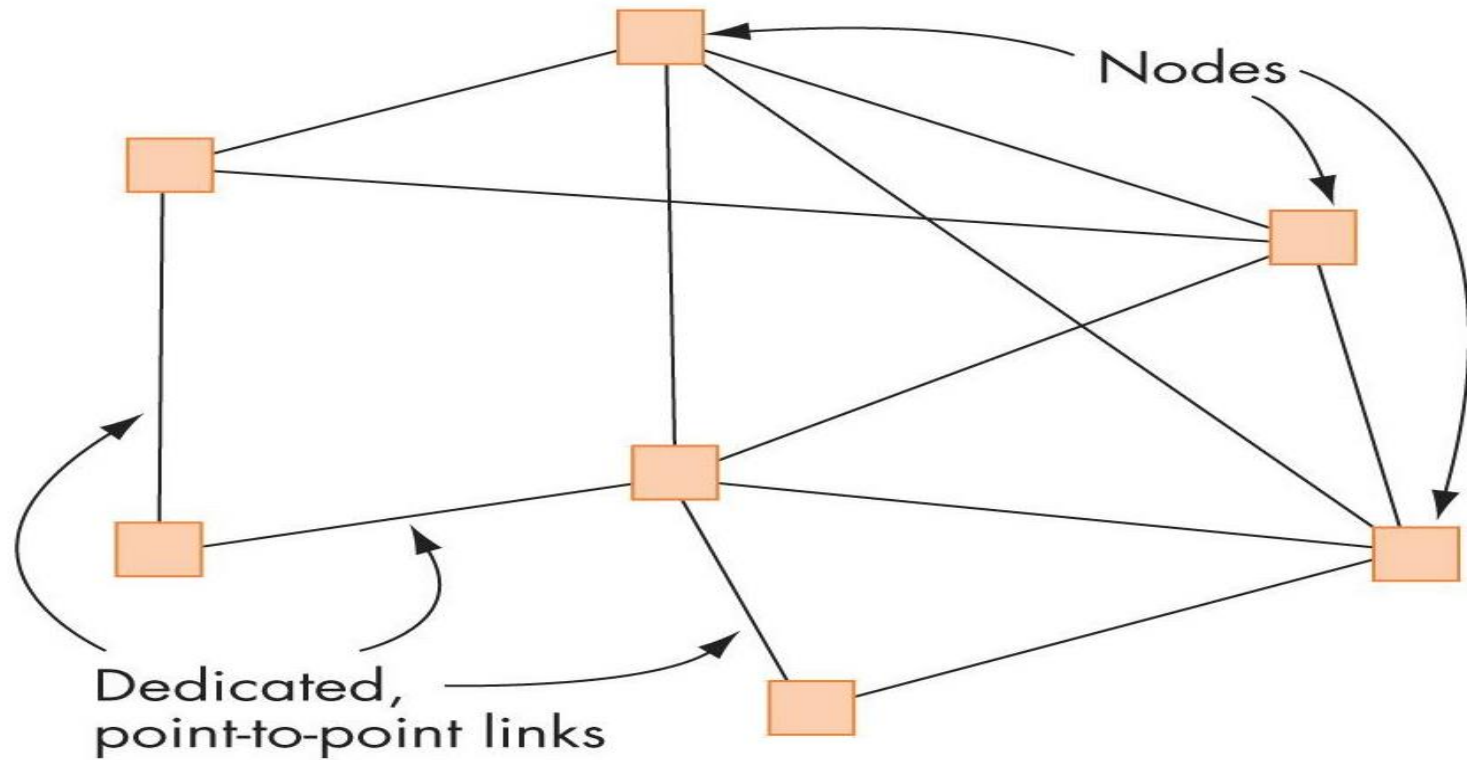


Figure 7.7  
Typical Structure of a Wide Area Network

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# Overall Structure of the Internet

- All real-world networks, including the Internet, are a mix of LANs and WANs
  - Example: A company or a college
    - One or more LANs connecting its local computers
    - Individual LANs interconnected into a wide-area company network

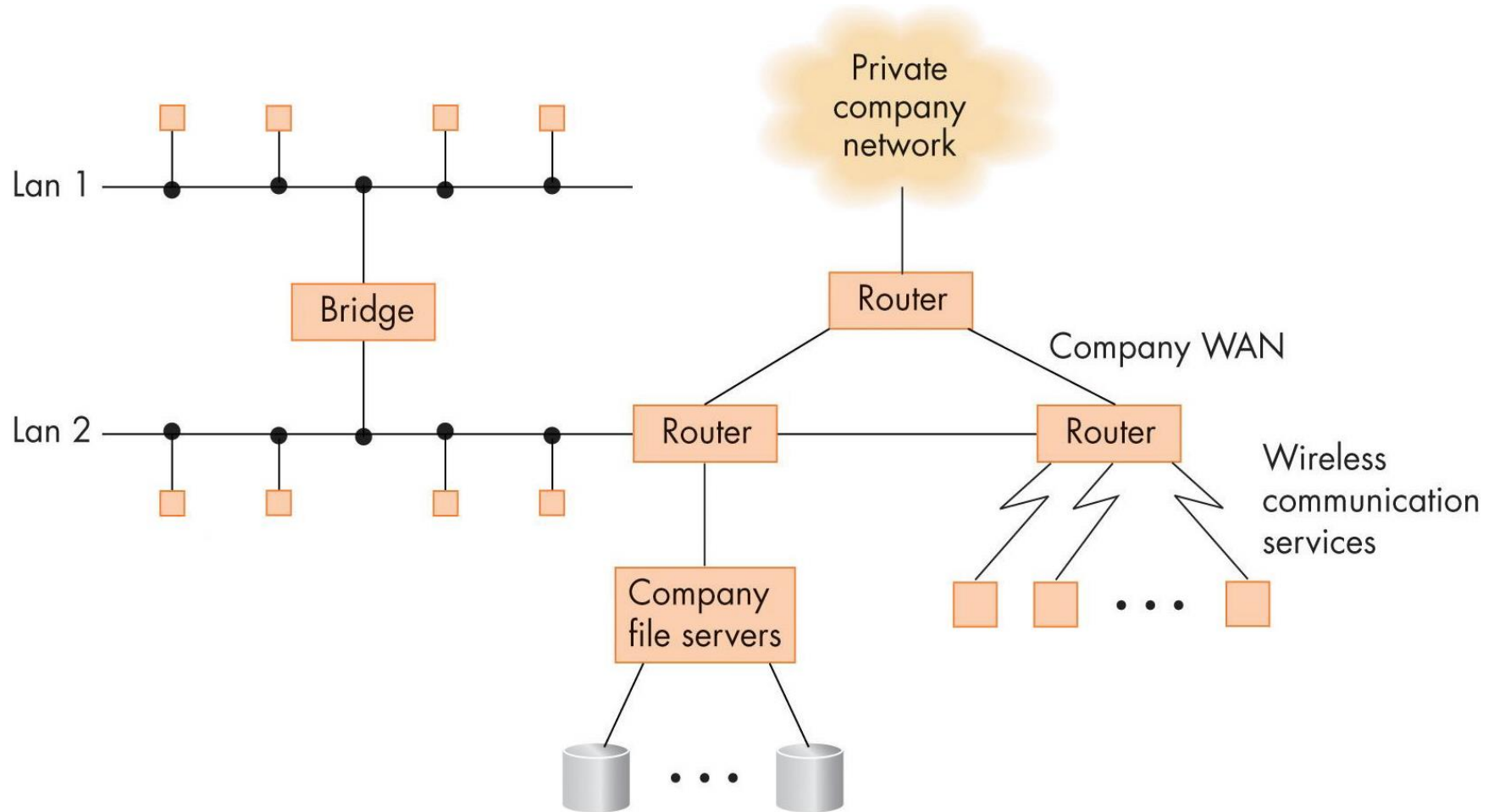


Figure 7.8(a)  
Structure of a Typical Company Network

# Overall Structure of the Internet (continued)

- Internet Service Provider (ISP)
  - A wide-area network
  - Provides a pathway from a specific network to other networks, or from an individual's computer to other networks
- ISPs are hierarchical
  - Interconnect to each other in multiple layers to provide greater geographical coverage

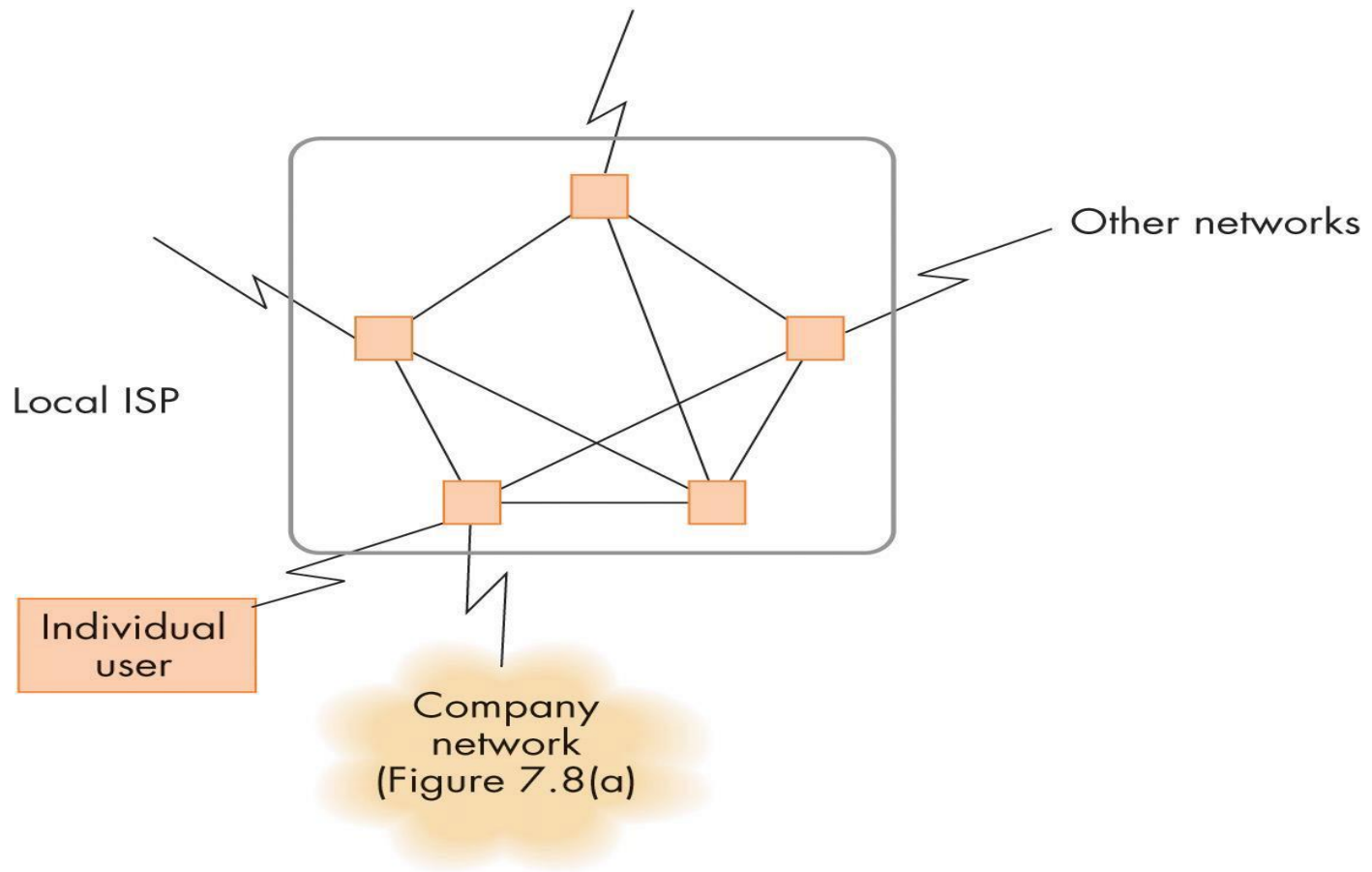


Figure 7.8(b)  
Structure of a Network Using an ISP

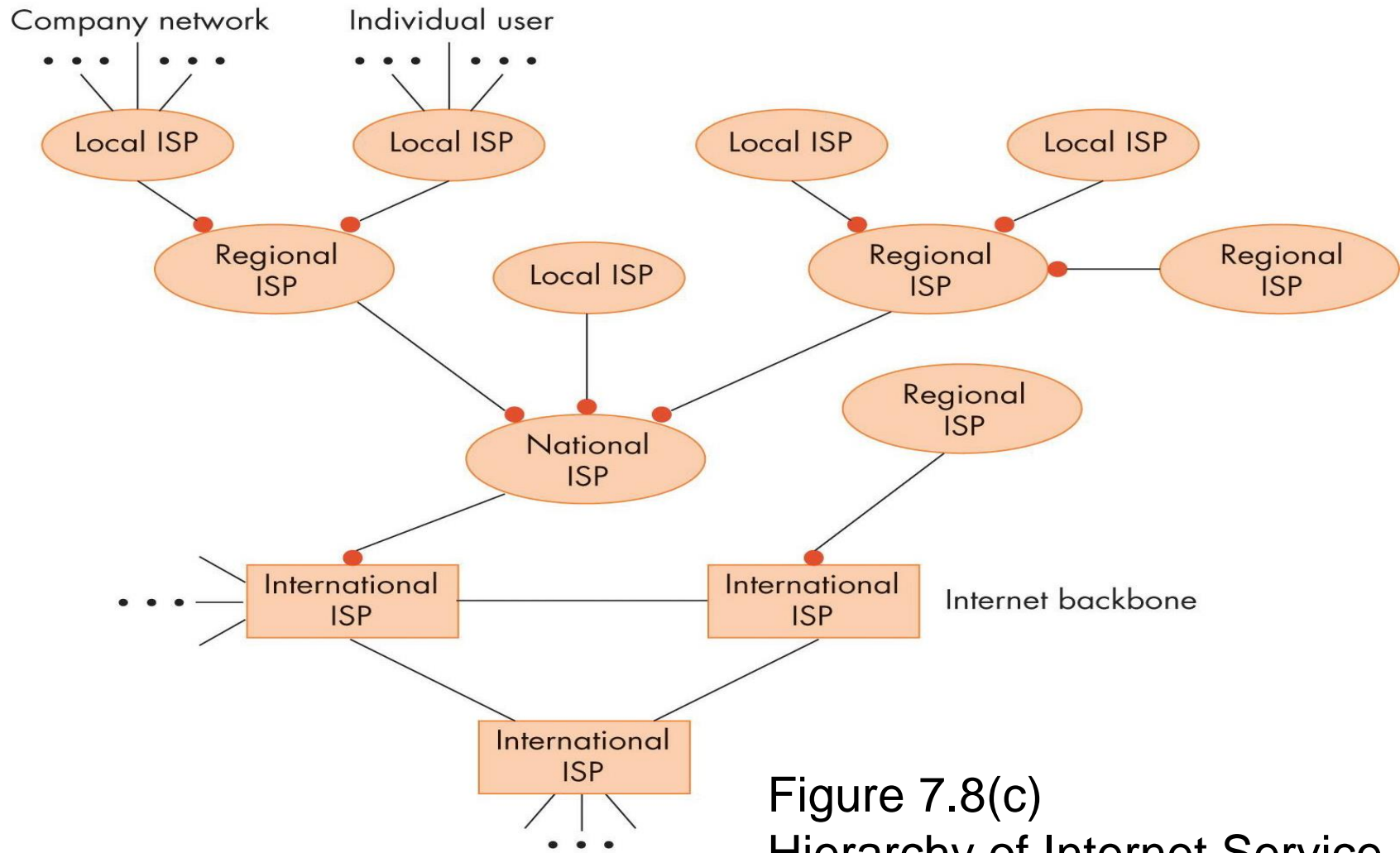


Figure 7.8(c)  
Hierarchy of Internet Service Providers

# Overall Structure of the Internet (continued)

## ■ Internet

- A huge interconnected “network of networks”
- Includes nodes, LANs, WANs, bridges, routers, and multiple levels of ISPs
- Early 2008
  - 541 million nodes (hosts)
  - Hundreds of thousands of separate networks located in over 225 countries



# Communication Protocols

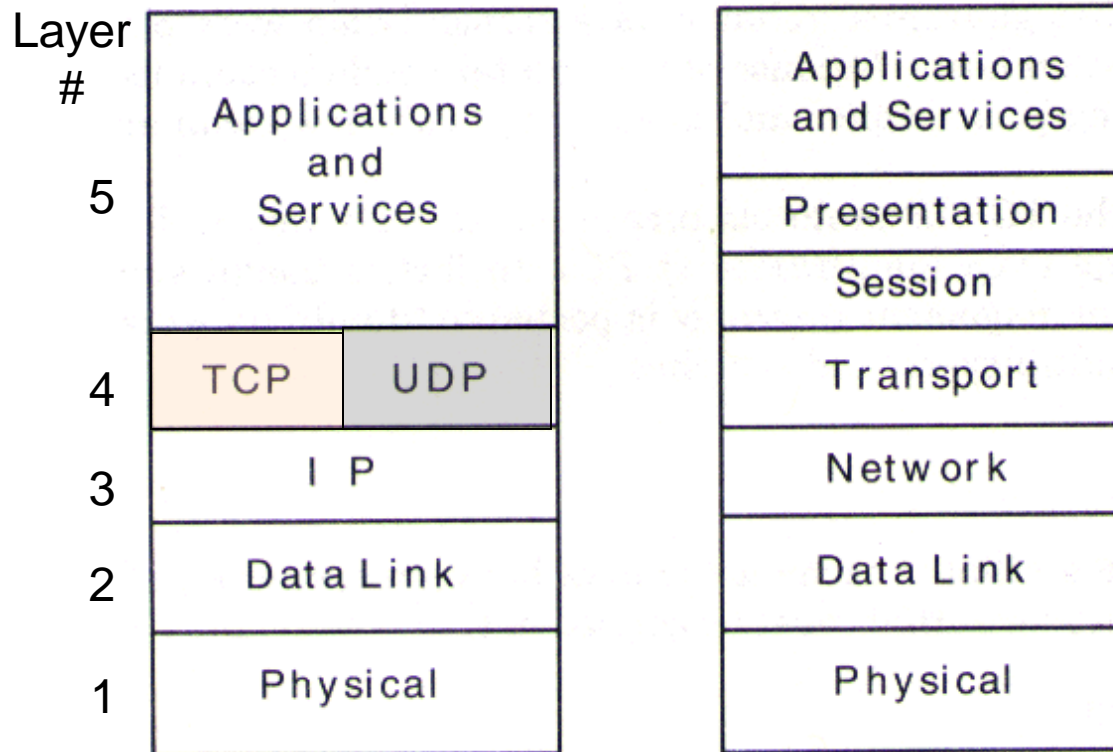
- A protocol
  - A mutually agreed upon set of rules, conventions, and agreements for the efficient and orderly exchange of information
- TCP/IP
  - The Internet protocol hierarchy
  - Governs the operation of the Internet
  - Five layers

LAYER	NAME	EXAMPLES
5	Application	HTTP, SMTP, FTP
4	Transport	TCP, UDP
3	Network	IP
2b	Logical Link Control	PPP, Ethernet
2a	Medium Access Control	Ethernet
1	Physical	Modem, DSL, Cable Modem

} Data Link Layer

Figure 7.10  
The Five-Layer TCP/IP Internet Protocol Hierarchy

# *OSI 7-Layer Model compared with TCP/IP 5-Layer Model*



<http://www.technology.niagarac.on.ca/courses/ctec1906/notes/images/tcpip1.gif>

# Physical Layer

- Protocols govern the exchange of binary digits across a physical communication channel
  - *How to detect when a bit is present on the line?*
  - *How long will that bit remain on the line?*
  - *Will the bit be in the form of an analog or digital signal?*
  - *What voltage levels used to represent a 0 and a 1?*
  - *What shape is the connector between the computer and the transmission line?*
- Goal: create a “bit pipe” between two computers

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# Data Link Layer

- Protocols carry out
  - Error handling
  - Framing
- Creates an error-free message pipe
- Composed of two services
  - Layer 2a: Medium access control
  - Layer 2b: Logical link control

# Data Link Layer (continued)

- Medium access control protocols
  - Determine how to arbitrate ownership of a shared line when multiple nodes want to send at the same time
- Logical link control protocols
  - Ensure that a message traveling across a channel from source to destination arrives correctly

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# Network Layer

- Delivers a message from the site where it was created to its ultimate destination
- Critical responsibilities
  - Create a universal addressing scheme for all network nodes
  - Deliver messages between any two nodes in the network

# Network Layer (continued)

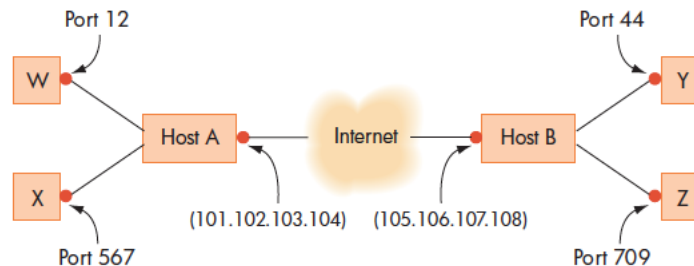
- Provides a true “network delivery service”
  - Messages are delivered between any two nodes in the network, regardless of where they are located
- IP (Internet Protocol) layer
  - Network layer in the Internet
  - IP Address of [www.cs.kent.edu](http://www.cs.kent.edu) (131.123.35.61)
    - In binary: 131 123 35 61
    - 10000011 01111011 00100011 00111101



# Transport Layer

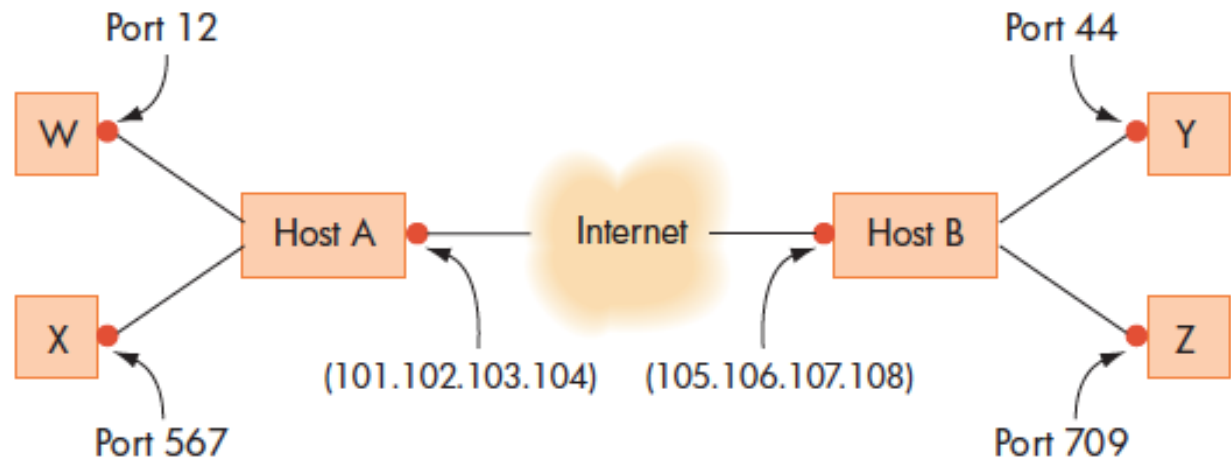
- Provides a high-quality, error-free, order-preserving, end-to-end delivery service
- TCP (Transport Control Protocol)
  - Primary transport protocol on the Internet
  - Requires the source and destination programs to initially establish a connection

**FIGURE 7.14**  
*Relationship between IP  
Addresses and Port Numbers*



**FIGURE 7.14**

*Relationship between IP  
Addresses and Port Numbers*



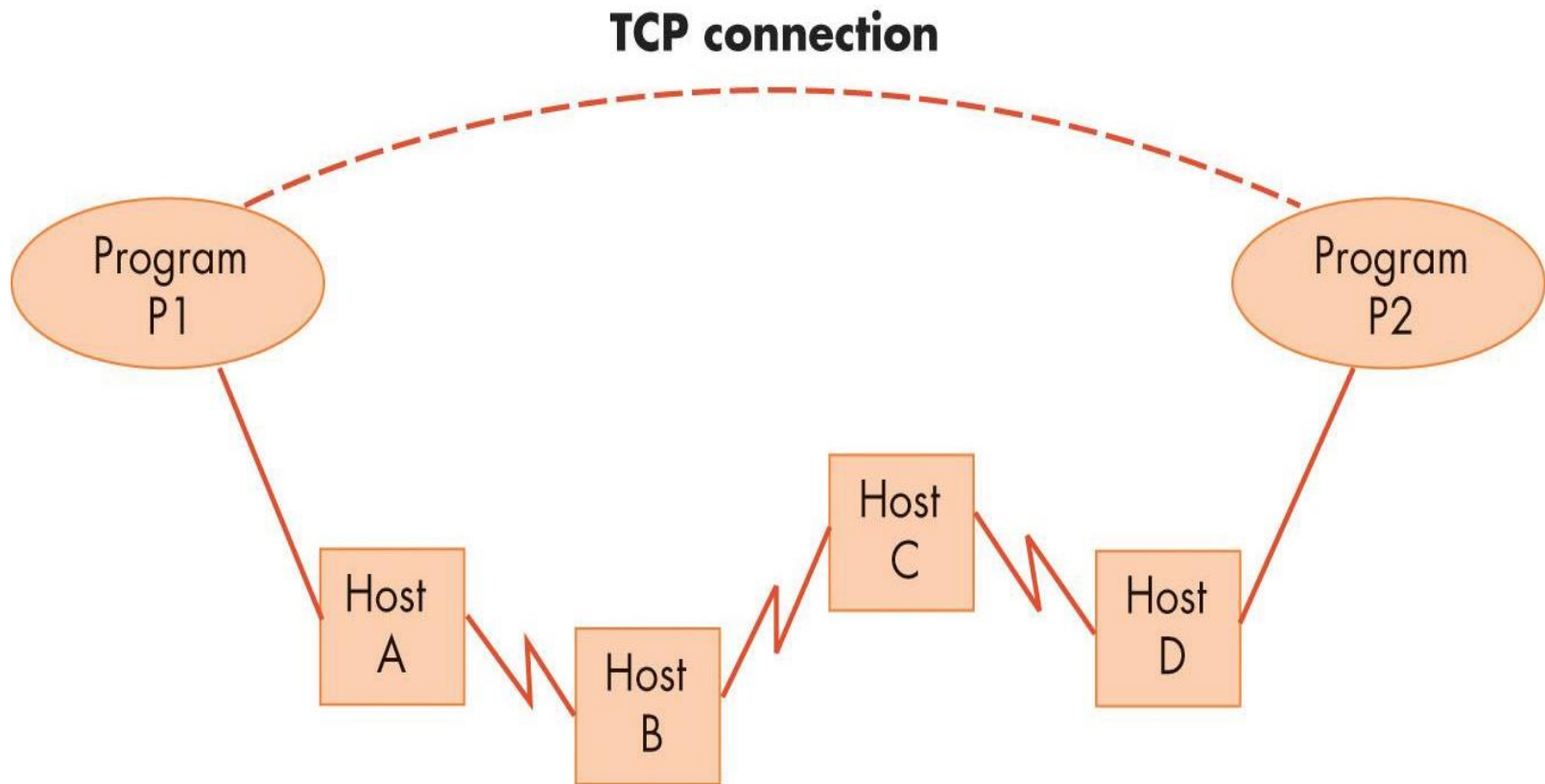


Figure 7.15  
Logical View of a TCP Connection

# Application Layer

- Implements the end-user services provided by a network
- There are many application protocols
  - HTTP
  - SMTP
  - POP3
  - IMAP
  - FTP

## WELL-KNOWN

ACRONYM	NAME	APPLICATION	PORT
HTTP	Hypertext Transfer Protocol	Accessing web pages	80
SMTP	Simple Mail Transfer Protocol	Sending electronic mail	25
POP3	Post Office Protocol	Receiving electronic mail	110
IMAP	Internet Mail Access Protocol	Receiving electronic mail	143
FTP	File Transfer Protocol	Accessing remote files	21
TELNET	Terminal Emulation Protocol	Remote terminal access	23
DNS	Domain Name Service	Translating symbolic host names to 32-bit IP addresses	42

Figure 7.16  
Some Popular Application Protocols on the Internet

# Application Layer (continued)

- Uniform Resource Locator (URL)

- A symbolic string that identifies a Web page

- Form

protocol://host address/page

- The most common Web page format is hypertext information

- Accessed using the HTTP protocol

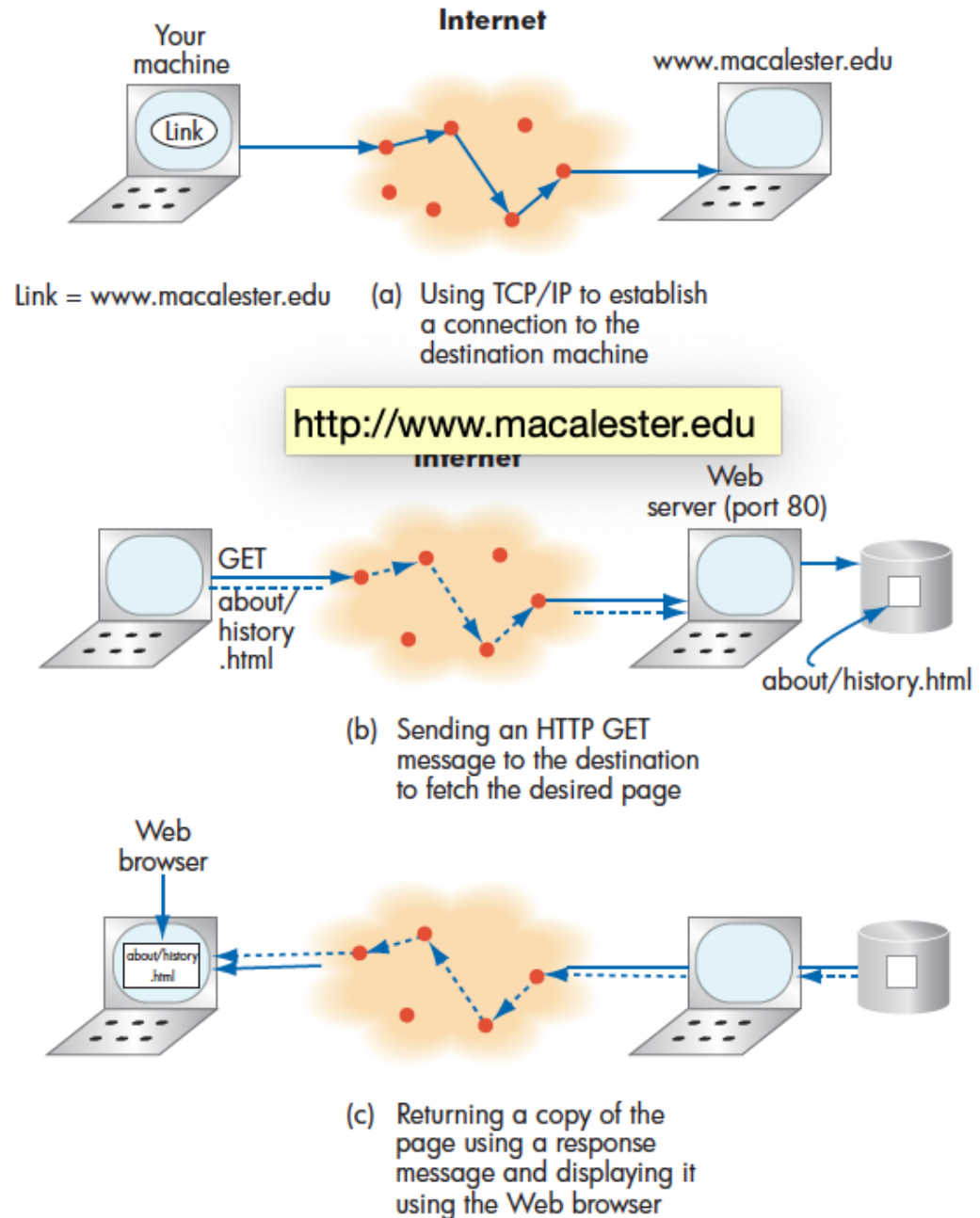
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## *Application Layer (continued)*

- Hypertext Transfer Protocol (HTTP)
  1. Establish a connection between client and server
  2. Request the web page (request message)
  3. Response w/ status of request, if successful, the requested information (response message)

**FIGURE 7.17**

*Behavior of the HTTP  
Application-Level Protocol*





# *The Pieces Working Together*

- Pieces working together
  1. Browser scans URL, extracts host name
  2. Browser asks TCP to establish connection on port 80
  3. Once TCP connect. established, browser constructs a GET message

```
GET /~ssteinf/fa/classes/intro.sp08/index.html HTTP /1.1
Host: www.cs.kent.edu
Accept-language: English
```

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## *The Pieces Working Together (cont'd)*

4. The GET message transmitted across the Internet, rec'd by Web server using TCP/IP stack
5. GET message rec'd, server locates page, creates HTTP response message with a "Found" message and page, closes TCP connection once page sent.
6. HTTP response message transmitted across the Internet
7. Message delivered to your machine, page is displayed. TCP connection terminated.

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# Network Services and Benefits

- Services offered by computer networks
  - Electronic mail (email)
  - Bulletin boards
  - News groups
  - Chat rooms
  - Resource sharing
    - Physical resources
    - Logical resources

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# Network Services and Benefits (continued)

- Services offered by computer networks
  - Client-server computing
  - Information sharing
  - Information utility
  - Electronic commerce (e-commerce)

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# A Brief History of the Internet and the World Wide Web: The Internet

- August 1962: First proposal for building a computer network
  - Made by J. C. R. Licklider of MIT
- ARPANET
  - Built by the Advanced Research Projects Agency (ARPA) in the 1960s
  - Grew quickly during the early 1970s

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# The Internet (continued)

- NSFNet: A national network built by the National Science Foundation (NSF)
- October 24, 1995: Formal acceptance of the term *Internet*
- Internet service providers start offering Internet access once provided by the ARPANET and NSFNet

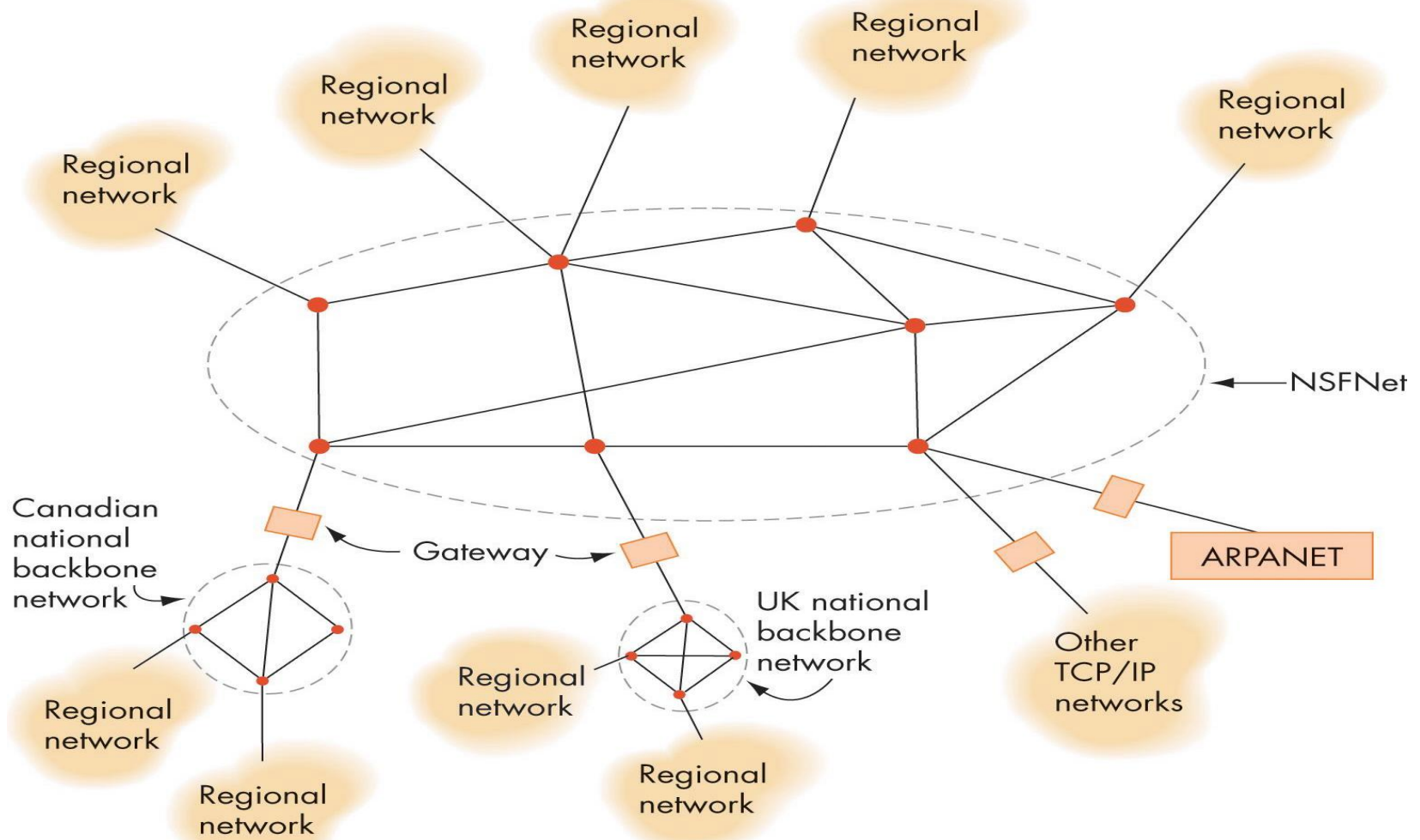


Figure 7.20  
State of Networking in the Late 1980s

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# The World Wide Web

- Development completed in May 1991
- Designed and built by Tim Berners-Lee
- Components
  - Hypertext
    - A collection of documents interconnected by pointers called links
  - URL (Uniform Resource Locator)
    - The worldwide identification of a Web page located on a specific host computer



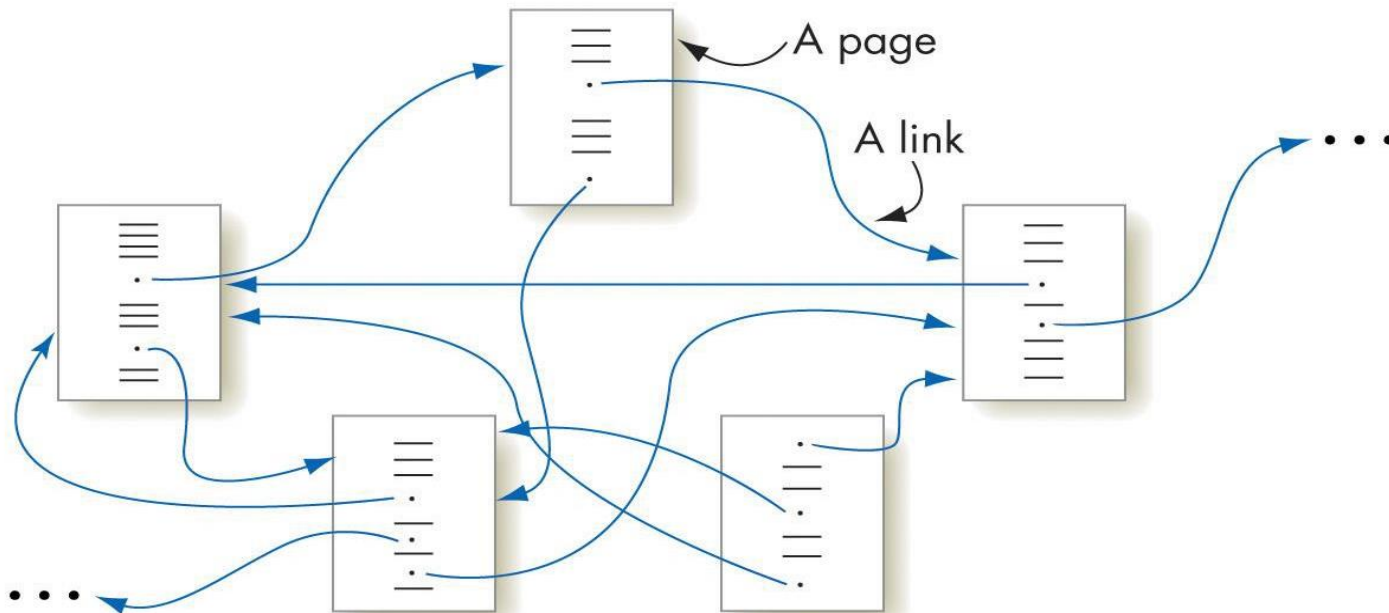


Figure 7.21  
Hypertext Documents

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# Summary of Level 3

- Virtual environment
  - Created by system software
  - Easy to use and easy to understand
  - Provides services such as
    - Resource management
    - Security
    - Access control
    - Efficient resource use
- Operating systems continue to evolve

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# Summary

- Computer network: A set of independent computer systems connected by telecommunication links
- Options for transmitting data on a network: Dial-up telephone lines, DSL, cable modem, Ethernet, Fast Ethernet
- Types of networks: Local area network (LAN) and wide area network (WAN)

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# Summary (continued)

- The Internet is a huge interconnected "network of networks"
- TCP/IP is the Internet protocol hierarchy, composed of five layers: physical, data link, network, transport, and application
- The World Wide Web is an information system based on the concept of hypertext