

Contents

Foreword xxiii

Introduction: Overview of Certification and How to Succeed xxiv

Part I Overview and Design of a Campus Network 2

Chapter 1 Campus Network Overview 5

“Do I Know This Already?” Quiz 5

Foundation Topics 9

Switching Functionality 9

Layer 2 Switching 10

Layer 3 Routing 10

Layer 3 Switching 11

Layer 4 Switching 12

Multilayer Switching (MLS) 12

Campus Network Models 12

Shared Network Model 13

LAN Segmentation Model 14

Network Traffic Models 17

Predictable Network Model 19

Hierarchical Network Design 19

Access Layer 20

Distribution Layer 21

Core Layer 21

Cisco Products in the Hierarchical Design 21

Access Layer Switches 22

Distribution Layer Switches 23

Core Layer Switches 24

Product Summary 25

Foundation Summary 27

Q&A 30

Chapter 2 Modular Network Design 33

“Do I Know This Already?” Quiz 33

Foundation Topics 37

Modular Network Design 37

The Switch Block 38

Sizing a Switch Block 39

The Core Block 41

Collapsed Core 42

Dual Core 43

Core Size in a Campus Network 45

	<i>Other Building Blocks</i>	45
	Server Farm Block	46
	Network Management Block	46
	Enterprise Edge Block	47
	Service Provider Edge Block	47
	Can I Use Layer 2 Distribution Switches?	48
	Foundation Summary	50
	Q&A	52
Part II	Building a Campus Network	54
Chapter 3	Switch Operation	57
	“Do I Know This Already?” Quiz	57
	Foundation Topics	61
	Layer 2 Switch Operation	61
	<i>Transparent Bridging</i>	61
	<i>Follow That Frame!</i>	63
	Multilayer Switch Operation	66
	<i>Types of Multilayer Switching</i>	66
	<i>Follow That Packet!</i>	67
	<i>Multilayer Switching Exceptions</i>	69
	Tables Used in Switching	69
	Content Addressable Memory (CAM)	70
	Ternary Content Addressable Memory (TCAM)	71
	TCAM Structure	71
	TCAM Example	72
	Port Operations in TCAM	74
	Troubleshooting Switching Tables	75
	CAM Table Operation	75
	TCAM Operation	76
	Foundation Summary	77
	Q&A	79
Chapter 4	Switch Configuration	83
	“Do I Know This Already?” Quiz	83
	Foundation Topics	87
	Switch Management	87
	Operating Systems	87
	Identifying the Switch	88
	Passwords and User Access	89
	Password Recovery	90
	Remote Access	90
	Inter-Switch Communication—Cisco Discovery Protocol	91

Switch File Management	91
<i>OS Image Files</i>	92
Filename Conventions	93
<i>Configuration Files</i>	93
<i>Other Catalyst Switch Files</i>	94
<i>Moving Catalyst Switch Files Around</i>	94
Troubleshooting from the Operating System	96
<i>Show Configuration and File Contents</i>	96
<i>Debugging Output</i>	97
<i>View CDP Information</i>	98
Foundation Summary	100
Q&A	103

Chapter 5 Switch Port Configuration 107

"Do I Know This Already?" Quiz	107
Foundation Topics	112
Ethernet Concepts	112
<i>Ethernet (10 Mbps)</i>	112
<i>Long Reach Ethernet (LRE)</i>	113
<i>Fast Ethernet</i>	114
Full-Duplex Fast Ethernet	115
<i>Gigabit Ethernet</i>	117
<i>10Gigabit Ethernet</i>	118
<i>Metro Ethernet</i>	119
Connecting Switch Block Devices	120
<i>Console Port Cables/Connectors</i>	120
<i>Ethernet Port Cables and Connectors</i>	121
<i>Gigabit Ethernet Port Cables and Connectors</i>	121
Switch Port Configuration	123
<i>Selecting Ports to Configure</i>	123
<i>Identifying Ports</i>	124
<i>Port Speed</i>	124
<i>Port Mode</i>	125
<i>Managing Error Conditions on a Switch Port</i>	125
Detecting Error Conditions	125
Automatically Recover from Error Conditions	126
<i>Enable and Use the Switch Port</i>	126
<i>Troubleshooting Port Connectivity</i>	126
Looking for the Port State	127
Looking for Speed and/or Duplex Mismatches	127
Foundation Summary	129
Q&A	133

Chapter 6 VLANs and Trunks 137

"Do I Know This Already?" Quiz	137
Foundation Topics	141
Virtual LANs	141
<i>VLAN Membership</i>	142
Static VLANs	142
Configuring Static VLANs	143
Dynamic VLANs	144
<i>Deploying VLANs</i>	144
End-to-End VLANs	145
Local VLANs	145
VLAN Trunks	146
<i>VLAN Frame Identification</i>	146
Inter-Switch Link Protocol	148
IEEE 802.1Q Protocol	148
<i>Dynamic Trunking Protocol</i>	150
VLAN Trunk Configuration	150
<i>VLAN Trunk Configuration</i>	150
Service Provider Tunneling	153
<i>IEEE 802.1Q Tunnels</i>	153
<i>Configuring a 802.1Q Tunnel</i>	155
<i>Layer 2 Protocol Tunnels</i>	155
<i>Configuring Layer 2 Protocol Tunneling</i>	156
<i>Ethernet over MPLS Tunneling</i>	157
<i>Troubleshooting VLANs and Trunks</i>	159
Foundation Summary	162
Q&A	164

Chapter 7 VLAN Trunking Protocol (VTP) 167

"Do I Know This Already?" Quiz	167
Foundation Topics	171
VLAN Trunking Protocol	171
<i>VTP Domains</i>	171
<i>VTP Modes</i>	171
<i>VTP Advertisements</i>	172
VTP Configuration	175
<i>Configuring a VTP Management Domain</i>	175
<i>Configuring the VTP Mode</i>	176
<i>Configuring the VTP Version</i>	177
<i>VTP Status</i>	178
VTP Pruning	179
<i>Enabling VTP Pruning</i>	181
Troubleshooting VTP	182
Foundation Summary	184
Q&A	186

Chapter 8 Aggregating Switch Links 189

- “Do I Know This Already?” Quiz 189
- Foundation Topics 193
- Switch Port Aggregation with EtherChannel 193
 - Bundling Ports with EtherChannel* 194
 - Distributing Traffic in EtherChannel* 194
 - Configuring EtherChannel Load Balancing* 195
- EtherChannel Negotiation Protocols 197
 - Port Aggregation Protocol (PAgP)* 197
 - Link Aggregation Control Protocol (LACP)* 198
- EtherChannel Configuration 198
 - Configuring a PAgP EtherChannel* 199
 - Configuring a LACP EtherChannel* 199
- Troubleshooting an EtherChannel 200
- Foundation Summary 204
- Q&A 206

Chapter 9 Traditional Spanning Tree Protocol 209

- “Do I Know This Already?” Quiz 209
- Foundation Topics 213
- IEEE 802.1D Overview 213
 - Bridging Loops* 213
 - Preventing Loops with Spanning Tree Protocol* 217
 - Spanning Tree Communication: Bridge Protocol Data Units* 217
 - Electing a Root Bridge* 218
 - Electing Root Ports* 220
 - Electing Designated Ports* 223
 - STP States* 225
 - STP Timers* 227
 - Topology Changes* 228
- Types of STP 229
 - Common Spanning Tree (CST)* 229
 - Per-VLAN Spanning Tree (PVST)* 229
 - Per-VLAN Spanning Tree Plus (PVST+)* 230
- Foundation Summary 231
- Q&A 234

Chapter 10 Spanning Tree Configuration 239

- “Do I Know This Already?” Quiz 239
- Foundation Topics 243
- STP Root Bridge 243
 - Root Bridge Placement* 243
 - Root Bridge Configuration* 246

	<i>Spanning Tree Customization</i>	248
	<i>Tuning the Root Path Cost</i>	248
	<i>Tuning the Port ID</i>	249
	Tuning Spanning Tree Convergence	250
	<i>Modifying STP Timers</i>	250
	Redundant Link Convergence	252
	<i>PortFast: Access Layer Nodes</i>	252
	<i>UplinkFast: Access Layer Uplinks</i>	253
	<i>BackboneFast: Redundant Backbone Paths</i>	254
	Troubleshooting STP	255
	Foundation Summary	257
	Q&A	258
Chapter 11	Protecting the Spanning Tree Protocol Topology	263
	“Do I Know This Already?” Quiz	263
	Foundation Topics	267
	Protecting Against Unexpected BPDUs	267
	<i>Root Guard</i>	267
	<i>BPDUs Guard</i>	268
	Protecting Against Sudden Loss of BPDUs	269
	<i>BPDUs Skew Detection</i>	270
	<i>Loop Guard</i>	270
	<i>UDLD</i>	271
	Troubleshooting STP Protection	273
	Foundation Summary	274
	Q&A	276
Chapter 12	Advanced Spanning Tree Protocol	279
	“Do I Know This Already?” Quiz	279
	Foundation Topics	283
	Rapid Spanning Tree Protocol (RSTP)	283
	<i>RSTP Port Behavior</i>	283
	<i>BPDUs in RSTP</i>	284
	<i>RSTP Convergence</i>	285
	Port Types	286
	Synchronization	287
	<i>Topology Changes and RSTP</i>	288
	<i>RSTP Configuration</i>	290
	Multiple Spanning Tree (MST) Protocol	290
	<i>MST Overview</i>	292
	<i>MST Regions</i>	292

<i>Spanning Tree Instances Within MST</i>	293
IST Instances	293
MST Instances	294
<i>MST Configuration</i>	295
Foundation Summary	298
Q&A	300

Part III Layer 3 Switching 302

Chapter 13 Multilayer Switching 305

“Do I Know This Already?” Quiz	305
Foundation Topics	309
InterVLAN Routing	309
<i>Types of Interfaces</i>	310
<i>Configuring InterVLAN Routing</i>	310
Layer 2 Port Configuration	310
Layer 3 Port Configuration	311
SVI Port Configuration	312
Multilayer Switching with CEF	312
<i>Traditional MLS Overview</i>	312
<i>CEF Overview</i>	313
<i>Forwarding Information Base (FIB)</i>	314
<i>Adjacency Table</i>	315
<i>Packet Rewrite</i>	316
<i>Configuring CEF</i>	316
<i>Fallback Bridging</i>	317
Verifying Multilayer Switching	318
<i>InterVLAN Routing</i>	318
<i>CEF</i>	319
<i>Fallback Bridging</i>	321
Foundation Summary	322
Q&A	324

Chapter 14 Router Redundancy and Load Balancing 327

“Do I Know This Already?” Quiz	327
Foundation Topics	331
Router Redundancy in Multilayer Switching	331
<i>Packet Forwarding Review</i>	331
<i>Hot Standby Router Protocol (HSRP)</i>	332
HSRP Router Election	332
Conceding the Election	333
HSRP Gateway Addressing	334
Load Balancing with HSRP	335
<i>Virtual Router Redundancy Protocol (VRRP)</i>	336

	<i>Gateway Load Balancing Protocol (GLBP)</i>	337
	Active Virtual Gateway	338
	Active Virtual Forwarder	339
	GLBP Load Balancing	340
	Enabling GLBP	340
	Server Load Balancing (SLB)	343
	<i>SLB Configuration</i>	344
	Server Farms	344
	Virtual Servers	345
	Verifying Redundancy and Load Balancing	346
	Foundation Summary	347
	Q&A	350
Chapter 15	Multicast	353
	“Do I Know This Already?” Quiz	353
	Foundation Topics	357
	Multicast Overview	357
	<i>Multicast Addressing</i>	358
	Routing Multicast Traffic	359
	<i>Multicast Trees</i>	359
	<i>Reverse Path Forwarding</i>	360
	IGMP	360
	IGMPv1	360
	IGMPv2	361
	PIM	361
	PIM Dense Mode	362
	PIM Sparse Mode	363
	PIM Sparse-Dense Mode	365
	PIM Version 1	365
	PIM Version 2	366
	Switching Multicast Traffic	367
	<i>IGMP Snooping</i>	367
	CGMP	368
	Verifying Multicast Routing and Switching	369
	<i>Multicast Routing with PIM</i>	369
	<i>Multicast Switching</i>	369
	<i>What Would Happen Without a Multicast Router?</i>	370
	Foundation Summary	371
	Q&A	373
Part IV	Campus Network Services	374
Chapter 16	Quality of Service Overview	377
	“Do I Know This Already?” Quiz	377
	Foundation Topics	381

The Need for Quality of Service	381
<i>Types of QoS</i>	382
Best Effort Delivery	382
Integrated Services Model	382
Differentiated Services Model	383
DiffServ QoS	383
<i>Layer 2 QoS Classification</i>	384
<i>Layer 3 QoS Classification with DSCP</i>	384
Class Selector	386
Drop Precedence	386
QoS Building Blocks	387
<i>Ingress Queueing</i>	388
<i>Classification, Trust, and Marking</i>	388
<i>Policers</i>	389
<i>Scheduling</i>	390
<i>Congestion Avoidance</i>	391
Tail Drop	391
Weighted Random Early Detection	392
Switch Port Queues	393
Foundation Summary	396
Q&A	398

Chapter 17 DiffServ QoS Configuration 401

“Do I Know This Already?” Quiz	401
Foundation Topics	405
Applying QoS Trust	406
<i>Trust QoS on an Interface</i>	406
<i>Do Not Trust any QoS Information</i>	407
<i>Mapping Inbound QoS Information</i>	407
Defining a QoS Policy	409
<i>Defining a QoS Class to Classify Traffic</i>	409
Classifying Traffic with an Access List	410
Classifying Traffic with NBAR	410
What Happens When NBAR Is Enabled?	411
<i>Defining a QoS Policy</i>	411
Identifying the QoS Class Maps	411
Marking QoS Information	412
Trusting QoS Information	412
Policing Classified Traffic	412
<i>Apply a QoS Policy to an Interface</i>	413
Tuning Egress Scheduling	414
Using Congestion Avoidance	414
<i>Mapping Internal DSCP Values to CoS Values for Queueing</i>	414
<i>Mapping Packets into Egress Queues</i>	415

<i>Avoiding Congestion by Using Tail Drop</i>	416
<i>Avoiding Congestion by Using WRED</i>	416
<i>Setting WRED Thresholds</i>	416
A QoS Configuration Example	417
<i>Configuring QoS Trust</i>	418
<i>Configuring a QoS Class to Classify Traffic</i>	419
<i>Configuring a QoS Policy to Act on Classified Traffic</i>	420
<i>Egress Queue Tuning</i>	421
Verifying and Troubleshooting QoS	422
Foundation Summary	425
Q&A	428

Chapter 18 IP Telephony 431

“Do I Know This Already?” Quiz	431
Foundation Topics	435
IP Telephony Overview	435
Inline Power	435
<i>How Inline Power Works</i>	436
<i>Configuring Inline Power</i>	437
Voice VLANs	437
<i>Voice VLAN Configuration</i>	438
Voice QoS	440
<i>QoS Trust</i>	440
<i>Voice Packet Classification</i>	441
<i>Queuing for Voice Traffic</i>	442
Verifying Inline Power, Voice VLANs, and Voice QoS	442
<i>Verifying Inline Power</i>	443
<i>Verifying Voice VLANs</i>	443
<i>Verifying Voice QoS</i>	444
Foundation Summary	448
Q&A	449

Chapter 19 Securing Switch Access 451

“Do I Know This Already?” Quiz	451
Foundation Topics	455
Switch AAA	455
<i>Authentication</i>	455
<i>Authorization</i>	457
<i>Accounting</i>	459
Port Security	460
Port-Based Authentication	461
<i>802.1x Configuration</i>	462
Foundation Summary	464
Q&A	466

Chapter 20 Securing with VLANs 469

- “Do I Know This Already?” Quiz 469
- Foundation Topics 473
- VLAN Access Lists 473
 - VACL Configuration* 473
- Private VLANs 474
 - Private VLAN Configuration* 477
 - Configure the Private VLANs 477
 - Associate Ports with Private VLANs 477
 - Associate Secondary VLANs to a Primary VLAN SVI 479
- Switch Port Monitoring 480
 - Local SPAN and VSPAN* 481
 - Local SPAN and VSPAN Configuration 482
 - Remote SPAN* 484
 - Remote SPAN Configuration 485
- Foundation Summary 488
- Q&A 491

Part V Scenarios for Final Preparation 494

Chapter 21 Scenarios for Final Preparation 497

- Scenario 1: Trunking and DTP 497
- Scenario 2: VLANs, Trunking, and VTP 499
- Scenario 3: Traditional STP 500
- Scenario 4: Advanced STP 500
- Scenario 5: Router Redundancy with HSRP and GLBP 501
- Scenario 6: Multicast 503
- Scenario 7: QoS in a Switched Network 504
- Scenario 8: Securing Access and Managing Traffic in a Switched Network 505
- Scenario Answers 506
 - Scenario 1 Answers 506
 - Scenario 2 Answers 506
 - Scenario 3 Answers 507
 - Scenario 4 Answers 508
 - Scenario 5 Answers 509
 - Scenario 6 Answers 510
 - Scenario 7 Answers 510
 - Scenario 8 Answers 512

Part VI Appendix 514

Appendix A Answers to Chapter “Do I Know This Already?” Quizzes and Q&A Sections 517

Index 582