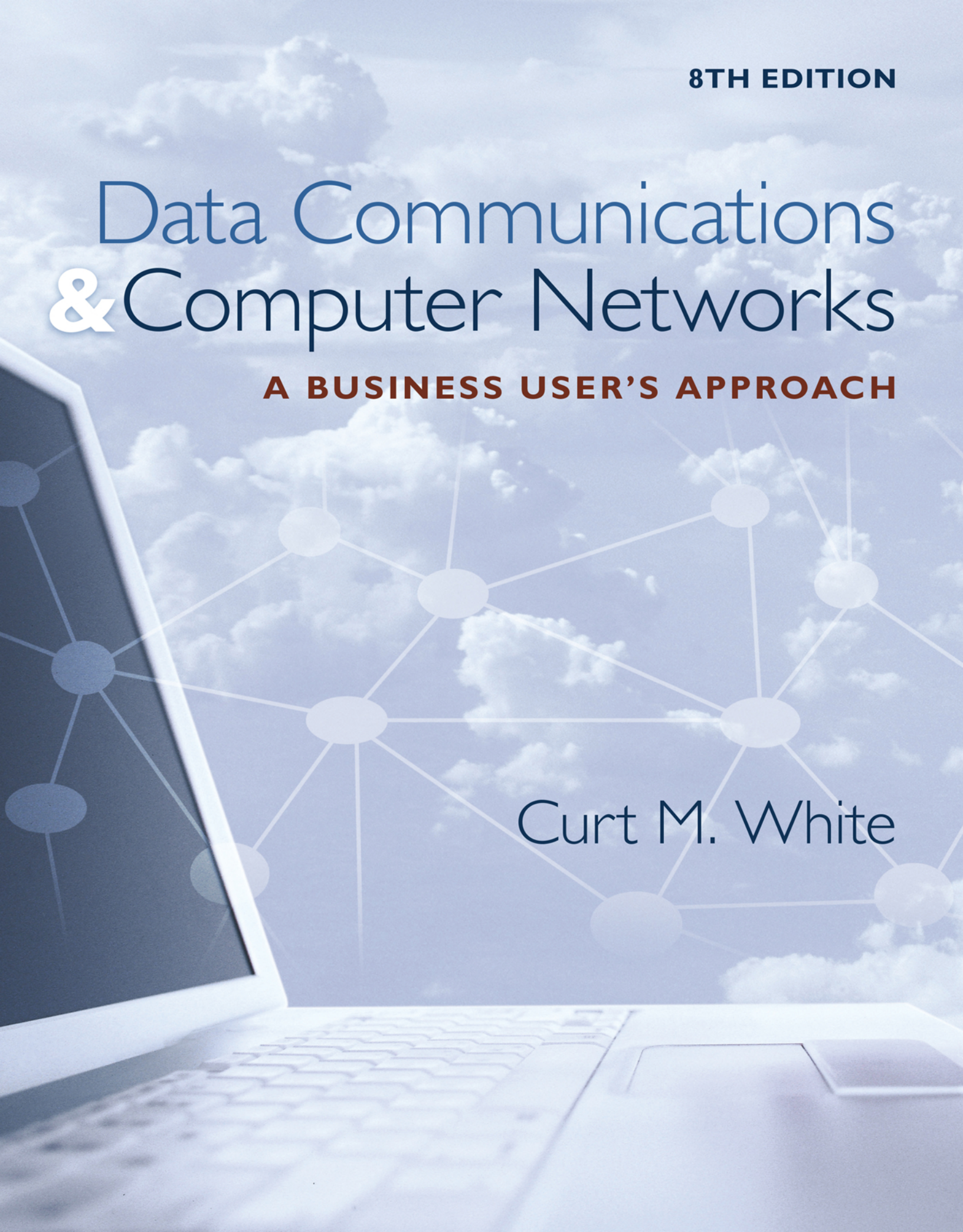
8TH EDITION

Data Communications & Computer Networks

A BUSINESS USER'S APPROACH



Curt M. White

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Curt M. White
DePaul University

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Data Communications & Computer Networks: A Business User's Approach, Eighth Edition
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To Kathleen, Hannah Colleen, and
Samuel Memphis—it's never boring

Brief Contents

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Preface

Today's business world could not function without data communications and computer networks. Most people cannot make it through an average day without coming in contact with or using some form of computer network. In the past, this field of study occupied the time of only engineers and technicians, but it now involves business managers, end users, programmers, and just about anyone who might use a telephone or computer! Because of this, *Data Communications & Computer Networks: A Business User's Approach*, Eighth Edition maintains a business user's perspective on this vast and increasingly significant subject.

In a generic sense, this book serves as an owner's manual for the individual computer user. In a world in which computer networks are involved in nearly every facet of business and personal life, it is paramount that each of us understands the basic features, operations, and limitations of different types of computer networks. This understanding will make us better managers, better employees, and simply better computer users. As a computer network *user*, you will probably not be the one who designs, installs, and maintains the network. Instead, you will have interactions—either direct or indirect—with the individuals who do. Reading this book should give you a strong foundation in computer networks, which will enable you to work effectively with network administrators, network installers, and network designers.

Here are some of the many scenarios in which the knowledge contained in this book would be particularly useful:

- You work for a company and must deal directly with a network specialist. To better understand the specialist and be able to conduct a meaningful dialog with him or her, you need a basic understanding of the many aspects of computer networks.
- You are a manager within a company and depend on a number of network specialists to provide you with recommendations for the company's network. You do not want to find yourself in a situation in which you must blindly accept the recommendations of network professionals. To ensure that you can make intelligent decisions regarding network resources, you need to know the basic concepts of data communications and computer networks.
- You work in a small company, in which each employee wears many hats. Thus, you may need to perform some level of network assessment, administration, or support.

- You have your own business and need to fully understand the advantages of using computer networks to support your operations. To optimize those advantages, you should have a good grasp of the basic characteristics of a computer network.
- You have a computer at home or at work, and you simply wish to learn more about computer networks.
- You have realized that to keep your job skills current and remain a key player in the information technology arena, you must understand how different computer networks work and become familiar with their advantages and shortcomings.

Audience

Data Communications & Computer Networks: A Business User's Approach, Eighth Edition is intended for a one-semester course in business data communications for students majoring in business, information systems, management information systems, and other applied fields of computer science. Even computer science departments will find the book valuable, particularly if the students read the Details sections accompanying most chapters. It is a readable resource for computer network users that draws on examples from business environments.

In a university setting, this book can be used at practically any level above the first year. Instructors who wish to use this book at the graduate level can draw on the many advanced projects provided at the end of each chapter to create a more challenging environment for the advanced student.

Defining Characteristics of This Book

The major goal of this eighth edition is the same as that of the first edition: to go beyond simply providing readers with a handful of new definitions, and instead introduce them to the next level of details found within the fields of computer networks and data communications. This higher level of detail includes the network technologies and standards necessary to support computer network systems and their applications. This book is more than just an introduction to advanced terminology. It involves introducing concepts that will help the reader achieve a more in-depth understanding of the often complex topic of data communications. It is hoped that once readers attain this in-depth understanding, the topic of networks and data communications will be less intimidating to them. To facilitate this understanding, the book strives to maintain high standards in three major areas: readability, a balance between the technical and the practical, and currency.

Readability

Great care has been taken to provide the technical material in as readable a fashion as possible. Each new edition has received a complete rewrite, in which every sentence has been reexamined in an attempt to convey the concepts as clearly as possible. Given the nature of this book's subject matter, the use of terminology is unavoidable. However, every effort has been made to present terms in a clear fashion, with minimal use of acronyms and even less use of computer jargon.

Balance between the Technical and the Practical

As in the very successful first edition, a major objective in writing *Data Communications & Computer Networks*, Eighth Edition was to achieve a good balance between the more technical aspects of data communications and its everyday practical aspects. Throughout each chapter, there are sections entitled "Details," which delve into the more specialized aspects of the topic at hand.

Should readers not have time to explore this technical information, they can skip these Details sections without missing out on the basic concepts of the topic.

Current Technology

Because of the fast pace of change in virtually all computer-related fields, every attempt has been made to present the most current trends in data communications and computer networks. Some of these topics include:

- More detail on arithmetic checksum
- An introduction to a number of new terms and concepts such as: zero client, Internet of Things, socially-engineered attack, malware, campus area network, near field communications, and Lightning interface
- The most recent Ethernet standard of 40 GbE and 100 GbE
- An update on Transport Layer Security (TLS) and Hypertext Transfer Protocol Secure (HTTPS)
- The most recent Wi-Fi standard for wireless local area networks: IEEE 802.11ac

It is also important to remember the many older technologies still in prevalent use today. Discussions of these older technologies can be found, when appropriate, in each chapter of this book.

Organization

The organization of *Data Communications & Computer Networks*, Eighth Edition roughly follows that of the TCP/IP protocol suite, from the physical layer to the upper layers. In addition, the book has been carefully designed to consist of 13 chapters in order to fit well into a typical 15- or 16-week semester (along with any required exams). Although some chapters may not require an entire week of study, other chapters may require more than one week. The intent was to design a balanced introduction to the study of computer networks by creating a set of chapters that is cohesive but at the same time allows for flexibility in the week-to-week curriculum.

Thus, instructors may choose to emphasize or de-emphasize certain topics, depending on the focus of their curriculums. If all 13 chapters cannot be covered during one term, it is possible for the instructor to concentrate on certain chapters. For example, if the curriculum's focus is information systems, the instructor might concentrate on Chapters 1, 3, 4, 6–8, 10, 12, and 13. If the focus is on the more technical aspects of computer networks, the instructor might concentrate on Chapters 1–11. It is the author's recommendation, however, that all chapters be covered in some level of detail.

Features

To assist readers in better understanding the technical nature of data communications and computer networks, each chapter contains a number of significant features. These features are based on older, well-tested pedagogical techniques as well as some newer techniques.

Opening Case

Each chapter begins with a short case or vignette that emphasizes the main concept of the chapter and sets the stage for exploration. These cases are designed to spark readers' interest and create a desire to learn more about the chapter's concepts.

Learning Objectives

Following the opening case is a list of learning objectives that should be accomplished by the end of the chapter. Each objective is tied to the main sections of

the chapter. Readers can use the objectives to grasp the scope and intent of the chapter. The objectives also work in conjunction with the end-of-chapter summary and review questions, so that readers can assess whether they have adequately mastered the material.

Details

Many chapters contain one or more Details sections, which dig deeper into a particular topic. Readers who are interested in more technical details will find these sections valuable. Since the Details sections are physically separate from the main text, they can be skipped if the reader does not have time to explore this level of technical detail. Skipping these sections will not affect the reader's overall understanding of a chapter's material.

In Action

At the end of each chapter's main content presentation is an In Action example that demonstrates an application of the chapter's key topic in a realistic environment. Although a number of In Action examples include imaginary people and organizations, every attempt was made to make the hypothetical scenarios as representative as possible of situations and issues found in real-world business and home environments. Thus, the In Action examples help the reader visualize the concepts presented in the chapter.

End-of-Chapter Material

The end-of-chapter material is designed to help readers review the content of the chapter and assess whether they have adequately mastered the concepts. It includes:

- A bulleted summary that readers can use as a review of the key topics of the chapter and as a study guide.
- A list of the key terms used within the chapter.
- A list of review questions that readers can use to quickly check whether or not they understand the chapter's key concepts.
- A set of exercises that draw on the material presented in the chapter.
- A set of Thinking Outside the Box exercises, which are more in-depth in nature and require readers to consider various possible alternative solutions by comparing their advantages and disadvantages.
- A set of Hands-On Projects that require readers to reach beyond the material found within the text and use outside resources to compose a response. Many of these projects lend themselves nicely to writing assignments. Thus, they can serve as valuable tools for instructors, especially at a time when more and more colleges and universities are seeking to implement "writing across the curriculum" strategies.

Glossary

At the end of the book, you will find a glossary that includes the key terms from each chapter.

Student Online Companion

The student online companion for this book can be found at *www.cengagebrain.com*, and search by title, author name, or ISBN. It contains a number of features, including:

- Hands-on labs that allow students to practice one or more of the chapter concepts
- A set of more in-depth discussions on older topics such as X.21, dial-up modems, ISDN, Dijkstra's algorithm, SDLC, and BISYNC
- Suggestions for further readings on numerous topics within the book

This Web site also presents visual demonstrations of many key data communications and networking concepts introduced in this text. A visual demonstration accompanies the following concepts:

- Chapter 1: Introduction to Computer Networks and Data Communications—Layer encapsulation example
- Chapter 4: Making Connections—RS-232 example of two modems establishing a connection
- Chapter 5: Making Connections Efficient: Multiplexing and Compression—Example of packets from multiple sources coming together for synchronous TDM, and a second example demonstrating statistical TDM
- Chapter 6: Errors, Error Detection, and Error Control—Sliding window example using ARQ error control
- Chapter 7: Local Area Networks: Part I—CSMA/CD example with workstations sending packets and collisions happening
- Chapter 7: Local Area Networks: Part I—Two LANs with a bridge showing how bridge tables are created and packets routed; a second example shows one LAN with a switch in place of a hub
- Chapter 9: Introduction to Metropolitan Area Networks and Wide Area Networks—Datagram network sending individual packets; and virtual circuit network first creating a connection and then sending packets down a prescribed path
- Chapter 10: The Internet—Domain Name System as it tries to find the dotted decimal notation for a given URL

Changes to the Eighth Edition

In order to keep abreast of the changes in computer networks and data communications, this Eighth Edition has incorporated many updates and additions in every chapter, as well as some reorganization of sections within chapters. Here's a summary of the major concepts that can be found in each of the following chapters:

Chapter 1, Introduction to Computer Networks and Data Communications, introduces rewrite on the different types of computer networks, along with many of the major concepts that will be discussed in the following chapters, with an emphasis on the TCP/IP protocol suite followed by the OSI models. The topic of convergence has been introduced in this first chapter and will be revisited as needed in subsequent chapters.

Chapter 2, Fundamentals of Data and Signals, covers basic concepts that are critical to the proper understanding of all computer networks and data communications.

Chapter 3, Conducted and Wireless Media, introduces the different types of media for transmitting data. The topic of near field communications was introduced.

Chapter 4, Making Connections, discusses how a connection or interface is created between a computer and a peripheral device, with a stronger emphasis on the USB interface. The Apple Lightning interface was added to the other types of interfaces.

Chapter 5, Making Connections Efficient: Multiplexing and Compression, introduces the topic of compression. Lossless compression techniques such as run-length encoding are discussed, as well as lossy compression techniques such as MP3 and JPEG.

Chapter 6, Errors, Error Detection, and Error Control, explains the actions that can take place when a data transmission produces an error. The concept of arithmetic checksum, as it is used on the Internet, is included, and has been expanded in the edition.

Chapter 7, Local Area Networks: Part I, is devoted to the basic concepts of local area networks. These two chapters on local area networks have

been reorganized. The topics of minimum spanning tree, link aggregation, and quality of service were introduced in the previous edition. In this edition, we add to the list of Ethernet versions with 40 gigabit Ethernet and 100 gigabit Ethernet.

Chapter 8, Local Area Networks: Part II, introduces wireless local area networks and discusses the various network operating systems and other network software, with updated material on Microsoft, Linux, Unix, and the MAC OS X Server. The zero-client workstation was introduced along with the latest Wi-Fi version IEEE 802.11ac.

Chapter 9, Introduction to Metropolitan Area Networks and Wide Area Networks, introduces the basic terminology and concepts of both metropolitan area networks and wide area networks. Cloud computing is also introduced.

Chapter Ten, The Internet, delves into the details of the Internet, including TCP/IP, DHCP, ARP, MPLS, and DHCP. The new topic of the Internet of Things (IoT) was introduced.

Chapter 11, Voice and Data Delivery Networks, provides a detailed introduction to the area of telecommunications—in particular, networks that specialize in local and long-distance delivery of data. Frame relay, asynchronous transfer mode, and MPLS/VPN are presented as viable data link layer protocols.

Chapter 12, Network Security, covers the current trends in network security. The topics of malware, Transport Layer Security (TLS), and Hypertext Transfer Protocol Secure (HTTPS) were updated, and the concept of socially engineered attacks was introduced.

Chapter 13, Network Design and Management, introduces the systems development life cycle, feasibility studies, capacity planning, and baseline studies, and shows how these concepts apply to the analysis and design of computer networks.

Teaching Tools

The following supplemental materials are available when this book is used in a classroom setting. All of the teaching tools available with this book are provided to the instructor on a single CD-ROM. Many can also be found at the Cengage Web site (*login.cengage.com/sso*).

Electronic Instructor's Manual—The Instructor's Manual that accompanies this textbook includes additional instructional material to assist in class preparation, including Sample Syllabi, Chapter Outlines, Technical Notes, Lecture Notes, Quick Quizzes, Teaching Tips, Discussion Topics, and Key Terms.

ExamView®—This textbook is accompanied by ExamView, a powerful testing software package that allows instructors to create and administer printed, computer (LAN-based), and Internet exams. ExamView includes hundreds of questions that correspond to the topics covered in this text, enabling students to generate detailed study guides that include page references for further review. The computer-based and Internet testing components allow students to take exams at their computers and also save the instructor time by grading each exam automatically.

PowerPoint Presentations—This book comes with Microsoft PowerPoint slides for each chapter. These are included as a teaching aid for classroom presentation, to make available to students on the network for chapter review, or to be printed for classroom distribution. Instructors can add their own slides for additional topics they introduce to the class.

Acknowledgments

Producing a textbook requires the skills and dedication of many people. Unfortunately, the final product displays only the author's name on the cover and not the names of those who provided countless hours of input and professional advice.

I would first like to thank the people at Cengage Learning for being so vitally supportive and one of the best teams an author could hope to work with: Charles McCormick, Jr., Senior Acquisitions Editor; Kate Mason, Senior Product Manager; and Divya Divakaran, Content Project Manager.

I must also thank my colleagues at DePaul University who listened to my problems, provided ideas for exercises, proofread some of the technical chapters, and provided many fresh ideas when I could think of none myself.

Finally, I thank my family: my wife Kathleen, my daughter Hannah, and my son Samuel. It is your continuing love and support that keep me going, day after day, week after week, and month after month.

Curt M. White

Chapter 1

Introduction to Computer Networks and Data Communications

OBJECTIVES

After reading this chapter, you should be able to:

- Define the basic terminology of computer networks
- Recognize the individual components of the big picture of computer networks
- Recognize the common examples of computer networks
- Define the term "convergence" and describe how it applies to computer networks
- Cite the reasons for using a network architecture and explain how they apply to current network systems
- List the layers of the TCP/IP protocol suite and describe the duties of each layer
- List the layers of the OSI model and describe the duties of each layer
- Compare the TCP/IP protocol suite and OSI model, and list their differences and similarities

MAKING PREDICTIONS is a difficult task, and predicting the future of computing is no exception. History is filled with computer-related predictions that were so inaccurate that today they are amusing. For example, consider the following predictions:

> "I think there is a world market for maybe five computers." *Thomas Watson, chairman of IBM, 1943*

> "I have traveled the length and breadth of this country, and talked with the best people, and I can assure you that data processing is a fad that won't last out the year." *Editor in charge of business books for Prentice Hall, 1957*

> "There is no reason anyone would want a computer in their home." *Ken Olsen, president and founder of Digital Equipment Corporation, 1977*

> "640K ought to be enough for anybody." *Bill Gates, 1981*

> "We believe the arrival of the PC's little brother [PCjr] is as significant and lasting a development in the history of computing as IBM's initial foray into microcomputing has proven to be." PC Magazine, *December 1983 (The PCjr lasted less than one year.)*

Apparently, no matter how famous you are or how influential your position, it is very easy to make very bad predictions. Nevertheless, it is hard to imagine that anyone can make a prediction worse than any of those above. Buoyed by this false sense of optimism, let us make a few forecasts of our own:

> Someday before you head out the door, you will reach for your umbrella, and it will tell you what kind of weather to expect outside. A radio signal will connect the umbrella to a local weather service that will download the latest weather conditions for your convenience.

> Someday you will be driving a car, and if you go faster than some predetermined speed, the car will send a text message to your parents informing them of your "driving habits."

> Someday we will wear a computer—like a suit of clothes—and when we shake hands with a person, data will be transferred down our skin, across the shaking hands, and into the other person's "computer."

> Sometime in the not too distant future, you will place some hot dogs and hamburgers on the grill and then go inside to watch the ball game. Suddenly, you will get a message on your cell phone: "Your food is done cooking."

Someday you will have a car battery that, when the power in the battery gets too weak to start the car, will call you on your cell phone to inform you that you need a replacement or a charge.

One day you will be in a big city and place a call on your cell phone to request a taxi. The voice on the other end will simply say, "Stay right where you are. Do you see the taxi coming down the street? When it stops in front of you, hop in."

Someday you will be driving in a big city and your phone or Global Positioning System (GPS) device will tell you where the nearest empty parking spot on the street is.

Do these predictions sound far-fetched and filled with mysterious technologies that only scientists and engineers can understand? They shouldn't, because they are not predictions. They are scenarios happening today with technologies that already exist. What's more, none of these advances would be possible today were it not for computer networks and data communications.

INTRODUCTION

The world of computer networks and data communications is a surprisingly vast and increasingly significant field of study. Once considered primarily the domain of network engineers and technicians, computer networks now involve business managers, computer programmers, system designers, office managers, home computer users, and everyday citizens. It is virtually impossible for the average person on the street to spend 24 hours without directly or indirectly using some form of computer network.

Ask any group, "Has anyone used a computer *network* today?" and more than one-half of the people might answer, "Yes." Then ask the others, "How did you get to work, school, or the store today if you did not use a computer network?" Most transportation systems use extensive communication networks to monitor the flow of vehicles and trains. Expressways and highways have computerized systems for controlling traffic signals and limiting access during peak traffic times. Some major cities are placing the appropriate hardware inside city buses and trains so that the precise location of each bus and train is known. This information enables the transportation systems to keep the buses evenly spaced and more punctual, and allows the riders to know when the next bus or train will arrive.

In addition, more and more people are using satellite-based GPS devices in their cars and on cell phones to provide driving directions and avoid traffic hotspots. Similar systems can unlock your car doors if you leave your keys in the ignition and can locate your car in a crowded parking lot—beeping the horn and flashing the headlights if you cannot remember where you parked.

But even if you didn't use mass transit or a GPS device in your car today, there are many other ways to use a computer network. Businesses can order parts and inventory on demand and build products to customer-designed specifications electronically, without the need for paper. Online retail outlets can track every item you look at or purchase. Using this data, they can make recommendations of similar products and inform you in the future when a new product becomes available. Twenty-four-hour banking machines can verify the user's identity by taking the user's thumbprint.

In addition, cable television continues to expand, offering extensive programming, pay-per-view options, video recording, digital television and music, and multi-megabit connectivity to the Internet. The telephone system, the oldest and most extensive network of communicating devices, continues to become

more of a computer network every day. The most recent "telephone" networks can now deliver voice, Internet, and television over a single connection. Cellular telephone systems cover virtually the entire North American continent and include systems that allow users to upload and download data to and from the Internet, send and receive images, and download streaming video such as television programs. That handheld device you are holding can play music, make phone calls, take pictures, surf the Web, and let you play games while you wait for the next train.

Welcome to the amazing world of computer networks! Unless you have spent the last 24 hours in complete isolation, it is nearly impossible to *not* have used some form of computer networks and data communications. Because of this growing integration of computer networks and data communications into business and life, we cannot leave this area of study to technicians. All of us—particularly information systems, business, and computer science students—need to understand the basic concepts. Armed with this knowledge, we not only will be better at communicating with network specialists and engineers, but also will become better students, managers, and employees.

THE LANGUAGE OF COMPUTER NETWORKS

Over the years, numerous terms and definitions relating to computer networks and data communications have emerged. To gain insight into the many subfields of study, and to become familiar with the emphasis of this textbook, let us examine the more common terms and their definitions.

A **computer network** is an interconnected group of computers and computing equipment using either wires or radio waves that can share data and computing resources. Computer networks that use radio waves are termed **wireless** and can involve broadcast radio, microwaves, or satellite transmissions. Networks spanning an area of several meters around an individual are called **personal area networks (PANs)**. Personal area networks include devices such as laptop computers, smart cell phones, music players, and wireless connections. Networks that are a little larger in geographic size—spanning a room, a floor within a building, or an entire building—are **local area networks (LANs)**. Collections of local area networks that cover a campus (such as a college campus or a business campus) are often called **campus area networks (CANs)**. Networks that serve an area up to roughly 50 kilometers—approximately the area of a typical city—are called **metropolitan area networks (MANs)**. Metropolitan area networks are high-speed networks that interconnect businesses with other businesses and the Internet. Large networks encompassing parts of states, multiple states, countries, and the world are **wide area networks (WANs)**. Chapters 9 and 10 concentrate on wide area networks and metropolitan area networks, and Chapters 7 and 8 concentrate on local area networks and campus area networks.

A very common expression that we hear today is something like "we should store the data on the cloud" or "the application is in the cloud." The key concept here is **cloud** and the way we now use it. (Similar words or phrases that are commonly used today are **network cloud** and **cloud computing**.) Very often the cloud is simply the Internet. When a company places data or applications on some Web site on the Internet and allows people to access them, we often say the application we are using is cloud-based. One of the more visible examples of cloud computing is storing one's music and/or books at a remote location on the Internet rather than on a local device. Major corporations such as Amazon and Apple allow users to store personal data and recent purchases on their clouds. Companies such as Microsoft and Google (as well as many others) allow us to use cloud-based applications such as word processors and spreadsheets. The actual code that runs the word processor or spreadsheet does not exist on the user's computer but only exists on the Internet at some

corporate Web site. This way, we don't have to take the time or expense to download the application to an individual machine. We will examine the cloud concept in more detail in a later chapter.

The study of computer networks would be missing a large component without the introduction of two important building blocks: data and signals. Data is information that has been translated into a form more conducive to storage, transmission, and calculation. As we shall see in Chapter 2, a signal is used to transmit data. We define **data communications** as the transfer of digital or analog data using digital or analog signals. Once created, these analog and digital signals then are transmitted over conducted media or wireless media (both of which are discussed in Chapter 3).

Connecting devices to a computer, or a computer to a network, requires **interfacing**, a topic covered in Chapter 4. Because sending only one signal over a medium at one time can be an inefficient way to use the transmission medium, many systems perform multiplexing. **Multiplexing** is the transmission of multiple signals on one medium. For a medium to transmit multiple signals simultaneously, the signals must be altered so that they do not interfere with one another. **Compression** is another technique that can maximize the amount of data sent over a medium. Compression involves squeezing data into a smaller package, thus reducing the amount of time (as well as storage space) needed to transmit the data. Multiplexing and compression are covered in detail in Chapter 5.

When the signals transmitted between computing devices are corrupted and errors result, error detection and error control are necessary. These topics are discussed in detail in Chapter 6.

Once upon a time, a **voice network** transmitted telephone signals, and a **data network** transmitted computer data. Eventually, however, the differences between voice networks and data networks disappeared. The merging of voice and data networks is one example of the term **convergence**, an important topic that will be presented later in this chapter and further developed in subsequent chapters.

Computer security (covered in Chapter 12) is a growing concern of both professional computer support personnel and home computer users with Internet connections. **Network management** is the design, installation, and support of a network and its hardware and software. Chapter 13 discusses many of the basic concepts necessary to support properly the design and improvement of network hardware and software, as well as the more common management techniques used to support a network.

THE BIG PICTURE OF NETWORKS

If you could create one picture that tries to give an overview of a typical computer network, what might this picture include? Figure 1-1 shows such a picture. Note that this picture shows two wide area networks (WAN 1 and WAN 2) and two local area networks (LAN 1 and LAN 2). Although a full description of the different components constituting wide area and local area networks is not necessary at this time, it is important to note that most LANs often include the following hardware:

- **Workstations**, which are personal computers (or microcomputers, desktops, laptops, or tablets, to name a few) or smart phones (or other handheld devices) where users reside
- **Servers**, which are the computers that store network software and shared or private user files
- **Switches**, which are the collection points for the wires that interconnect the workstations
- **Routers**, which are the connecting devices between local area networks and wide area networks such as the Internet

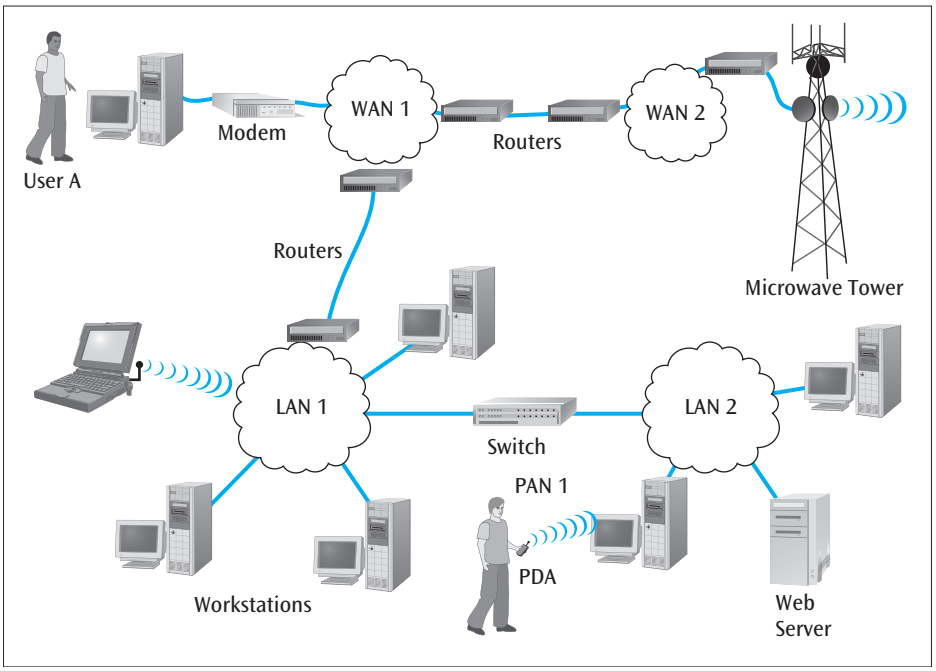

Figure **1-1** An overall view of the interconnection between different types of networks

There are also many types of wide area networks. Although many different technologies are used to support wide area networks, all wide area networks include the following components:

- **Nodes**, which are the computing devices that allow workstations to connect to the network and that make the decisions about where to route a piece of data
- Some type of high-speed transmission line, which runs from one node to another
- A **subnetwork**, which consists of the nodes and transmission lines, collected into a cohesive unit

To see how the local area networks and wide area networks work together, consider User A (in the upper-left corner of Figure 1-1), who wishes to retrieve a Web page from the Web server shown in the lower-right corner. To do this, User A's computer must have both the necessary hardware and software required to communicate with the first wide area network it encounters, WAN 1—User A's Internet service provider. Assuming that User A's computer is connected to this wide area network through a DSL telephone line, User A needs some type of modem. Furthermore, if this wide area network is part of the Internet, User A's computer requires software that talks the talk of the Internet: TCP/IP (Transmission Control Protocol/Internet Protocol).

Notice that no direct connection exists between WAN 1, where User A resides, and LAN 2, where the Web server resides. To ensure that User A's Web page request reaches its intended receiver (the Web server), User A's software attaches the appropriate address information that WAN 1 uses to route User A's request to the router that connects WAN 1 to LAN 1. Once the request is on LAN 1, the switch-like device connecting LAN 1 and LAN 2 uses address information to pass the request to LAN 2. Additional address information then routes User A's Webpage request to the Web server, whose software accepts the request.

Under normal traffic and conditions, this procedure might take only a fraction of a second. When you begin to understand all the steps involved and the great number of transformations that a simple Web page request must undergo, the fact that it takes *only* a fraction of a second to deliver is amazing.

COMMON EXAMPLES OF COMMUNICATIONS NETWORKS

The beginning of this chapter described a few applications of computer networks and data communications that you encounter in everyday life. From that sampling, you can see that setting out all the different types of jobs and services that use some sort of computer network and data communications would generate an enormous list. Instead, let us examine basic communications networks that you might encounter on any typical day while at school, work, or at leisure. This will help us see how extensive the uses of data communications and computer networks are. In Figure 1-2, Katrina is sitting at a desk at school. On the desk are two computers: a desktop PC (provided by the school) and her personal laptop. In her hand is a cell phone. Let's try to identify each of the communications networks that Katrina might encounter.

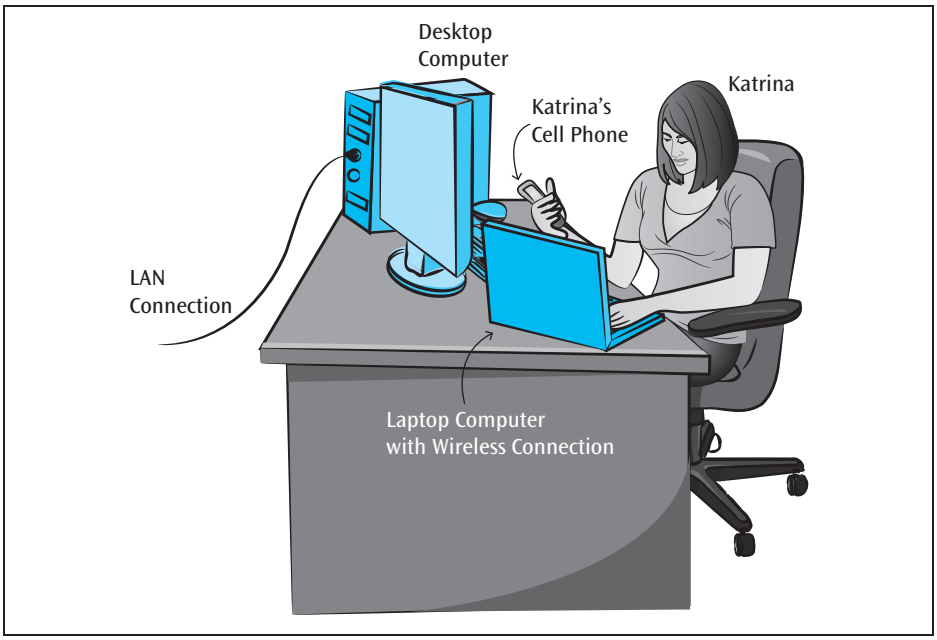

Figure 1-2 Katrina sitting at a desk at school, surrounded by networks and their connections

The desktop computer and the Internet

The desktop computer sitting on Katrina's desk is "connected" to the Internet via a cable at the back. ("Connected" was placed in quotations because as this book will hopefully demonstrate, it is a fairly involved process to connect a device to the Internet.) This is perhaps the most common network connection today and is found in virtually every business, every academic environment, and in many homes. The desktop computer—which also is commonly known as the personal computer, PC, microcomputer, laptop computer, notebook, netbook, or workstation—began to emerge in the late 1970s and early 1980s. (The term microcomputer is a good generic word for all these devices and we will use it often.)

In a business or education environment, the cable coming out the back of the desktop plugs into a wall jack and travels through the walls to some collection point, such as a network switch. This network switch, as we will see later, is part of a local area network. This local area network is possibly connected to other local area networks, but eventually connects to a router. From the router, we have some form of high-speed connection to a site which specializes in high-speed connections to the Internet.

The local area network, or LAN, as we shall see in Chapter 7, is an excellent tool for providing a connection to the Internet, as well as other networks, software, and peripherals. One way of stating the desktop-to-Internet example in the business/education world is the client/server system. In a **client/server system**, a user at a microcomputer, or client machine, issues a request for some form of data or service. This could be a request for a database record from a database server, a request for a Web page from a Web server, or a request to retrieve an e-mail message from an e-mail server. If the requested data is local, the request travels across the local system to a local server. If the requested data is not local, the request travels across the local system and then onto an external network, such as the Internet, to a remote server that contains a potentially large repository of data and/or programs. The remote server fills the request and returns the results to the client, displaying the results on the client's monitor. If users wish to print documents on a high-quality network printer, the LAN contains the network software necessary (a print server) to route their print requests to the appropriate printer. If users wish to access their e-mail from an e-mail server, the local area network provides a fast, stable connection between user workstations and the e-mail server. If a user wishes to access the Internet, the local area network provides an effective gateway to the outside world. Figure 1-3 shows a diagram of this type of desktop-to-Internet connection.

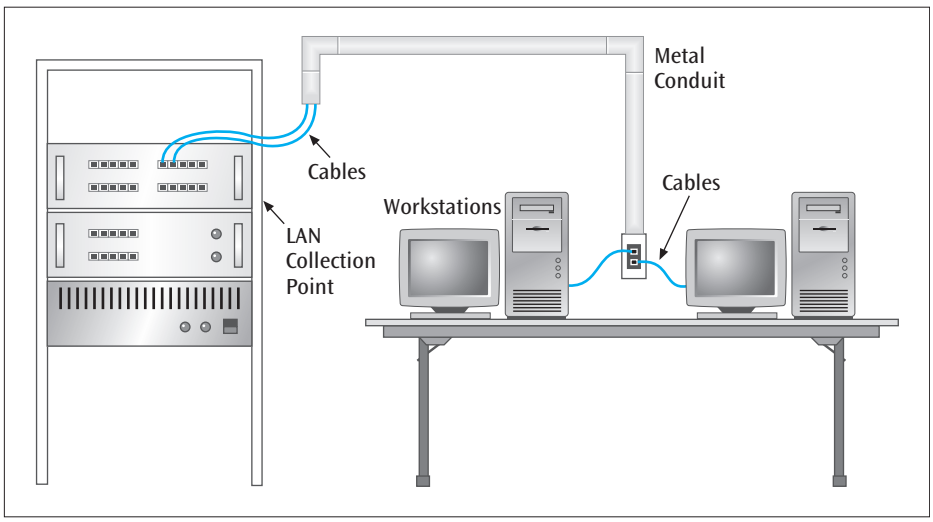

Figure **1-3** A desktop computer (or simply microcomputer) at work showing the connection between the user and the company's local area network.

What about connecting a microcomputer to the Internet when the microcomputer is in your home? Once upon a time, most home users connected their microcomputer to the Internet via a dial-up telephone line and a modem. This arrangement allowed for a maximum data transfer rate of roughly 56,000 bits per second (56 kbps). (These dial-up connections do not actually achieve 56 kbps, but that is a discussion we will have in a later chapter.) No longer is the dial-up modem the most often used connecting device. Today, a majority of home users either connect to the Internet using digital subscriber line (DSL) or access the Internet through a cable modem service. DSL and cable modems are capable of achieving much higher connection speeds (or data transfer rates) than dial-up connections and thus continue to grow in popularity. (In comparing the various data transfer rates of services and devices, we will use the convention in which lowercase k equals 1000. Also as part of the convention, lowercase b will refer to bits, while uppercase B refers to bytes, which is a collection of 8 bits.)

To communicate with the Internet using a dial-up, DSL, or cable modem connection, a user's computer must connect to another computer already communicating with the Internet. The easiest way to establish this connection is through the services of an Internet service provider (ISP). In this case, the user's computer needs to have the necessary software to communicate with the Internet. The Internet "talks" only TCP/IP, so users must use software that supports the TCP and IP protocols. Once the user's computer is talking TCP/IP, a connection to the Internet can be established. Figure 1-4 shows a typical home microcomputer-to-Internet connection.

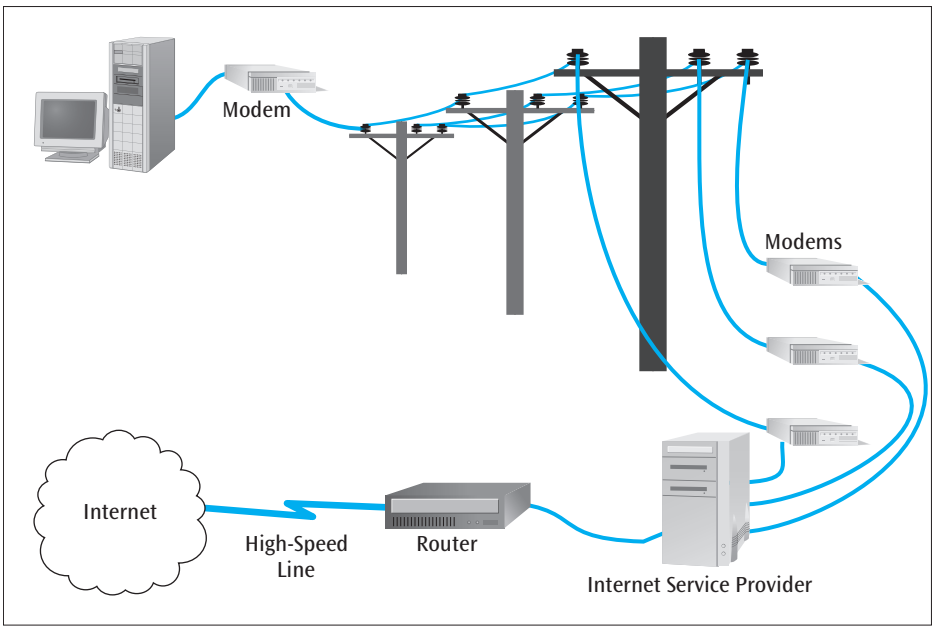

Figure 1-4 A microcomputer sending data over a DSL line to an Internet service provider and onto the Internet

A laptop computer and a wireless connection

Katrina also has a laptop sitting on her desk. Many laptops do not connect to a network using a fixed wire but instead connect via a wireless connection. This type of network connection continues to grow in popularity. A user working with a laptop, tablet, or even a smart cell phone uses wireless communications (often called Wi-Fi) to send and receive data to and from a wireless access point (wireless router). This access point is usually connected to a wired local area network and basically serves as the "bridge" between the wireless user device and the wired network. As we shall see in later chapters, there are different data communication **protocols** (sets of rules used by communication devices) for wireless local area networks and wired local area networks. While the flexibility of not having to physically cable your device to a wall jack is nice, we shall see that there are also limitations as to how far the wireless signals will travel.

Because both wireless local area networks and wired local area networks are standard in business, academic, and even many home environments, it should come as no surprise that having just one local area network is not going to get the job done. Many organizations need the services of multiple local area networks, and it may be necessary for these networks to communicate with each other. For example, the school that Katrina attends may want the local area network that supports its chemistry department to share an expensive color laser printer with its biology department's local area network. Fortunately, it is possible to connect two local area networks so that they can share peripherals as well

as software. The device that usually connects two or more LANs or segments of LANs is once again, the switch.

In some cases, it may be more important to *prevent* data from flowing between local area networks than to allow data to flow from one network to another. For instance, some businesses have political reasons for supporting multiple networks—each division may want its own network to run as it wishes. Additionally, there may be security reasons for limiting traffic flow between networks; or allowing data destined for a particular network to traverse other networks simply may generate too much network traffic. The switches that connect local area networks can help manage these types of services as well. For example, the switch can filter out traffic not intended for the neighboring network, thus minimizing the overall amount of traffic flow. Figure 1-5 provides an example of two LANs connected by a switch.

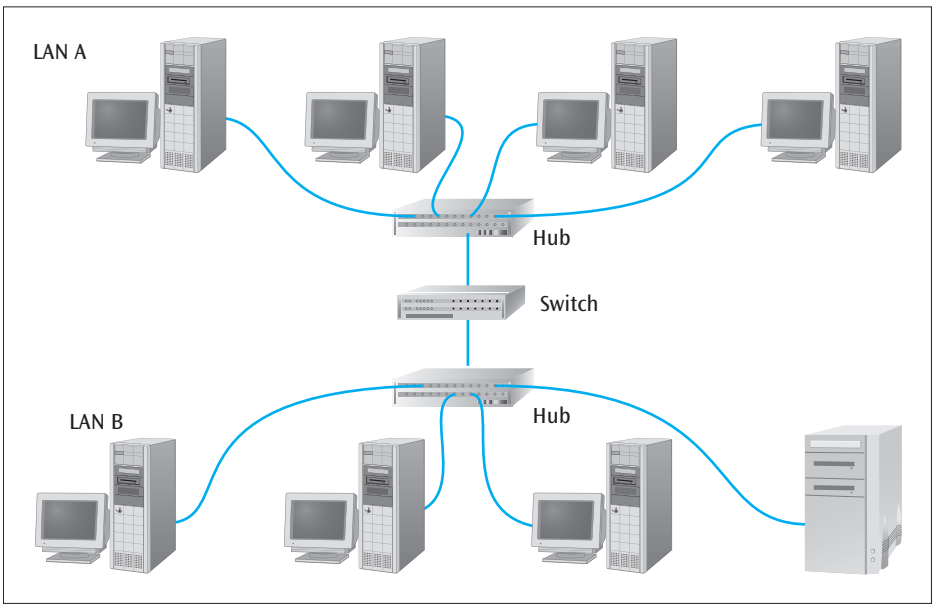

Figure 1-5 Two local area networks connected by a switch

As mentioned above, it is common to connect to the Internet using a smart cell phone and Wi-Fi signals. But what if you find yourself in a place where there are no Wi-Fi signals? If you still want to connect to the Internet, you will have to use a cell phone network, or cell phone system. Let's examine cell phone systems in more detail.

Cell phone systems

One of the most explosive areas of growth in recent years has been cell phone systems. Once upon a time, cell phones could only perform voice calls. But then the cell phone providers got us hooked on text messages. Soon people were sending more text messages than they were making voice calls. It wasn't too long after we became comfortable with making voice calls and sending text messages that cell phones started including low-resolution cameras. Now we could take grainy pictures, and shortly after that, even grainier videos of everyday events. If that wasn't enough, cell phones started to offer the capability of storing and playing music. Today, we use our cell phones to send endless text messages, download Web pages and videos from the Internet, listen to music, and take high-resolution pictures and video. The processing power built within modern smart phones rivals the mainframe computers of generations ago. The network infrastructure that is needed to support modern smart phones has also increased in dramatic fashion. Large numbers of cell towers cover the face of