Cisco Systems

FIRST-STEP SERIES

Computer Networking first-step

Your first step into the world of computer networking

- No experience required
- Includes clear and easily understood explanations
- Makes learning easy

Wendell Odom

The best-selling introductory networking author

ciscopress.com

Computer Networking first-step

Wendell Odom

Cisco Press
800 East 96th Street
Indianapolis, IN 46240

Computer Networking first-step

Wendell Odom

Copyright© 2004 Cisco Systems, Inc.

Published by:
Cisco Press
800 East 96th Street
Indianapolis, IN 46240 USA

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without written permission from the publisher, except for the inclusion of brief quotations in a review.

Printed in the United States of America 10 11 12 13

Tenth Printing September 2011

Library of Congress Cataloging-in-Publication Number: 2003108109

ISBN: 1-58720-101-1

Warning and Disclaimer

This book is designed to provide information about computer networking. Every effort has been made to make this book as complete and as accurate as possible, but no warranty or fitness is implied.

The information is provided on an "as is" basis. The author, Cisco Press, and Cisco Systems, Inc., shall have neither liability nor responsibility to any person or entity with respect to any loss or damages arising from the information contained in this book or from the use of the discs or programs that may accompany it.

The opinions expressed in this book belong to the author and are not necessarily those of Cisco Systems, Inc.

Publisher
John Wait

Editor-in-Chief
John Kane

Executive Editor
Brett Bartow

Cisco Representative
Anthony Wolfenden

Cisco Press Program Manager
Nannette M. Noble

Production Manager
Patrick Kanouse

Development Editor
Dayna Isley

Project Editor
San Dee Phillips

Copy Editor
Karen A. Gill

Technical Editors
Blair Buchanan, Ron Kovac, Scott Van de Houten, Paul Negron

Team Coordinator
Tammi Barnett

Book and Cover Designer
Louisa Adair

Compositor
Mark Shirar

Indexer
Tim Wright

Trademark Acknowledgments

All terms mentioned in this book that are known to be trademarks or service marks have been appropriately capitalized. Cisco Press or Cisco Systems, Inc., cannot attest to the accuracy of this information. Use of a term in this book should not be regarded as affecting the validity of any trademark or service mark.

Corporate and Government Sales

Cisco Press offers excellent discounts on this book when ordered in quantity for bulk purchases or special sales.

For more information please contact: U.S. Corporate and Government Sales 1-800-382-3419 corpsales@pearsontechgroup.com

For sales outside the U.S. please contact: International Sales international@pearsoned.com

Feedback Information

At Cisco Press, our goal is to create in-depth technical books of the highest quality and value. Each book is crafted with care and precision, undergoing rigorous development that involves the unique expertise of members from the professional technical community.

Readers' feedback is a natural continuation of this process. If you have any comments regarding how we could improve the quality of this book, or otherwise alter it to better suit your needs, you can contact us through e-mail at feedback@ciscopress.com. Please make sure to include the book title and ISBN in your message.

We greatly appreciate your assistance.

Corporate Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
www.cisco.com
Tel: 408 526-4000
800 553-NETS (6387)
Fax: 408 526-4100

European Headquarters
Cisco Systems International BV
Haarlerbergpark
Haarlerbergweg 13-19
1101 CH Amsterdam
The Netherlands
www-europe.cisco.com
Tel: 31 0 20 357 1000
Fax: 31 0 20 357 1100

Americas Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
www.cisco.com
Tel: 408 526-7660
Fax: 408 527-0883

Asia Pacific Headquarters
Cisco Systems, Inc.
Capital Tower
168 Robinson Road
#22-01 to #29-01
Singapore 068912
www.cisco.com
Tel: +65 6317 7777
Fax: +65 6317 7799

Cisco Systems has more than 200 offices in the following countries and regions. Addresses, phone numbers, and fax numbers are listed on the **Cisco.com Web site at www.cisco.com/go/offices.**

Argentina • Australia • Austria • Belgium • Brazil • Bulgaria • Canada • Chile • China PRC • Colombia • Costa Rica • Croatia • Czech Republic Denmark • Dubai, UAE • Finland • France • Germany • Greece • Hong Kong SAR • Hungary • India • Indonesia • Ireland • Israel • Italy Japan • Korea • Luxembourg • Malaysia • Mexico • The Netherlands • New Zealand • Norway • Peru • Philippines • Poland • Portugal Puerto Rico • Romania • Russia • Saudi Arabia • Scotland • Singapore • Slovakia • Slovenia • South Africa • Spain • Sweden Switzerland • Taiwan • Thailand • Turkey • Ukraine • United Kingdom • United States • Venezuela • Vietnam • Zimbabwe

Copyright © 2003 Cisco Systems, Inc. All rights reserved. CCIP, CCSP, the Cisco Arrow logo, the Cisco *Powered* Network mark, the Cisco Systems Verified logo, Cisco Unity, Follow Me Browsing, FormShare, iQ Net Readiness Scorecard, Networking Academy, and ScriptShare are trademarks of Cisco Systems, Inc.; Changing the Way We Work, Live, Play, and Learn, The Fastest Way to Increase Your Internet Quotient, and iQuick Study are service marks of Cisco Systems, Inc.; and Aironet, ASIST, BPX, Catalyst, CCDA, CCDP, CCIE, CCNA, CCNP, Cisco, the Cisco Certified Internetwork Expert logo, Cisco IOS, the Cisco IOS logo, Cisco Press, Cisco Systems, Cisco Systems Capital, the Cisco Systems logo, Empowering the Internet Generation, Enterprise/Solver, EtherChannel, EtherSwitch, Fast Step, GigaStack, Internet Quotient, IOS, IP/TV, iQ Expertise, the iQ logo, LightStream, MGX, MICA, the Networkers logo, Network Registrar, *Packet*, PIX, Post-Routing, Pre-Routing, RateMUX, Registrar, SlideCast, SMARTnet, StrataView Plus, Stratm, SwitchProbe, TeleRouter, TransPath, and VCO are registered trademarks of Cisco Systems, Inc. and/or its affiliates in the U.S. and certain other countries.

All other trademarks mentioned in this document or Web site are the property of their respective owners. The use of the word partner does not imply a partnership relationship between Cisco and any other company. (0303R)

Printed in the USA

About the Author

Wendell Odom, CCIE No. 1624, is a senior instructor for Skyline Advanced Technology Services (www.skylinecomputer.com), where he teaches a wide variety of introductory and advanced-level Cisco Systems networking courses. He has been in the networking industry for more than 20 years, working in both presale and postsale technical roles, as well as teaching networking concepts to beginners and CCIE candidates alike. Wendell is the author of numerous best-selling Cisco Press exam study guides, several of which focus on the Cisco Systems introductory-level certification: CCNA. His most recent works include *CCNA INTRO Exam Certification Guide*, *CCNA ICND Exam Certification Guide*, and *Cisco DQOS Exam Certification Guide*.

About the Technical Reviewers

Blair Buchanan's career in telecommunications has spanned nearly 30 years, during which time he has written communication software, participated in ISO standards development, and established a successful consultancy. Blair's involvement with Cisco began in 1991 when he designed his first router-based internetwork for the Canadian Department of National Defense. Shortly after, with the help of Cisco Canada, he became the world's first Learning Partner-based Cisco instructor. That company, Protocoles Standards de Communications (PSC) later merged with the U.S. firm Protocol Interface (PI) to form GeoTrain, which was acquired by Global Knowledge in 1999.

In April 1996, and on his first attempt, Blair earned his CCIE certification and became the 403rd CCIE, No. 1427. Since then, he has designed and audited internetworks for a variety of clients in both the enterprise and service provider sectors. His clients include Nortel Networks, the Government of Canada, Bell Canada, the Government of British Columbia, the Bank of Canada, PSINet, and Mouvement Desjardins.

Dr. Ron Kovac is currently employed with the Center for Information and Communication Sciences at Ball State University in Muncie, Indiana, as a full professor. The Center prepares graduate students in the field of telecommunications. Previous to this, Dr. Kovac was the telecommunication manager for the State of New York and an executive director for a large computing center located on the east coast. Dr. Kovac's previous studies included electrical engineering and education. Dr. Kovac has numerous publications and has done consulting in both the education and telecommunications fields, speaks worldwide on issues related to telecommunications, and holds numerous certifications, including the CCNA, CCAI, and the almost complete CCNP.

Paul Negron is a senior instructor with Skyline Advanced Technology Services, teaching authorized Cisco training courses to a wide range of audiences. Paul teaches the Implementing Cisco QoS course and advanced courses on topics such as BGP, MPLS, high-performance routing, and other CCNP courses.

Scott Van de Houten, CCIE No. 1640, is a distinguished systems engineer for the Technical Operations Group at Cisco Systems. He is currently a technical lead for the Enterprise Routing and Switching Technology Leadership Program. His responsibilities include developing customer requirements for the product teams and customer technical consulting. Scott has been with Cisco for 11 years and has worked as a network engineer for 17 years.

Dedications

For Fay and Raymond, my favorite parents, out of all the parents I've ever met.

Acknowledgments

The process of creating a technical book requires a lot of hard work from a lot of people. I am always amazed at how much the various editing processes improve what I first submit as the text for a book. I'd like to take this opportunity to thank some of the people who have had a big hand in putting this book together.

For this book, I was fortunate to have a great team of technical editors. A handful of technical folks get the opportunity to read over the text and the figures, and make comments. Their primary job is to help make sure that the book is technically accurate, but the good ones also make sure that the topics flow well together and would make sense to the reader. While they all did the core job well, in particular, my buddy Paul Negron, also from Skyline Advanced Technology Services, edited the book, and did a particularly good and gracious job of pointing out when I should change the flow between topics. Scott Van de Houten gets the award for the best tech editor at finding my technical mistakes, while offering lots of good analogies that I added to the text. Blair Buchanan did a nice job keeping the text appropriate for audiences outside the United States. And Dr. Ron Kovac excelled at watching the tone, thinking hard about the audience for the book at each step, and really helping the overall flow of topics.

This book posed a unique challenge compared with previous books because it is intended for people who have no direct experience with networking. Dayna Isley, who worked as the development editor for the book, not only did an excellent job managing the entire book-writing process, but she also did a great job helping me find the right depth for the topics in the book. Dayna provided countless great suggestions on the approach and tone of the book.

Brett Bartow worked with me on this book from initial concept, including working through refining the First-Step Series goals as well as the goals for this book. As always, Brett did a great job dealing with the full life cycle of what it takes to get the book done right.

Typically, I'm directly involved with the development editor, executive editor, and the technical editors. However, lots of people work behind the scenes—at least behind the scenes to me—to help to make the book better. Karen Gill did the copyediting, cleaning up some of the wording and flow with a fresh set of eyes. Patrick Kanouse's production team gets involved in the details of how the book will look on paper, managing the process of getting the book laid out, ready for the printer, and finally into the warehouse. In particular, San Dee Phillips took care of the project-editing tasks, managing the book's progress from completed draft until it was ready for the printer. To the people who made the book come together, thanks very much.

On the personal side, I'd like to acknowledge my lovely wife's contributions to the writing process once again. She's always a steadying force when the writing process gets to me. Thanks again, Doll! Also, no set of acknowledgments of mine would be complete without saying thanks to Jesus Christ, savior, friend, brother, and provider.

Contents at a Glance

Introduction xxii

Part I **Networking Basics** 3

Chapter 1 What Is a Network? 5

Chapter 2 A Network's Reason for Existence 17

Chapter 3 Building a Network: It All Starts with a Plan 37

Part II **Running the Local Department of (Network) Transportation** 63

Chapter 4 How to Build a Local (Network) Roadway 65

Chapter 5 Rules of the Road: How to Use the Local (Network) Roadway 87

Chapter 6 Reducing Congestion and Driving Faster on the Local (Network) Roadway 107

Chapter 7 Adding Local (Network) Roadways for No Extra Money 131

Part III **Shipping and Logistics: Commerce Using the (Network) Roadways** 151

Chapter 8 Shipping Goods over a (Network) Roadway 153

Chapter 9 Choosing Shipping Options When Transporting the Goods over the (Network) Roadway 181

Part IV **Navigating the Roadways to Find the Right Street Address** 205

Chapter 10 Delivering the Goods to the Right Street (IP) Address 207

Chapter 11 Knowing Where to Turn at Each Intersection (Router) 235

Chapter 12 Painting the Road Signs on Your Interstate (Internetwork) 263

Chapter 13 People Like Names, but Computers Like Numbers 279

Part V **Building an Interstate (Inter-LAN) Highway System** 293

Chapter 14 Leasing a (Network) Roadway Between Two Points 295

Chapter 15 Leasing a (Network) Roadway Between Lots of Places 315

Chapter 16 Driving from Home onto the Globally Interconnected (Internet) Roadway 333

Part VI **Securing the Network** 353

Chapter 17 Accepting the Right People and Rejecting the Wrong People 355

Chapter 18 Keeping a Watchful Eye Over Who Drives into Your (Network) Neighborhood 373

Part VII **Appendixes** 391

Appendix A Answers to Chapter Review Questions 393

Appendix B Converting IP Addresses Between Decimal and Binary 435

Glossary 459

Index 497

Contents

Introduction xxii

Part I **Networking Basics** 3

Chapter 1 What Is a Network? 5

No, Really, What Is a Network? 5
- What an Elephant—err, a Network—Looks Like 7
- Three Blind Men—The Server Guy, the Cabling Guy, and the Network Guy 8

Different Types of Traditional Computer Networks 11
- Big Company, Multiple Sites: An Enterprise WAN 11
- Just You and Me and the Whole World—The Internet 13

Chapter Summary 14
Chapter Review Questions 15

Chapter 2 A Network's Reason for Existence 17

Using the Network by Accident 17
Using the Network on Purpose 23
- Web Browsing 25
- Electronic Mail (E-Mail) 28
- Downloading and Transferring Files 32

Chapter Summary 34
Chapter Review Questions 35

Chapter 3 Building a Network: It All Starts with a Plan 37

Conforming to the Rules 37
- Rules, Schmools for Networking 39
- Examples of Good Rules for Networking 40
  - Traveling a Roadway for a Bit to Get a Byte 40
  - Example Rule for Sending the Bits 42
  - Sending the Bits a Packet (Package) at a Time 43
  - What to Do When the Bits Get Bashed 44

The Book(s) of Rules 45
- Proprietary Network Models Prevent Pervasive Population of Networking Devices 47
- Public Network Models Provide Pervasively Popular Networks 49
- How TCP/IP Standards Grow 50

Some Pretty Popular TCP/IP Protocols 50
Transmission Control Protocol (TCP) 50
Internet Protocol (IP) 52
TCP/IP Standards That Aren't TCP/IP Standards 53
Standards for Physical Networking Nearby 54
Standards for Physical Networking Far Away 54
How to Eat an Elephant, TCP/IP Style 56
How to Eat a T-Rex, OSI Style 57
T-Rex Versus the Elephant 58
Chapter Summary 60
Chapter Review Questions 61

Part II Running the Local Department of (Network) Transportation 63

Chapter 4 How to Build a Local (Network) Roadway 65

Driving Bits Across the Network Roadway 65
What's a Local-Area Network? 66
Transmitting Bits Across the Local Network Roadway 67
Driving Bits Across a Wire 69
The Need for a Two-Lane (Network) Road 71
The Equivalent of Asphalt: Cables 72
Painting the Lines on the Road: Connectors 74
Driving in the Right Lane (Pair) on the Road 76
Sharing the Local Roadway: Ethernet Hubs 78
Dirt Roads Versus the DOT 80
Chapter Summary 83
Chapter Review Questions 84

Chapter 5 Rules of the Road: How to Use the Local (Network) Roadway 87

Preparing for a Trip: How to Make Your Car (Data) "Street Legal" 87
LAN-Legal Data: An Ethernet Frame 88
Driving Where I Want and When I Want Is Pretty Cool 90
Why Wrecks (Collisions) Happen on Ethernet 90
How to Avoid Most Wrecks 91
What to Do When a Wreck Happens 92

Stopping at the Destination: What Happens When Someone Comes to See You 94
Are They Coming to Our House or the Neighbor's House? 94
Who Is It, Honey? 97
I Don't Understand a Thing You're Saying 99
Two Standards for Ethernet 101
Chapter Summary 103
Chapter Review Questions 104

Chapter 6 Reducing Congestion and Driving Faster on the Local (Network) Roadway 107

Reducing Congestion by Opening Up More Lanes on Each LAN 107
Hubs: A One-Lane Road 108
Switches: How to Create Dozens of Lanes on the LAN 109
The Perfect Roadway: No Wrecks Allowed! 112
Using Full Duplex: Making the Streets Two Way 114
Switches: The Rest of the Story 117
Painting the Road Signs: Learning MAC Addresses 117
The Forward Versus Filter Decision 118
What to Do When the Road Sign (Address Table) Doesn't List Your Destination 118
How to Go Everywhere at the Same Time 120
Summary of Switch Logic 120
I Feel the Need, the Need for Speed 121
A New, Improved, and Faster Ethernet—Let's Call It Fast Ethernet 121
If Fast Ethernet Is Good, Even Faster Is Better: Gigabit Ethernet 123
Ultra Super-Fast Fast Ethernet: 10 Gigabit Ethernet 124
Summary of Ethernet Speeds 124
A Switch for All Speeds 125
Chapter Summary 127
Chapter Review Questions 128

Chapter 7 Adding Local (Network) Roadways for No Extra Money 131

The Physical Reality Precedes the Virtual Reality 131
Physical LANs: It's All About Broadcasts 132
Master of Your Own (Broadcast) Domain 132
Multiple Physical LANs Require Multiple Switches 134
Virtual (LAN) Reality: One Switch, but Multiple LANs 137
How to Create a Virtual LAN 137
Why You Need More Than One LAN 140
If 100 Devices in a LAN Is Good, 1000 Devices Must Be Better 140
OSI Layer 8 Issues 141
OSI Layer 3 Design Goals 141
Saving Cash 142
Packing Your VLAN's Frames in a Trunk When Leaving the Switch 142
How to Pack Your Trunk for the Trip to the Other Switch 143
Tale of Two Trunking Protocols 146
Chapter Summary 146
Chapter Review Questions 147

Part III **Shipping and Logistics: Commerce Using the (Network) Roadways** 151

Chapter 8 Shipping Goods over a (Network) Roadway 153

Neither Rain, Nor Sleet, Nor Dark of Night: E-Mail 154
Dropping Off and Getting Your (e)Mail 154
Postal Address Versus E-Mail Address 156
Rules, Schmools: Even More Rules? 158
Protocols for Addressing the Envelope Correctly: Internet Message Formats 161
The KISS Principle and SMTP 161
What to Do When You Need a Little POP in Your Network 163
SMTP and POP3 Working Together 164
Building a Centralized Warehouse: File Transfer 166
Warehouse Lingo and Procedures 167
Rules, Schmools for FTP 171

Browsing Around the Internet Shopping Mall: The World Wide Web 172
Rules, Schmools for Web Retailing 174
Buy One, Get a Bunch for Free 175
Chapter Summary 177
Chapter Review Questions 178

Chapter 9 Choosing Shipping Options When Transporting the Goods over the (Network) Roadway 181

"Hello, I'm at Your Service" 182
Full-Service Shipping 184
Shipping Basics: Controlling Shipments Using Shipping Labels 184
Purchasing Insurance for Your (Network) Shipment 187
The Mechanics of Delivery Confirmation 188
Lose All You Want—We'll Make More 190
Big Box, Small Truck—What Do You Do? 192
Why Three Smaller Segments Is Better Than One Big Segment 194
My Little White Lie About Acknowledgments 194
Delivering the Package to the Right Person, Not Just the Right Address 196
The Chicken, the Egg, and the Destination Port of the First Segment 198
Starting Off on the Right Foot Using a TCP Connection 199
Chapter Summary 201
Chapter Review Questions 201

Part IV **Navigating the Roadways to Find the Right Street Address** 205

Chapter 10 Delivering the Goods to the Right Street (IP) Address 207

Navigation Basics: Driving to the Right Destination 208
IP as the Postmaster General of the Network 211
Knowing the Address Before Driving to the Destination 213
Putting a Name on the Shipping Label 216

How to Run a (Network) Postal Service 217
One Location, One Zip Code, One Network Number 217
Three Sizes Fit All 222
The Actual Class A, B, and C Network Numbers 226
Subdividing a Network into Subnets 227
The Problem: Wasting IP Host Addresses 228
The Solution: Subnetting Saves IP Host Addresses 229
Chapter Summary 231
Chapter Review Questions 232

Chapter 11 Knowing Where to Turn at Each Intersection (Router) 235

A Short Trip from Your House (PC) to the Local Store (Server) 236
Overview of the End-to-End Routing Process 237
Step 1: Leaving Your Neighborhood the Same Way, Every Time 238
Getting into Your Car to Drive to Lunch 240
Learning How to Go to the Default Post Office (Router) 243
Summary of Step 1 246
Step 2: Choosing Which Road to Take at the First Intersection 247
The Useful but Short Life of an Ethernet Frame 248
Deciding Where to Go Next 249
Yet Another Ethernet Data Link Frame 251
Summary of Step 2 253
Step 3: Choosing Which Road to Take at the Final Intersection 253
The Still Useful, but Still Short Life of an Ethernet Frame 253
The Routing Table at R2: Same Destination, Different Forwarding Instructions 254
Yet Another Short-Lived Ethernet Frame 255
Other Rules of the Road 256
Routing with Subnets 256
How to Drive When You Aren't Leaving the Neighborhood (Subnet) 258
Chapter Summary 259
Chapter Review Questions 259

Chapter 12 Painting the Road Signs on Your Interstate (Internetwork) 263

Routing to Nearby Places 263
Painting Road Signs and Other Long-Lasting Directions 266
Dynamically Learning and Changing Routing Tables 268
Picking the Best Road (Route) 271
Introducing the Long List of Routing Protocols 274
Chapter Summary 275
Chapter Review Questions 276

Chapter 13 People Like Names, but Computers Like Numbers 279

Looking Up the Name and Number in the Phone Book (Host Table) 280
Asking Someone Else to Look Up the Phone Number (IP Address) for You 281
Asking for Name Resolution Help Inside the Company 282
Asking for Name Resolution Help Outside the Company 284
How Names Should Be Formatted 288
Chapter Summary 289
Chapter Review Questions 290

Part V **Building an Interstate (Inter-LAN) Highway System** 293

Chapter 14 Leasing a (Network) Roadway Between Two Points 295

Leasing the Cable When You Can't Run the Cable 296
You Can't Lease the Cross-Over Cable, So Lease Something Almost Just Like It 297
It's Not Really a 450-Mile Cable, but It Works Like One 298
The Many Personalities of a WAN Link 300
Differences Between a Cross-Over Cable and a Leased Circuit 301
I Feel the Need, the Need for Speed 302
The Need to Control the Speed 303
Double Your Speed at No Cost 304

A WAN Link Installation Plan 305
Routers and WANs: A Match Made in Heaven 306
You Can't Just Send Data; You Have to Send a Frame 307
Addressing on WAN Serial Links 309
The Choice of Two Data Link Protocols 309
Chapter Summary 310
Chapter Review Questions 311

Chapter 15 Leasing a (Network) Roadway Between Lots of Places 315

Making the Telco Look Like One Big Whopping Switch 316
Cabling a Router to the Big Frame Relay Switch 316
Basic Logic Used by the Big Whopping Frame Relay Switch 318
If Two Sites Are Good, Three (or More) Must Be Better 320
It's Virtually Like a Leased Circuit, So Let's Call It a Virtual Circuit 321
Faster, Cheaper, Better—You Can't Go Wrong with Frame Relay 322
You Can Still Use Serial Links, but It Will Cost You Up Front 323
Get Your Free Bandwidth Here! Free Bits! 324
Routers and WANs: Still a Match Made in Heaven 326
You Can't Just Send Data—You Have to Send a Frame Relay Frame 328
Addressing Is Much More Interesting on Frame Relay Than on Serial Links 329
Chapter Summary 330
Chapter Review Questions 330

Chapter 16 Driving from Home onto the Globally Interconnected (Internet) Roadway 333

Once on the Interstate (Internet), You Can Go Anywhere 334
Using a Phone Line for Data 336
Making Data Sound Like Voice 337
What Phones Do for Voice, Modems Do for Data 339
How Fast Can You Talk? 342
Calling the Internet! Calling the Internet! 342
Now That I Know How to Talk, Whom Should I Call? 343
Now That I Know Whom to Call, What Do I Say? 344

Using the Phone Line for Data—the DSL Way 345
Dr. Analog Voice and Mr. Hiding Digital 346
Faster Is Better 348
Sending Data from Home Without Using a Phone Line 349
Chapter Summary 350
Chapter Review Questions 351

Part VI **Securing the Network** 353

Chapter 17 Accepting the Right People and Rejecting the Wrong People 355

Safe Driving by Using AAA 355
Checking for Fake Drivers' (Users') Licenses 356
Hey! How Did You Get in Here? 359
Checking the License to Find Out if He Can Drive That Kind of Vehicle 359
Tracking Drivers' (Users') Violations 360
Making Sure (Internet) Drivers Have Valid Drivers' Licenses 361
No Appls Yet? Be a Good CHAP and Ask PAP 362
Stopping Someone from Using Your License (Password) 364
You're Wearing Your Credit Card Number on Your T-Shirt 367
Chapter Summary 370
Chapter Review Questions 371

Chapter 18 Keeping a Watchful Eye Over Who Drives into Your (Network) Neighborhood 373

Setting the Ground Rules 373
Enforcing the Ground Rules 378
Ways to Watch Your (Network) Neighborhood 379
Deciding When to Stop the Traffic 381
Safe Places Outside of Your Neighborhood (Network) 383
Using the Police to Watch for Bad Guys 384
Watching for Wolves in Sheep's Clothing 385
Avoiding Catching Cold 386
Profiling What the Bad Guys Want to Do 387
Chapter Summary 387
Chapter Review Questions 388

Part VII **Appendixes** 391

Appendix A Answers to Chapter Review Questions 393

Appendix B Converting IP Addresses Between Decimal and Binary 435

Glossary 459

Index 497

Introduction

Often, learning something new can be a chore, particularly with computer technology. In fact, because you've obviously been searching for a book long enough to at least have opened up this one, you've probably looked at a few other books as well. There's no problem finding networking books—there are tons of them—but almost all of them are geared toward people who want to be networking geeks, and the books frequently get deep and technical in a hurry. They're like the old joke where one guy walks through a door with an unseen long drop to the ground below, and his buddy shouts out, "Watch out for that first step. It's a doozy!"

Computer Networking First-Step is an easy first step toward learning about networking, instead of taking a doozy of a step off the networking ledge. With *Computer Networking First-Step*, you don't have to worry about the pain normally associated with getting into something new. This book is designed and written assuming that you come to the game with no experience at all with the topics, but with a lot of interest in them.

This book is intended for anyone who needs to know a little about networking, but it also requires almost no prerequisite knowledge. You might want to know a little about networking, but not a lot, because that's all you need to know for your job. For instance, maybe you're in sales, and you need to be able to talk to networking geeks. Or maybe you work in another information technology (IT) area where you talk to the networking folks occasionally, and you need to be able to have more meaningful conversations. Or maybe you want to learn a lot about networking, but you aren't sure where to start. Simply put, if you're getting started with networking, this book is for you. If you've used a computer before, you've got the right prerequisite knowledge coming into this book.

When you finish reading this book, you will know enough to talk to people about how networks operate. You won't be an expert at any one part of networking, but you will understand the basic concepts behind a wide variety of technologies used in a typical network today. If your goal is to have a conversational level of knowledge, this book will do it for you. If your goal is to become a networking professional, but you don't have much knowledge or experience yet, this book will help you start down that path.

Interested? The next few pages will give you a little more detail about what's between the covers. Then you can dive in to the first chapter and start learning about networking!

There's a Lot Here, but Then Again, There's Not

Computer Networking First-Step covers a lot of topics, so there are many chapters, but each chapter averages 20 pages. And with the book's conversational style, you can grab it when you have 15 spare minutes and complete another chapter. If you're using this book to get started and want to learn networking even deeper, you'll want to take a few more minutes to study the questions and review the terms. In short, you'll find a lot of topics here, but they're pretty much in bite-sized pieces for easy digestion.

The part and chapter titles, as well as the headings inside the chapters, are purposefully nontechie. It seems silly to title things using terms that you might not have heard about before. But you might have heard of a few networking terms, so if you want a little better idea of the main topics in each major part of this book and each chapter, take a look at the following comments about what's hidden inside.

Part I: Networking Basics

Part I covers a broad brush of the basics of networking, with examples referencing tools that many computer users use every day:

- **Chapter 1, "What Is a Network?"**—Defines the basic terms, including defining what different people might mean when they use the term "network."
- **Chapter 2, "A Network's Reason for Existence"**—Covers networks and networking from a user's perspective.
- **Chapter 3, "Building a Network: It All Starts with a Plan"**—Explains the concepts behind an architectural model that vendors use to build networking products and engineers use to implement a particular network.

Part II: Running the Local Department of (Network) Transportation

After Part I's broad coverage, Part II takes a closer look at the basics of small networks, called local-area networks (LANs), using analogies with how the U.S. Department of Transportation (DOT) builds roads:

- **Chapter 4, "How to Build a Local (Network) Roadway"**—Using analogies with how the U.S. DOT builds roads, this chapter shows how to physically construct a LAN using cabling, PCs, and other networking gear.
- **Chapter 5, "Rules of the Road: How to Use the Local (Network) Roadway"**—Just as you need to obey traffic laws, data must follow the traffic laws of the LAN. This chapter tells you how to pass a LAN driving test.
- **Chapter 6, "Reducing Congestion and Driving Faster on the Local (Network) Roadway"**—It's more fun to drive a fast car. This chapter covers how to do the equivalent with LANs.
- **Chapter 7, "Adding Local (Network) Roadways for No Extra Money"**—It's free, and it's better in many cases. "It" is a thing called virtual LANs (VLANs), which allow you to create lots of LANs with no additional hardware.

Part III: Shipping and Logistics: Commerce Using the (Network) Roadways

This part changes the focus to what the end user of a network experiences—the applications. Chapters draw analogies with doing business by shipping goods to market over the roadways:

- **Chapter 8, "Shipping Goods over a (Network) Roadway"**—This chapter focuses on applications that the end user of a network uses—things that you have probably already done yourself, such as use a web browser to look at a website.
- **Chapter 9, "Choosing Shipping Options When Transporting the Goods over the (Network) Roadway"**—Behind the scenes, applications need services from other things in the network, just like most companies use a large shipping company for shipping products. This chapter looks at those basic services.

Part IV: Navigating the Roadways to Find the Right Street Address

The person driving the shipping truck needs to get to the right street address. Part IV covers the equivalent idea in networking, defining how data is delivered across any network, including the Internet:

- **Chapter 10, "Delivering the Goods to the Right Street (IP) Address"**—Internet Protocol (IP) defines logical addresses—the equivalent of a street address. This chapter defines how networking devices together deliver data from one computer to another using IP addresses.
- **Chapter 11, "Knowing Where to Turn at Each Intersection (Router)"**—One of the more important types of networking devices is called a *router*. This chapter covers how routers work, with analogies drawn to how a driver makes decisions about where to turn at each intersection.
- **Chapter 12, "Painting the Road Signs on Your Interstate (Internetwork)"**—If you take a trip, you might rely on road signs to tell you where to turn. Routers can do the networking equivalent of posting road signs, which is explained in this chapter.
- **Chapter 13, "People Like Names, but Computers Like Numbers"**—Let's face it: Computers are better at math than we are. This chapter explains how networks let us use names (such as www.ciscopress.com), and how the computer converts those names to numbers that are more useful to the computer.

Part V: Building an Interstate (Inter-LAN) Highway System

When computers in the network are far apart, the physical connections are called wide-area networks (WANs). This part explains three major branches of WANs, all of which require that you lease someone else's physical network because of the impracticality of having everyone run cables for hundreds of miles:

- **Chapter 14, "Leasing a (Network) Roadway Between Two Points"**—This chapter covers how two routers at two different physical sites can send data using the equivalent of a never-ending telephone call between the two routers.

- **Chapter 15, "Leasing a (Network) Roadway Between Lots of Places"**—If you have more than two routers at different sites, it's cheaper to use a different type of WAN, called Frame Relay, as explained in this chapter.
- **Chapter 16, "Driving from Home onto the Globally Interconnected (Internet) Roadway"**—Most everyone knows about the Internet. But what really happens when you connect to the Internet from home? This chapter covers the high points.

Part VI: Securing the Network

This part highlights how to protect your network from both the curious and the malicious people on the Internet:

- **Chapter 17, "Accepting the Right People and Rejecting the Wrong People"**—You shouldn't just let anyone use a network. This chapter hits the key points of how to make sure only the right people use your network.
- **Chapter 18, "Keeping a Watchful Eye Over Who Drives into Your (Network) Neighborhood"**—This chapter covers how to set up ground rules for what's allowed into your network from the Internet, and how to watch for crackers who might try to cause harm to your network.

Part VII: Appendixes

- **Appendix A, "Answers to Chapter Review Questions"**—Each chapter ends with a "Chapter Review Questions" section that contains some open-ended questions. This appendix repeats the questions and lists answers as well.
- **Appendix B, "Converting IP Addresses Between Decimal and Binary"**—The coverage of IP in Chapter 10 doesn't require you to think about IP addresses in binary. However, for any of you who are interested in learning networking more deeply after reading this book, this appendix can help you with some of the basic math relating to IP addressing.

Glossary

The college professor who first taught me about networking, Dr. Phil Enslow, used to say that 80 percent of networking was understanding the lingo and then understanding how other people used the same lingo. The Glossary will be a valuable tool as you build up your lexicon for having conversations about networking.

Who Ought to Read This Book

This book is meant for anyone who wants a comfortable introduction to a broad variety of networking topics. That's not to say this book doesn't tell you some important technical details, because it does. Primarily, this book is purposefully designed for people who want a solid understanding of the basics of networking, plus a good working knowledge of the terminology that networking professionals use every day.

That said, there are a few specific types of people who come to mind that will especially benefit from this book:

People who are beginning their quest to become networking techies. Anyone who wants to work in the computer networking arena has to start learning somewhere, and this book is an excellent starting point. Whether you are in school and using this book as part of a course, or you are learning on your own, this book can start you on a career in networking.

IT professionals who are looking to know more about networking. If you're already in the IT arena but don't know a lot about computer networking, this book can help you as well. You've probably already heard a fair amount of the lingo used by networking types, but now you want to know what they really mean by it all. This book is for you! It covers hundreds of terms with explanations in the context of how you normally build a corporate network.

People who need to talk to the people who build networks, but who have no need to know how to build networks themselves. Lots of people have jobs that require them to have a general idea about how networks work, but without needing to make them work. For instance, businesses that sell networking hardware and software have people who work for them—salesmen, accountants, operations, consultants, customer service reps, and administrators—and all of them can benefit from knowing a little about networking. Also, some companies don't sell hardware and software, but they sell services that rely completely on networking. Insurance companies, banks, shipping companies, and many others rely on their networks for the core business functions. If you want to understand what the network engineers are saying, this book will help!

People who want to pass networking certification exams but who need more background. If you want to get some good résumé material so that you can get a job in networking, you should try to get some networking certifications. Many people need a little more background before diving into the books and courses related to entry-level networking certifications, and this book can help.

Still Hungry? Try Another *First-Step*

Some of you might be thinking something like, "Well, I already know something about networking, and maybe this book can fill in some holes. I really like the approach and comfort of using this book, but what I really want to know a lot about is security, and there are only two chapters on security. What I really need is a *First-Step* book on computer security!"

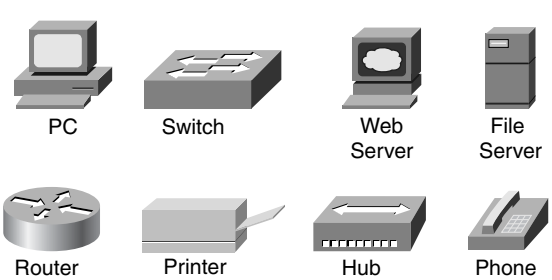
Well, if you really thought that, the book *Network Security First-Step* is meant for you. Cisco Press introduced the *First-Step Series* in the spring of 2004. You can check http://ciscopress.com/firststep for more information on any new titles. The goal of the *First-Step* books is to provide an easy first step into whatever networking technology is covered by the book. Each *First-Step* book meets you at the beginner stage for the technologies in the book. For instance, *Network Security First-Step* covers some of the basics of a protocol called TCP/IP, but it focuses specifically on network security.

Stuff You'll Find in This Book

This book includes several features to help you digest the materials with minimal heartburn. With the solid foundation gained through this book, you can learn things about new technology more easily, talk networking with others, or be better prepared to begin a career in networking:

- **Chapter objectives**—Every chapter begins with a list of objectives that are addressed in the chapter. The objectives are revisited in the chapter summary.
- **Highlighted keywords and Glossary**—Throughout this book, you will see terms formatted with bold and italics. These terms are particularly significant in networking. So, if you find you aren't familiar with the term or at any point need a refresher, simply look up the term in the Glossary toward the end of the book to find a full definition.
- **Chapter summaries**—Every chapter concludes with a comprehensive chapter summary that reviews chapter objectives, ensuring complete coverage and discussing the chapter's relationship to future content.
- **Chapter review questions**—Every chapter concludes with review questions. These questions test the basic ideas and concepts covered in each chapter. You can find the answers to the questions in Appendix A.
- **Nontechie headings and titles**—The titles and headings used throughout this book avoid the use of technical terms when possible, focusing instead on words that connote something about the underlying concepts.

The illustrations in this book use the following icons for networking devices and connections:



For More Information...

If you have any comments about this book, you can submit those through the ciscopress.com website. Simply go to the website, select Contact Us, and type in your message.

I hope you enjoy your first step into a deeper knowledge of networking, and I trust that these first steps will be a doozy of a good learning experience!

This page intentionally left blank

What You Will Learn

After reading this chapter, you should be able to

- ✔ Explain how computers can communicate binary 1s and 0s using electricity
- ✔ List the components of popular LAN cables and connectors
- ✔ Compare and contrast straight-through and cross-over Ethernet cables
- ✔ Explain the operation of an Ethernet hub
- ✔ Summarize the benefits of using a structured cabling system

CHAPTER 4

How to Build a Local (Network) Roadway

So far in this book, you have read about how networks allow computers to communicate. Networks include software, some of which sits in the computers, and some of which sits in routers. The network also includes hardware, such as the network interface cards (NICs) in the PCs, mentioned in Chapter 3, "Building a Network: It All Starts with a Plan." Finally, networks include cabling, which provide a physical means to transmit bits across a network.

This chapter is the first one in this book's second major part: "Running the Local Department of (Network) Transportation." In the United States, most cities, all states, and the U.S. federal government have a department of transportation (DOT). Each DOT plans, builds, and fixes problems with roadways. You can learn a lot about networking by comparing networks to roads.

Driving Bits Across the Network Roadway

I just got back from lunch at one of my favorite lunch places: La Frontera Mex-Mex Grill. When it was time for lunch, I got in my car, drove to the restaurant, ordered my usual—numero dos, con pollo, por favor—and drove back home.

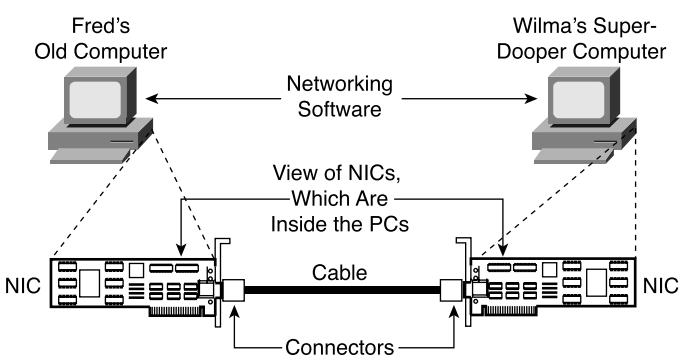
When I got home, my wife said, "So you drove over that really cool street outside our house on your way to lunch, huh?" Yeah, right. Who cares what roads I drove on? It's where I drive *to* that's important.

Well, to know networking well, you need to know some of the basics about the networking equivalent of roads. If you find yourself really getting interested in what's in the next few pages, you might just be one of those people who really would like a career working with the technical side of networking. If not, you should at least know the concepts so that you can communicate with the networking geeks of the world and have a firm understanding of networking.

What's a Local-Area Network?

Chapter 3 defined a local-area network (LAN) as a network in which the devices are relatively close together. Of course, a network, once again according to this book, includes computers, software, hardware, and cabling that allow the computers to communicate. Although this definition is accurate, you really do not get a detailed picture of a LAN this way. So, Figure 4-1 shows a LAN, which is one you've seen before in Chapter 3.

Figure 4-1 Components of a Simple LAN



In this case, the LAN consists of some obvious elements. First, you need at least two computers. The computers need to have networking software; otherwise, they will never attempt to communicate. They also need the physical ability to transmit bits from one computer to the other—hence the need for the ***cable*** and the NICs in each computer. (Figure 4-1 shows the NICs outside the PCs so that you can see them, but they are typically inside the PCs.)

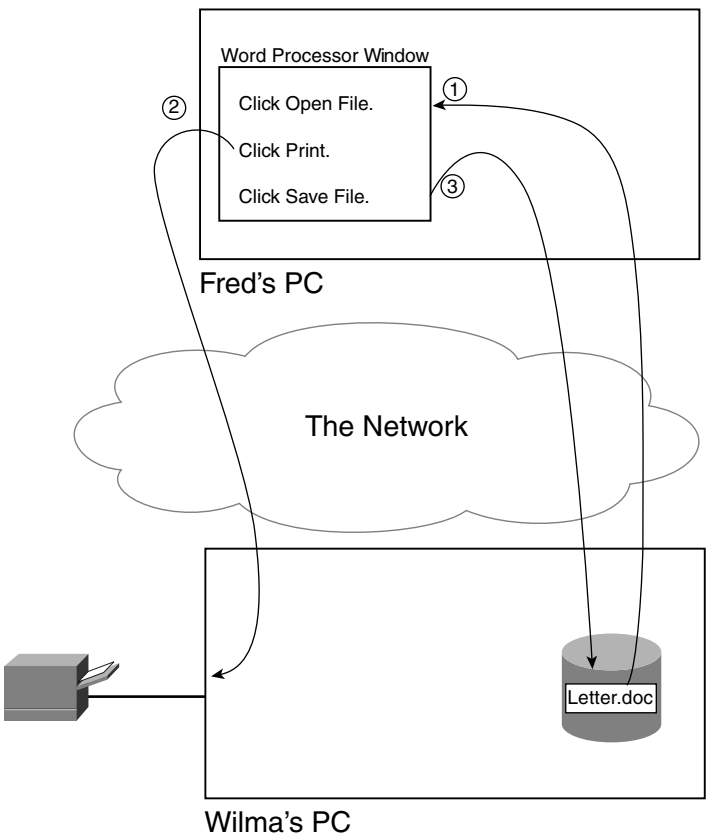
LANs do not get any simpler than this one. Larger LANs can get much more complex, with lots more components like networking hubs and switches, which you will learn more about in the next few chapters.

In this chapter, you learn about how computers can transfer bits across the network roadway. The topics covered here might be the equivalent of what a DOT engineer might talk about over lunch with a stranger: "Hey, you know we're going to be paving Parker-Puckett Parkway pretty soon. Pretty cool, huh?" The reply, "Hey, isn't that near that Mexican place, La Frontera?" And the response from a true DOT engineer: "I don't know—don't care. That's *beside* the road. I just care about the road." Likewise, some network engineers think of the LAN as the cable, possibly the NICs, but they typically don't care a lot about the computers that happen to be connected to the cabling. Likewise, this chapter focuses more on how computers send bits to each other, rather than the applications that run on those computers.

Transmitting Bits Across the Local Network Roadway

Back in Chapter 2, "A Network's Reason for Existence," you saw an example where Fred opened a file that sat on Wilma's disk drive. Later, Fred printed the file on the printer connected to Wilma's computer, and finally, Fred saved the file back on Wilma's disk drive. Figure 4-2 shows the process, in sequence.

Figure 4-2 Basic Flow with Fred Using a File/Print Server



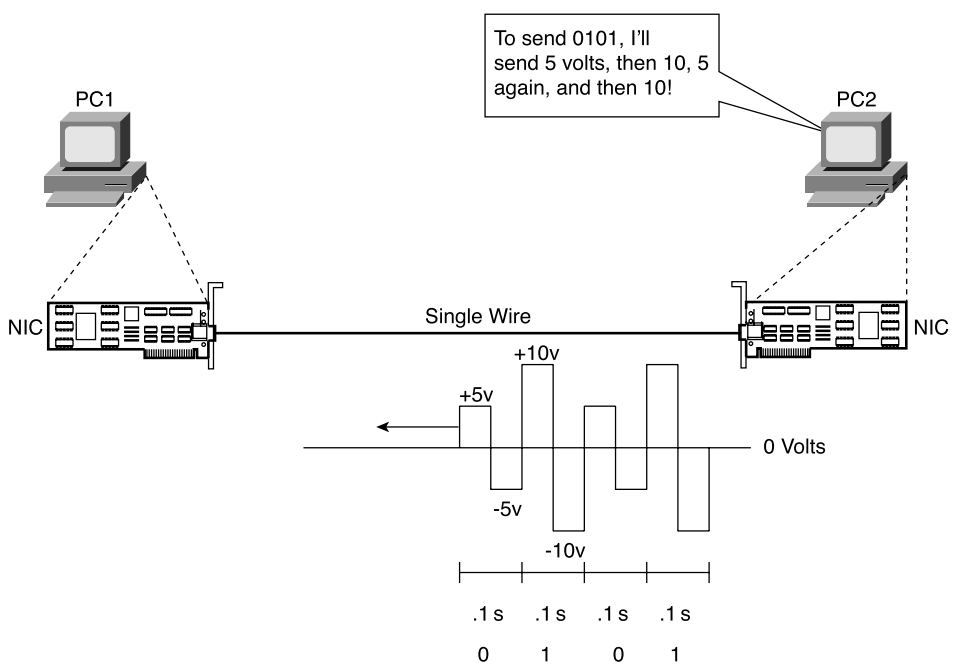
For this process to work, Fred and Wilma must be able to cause a ***bunch of bits*** that sit in memory in one computer to be sent to the other computer. A file is just a bunch of bits. So, imagine that by using a word processing program on a single computer, you can open a file, read the contents, and edit and change the file. Similarly, if you can send the same bits in that file to another computer across the network, you or someone else can edit the file by using the same word processing program on that computer. So, for a network to work, the network needs to be able to get a bunch of bits from one computer to another.

Driving Bits Across a Wire

To send one binary code from one device to another, the sending device puts some electricity on the wire. Electrical signals have many characteristics that a NIC can control and vary. By varying one of these features to two different values, with one value meaning binary 1 and one meaning binary 0, you can transfer data over the wire.

For example, imagine that both PC1 and PC2 have a NIC, and there is a single wire connecting the two cards. The wire is just a skinny, long piece of copper, and copper conducts electricity very well. Now, imagine that the ***encoding standard*** used by the company that made the NIC defines that a binary 0 is represented by a voltage of ±5 volts, and a binary 1 is represented with ±10 volts. Encoding is the term that refers to a set of rules that defines what a sender should make the electrical signal look like to imply a binary 0 or a binary 1. Figure 4-3 depicts the general idea.

Figure 4-3 Basics of Data Transmission Across a Wire



In the figure, PC2 generates some electricity on the wire. In this case, PC2 wants to send the binary value 0101. So, it sends a 5-volt signal, then 10 volts, then 5 volts, and then 10, because the imaginary encoding scheme in this example states that 5 volts means 0, and 10 volts means 1. PC1, on the other end of the wire, senses the incoming electrical signal and interprets the electricity, using that same set of encoding rules to mean 0101, exactly as PC2 intended.

Note that the graph shown in Figure 4-3 shows a discrete, or constant, voltage. Because the X-axis (horizontal axis) represents time, when the voltage changes, it changes immediately to the next value. The use of discrete, constant values, which are then instantly changed to other possible discrete values (as in Figure 4-3), is called ***digital transmission***. To transmit binary numbers, or ***binary digits***, it is useful to transmit the data using digital transmission.

For the digital transmission of data to work correctly, not only must the sender and receiver agree to what electrical characteristics mean a binary 0 or 1, but they also must agree to the rate at which the bits are transmitted over the wire. In Figure 4-3, the receiver (PC1) must think about the electrical signal at different points in time, on a regular interval. Likewise, the sender (PC2) must use this same regular time interval to decide when it should change the digital electrical signal. For instance, if PC2 varied the voltage to mean either 0 or 1 every .1 seconds, and PC1 sampled the incoming electrical signal every .1 seconds, they could transfer 10 bits in a second. The speed of this network connection would be 10 bits per second.

If the two PCs did not agree on the transmission speed, the devices couldn't transfer the binary information. For instance, imagine that PC2 thought the speed was 10 bits per second, meaning it should encode a new bit every 1/10 of a second. If PC1 thought that it should be receiving a bit 20 times per second, it would sample the incoming electrical signal every 1/20 of a second. PC1 would think it was sending 10 bits each second, and PC2 would think it received 20 bits.

The term ***bps*** (short for bits per second) often refers to the speed of networking connections. Note that the unit is bits, not bytes. In real life, LANs typically run at much higher speeds, with a slow LAN transmitting at 10 million bits per second (Mbps, also called megabits per second).

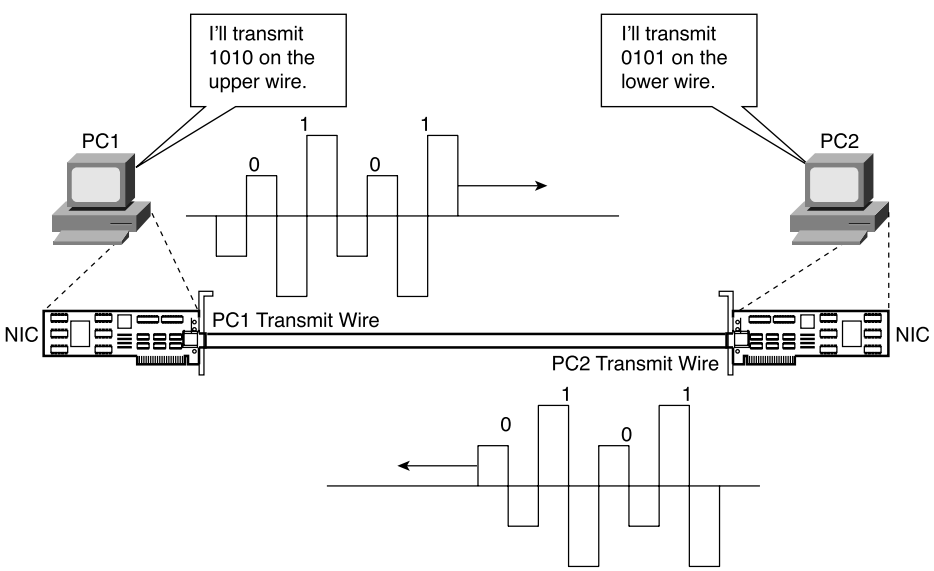
Notice that Figure 4-3 represents electricity as a square ***waveform***, with positive and negative voltages. You don't really need to worry about the electrical details, but as you progress through learning about networking, you will see other drawings like this one. The networking cards use an alternating current, or AC. The positive voltage means the current is in one direction, and the negative current means the current runs in the opposite direction.

The Need for a Two-Lane (Network) Road

In Figure 4-3, PC2 sends an electrical signal to PC1. As it turns out, if PC1 tried to send some electricity to PC2 at the same time, over the same wire, the electrical signals would overlap, and neither PC1 nor PC2 could understand what was sent.

To solve the problem, PC1 and PC2 need to use two wires—one for PC1 to send bits to PC2, and one for PC2 to send to PC1. Figure 4-4 shows two wires, with PC1 and PC2 sending and receiving at the same time.

Figure 4-4 Concurrent Data Transmission Across Two Different Wires

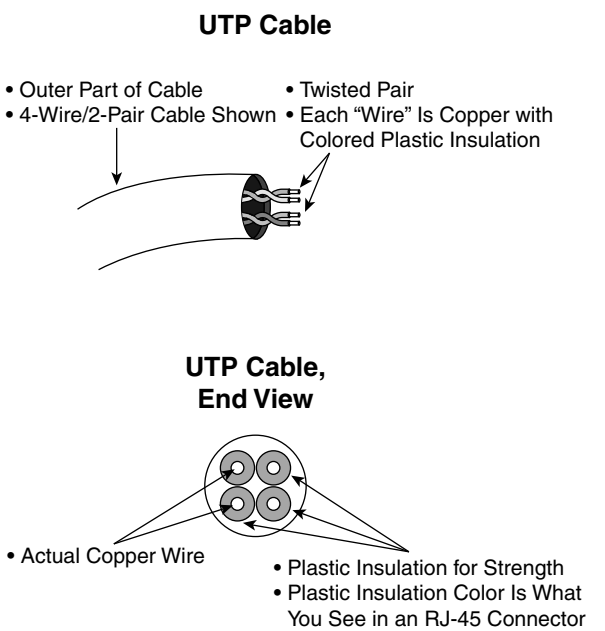


The Equivalent of Asphalt: Cables

You can get in your car and drive around your yard, the sidewalk, in your neighbor's yard, or through the park. Of course, it's better if you drive on the road! The earlier examples in this chapter showed NICs using a single copper wire for data transmission in each direction. But rather than just have a couple of wires somehow stuck into the side of the cards, in real life, we use cabling and connectors to manage the wires, making the job of the electrician much more comfortable and convenient.

The copper wires that networking cards use are encased inside a cable. The cable is made from plastic, with the copper wires inside the cable. Figure 4-5 shows a drawing of the most popular type of cabling used for LANs today.

Figure 4-5 Typical LAN Cable

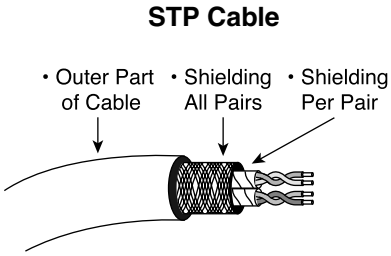


If you look closely at this figure, you can see each copper wire, as well as the plastic coating on the wire. The copper wire is thin, making it brittle. In fact, the wire could easily break in your hand. To help prevent the wire from breaking, a thin plastic coating is painted onto each wire. Conveniently, each wire uses a different color of plastic coating, so you can look at each end of the cable and figure out which wire is which. As you might guess, and as you will learn more about in the next few pages, it is important that you can identify a particular wire on each end of the cable.

Also note that the wires in Figure 4-5 are twisted together in pairs. Each pair of wires is cleverly called a ***twisted pair***. The term refers to a pair of wires twisted around each other to reduce the amount of electrical interface on the wires. In layman's terms, ***electromagnetic interference (EMI)*** occurs when electrical signals that exist in the air—caused by other wires or other nearby electrically powered devices—change the electrical currents on the wire. If outside EMI changes the signal on the wire, the receiving computer might misinterpret a 0 as a 1 or a 1 as a 0, or it might not have a clue what the sender really sent. Sending the electrical signals over a twisted pair rather than a single wire eliminates a lot of EMI effects. (Besides, the wires are pretty skinny anyway, and copper is cheap, so why not use two?)

Another thing that can be added to the cable to reduce EMI is shielding. Shielding, as the name implies, shields the wires inside the cable from the effects of EMI. However, shielded cabling has more stuff in it, making the cable less bendable and more expensive to produce. Shielded cables are called ***shielded twisted pair (STP)***, and you could probably guess that unshielded cables are called ***unshielded twisted pair (UTP)***. LAN technology has evolved to the point where less expensive UTP cabling can be used in most environments, with STP cabling being used in environments where significant EMI issues exist. Figure 4-5 showed UTP cabling; Figure 4-6 shows an example of an STP cable.

Figure 4-6 Shielded Twisted Pair (STP) Cabling



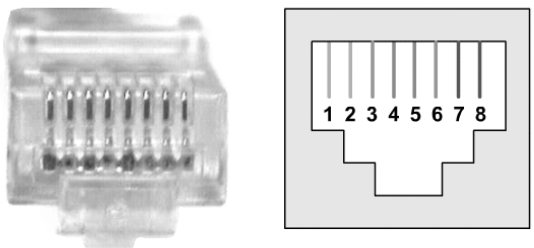
Painting the Lines on the Road: Connectors

Imagine that you see a new road that has just been paved. The road is so new that the DOT hasn't even painted the lines yet. So, you turn onto the road and enjoy the ride. After a couple of miles, you look up and see that someone else is on the road—a huge, speeding truck—and the driver wants to take his half of the road in the middle of the road. After swerving off the road, you might think to yourself, "Boy, that reminds me of one of the reasons that you use connectors on the end of networking cables!"

Okay, that's far fetched, but it does lead into a key point about connectors. If roads had no lanes, and there were no traffic laws, the roads would be pretty dangerous so the DOT paints lines on the road to create traffic lanes. Similarly, connectors line up the wires on the end of a cable into well-defined physical locations inside the connector. Essentially, each wire in the cable is identified by color, and each colored wire has a specific reserved place inside the connector that the electrician attaches to the end of the cable. The connectors put the wires into the right place, just like the lines on a road guide cars into the right place.

An electrician can take a cable and attach a connector to the end of it. When he attaches the cable to a connector, each of the wires protrudes into the connector so that the electricity can flow when connected to a device. The tip of the exposed wire in the connector is called a pin. A ***pin*** is nothing more than a physical position in the end of the connector in which the copper part of the wire sits. You can think of a pin like you think of a lane on a road. Figure 4-7 shows a photo of a typical connector, called an ***RJ-45 connector***, along with a drawing of the same connector.

Figure 4-7 Typical Networking Connector (RJ-45)

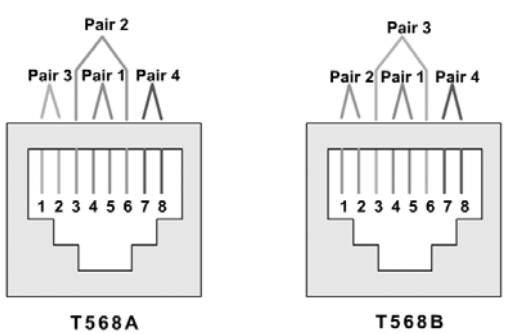


The Telecommunications Industry Association (TIA) and Electrical Industries Alliance (EIA) define standards for cables and connectors. For instance, they define how to use an RJ-45 connector for LANs and options for several types of UTP cabling. (You can learn more about TIA and EIA by going to their websites, at http://www.tiaonline.org and http://www.eia.org.)

If you have never seen an RJ-45 connector, and you use Ethernet LANs at work or school, you could remove the cable from your PC's network card and look at it. In most cases, the cable will be using an RJ-45 connector. (Ethernet is by far the most popular type of LAN today. You'll read more about it in the next several chapters.)

The EIA/TIA defines standards for which wires fit into which pins when you make a cable for use with Ethernet. Two of those standards are shown in Figure 4-8.

Figure 4-8 Pinout Options for RJ-45 Connectors



Each of the drawings in the figure represents an RJ-45 connector. The RJ-45 connector allows eight wires to be inserted into it. EIA/TIA standards suggest the numbering schemes for the eight pin locations and the pairs of wires, knowing that a twisted pair is needed for data transmission. The standard also specifies which color of wire goes into pin position 1, 2, and so on.

The RJ-45 connectors have clips on the side that allow you to easily insert the connector into the plug (hole) in the networking card in a computer. At that point, the connector is secure and should stay put. If you push the clip close to the rest of the connector, it releases the connector from the card. So, the clip helps keep the connector secure and allows you to pull the connector out when you are ready.

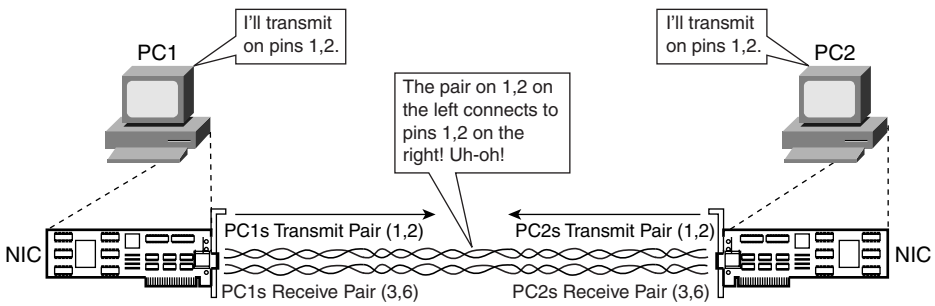
So, why does all this matter? In the next few pages, it will all come together as you see how NICs try to use the cables and wires.

Driving in the Right Lane (Pair) on the Road

Refer to the simple network of Figure 4-1 early in this chapter. That network consisted of two PCs, each with a networking card, and a cable between them. So far, you've learned the basics about wires, cables, and connectors. However, there's one last important thing about basic LAN data transmission that you need to know, and it relates to which wires are used for actual data transmission by Ethernet LANs.

Ethernet NICs in PCs try to send data over the twisted pair that uses pins 1 and 2 of an RJ-45 connector. These same NICs expect to receive data on the twisted pair that uses pins 3 and 6. However, without the right kind of cabling, two Ethernet NICs cannot communicate. Figure 4-9 depicts the effect when both NICs try to send using the twisted pair that uses pins 1 and 2.

Figure 4-9 Both PCs Using the Same Pair (Lane) to Send Data



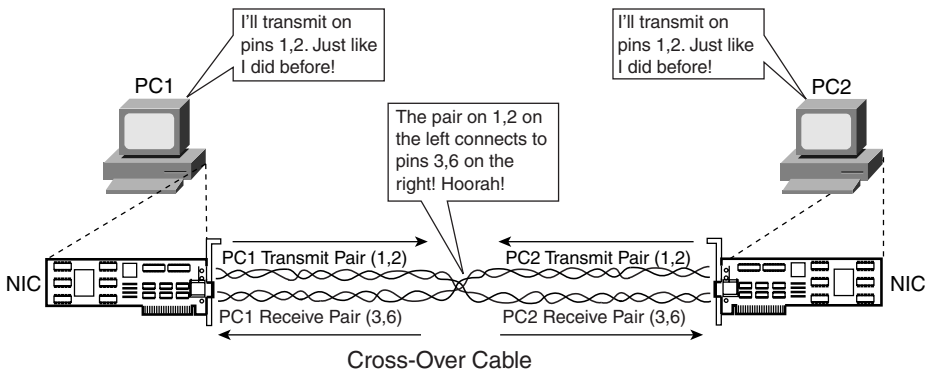
(Rather than clutter the figure with more cabling, I just drew the two pairs of wires; the wires do indeed sit inside a single cable, with RJ-45 connectors on each end.)

The cable in Figure 4-9 puts one end of a wire in pin 1 of one connector, and the other end into pin 1 of the other connector. Pin 2 on one end of the cable connects to pin 2 on the other side; and so on, for all eight wires. A cable with the wires connected in this manner is called a ***straight-through cable***.

Okay, back to the problem illustrated in Figure 4-9. As you can see from the bubbles in the figure, both PC's NICs send on the twisted pair at pins 1 and 2. That electricity goes over the wires and enters the other NIC on pins 1 and 2. But, the NICs aren't receiving data on pins 1 and 2! That's because Ethernet NICs try to send on pins 1 and 2, and they receive data on the pair at pins 3 and 6. In this case, both PCs send, but neither receives data.

The solution is to use a cross-over cable. ***Cross-over cables*** connect the wire at pin 1 on one end of the cable with pin 3 on the other end; the wire at pin 2 with pin 6 on the other end; the wire at pin 3 with pin 1 at the other side; and the wire at pin 6 with pin 2 at the other side. The result: The PCs can receive the data sent by the other device! Figure 4-10 shows the basic idea.

Figure 4-10 PCs Using Different Pairs (Lanes) to Send Data



Now you know the basics of how you can allow two PCs to attach to a cable and transfer bits between each other. This chapter focuses on how to build the local network roadway—essentially, the networking components that allow bits to be transferred. Next, you'll read about how to connect several devices on an Ethernet LAN, using a device called a hub.

Sharing the Local Roadway: Ethernet Hubs

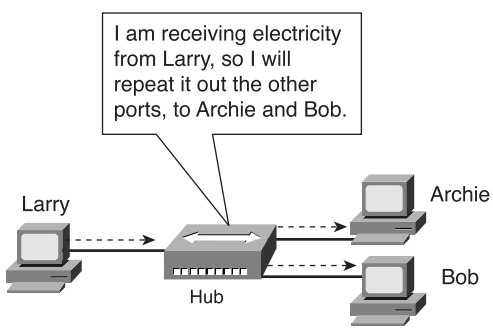
An old friend of mine is a native of San Francisco and still lives there. The traffic is horrible there, in part due to the need for lots of people to commute across the San Francisco Bay. There simply aren't enough bridges for the number of cars that need to cross the Bay. His solution: Fill in the Bay with dirt and pave the whole thing. Then there would be plenty of roads to allow people to cross the Bay.

If you tried to connect 10 PCs in a network, using a cross-over cable between NICs (as shown in figure 4-10), you would begin to do the equivalent of paving the San Francisco Bay. You know how two computers can use Ethernet NICs with a cross-over cable to communicate. However, to connect to other PCs, you would need more Ethernet NICs, and your PC probably does not have enough room for

all the cards. Also, you would need to run cables between your PC and all the other PCs, or at least get the electrician to run the cables. If you tried to do this for 100 PCs on the same floor of the building, and every PC wanted to connect to every other, you would have 99 cables connected to 99 NICs inside each PC!

The alternative to running a cable to every other PC is to run a cable from each PC to a wiring closet and connect the cables to a networking device, called an Ethernet hub. An ***Ethernet hub*** provides several functions, but mainly it allows the electrician to cable each device to the hub using only a single NIC and single cable, eliminating the cabling problem. The hub simply listens for incoming electrical signals, and when received, the hub repeats the same electrical signal to every other device that's connected to the hub. Figure 4-11 shows the basic operation.

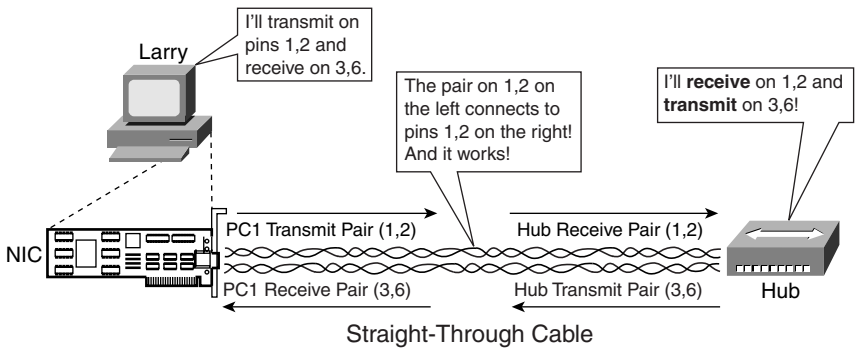
Figure 4-11 Ethernet Hub Repeats Everything It Hears



As seen in the figure, Larry sends data to the hub, and the hub repeats what Larry sent out the cables to Archie and Bob. It's that simple!

Figure 4-11 shows cabling, but it does not show which pairs of wires are used. Interestingly, the hub expects straight-though Ethernet cabling between itself and the PCs. Why is that? Well, the people who make hubs, knowing that Ethernet NICs in PCs send on the twisted pair that uses pins 1 and 2 and receive on twisted pair that uses pins 3 and 6, do the opposite. Therefore, a straight-through cable works between a PC NIC and a hub. Figure 4-12 illustrates the concept.

Figure 4-12 Hubs Use Straight-Through Cabling to PCs



The hub's logic is simple:

1. Receive traffic on pins 1 and 2 on each physical interface.
2. When received, repeat the same electrical signal out all other ports, except the one in which the data was received.
3. When repeating out other ports, repeat the traffic out pins 3 and 6 so that the PCs will be listening.

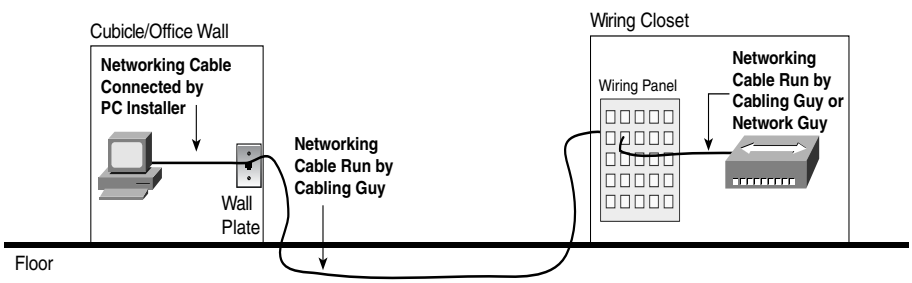
Dirt Roads Versus the DOT

You can spend a long time working around or in the networking arena and not ever need to worry about how structured cabling works. This section gives you a brief glimpse into the world of structured cabling, just so you know what people are talking about if they bring it up.

You can go to the store and buy premade Ethernet UTP cables with RJ-45 connectors on them. You can even buy a hub—and for not a lot of money, typically less than $20. You could then connect a bunch of computers to the hub using the straight-through Ethernet cables, and voilà, you have a network, or at least the part that allows the computers to send and receive data. Running your own cabling is quick and easy.

In a real network in a real building, you will not typically get away with stringing cables on top of the carpet, over people's cubicles, and so on. Instead, you should allow the electricians to do their job right, which means that the cables will run either under the floor or inside the ceiling. Also, instead of a single cable from a PC to the hub, the equivalent will be created. First, you install a short cable from the PC to a wall plate. The electrician runs another cable from the back of the wall plate to the wiring closet into a patch panel. Finally, either the electrician or the network engineer connects a cable from the patch panel in the wiring closet to the hub. Together, these cables provide two twisted pair between the PC NIC and the hub. Figure 4-13 shows the major components.

Figure 4-13 Major Components of a Structured Wiring Plan



Structured wiring allows the electrician to take care of the difficult part of cabling, with a minimum of cost, effort, and clutter, while still making sure that the cabling works correctly. Even though multiple cables are used, the net result of the cabling simply needs to ensure that the correct twisted pairs end up at the right place in the connectors at the endpoints. And the only cables that the people in the offices can see are the short ones between the PC and the wall plate; the rest of the cables are hidden.

Imagine that if instead of structured wiring, the electrician simply ran a single cable from the computer, under the floor, and straight into the hub in the wiring closet. Later, the person in the cubicle decides that she wants her PC on the left side of her desk, and she might discover that the cable is too short. So what does she do? She calls the electrician and asks for another cable to be run.

Of course, the electrician probably isn't going to want to run a new cable from the cubicle to the wiring closet. If he had used structured wiring, he could have run a cable from the wall plate to the patch panel in the wiring closet. A ***patch panel***, sometimes called a ***wiring panel***, provides the electrician a place to connect the actual wires in the cable on one side of the panel. On the other side, receptacles, much like the ones in the wall plate in the cubicle, allow the electrician or network engineer to use a short cable to connect those pairs of wires to some other devices, such as the hub shown in Figure 4-13.

Because the patch panel is located in a well-known place, and because the wall plate in the cubicles does not move, the electrician can do the hard part (running the cables under the floor) once. If the PC in the cubicle needs to be moved farther away from the wall, the PC user can get a slightly longer patch cable. A ***patch cable*** is simply a short LAN cable. Likewise, inside the wiring closet, short patch cables can be used to connect from the patch panel to the networking device, such as the hub shown in Figure 4-13.

You can think of structured wiring as the equivalent of having the DOT build your roads versus just using dirt roads. It takes time, planning, effort, and more cost, but in the end, you have a much better road system. With structured wiring, you end up with much better wiring and far less clutter. Furthermore, you can make changes without a lot of effort.

The benefits of structured cabling can be summarized as follows:

- Helps minimize the need for running new cables because the distance from each wall plate to the wiring panel can be determined easily
- Allows PC installers to run a short patch cable from the wall plate to the PC, without requiring help from the electrician
- Allows network engineers to run a short patch cable from the wiring panel to the networking devices, such as a hub
- Helps keep the wiring closet more organized

Chapter Summary

Computers communicate by transmitting an electrical signal over wires, with differing electrical characteristics meaning binary 0 and binary 1. For effective communication, both transmit and receive paths are needed; with a single path, the electrical signals would overlap, confusing the meaning of both electrical signals. Also, a twisted pair of wires is used for transmission in each direction because a twisted pair reduces the impact of electromagnetic interference on the wires, which in turn reduces transmission errors.

LAN UTP cabling includes up to four twisted pairs of unshielded wires, typically terminated with RJ-45 connectors. Although four pairs are supported, only two pairs are needed for Ethernet LAN communications—one pair for each direction of transmission. Depending on which devices are being connected, you might need a cross-over cable or a straight-through cable, ensuring that the pair used for transmission by one device connects to the pair used for receiving data on the other device.

Ethernet hubs allow multiple devices to connect to it, with the result that all devices receive a copy of whatever each device sends to the hub. By doing so, each device needs a single NIC and a single cable connecting it to the LAN hub, while allowing all devices to communicate with all other devices.

Finally, a structured wiring plan helps prevent unnecessary cabling runs inside the difficult-to-reach parts of the physical location (under the floor or in the ceiling). It also allows other personnel to change cabling later, without involving the electrician.

Chapter Review Questions

You can find the answers to the following questions in Appendix A, "Answers to Chapter Review Questions."

1. Give an example of how a computer might transmit binary 0s and 1s using variations in voltage on a wire.
2. Imagine that two computers are sending and receiving data over a wire. How often would the receiving device need to sample the electrical signal on the wire if the standard called for 20 bps transmission speed?
3. As explained in the chapter, do computers usually transmit data over the same wires they use to receive data? Why or why not?
4. As explained in the chapter, do computers usually transmit data over a single wire, or do they use two wires?
5. How many wires can fit inside the end of an RJ-45 connector?
6. How many wires are needed for a PC to successfully send and receive data to another PC using an Ethernet LAN cable with RJ-45 connectors?
7. Explain why a straight-through LAN cable does not work when connecting two PCs directly, just using the cable.
8. Explain why a cross-over LAN cable *does* work when connecting two PCs directly, just using the cable.
9. Explain why a straight-through LAN cable works when connecting a PC to a hub.

10. What is the main difference between UTP and STP cabling? Which is more popular today?

11. List some of the key benefits of a structured cabling plan.

12. Imagine a hub with ten physical ports, and cables connecting each port to ten different PCs. The hub receives an electrical signal from the PC on port 1. Where does the hub forward the electrical signal?

13. Define the term "pin" in relation to an RJ-45 connector.

INDEX

Numerics

4-wire circuits, 298, 300–301
10 Gigabit Ethernet, 124
10/100 cards, 127
10BaseT, 122
100BaseT, 122
802.1Q trunking, 146
802.3 committee, 101
802.3ae working group, 10 Gigabit Ethernet, 124
802.3u working group, Fast Ethernet, 122

A

AAA
accounting, 360–361
authentication, with username and password, 356–359
authorization, 359–360
access links, 317, 460
access rates, 325
accounting, 360–361
acknowledgment number field, TCP header, 189
acknowledgment numbers, 51
addressing
Ethernet, 94–96
on WAN links, 309
amplitude, 339
analog modems, 341
analog signals, properties, 338–339
anti-virus software, 386–387
application layer protocols, 181, 184
applications
e-mail, 28–31
file read, 18
file transfer, 32–33, 38
file write, 18
web browsers, 25–26
word processing, 18
ARP (Address Resolution Protocol), 240
broadcasts, 244
replies, 245
ARP cache, 246
assigning IP addresses to interfaces, 264–265
asymmetric transmission rates, 348

authentication, 356–357, 362
CHAP, 365–366
PAP, 362–364
POP3, 163
with username and password, 356–359
authentication servers, 357
authoritative DNS servers, 289
authorization, 359–360
autonegotiation, 126–127

B

bandwidth, 302
BGP (Border Gateway Protocol), 274
binary digits, 41
binary numbering systems, 438–439
converting to decimal, 440–441
converting to hexadecimal, 450, 456
equivalent hexadecimal numbers, 95–97
IP addresses, converting to decimal IP addresses, 449–450
bits, 41
bps (bits per second), 70
broadcast addresses, 120
broadcast domains, 132. See also VLANs
broadcasting, 132
ARP broadcasts, 244
browsers, 25–26, 172
loading web pages, 175–176
buffers, 113–114
bytes, 41

C

cabling, 9
cross-over cabling, 77
data transmission across LANs, 68–72
connectors, 74–75
digital transmission, 70–71
STP, 73
twisted pair, 73
UTP, 73
patch panels, 82
straight-through cabling, 77
structured wiring plans, 80–82
canonical format (IP addresses), 212, 447
CATV, 349

CHAP (Challenge Handshake Authentication Protocol), 365–366
CIR (committed information rate), 325, 463
Cisco PIX Firewall, 379
Class B networks, 224
Class C networks, 224–225
classes of networks, 223–227
subnetting, 227–231
clear-text, 364
client software (VPNs), 369
clients, 377
clockrate, 302
clouds, 6, 13
collisions, 90
causes of, 90
Ethernet, CSMA/CD, 91–92
co-location, 347
comparing
e-mail and FTP, 167, 169
Ethernet and Frame Relay switching, 319
LANs and WANs, 295
phones and modems, 339–340
TCP/IP and OSI networking model, 58
components of LANs, 66–67
computer viruses, 386–387
concentrators, 369
conceptual model of e-mail versus web, 29
configuring routers, 264–265
dynamic routes, 268–270
static routes, 267
congestion
hubs, 107–108
reducing with LAN switches, 109–111
buffers, 113–114
full-duplex transmission, 115
connecting
to Frame Relay switches, 317
to Internet, 343–344
CATV, 349
DSL, 346–348
PPP, 345
connection establishment, TCP, 200–201
connectivity, 333–335
Ethernet LANs, 76
hubs, 78–79
physical, 39

connectors, 40, 74–75
RJ-45, 74
pinout options, 76
content, 172
conventions of IP addressing, 221
conversion
converting
binary IP addresses to decimal IP addresses, 449–450
binary to decimal, 440–441
decimal IP addresses to binary IP addresses, 441–447
decimal-to-hexadecimal-to-binary values, 450, 456
COs (central offices), 298
crackers, 385
creating VLANs, 137–138
cross-over cables, 77
leased lines, 301–302
CSMA/CD (carrier-sense multiple access/collision detection), 91–92
CSU/DSU (channel service unit/data service unit), 303

D

data link framing on WANs, 307–308
data link layer protocols, 308
data transmission
electrical interference, 44
error recovery, 45
over LANs, 67–70
cabling, 72–73
connectors, 74–75
digital transmission, 70–71
packets, 43
decapsulation in IP routing process, 248
decimal numbering system, 436–437
converting to binary, 441–449
converting to hexadecimal, 450, 456
decryption, 368, 370
default gateways, 238
denial of service attacks, 385
depletion of IP addresses, 228
deploying VLANs, reasons for, 140–142
destination address field (Ethernet), 94
destination IP address field, 213

devices
broadcast domains, 132
DSLAMs, 347
Frame Relay switches, 316–317
hubs, 78–79
congestion, 107–108
LAN switches, 107
full-duplex transmission, 115
reducing congestion, 109–114
modems, 25, 339–340
analog, 341
DSL, 347
operation, 341–342
transmission speeds, 342
routers, 209
forwarding to WAN links, 306
switches
autonegotiation, 126–127
creating VLANs, 137–138
flooding, 118–119
forwarding decisions, 110
learning MAC addresses, 117–118
MAC address table, 111
supporting multiple speeds, 125
trunking, 143–146
trunks, 143
WAN switches, 299
DHCP (Dynamic Host Configuration Protocol) in IP routing process, 243–244
diagrams, clouds, 6
digital transmission, 70–71, 338
directly connected subnets, 265
disk drives, 21
DIX Ethernet, 101
versus 802.3, 102
DLCIs (data-link connection identifiers), 319–320, 466
Inverse ARP messages, 329
DMZs (demilitarized zones), 383
DNS (Domain Name System), 281–282
authoritative DNS servers, 289
domains, 288
name format, 288
name resolution process, 283–288
root DNS servers, 288
servers, 158, 282
domains, 288
dotted decimal notation, 212, 447
downloading files, 32–33, 38
DSL (Digital Subscriber Line), 345
co-location, 347
connecting to Internet, 346
modems, 347
transmission speeds, 348
variants, 348

DSLAMs (DSL access multiplexers), 347
dynamic routes, 268
routing updates, 269–270
dynamically assigned port numbers, 199

E

EHLO (Extended Hello) command, 162
EIA/TIA (Electrical Industries Alliance/Telecommunications Industry Association), 75
electrical interference, 44
e-mail, 28–31, 155
addresses, 156
client, 31, 159
comparing with FTP, 167–169
Internet message formats, 161
POP3, 163
sending, 155
SMTP, 161
TCP/IP standards, 158
two-part addresses, 157
EMI (electromagnetic interference), 73
encapsulation, 88, 185, 215
HTTP, 242
in IP routing process, 240–243
over WAN links, 308
TCP, 186
encoding standards, 69, 42–43
encryption, 368
end-to-end routing process, 237–238, 253–254
ARP, 240
decapsulation, 248
default gateways, 238
DHCP, 243–244
encapsulation, 240–243
Ethernet framing, 251–252
finding web server MAC address, 255
routing table lookups, 249–251
with subnets, 256–258
enterprise networks, 22–24
Internet connections
firewalls, 378–381, 383
identifying allowable traffic, 373–378
WANs, 11–12
ephemeral port numbers, 199
error checking, FCS field, 99–100
error detection, 100

error recovery, 45, 100
TCP, 50, 187–188, 191
Ethernet, 88. ***See also*** **Fast Ethernet**
10 Gigabit Ethernet, 124
802.3 committee, 101
addressing, 94–96
broadcasting, 132
collisions, 90
CSMA/CD, 91–92
encapsulation, 88
frames, 88
framing, 251–252
Gigabit Ethernet, 123
headers, 89
source address field, 97–98
jamming signals, 93
LANs
connectivity, 76
hubs, 78–79
NICs, 76
10/100 cards, 127
standards, 101
trailers, FCS field, 99–100
Exterior Routing Protocols, 274
external CSU/DSU, 303

F

Fast Ethernet, 121–122
FCS (frame check sequence) field, 99–100), 241, 329
file read, 18
file servers, 20
file services, 21
file write, 18
files, transferring, 32–33, 38
filtering decisions, 118
filtering traffic with firewalls, 381–383
firewalls, 378–380
DMZs, 383
inside interface, 381
outside interface, 381
traffic filtering logic, 381–383
flooding, 118–119
flow, monitoring with firewalls, 379
format
of DNS names, 288
of Internet messages, 161
forward acknowledgment, 51, 190
forwarding decisions, 110, 251
versus filter decision, 118
forwarding frames on VLANs, 143
forwarding IP packets over WAN links, 307–308

Frame Relay, 315, 319, 336
access links, 317
CIR, 325
DLCIs, 319–320
FCS field, 329
full mesh, 321
Inverse ARP messages, 329
PVCs, 321
routing, 326–327
three-site networks, 323
VCs, 321
versus leased lines, 320, 324
Frame Relay Forum, 318
Frame Relay switches, 316–317
frames, 88, 215
broadcasting, 120, 132
buffering, 113–114
Ethernet, collisions, 90
flooding, 118–119
forward versus filter decision, 118
framing, 307–308
frequency, 339
FTP (File Transfer Protocol), 167, 170–171
comparing with email, 167–169
full-duplex transmission, 115
on WAN links, 304
full-mesh Frame Relay, 321

G-H

gateways, 49
GET command (FTP), 170
Gigabit Ethernet, 123

hackers, 385
half-duplex transmission, 115
HDLC (high-level data link control), 308
headers, 51
acknowledgment numbers, 51
Ethernet, 89
destination address field, 94
preamble, 89
source address field, 95–98
IP, 53
TCP, 186
TCP destination port field, 197
TCP source port field, 198
hexadecimal values, 95–97
converting to decimal and binary values, 450, 456
home pages, 174
host names (TCP/IP), 282
host-based IDSs, 385
hosts, 212
HTML (Hypertext Markup Language), 175

HTTP (Hypertext Transfer Protocol), 57, 174
encapsulation, 242
loading web pages from browsers, 176
hubs, Ethernet, 78–79

I

identifying
allowable traffic for enterprise network Internet connections, 373–378
IDSs (Intrusion Detection Systems), 385. ***See also*** **firewalls**
network-based, 385
signatures, 387
IEEE (Institute of Electrical and Electronic Engineers), 54
IEEE 802.1Q committee, VLAN trunking, 146
IEEE 802.3
autonegotiation, 126–127
Ethernet specifications, 124
IETF (Internet Engineering Task Force), 49
implementing VLANs, reasons for, 140–142
inside interface, 382
installing WAN links, 305
Interior Routing Protocols, 274
internal CSU/DSU, 303
Internet, 13, 23–24
connecting to, 333–335, 343–344
CATV, 349
DSL, 346–348
PPP, 345
DMZs, 383
e-mail, 28–31
file transfer, 32–33, 38
firewalls, 378–380
traffic filtering logic, 381–383
identifying allowable inbound traffic, 373–378
IDSs, 385
modems, 25
web browsers, 25–26
Internet message formats, 161
internetwork layer (TCP/IP model), 59
internetworks, 210, 237
Inverse ARP messages, 329
IP (Internet Protocol), 52–53

IP addresses, 211, 221
assigning to interfaces, 264–265
canonical format, 212
conventions, 221
converting to binary, 447–449
converting to decimal, 449–450
destination IP address field, 213
DNS name resolution, 283–288
hosts, 212
name resolution, 216
network classes, 223–227
network number, 222
NICs, 212
octets, 212
routing process, 217–220
source IP address field, 213–214
subnetting, 227–231
IP networks, 222
IP packets, 214, 263
IP routing
end-to-end routing process, 237–238, 253–254
ARP, 240
decapsulation, 248
default gateways, 238
DHCP, 243–244
encapsulation, 240–243
Ethernet framing, 251–252
finding web server MAC address, 255
routing table lookups, 249–251
with subnets, 256–258
ISL (Inter-Switch Link), 146
ISPs (Internet service providers), 13, 23, 335
authentication, 362
with CHAP, 365–366
with PAP, 362–364
connecting to Internet, 333–335, 343–344
CATV, 349
DSL, 346–348
PPP, 345
ITU (International Telecommunications Union), 55

J-K

jamming signals, 93

Kerberos, 357–359
KISS (Keep It Simple, Stupid) principle, 46

L

LAN switches, 107. *See also* LANs
autonegotiation, 126–127
flooding, 118–119
forwarding decisions, 110
MAC address table, 111
learning process, 117–118
reducing congestion, 109–111
buffers, 113–114
full-duplex transmission, 115
supporting multiple speeds, 125
LANs, 54. *See also* VLANs
broadcasting, 132
components of, 66–67
data transmission, 67–70
cabling, 72–73
connectors, 74–75
digital, 70–71
Ethernet, 88
10 Gigabit Ethernet, 124
802.3 committee, 101
addressing, 94–96
collisions, 90
connectivity, 76
CSMA/CD, 91–92
encapsulation, 88
Fast Ethernet, 122
frames, 88
Gigabit Ethernet, 123
headers, 89
hubs, 78–79
jamming signal, 93
source address field, 97–98
standards, 101
hubs, congestion, 107–108
physical LANs, creating, 134–136
structured wiring plans, 80–82
versus WANs, 295
LANs (local-area networks), 11
Layer 8, 141
layers of TCP/IP model, 56–57
comparing to OSI model layers, 59
learning
dynamic routes, routing updates, 271
MAC addresses, 117–118
leased circuits, 301
leased lines, 55, 297–302, 336
analog transmission, 339
creating, 305
digital transmission, 338
versus Frame Relay, 320, 324
voice traffic, 337
LLC (Logical Link Control), 101
loading web pages from browsers, 175–176
local host file, 280–281
local loop, 336
logical addressing, 52
loopback circuits, 93

M

MAC (Media Access Control), 101
addresses, 102, 111
learning, 117–118
unicast, 120
Mbps (megabits per second), 70
message digest, 366
messages, SMTP, 161
Metcalfe, Robert, 101
metrics, 272–273
modems, 25, 339–340
analog, 341
DSL, 347
operation over PSTN, 341–342
transmission speeds, 342
modulation, 341
monitoring traffic with firewalls, 379–380
moving files, 32–33, 38
mss (maximum segment size), 192
multiaccess networks, Frame Relay VCs, 321

N

name resolution, 216
network analysis tools, 365
network applications
e-mail, 28–31
file read, 18
file transfer, 32–33, 38
file write, 18
web browers, 25–26
network classes, 223–227
network clouds, 21
network engineers, 10
network layer protocols, 59
network number, 222, 226–227
Class A networks, 221
Class B networks, 221
Class C networks, 221
network services, 18
network utilities, 9
networking models, 47
OSI, 57–58
proprietary, 47–48
public, 49
TCP/IP, 50–53
layers, 56–57
networking protocols, 44

networking standards, 37, 40
data transmission, 42–43
electrical interference, 44
error recovery, 45
IEEE, 54
ITU, 55
networks
Frame Relay VCs, 321
IP
classes, 223–227
subnetting, 227–231
subnetting, 229, 231
next-hop routers, 250
NICs (network interface cards), 39, 65, 212
10/100 cards, 127
autonegotiation, 126–127
Ethernet, 76
loopback circuits, 93
numbering systems
binary, converting to decimal and hexadecimal values, 450, 456
hexadecimal, converting to decimal and binary values, 95–97, 450, 456

O

octets, 212
open networking models, 49
TCP/IP, 50
IP, 52–53
TCP, 50
OS (operating system), 182
OSI reference model, 57–58
application layer protocols, 184
Layer 8, 141
transport layer protocols, 182–183
TCP, 184—201
versus TCP/IP model, 58
outside interfaces, 381

P

packets, 43–44, 214, 252, 263
acknowledgment numbers, 51
encapsulation, 215
error recovery, 45
forward acknowledgment, 51
headers, 51
IP, 214–216
header, 53
sequence numbers, 51
versus segments, 214

PAP (Password Authentication Protocol), 362–364
passwords, 356
clear-text, 364
patch panels, 82
PCs (personal computers), 6
phones, comparing with modems, 339–340
physical connectivity, 39
cabling, cross-over, 77
connectors, 40, 74–75
structured wiring plans, 80–82
physical LANs, creating, 134–136
pins, 74
PIX Firewall, 379
point-to-point links, 301
POP (point of presence), 343
POP3, 159, 163
and SMTP, 164
port numbers, TCP, 198
PPP (Point-to-Point Protocol), 308, 344
preamble, 89
print servers, 21
print services, 21
proprietary networking models, 47–48
protocols, 44
PSTN (public switched telephone network), 337
public networking models, 49
TCP/IP, 50
IP, 52–53
TCP, 50
PUT command (FTP), 170
PVCs (permanent virtual circuits), 321, 325

R

RADIUS, 364
reducing congestion with LAN switches, 109–111
buffers, 113–114
full-duplex transmission, 115
resolving DNS names to IP addresses, 216, 283–288
RFCs (requests for comments), 50, 159
RJ-45 connectors, 74
pinout options, 76
root DNS servers, 288
routers, 209
configuring, 264–265
dynamic routes, configuring, 268
forwarding to WAN links, 306
IP, forwarding packets over WAN links, 307–308

next-hop, 250
static routes, configuring, 267
routing, 52, 209–210
assigning IP addresses to interfaces, 264–265
directly connected subnets, 265
end-to-end routing process, 237–238, 253–254
ARP, 240
decapsulation, 248
default gateways, 238
DHCP, 243–244
encapsulation, 240–243
Ethernet framing, 251–252
finding web server MAC address, 255
routing table lookups, 249–251
with subnets, 256–258
IP addresses, 211, 217–220
canonical format, 212
conventions, 221
destination IP address field, 213
hosts, 212
network classes, 223–227
network number, 222
NICs, 212
octets, 212
source IP address field, 213–214
subnetting, 227–231
static IP, 267
routing protocols, 268
metrics, 272–273
routing tables, 53, 247
lookups, 249–251
routing updates, 269–270

S

security
accounting, 360–361
anti-virus software, 386–387
authentication, 356–357, 362
CHAP, 365–366
PAP, 362–364
with username and password, 356–359
authorization, 359–360
firewalls, 378–380
DMZs, 383
traffic filtering logic, 381–383
identifying allowable traffic on enterprise network Internet connection, 373–378

IDSs, 385
network-based, 385
signatures, 387
VPNs, 368–370
segments, 193
mss, 192
TCP, 187
versus packets, 214
sending email, 155
sequence number field (TCP header), 189
sequence numbers, 51
serial interfaces, 298
CSU/DSU, 303
serial links, 301
addressing, 309
SEs (sales engineers), 298
signatures, 387
single broadcast domains, 133
single site networks, 6
SMTP (Simple Mail Transfer Protocol) , 159, 161
and POP3, 164
Sneakernet, 20
sniffers, 365
software, e-mail client, 159
source address field (Ethernet header), 95, 97–98
source IP address field, 213–214
standards, 37, 40
encoding, 69
Ethernet, 101
networking models, 47
data transmission, 42–45
proprietary, 47–48
public, 49–53
OSI reference model, 57–58
standards bodies
IEEE, 54
ITU, 55
static IP routes, 267
STP (shielded twisted pair), 73
straight-through cables, 77
structured wiring plans, 80–82
subnets, 227–231
directly connected, 265
end-to-end routing process, 256–258
switch ports, 10, 111
switches
autonegotiation, 126–127
creating multiple physical LANs, 134–136
flooding, 118–119
forwarding decisions, 110
Frame Relay, 316
MAC addresses
learning, 117–118
table, 111

reducing congestion, 109–111
buffers, 113–114
full-duplex transmission, 115
supporting multiple speeds, 125
trunking, 143–144, 146
VLANs
creating, 137–138
forwarding decisions, 143
frame forwarding, 139–140
reasons for implementing, 140–142
SYN flag bit (TCP), 380

T

T1 lines, 302
TCP (Transmission Control Protocol), 50, 184, 215, 379
connection establishment, 171, 200–201
error recovery, 187–188, 191
forward acknowledgment, 190
headers, 186
destination port field, 197
port numbers, 198
segmentation, 187, 193
SYN flag bit, 380
TCP/IP, 49–50
DNS, 281–282
name format, 288
name resolution, 283–288
root DNS servers, 288
e-mail standards, 158
IP addressing, 52–53, 221
subnets, 228
local host file, 280–281
networking model
layers, 56–57, 215
versus OSI model, 58
TCP, 50
telcos
COs, 298
Frame Relay service, 319
leased lines, 298–302
SEs, 298
telephone switches, 340
three-site Frame Relay networks, 323
traffic
filtering with firewalls, 381–383
monitoring with PIX Firewall, 379–380
trailers (Ethernet), FCS field, 99–100
transferring files, 32–33, 38
with FTP, 167, 170–171

transmission speeds
CIR, 325
of DSL, 348
of modems, 342
of WAN links, 302
transport layer protocols, 58, 181–183
TCP, 184
connection establishment, 200–201
error recovery, 187–188, 191
headers, 186
port numbers, 198
segmentation, 193
segments, 187
trunking, 143–146
802.1Q, 146
ISL, 146
twisted pair cabling, 73
two-part email addresses, 157
types of WANs, 336

U

unicast MAC addresses, 120
uploading files, 32
URLs (uniform resource locators), 27, 174
usernames, 356
authentication, 356–359
clear-text, 364
UTP (unshielded twisted pair), 73

V

VCs (virtual circuits), 321
CIR, 325
vendor consortiums, 318
vendor-proprietary networking models, 47–48
viruses, 385–387
VLANs, 131
creating, 137–138
frame forwarding, 139–140
reasons for implementing, 140, 142
switch logic, 143
trunking, 143–146
802.1Q, 146
ISL, 146
voice circuits, 337
voltage, 42
VPNs (virtual private networks), 368–370

W

wall plates, 9
WANs, 11–12, 54
data link framing, 307–308
Ethernet-based, 297
Frame Relay, 315, 319
access links, 317
CIR, 325
DLCIs, 319–320
FCS field, 329
full mesh, 321
Inverse ARP messages, 329
PVCs, 321
routing, 326–327
three-site networks, 323
VCs, 321
verus leased lines, 320, 324
leased lines, 297–302, 336
analog transmission, 339
digital transmission, 338
voice traffic, 337
links, 296, 300
addressing, 309
full-duplex transmission, 304
installing, 305
transmission speeds, 302
serial interfaces, 298
CSU/DSU, 303
types, 336
versus LANs, 295
waveform, 71
web addresses, 27
web browsers, 25–26, 172
web clients, 172
web pages, 26
loading from browsers, 175–176
web servers, 26, 172
websites, 26, 172
well-known ports, 199, 380
wiring closets, 7
wall plates, 9
wiring panels, 9, 82
word processing applications, 18
WWW (World Wide Web), 172