Business Data Communications and Networking

THIRTEENTH EDITION

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Business Data Communications and Networking

Thirteenth Edition

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WILEY

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To my son Alec,

Alan

To all curious minds who want to know how
today’s modern world works.

Alexandra

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Alexandra has been teaching business data communications to both undergraduate and graduate students for several years. In addition, she has been teaching classes on information technology strategy and most recently won the Dean's Award for Undergraduate Teaching Excellence while teaching at the University of Arizona.

Dr. Jerry FitzGerald wrote the early editions of this book in the 1980s. At the time, he was the principal in Jerry FitzGerald & Associates, a firm he started in 1977.

PREFACE

The field of data communications has grown faster and become more important than computer processing itself. Though they go hand in hand, the ability to communicate and connect with other computers and mobile devices is what makes or breaks a business today. There are three trends that support this notion. First, the wireless LAN and Bring-Your-Own-Device (BYOD) allow us to stay connected not only with the workplace but also with family and friends. Second, computers and networks are becoming an essential part of not only computers but also devices we use for other purpose, such as home appliances. This Internet of things allows you to set the thermostat in your home from your mobile phone, can help you cook a dinner, or eventually can allow you to drive to work without ever touching the steering wheel. Lastly, we see that a lot of life is moving online. At first this started with games, but education, politics, and activism followed swiftly. Therefore, understanding how networks work; how they should be set up to support scalability, mobility, and security; and how to manage them is of utmost importance to any business. This need will call not only for engineers who deeply understand the technical aspects of networks but also for highly social individuals who embrace technology in creative ways to allow business to achieve a competitive edge through utilizing this technology. So the call is for you who are reading this book—you are at the right place at the right time!

PURPOSE OF THIS BOOK

Our goal is to combine the fundamental concepts of data communications and networking with practical applications. Although technologies and applications change rapidly, the fundamental concepts evolve much more slowly; they provide the foundation from which new technologies and applications can be understood, evaluated, and compared.

This book has two intended audiences. First and foremost, it is a university textbook. Each chapter introduces, describes, and then summarizes fundamental concepts and applications. Management Focus boxes highlight key issues and describe how networks are actually being used today. Technical Focus boxes highlight key technical issues and provide additional detail. Mini case studies at the end of each chapter provide the opportunity to apply these technical and management concepts. Hands-on exercises help to reinforce the concepts introduced in the chapter. Moreover, the text is accompanied by a detailed Instructor's Manual that provides additional background information, teaching tips, and sources of material for student exercises, assignments, and exams. Finally, our Web page contains supplements to our book.

Second, this book is intended for the professional who works in data communications and networking. The book has many detailed descriptions of the technical aspects of communications from a business perspective. Moreover, managerial, technical, and sales personnel can use this book to gain a better understanding of fundamental concepts and trade-offs not presented in technical books or product summaries.

WHAT'S NEW IN THIS EDITION

The thirteenth edition maintains the three main themes of the twelfth edition, namely, (1) how networks work (Chapters 1–5); (2) network technologies (Chapters 6–10); and (3) network security and management (Chapters 11 and 12). In the new edition, we removed older technologies and replaced them with new ones. Accordingly, new hands-on activities and questions have been added at the end of each chapter that guide students in understanding how to select technologies to build a network that would support an organization's business needs. In addition to this overarching change, the thirteenth edition has three major changes from the twelfth edition:

First, at the end of each chapter, we provide key implications for cyber security that arise from the topics discussed in the chapter. We draw implications that focus on improving the management of networks and information systems as well as implications for cyber security of an individual and an organization.

The second major change is that in Chapter 5 we have revised the way we explain how TCP/IP works to make it clearer and more streamlined.

Third, we have revised the security chapter (Chapter 11) to consider some of the newer threats and responses.

LAB EXERCISES
www.wiley.com/college/fitzgerald

This edition includes an online lab manual with many hands-on exercises that can be used in a networking lab. These exercises include configuring servers and other additional practical topics.

ONLINE SUPPLEMENTS FOR INSTRUCTORS
www.wiley.com/college/fitzgerald

Instructor's supplements comprise an Instructor's Manual that includes teaching tips, war stories, and answers to end-of-chapter questions; a Test Bank that includes true-false, multiple choice, short answer, and essay test questions for each chapter; and Lecture Slides in PowerPoint for classroom presentations. All are available on the instructor's book companion site.

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PART ONE INTRODUCTION

CHAPTER 1

INTRODUCTION TO DATA COMMUNICATIONS

This chapter introduces the basic concepts of data communications. It describes why it is important to study data communications and introduces you to the three fundamental questions that this book answers. Next, it discusses the basic types and components of a data communications network. Also, it examines the importance of a network model based on layers. Finally, it describes the three key trends in the future of networking.

OBJECTIVES

- Be aware of the three fundamental questions this book answers
- Be aware of the applications of data communications networks
- Be familiar with the major components of and types of networks
- Understand the role of network layers
- Be familiar with the role of network standards
- Be aware of cyber security issues
- Be aware of three key trends in communications and networking

OUTLINE

1.1 INTRODUCTION

What Internet connection should you use? Cable modem or DSL (formally called Digital Subscriber Line)? Cable modems are supposedly faster than DSL, providing data speeds of 50 Mbps to DSL's 1.5–25 Mbps (million bits per second). One cable company used a tortoise to represent DSL in advertisements. So which is faster? We'll give you a hint. Which won the race in the fable, the tortoise or the hare? By the time you finish this book, you'll understand which is faster and why, as well as why choosing the right company as your **Internet service provider (ISP)** is probably more important than choosing the right technology.

Over the past decade or so, it has become clear that the world has changed forever. We continue to forge our way through the Information Age—the second Industrial Revolution, according to John Chambers, CEO (chief executive officer) of Cisco Systems, Inc., one of the world's leading networking technology companies. The first Industrial Revolution revolutionized the way people worked by introducing machines and new organizational forms. New companies and industries emerged, and old ones died off.

The second Industrial Revolution is revolutionizing the way people work through networking and data communications. The value of a high-speed data communications network is that it brings people together in a way never before possible. In the 1800s, it took several weeks for a message to reach North America by ship from England. By the 1900s, it could be transmitted within an hour. Today, it can be transmitted in seconds. Collapsing the *information lag* to Internet speeds means that people can communicate and access information anywhere in the world regardless of their physical location. In fact, today's problem is that we cannot handle the quantities of information we receive.

Data communications and networking is a truly global area of study, both because the technology enables global communication and because new technologies and applications often emerge from a variety of countries and spread rapidly around the world. The World Wide Web, for example, was born in a Swiss research lab, was nurtured through its first years primarily by European universities, and exploded into mainstream popular culture because of a development at an American research lab.

One of the problems in studying a global phenomenon lies in explaining the different political and regulatory issues that have evolved and currently exist in different parts of the world. Rather than attempt to explain the different paths taken by different countries, we have chosen simplicity instead. Historically, the majority of readers of previous editions of this book have come from North America. Therefore, although we retain a global focus on technology and its business implications, we focus mostly on North America.

This book answers three fundamental questions.

First, how does the Internet work? When you access a website using your computer, laptop, iPad, or smartphone, what happens so that the page opens in your Web browser? This is the focus in Chapters 1–5. The short answer is that the software on your computer (or any device) creates a message composed in different software languages (HTTP, TCP/IP, and Ethernet are common) that requests the page you clicked. This message is then broken up into a series of smaller parts that we call packets. Each packet is transmitted to the nearest router, which is a special-purpose computer whose primary job is to find the best route for these packets to their final destination. The packets move from router to router over the Internet until they reach the Web server, which puts the packets back together into the same message that your computer created. The Web server reads your request and then sends the page back to you in the same way—by composing a message using HTTP, TCP/IP, and Ethernet and then sending it as a series of smaller packets back through the Internet that the software on your computer puts together into the page you requested. You might have heard a news story that the U.S. or Chinese government can read your email or see what websites you're visiting. A more shocking truth is that the person sitting next you at a coffee shop might be doing exactly the same thing—reading all the packets that come from or go to your laptop. How is this possible, you ask? After finishing Chapter 5, you will know exactly how this is possible.

Second, how do I design a network? This is the focus of Chapters 6–10. We often think about networks in four layers. The first layer is the Local Area Network, or the LAN (either wired or wireless), which enables users like you and me to access the network. The second is the backbone network that connects the different LANs within a building. The third is the core network that connects different buildings on a company's campus. The final layer is connections we have to the other campuses within the organization and to the Internet. Each of these layers has slightly different concerns, so the way we design networks for them and the technologies we use are slightly different. Although this describes the standard for building corporate networks, you will have a much better understanding of how your wireless router at home works. Perhaps more importantly, you'll learn why buying the newest and fastest wireless router for your house or apartment is probably not a good way to spend your money.

Finally, how do I manage my network to make sure it is secure, provides good performance, and doesn't cost too much? This is the focus of Chapters 11 and 12. Would it surprise you to learn that most companies spend between $1,500 and $3,500 per computer per year on network management and security? Yup, we spend way more on network management and security each year than we spend to buy the computer in the first place. And that's for well-run networks; poorly run networks cost a lot more. Many people think network security is a technical problem, and, to some extent, it is. However, the things people do and don't do cause more security risks than not having the latest technology. According to Symantec, one of the leading companies that sell antivirus software, about half of all security threats are not prevented by their software. These threats are called targeted attacks, such as phishing attacks (which are emails that look real but instead take you to fake websites) or ransomware (software apps that appear to be useful but actually lock your computer and demand a payment to unlock it). Therefore, network management is as much a people management issue as it is a technology management issue.

By the time you finish this book, you'll understand how networks work, how to design networks, and how to manage networks. You won't be an expert, but you'll be ready to enter an organization or move on to more advanced courses.

MANAGEMENT FOCUS

1-1 Career Opportunities

It's a great time to be in information technology (IT)! The technology-fueled new economy has dramatically increased the demand for skilled IT professionals. According to the U.S. Bureau of Labor Statistics and Career Profiles (http://www.careerprofiles.info), 2 out of 10 fastest growing occupations are computer network administrator and computer systems analyst, which is expected to grow by 22% over the next 10 years with an annual median salary of $72,500—not counting bonuses. There are two reasons for this growth. First, companies have to continuously upgrade their networks and thus need skilled employees to support their expanding IT infrastructure. Second, people are spending more time on their mobile devices, and because employers are allowing them to use these personal devices at work (i.e., BYOD, or bring your own device), the network infrastructure has to support the data that flow from these devices as well as to make sure that they don't pose a security risk.

With a few years of experience, there is the possibility to work as an information systems manager, for which the median annual pay is as high as $117,780. An information systems manager plans, coordinates, and directs IT-related activities in such a way that they can fully support the goals of any business. Thus, this job requires a good understanding not only of the business but also of the technology so that appropriate and reliable technology can be implemented at a reasonable cost to keep everything operating smoothly and to guard against cybercriminals.

Because of the expanding job market for IT and networking-related jobs, certifications become important. Most large vendors of network technologies, such as the Microsoft Corporation and Cisco Systems Inc., provide certification processes (usually a series of courses and formal exams) so that individuals can document their knowledge. Certified network professionals often earn $10,000 to $15,000 more than similarly skilled uncertified professionals—provided that they continue to learn and maintain their certification as new technologies emerge.

Adapted from: http://jobs.aol.com, "In Demand Careers That Pay $100,00 a Year or More"; www.careerpath.com, "Today's 20 Fastest-Growing Occupations"; www.cnn.com, "30 Jobs Needing Most Workers in Next Decade," http://www.careerprofiles.info/top-careers.html.

1.2 DATA COMMUNICATIONS NETWORKS

Data communications is the movement of computer information from one point to another by means of electrical or optical transmission systems. Such systems are often called *data communications networks*. This is in contrast to the broader term *telecommunications*, which includes the transmission of voice and video (images and graphics) as well as data and usually implies longer distances. In general, data communications networks collect data from personal computers and other devices and transmit those data to a central server that is a more powerful personal computer, minicomputer, or mainframe, or they perform the reverse process, or some combination of the two. Data communications networks facilitate more efficient use of computers and improve the day-to-day control of a business by providing faster information flow. They also provide message transfer services to allow computer users to talk to one another via email, chat, and video streaming.

TECHNICAL FOCUS

1-1 Internet Domain Names

Internet address names are strictly controlled; otherwise, someone could add a computer to the Internet that had the same address as another computer. Each address name has two parts, the computer name and its domain. The general format of an Internet address is therefore computer.domain. Some computer names have several parts separated by periods, so some addresses have the format computer.computer.computer.domain. For example, the main university Web server at Indiana University (IU) is called www.indiana.edu, whereas the Web server for the Kelley School of Business at IU is www.kelley.indiana.edu.

Since the Internet began in the United States, the American address board was the first to assign domain names to indicate types of organizations. Some common U.S. domain names are as follows:

EDU	for an educational institution, usually a university
COM	for a commercial business
GOV	for a government department or agency
MIL	for a military unit
ORG	for a nonprofit organization

As networks in other countries were connected to the Internet, they were assigned their own domain names. Some international domain names are as follows:

CA	for Canada
AU	for Australia
UK	for the United Kingdom
DE	for Germany

New top-level domains that focus on specific types of businesses continue to be introduced, such as the following:

AERO	for aerospace companies
MUSEUM	for museums
NAME	for individuals
PRO	for professionals, such as accountants and lawyers
BIZ	for businesses

Many international domains structure their addresses in much the same way as the United States does. For example, Australia uses *EDU* to indicate academic institutions, so an address such as xyz.edu.au would indicate an Australian university.

For a full list of domain names, see www.iana.org/domains/root/db.

1.2.1 Components of a Network

There are three basic hardware components for a data communications network: a server (e.g., personal computer, mainframe), a client (e.g., personal computer, terminal), and a circuit (e.g., cable, modem) over which messages flow. Both the server and client also need special-purpose network software that enables them to communicate.

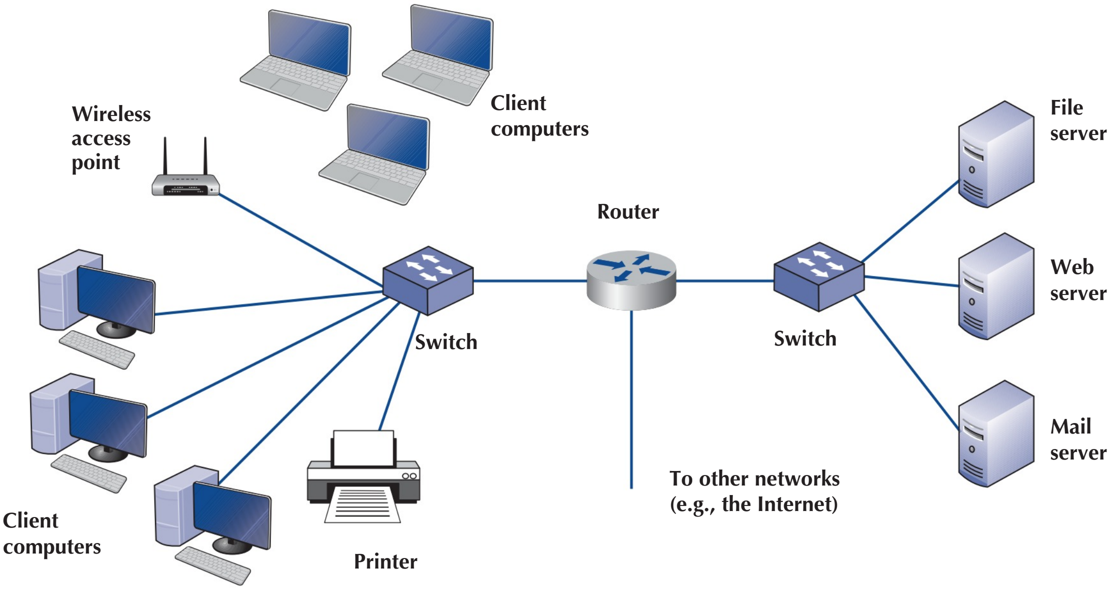


FIGURE 1-1 Example of a local area network (LAN)

The **server** stores data or software that can be accessed by the clients. In client–server computing, several servers may work together over the network with a client computer to support the business application.

The **client** is the input–output hardware device at the user's end of a communication circuit. It typically provides users with access to the network and the data and software on the server.

The **circuit** is the pathway through which the messages travel. It is typically a copper wire, although fiber-optic cable and wireless transmission are becoming common. There are many devices in the circuit that perform special functions such as switches and routers.

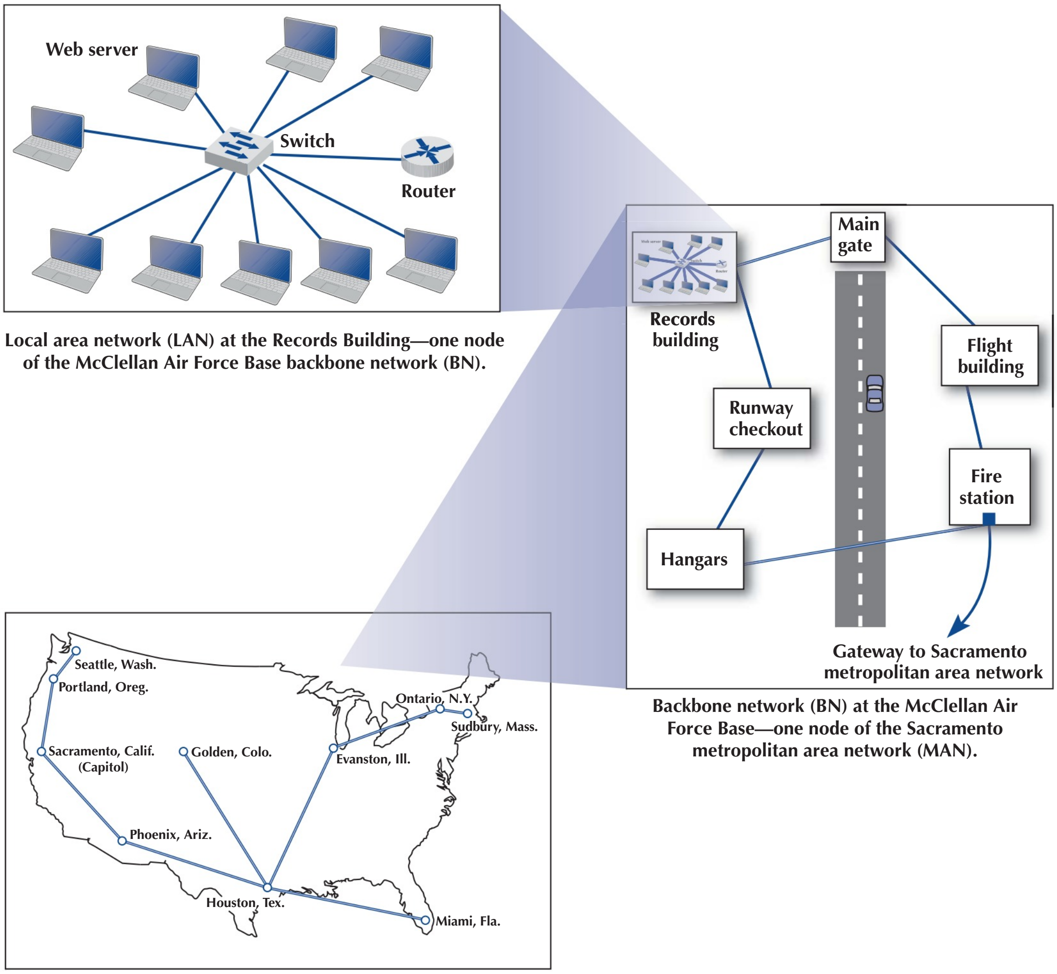
Strictly speaking, a network does not need a server. Some networks are designed to connect a set of similar computers that share their data and software with each other. Such networks are called **peer-to-peer networks** because the computers function as equals, rather than relying on a central server to store the needed data and software.

Figure 1-1 shows a small network that has several personal computers (clients) connected through a **switch** and **cables** (circuit) and wirelessly through a **wireless access point**(AP). In this network, messages move through the switch to and from the computers. The **router** is a special device that connects two or more networks. The router enables computers on this network to communicate with computers on the same network or on other networks (e.g., the Internet).

The network in Figure 1-1 has three servers. Although one server can perform many functions, networks are often designed so that a separate computer is used to provide different services. The **file server** stores data and software that can be used by computers on the network. The **Web server** stores documents and graphics that can be accessed from any Web browser, such as Internet Explorer. The Web server can respond to requests from computers on this network or any computer on the Internet. The **mail server** handles and delivers email over the network. Servers are usually personal computers (often more powerful than the other personal computers on the network) but may be mainframes too.

1.2.2 Types of Networks

There are many different ways to categorize networks. One of the most common ways is to look at the geographic scope of the network. Figure 1-2 illustrates three types of networks: local area



Local area network (LAN) at the Records Building—one node of the McClellan Air Force Base backbone network (BN).

Backbone network (BN) at the McClellan Air Force Base—one node of the Sacramento metropolitan area network (MAN).

Wide area network (WAN) showing Sacramento connected to nine other cities throughout the United States.

FIGURE 1-2 The hierarchical relationship of a LAN to a BN to a WAN. BAN = backbone network; LAN = local area network; WAN = wide area network

networks (LANs), backbone networks (BNs), and wide area networks (WANs). The distinctions among these are becoming blurry because some network technologies now used in LANs were originally developed for WANs, and vice versa. Any rigid classification of technologies is certain to have exceptions.

A **local area network (LAN)** is a group of computers located in the same general area. A LAN covers a clearly defined small area, such as one floor or work area, a single building, or a group of buildings. The upper-left diagram in Figure 1-2 shows a small LAN located in the records building at the former McClellan Air Force Base in Sacramento. LANs support high-speed data transmission compared with standard telephone circuits, commonly operating 100 million bits per second (100 Mbps). LANs and wireless LANs are discussed in detail in Chapter 6.

Most LANs are connected to a **backbone network (BN)**, a larger, central network connecting several LANs, other BNs, MANs, and WANs. BNs typically span from hundreds of feet to several miles and provide very high-speed data transmission, commonly 100–1,000 Mbps. The second diagram in Figure 1-2 shows a BN that connects the LANs located in several buildings at McClellan Air Force Base. BNs are discussed in detail in Chapter 7.

Wide area networks (WANs) connect BNs and MANs (see Figure 1-2). Most organizations do not build their own WANs by laying cable, building microwave towers, or sending up satellites (unless they have unusually heavy data transmission needs or highly specialized requirements, such as those of the Department of Defense). Instead, most organizations lease circuits from IXCs (e.g., AT&T, Sprint) and use those to transmit their data. WAN circuits provided by IXCs come in all types and sizes but typically span hundreds or thousands of miles and provide data transmission rates from 64 Kbps to 10 Gbps. WANs are discussed in detail in Chapter 8.

Two other common terms are **intranets** and **extranets**. An intranet is a LAN that uses the same technologies as the Internet (e.g., Web servers, Java, HTML [Hypertext Markup Language]) but is open to only those inside the organization. For example, although some pages on a Web server may be open to the public and accessible by anyone on the Internet, some pages may be on an intranet and therefore hidden from those who connect to the Web server from the Internet at large. Sometimes, an intranet is provided by a completely separate Web server hidden from the Internet. The intranet for the Information Systems Department at Indiana University, for example, provides information on faculty expense budgets, class scheduling for future semesters (e.g., room, instructor), and discussion forums.

An extranet is similar to an intranet in that it, too, uses the same technologies as the Internet but instead is provided to invited users outside the organization who access it over the Internet. It can provide access to information services, inventories, and other internal organizational databases that are provided only to customers, suppliers, or those who have paid for access. Typically, users are given passwords to gain access, but more sophisticated technologies such as smart cards or special software may also be required. Many universities provide extranets for Web-based courses so that only those students enrolled in the course can access course materials and discussions.

1.3 NETWORK MODELS

There are many ways to describe and analyze data communications networks. All networks provide the same basic functions to transfer a message from sender to receiver, but each network can use different network hardware and software to provide these functions. All of these hardware and software products have to work together to successfully transfer a message.

One way to accomplish this is to break the entire set of communications functions into a series of **layers**, each of which can be defined separately. In this way, vendors can develop software and hardware to provide the functions of each layer separately. The software or hardware can work in any manner and can be easily updated and improved, as long as the interface between that layer and the ones around it remains unchanged. Each piece of hardware and software can then work together in the overall network.

There are many different ways in which the network layers can be designed. The two most important network models are the Open Systems Interconnection Reference (OSI) model and the Internet model. Of the two, the Internet model is the most commonly used; few people use the OSI model, although understand it is commonly required for network certification exams.

1.3.1 Open Systems Interconnection Reference Model

The **Open Systems Interconnection Reference model** (usually called the **OSI model** for short) helped change the face of network computing. Before the OSI model, most commercial networks used by businesses were built using nonstandardized technologies developed by one vendor (remember that the Internet was in use at the time but was not widespread and certainly was not commercial). During the late 1970s, the International Organization for Standardization (ISO) created the Open System Interconnection Subcommittee, whose task was to develop a framework of standards for computer-to-computer communications. In 1984, this effort produced the OSI model.

FIGURE 1-3

Network models. OSI = Open Systems Interconnection Reference

OSI Model	Internet Model	Groups of Layers	Examples
7. Application Layer	5. Application Layer	*Application Layer*	Internet Explorer and Web pages
6. Presentation Layer			
5. Session Layer			
4. Transport Layer	4. Transport Layer	*Internetwork Layer*	TCP/IP software
3. Network Layer	3. Network Layer		
2. Data Link Layer	2. Data Link Layer	*Hardware Layer*	Ethernet port, Ethernet cables, and Ethernet software drivers
1. Physical Layer	1. Physical Layer		

The OSI model is the most talked about and most referred to network model. If you choose a career in networking, questions about the OSI model will be on the network certification exams offered by Microsoft, Cisco, and other vendors of network hardware and software. However, you will probably never use a network based on the OSI model. Simply put, the OSI model never caught on commercially in North America, although some European networks use it, and some network components developed for use in the United States arguably use parts of it. Most networks today use the Internet model, which is discussed in the next section. However, because there are many similarities between the OSI model and the Internet model, and because most people in networking are expected to know the OSI model, we discuss it here. The OSI model has seven layers (see Figure 1-3).

Layer 1: Physical Layer The *physical layer* is concerned primarily with transmitting data bits (zeros or ones) over a communication circuit. This layer defines the rules by which ones and zeros are transmitted, such as voltages of electricity, number of bits sent per second, and the physical format of the cables and connectors used.

Layer 2: Data Link Layer The *data link layer* manages the physical transmission circuit in layer 1 and transforms it into a circuit that is free of transmission errors as far as layers above are concerned. Because layer 1 accepts and transmits only a raw stream of bits without understanding their meaning or structure, the data link layer must create and recognize message boundaries; that is, it must mark where a message starts and where it ends. Another major task of layer 2 is to solve the problems caused by damaged, lost, or duplicate messages so the succeeding layers are shielded from transmission errors. Thus, layer 2 performs error detection and correction. It also decides when a device can transmit so that two computers do not try to transmit at the same time.

Layer 3: Network Layer The *network layer* performs routing. It determines the next computer to which the message should be sent, so it can follow the best route through the network and finds the full address for that computer if needed.

Layer 4: Transport Layer The *transport layer* deals with end-to-end issues, such as procedures for entering and departing from the network. It establishes, maintains, and terminates logical connections for the transfer of data between the original sender and the final destination of the message. It is responsible for breaking a large data transmission into smaller packets (if needed), ensuring that all the packets have been received, eliminating duplicate packets, and performing flow control to ensure that no computer is overwhelmed by the number of messages it receives. Although error control is performed by the data link layer, the transport layer can also perform error checking.

Layer 5: Session Layer The *session layer* is responsible for managing and structuring all sessions. Session initiation must arrange for all the desired and required services between session participants, such as logging on to circuit equipment, transferring files, and performing security checks. Session termination provides an orderly way to end the session, as well as a means to abort a session prematurely. It may have some redundancy built in to recover from a broken transport (layer 4) connection in case of failure. The session layer also handles session accounting so the correct party receives the bill.

Layer 6: Presentation Layer The *presentation layer* formats the data for presentation to the user. Its job is to accommodate different interfaces on different computers so the application program need not worry about them. It is concerned with displaying, formatting, and editing user inputs and outputs. For example, layer 6 might perform data compression, translation between different data formats, and screen formatting. Any function (except those in layers 1 through 5) that is requested sufficiently often to warrant finding a general solution is placed in the presentation layer, although some of these functions can be performed by separate hardware and software (e.g., encryption).

Layer 7: Application Layer The *application layer* is the end user's access to the network. The primary purpose is to provide a set of utilities for application programs. Each user program determines the set of messages and any action it might take on receipt of a message. Other network-specific applications at this layer include network monitoring and network management.

1.3.2 Internet Model

The network model that dominates current hardware and software is a more simple five-layer **Internet model**. Unlike the OSI model that was developed by formal committees, the Internet model evolved from the work of thousands of people who developed pieces of the Internet. The OSI model is a formal standard that is documented in one standard, but the Internet model has never been formally defined; it has to be interpreted from a number of standards. The two models have very much in common (see Figure 1-3); simply put, the Internet model collapses the top three OSI layers into one layer. Because it is clear that the Internet has won the "war," we use the five-layer Internet model for the rest of this book.

Layer 1: The Physical Layer The **physical layer** in the Internet model, as in the OSI model, is the physical connection between the sender and receiver. Its role is to transfer a series of electrical, radio, or light signals through the circuit. The physical layer includes all the *hardware* devices (e.g., computers, modems, and switches) and physical *media* (e.g., cables and satellites). The physical layer specifies the type of connection and the electrical signals, radio waves, or light pulses that pass through it. Chapter 3 discusses the physical layer in detail.

Layer 2: The Data Link Layer The **data link layer** is responsible for moving a message from one computer to the next computer in the network path from the sender to the receiver. The data link layer in the Internet model performs the same three functions as the data link layer in the OSI model. First, it controls the physical layer by deciding when to transmit messages over the media. Second, it formats the messages by indicating where they start and end. Third, it detects and may correct any errors that have occurred during transmission. Chapter 4 discusses the data link layer in detail.