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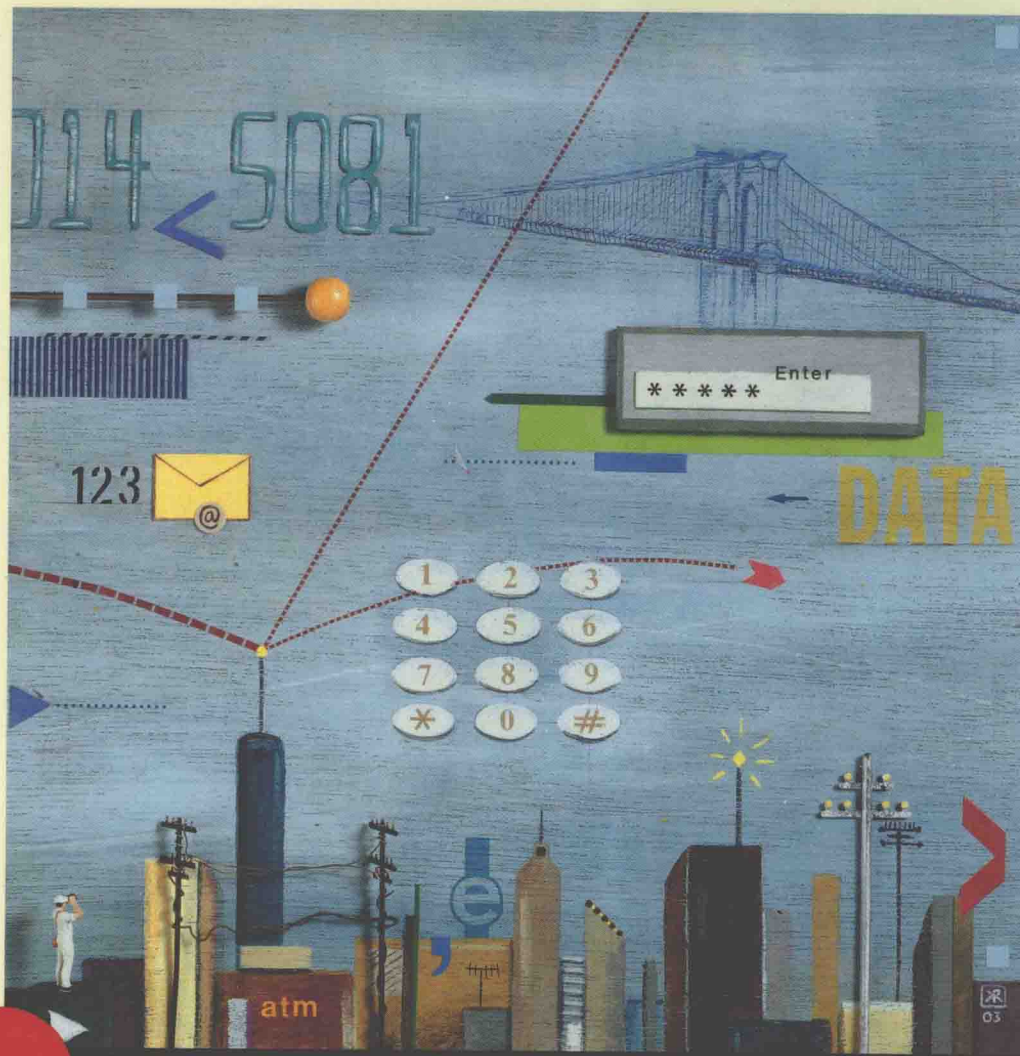
THIRD EDITION

Data Communications & Computer Networks

A BUSINESS USER'S APPROACH

Curt M. White



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Data Communications and Computer Networks

A Business User's Approach

Third Edition

Curt M. White
DePaul University

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Rakefet Kenaan

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

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 used to occupy the time of only engineers and technicians, but it now involves business managers, end users, programmers, and just about anyone you can imagine who might use a telephone or computer! Because of this, *Data Communications and Computer Networks: A Business User's Approach, Third Edition* maintains its 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, Third 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. 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 third 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 data communications will be less intimidating to them. To facilitate this understanding, this 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 an even lesser use of computer jargon.

Balance between the Technical and the Practical

As in the very successful first edition, a major objective in *Data Communications and Computer Networks, Third 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. If a reader does not have time to explore this technical information, the reader 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:

- Latest wireless technologies
- Modern multiplexing techniques, such as discrete multitone and wavelength division multiplexing
- Switching in local area networks
- Advanced encryption standards and digital signatures
- Frame relay and Asynchronous Transfer Mode
- Cable modems
- Current LAN network operating systems (Novell NetWare 6 and Windows 2003)
- Internet2 and IPv6
- Local Multipoint Distribution Service and Multichannel Multipoint Distribution Service

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.

Since it is impossible for a textbook to keep abreast of the quickly changing field of computer networks, the author has provided a series of Web pages *(http://facweb.cs.depaul.edu/cwhite/Book/ChapterUpdates.htm)* that feature some of the more recent developments in each major area of technology.

Organization

The organization of *Data Communications and Computer Networks, Third Edition* roughly follows that of the OSI model, from the physical layer to the upper layers. In addition, the book has been carefully designed to consist of 14 chapters in order to fit well into a typical 15- or 16-week semester (along with any required exams). While 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 14 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 One, Three, Four, Six, Seven, Eight, Nine, Eleven, Thirteen, and Fourteen. If the focus is on the more technical aspects of computer networks, the instructor might concentrate on Chapters One through Eleven. 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 both 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 the sections valuable. Since these 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 the 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 persons and organizations, every attempt was made to make the hypothetical scenarios as representative as possible of situations and issues found in 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 if 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 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.

CD-ROM

An interactive CD-ROM containing visual demonstrations of many key data communications and networking concepts accompanies this text. Whenever a concept being discussed in the text is also covered in the CD-ROM, the reader is prompted by the text to run a corresponding interactive animation. These prompts appear in the following chapters and direct readers to visual demonstrations of the following concepts:

- Chapter One: Introduction to Computer Networks and Data Communications—Layer encapsulation example
- Chapter Two: Fundamentals of Data and Signals—dB loss and gain example
- Chapter Four: Making Connections—RS-232 example of two modems establishing a connection
- Chapter Five: Multiplexing: Sharing a Medium—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: The Basics—CSMA/CD example with workstations sending packets and collisions happening
- Chapter Eight: Local Area Networks: Internetworking—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 Ten: Introduction to Metropolitan Area Networks and Wide Area Networks—Datagram network sending individual packets; and virtual circuit network first creating a connection then sending packets down a prescribed path
- Chapter Eleven: The Internet—Domain Name System as it tries to find the dotted decimal notation for a given URL

Changes to the Third Edition

In order to keep abreast of the changes in computer networks and data communications, this third 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 the many types of computer network configurations, along with many of the major concepts that will be discussed in the following chapters, such as the OSI and Internet models. Some network configurations have been simplified and combined, and terminology for the TCP/IP Protocol Suite has been uniformly incorporated.

Chapter Two, Fundamentals of Data and Signals, covers basic concepts that are critical to the proper understanding of all computer networks and data communications. New sections on Unicode and bipolar encoding were added, while more detailed explanations of quantization and Nyquist and Shannon calculations were provided.

Chapter Three, Conducted and Wireless Media, introduces the different types of media for transmitting data. New sections on free space optics, ultra-wideband transmissions, and Wi-Fi local area networks were added, and the section on cellular telephones was updated to include EDGE, GPRS, and 1xRTT technologies. The discussion of Categories 1, 2 and 4 unshielded twisted pair was reduced. The section on media selection criteria was updated to include right-of-way issues.

Chapter Four, Making Connections, discusses how a connection or interface is created between two communicating devices, such as a computer and a modem. New topics introduced in this chapter include RAID, SCSI, iSCSI, InfiniBand, and Fibre Channel.

Chapter Five, Multiplexing: Sharing a Medium, describes how two or more devices can share a single medium. The discussion on wavelength division multiplexing was enhanced to include the distinctions between dense and coarse wavelength division multiplexing, and a new section on discrete multitone as well as a new Details section on Optical Spatial Division Multiplexing, Orthogonal Frequency Division Multiplexing, and Optical Time Division Multiplexing were added.

Chapter Six, Errors, Error Detection, and Error Control, explains the actions that can take place when a data transmission produces an error. Additions include improved ARQ error control examples.

Chapter Seven, Local Area Networks: The Basics, is devoted to the basic concepts of local area networks, including the most popular topologies and systems. New material includes advanced coverage of wireless local area networks and CSMA/CA, as well as 10 Gbps local area networks. The coverage of token ring networks was reduced, and the coverage of 100VG-AnyLAN was eliminated.

Chapter Eight, Local Area Networks: Internetworking, investigates how local area networks connect internally and to one another, and includes updated and expanded material on LAN switches, routers, and virtual LANs, as well as new topics like server appliances and server blades. The discussion on using a bridge to interconnect networks was trimmed, and a discussion on the more modern device, the switch, was added.

Chapter Nine, Local Area Networks: Software and Support Systems, discusses the various network operating systems and other network software, with new material on Novell NetWare version 6 and updated material on Windows 2003.

Chapter Ten, Introduction to Metropolitan Area Networks and Wide Area Networks, contains a rewrite of the discussion on Dijkstra's least-cost algorithm (which should now be much more clear), and the chapter no longer uses the term "subnet" to describe the underlying construction of a wide area network. Two new Details sections, on RIP and OSPF routing protocols, were added.

Chapter Eleven, The Internet, delves into the details of the Internet, including TCP, IP, DNS, and the World Wide Web. The discussion on the topic of Voice over IP was expanded to include the concepts of SIP and ENUM, and a new section on Instant Messaging was added.

Chapter Twelve, Telecommunications Systems, provides a detailed introduction to the area of telecommunications, with updated material on DSL, frame relay, and Asynchronous Transfer Mode.

Chapter Thirteen, Network Security, covers the current trends in network security. The entire chapter was reorganized into a more logical fashion, covering the latest concepts in standard system attacks, physical protection, controlling access, securing data, and securing communications. New topics such as steganography and wireless security were introduced.

Chapter Fourteen, 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. The section on the systems development life cycle was trimmed, while the section on network diagnostic tools was updated.

In addition to the changes made to each chapter's topical coverage, all chapters saw an increase in end-of-chapter material, including newly added exercises, Thinking Outside the Box exercises, and projects. Also, most chapters contain at least two In Action examples—many of which have been updated—that pull together the chapter concepts using real-life examples.

Teaching Supplements

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 Course Technology Web site (*www.course.com*).

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.

Distance Learning—Course Technology is proud to present online courses in WebCT and Blackboard, to provide the most complete and dynamic learning experience possible. When you add online content to one of your courses, you're adding a lot: Practice Tests, Syllabi, Case Projects, and more. Most of all, you are providing a gateway to the twenty-first century's most important information resource. We hope you will make the most of your course, both online and offline. For more information on how to bring distance learning to your course, contact your local Course Technology sales representative.

Finally, the author's Web page *(http://facweb.cs.depaul.edu/cwhite/Book/ChapterUpdates.htm)* contains recent information on topics that were introduced in the text. Since the material in this field evolves so quickly, the author's Web pages can be used to keep the reader up to date.

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 supportive and one of the best teams an author could hope to work with: Jennifer Locke, Managing Editor; Mirella Misiaszek, Associate Product Manager; and Daphne Barbas, Production Editor. Another person who is amazingly vital to the production of a textbook is the development editor, Saher Alam.

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Curt M. White

Brief Contents

Contents