ALAN DENNIS

NETWORKING

IN THE INTERNET AGE

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ALAN DENNIS
Indiana University

JOHN WILEY & SONS, INC.

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PRODUCTION MANAGEMENT SERVICES	Hermitage Publishing Services
COVER PHOTOGRAPH	Steven Hunt/The Image Bank

This book was set in Times Roman by Hermitage Publishing Services and printed and bound by Donnelley Crawfordsville. The cover was printed by Phoenix Color Corporation.

This book is printed on acid-free paper. ♾

ISBN: 0-471-20189-8

Printed in the United States of America

10 9 8 7 6 5 4 3 2

To Eileen and Alec

ABOUT THE AUTHOR

Alan Dennis is a Professor of Information Systems in the Kelley School of Business at Indiana University, and holds the John T. Chambers Chair in Internet Systems. The Chambers Chair was established to honor John Chambers, president and chief executive officer of Cisco Systems Inc., the worldwide leader in networking technologies for the Internet.

Prior to joining Indiana University, Professor Dennis spent nine years at The University of Georgia, where he won Richard B. Russell Award for Excellence in Undergraduate Teaching. Professor Dennis has a bachelor's degree in computer science from Acadia University in Nova Scotia, Canada and an MBA from Queen's University in Ontario, Canada. His Ph.D. in management information systems is from the University of Arizona. Prior to entering the Arizona doctoral program, he spent three years on the faculty of the Queen's School of Business.

Professor Dennis has extensive experience in the development and application of groupware and Internet technologies, and developed a Web-based groupware package called Consensus @nyWARE,™ now owned by SoftBicycle Corporation. He has won seven awards for theoretical and applied research, and has published more than 80 business and research articles, including those in *Management Science, MIS Quarterly, Information Systems Research, Academy of Management Journal, Organizational Behavior and Human Decision Making, Journal of Applied Psychology, Communications of the ACM,* and *IEEE Transactions on Systems, Man, and Cybernetics.* His first book, co-authored with his wife Eileen, was *Getting Started with Microcomputers,* published in 1986.

Professor Dennis is also an author (along with Barbara Wixom of the University of Virginia) of *Systems Analysis and Design: An Applied Approach, Systems Analysis and Design: An Object-oriented Approach with UML* (with Barbara Wixom of the University of Virginia and David Tegarden of Virginia Tech), and *Business Data Communications and Networking* (with Jerry FitzGerald), all available from Wiley. Dennis is the co-chair of the Internet Technologies Track of the Hawaii International Conference on System Sciences. He has served as a consultant to BellSouth, Boeing, IBM, Hughes Missile Systems, the U.S. Department of Defense, and the Australian Army.

PREFACE

Over the past years, many fundamental changes have occurred in data communications and networking that will shape the future for decades to come. Networking applications such as the Internet and World Wide Web have exploded into the business world. High speed modems providing megabit data rates over regular telephone lines are becoming common. New local area network (LAN) and backbone technologies providing gigabit speeds are now available, with wireless technologies becoming widely accepted. Metropolitan area network (MAN) and wide area network (WAN) technologies providing terabit and petabit speeds are on the horizon. The integration of voice and data communication is moving forward rapidly.

The Internet and the technologies it uses (e.g., TCP/IP) have become a unifying force in networking. The Internet is *the* standard for the design and interconnection of networks today; it is the glue that holds quite literally millions of networks together. At the same time as we have seen the rise of the Internet, we have also seen Ethernet become the dominant technology in LANs and backbones. The simplicity and elegance of Ethernet, coupled with its widespread adoption, has driven most competing technologies from the marketplace. As the Internet has become *the* standard for designing and interconnecting networks, Ethernet has become *the* standard for network hardware for most businesses, universities, and even homes. Wireless Ethernet now offers even greater potential, as does the movement of Ethernet into MANs and WANs.

Perhaps the most important change over the past decade has been the recognition of the strategic importance of networking in both the public and private sector. Today, almost all computers are networked. As we move into the 21st century, we now realize that the importance of the network has surpassed the importance of the computer.

Purpose of This Book

The goal of this book is to provide a fundamental understanding of how networks operate in the Internet age.

- It provides a solid conceptual and practical understanding of how current network technologies operate (including those not yet in widespread commercial production); it deliberately omits several older legacy technologies (e.g., token ring, SNA).
- It provides frameworks to analyze the benefits and limitations of these technologies to help managers choose among them, and—most importantly—to analyze the benefits and limitations of future technologies not yet developed.

- It provides some insight in to the design, management, and security aspects of these networks.

This book has two intended audiences. First and foremost, it is a university textbook. Each chapter introduces, describes, and then summarizes fundamental concepts and applications. Management focus boxes highlight key issues and describe how networks are actually being used today. Technical focus boxes highlight key technical issues and provide additional detail. Minicases at the end of each chapter provide the opportunity to apply these technical and management concepts. Moreover, the text is accompanied by a detailed *Instructor's Manual,* that provides additional background information, teaching tips, and sources of material for student exercises, assignments, and exams. Finally, our Web page (at www.wiley.com/college/dennis) will continue to update the book.

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

Overview of the Book

The book begins with a summary of the history of networks and then turns to the fundamental network model that forms the foundation for much of networking: the OSI model. The OSI model is the primary organizing model for virtually all of networking today, and is used as the organizing theme for this book.

Chapter 2 starts at the top of the OSI model by examining the application layers. This chapter explains application architectures (e.g., client server) and how the Web, e-mail, and other Internet applications work.

Chapter 3 moves to the next set of layers in the OSI model, the Internetworking layers (Transport and Network). This chapter explains what these layers do, with a focus on TCP/IP. At the end of this chapter, you should have a solid understanding of how the Internet works.

The next chapters (3-8) examine the hardware layers (data link and physical) for each basic type of network: local area networks, backbone networks, metropolitan and wide area networks, the Internet, and wireless local area networks. Each chapter focuses on the dominant technologies used in these types of networks, and presents a framework for analyzing their performance that can be used to understand the benefits and limitations of today's technologies, as well as future technologies that have not yet been developed.

The final chapters (9-11) examine management aspects of networking, including network design, network security, and network management.

Supplements

The text is accompanied by several supplements for instructors:

- An Instructor's Manual prepared by Tim Kelly of Robert Morris University, provides additional background information, teaching tips, war stories, answers to the

end of chapter questions, and sources of material for student exercises and assignments.

- A Test Bank, prepared by Mary Burns of the University of South Florida, Sarasota, provides approximately 80 test questions for each chapter in multiple choice, true/false, and short answer formats. A computerized version of the test bank will also be available.
- PowerPoint slides, created by Gene Mesher of California State University, Sacramento, provide full color lecture notes that highlight key concepts and figures from the text.
- Web Resources, created by Michael Much of Hennepin Technical College, provide instructors and students with weblinks to resources that can help to reinforce and build upon the major concepts in each chapter. See www.wiley.com/college/dennis.

Acknowledgments

My thanks to the many people who contributed to the preparation of this book. I am indebted to the staff at John Wiley & Sons for their support, including: Beth Lang Golub, Information Systems editor; Cynthia Snyder, assistant editor; Lorraina Raccuia, editorial assistant; Norine Pigliucci, senior production editor; Harry Nolan, senior designer; and Gitti Lindner, marketing manager.

I would also like to thank the reviewers for their assistance, often under short deadlines:

John Griffin, Weber State University
Brian Janz, University of Memphis
William Hartman, Nova Southeastern University
Gene Mesher, California State University, Sacramento
Ron Pike, California State University, Chico

And finally, thanks to my friends at Cisco for their advice and support:

John Chambers
John Morgridge
Craig Smythe
Mike Snively
Scott Sprinkle

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PHOTO CREDIT LIST

Chapter 2

Page 57: Adrian Weinbrecht/Stone.

Chapter 4

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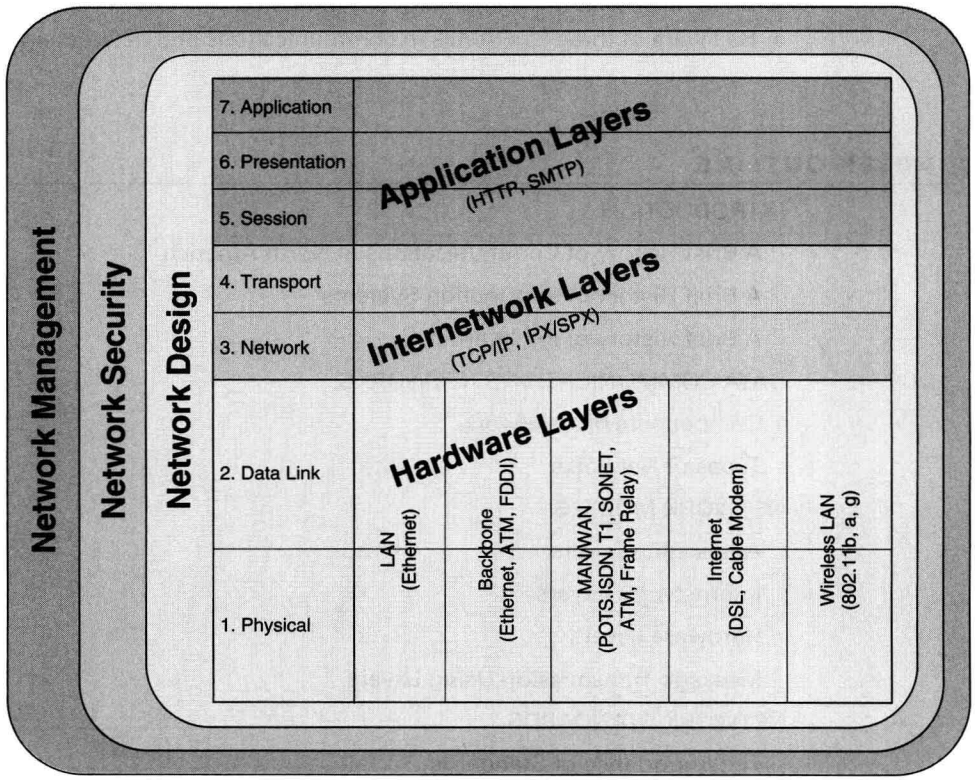
CHAPTER 1

INTRODUCTION TO DATA COMMUNICATIONS



THIS CHAPTER introduces the basic concepts of data communications. It begins by describing why it is important to study data communications and how the invention of the telephone, the computer, and the Internet have transformed the way we communicate. Next, the basic types and components of a data communications network are discussed.

The importance of a network model based on layers and the importance of network standards are examined. The chapter concludes with an overview of three key trends in the future of networking.

OBJECTIVES

- Be aware of the history of communications, information systems, and the Internet
- Be aware of the applications of data communications networks
- Be familiar with the major components of and types of networks
- Understand the role of network layers
- Be familiar with the role of network standards
- Be aware of three key trends in communications and networking

CHAPTER OUTLINE

INTRODUCTION

Over the past few years, it has become clear that world has changed forever. We are now in the information age — the second Industrial Revolution, according to John Chambers, CEO of Cisco, one of the world's leading data communications and networking technology companies. The first Industrial Revolution revolutionized the way people worked by introducing machines and new organizational forms. New companies and industries emerged and old ones died off.

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

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

One of the problems in studying a global phenomenon lies in explaining the different political and regulatory issues that have evolved and currently exist in different parts of the world. Rather than attempt to explain the different paths taken by different countries, we have chosen simplicity instead. While we retain a global focus on technology and its busi-

MANAGEMENT FOCUS 1-1

CAREER OPPORTUNITIES

It's a great time to be in information technology. The technology-fueled new economy has dramatically increased the demand for skilled IT professionals. The U.S. Bureau of Labor Statistics estimates that there are currently 80,000 IT jobs that are unfilled. IT salaries have responded, and have risen rapidly. Annual starting salaries for our undergraduates at Indiana University range from $40,000 to $50,000. While all areas of IT have shown rapid growth, the fastest salary growth has been for those with skills in Internet development, networking, and telecommunications. People with a few years of experience in these areas can make $65,000 to $80,000—not counting bonuses.

The demand for networking expertise is growing for two reasons. First, the Internet and communication deregulation has significantly changed how businesses operate and has spawned thousands of small startup companies. Second, there has been a host of new hardware and software innovations that have significantly changed the way networking is done.

These trends and the shortage of qualified network experts has also led to the rise in certification. Most large vendors of network technologies such as Microsoft, Cisco, and Novell provide certification processes (usually a series of courses and formal exams) so that individuals can document their knowledge. Certified network professionals often earn $10,000 to $20,000 more than similarly skilled uncertified professionals—provided they continue to learn and maintain their certification as new technologies emerge.