DATA COMMUNICATIONS AND COMPUTER NETWORKS

A BUSINESS USER'S APPROACH

7TH EDITION

CURT M. WHITE

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SEVENTH EDITION

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A Business User's Approach

Curt M. White
DePaul University

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To Kathleen, Hannah Colleen, and
Samuel Memphis—it's never boring

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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 and Computer Networks: A Business User's Approach, Seventh 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 and Computer Networks: A Business User's Approach, Seventh 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 seventh 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 re-examined 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 and Computer Networks, Seventh 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:

- Introduction to Thunderbolt interface
- Updated information on IPv6
- Spanning tree algorithm, link aggregation, and quality of service for LANs
- Latest wireless technologies
- Updated examples on multiplexing techniques
- Greater emphasis on switching in local area networks
- Advanced encryption standards
- Compression techniques
- Current LAN network operating systems (Windows Server®, UNIX®and Linux®)
- Introduction to cloud computing

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 and Computer Networks, Seventh 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 One: Introduction to Computer Networks and Data Communications—Layer encapsulation example
- Chapter Four: Making Connections—RS-232 example of two modems establishing a connection
- Chapter Five: 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 Six: Errors, Error Detection, and Error Control—Sliding window example using ARQ error control
- Chapter Seven: Local Area Networks: Part One—CSMA/CD example with workstations sending packets and collisions happening
- Chapter Seven: Local Area Networks: Part One—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 Nine: 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 Ten: The Internet—Domain Name System as it tries to find the dotted decimal notation for a given URL

Changes to the Seventh Edition

In order to keep abreast of the changes in computer networks and data communications, this Seventh 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 changes that can be found in each of the following chapters:

Chapter One, Introduction to Computer Networks and Data Communications, introduces an update on the many types of computer network connections, 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 Two, Fundamentals of Data and Signals, covers basic concepts that are critical to the proper understanding of all computer networks and data communications.

Chapter Three, Conducted and Wireless Media, introduces the different types of media for transmitting data. The section on cellular telephones was updated to include the latest cell phone technologies.

Chapter Four, 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.

Chapter Five, 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. Examples of multiplexing have been updated.

Chapter Six, 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.

Chapter Seven, Local Area Networks: Part One, 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 have been introduced. The local area network switch has been given more prominence, to reflect its current importance in the industry.

Chapter Eight, Local Area Networks: Part Two, 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.

Chapter Nine, 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, DNS, and the World Wide Web. Additional information on IP addresses and IPv6 has been included. A discussion on the topic of Voice over IP is included, as well as the material on MPLS, service level agreements, and convergence.

Chapter Eleven, 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. The topic of basic dial-up telephone service was reduced to better reflect its diminishing importance in today's technology markets.

Chapter Twelve, Network Security, covers the current trends in network security. The topic of firewalls was updated.

Chapter Thirteen, 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 Course Technology for being so vitally

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Finally, I thank my family: my wife Kathleen, my daughter Hannah, and my son Samuel. It was your love and support (again!) that kept me going, day after day, week after week, and month after month.

Curt M. White

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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 basic network layouts
- 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 transfer 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 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 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 network 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 interconnection of computers and computing equipment using either wires or radio waves and 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, personal digital assistants, and wireless connections. Networks that are a little larger in geographic size—spanning a room, a floor within a building, a building, or a campus—are **local area networks (LANs)**. 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 Seven and Eight concentrate on local area networks, and Chapters Nine, Ten, and Eleven concentrate on metropolitan area networks and wide area networks.

The study of computer networks usually begins with 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 Two, 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 Three).

Connecting devices to a computer, or a computer to a network, requires interfacing, a topic covered in Chapter Four. 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 Five.

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 Six.

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 **convergence**, an important topic that will be presented later in this chapter and further developed in subsequent chapters.

Computer security (covered in Chapter Twelve) 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 Thirteen 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, and it includes examples of local, personal, and wide area networks. Note that this picture shows two different types of local area networks (LAN 1 and LAN 2). Although a full description of the different components constituting a local area network is not necessary at this time, it is important to note that most LANs include the following hardware:

- **Workstations**, which are personal computers/microcomputers (desktops, laptops, netbooks, handhelds, etc.) 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

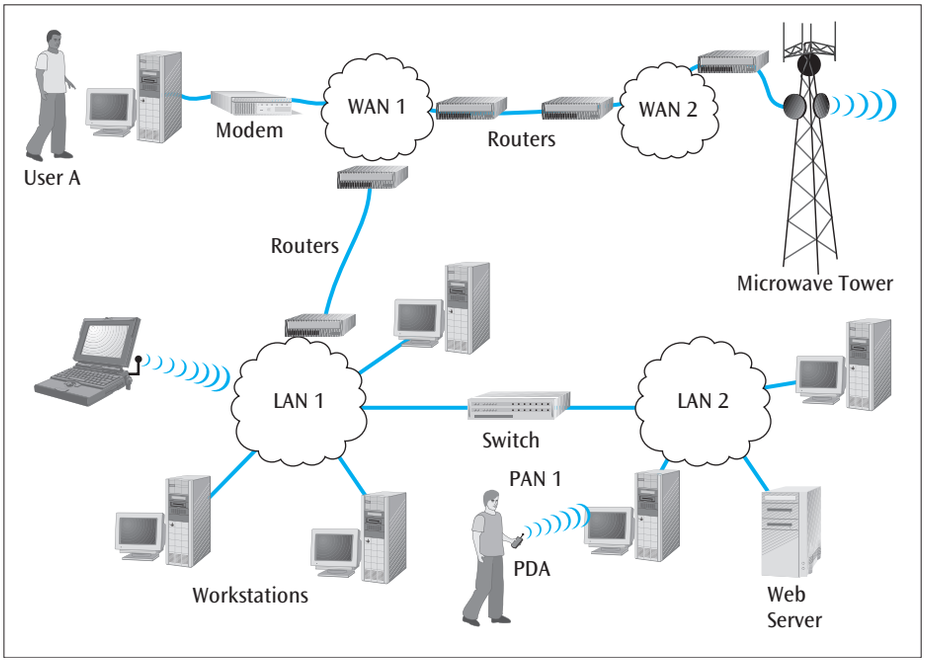

Figure 1-1 An overall view of the interconnection between different types of networks

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**, or **cloud**, 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 Web page 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.

COMMUNICATIONS NETWORKS—BASIC LAYOUTS

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 network systems and their layouts to see how extensive the uses of data communications and computer networks are. The basic layouts that we will examine include:

- Microcomputer-to-local area network
- Microcomputer-to-Internet
- Local area network-to-local area network
- Personal area network-to-workstation
- Local area network-to-metropolitan area network
- Local area network-to-wide area network
- Wide area network-to-wide area network
- Sensor-to-local area network
- Satellite and microwave
- Cell phones
- Terminal/microcomputer-to-mainframe computer

Microcomputer-to-local area network layouts

Perhaps the most common network layout today, the microcomputer-to-local area network layout is found in virtually every business and academic environment—and even in many homes. The microcomputer—which also is commonly known as the personal computer, PC, desktop computer, laptop computer, notebook, netbook, or workstation—began to emerge in the late 1970s and early 1980s. (For the sake of consistency, we will use the older term "microcomputer" to signify any type of computer based on a microprocessor, disk drive, and memory.) The LAN, as we shall see in Chapter Seven, is an excellent tool for providing a gateway to other networks, software, and peripherals. In some LANs, the data set that accompanies application software resides on a central computer called a server. Using microcomputers connected to a LAN, end users can request and download the data set, then execute the application on their computers. If users wish to print documents on a high-quality network printer, the LAN contains the network software necessary to route their print requests to the appropriate printer. If users wish to access their e-mail from the corporate 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 1-2 shows a diagram of this type of microcomputer-to-local area network layout.

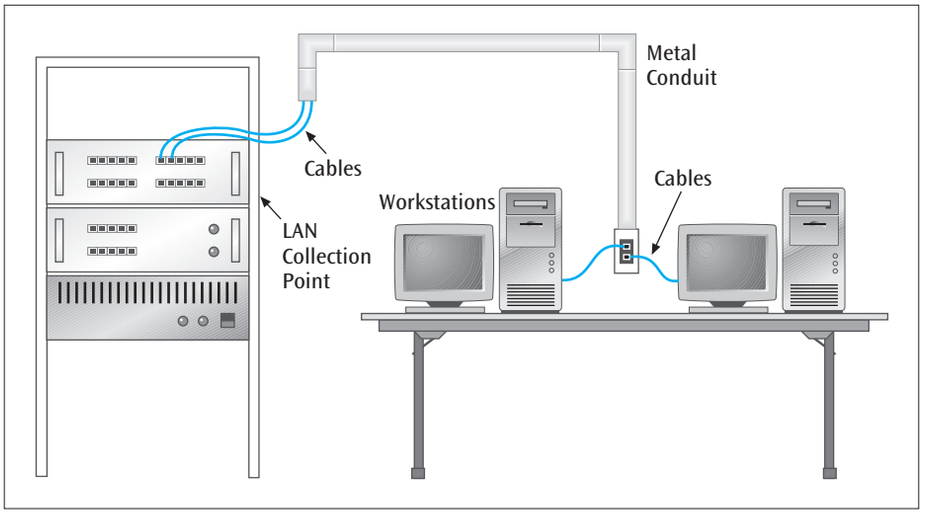

Figure 1-2 A microcomputer lab, showing the cabling that exits from the back of a workstation and runs to a LAN collection point

One common form of microcomputer-to-local area network layout in the business 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 or a request to retrieve an e-mail message from an e-mail server. This request travels across the system to a server that contains a large repository of data and/or programs. The server fills the request and returns the results to the client, displaying the results on the client's monitor.

A type of microcomputer-to-local area network layout that continues to grow in popularity is the wireless layout. A user sitting at a workstation or laptop uses wireless communications to send and receive data to and from a wireless access point. This access point is connected to the local area network and basically serves as the "bridge" between the wireless user device and the wired network. Although this setup uses radio frequency transmissions, we still consider it a microcomputer-to-local area network layout.

Microcomputer-to-Internet layouts

With the explosive growth of the Internet and the desire of users to connect to the Internet from home (either for pleasure or work-related reasons), the microcomputer-to-Internet layout continues to grow steadily. Originally, most home users connected 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). (The connections do not actually achieve 56 kbps, but that is a discussion we will have in Chapter Eleven.) No longer is the dial-up modem the most often used layout. 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. All of these telecommunications services will be examined in more detail in Chapter Eleven. (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.)

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 1-3 shows a typical microcomputer-to-Internet layout.

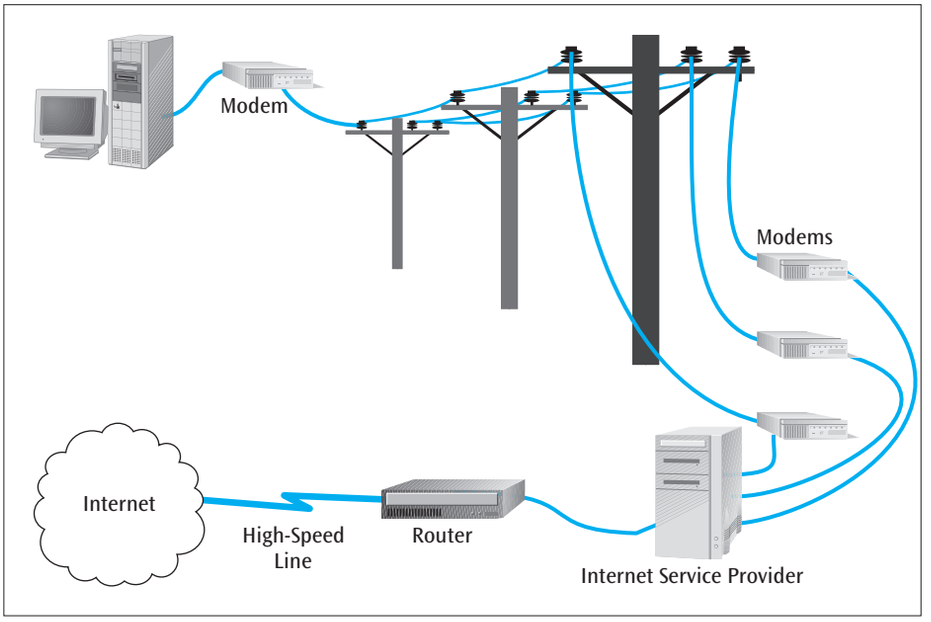

Figure 1-3 A microcomputer/workstation sending data over a DSL line to an Internet service provider and onto the Internet

Local area network-to-local area network layouts

Because the local area network is a standard in business and academic environments, it should come as no surprise that many organizations need the services of multiple local area networks and that it may be necessary for these LANs to communicate with each other. For example, a company may want the local area network that supports its research department to share an expensive color

laser printer with its marketing 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 devices that usually connect two or more LANs are the switch and router.

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. Devices 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 1-4 provides an example of two LANs connected by a switch.

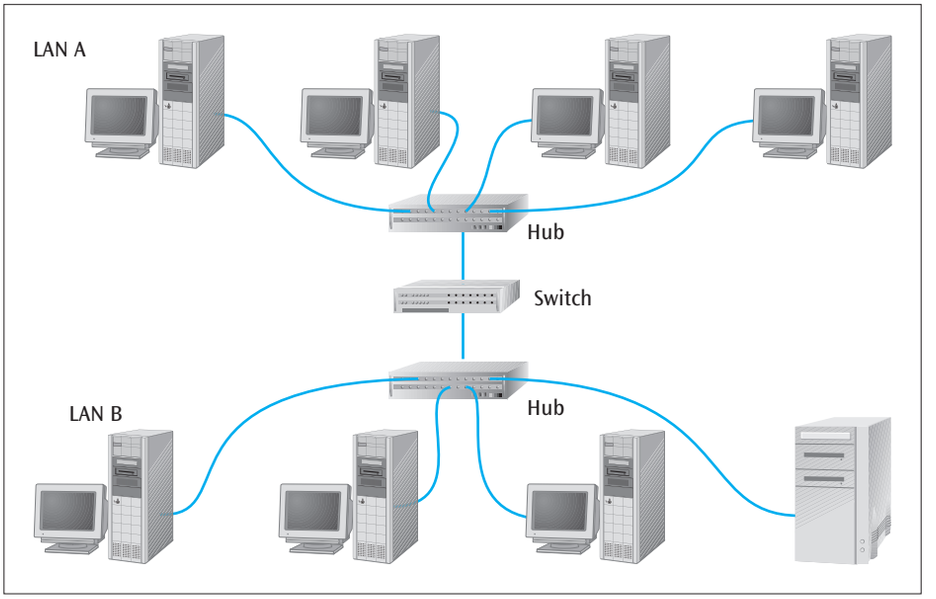

Figure 1-4 Two local area networks connected by a switch

Personal area network-to-workstation layouts

The personal area network was created in the late 1990s and is one of the newer forms of computer networks. Using wireless transmissions with devices such as personal digital assistants (PDAs), laptop computers, and portable music players, an individual can transfer voice, data, and music from handheld devices to other devices such as microcomputer workstations (see Figure 1-5). Likewise, a user can download data from a workstation to one of these portable devices. For example, a user might use a PDA to record notes during a meeting. Once the meeting is over, the user can transmit the notes over a wireless connection from the PDA to his or her workstation. The workstation then runs a word processor to clean up the notes, and the formatted notes are uploaded to a local area network for corporate dissemination. Another example is the hands-free Bluetooth-enabled connection that people hang on their ear so they can converse with their cell phone without placing the cell phone up to their ear. It is also very common now to transfer digital photos and videos from cameras to microcomputers using short-range, wireless signals.

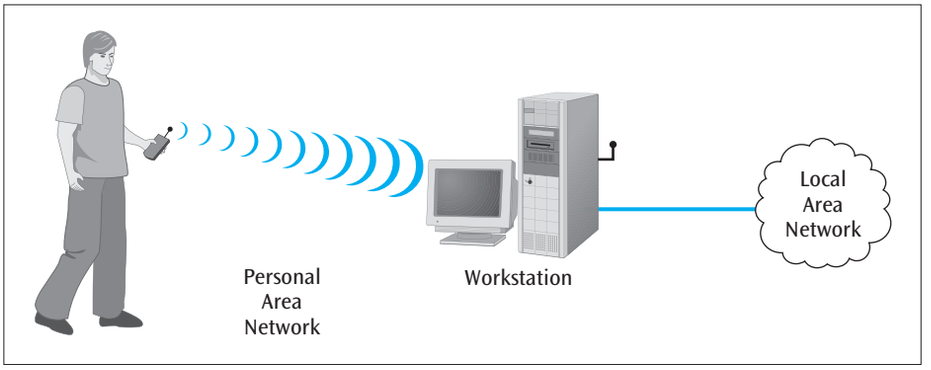

Figure 1-5 A user transferring data from a personal digital assistant via a personal area network to a workstation attached to a local area network

Local area network-to-metropolitan area network layouts

Toward the end of the twentieth century, a new form of network appeared that interconnected businesses within a metropolitan area. Typically, this interconnection uses only fiber-optic links at extremely high speeds. These new networks are labeled metropolitan area networks. A metropolitan area network is a high-speed network that interconnects multiple sites within a close geographic region, such as a large urban area. For example, businesses that require a high-speed connection to their Internet service providers might use a metropolitan area network for interconnection (see Figure 1-6). As we shall see in more detail in Chapter Nine, metropolitan area networks are a cross between local area networks and wide area networks. They can transfer data at fast LAN speeds but over larger geographic regions than typically associated with a local area network.

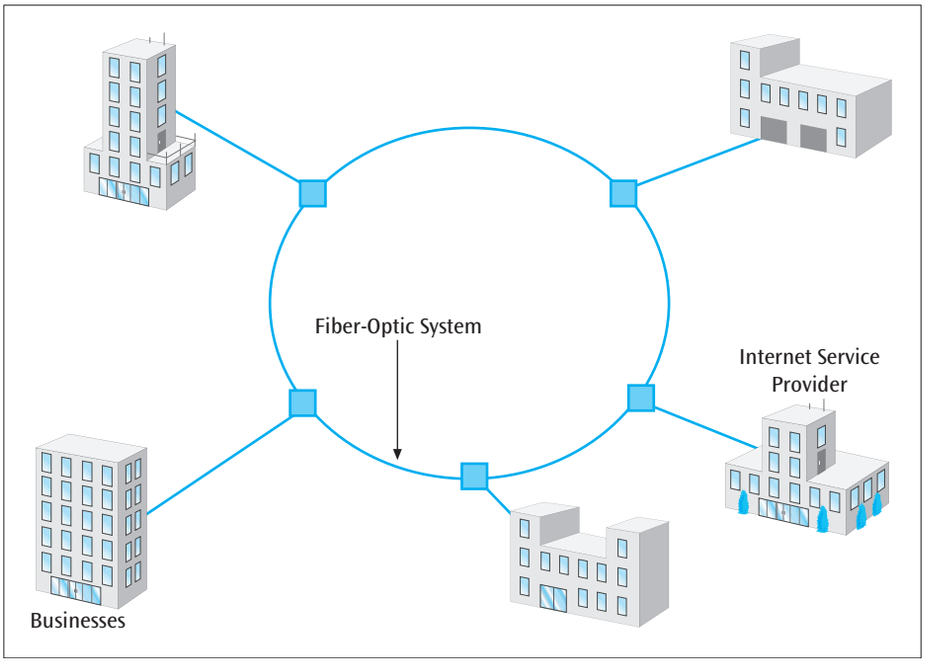

Figure 1-6 Businesses interconnected within a large metropolitan area via a metropolitan area network

Local area network-to-wide area network layouts

You have already seen that the local area network is commonly found in business and academic environments. If a user working at a microcomputer connected to a local area network wishes to access the Internet (a wide area