



Practice tests



Video Training



Flash Cards



Review Exercises



Study Planner

CCNP and CCIE Enterprise Core

ENCOR 350-401

2nd Edition

BRADLEY EDGEWORTH, CCIE® No. 31574

RAMIRO GARZA RIOS, CCIE® No. 15469

JASON GOOLEY, CCIE® No. 38759

DAVID HUCABY, CCIE® No. 4594

Contents

Introduction xli

Part I Forwarding

Chapter 1 Packet Forwarding 2

“Do I Know This Already?” Quiz 2

Foundation Topics 3

Network Device Communication 3

Layer 2 Forwarding 4

Collision Domains 5

Virtual LANs 7

Access Ports 11

Trunk Ports 12

Layer 2 Diagnostic Commands 15

Layer 3 Forwarding 19

Local Network Forwarding 19

Packet Routing 20

IP Address Assignment 21

Verification of IP Addresses 24

Forwarding Architectures 26

Process Switching 26

Cisco Express Forwarding 27

Ternary Content Addressable Memory 27

Centralized Forwarding 28

Distributed Forwarding 28

Software CEF 29

Hardware CEF 30

SDM Templates 30

Exam Preparation Tasks 32

Review All Key Topics 32

Complete Tables and Lists from Memory 33

Define Key Terms 33

Use the Command Reference to Check Your Memory 33

References in This Chapter 34

Part II Layer 2

Chapter 2 Spanning Tree Protocol 36

“Do I Know This Already?” Quiz 36

Foundation Topics 38

Spanning Tree Protocol Fundamentals 38

 IEEE 802.1D STP 38

802.1D Port States 39

802.1D Port Types 39

STP Key Terminology 39

 Building the STP Topology 41

Spanning Tree Path Cost 41

Root Bridge Election 41

Locating Blocked Designated Switch Ports 45

Verification of VLANs on Trunk Links 48

 STP Topology Changes 49

Converging with Direct Link Failures 50

Indirect Failures 52

Rapid Spanning Tree Protocol 53

 RSTP (802.1W) Port States 54

 RSTP (802.1W) Port Roles 54

 RSTP (802.1W) Port Types 54

 Building the RSTP Topology 55

 RSTP Convergence 55

Exam Preparation Tasks 56

Review All Key Topics 56

Complete Tables and Lists from Memory 56

Define Key Terms 56

Use the Command Reference to Check Your Memory 56

Chapter 3 Advanced STP Tuning 58

“Do I Know This Already?” Quiz 58

Foundation Topics 59

STP Topology Tuning 59

 Placing the Root Bridge 60

 Modifying STP Root Port and Blocked Switch Port Locations 63

 Modifying STP Port Priority 66

Additional STP Protection Mechanisms 67

 Root Guard 68

STP Portfast	68
BPDU Guard	70
BPDU Filter	72
Problems with Unidirectional Links	73
<i>STP Loop Guard</i>	74
<i>Unidirectional Link Detection</i>	75
Review All Key Topics	76
Exam Preparation Tasks	76
Complete Tables and Lists from Memory	77
Define Key Terms	77
Use the Command Reference to Check Your Memory	77
Chapter 4 Multiple Spanning Tree Protocol	80
“Do I Know This Already?” Quiz	80
Foundation Topics	81
Multiple Spanning Tree Protocol	81
MST Instances (MSTIs)	83
MST Configuration	84
MST Verification	85
MST Tuning	87
Common MST Misconfigurations	89
<i>VLAN Assignment to the IST</i>	89
<i>Trunk Link Pruning</i>	90
MST Region Boundary	90
<i>MST Region as the Root Bridge</i>	91
<i>MST Region Not a Root Bridge for Any VLAN</i>	91
Exam Preparation Tasks	92
Review All Key Topics	92
Complete Tables and Lists from Memory	92
Define Key Terms	92
Use the Command Reference to Check Your Memory	92
Chapter 5 VLAN Trunks and EtherChannel Bundles	94
“Do I Know This Already?” Quiz	94
Foundation Topics	96
VLAN Trunking Protocol	96
VTP Communication	97
VTP Configuration	98
VTP Verification	99
Dynamic Trunking Protocol	101

EtherChannel Bundle	104
Dynamic Link Aggregation Protocols	106
<i>PAgP Port Modes</i>	106
<i>LACP Port Modes</i>	106
<i>EtherChannel Configuration</i>	107
Verifying EtherChannel Status	108
Viewing EtherChannel Neighbors	110
LACP	112
PAgP	113
Verifying EtherChannel Packets	113
LACP	113
PAgP	114
Advanced LACP Configuration Options	114
LACP Fast	115
<i>Minimum Number of EtherChannel Member Interfaces</i>	115
<i>Maximum Number of EtherChannel Member Interfaces</i>	116
LACP System Priority	117
LACP Interface Priority	118
Troubleshooting EtherChannel Bundles	118
Load Balancing Traffic with EtherChannel Bundles	119
Exam Preparation Tasks	121
Review All Key Topics	121
Complete Tables and Lists from Memory	121
Define Key Terms	121
Use the Command Reference to Check Your Memory	121

Part III Routing

Chapter 6 IP Routing Essentials 124

“Do I Know This Already?” Quiz	124
Foundation Topics	126
Routing Protocol Overview	126
Distance Vector Algorithms	128
Enhanced Distance Vector Algorithms	129
Link-State Algorithms	130
Path Vector Algorithm	131
Path Selection	132

	Prefix Length	133
	Administrative Distance	133
	Metrics	135
	<i>Equal-Cost Multipathing</i>	135
	<i>Unequal-Cost Load Balancing</i>	136
	Static Routing	137
	Static Route Types	138
	<i>Directly Attached Static Routes</i>	138
	<i>Recursive Static Routes</i>	139
	<i>Fully Specified Static Routes</i>	141
	Floating Static Routing	141
	Static Routes to Null Interfaces	143
	IPv6 Static Routes	145
	Policy-based Routing	146
	Virtual Routing and Forwarding	149
	Exam Preparation Tasks	151
	Review All Key Topics	152
	Complete Tables and Lists from Memory	152
	Define Key Terms	152
	Use the Command Reference to Check Your Memory	153
Chapter 7	EIGRP	154
	“Do I Know This Already?” Quiz	154
	Foundation Topics	156
	EIGRP Fundamentals	156
	Autonomous Systems	157
	EIGRP Terminology	157
	Topology Table	159
	EIGRP Neighbors	160
	Path Metric Calculation	160
	Wide Metrics	162
	Metric Backward Compatibility	163
	Load Balancing	163
	Failure Detection and Timers	164
	Convergence	164
	Route Summarization	166

Exam Preparation Tasks	167
Review All Key Topics	167
Complete Tables and Lists from Memory	167
Define Key Terms	168
References in This Chapter	168

Chapter 8 OSPF 170

“Do I Know This Already?” Quiz	170
Foundation Topics	172
OSPF Fundamentals	172
Inter-Router Communication	174
OSPF Hello Packets	175
Router ID	175
Neighbors	175
Designated Router and Backup Designated Router	176
OSPF Configuration	178
OSPF Network Statement	178
Interface-Specific Configuration	180
Statically Setting the Router ID	180
Passive Interfaces	181
Requirements for Neighbor Adjacency	181
Sample Topology and Configuration	181
Confirmation of Interfaces	184
Verification of OSPF Neighbor Adjacencies	185
Verification of OSPF Routes	186
Default Route Advertisement	187
Common OSPF Optimizations	188
Link Costs	189
Failure Detection	189
<i>Hello Timer</i>	190
<i>Dead Interval Timer</i>	190
<i>OSPF Timers</i>	190
DR Placement	190
<i>Designated Router Elections</i>	190
<i>DR and BDR Placement</i>	192
OSPF Network Types	194

	<i>Broadcast</i>	194
	<i>Point-to-Point Networks</i>	195
	<i>Loopback Networks</i>	196
	Exam Preparation Tasks	198
	Review All Key Topics	198
	Complete Tables and Lists from Memory	199
	Define Key Terms	199
	Use the Command Reference to Check Your Memory	199
	References in This Chapter	200
Chapter 9	Advanced OSPF	202
	“Do I Know This Already?” Quiz	202
	Foundation Topics	204
	Areas	204
	Area ID	207
	OSPF Route Types	207
	Link-State Advertisements	209
	LSA Sequences	210
	LSA Age and Flooding	210
	LSA Types	210
	<i>LSA Type 1: Router Link</i>	210
	<i>LSA Type 2: Network Link</i>	213
	<i>LSA Type 3: Summary Link</i>	213
	Discontiguous Networks	217
	OSPF Path Selection	218
	Intra-Area Routes	218
	Inter-Area Routes	219
	Equal-Cost Multipathing	220
	Summarization of Routes	220
	Summarization Fundamentals	221
	Inter-Area Summarization	222
	Summarization Metrics	222
	Configuration of Inter-Area Summarization	223
	Route Filtering	224
	Filtering with Summarization	225
	Area Filtering	225

Exam Preparation Tasks	228
Review All Key Topics	228
Complete Tables and Lists from Memory	228
Define Key Terms	228
Use the Command Reference to Check Your Memory	229
References in This Chapter	229

Chapter 10 OSPFv3 230

“Do I Know This Already?” Quiz	230
Foundation Topics	231
OSPFv3 Fundamentals	231
OSPFv3 Link-State Advertisement	232
OSPFv3 Communication	232
OSPFv3 Configuration	233
OSPFv3 Verification	235
Passive Interface	237
Summarization	238
Network Type	239
IPv4 Support in OSPFv3	240
Exam Preparation Tasks	242
Review All Key Topics	242
Complete Tables and Lists from Memory	242
Define Key Terms	242
Use the Command Reference to Check Your Memory	242
References in This Chapter	243

Chapter 11 BGP 244

“Do I Know This Already?” Quiz	244
Foundation Topics	246
BGP Fundamentals	246
Autonomous System Numbers	246
Path Attributes	247
Loop Prevention	247
Address Families	248
Inter-Router Communication	248
<i>BGP Session Types</i>	249
<i>BGP Messages</i>	252

BGP Neighbor States	253
<i>Idle</i>	254
<i>Connect</i>	254
<i>Active</i>	254
<i>OpenSent</i>	254
<i>OpenConfirm</i>	255
<i>Established</i>	255
Basic BGP Configuration	255
Verification of BGP Sessions	257
Route Advertisement	260
Receiving and Viewing Routes	262
BGP Route Advertisements from Indirect Sources	265
IPv4 Route Summarization	268
Aggregate Address	269
Atomic Aggregate	274
Route Aggregation with AS_SET	276
Multiprotocol BGP for IPv6	278
IPv6 Configuration	279
IPv6 Route Summarization	284
Exam Preparation Tasks	285
Review All Key Topics	285
Complete Tables and Lists from Memory	286
Define Key Terms	286
Use the Command Reference to Check Your Memory	286
References in This Chapter	287
Chapter 12 Advanced BGP	288
“Do I Know This Already?” Quiz	288
Foundation Topics	290
BGP Multihoming	291
Resiliency in Service Providers	291
Internet Transit Routing	292
Branch Transit Routing	293
Conditional Matching	295
Access Control Lists	295
<i>Standard ACLs</i>	295

<i>Extended ACLs</i>	296
<i>BGP Network Selection</i>	296
Prefix Matching	297
<i>Prefix Lists</i>	299
<i>IPv6 Prefix Lists</i>	299
Regular Expressions (regex)	300
Route Maps	301
Conditional Matching	302
<i>Multiple Conditional Match Conditions</i>	303
<i>Complex Matching</i>	304
Optional Actions	304
The continue Keyword	305
BGP Route Filtering and Manipulation	306
Distribute List Filtering	307
Prefix List Filtering	308
AS_Path ACL Filtering	309
Route Maps	311
Clearing BGP Connections	313
BGP Communities	313
Well-Known Communities	314
Enabling BGP Community Support	314
Conditionally Matching BGP Communities	315
Setting Private BGP Communities	317
Understanding BGP Path Selection	318
Routing Path Selection Using Longest Match	319
BGP Best Path Overview	320
<i>Weight</i>	321
<i>Local Preference</i>	322
<i>Locally Originated via Network or Aggregate Advertisement</i>	323
<i>Accumulated Interior Gateway Protocol Metric</i>	323
<i>Shortest AS Path</i>	324
<i>Origin Type</i>	325
<i>Multi-Exit Discriminator</i>	326
<i>eBGP over iBGP</i>	327
<i>Lowest IGP Metric</i>	327
<i>Prefer the Path from the Oldest eBGP Session</i>	328

<i>Router ID</i>	328
<i>Minimum Cluster List Length</i>	329
<i>Lowest Neighbor Address</i>	329
Exam Preparation Tasks	329
Review All Key Topics	330
Complete Tables and Lists from Memory	330
Define Key Terms	330
Use the Command Reference to Check Your Memory	331
References in This Chapter	332
Chapter 13 Multicast	334
“Do I Know This Already?” Quiz	334
Foundation Topics	337
Multicast Fundamentals	337
Multicast Addressing	340
Layer 2 Multicast Addresses	342
Internet Group Management Protocol	343
IGMPv2	344
IGMPv3	346
IGMP Snooping	346
Protocol Independent Multicast	349
PIM Distribution Trees	349
<i>Source Trees</i>	349
<i>Shared Trees</i>	350
PIM Terminology	352
PIM Dense Mode	354
PIM Sparse Mode	357
<i>PIM Shared and Source Path Trees</i>	357
<i>Shared Tree Join</i>	358
<i>Source Registration</i>	358
<i>PIM SPT Switchover</i>	358
<i>Designated Routers</i>	359
Reverse Path Forwarding	360
PIM Forwarder	361
Rendezvous Points	363

Static RP	364
Auto-RP	364
<i>Candidate RPs</i>	364
<i>RP Mapping Agents</i>	365
PIM Bootstrap Router	366
<i>Candidate RPs</i>	366
Exam Preparation Tasks	367
Review All Key Topics	367
Complete Tables and Lists from Memory	368
Define Key Terms	368
References in This Chapter	369

Part IV Services

Chapter 14 Quality of Service (QoS) 370

“Do I Know This Already?” Quiz	371
Foundation Topics	374
The Need for QoS	374
Lack of Bandwidth	374
Latency and Jitter	374
<i>Propagation Delay</i>	375
<i>Serialization Delay</i>	375
<i>Processing Delay</i>	376
<i>Delay Variation</i>	376
Packet Loss	376
QoS Models	377
Modular QoS CLI	379
Classification and Marking	381
Classification	381
<i>Layer 7 Classification</i>	382
MQC Classification Configuration	382
Marking	385
<i>Layer 2 Marking</i>	385
<i>Priority Code Point (PCP)</i>	386
<i>Layer 3 Marking</i>	386
DSCP Per-Hop Behaviors	387
<i>Class Selector (CS) PHB</i>	388
<i>Default Forwarding (DF) PHB</i>	388
<i>Assured Forwarding (AF) PHB</i>	388

<i>Expedited Forwarding (EF) PHB</i>	390
Scavenger Class	391
Trust Boundary	391
Class-Based Marking Configuration	392
A Practical Example: Wireless QoS	393
Policing and Shaping	394
Placing Policers and Shapers in the Network	395
Markdown	395
Token Bucket Algorithms	395
Class-Based Policing Configuration	398
Types of Policers	399
<i>Single-Rate Two-Color Markers/Policers</i>	399
<i>Single-Rate Three-Color Markers/Policers (srTCM)</i>	400
<i>Two-Rate Three-Color Markers/Policers (trTCM)</i>	403
Congestion Management and Avoidance	406
Congestion Management	406
Congestion-Avoidance Tools	408
CBWFQ Configuration	410
Exam Preparation Tasks	414
Review All Key Topics	414
Complete Tables and Lists from Memory	415
Define Key Terms	416
Use the Command Reference to Check Your Memory	416
References in This Chapter	417
Chapter 15 IP Services	418
“Do I Know This Already?” Quiz	418
Foundation Topics	420
Time Synchronization	420
Network Time Protocol	420
NTP Configuration	421
Stratum Preference	424
NTP Peers	424
Precision Time Protocol (PTP)	425
PTP Configuration	427
First-Hop Redundancy Protocol	429
Object Tracking	430

Hot Standby Router Protocol	432
Virtual Router Redundancy Protocol	438
<i>VRRPv2 Configuration</i>	438
<i>VRRPv3 Configuration</i>	440
Gateway Load Balancing Protocol	441
Network Address Translation	446
NAT Topology	447
Static NAT	449
<i>Inside Static NAT</i>	449
<i>Outside Static NAT</i>	452
Pooled NAT	455
Port Address Translation	458
Exam Preparation Tasks	461
Review All Key Topics	461
Complete Tables and Lists from Memory	462
Define Key Terms	462
Use the Command Reference to Check Your Memory	462

Part V Overlay

Chapter 16 Overlay Tunnels 466

“Do I Know This Already?” Quiz	467
Foundation Topics	469
Generic Routing Encapsulation (GRE) Tunnels	469
GRE Tunnel Configuration	470
GRE Configuration Example	472
Problems with Overlay Networks: Recursive Routing	474
IPsec Fundamentals	475
Authentication Header	476
Encapsulating Security Payload	477
Transform Sets	478
Internet Key Exchange	480
IKEv1	480
<i>IKEv2</i>	482
IPsec VPNs	484
<i>Site-to-Site (LAN-to-LAN) IPsec VPNs</i>	486
<i>Cisco Dynamic Multipoint VPN (DMVPN)</i>	486

	<i>Cisco Group Encrypted Transport VPN (GET VPN)</i>	486
	<i>Cisco FlexVPN</i>	486
	<i>Remote VPN Access</i>	486
	<i>Site-to-Site IPsec Configuration</i>	486
	<i>Site-to-Site GRE over IPsec</i>	487
	<i>Site-to-Site VTI over IPsec</i>	493
	Cisco Locator/ID Separation Protocol (LISP)	495
	LISP Architecture and Protocols	497
	LISP Routing Architecture	497
	LISP Control Plane	497
	LISP Data Plane	498
	LISP Operation	499
	Map Registration and Notification	499
	Map Request and Reply	500
	LISP Data Path	501
	Proxy ETR (PETR)	502
	Proxy ITR (PITR)	503
	Virtual Extensible Local Area Network (VXLAN)	504
	Exam Preparation Tasks	507
	Review All Key Topics	507
	Complete Tables and Lists from Memory	508
	Define Key Terms	508
	Use the Command Reference to Check Your Memory	509
Part VI	Wireless	
Chapter 17	Wireless Signals and Modulation	510
	“Do I Know This Already?” Quiz	510
	Foundation Topics	512
	Understanding Basic Wireless Theory	512
	Understanding Frequency	514
	Understanding Phase	519
	Measuring Wavelength	519
	Understanding RF Power and dB	520
	Important dB Laws to Remember	522
	Comparing Power Against a Reference: dBm	524
	Measuring Power Changes Along the Signal Path	525
	Free Space Path Loss	527

<i>Understanding Power Levels at the Receiver</i>	530
Carrying Data Over an RF Signal	531
Maintaining AP–Client Compatibility	533
Using Multiple Radios to Scale Performance	535
<i>Spatial Multiplexing</i>	535
<i>Transmit Beamforming</i>	536
<i>Maximal-Ratio Combining</i>	538
Maximizing the AP–Client Throughput	538
Exam Preparation Tasks	540
Review All Key Topics	540
Complete Tables and Lists from Memory	540
Define Key Terms	541

Chapter 18 Wireless Infrastructure 542

“Do I Know This Already?” Quiz	542
Foundation Topics	545
Wireless Deployment Models	545
Autonomous Deployment	545
Cisco AP Operation	547
Cisco Wireless Deployments	548
Pairing Lightweight APs and WLCs	552
AP States	552
Discovering a WLC	554
Selecting a WLC	555
Maintaining WLC Availability	556
Segmenting Wireless Configurations	557
Leveraging Antennas for Wireless Coverage	559
Radiation Patterns	560
Gain	562
Beamwidth	563
Polarization	563
Omnidirectional Antennas	564
Directional Antennas	567
Exam Preparation Tasks	570
Review All Key Topics	570
Complete Tables and Lists from Memory	571
Define Key Terms	571

Chapter 19 Understanding Wireless Roaming and Location Services 572

- “Do I Know This Already?” Quiz 572
- Foundation Topics 574
- Roaming Overview 574
 - Roaming Between Autonomous APs 574
 - Intracontroller Roaming 577
- Intercontroller Roaming 579
 - Layer 2 Roaming 579
 - Layer 3 Roaming 581
 - Scaling Mobility with Mobility Groups 583
- Locating Devices in a Wireless Network 584
- Exam Preparation Tasks 587
- Review All Key Topics 587
- Complete Tables and Lists from Memory 588
- Define Key Terms 588

Chapter 20 Authenticating Wireless Clients 590

- “Do I Know This Already?” Quiz 590
- Foundation Topics 592
- Open Authentication 593
- Authenticating with Pre-Shared Key 595
- Authenticating with EAP 597
 - Configuring EAP-Based Authentication with External RADIUS Servers 600
 - Verifying EAP-Based Authentication Configuration 602
- Authenticating with WebAuth 603
- Exam Preparation Tasks 606
- Review All Key Topics 606
- Complete Tables and Lists from Memory 606
- Define Key Terms 606

Chapter 21 Troubleshooting Wireless Connectivity 608

- “Do I Know This Already?” Quiz 608
- Foundation Topics 610
- Troubleshooting Client Connectivity from the WLC 611
 - Checking the Client’s Association and Signal Status 613
 - Checking the Client Properties 614

Checking the AP Properties	614
Checking the Client Security	615
Troubleshooting the Client	615
Troubleshooting Connectivity Problems at the AP	617
Exam Preparation Tasks	620
Review All Key Topics	620
Complete Tables and Lists from Memory	620
Define Key Terms	620

Part VII Architecture

Chapter 22 Enterprise Network Architecture 622

“Do I Know This Already?” Quiz	622
Foundation Topics	624
Hierarchical LAN Design Model	624
Access Layer	625
Distribution Layer	627
Core Layer	628
High Availability Network Design	629
High Availability Technologies	630
SSO and NSF	630
SSO/NSF with GR	631
SSO/NSF with NSR	631
SSO/NSF with NSR and GR	631
Enterprise Network Architecture Options	632
Two-Tier Design (Collapsed Core)	632
Three-Tier Design	634
Layer 2 Access Layer (STP Based)	634
Layer 3 Access Layer (Routed Access)	636
Simplified Campus Design	637
Software-Defined Access (SD-Access) Design	640
Exam Preparation Tasks	640
Review All Key Topics	640
Complete Tables and Lists from Memory	640
Define Key Terms	640

Chapter 23 Fabric Technologies	642
“Do I Know This Already?” Quiz	643
Foundation Topics	645
Software-Defined Access (SD-Access)	645
What Is SD-Access?	646
SD-Access Architecture	646
Physical Layer	647
Network Layer	647
Underlay Network	648
Overlay Network (SD-Access Fabric)	649
SD-Access Fabric Roles and Components	652
Fabric Control Plane Node	653
Fabric Border Nodes	654
Fabric Wireless Controller (WLC)	654
SD-Access Fabric Concepts	655
Controller Layer	656
Management Layer	657
Cisco DNA Design Workflow	658
Cisco DNA Policy Workflow	658
Cisco DNA Provision Workflow	659
Cisco DNA Assurance Workflow	660
Software-Defined WAN (SD-WAN)	661
Cisco SD-WAN Architecture	661
vBond Orchestrator	662
vManage NMS	663
vSmart Controller	663
Cisco SD-WAN Edge Devices	663
vAnalytics	664
Cisco SD-WAN Cloud OnRamp	664
SD-WAN Policy	665
Application-Aware Routing	665
Cloud OnRamp for SaaS	666
Cloud OnRamp for IaaS	668
Exam Preparation Tasks	669
Review All Key Topics	669
Complete Tables and Lists from Memory	670
Define Key Terms	670

Chapter 24 Network Assurance 672

“Do I Know This Already?” Quiz 672

Foundation Topics 674

Network Diagnostic Tools 675

- ping 675
- traceroute 680

Debugging 685

- Conditional Debugging 692
- Simple Network Management Protocol (SNMP) 695
- syslog 701

NetFlow and Flexible NetFlow 706

Switched Port Analyzer (SPAN) Technologies 716

- Local SPAN 717
- Specifying the Source Ports 717
- Specifying the Destination Ports* 718
- Local SPAN Configuration Examples* 719
- Remote SPAN (RSPAN) 720
- Encapsulated Remote SPAN (ERSPAN) 722
- Specifying the Source Ports* 722
- Specifying the Destination* 723

IP SLA 724

Cisco DNA Center Assurance 728

Exam Preparation Tasks 734

Review All Key Topics 735

Complete Tables and Lists from Memory 735

Define Key Terms 735

Part VIII Security

Chapter 25 Secure Network Access Control 736

“Do I Know This Already?” Quiz 736

Foundation Topics 738

Network Security Design for Threat Defense 738

Next-Generation Endpoint Security 741

- Cisco Talos 741
- Cisco Secure Malware Analytics (Threat Grid) 742
- Cisco Advanced Malware Protection (AMP) 742

Cisco Secure Client (AnyConnect)	744
Cisco Umbrella	744
Cisco Secure Web Appliance (WSA)	746
<i>Before an Attack</i>	746
<i>During an Attack</i>	747
<i>After an Attack</i>	748
Cisco Secure Email (ESA)	748
Cisco Secure IPS (FirePOWER NGIPS)	749
Cisco Secure Firewall (NGFW)	751
Cisco Secure Firewall Management Center (FMC)	753
Cisco Secure Network Analytics (Stealthwatch Enterprise)	753
Cisco Secure Cloud Analytics (Stealthwatch Cloud)	755
<i>Cisco Secure Cloud Analytics Public Cloud Monitoring</i>	755
<i>Cisco Secure Network Analytics SaaS</i>	755
Cisco Identity Services Engine (ISE)	756
Network Access Control (NAC)	758
802.1x	758
<i>EAP Methods</i>	760
<i>EAP Chaining</i>	762
MAC Authentication Bypass (MAB)	762
Web Authentication (WebAuth)	764
<i>Local Web Authentication</i>	764
<i>Central Web Authentication with Cisco ISE</i>	765
Enhanced Flexible Authentication (FlexAuth)	766
Cisco Identity-Based Networking Services (IBNS) 2.0	766
Cisco TrustSec	766
<i>Ingress Classification</i>	767
<i>Propagation</i>	768
<i>Egress Enforcement</i>	770
MACsec	772
<i>Downlink MACsec</i>	774
<i>Uplink MACsec</i>	774
Exam Preparation Tasks	774
Review All Key Topics	774
Complete Tables and Lists from Memory	775
Define Key Terms	776

Chapter 26 Network Device Access Control and Infrastructure Security 778

“Do I Know This Already?” Quiz 778

Foundation Topics 781

Access Control Lists (ACLs) 781

- Numbered Standard ACLs 782
- Numbered Extended ACLs 783
- Named ACLs 784
- Port ACLs (PACLs) and VLAN ACLs (VACLs) 785
 - PACLs 785
 - VACLs 786
- PACL, VACL, and RAACL Interaction 787

Terminal Lines and Password Protection 788

- Password Types 789
- Password Encryption 789
- Username and Password Authentication 790
- Configuring Line Local Password Authentication 790
- Verifying Line Local Password Authentication 791
- Configuring Line Local Username and Password Authentication 792
- Verifying Line Local Username and Password Authentication 792
- Privilege Levels and Role-Based Access Control (RBAC) 793
- Verifying Privilege Levels 794
- Controlling Access to vty Lines with ACLs 796
- Verifying Access to vty Lines with ACLs 796
- Controlling Access to vty Lines Using Transport Input 797
- Verifying Access to vty Lines Using Transport Input 798
- Enabling SSH vty Access 800
- Auxiliary Port 802
- EXEC Timeout 802
- Absolute Timeout 802

Authentication, Authorization, and Accounting (AAA) 803

- TACACS+ 803
- RADIUS 804
 - Configuring AAA for Network Device Access Control 805
 - Verifying AAA Configuration 809

Zone-Based Firewall (ZBFW) 809

- The Self Zone 810

The Default Zone	810
ZBFW Configuration	811
Verifying ZBFW	816
Control Plane Policing (CoPP)	817
Configuring ACLs for CoPP	817
Configuring Class Maps for CoPP	818
Configuring the Policy Map for CoPP	819
Applying the CoPP Policy Map	819
Verifying the CoPP Policy	820
Device Hardening	822
Exam Preparation Tasks	823
Review All Key Topics	823
Complete Tables and Lists from Memory	824
Define Key Terms	824
Use the Command Reference to Check Your Memory	824

Part IX SDN

Chapter 27 Virtualization 826

“Do I Know This Already?” Quiz	826
Foundation Topics	828
Server Virtualization	828
Virtual Machines	828
Containers	830
Virtual Switching	831
Network Functions Virtualization	833
NFV Infrastructure	834
Virtual Network Functions	834
Virtualized Infrastructure Manager	834
Element Managers	835
Management and Orchestration	836
Operations Support System (OSS)/Business Support System (BSS)	836
VNF Performance	836
OVS-DPDK	839
PCI Passthrough	840
SR-IOV	841
Cisco Enterprise Network Functions Virtualization (ENFV)	842

Cisco ENFV Solution Architecture 843

Exam Preparation Tasks 847

Review All Key Topics 847

Complete Tables and Lists from Memory 848

Define Key Terms 848

Chapter 28 Foundational Network Programmability Concepts 850

“Do I Know This Already?” Quiz 850

Foundation Topics 854

Command-Line Interface 854

Application Programming Interface 855

Northbound API 855

Southbound API 856

Representational State Transfer (REST) APIs 856

API Tools and Resources 857

Introduction to Postman 857

Data Formats (XML and JSON) 860

Cisco DNA Center APIs 862

Cisco vManage APIs 867

Data Models and Supporting Protocols 870

YANG Data Models 870

NETCONF 872

RESTCONF 876

Cisco DevNet 877

Documentation 878

Learn 878

Technologies 878

Community 879

Events 879

GitHub 880

Basic Python Components and Scripts 882

Exam Preparation Tasks 889

Review All Key Topics 889

Complete Tables and Lists from Memory 890

Define Key Terms 890

References in This Chapter 890

Chapter 29 Introduction to Automation Tools 892

- “Do I Know This Already?” Quiz 892
- Foundation Topics 894
- Embedded Event Manager 894
 - EEM Applets 895
 - EEM and Tcl Scripts 899
 - EEM Summary 901
- Agent-Based Automation Tools 902
 - Puppet 902
 - Chef 904
 - SaltStack (Agent and Server Mode) 909
- Agentless Automation Tools 912
 - Ansible 912
 - Puppet Bolt 922
 - SaltStack SSH (Server-Only Mode) 923
 - Comparing Tools 924
- Exam Preparation Tasks 925
- Review All Key Topics 925
- Complete Tables and Lists from Memory 925
- Define Key Terms 925

Chapter 30 Final Preparation 926

- Getting Ready 926
- Tools for Final Preparation 927
 - Pearson Test Prep Practice Test Software and Questions on the Website 927
 - Accessing the Pearson Test Prep Software Online* 927
 - Accessing the Pearson Test Prep Software Offline* 928
 - Customizing Your Exams 928
 - Updating Your Exams 929
 - Premium Edition 929
 - Chapter-Ending Review Tools 930
- Suggested Plan for Final Review/Study 930
- Summary 930

Chapter 31 ENCOR 350-401 Exam Updates 932

- The Purpose of This Chapter 932
 - About Possible Exam Updates 932

Impact on You and Your Study Plan 933

News About the Next Exam Release 934

Updated Technical Content 934

Appendix A Answers to the “Do I Know This Already?” Questions 936

Glossary 956

Index 978

Online Elements

Appendix B Memory Tables

Appendix C Memory Tables Answer Key

Appendix D Study Planner

Glossary

Sample pages

CHAPTER 10

OSPFv3

This chapter covers the following subjects:

- **OSPFv3 Fundamentals:** This section provides an overview of the OSPFv3 routing protocol and the similarities to OSPFv2.
- **OSPFv3 Configuration:** This section demonstrates the configuration and verification of an OSPFv3 environment.
- **IPv4 Support in OSPFv3:** This section explains and demonstrates how OSPFv3 can be used for exchanging IPv4 routes.

OSPF Version 3 (OSPFv3), which is the latest version of the OSPF protocol, includes support for both the IPv4 and IPv6 address families. The OSPFv3 protocol is not backward compatible with OSPFv2, but the protocol mechanisms described in Chapters 8, “OSPF,” and 9, “Advanced OSPF,” are essentially the same for OSPFv3. This chapter expands on Chapter 9 and discusses OSPFv3 and its support of IPv6.

“Do I Know This Already?” Quiz

The “Do I Know This Already?” quiz enables you to assess whether you should read the entire chapter. If you miss no more than one of these self-assessment questions, you might want to move ahead to the “Exam Preparation Tasks” section. Table 10-1 lists the major headings in this chapter and the “Do I Know This Already?” quiz questions covering the material in those headings so you can assess your knowledge of these specific areas. The answers to the “Do I Know This Already?” quiz appear in Appendix A, “Answers to the ‘Do I Know This Already?’ Questions.”

Table 10-1 “Do I Know This Already?” Foundation Topics Section-to-Question Mapping

Foundation Topics Section	Questions
OSPFv3 Fundamentals	1–2
OSPFv3 Configuration	3–4
IPv4 Support in OSPFv3	5

1. OSPFv3 uses _____ packet types for inter-router communication.
 - a. three
 - b. four
 - c. five
 - d. six
 - e. seven

2. The OSPFv3 hello packet uses the _____ for the destination address.
 - a. MAC address 00:C1:00:5C:00:FF
 - b. MAC address E0:00:00:06:00:AA
 - c. IP address 224.0.0.8
 - d. IP address 224.0.0.10
 - e. IPv6 address FF02::A
 - f. IPv6 address FF02::5
3. How do you enable OSPFv3 on an interface?
 - a. Use the command **network prefix/prefix-length** under the OSPF process.
 - b. Use the command **network interface-id** under the OSPF process.
 - c. Use the command **ospfv3 process-id ipv6 area area-id** under the interface.
 - d. Nothing. OSPFv3 is enabled on all IPv6 interfaces upon initialization of the OSPF process.
4. True or false: On a brand-new router installation, OSPFv3 requires only that an IPv6 link-local address be configured and that OSPFv3 be enabled on that interface to form an OSPFv3 neighborship with another router.
 - a. True
 - b. False
5. True or false: OSPFv3 support for IPv4 networks only requires that an IPv4 address be assigned to the interface and that the OSPFv3 process be initialized for IPv4.
 - a. True
 - b. False

Foundation Topics



OSPFv3 Fundamentals

OSPFv3 is different from OSPFv2 in the following ways:

- **Support for multiple address families:** OSPFv3 supports IPv4 and IPv6 address families.
- **New LSA types:** New LSA types have been created to carry IPv6 prefixes.
- **Removal of addressing semantics:** The IP prefix information is no longer present in the OSPF packet headers. Instead, it is carried as LSA payload information, making the protocol essentially address family independent, much like IS-IS. OSPFv3 uses the term *link* instead of *network* because the SPT calculations are per link instead of per subnet.
- **LSA flooding:** OSPFv3 includes a new link-state type field that is used to determine the flooding scope of LSA, as well as the handling of unknown LSA types.
- **Packet format:** OSPFv3 runs directly over IPv6, and the number of fields in the packet header has been reduced.

- **Router ID:** The router ID is used to identify neighbors, regardless of the network type in OSPFv3. When you're configuring OSPFv3 on IOS routers, the ID must always be manually assigned in the routing process.
- **Authentication:** Neighbor authentication has been removed from the OSPF protocol and is now performed through IPsec extension headers in the IPv6 packet.
- **Neighbor adjacencies:** OSPFv3 inter-router communication is handled by IPv6 link-local addressing. Neighbors are not automatically detected over non-broadcast multiple access (NBMA) interfaces. A neighbor must be manually specified using the link-local address. IPv6 allows for multiple subnets to be assigned to a single interface, and OSPFv3 allows for neighbor adjacency to form even if the two routers do not share a common subnet.
- **Multiple instances:** OSPFv3 packets include an instance ID field that may be used to manipulate which routers on a network segment are allowed to form adjacencies.

NOTE RFC 5340 provides in-depth coverage of all the differences between OSPFv2 and OSPFv3.

OSPFv3 Link-State Advertisement

The OSPF link-state database information is organized and advertised differently in Version 3 than in Version 2. OSPFv3 modifies the structure of the router LSA (type 1), renames the network summary LSA to inter-area prefix LSA, and renames the ASBR summary LSA to inter-area router LSA. The principal difference is that the router LSA is only responsible for announcing interface parameters such as the interface type (point-to-point, broadcast, NBMA, point-to-multipoint, and virtual links) and metric (cost).

IP address information is advertised independently by two new LSA types:

- Intra-area prefix LSA
- Link LSA

The OSPF Dijkstra calculation used to determine the shortest path tree (SPT) only examines the router and network LSAs. Advertising the IP prefix information using new LSA types eliminates the need for OSPF to perform full shortest path first (SPF) tree calculations every time a new IP address (prefix) is added or changed on an interface. The OSPFv3 link-state database (LSDB) creates a shortest path topology tree based on links instead of networks.

OSPFv3 Communication

OSPFv3 packets use protocol number 89 in the IPv6 header, and routers communicate with each other using the local interface's IPv6 link-local address as the source. It also uses the

Answers to the "Do I Know This Already?" quiz:

1 C 2 F 3 C 4 B 5 B

same five packet types and logic as OSPFv2. Depending on the packet type, the destination address is either a unicast link-local address or a multicast link-local scoped address:

- **FF02::05:** OSPFv3 AllSPFRouters
- **FF02::06:** OSPFv3 AllDRouters

Every router uses the AllSPFRouters multicast address FF02::5 to send OSPF hello messages to routers on the same link. The hello messages are used for neighbor discovery and detecting whether a neighbor relationship is down. The DR and BDR routers also use this address to send link-state update and flooding acknowledgment messages to all routers.

Non-DR/BDR routers send an update or link-state acknowledgment message to the DR and BDR by using the AllDRouters address FF02::6.

OSPFv3 Configuration

The process of configuring OSPFv3 involves the following steps:

- Step 1.** Initialize the routing process. As a prerequisite, **ipv6 unicast-routing** must be enabled on the router. Afterward, the OSPFv3 process is configured with the command **router ospfv3 [process-id]**.
- Step 2.** Define the router ID. The command **router-id router-id** assigns a router ID to the OSPF process. The router ID is a 32-bit value that does not need to match an IPv4 address. It may be any number in IPv4 address format (for example, 0.1.2.3), as long as the value is unique within the OSPF domain.
OSPFv3 uses the same algorithm as OSPFv2 for dynamically locating the RID. If there are not any IPv4 interfaces available, the RID is set to 0.0.0.0 and does not allow adjacencies to form.
- Step 3.** (Optional) Initialize the address family. The address family is initialized within the routing process with the command **address-family (ipv6 | ipv4) unicast**. The appropriate address family is enabled automatically when OSPFv3 is enabled on an interface.
- Step 4.** Enable OSPFv3 on an interface. The interface command **ospfv3 process-id ipv6 area area-id** enables the protocol and assigns the interface to an area.

NOTE OSPFv3 does not use the network statement for initializing interfaces.

Figure 10-1 displays a simple four-router topology to demonstrate OSPFv3 configuration. Area 0 consists of R1, R2, and R3, and Area 34 contains R3 and R4. R3 is the ABR.



Figure 10-1 OSPFv3 Topology

Example 10-1 provides the OSPFv3 and IPv6 address configurations for R1, R2, R3, and R4. IPv6 link-local addressing has been configured so that all router interfaces reflect their local numbers (for example, R1's interfaces are set to FE80::1) in addition to traditional IPv6 addressing. The link-local addressing is statically configured to assist with any diagnostic output in this chapter. The OSPFv3 configuration has been highlighted in this example.

Example 10-1 *IPv6 Addressing and OSPFv3 Configuration*

```
R1
interface Loopback0
  ipv6 address 2001:DB8::1/128
  ospfv3 1 ipv6 area 0
!
interface GigabitEthernet0/1
  ipv6 address FE80::1 link-local
  ipv6 address 2001:DB8:0:1::1/64
  ospfv3 1 ipv6 area 0
!
interface GigabitEthernet0/2
  ipv6 address FE80::1 link-local
  ipv6 address 2001:DB8:0:12::1/64
  ospfv3 1 ipv6 area 0
!
router ospfv3 1
  router-id 192.168.1.1
```

```
R2
interface Loopback0
  ipv6 address 2001:DB8::2/128
  ospfv3 1 ipv6 area 0
!
interface GigabitEthernet0/1
  ipv6 address FE80::2 link-local
  ipv6 address 2001:DB8:0:12::2/64
  ospfv3 1 ipv6 area 0
!
interface GigabitEthernet0/3
  ipv6 address FE80::2 link-local
  ospfv3 1 ipv6 area 0
!
router ospfv3 1
  router-id 192.168.2.2
```

```
R3
interface Loopback0
  ipv6 address 2001:DB8::3/128
```



```

ospfv3 1 ipv6 area 0
!
interface GigabitEthernet0/2
  ipv6 address FE80::3 link-local
  ipv6 address 2001:DB8:0:23::3/64
ospfv3 1 ipv6 area 0
!
interface GigabitEthernet0/4
  ipv6 address FE80::3 link-local
  ipv6 address 2001:DB8:0:34::3/64
ospfv3 1 ipv6 area 34
!
router ospfv3 1
  router-id 192.168.3.3

```

```

R4
interface Loopback0
  ipv6 address 2001:DB8::4/128
  ospfv3 1 ipv6 area 34
!
interface GigabitEthernet0/1
  ipv6 address FE80::4 link-local
  ipv6 address 2001:DB8:0:4::4/64
ospfv3 1 ipv6 area 34
!
interface GigabitEthernet0/3
  ipv6 address FE80::4 link-local
  ipv6 address 2001:DB8:0:34::4/64
ospfv3 1 ipv6 area 34
!
router ospfv3 1
  router-id 192.168.4.4

```

NOTE Earlier versions of IOS used the commands `ipv6 router ospf` for initialization of the OSPF process and `ipv6 ospf process-id area area-id` for identification of the interface. These commands are considered legacy and should be migrated to the ones used in this book.



OSPFv3 Verification

The commands for viewing OSPFv3 settings and statuses are similar to those used in OSPFv2; they essentially replace `ip ospf` with `ospfv3 ipv6`. Supporting OSPFv3 requires verifying the OSPFv3 interfaces, neighborhood, and the routing table.

For example, to view the neighbor adjacency for OSPFv2, the command `show ip ospf neighbor` is executed, and for OSPFv3, the command `show ospfv3 ipv6 neighbor` is used. Example 10-2 shows this command executed on R3.

Example 10-2 *Identifying R3's OSPFv3 Neighbors*

```
R3# show ospfv3 ipv6 neighbor
```

```
OSPFv3 1 address-family ipv6 (router-id 192.168.3.3)
```

Neighbor ID	Pri	State	Dead Time	Interface ID	Interface
192.168.2.2	1	FULL/DR	00:00:32	5	GigabitEthernet0/2
192.168.4.4	1	FULL/BDR	00:00:33	5	GigabitEthernet0/4

Example 10-3 shows R1's GigabitEthernet0/2 OSPFv3-enabled interface status with the command `show ospfv3 interface [interface-id]`. Notice that address semantics have been removed compared to OSPFv2. The interface maps to the interface ID value 3 rather than an IP address value, as in OSPFv2. In addition, some helpful topology information describes the link. The local router is the DR (192.168.1.1), and the adjacent neighbor router is the BDR (192.168.2.2).

Example 10-3 *Viewing the OSPFv3 Interface Configuration*

```
R1# show ospfv3 interface GigabitEthernet0/2
```

```
GigabitEthernet0/2 is up, line protocol is up
```

```
Link Local Address FE80::1, Interface ID 3
```

```
Area 0, Process ID 1, Instance ID 0, Router ID 192.168.1.1
```

```
Network Type BROADCAST, Cost: 1
```

```
Transmit Delay is 1 sec, State DR, Priority 1
```

```
Designated Router (ID) 192.168.1.1, local address FE80::1
```

```
Backup Designated router (ID) 192.168.2.2, local address FE80::2
```

```
Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
```

```
Hello due in 00:00:01
```

```
Graceful restart helper support enabled
```

```
Index 1/1/1, flood queue length 0
```

```
Next 0x0(0)/0x0(0)/0x0(0)
```

```
Last flood scan length is 0, maximum is 4
```

```
Last flood scan time is 0 msec, maximum is 0 msec
```

```
Neighbor Count is 1, Adjacent neighbor count is 1
```

```
Adjacent with neighbor 192.168.2.2 (Backup Designated Router)
```

```
Suppress hello for 0 neighbor(s)
```

A brief version of the OSPFv3 interface settings can be viewed with the command `show ospfv3 interface brief`. The associated process ID, area, address family (IPv4 or IPv6), interface state, and neighbor count are provided in the output.

Example 10-4 demonstrates this command being executed on the ABR, R3. Notice that some interfaces reside in Area 0, and others reside in Area 34.

Example 10-4 *Viewing a Brief Version of OSPFv3 Interfaces*

```
R3# show ospfv3 interface brief
```

Interface	PID	Area	AF	Cost	State	Nbrs	F/C
Lo0	1	0	ipv6	1	LOOP	0/0	
Gi0/2	1	0	ipv6	1	BDR	1/1	
Gi0/4	1	34	ipv6	1	DR	1/1	

The OSPFv3 IPv6 routing table is viewed with the command **show ipv6 route ospf**. Intra-area routes are indicated with *O*, and inter-area routes are indicated with *OI*.

Example 10-5 shows this command being executed on R1. The forwarding address for the routes is the link-local address of the neighboring router.

Example 10-5 *Viewing the OSPFv3 Routes in the IPv6 Routing Table*

```
R1# show ipv6 route ospf
! Output omitted for brevity
IPv6 Routing Table - default - 11 entries
    RL - RPL, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
    OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
..
O   2001:DB8::2/128 [110/1]
    via FE80::2, GigabitEthernet0/2
O   2001:DB8::3/128 [110/2]
    via FE80::2, GigabitEthernet0/2
OI  2001:DB8::4/128 [110/3]
    via FE80::2, GigabitEthernet0/2
OI  2001:DB8:0:4::/64 [110/4]
    via FE80::2, GigabitEthernet0/2
O   2001:DB8:0:23::/64 [110/2]
    via FE80::2, GigabitEthernet0/2
OI  2001:DB8:0:34::/64 [110/3]
    via FE80::2, GigabitEthernet0/2
```

Passive Interface

OSPFv3 supports the ability to mark an interface as passive. The command is placed under the OSPFv3 process or under the specific address family. Placing the command under the global process cascades the setting to both address families. An interface is marked as being passive with the command **passive-interface interface-id** or globally with **passive-interface default**, and then the interface is marked as active with the command **no passive-interface interface-id**.

Example 10-6 shows how to make the LAN interface on R1 explicitly passive and how to make all interfaces passive on R4 while marking the Gi0/3 interface as active.

Example 10-6 *Configuring OSPFv3 Passive Interfaces*

```
R1(config)# router ospfv3 1
R1(config-router)# passive-interface GigabitEthernet0/1

R4(config)# router ospfv3 1
R4(config-router)# passive-interface default
22:10:46.838: %OSPFv3-5-ADJCHG: Process 1, IPv6, Nbr 192.168.3.3 on
GigabitEthernet0/3 from FULL to DOWN, Neighbor Down: Interface down or detached
R4(config-router)# no passive-interface GigabitEthernet 0/3
```

The active/passive state of an interface is verified by examining the OSPFv3 interface status using the command **show ospfv3 interface [interface-id]** and searching for the *Passive* keyword. In Example 10-7, R1 confirms that the Gi0/3 interface is passive.

Example 10-7 *Viewing an OSPFv3 Interface State*

```
R1# show ospfv3 interface GigabitEthernet 0/1 | include Passive
No Hellos (Passive interface)
```

Summarization

The ability to summarize IPv6 networks is as important as summarizing routes in IPv4 (and it may even be more important, due to hardware scale limitations). Example 10-8 shows the IPv6 routing table on R4 before summarization is applied on R3.

Example 10-8 *R4's IPv6 Routing Table Before Summarization*

```
R4# show ipv6 route ospf | begin Application
    1A - LISP away, a - Application
OI  2001:DB8::1/128 [110/3]
    via FE80::3, GigabitEthernet0/3
OI  2001:DB8::2/128 [110/2]
    via FE80::3, GigabitEthernet0/3
OI  2001:DB8::3/128 [110/1]
    via FE80::3, GigabitEthernet0/3
OI  2001:DB8:0:1::/64 [110/4]
    via FE80::3, GigabitEthernet0/3
OI  2001:DB8:0:12::/64 [110/3]
    via FE80::3, GigabitEthernet0/3
OI  2001:DB8:0:23::/64 [110/2]
    via FE80::3, GigabitEthernet0/3
```

Summarizing the Area 0 router's loopback interfaces (2001:db8:0::1/128, 2001:db8:0::2/128, and 2001:db8:0::3/128) removes three routes from the routing table.

NOTE A common mistake with summarization of IPv6 addresses is to confuse hex with decimal. We typically perform summarization logic in decimal, and the first and third digits in a hextet should not be confused as decimal values. For example, the first hextet of the IPv6 address 2001::1/128 is 2001. When we separate those values further, it is not 20 and 1 in decimal format. The decimal values in that hextet are 32 (20 in hex) and 1 (1 in hex).

Key Topic

Summarization of internal OSPFv3 routes follows the same rules as in OSPFv2 and must occur on ABRs. In our topology, R3 summarizes the three loopback addresses into the 2001:db8:0:0::/65 network. Summarization involves the command `area area-id range prefix/prefix-length`, which resides under the address family in the OSPFv3 process.

Example 10-9 shows R3's configuration for summarizing these prefixes.

Example 10-9 *IPv6 Summarization*

```
R3# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
R3(config)# router ospfv3 1
R3(config-router)# address-family ipv6 unicast
R3(config-router-af)# area 0 range 2001:db8:0:0::/65
```

Example 10-10 shows R4's IPv6 routing table after configuring R3 to summarize the Area 0 loopback interfaces. The summary route is highlighted in this example.

Example 10-10 *R4's IPv6 Routing Table After Summarization*

```
R4# show ipv6 route ospf | begin Application
      1A - LISP away, a - Application
OI 2001:DB8::/65 [110/4]
    via FE80::3, GigabitEthernet0/3
OI 2001:DB8:0:1::/64 [110/4]
    via FE80::3, GigabitEthernet0/3
OI 2001:DB8:0:12::/64 [110/3]
    via FE80::3, GigabitEthernet0/3
OI 2001:DB8:0:23::/64 [110/2]
    via FE80::3, GigabitEthernet0/3
```

Network Type

OSPFv3 supports the same OSPF network types as OSPFv2. Example 10-11 shows that R2's Gi0/3 interface is set as a broadcast OSPF network type and is confirmed as being in a DR state.

Example 10-11 *Viewing the Dynamic Configured OSPFv3 Network Type*

```
R2# show ospfv3 interface GigabitEthernet 0/3 | include Network
      Network Type BROADCAST, Cost: 1
R2# show ospfv3 interface brief
Interface  PID  Area  AF      Cost  State Nbrs F/C
Lo0        1    0     ipv6    1     LOOP 0/0
Gi0/3     1    0     ipv6    1     DR   1/1
Gi0/1     1    0     ipv6    1     BDR  1/1
```

The OSPFv3 network type is changed with the interface parameter command `ospfv3 network {point-to-point | broadcast}`. Example 10-12 shows the interfaces associated with the 2001:DB8:0:23::/64 network being changed to point-to-point.

Example 10-12 *Changing the OSPFv3 Network Type*

```
R2# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
R2(config)# interface GigabitEthernet 0/3
R2(config-if)# ospfv3 network point-to-point

R3(config)# interface GigabitEthernet 0/2
R3(config-if)# ospfv3 network point-to-point
```

After the changes are typed in, the new settings are verified in Example 10-13. The network is now a point-to-point link, and the interface state shows as P2P for confirmation.

Example 10-13 *Viewing the Statically Configured OSPFv3 Network Type*

```
R2# show ospfv3 interface GigabitEthernet 0/3 | include Network
Network Type POINT_TO_POINT, Cost: 1
R2# show ospfv3 interface brief
```

Interface	PID	Area	AF	Cost	State	Nbrs	F/C
Lo0	1	0	ipv6	1	LOOP	0/0	
Gi0/3	1	0	ipv6	1	P2P	1/1	
Gi0/1	1	0	ipv6	1	BDR	1/1	

IPv4 Support in OSPFv3

RFC 5838 specifies that OSPFv3 should support multiple address families by setting the instance ID value from the IPv6 reserved range to the IPv4 reserved range (64 to 95) in the link LSAs.

Enabling IPv4 support for OSPFv3 is straightforward:

Key Topic

- Step 1.** Ensure that the IPv4 interface has an IPv6 address (global or link local) configured. Remember that configuring a global address also places a link-local address; alternatively, a link-local address can statically be configured.
- Step 2.** Enable the OSPFv3 process for IPv4 on the interface with the command `ospfv3 process-id ipv4 area area-id`.

Using the topology shown in Figure 10-1, IPv4 addressing has been placed onto R1, R2, R3, and R4 using the conventions outlined earlier. Example 10-14 demonstrates the deployment of IPv4 using the existing OSPFv3 deployment.

Example 10-14 *Configuration Changes for IPv4 Support*

```
R1(config)# interface Loopback 0
R1(config-if)# ospfv3 1 ipv4 area 0
R1(config-if)# interface GigabitEthernet0/1
R1(config-if)# ospfv3 1 ipv4 area 0
R1(config-if)# interface GigabitEthernet0/2
R1(config-if)# ospfv3 1 ipv4 area 0
```

```
R2(config)# interface Loopback 0
R2(config-if)# ospfv3 1 ipv4 area 0
R2(config-if)# interface GigabitEthernet0/1
R2(config-if)# ospfv3 1 ipv4 area 0
R2(config-if)# interface GigabitEthernet0/3
R2(config-if)# ospfv3 1 ipv4 area 0
```

```
R3(config)# interface Loopback 0
R3(config-if)# ospfv3 1 ipv4 area 0
R3(config-if)# interface GigabitEthernet0/2
R3(config-if)# ospfv3 1 ipv4 area 0
```

```
R3(config-if)# interface GigabitEthernet0/4
R3(config-if)# ospfv3 1 ipv4 area 34
```

```
R4(config)# interface Loopback 0
R4(config-if)# ospfv3 1 ipv4 area 34
R4(config-if)# interface GigabitEthernet0/1
R4(config-if)# ospfv3 1 ipv4 area 34
R4(config-if)# interface GigabitEthernet0/3
R4(config-if)# ospfv3 1 ipv4 area 34
```

Example 10-15 verifies that the routes were exchanged and installed into the IPv4 RIB.

Example 10-15 Verifying IPv4 Route Exchange with OSPFv3

```
R4# show ip route ospfv3 | begin Gateway
Gateway of last resort is not set

    10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
O IA    10.1.1.0/24 [110/4] via 10.34.1.3, 00:00:39, GigabitEthernet0/3
O IA    10.12.1.0/24 [110/3] via 10.34.1.3, 00:00:39, GigabitEthernet0/3
O IA    10.23.1.0/24 [110/2] via 10.34.1.3, 00:00:39, GigabitEthernet0/3
    192.168.1.0/32 is subnetted, 1 subnets
O IA    192.168.1.1 [110/3] via 10.34.1.3, 00:00:39, GigabitEthernet0/3
    192.168.2.0/32 is subnetted, 1 subnets
O IA    192.168.2.2 [110/2] via 10.34.1.3, 00:00:39, GigabitEthernet0/3
    192.168.3.0/32 is subnetted, 1 subnets
O IA    192.168.3.3 [110/1] via 10.34.1.3, 00:00:39, GigabitEthernet0/3
```

The command `show ospfv3 interface [brief]` displays the address families enabled on an interface. When IPv4 and IPv6 are both configured on an interface, an entry appears for each address family. Example 10-16 lists the interfaces and associated address families.

Example 10-16 Listing of OSPFv3 Interfaces and Their Address Families

```
R4# show ospfv3 interface brief
```

Interface	PID	Area	AF	Cost	State	Nbrs	F/C
Lo0	1	34	ipv4	1	LOOP	0/0	
Gi0/1	1	34	ipv4	1	DR	1/1	
Gi0/3	1	34	ipv4	1	DR	1/1	
Lo0	1	34	ipv6	1	LOOP	0/0	
Gi0/1	1	34	ipv6	1	DR	0/0	
Gi0/3	1	34	ipv6	1	BDR	1/1	

Example 10-17 shows how to view the OSPFv3 neighbors to display the neighbors enabled for IPv4 and IPv6 as separate entities.

Example 10-17 *Verifying OSPFv3 IPv4 Neighbors*

```

R4# show ospfv3 neighbor

      OSPFv3 1 address-family ipv4 (router-id 192.168.4.4)

Neighbor ID      Pri   State           Dead Time   Interface ID  Interface
192.168.3.3      1    FULL/BDR        00:00:30   6             GigabitEthernet0/3

      OSPFv3 1 address-family ipv6 (router-id 192.168.4.4)

Neighbor ID      Pri   State           Dead Time   Interface ID  Interface
192.168.3.3      1    FULL/DR         00:00:31   6             GigabitEthernet0/3
192.168.3.3 1  FULL/DR 00:00:31 6 GigabitEthernet0/3

```

Exam Preparation Tasks

You have a couple of choices for exam preparation: the exercises here, Chapter 30, “Final Preparation,” and the exam simulation questions in the Pearson Test Prep Software Online.

Review All Key Topics

Review the most important topics in the chapter, noted with the Key Topic icon in the outer margin of the page. Table 10-2 lists these key topics and the page number on which each is found.

**Table 10-2** Key Topics for Chapter 10

Key Topic Element	Description	Page
Section	OSPFv3 Fundamentals	231
Section	OSPFv3 Verification	235
Paragraph	OSPFv3 summarization	238
List	IPv4 support on OSPFv3	240

Complete Tables and Lists from Memory

There are no memory tables in this chapter.

Define Key Terms

There are no key terms in this chapter.

Use the Command Reference to Check Your Memory

Table 10-3 lists the important commands from this chapter. To test your memory, cover the right side of the table with a piece of paper, read the description on the left side, and see how much of the command you can remember.

Table 10-3 Command Reference

Task	Command Syntax
Configure OSPFv3 on a router and enable it on an interface	<code>router ospfv3 [process-id]</code> <code>interface interface-id</code> <code>ospfv3 process-id {ipv4 ipv6} area area-id</code>
Configure a specific OSPFv3 interface as passive	<code>passive-interface interface-id</code>
Configure all OSPFv3 interfaces as passive	<code>passive-interface default</code>
Summarize an IPv6 network range on an ABR	<code>area area-id range prefix/prefix-length</code>
Configure an OSPFv3 interface as a point-to-point or broadcast network type	<code>ospfv3 network {point-to-point broadcast}</code>
Display OSPFv3 interface settings	<code>show ospfv3 interface [interface-id]</code>
Display OSPFv3 IPv6 neighbors	<code>show ospfv3 ipv6 neighbor</code>

References in This Chapter

RFC 5340, *OSPF for IPv6*, R. Coltun, D. Ferguson, J. Moy, A. Lindem, and IETF. <http://www.ietf.org/rfc/rfc5340.txt>, July 2008.

RFC 5838, *Support of Address Families in OSPFv3*, A. Lindem, S. Mirtorabi, A. Roy, M. Barnes, R. Aggarwal, and IETF. <http://www.ietf.org/rfc/rfc5838.txt>, April 2010.

Edgeworth, Brad, Aaron Foss, and Ramiro Garza Rios, *IP Routing on Cisco IOS, IOS XE, and IOS XR*. Indianapolis: Cisco Press, 2014.

Cisco IOS Software Configuration Guides. <http://www.cisco.com>.