

CCIE™ 350-001: Routing and Switching Prep Kit

BaerWolf, Inc.

Contents at a Glance

Introduction 1

I Topic Overview 7

- 1** General Network Overview 9
- 2** General Topic Overview 25

II The LAN 55

- 3** Ethernet 57
- 4** Token-Ring and FDDI 71
- 5** LANE—LAN Emulation 85

III Switching and Bridging 103

- 6** LAN Switching 105
- 7** Other Bridging Technologies 123

IV Routing TCP/IP 149

- 8** TCP/IP 151
- 9** Routing Concept Overview 179
- 10** RIP 195
- 11** IGRP and EIGRP 209
- 12** OSPF 227
- 13** BGP 245
- 14** Managing Routing 261

V Other Network Protocols 287

- 15** IPX: Internet Packet Exchange 289
- 16** AppleTalk 307
- 17** Other LAN Protocols 325

VI The WAN 337

- 18** ISDN and DDR 339
- 19** X.25 365
- 20** Frame Relay 393
- 21** ATM: Asynchronous Transfer Mode 413

VII Appendixes 429

- A** Objectives Index 431
- B** Glossary 443
- C** CCIE Certification Process and Testing Tips 475
- D** Alternative Resources 481
- E** Using the CD-ROM 483
- F** Lab Exercises 485

Index 493

que®

A Division of Macmillan Computer Publishing, USA
201 W. 103rd Street
Indianapolis, Indiana 46290

CCIE™ 350-001: Routing and Switching Prep Kit

Copyright© 2000 by Que® Corporation.

All rights reserved. No part of this book shall be reproduced, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without written permission from the publisher. No patent liability is assumed with respect to the use of the information contained herein. Although every precaution has been taken in the preparation of this book, the publisher and author assume no responsibility for errors or omissions. Nor is any liability assumed for damages resulting from the use of the information contained herein.

International Standard Book Number: 0-7897-2359-x

Library of Congress Catalog Card Number: 00-100682

Printed in the United States of America

First Printing: June, 2000

02 01 00 4 3 2 1

Trademarks

All terms mentioned in this book that are known to be trademarks or service marks have been appropriately capitalized. Que Corporation 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.

CCIE is a trademark of Cisco Systems, Inc.

Warning and Disclaimer

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 provided is on an “as is” basis. The author(s) and the publisher 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 CD-ROM or programs accompanying it.

Credits

Associate Publisher

Greg Wiegand

Acquisitions Editor

Tracy Williams

Development Editors

Rick Kughen

Hugh Vandivier

Managing Editor

Thomas Hayes

Project Editor

Tonya Simpson

Copy Editor

Michael Dietsch

Indexer

Kevin Kent

Proofreader

Maribeth Echard

Technical Editor

Matthew Luallen

Team Coordinator

Vicki Harding

Media Developer

Jay Payne

Interior Designer

Anne Jones

Cover Designers

Anne Jones

Kevin Spear

Copywriter

Eric Borgert

Production

Darin Crone

Acknowledgments

I would like to thank the engineers and consultants of Lucent NetworkCare (listed below) for their collective expertise and effort that was invested in this book. Most of you wrote your contributions in addition to serving your clients on a full-time basis. I thank you on behalf of myself, BaerWolf, Inc., Macmillan Publishing (Que), and the readers.

I would also like to thank BaerWolf, Inc. for entrusting me with this project. I have endeavored to coordinate this effort with your best interest in mind and contribute my technical expertise wherever needed.

Finally, I must thank my wife. Over the last five months you have unconditionally encouraged me—despite the very long hours, lack of time off, and the mental energy that I have spent on this project instead of on you and our beautiful four-month-old son. I am forever in your debt for your faith, strength, friendship, and love.

—*Tom Knobel-Piehl, Coordinating Author*

About the Authors

BaerWolf, Inc. delivers targeted training solutions for businesses that specifically address their unique training needs. The most popular BaerWolf services for the IT and skills development markets include programming, networking, IT management, and the development of programming and networking course content like you see in this Cisco Certified Internetwork Expert (CCIE) book.

BaerWolf works with you to develop a training program uniquely suited to your situation and circumstances. With BaerWolf, training is delivered to you when you need it, where you need it, and in a format that best matches your desired learning style. Our customized approach to training solutions includes helping you assess your training goals, determining the existing skills of those who need training, and delivering the training to you in the method you want, including in a classroom, mentoring, in a lab/workshop, online, as self-study materials, or a combination of these methods.

BaerWolf's long list of satisfied clients include Andersen Consulting, Boeing, Born Information Services Group, Gateway 2000, Lutheran Brotherhood, Macmillan USA, Mayo Medical Center, MCC Behavioral Care, and US West Communications, Inc. We look forward to adding your company to this list. Contact us today at <http://www.baerwolf.com>.

Lucent Technologies NetworkCare is a global provider of network consulting and software solutions for the full lifecycle of a network, including planning and design, implementation, and operations. Lucent NetworkCare maintains expertise in the most complex

network technologies and multivendor environments plus offers industry-leading software solutions for managing and optimizing application-ready networks.

An approach to helping customers stay ahead of network problems is at the heart of Lucent NetworkCare's Network Engagement Methodology (NEM). This collaborative knowledge management tool helps assure quality, consistency, and best practices in every Lucent NetworkCare network consulting engagement.

At the root of NEM is Lucent NetworkCare's Network Lifecycle Methodology (NLM), the basis for providing quality solutions to NetworkCare's clients. NLM provides the consultants with a framework for applying their technology expertise during the various stages of the network lifecycle to assure maximum client benefits from our services.

This book was written through a collaborative effort with BaerWolf, Inc. and more than a dozen Lucent NetworkCare engineers and consultants who are subject-matter experts averaging more than 10 years' networking experience, and most of whom are Cisco Certified Internetwork Experts (CCIE), Cisco Certified Network Professionals (CCNP), Cisco Certified Networking Associates (CCNA), and/or Cisco Certified Design Associates (CCDA).

Lucent NetworkCare: Solving your most challenging network problems with the best minds in the business. Visit us at <http://www.networkcare.com>.

Contributing Authors

John Hein

Jim Stewart

Russ Campbell

Sean Boulter

Clair LaBrie

Mike Balistreri

Mike Speed

John Markatos

Rajvir Wadhwa

Dan Overland

Jon Grubbs

Dennis Olds

Sean Snyder

Glenn Boyle

Dave McMillan

Tell Us What You Think!

As the reader of this book, *you* are our most important critic and commentator. We value your opinion and want to know what we're doing right, what we could do better, what areas you'd like to see us publish in, and any other words of wisdom you're willing to pass our way.

As an associate publisher for Que, I welcome your comments. You can fax, email, or write me directly to let me know what you did or didn't like about this book—as well as what we can do to make our books stronger.

Please note that I cannot help you with technical problems related to the topic of this book, and that due to the high volume of mail I receive, I might not be able to reply to every message.

When you write, please be sure to include this book's title and author as well as your name and phone or fax number. I will carefully review your comments and share them with the author and editors who worked on the book.

Fax: 317-581-4666

Email: certification@macmillanusa.com

Mail: Associate Publisher

Que

201 West 103rd Street

Indianapolis, IN 46290 USA

Table of Contents

Introduction 1

I TOPIC OVERVIEW 7

1 General Network Overview 9

OSI Model 10

Seven-Layer Model 10

OSI Protocol Map 12

Switching Versus Routing 13

Tunneling 13

Layer 2 Standards 14

802.3 14

Ethernet 15

802.2 (LLC) 15

802.5 15

802.6 16

FDDI 16

Protocol Functions 17

Connection-Oriented Versus Connectionless Protocols 17

Handshaking 17

ACKs 18

Windowing 18

Flow Control 18

MTU 19

Error Checking 19

Termination 19

Interface Speeds 19

LAN Interfaces 19

WAN Interfaces 20

Summary 20

2 General Topic Overview 25

Binary, Decimal, and Hex 26

Access Lists 27

IP Access Lists 29

ICMP 31

TCP and UDP 31

IPX Access Lists 31

SAP Filter 32

NLSP Filter 32

<i>AppleTalk Access Lists</i>	32
Network Filter	32
Cable Range Filter	33
Range Filter	33
Zone Filter	33
NBP Filter	33
<i>Distribute Lists</i>	33
<i>Access Class</i>	34
Performance Management	34
<i>Queuing</i>	34
Priority Queuing Commands	35
Custom Queuing Commands	35
<i>Resource Reservation Protocol (RSVP)</i>	36
<i>Compression</i>	36
<i>Load Balancing</i>	37
Security	37
AAA	37
TACACS	38
RADIUS	38
Firewalls	39
<i>Encryption Keys and DES</i>	40
Multiservice Technologies	40
H.323	41
Codecs	41
SS7	41
<i>Real-Time Transport Protocol (RTP)</i>	42
Cisco Device Operation	42
<i>Router Infrastructure Review</i>	42
<i>Router Management</i>	43
<i>Cisco Discovery Protocol (CDP)</i>	46
<i>Simple Network Management Protocol (SNMP)</i>	47
<i>The Cisco Hierarchical Internetworking Model</i>	48
Summary	48

II THE LAN 55

3 Ethernet 57

Definition and Architecture	58
Media Access Control Layer	59
Carrier Sense and Collision Detection	60

IEEE 802.3 MAC Frame and Address Format	62
Ethernet II Versus IEEE 802.3	63
Gigabit Ethernet	64
Limitations and Troubleshooting	65
Summary	65
4 Token-Ring and FDDI	71
Token-Ring	72
<i>Token-Ring Operation</i>	73
<i>Frame Format</i>	73
<i>Token-Ring Fault-Management Mechanisms</i>	75
<i>Priority Scheme</i>	76
Fiber Distributed Data Interface	76
<i>FDDI Specifications</i>	77
<i>Physical Features</i>	77
<i>FDDI Fault-Management Features</i>	78
<i>Bandwidth Features</i>	79
<i>Frame Format</i>	79
5 LANE—LAN Emulation	85
LANE Components	86
<i>Virtual Connection Types for LANE</i>	88
LANE Communications	90
<i>LEC Setup</i>	90
<i>LEC Communication</i>	92
Configurations	93
<i>LEC Configuration</i>	94
<i>LES/BUS Configuration</i>	94
<i>LECS Configuration Example</i>	94
<i>Obtain LES NSAP Address Configuration</i>	95
Simple Server Replication Protocol (SSRP)	95
Summary	97

III SWITCHING AND BRIDGING 103

6 LAN Switching	105
Transparent Bridging	106
<i>Configuration of Transparent Bridging</i>	107
Spanning Tree Protocol (STP)	107
<i>Bridge Protocol Data Unit (BPDU)</i>	108
<i>Interface Modes</i>	109

- VLANs 111
- Trunking 111
 - Trunk Modes* 112
 - Trunk Configuration* 112
- EtherChannel 113
 - EtherChannel Modes* 113
 - EtherChannel Configuration* 113
- VLAN Trunk Protocol (VTP) 114
 - VTP Messages* 115
 - VTP Configuration* 116
- Multicast Management 116
 - Internet Group Management Protocol (IGMP)* 116
 - Cisco Group Management Protocol (CGMP)* 117
- Summary 117

7 Other Bridging Technologies 123

- Nonroutable Protocols 124
- Concurrent Routing and Bridging 124
 - Understanding CRB* 125
 - Configuring CRB* 125
- Integrated Routing and Bridging 126
 - Understanding IRB* 126
 - Configuring IRB* 127
- Source-Route Bridging 127
 - Understanding SRB* 128
 - Understanding RIF Fields* 129
 - Constructing a RIF* 131
 - Configuring Pure SRB* 132
 - Configuring Multiport SRB* 133
- Remote Source-Route Bridging 134
 - Understanding and Configuring RSRB* 134
- Source-Route Transparent Bridging 135
 - Configuring SRT* 136
- Source-Route Translational Bridging 136
 - Understanding Ethernet to Token-Ring MAC Conversion* 136
 - Configuring Basic SR/TLB* 137
- Data-Link Switching 139
 - DLSw Terms* 139
 - DLSw Operation* 140
 - Configuring DLSw* 141
 - Command Output Examples* 142

IV ROUTING TCP/IP 149

8 TCP/IP 151

IP 152

Header Format 152

IP Addressing 154

Address Masks 156

Address Resolution Protocol (ARP) 158

Transmission Control Protocol (TCP) 160

Features 160

Header Format 161

TCP Connection Establishment 163

User Datagram Protocol (UDP) 163

Well-Known TCP/UDP Ports 164

Domain Name Service (DNS) 165

Internet Control Message Protocol (ICMP) 166

Hot Standby Routing Protocol (HSRP) 167

Dynamic Host Configuration Protocol (DHCP) 168

Network Address Translation (NAT) 169

Summary 171

9 Routing Concept Overview 179

Loop Prevention Techniques 180

Split Horizon 180

Poison Reverse 181

Other Mechanisms 182

Link State Versus Distance Vector 183

Classful Versus Classless Routing 184

Route Selection 184

Static and Default Routes 185

Default Administrative Distances 189

Summary 190

10 RIP 195

Routing Metrics 196

Route Updates 197

RIP Timers 198

RIPv1 199

RIPv2 200

Configuration Examples 202

Summary 205

11 IGRP and EIGRP 209

- IGRP 210
 - Stability Features* 211
 - Route Metrics* 212
 - Route Updates* 213
 - Monitoring IGRP* 214
 - IGRP Configuration Example* 216
- EIGRP 217
 - Route Metrics* 217
 - Components* 217
 - Route Summarization* 219
 - Bandwidth Control* 220
 - Adjacency Process* 220
 - Route Convergence* 220
 - EIGRP Configuration Examples* 221
 - Sample Configuration 222
- Summary 223

12 OSPF 227

- OSPF Features 228
 - Metric* 228
 - Bandwidth Conservation* 229
 - Fast Convergence* 229
 - Hierarchical Design* 230
 - VLSM Support* 230
 - Authentication* 230
 - Memory Requirements* 230
 - Processor Power* 230
- OSPF Operation 231
 - Establishing Neighbors* 231
 - DR and BDR Election* 231
- Route Discovery 232
 - Route Selection* 232
 - Route Maintenance* 233
- Hierarchy and Components 233
 - Area Types* 233
 - Router Types* 234
 - LSA Types* 235
 - Virtual Links* 236

Configuration Examples	236
<i>Basic OSPF Configuration</i>	236
<i>Stub Area Configuration</i>	237
<i>Virtual Link Configuration</i>	238
<i>Troubleshooting Commands</i>	239
Summary	239
13 BGP	245
Design Elements and Definitions	246
Route Maps, Filters, and Neighbors (Peers)	247
<i>Route Maps</i>	247
<i>Filters</i>	248
Filter by Route Example	248
Filter by Path Example	249
Filter by Community Example	249
<i>Neighbors/Peers</i>	250
Decision Algorithm	250
Interior Border Gateway Protocol (IBGP)	252
Exterior Border Gateway Protocol (EBGP)	252
<i>CIDR (Classless Inter-Domain Routing)</i>	253
Other BGP Associated Terms and Commands	254
<i>Autonomous System</i>	254
<i>Neighbor Definition</i>	254
<i>To Validate BGP Peer Connections</i>	254
<i>Redistribution</i>	255
<i>BGP Backdoor Command</i>	255
<i>Multi-Exit Discriminator (MED)</i>	255
<i>Methods of Route Manipulation</i>	255
<i>Basics of Route Maps</i>	255
<i>Communities</i>	256
<i>Confederation</i>	256
<i>Route Flap Dampening</i>	256
<i>Route Reflectors</i>	257
Summary	257
14 Managing Routing	261
Route Redistribution	262
<i>Metric Issues</i>	262
<i>Summarization Issues</i>	264
<i>Route Tagging</i>	266

Route Management	267
<i>Passive Interfaces</i>	268
<i>Distribute Lists</i>	268
<i>Policy Routing</i>	270
<i>Route Selection</i>	273
Multicast Management	275
<i>Protocol Independent Multicast (PIM)</i>	275
Dense Mode	275
Sparse Mode	275
Sparse-Dense Mode	277
<i>Distance Vector Multicast Routing Protocol (DVMRP)</i>	278
<i>Internet Group Management Protocol (IGMP)</i>	280
<i>Cisco Group Management Protocol (CGMP)</i>	281
Summary	281

V OTHER NETWORK PROTOCOLS 287

15 IPX: Internet Packet Exchange 289

Frame Format	290
IPX Addressing	290
Encapsulation Types	291
<i>Ethernet</i>	291
<i>Token-Ring</i>	292
<i>FDDI</i>	292
<i>Serial</i>	292
Service Advertisement Protocol (SAP)	293
Get Nearest Server	293
IPX Configuration Fundamentals	293
ipxwan	294
IPX Routing	294
<i>IPX RIP</i>	294
<i>IPX EIGRP</i>	295
<i>IPX NLSP</i>	295
Basic IPX Configuration Example	295
<i>R1</i>	296
<i>R2</i>	296
<i>R3</i>	297
<i>R4</i>	297
<i>R7</i>	297

<i>Identifying Routes</i>	297
<i>Identifying Servers</i>	299
Filtering IPX Network Traffic	300
<i>Access Lists</i>	300
Standard Access Lists	300
Extended Access Lists	300
SAP Filters	301
Summary	302
16 AppleTalk	307
AppleTalk Protocol Suite	308
Addressing	310
<i>Addressing Structure</i>	310
<i>Address Assignment</i>	311
Zones	312
Services	312
<i>DDP</i>	312
<i>AARP</i>	313
<i>AEP</i>	314
<i>ATP</i>	314
<i>NBP</i>	315
<i>ZIP</i>	315
<i>ASP</i>	316
<i>ADSP</i>	316
<i>PAP</i>	316
<i>AFP</i>	316
AppleTalk Routing	317
<i>RTMP</i>	318
<i>AURP</i>	318
<i>AppleTalk EIGRP</i>	319
Configuration Commands	319
Summary	320
17 Other LAN Protocols	325
DECnet	326
Addressing	327
Routing	327
Configuration	328
NetBIOS	330
Summary	331

VI THE WAN 337

18 ISDN and DDR 339

ISDN	340
<i>ISDN Function Groups and Reference Points</i>	340
<i>ISDN Protocols (HDLC and LAPD)</i>	342
PPP	345
<i>PPP Features</i>	345
<i>PPP Frame Format</i>	347
<i>PPP Protocols</i>	348
<i>ISDN and DDR</i>	349
Interesting Traffic	350
<i>Dialer Maps</i>	351
<i>ISDN Callback</i>	352
<i>ISDN and Dial Backup</i>	352
More Examples	354
<i>Example 1</i>	354
<i>Example 2</i>	355
<i>Example 3</i>	356
<i>Example 4</i>	357
<i>Example 5</i>	357
<i>Example 6</i>	358
<i>Example 7</i>	358
Summary	359

19 X.25 365

Features	366
X.25 and the OSI Model	367
Addressing	368
X.25 Routing	369
Encapsulation	369
<i>X.25 Over TCP/IP (XOT)</i>	370
Route Tables	371
Link Access Procedure Balanced (LAPB)	372
Error Control/Recovery	374
Flow Control/Windowing	376
<i>Sliding Window Flow Control</i>	376
<i>Buffering Flow Control</i>	377
<i>Source-Quench Messages</i>	377

Signaling	377
Mapping	378
Switched Virtual Circuit (SVC)/Permanent Virtual Circuit (PVC)	380
Protocol Translation	383
Configuration Example	386
Summary	387

20 Frame Relay 393

Frame Relay Overview	394
Permanent Virtual Circuits and DLCIs	395
Link Management Interface (LMI)	396
Frame Relay and Layer 3 Addressing	398
<i>Inverse ARP</i>	399
<i>Frame Relay Maps</i>	400
<i>Subinterfaces</i>	401
Frame Relay Traffic Management	403
Cisco's Implementation of Traffic Shaping	405
Summary	408

21 ATM: Asynchronous Transfer Mode 413

PVCs and SVCs	414
ATM Interfaces	414
<i>PNNI</i>	415
<i>ATM Cell Header Format</i>	416
<i>ATM Protocol Reference Model</i>	416
<i>ATM Addressing</i>	417
<i>ATM Signaling</i>	418
ATM Features and Terminology	419
<i>Service Specific Convergence Protocol (SSCOP)</i>	419
<i>Interim-Interswitch Signaling Protocol (IISP)</i>	419
<i>Quality of Service (QoS)</i>	419
Configuration Examples	420
<i>ATM Permanent Virtual Circuit (PVC) Configuration Examples Using AAL5snap and AAL5mux Encapsulations</i>	420
<i>ATM Switched Virtual Circuit (SVC) Configuration Example</i>	422
Summary	423

VII APPENDIXES 429

- A Objectives Index 431
- B Glossary 443
- C CCIE Certification Process and Testing Tips 475
- D Alternative Resources 481
- E Using the CD-ROM 483
- F Lab Exercises 485

For years now, data networks have become increasingly important. At first, networks were just a large corporate phenomenon. Now, almost any business with more than a few computers or more than one location has a data network. And now, with the growth of the Internet, many people's home computers are often connected to a network. As data networks grow in size and importance, there must be a corresponding growth of people required to design, build, and maintain them.

Cisco invented the router and has been selling networking products since 1986. Since then, the company has maintained a definitive lead in the data networking marketplace. Some people estimate that 85% of routers and switches are Cisco products. Regardless of the exact number (which is hard to definitively prove), Cisco is and probably will be a major player for a long time to come.

So, two factors should reinforce your decision to obtain Cisco certification:

- The continual rise in the importance of data networks
- Cisco's market leadership in much of this market

So, if you are an entrepreneurial individual who is interested in computers, you'll see these two factors and notice a growing employment market for people trained in Cisco networking products. Cisco certainly saw this, and that is why Cisco developed its certification series.

Intended Audience and Prerequisites

This book is written for intermediate to advanced network engineers who have at least some hands-on experience. Some topics, even some whole chapters, assume you have a certain familiarity with networks. We wrote this book

like this for two reasons. First, the CCIE is one of the most advanced professional certifications in the world. It certainly is the most advanced network-related technical certification. It is unrealistic for an average person to be able to read a single book and be able to pass the CCIE Written Exam. Also, the amount of material that would be required to take a complete novice to the level of knowledge required to pass the CCIE Written Exam would not fit within the covers of a single book.

We recommend at least two years of solid hands-on data networking professional experience (that is, not just tech college, college, or university classes) before seriously pursuing the CCIE certification. You might be able to pass the written exam, but you'd have to take the lab exam within a year, and classroom experience is just not enough to offer you a reasonable chance of success.

However, if you have two years of experience, we strongly encourage you to take this big step in your career. CCIEs are in extremely high demand. Not only is a CCIE a great thing to put on your résumé, but it will help you immensely when it comes time to discuss your salary and benefits package!

Cisco Certifications and the CCIE

The CCIE was Cisco's original professional certification. The company wanted to design a program that would define people as definitive experts in the field of data networking with Cisco equipment. The program is designed to prevent people from successfully completing it if all they use for preparation is "book knowledge." Cisco wanted to ensure that people with a CCIE have knowledge *and* excellent hands-on ability (that is, experience). The company accomplished this by designing a two-step program: a written exam and a hands-on lab exam. The written exam could be taken at the same places as other certification exams (such as Microsoft's MCSE exams). But the lab exam was originally offered only at Cisco's headquarters in San Jose, California. The lab exam was (and is) a two-day hands-on affair. It is proctored and graded by a Cisco staff expert and includes configuration and troubleshooting of a variety of general and Cisco-specific technologies.

After the CCIE program was established and running, Cisco implemented a number of other certifications. Two of these, CCNA and CCNP, have a twofold purpose. First, they offer more people the chance to attain some level of certification at different knowledge and skill levels. Second, they form a track to prepare people for the CCIE. CCNA and CCNP certifications are not prerequisites for a CCIE, as some people think. However, they can be useful in your CCIE preparation, either as training or as validation of your skills before attempting the challenge of the CCIE. More information on these certifications can be found on Cisco's Web site:

<http://cco-sj-2.cisco.com/warp/public/10/wwtraining/certprog/index.html>