**Chapter 7**

**Computer Networks and Cloud Computing**

**A Guide to this Instructor’s Manual:**

We have designed this Instructor’s Manual to supplement and enhance your teaching experience through classroom activities and a cohesive chapter summary.

This document is organized chronologically, using the same headings that you see in the textbook. Under the headings you will find: lecture notes that summarize the section, Teaching Tips, Class Discussion Topics, and Additional Projects and Resources. Pay special attention to teaching tips and activities geared towards quizzing your students and enhancing their critical thinking skills.

In addition to this Instructor’s Manual, our Instructor’s Resources also contain PowerPoint Presentations, Test Banks, and other supplements to aid in your teaching experience.

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| **At a Glance** |

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| Lecture Notes |

**Overview**

Chapter 7 introduces the concept of computer networks. It describes the different kinds of networks: wired and wireless. It explains how local area networks, wide area networks, and the Internet function. The chapter explains what a protocol is and introduces the layers of protocol hierarchy that make networks function. These layers include the physical layer, the data link layer, the network layer, the transport layer, and the application layer. For each layer, the chapter describes sample protocols, for example, TCP/IP and HTTP, among others. Finally, the chapter discusses the benefits and services we have come to take for granted and a history of the development of the Internet and the World Wide Web.

# **Learning Objectives**

* Describe and compare different network technologies, including dial-up, broadband, and wireless
* Explain how different kinds of networks (LAN, WLAN, WAN) are connected, and how communication works in each
* Explain the importance of standards and protocols for communication among computing devices
* Name the layers of the network protocol hierarchy, and describe the purpose of each layer
* Name four services that computer networks provide and explain their social impact
* Explain cloud computing and discuss its potential benefits
* Describe the highlights of the history of the Internet and the web

# **Teaching Tips**

**7.1 Introduction**

1. The invention of the computer network has, and continues to have, a revolutionary impact on society. Discuss possibilities and pitfalls from the spread of information and misinformation and the effect it has on commerce, including small and large businesses.
2. There is a lot of terminology in this chapter. Help students to determine what terminology you care about, and flesh out the terminology with concrete examples.

**7.2 Basic Networking Concepts**

1. Introduce the terms **computer network** and **nodes**. Note that nodes may be anything from smartphones to supercomputers. Networks may be wired or wireless and have used many different technologies.
2. Introduce the term **switched, dial-up telephone lines**, which carry an analog signal. A **modem** changes either the amplitude or frequency of a standard carrier wave to encode ones and zeros. **Bandwidth** is the speed of transmission of the binary signal. Ask students if they have ever had dial-up Internet service. Play a sound file or video file of the sound a modem makes when connecting. Note that as of January 2017, there are only 2.1 million people still using a dial-up connection.
3. Introduce the term **broadband** for high-speed network connections. Home connections typically use either **digital subscriber lines (DSL)** or **cable modems.** Compare the range of speeds with dial-up speeds, and note the asymmetric download versus upload speeds. Commercial and institutional access uses dedicated lines; introduce the terms **Ethernet** and **Fast Ethernet.** Discuss newer standards for **gigabit networking**, including the **gigabit Ethernet standard** adopted by the **IEEE (Institute of Electrical and Electronics Engineers)** and the upcoming 10-gigabit Ethernet standard.
4. Introduce the term **wireless data communication**. Emphasize the new and growing importance worldwide of **mobile computing**. Introduce the term **wireless local area network (WLAN)**, such as you might find in libraries or coffee shops. Other related terms to introduce: **Wi-Fi, IEEE 802.11 wireless network standard**, **Wi-Fi hot spot**, and **metropolitan area network**. Describe two alternative wireless systems: **Bluetooth** and **wireless wide area network (WWAN)**. Discuss how the Wi-Fi name was a play on words from the term Hi-Fi (short for high fidelity), but at no point did it ever mean “wireless fidelity.”
5. Discuss the **IEEE 802.11 wireless network standard** and how it functions. Talk about wireless routers sometimes being termed a **Wi-Fi hot spot.**
6. Introduce the term **local area network (LAN)**; LANs are centered on a single locality, typically privately managed. LAN topologies are varied and important (e.g., **bus**, **ring**, and **star**). LANs may be wired using a **shared cable** system, with a single cable strung through a building. If distances are too great for a single cable, multiple cables connected by a **repeater** or **bridge** implement the shared cable model. The alternative uses a **switch**: a wiring closet connects each Ethernet jack to the switch, where the shared cable resides.
7. Introduce the term **wide area network (WAN)**; WANs are networks that span large distances and involve external providers. WANs use **dedicated point-to-point lines** between computers rather than shared lines. Introduce the term **store-and-forward, packet-switched** technology as typical of WANs; **packets** of data are sent from node to node. **Internet service providers (ISPs)** provide access to the Internet through their WAN. Emphasize the hierarchy of layers of ISPs required to form the **Internet**.
8. Talk about the newcomers to the area networks: **personal area network** (**PAN**)like phone hotspots, and **metropolitan area network** (**MAN**) that may cover from a few city blocks to an entire city. A MAN could be viewed as a kind of **wide area wireless LAN** (**WWLAN**)**.**
9. Show students Figure 7.13, and point out the huge increase in the number of nodes that help to make up the Internet as we now know it.

**Quick Quiz 1**

1. Internet service with speeds greater than 25Mbps is called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

Answer: broadband

1. (True or false) A Wi-Fi hot spot is when computers can connect to the Internet through a nearby wireless base station that is wired to a network.

Answer: True

1. (True or false) Users need to use an Internet service provider to access a LAN.

Answer: False

1. Name one common topology for local area networks (LANs).

Answer: Star, bus, or ring

1. Most WANs use \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ technology to transmit messages.

Answer: store-and-forward, packet-switched

1. What is the purpose of a router?

Answer: It routes messages between two distinct networks of any type.

**7.3 Communication Protocols**

1. Explain the term **protocol**, and use everyday examples like telephone etiquette or what to do when meeting someone in a professional setting. Establishing protocols and standards is critical to enabling computers to talk to each other or to peripherals, the way that macOS can talk to Windows and both can talk to the same printer. Introduce **Internet Society**, an international society designed to make protocols. Introduce the terms **protocol hierarchy/protocol stack** and **TCP/IP**.

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| ***Teaching Tip*** | Encourage students to explore the website for the Internet Society. [www.isoc.org/internet](http://www.isoc.org/internet) |

1. Introduce the term **Physical layer protocols**. Emphasize the low level of these protocols. The bulleted list at the start of the Physical Layer section (page 357) is an important list to go over, highlighting an example for each. It might be instructive to bring in some old cables to show students that these standards change over time.
2. The Data Link layer is responsible for **error detection** and **correction** and **framing**. Introduce the term **Medium Access Control protocols** that determine which nodes can use a shared line at a given time and how **collisions** are handled. When connections are point-to-point, Layer 2b protocols handle errors. Introduce the term **Logical Link Control protocols** and the **ARQ algorithm** for this purpose. The ARQ algorithm requires the receiver to check for errors in the transmitted packet and to send an **acknowledgement message (ACK)** if the packet has no errors.

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| ***Teaching Tip*** | Because protocols fundamentally mediate communication among two or more entities, they offer the chance for students to learn by doing. Pick a protocol, like the Medium Access Control protocols, and have students act them out. You could choose one protocol at each level to be performed. End each performance with a discussion of how the protocol worked. Alternatively, assign teams of students to develop a video demonstration of particular protocols. |

1. Introduce the term **Network layer protocols**. These protocols control how messages pass across a network of computers: an agreed-upon addressing method for telling where the destination is and a process for finding a route from any node to any other. Introduce the term **IP (Internet protocol)**, the current standard for the Internet. Introduce the terms **host names** and **IP addresses** for human and machine addressing. The **Domain Name System (DNS)** maps human-friendly host names to their IP addresses. Introduce the term **routing**, and emphasize the complexity of network routing tasks: networks can be huge, it must be done quickly, and networks are constantly changing.
2. Introduce the term **Transport layer protocols**. These protocols control how to route messages to specific applications running on a given computer. Introduce the term **port number**, and show students the Assigned Numbers on the Internet for which port numbers belong to which standard applications. Use the post office metaphor for discussing the unreliability of the Network layer and the use to **TCP (Transport Control Protocol)** for making reliable message delivery.
3. Introduce the term **Application layer protocols**, which describe high-level communication protocols used by applications. Introduce the terms **Hypertext Transfer Protocol (HTTP)** and **Uniform Resource Locator (URL)** as one example of an Application layer protocol.

**Quick Quiz 2**

1. The main task of the Network layer is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

Answer: to handle delivery of messages across a network of computers, including addressing schemes and routing of messages.

1. (True or false) Medium Access Control protocols manage the physical layer: how bits are transmitted over different kinds of wires.

Answer: False

1. (True or false) A DNS server translates URLs into addresses on the web.

Answer: False

1. List the layers in the Internet protocol hierarchy.

Answer: Physical layer, Data Link layer (may be broken into Medium Access Control and Logical Link Control), Network layer, Transport layer, and Application layer

1. When a collision occurs, the colliding \_\_\_\_\_\_\_ immediately stop sending, wait a random amount of time, and then attempt to resend.

Answer: nodes

1. The automatic repeat request (ARQ) algorithm is the basis for all \_\_\_\_\_\_\_ protocols currently in use.

Answer: Data Link Control

**7.4 Network Services and Benefits**

1. Introduce the term **electronic mail (email)** as an example of the value of the Internet for supporting interpersonal communications. Discuss the proliferation of **spam** (unsolicited bulk email). Discuss the term **bulletin board system (BBS)** and its evolution into **Internet forums** and **chat rooms**. Discuss **texting** and messaging services like WhatsApp and iMessages as new means of fast communication.
2. Talk about the proliferation of **social networking** and its similarity to the old-style BBS of the 1980s and 1990s. Talk about the pros and cons of social networking.
3. Introduce the term **resource sharing**, another service of the Internet: sharing of physical and logical resources (printers, servers, software, and data). Introduce the terms **print servers** and **file servers**. Discuss the importance of the **client/server computing** model, where some nodes provide services and others are clients using the services. A **distributed database** shares information across the Internet; a **data warehouse** stores massive amounts of data. Introduce the terms **groupware** and **wiki** for collaborative software (talk about the impact of Wikipedia).
4. Introduce the term **electronic commerce (ecommerce)**. Ask how often students use the Internet for ecommerce. Talk about the globalization of the marketplace through ecommerce. This is another point at which you could start a discussion on pros and cons. How can ecommerce help local business, and how can it harm local business?

**7.5 Cloud Computing**

1. Discuss the limitations of the client/server model (initial costs, operating costs, upgrades, etc.).
2. Explain that with **cloud computing** servers can be located anywhere and do not need to be maintained by the organization.
3. Cloud-based servers can be part of an integrated collection of servers, called a **server farm**.
4. The term **virtualization** means the separation of a service from the entity providing the service. It is one of the fundamental properties of cloud computing.
5. Many types of cloud services exist, such as infrastructure services, application services, and the most sophisticated, the platform and development services. Discuss the various well-known cloud storage services like iCloud and Google Drive, and contrast that against application services like TurboTax, Google Docs, and so forth.
6. Cloud-based systems offer lower costs and elasticity of demand. Often individual cloud services are offered for free, with a small amount of storage, or limited feature set. Larger storage capacities and more robust feature sets can then be subscribed to at a monthly rate.

**7.6 A History of the Internet and the World Wide Web**

1. As a way of introducing this historical review, ask students to think about where the Internet and the World Wide Web came from. What changes have they seen in their lifetimes? Share the changes you have seen.

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| ***Teaching Tip*** | Refer students to the following page for the full “Brief History of the Internet” document referred to in the text: <http://www.isoc.org/internet/history/brief.shtml> |

1. In 1962, Licklider (of MIT) described “The Galactic Network.” Note how similar this vision is to the modern Internet.
2. Stress the importance of ARPA to early development and its implementation of theoretical ideas about protocols, packets, and routing. ARPANET began in the late 1960s; email was developed in 1972 and grew quickly. Other independent networks developed include HEPNet, CSNET, MFENet, SNA, and DECNet.
3. Introduce the term **internetworking**, developed to bring order to the chaos of networks. Any WAN can do what it wants internally but must use standard addressing and protocols for communication with other WANs.
4. Introduce the term **gateway**, a device for translating between WANs. TCP/IP was the agreed “language” for internetwork communications.
5. TCP/IP was modified to work with LANs in the early 1980s. Introduce the ideas of Telnet and FTP as additional applications. NSFNet was designed in mid-1980s as an alternative to ARPANET, not restricted to military grantees.
6. Introduce the term **World Wide Web**, and discuss its origins as a user-friendly tool for information sharing about high-energy physics. Introduce the term **hypertext**. Note the importance of its usability and intuitive interface, easy integration of multimedia, and the fact that its technology was made freely available initially.

**7.7 Conclusion**

1. Over the course of five decades, networking has changed enormously.
2. Remind students that the Internet is now a way to provide the average citizens with information, allow them to shop, connect with long lost friends, keep up with the news, and be entertained.
3. The biggest concern is the growth and direction of networking technology and how it will be managed and controlled.
4. “*If the Internet stumbles, it will not be because we lack for technology, vision, or motivation. It will be because we cannot set a direction and march collectively into the future.”*

# **Class Discussion Topics**

1. In the course of a typical week, what kinds of computer networks do you use? How many different kinds can you now recognize? How aware have you been of differences in these networks, or do they all create a similar virtual environment? Imagine the next new innovation in network technology—what would it look like and what could it do?
2. How do the different layers of the protocol hierarchy interact with each other? Why do we need to have two different layers that work on error detection and correction?
3. What are some positives that have occurred with the development of the Internet and the World Wide Web? What are some problems associated with these tools?
4. Name some ways in which computer network systems use the concept of abstraction to make the task of building a functioning network feasible.
5. Discuss the direction the Internet is going today. Think about the final quote and talk about whether or not the Internet is moving collectively into the future or if there are too many influences trying to pull at its corners. How does the proliferation of fake news affect the reputation and reliability of the Internet?

# **Additional Projects**

1. Look up online information about the UDP Transport layer protocol. How does it differ from TCP, and when is it used?
2. Form a group of students, and act out the Medium Access Control protocol used by shared-line Ethernet networks. Each student is a node in the network. Each student should work out the answer to an arithmetic problem and then should broadcast it by speaking out loud. When two students speak at once, it’s a collision. Use the specified collision recovery approach. How well does it work to ensure that each person gets to communicate?
3. Research the meaning of the four groups of numbers in an IP address. What do they mean? Why does a lab computer on campus have a certain set of numbers? How about a computer off campus? Why can two computers on two separate LANs have the same IP address?

# **Additional Resources**

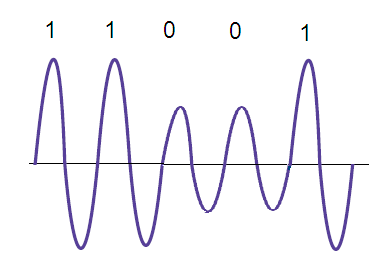
1. A copy of an article by Licklider about his vision for human-computer interaction and computer networks: <ftp://gatekeeper.research.compaq.com/pub/DEC/SRC/research-reports/SRC-061.pdf>
2. Computer History Museum online exhibit about computer networks: <http://www.computerhistory.org/internet_history/index.html>
3. Go more in depth to the history of the Internet:  
   <http://www.internetsociety.org/internet/what-internet/history-internet/brief-history-internet>
4. Learn about Robert Metcalf, one of the creators of Ethernet:  
   http://www.networkworld.com/article/2202019/lan-wan/living-legends--ethernet-inventor-bob-metcalfe.html

**Key Terms**

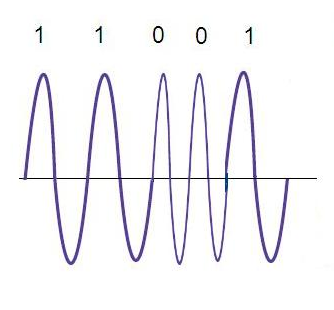
* **Acknowledgement message (ACK)**: A network control message that says that your message correctly arrived at its destination.
* **Application layer protocols**: The rules for implementing the end-user services provided by a network.
* **ARQ algorithm**: Automatic repeat request algorithm, the basis for all Data Link Control protocols in current use.
* **Bandwidth**: Capacity for transmitting data.
* **Bluetooth**: A low-power wireless standard used to communicate between devices located quite close to each other, typically no more than 30–50 feet (10–15 meters).
* **Bridge**: A “smarter” device than a repeater that has knowledge about the nodes located on each separate network. It examines every message to see if it should be forwarded from one network to another.
* **Broadband**: Any communication link with a transmission rate exceeding 25Mbps. Typical broadband options for home users are cable modem and digital subscriber line (DSL).
* **Broadcasting**: Messages are sent by a node on a local area network to every other node on that same LAN.
* **Bulletin board system (BBS)**: Shared public file system where anyone can post messages and everyone is free to read the postings of others.
* **Bus**: LAN topology in which all nodes are connected to a single, shared communication line.
* **Cable modem**: Technology that makes use of the links that deliver cable TV signals into your home, so it is offered by cable TV providers.
* **Chat rooms:** Real-time forums where people can exchange ideas on any topic they want.
* **Client/server computing**: The style of computing wherein some nodes provide services while the remaining nodes are users (or clients) of those services.
* **Cloud computing**: Server nodes provide services to client nodes without having to be local to the client population.
* **Collision**: When two or more nodes on a shared link transmit at the same time and destroy each other’s messages.
* **Computer network**: A set of independent computer systems connected by telecommunication links for the purpose of sharing information and resources.
* **Data warehouse**: Nodes that contain massive amounts of information that can be electronically searched for specific facts or documents.
* **Dedicated point-to-point line**: A line that directly connects two machines.
* **Digital subscriber line (DSL)**: Uses the same wires that carry regular telephone signals into your home and therefore is provided by either your local telephone company or someone certified to act as their intermediary. Although it uses the same wires, a DSL signal uses a different set of frequencies, and it transmits digital rather than analog signals.
* **Domain Name System (DNS)**: Converts from a symbolic host name such as Macalester.edu to its 32-bit IP address.
* **Electronic commerce (ecommerce)**: A general term applied to any use of computers and networking to support the paperless exchange of goods, information, and services in the commercial sector.
* **Electronic mail (email)**: The single most popular application of networks for the last 30 years.
* **Error detection and correction**: The process of determining whether a message did or did not arrive correctly and, if not, getting a correct copy of that information.
* **Ethernet**: The most widely used broadband technology.
* **Fast Ethernet**: Transmits at 100 Mbps over coaxial cable, fiber-optic cable, or regular twisted-pair copper wire.
* **File server**: Shared disk(s) available across a network.
* **Firewall**: A software component that controls access from a network to a computer system.
* **Framing**: Identifying the start and end of a message.
* **Gateway**: A device that makes internetwork connections and provides routing between different WANs.
* **Gigabit Ethernet standard**: IEEE standard that supports communication on an Ethernet cable at 1,000 Mbps (1 Gbps).
* **Gigabit networking**: Transmission lines that support speeds of 1 billion bits per second (Gbps).
* **Groupware**: Software that facilitates the efforts of individuals connected by a network and working on a single, shared project.
* **Host name**: The symbolic, character-oriented name assigned to a host computer.
* **Hypertext**: A collection of documents interconnected by pointers, called links.
* **Hypertext Transfer Protocol (HTTP)**: The protocol used by the World Wide Web to transfer pages of information coded in hypertext markup language (HTML).
* **IEEE (Institute of Electrical and Electronics Engineers)**: International professional society responsible for developing industrial standards in the area of telecommunications.
* **IEEE 802.11 wireless network standards**: Another name for Wi-Fi.
* **Internet**: A huge, interconnected “network of networks” that includes nodes, LANs, WANs, bridges, routers, and multiple levels of ISPs.
* **Internet forums**: Support the real-time exchange of messages. In addition to simply posting a message that can be read at a later time, they also support interactive messaging—what the sender types appears immediately on the screen of one or more individuals, allowing for the direct exchange of ideas.
* **Internet Service Provider (ISP)**: A business whose purpose is to provide access from a private network (such as a corporate or university network) to the Internet or from an individual’s computer to the Internet.
* **Internet Society**: A nonprofit, nongovernmental, professional society composed of more than 100 worldwide organizations (e.g., foundations, governmental agencies, educational institutions, companies) in 180 countries united by the common goal of maintaining the viability and health of the Internet.
* **Internetworking**: A concept first developed by Robert Kahn or ARPA that any WAN is free to do whatever it wants internally.
* **IP (Internet Protocol)**: The network layer in the Internet.
* **IP address**: The 32-bit binary address that the Internet uses to actually identify a given host computer.
* **Local area network (LAN)**: A network that connects hardware devices such as computers, printers, and storage devices that are all in close proximity.
* **Logical Link Control protocols**: Ensure that the message traveling across this channel from source to destination arrives correctly.
* **Medium Access Control protocols**: Determine how to arbitrate ownership of a shared line when multiple nodes want to send messages at the same time.
* **Mesh network**: A wireless network that is spread out by nodes connecting to other nodes via direct links, spreading out the signal.
* **Metropolitan area network (MAN)**: A wireless network whose scope is larger than a few hundred feet, often covering several blocks or even an entire metropolitan area.
* **Mobile computing**: The ability to deliver data to users regardless of their location.
* **Modem**: A device that modulates, or alters, a standard analog signal called a carrier so that it encodes binary information.
* **Network layer protocols**: Ensure that a message is delivered from the site where it was created to its ultimate destination.
* **Node**: An individual computer on a network; also called a host.
* **Packet**: An information block with a fixed maximum size that is transmitted through the network as a single unit.
* **Personal area network (PAN)**: A collection of privately owned interconnected digital devices all located in close proximity.
* **Physical layer protocols**: Govern the exchange of binary digits across a physical communication channel, such as a fiber-optic cable, copper wire, or wireless radio channel.
* **Port number**: A numeric identification of a program running on a host computer. It is used by the transport control protocols.
* **Print servers**: Shared printers available across a network.
* **Protocol**: In networking, a mutually agreed-upon set of rules, conventions, and agreements for the efficient and orderly exchange of information.
* **Protocol hierarchy (protocol stack)**: The hierarchical set of network protocols that are used to transmit messages across a network.
* **Radio frequency identifier (RFID)**: A communications device that has its own Internet address—sometimes referred to as “Internet-ready” devices such as smart thermostats.
* **Repeater**: A device that simply amplifies and forwards a signal.
* **Resource sharing**: The ability to share physical resources, such as a printer or storage device, as well as logical resources, such as software, data, and information.
* **Ring**: LAN topology that connects the network nodes in a circular fashion, with messages circulating around the ring in either a clockwise or counterclockwise direction until they reach their destination.
* **Router**: A device that connects networks.
* **Routing**: Selecting a specific path for information to travel through a network, generally by the shortest route.
* **Server farm**: An integrated collection of machines providing services over a network that would not be possible using only a single device. The backbone to cloud computing.
* **Shared cable**: A wire (such as twisted-pair copper wire, coaxial cable, or fiber-optic cable) is literally strung around and through a building. Users tap into the cable at its nearest point.
* **Social networks**: Systems that create communities of users who share common interests and activities and which provide multiple methods of online interaction.
* **Spam**: Electronic junk mail.
* **Star**: LAN topology that has a single central node that is connected to all other sites. This central node can route information directly to any other node in the LAN. Messages are first sent to the central site, which then forwards them to the correct location.
* **Store-and-forward, packet-switched technology**: Technology used by WANs to deliver messages; a message “hops” from one node to another to make its way from source to destination.
* **Switch**: A device that allows you to build a LAN without having to crawl around looking for the shared cable.
* **Switched, dial-up telephone lines**: When you dial a telephone number, a circuit (i.e., a path) is temporarily established between the caller and callee.
* **TCP (Transport Control Protocol)**: The primary transport protocol on the Internet.
* **TCP/IP**: Transport Control Protocol/Internet Protocol; the name of the specific protocol stack used in the Internet.
* **Texting**: Primarily sent in SMS (Short Message Service), it may also refer to newer applications like iMessage, WhatsApp, and Facebook Messenger.
* **Transport layer protocols**: Create a “program-to-program” delivery service, in which we don’t simply move messages from one host to another but from a specific program at the source to another specific program at the destination.
* **Uniform Resource Locator (URL)**: A symbolic string that identifies a webpage.
* **Virtualization**: The separation of services from the entities providing those services.
* **Wi-Fi**: Wireless transmissions that use IEEE 802.11 standards for local wireless access.
* **Wi-Fi hot spot**: Wireless base station (router).
* **Wide area network (WAN)**: Connects devices that are not in close proximity but rather are across town, across the country, or across the ocean.
* **Wiki**: A set of webpages that everyone is free to access, add to, or modify.
* **Wireless data communication**: Transmitting data using radio, microwave, and infrared signals.
* **Wireless local area network (WLAN)**: A wireless network in which the user transmits from his or her computer to a local wireless base station, often referred to as a wireless router, that is no more than a few hundred feet away. This base station is then connected to a traditional wired network, such as a DSL or cable modem, to provide full Internet access.
* **Wireless wide area network (WWAN)**: Nodes (often a table or smartphone) transmit messages to a remote base station provided by a telecommunications company, which may be located many miles away. The base station is usually a large cellular antenna placed on top of a tower or building, providing both long-distance voice and data communication services to any system within sight of the tower.
* **World Wide Web**: The hypertext information system developed by Tim Berners-Lee at CERN in the late 1980s.

**Solutions to End-of-Chapter Exercises**

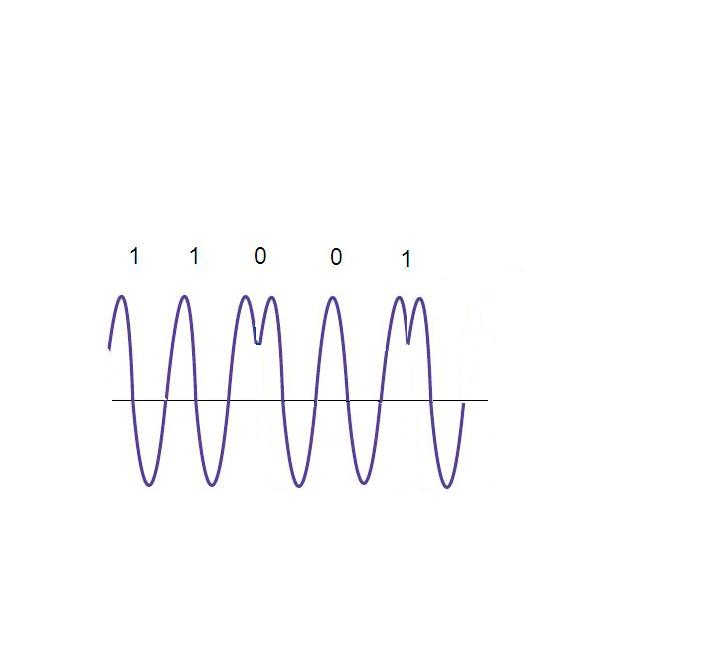
1. a. Here 1 is represented with a high amplitude (height of the wave) and 0 with a low amplitude.



b. Here 1 is represented with a low frequency (number of waves per second) and 0 with a high frequency.



1. The phase of a carrier wave is the left-right location of the wave. Phase modulation occurs when the carrier wave is shifted left from its standard position. A change in binary signal from 1 to 0 or 0 to 1 is detected by this change of "shift" in phase.



1. In an analog environment a signal can take on any value so it is theoretically impossible to determine exactly how much noise has been added to the carrier wave, and it is difficult to reconstruct its original uncorrupted shape. However, with a digital signal there is only a discrete set of allowable values so it may be possible to restore the corrupted signal to its original state. For example, if 0 volts represents logical zero while 10 volts is a logical 1, we could take a corrupted signal and say that all values from 0-5 volts are to be reset to 0 volts (logical 0) while all values 5.01 volts and above are to be reset to 10 volts (logical 1). While we might be wrong in our reconstruction, there is a good likelihood that we will be able to reconstruct the original signal exactly.
2. The total number of pixels is 1280 × 840 = 1,075,200 pixels  
   The total number of total bits to transfer is 1,075,200 × 8 = 8,601,600  
   a. A 56 Kbps modem  
    8,601,600 bits /56,000 bits per second = 153.6 seconds  
   b. A 1.5 Mbps DSL line  
    8,601,600 bits /1,500,000 bits per second = 5.7344 seconds  
   c. A 100 Mbps Ethernet link  
    8,601,600 bits/100,000,000 bits per second = 0.086016 seconds
3. 1440 × 900 = 1.296 million pixels × 16 bits/pixel = 20.736 million bits. In order to transmit this amount of information in a time of 0.01 seconds, we need a link speed X such that:

20.736 × 106 bits ÷ X bits/second = 0.01 seconds

X = 2.0736 gigabits/second

1. a. Recall from chapter 5 that a megabyte can store about 2.5 books. Therefore, to store one million books, we would need 1,000,000 books / 2.5 books/Mbyte = 400,000 Mbytes = 400 Gbytes = 400,000,000,000 bytes.

b. The number of bits to be transferred is 400,000,000,000 × 8 = 3.2 × 1012 bits = 3,200,000 Mbits. At the rate of 10 Mbps, the transfer time would be

3,200,000 Mbits / 10 Mbits/second = 320,000 seconds = 3.7 days

At the rate of 1 Gbps = 1000 Mbps, the transfer time would be

3,200,000 Mbits / 1000 Mbits/second = 3,200 seconds = 53 minutes

**7.** The address field is needed in an Ethernet LAN protocol so that the message may be directed to one particular machine. Each machine receives the broadcast message, checks the address field, and accepts the message only if the address field contains its own address. One may want to either omit the address field entirely or use some “special” address value in the address field in the special situation where a message is being sent to every computer on the network.

**8**. In a very heavily loaded network, the Ethernet protocol would perform poorly. Many computers will be waiting for line access and then attempting to send simultaneously, which will result in many collisions. Then they must wait random amounts of time before attempting to retransmit their messages. The network user will see a slow response time.

1. The advantage to creation of a centralized LAN in which one node would be in charge of all decisions about who can send a message and who must wait is that there would be no collisions. The single node will schedule all the nodes’ message sending activities, and each node can do other useful work until its scheduled time to transmit occurs, rather than continuously testing for the opportunity to access the line.
2. While the scheme of waiting a random amount of time to retransmit after a collision may diminish the chances of future collisions, there is no fixed time limit within which a machine is guaranteed the ability to send. It is theoretically possible to have a sufficient number of collisions that any maximum time value T can be exceeded.
3. a. The smallest number of point-to-point communication links such that every node in the network is able to talk to every other node is N-1.

b. The type of interconnection structure that should be used if one is worried about having a disconnected network is one with redundant paths between any two nodes. In the extreme, the network could be completely connected, where each node is connected to every other node.

1. The main advantage is redundancy in cases of 1) failure or 2) heavy traffic. If there are two distinct paths from A to B then a failure of a line along one of those links may not necessarily make it impossible for these two nodes to communicate. Secondly, if there is a good deal of traffic between A and B we can split that traffic between the two (or more) different routes and not cause as much congestion as if we had routed all of the traffic on the same path.
2. The store-and-forward protocol would send a message from A to B and wait for the acknowledgement message. When it did not come back it would retransmit the message, over and over. As described in the chapter the protocol would result in a never ending cycle of sending messages and waiting for the ACK that never will come. A modification we could make to this protocol to handle this particular situation would be to set an upper bound on the number of attempts we make along any given path. After N transmissions and N failures to receive an acknowledge packet from B, A can then look for another path on which to retransmit. If there are no alternative paths then the message cannot be delivered and A must give up.
3. A modification to the protocol that would make it more efficient and not cause the sender to have to stop each time it sends a message is to have the sender continually send packets and store local copies. When an ACK is received for a packet, the sender checks the sequence number and discards the local copy of that packet. Packets for which an ACK is not received can in time be retransmitted. In this protocol the receiver could receive packets out-of-order, but can use the sequence number to reassemble the packets in the correct order.
4. Using an ARQ algorithm, the sender would need to send 100 copies of the message with a separate address for each copy. Each copy would be forwarded through the network to its appropriate destination. This is much less efficient than in an Ethernet network which is basically designed as a broadcast medium.

**16.** a. The number of simple paths from node A to G is 7.  
 ABCG  
 ABECG  
 ABEDCG  
 AFG  
 ADCG  
 ADEBCG  
 ADECG  
  
 b. There are two shortest paths from A to G, ADECG and ABECG, both of which have a cost of 10.

c. If node E fails, then both of the shortest paths fail, as do several of the other paths. The only remaining paths are ABCG, ADCG, and AFG, all of which have a cost of 11.

17. There are times when this heuristic will work and get the message to its intended destination in a reasonable time. For example, assume we want to route a message from A to D using the following network:

3 4 5

A B C D

5 5 4 4

E F

6

The heuristic starts out by routing the message from A to B, the lowest cost link of the two that go out from A. Then it selects BC because that is the lowest cost line of those that do not immediately return to A. Next it selects CF, since it is the lowest cost line that does not go directly back to B. Finally, it selects the line FD, and it has arrived at its destination via the route ABCFD. The total cost of this route is 3+4+4+4 = 15 units. This is not the lowest cost path, which would be ABCD at a cost of 3+4+5 = 12 units. But it did do a reasonably good job.

However, the question asks whether it *always* delivers the message to its destination, and the answer to that is no. For example, what if we want to deliver a message from A to C in the following configuration:

2 8

A B C

3 3 4

D

As it currently stands, the algorithm will route the message from A to B, then to D, then back to A, making an infinite number of repetitions of the cycle ABDABDABDABD…

**18.** A gateway’s responsibilities include making the internetwork connections and providing routing between different WANs. More specifically, gateways must convert between different addressing schemes, message formats, and send/receive protocols. The advent of the standard TCP/IP protocol has made this task easier.

**19.** The data-link layer can only handle packets between nodes that are directly connected. It is the job of the network layer protocols to deliver a message from where it was created to its ultimate destination. The network layer might misinterpret an address and route the message to C instead of D. It might fail to route around a broken link between B and D or a failed node at B.

**20.** The advantages are:

a. You can send each piece via a different route to help balance traffic

b. If there is an error in a single packet it only destroys that packet, not the entire message

c. You can better service your traffic because you can send one packet from program A, then a packet from program B, etc. This gives each program a little piece of service rather than making it wait for an entire message to be sent.

**21.** Research on the Web required.

**22.**

a. When you store data locally it is available to you even when network access to the outside world is temporarily down. However, when you store data in the cloud you must have Internet access to get to your critically important data. Thus, when using the cloud you become totally dependent on a reliable network connection and highly vulnerable to network outages, which could bring your business to a halt.

b. When data is stored locally you are free to choose the level of security you wish to provide. For example, do you want to encrypt your data and, if so, using what strength encryption algorithm? What kind of authentication procedure do you wish to implement? These are all decisions that you can make. However, when data is stored in the cloud, you must accept the security procedures and protocols provided for you by your cloud provider. Hopefully, they will be acceptable and will meet your security needs, but if not there is nothing you can do to change them.

c. Your cloud provider is the one who decides exactly which data formats will be accepted for storage on its servers. For example, if you need to back up photographic information will your cloud provider accept JPG, GIF, and TIFF images? What about PNG or BMP? These decisions are out of your control. This is especially important when you wish to store “legacy” data–information represented in an older format that is no longer used. Your cloud provider may not be willing to accept data in this older format, requiring you to either store it locally or convert it to a different representation.

d. When data storage is handled locally, there is always a person on site you can contact to answer your questions about how to access a piece of information or fix a problem. When the data is moved off site, so is the customer support and help staff. Now to answer a problem, you must call your cloud service provider and hope that they have sufficiently knowledgeable personnel available to answer your question. Otherwise you may be sitting on hold for hours or talking to someone overseas who has no idea how to solve your problem.

**Challenge Work**

Research on the Web required. Most documentation available online is probably too detailed and technical for most students. You might look for resources aimed at the novice user before assigning this problem.