



Numerics

- 6PE (IPv6 provider edge router), 392, 400
 - designing with BGP confederations, 419
 - designing with BGP route reflectors, 415–418
 - inter-AS 6PE deployment, 419–421
 - inter-MP-BGP session establishment, 405–407
 - IPv6 datagram forwarding across MPLS backbone, 412–415
 - IPv6 route exchange between CE and PE routers, 401–404
 - labeled IPv6 MP-BGP prefixes, configuring, 407–411
 - route redistribution, 405–407
 - versus MPLS VPN, 392

A

- AAA (authentication, authorization and accounting)
 - authentication
 - CE-to-CE, 238–240
 - LCP, 28
 - neighbor authentication, 230–231
 - between PE routers, 235–236
 - on PE/CE circuits, 232, 234–235
 - on P-networks, 236–237
 - per-VRF AAA, 105–110
 - RADIUS, 33–35
 - AV pairs, 35–36
 - VSAAs, 35–36
 - access protocols
 - DHCP, 36–37
 - PPP, 27
 - L2TP, 29–30
 - LCP, 27–29
 - RADIUS, 33–35
 - AV pairs, 35–36
 - VSAAs, 35–36
 - VPDNs, 31–33

- access technology integration with MPLS-based VPNs, 17
- accessing common services with PE-NAT, 205–208
- access-lists, limiting access to PE/CE circuits, 252–256
- address pools, ODAPs, 99–105
- addressing, IPv6, 394
 - interface ID, 394
 - public address space, 396
- advanced MPLS VPN remote access features of Cisco IOS Software
 - ODAPs, 99–105
 - per-VRF AAA, 105–110
- Advertising Router field (LSA), 124
- antilabel spoofing, 230
- applications (MPLS), 13
- architecture
 - control plane
 - troubleshooting, 432
 - verifying label exchange, 436–437
 - verifying local TDP/LDP parameters, 433
 - verifying TDP/LDP Hello protocol, 433–434
 - verifying TDP/LDP session state, 435
 - customer control plane, 425
 - data plane, 426
 - troubleshooting, 437–438
 - point-to-point, 6–16, 23–24, 28–31, 34–40, 49, 51, 58, 63, 75–94, 100, 107, 112, 118–153, 163–165, 170–171, 175–179, 185–188, 197–207, 214, 226–239, 257–272, 277, 281, 287–306, 315, 317, 321, 324, 330, 335–336, 338–367, 379–380, 391–405, 416–432, 440–446
 - provider control plane, 426
- ATM (Asynchronous Transfer Mode)
 - PPPoA, configuring DSL access to MPLS VPN, 82–85
- attributes (BGP), UPDATE authenticator, 240

authentication

CE-to-CE, 238–240

LCP, 28

neighbor authentication, 230–231

between PE routers, 235–236

on PE/CE circuits, 232–235

on P-networks, 236–237

automatic route filtering, 15

AV (attribute value) pairs, 35–36

B

backbone connectivity

connecting with virtual router, 182–195

in Carrier's Carrier architecture, 271–273

dynamic routing between CSC PE/CE
routers, 276–277

external route exchange, 277–279

internal route exchange, 273

static routing between CSC PE/CE
routers, 274–275

troubleshooting, 427

verifying end-to-end LSP, 427–429

backdoor links, 131–136

back-to-back VRFs, 298–300

BGP

between PE/CE routers, 289–290

extended community attributes for OSPF
routers, 126–127IPv6 configuration on Cisco IOS Software,
399–400

multi-VRF configuration, 174–178

route filtering on CSC CE routers to PE router
links, 291

UPDATE authenticator attribute, 240

BOOTP messages, 36–37

C

C routers, 6

capability vrf-lite command, 173

Carrier's Carrier architecture, 268–269

backbone connectivity, 271–273

dynamic routing between CSC PE/CE
routers, 276–277

external route exchange, 277–279

internal route exchange, 273

static routing between CSC PE/CE
routers, 274–275

hierarchical VPNs, 294–295

route types, 269–271

CE (customer edge) routers, 6

controlling routes injected into VRF, 241–242

with eBGP, 247–249

with Multiprotocol BGP, 245–247

with OSPF, 250

with RIPv2, 243–244

GRE tunneling, 344

multi-VRF functionality

BGP configuration, 174–178

configuring, 161–170

OSPF configuration, 170–174

overlapping VPN configuration, 179–181

pinging between, 440–441

with firewall functionality, 263

CEF (Cisco Express Forwarding) switching,

verifying operation, 429, 442

CE-to-CE authentication, 238–240

CE-to-CE Authentication Token, 240

CHAP (Challenge Handshake Authentication
Protocol), 28

three-way handshakes, 28–29

circuit addresses, preventing overlap, 225

Cisco IOS Software

advanced MPLS VPN remote access features

ODAPs, 99–105

per-VRF AAA, 105–110

- IPv4+Labels, 289–290
 - BGP next hop exchange, 326–329
 - route filtering on CSC CE routers to PE
 - router links, 291–293
- IPv6, configuring, 398–400
- MPLS VPN remote access features, 25–26
- commands
 - capability vrf-lite, 173
 - ip vrf receive, 198
 - redistribute bgp, 140
 - show ip route vrf, 444–445
 - show mpls interface, 431
 - show vpdn session, 53
- common server VRF configuration, 209
- comparing MPLS VPN and 6PE, 392
- configuring
 - 6PE
 - IPv6 datagram forwarding across MPLS backbone, 412–415
 - labeled IPv6 MP-BGP prefixes, 407, 409–411
 - route reflectors, 415–418
 - with BGP confederations, 419
 - with BGP route reflectors, 415–418
- Cisco IOS Software, IPv6, 398–400
- dial backup for MPLS VPN access, 75–77
- dial-in access
 - via direct ISDN, 57–61
 - via L2TP VPDN, 40–56
- dial-out access via LSDO, 62–64
 - downloading static routes, 69–73
 - LAC/NAS configuration, 66
 - RADIUS attributes, 66
 - verifying VRF-aware LSDO operation, 67–69
 - VHG/PE router configuration, 64–65
- dial-out access without LSDO, 73–74
- DSL access to MPLS VPN, 77–79
 - PPPoA, 82–85, 89–93
 - PPPoE, 86–88, 90–93
 - RFC 1483 bridged encapsulation, 80–81
 - RFC 1483 routed encapsulation, 79
- MPLS VPN remote access
 - ODAPs, 99, 101–105
 - per-VRF AAA, 105–110
 - via cable, 93–98
- sham-links, 133–136
- VRF
 - multi-VRF functionality, 161–178
 - PE-NAT, 199–217
 - selection based on source IP address, 195–198
- connectionless VPNs, 6, 8–9
- connection-oriented VPNs, 6–8
- connectivity
 - between ISPs, 296–297
 - back-to-back VRFs, 298–300
 - external Multiprotocol BGP, 306–314
 - Multihop MP-eBGP, 315–325
 - requirements, 297–298
 - route distribution across ASBR-ASBR links, 301–305
 - EIGRP, PE-CE connectivity, 152
 - extended community attribute (BGP), 156–158
 - requirements, 152
 - route propagation with Multiprotocol BGP, 155–156
 - separation of VPN routing information, 153–155
 - VRF route types, 158–159
 - IS-IS, PE-CE connectivity, 136
 - level 1 topology, 145, 149–150
 - level 1-2 topology, 141–144
 - level 2 topology, 147–148
 - requirements, 137–138
 - route propagation with Multiprotocol BGP, 139–140
 - routing loop prevention, 151
 - separation of VPN routing information, 138–139

- OSPF, PE-CE connectivity, 119
 - basic operation, 121–122
 - controlling LSA type generation, 127–128
 - extended community attribute (BGP), 126–127
 - monitoring processes inside VRF, 124–126
 - MPLS VPN Superbackbone, 120
 - process-id, 123
 - requirements, 120
 - router-id, modifying, 124
 - routing loop prevention, 129–130
 - sham-links, 120
 - VPN client backdoor links, 131–136
- overlapping circuit addresses, 225
- control plane, 10
 - troubleshooting, 432
 - verifying label exchange, 436–437
 - verifying local TDP/LDP parameters, 433
 - verifying TDP/LDP Hello protocol, 433–434
 - verifying TDP/LDP session state, 435
- controlling
 - access to extranet VPNs, 256–259
 - LSA type generation at PE routers, 127–128
 - routes injected into VRF, 241–242
 - with eBGP as PE/CE routing protocol, 247–249
 - with Multiprotocol BGP, 245–247
 - with OSPF as PE/CE routing protocol, 250
 - with RIPv2, 243–244
- core networks, visibility to customer VPN, 226–227
- C-packets, forwarding, 365–366
- customer control plane, 425

D

- data plane, 426
 - oversized packets, 438
 - troubleshooting, 437–438
- Data-MDT, 355–359, 378–384
 - joins, 357
- default routes, shared Internet access, 260
- Default-MDTs, 352, 355
 - multicast tunnel interfaces, 372–374
- deploying
 - 6PE
 - BGP route reflectors, 415–418
 - inter-AS deployment, 419–421
 - IPv6 datagram forwarding across MPLS backbone, 412–415
 - IPv6 route exchange between PE and CE routers, 401, 403–404
 - labeled IPv6 MP-BGP prefixes, 407–411
 - MP-BGP session establishment, 405–407
 - with existing BGP confederations, 419
 - IPv6, 391–394
 - sham-links, 134
- devices, MPLS, 10–13
- DHCP, 36–37
- DHCP Relay, VPN support, 110–114
- dial backup for MPLS VPN access, 75–77
- dial-in access
 - via direct ISDN, 57, 59
 - NAS/PE router configuration, 59–60
 - RADIUS server attributes, 60
 - SOHO router configuration, 61
 - verifying dial-in operation, 61
 - via L2TP VPDN, 40–41
 - aggregating remote user host addresses, 55–56
 - configuring access between RADIUS servers, 48–51
 - NAS/LAC configuration, 42

- RADIUS server attributes, 43–44, 47–48
- verifying dial-in, 51–55
- VHG/PE router configuration, 44–46
- dial-out access
 - via LSDO, 62–64
 - downloading static routes, 69–73
 - LAC/NAS configuration, 66
 - RADIUS attributes, 66
 - verifying VRF-aware LSDO operation, 67–69
 - VHG/PE router configuration, 64–65
 - without LSDO, 73–74
- direct dial-in access via ISDN, 57, 59
 - NAS/PE router configuration, 59–60
 - RADIUS server attributes, 60
 - SOHO router configuration, 61
 - verifying dial-in operation, 61
- distribution trees, 334
 - Default-MDT, 347
- DMT (Discrete Multitone), 77
- DOCSIS, MPLS VPN access via cable, 93, 95–96
 - head end PE router configuration, 96
 - verifying configuration, 98
- dotted decimal notation, IPv6 addresses, 396
- downloading static routes from AAA server, 69–73
- DSL (Digital Subscriber Line), MPLS VPN access
 - configuring, 77, 79–81
 - via PPPoA, 82–85, 89, 91, 93
 - via PPPoE, 86–88, 90–91, 93
- dynamic routing between CSC PE/CE routers, 276–277

E

- eBGP (external BGP), controlling routes injected into VRF, 247–249
- egress CE-PE routing exchange, troubleshooting, 444–445
- EIGRP (Enhanced IGRP)
 - External Information Extended Community attributes, 158
 - PE-CE connectivity, 152
 - extended community attribute (BGP), 156–158
 - requirements, 152
 - route propagation with Multiprotocol BGP, 155–156
 - separation of VPN routing information, 153–155
 - VRF route types, 158–159
- enabling multicast in VRFs, 371
- end-to-end LSP, verifying, 427, 429
- Ethernet, configuring DSL access to MPLS VPN with PPPoE, 86–88
- extended BGP communities, 15
 - exchange between VPN sites, 277–279
 - external routes, 270
 - for EIGRP routes, 156–158
 - for OSPF routes, 126–127
- extended community attribute, CE-to-CE Authentication Token, 240
- External Multiprotocol BGP, 306
- extranet VPNs, restricting access, 256, 259

F

- FIB (forwarding information base), 10
- filtering routes accessing PE/CE circuits, 252–256
- firewalls
 - co-locating for Internet access, 261
 - PE-NAT shared firewall functionality, 213–217
 - restricting access to extranet VPNs, 256, 259
- forwarding
 - C-packets, 365–366
 - P-packets, 366

G

- GRE (generic routing encapsulation)
 - creating virtual links between adjacent routers, 182–195
 - MDTs, 352
 - Data-MDT, 355–359
 - Default MDTs, 352–355
 - MTI, 359–360

H

- HFC (hybrid fiber-coaxial) networks, 93–96
 - configuring MPLS VPN access via cable, 96–98
- hiding core network addresses, 228
- hierarchical VPNs, 294–295
- hub-and-spoke Internet access with global routing table, 262

I

- impetus for IPv6 implementation, 389–390
- implementing
 - 6PE
 - BGP route reflectors, 415–418
 - inter-AS deployment, 419–421
 - IPv6 datagram forwarding across MPLS backbone, 412–415
 - IPv6 route exchange between PE and CE routers, 401–404
 - labeled IPv6 MP-BGP prefixes, 407–411
 - MP-BGP session establishment, 405–407
 - with existing BGP confederations, 419
 - IPv6, 391–394
 - motivation for, 389–390
 - independent control label assignment, 436
 - ingress CE-PE routing exchange, troubleshooting, 452–453
 - inherent security capabilities, 224
 - address space separation, 224–226
 - core network visibility, 226–227
 - resistance to label spoofing, 228–229
 - static labels, 230
 - inter-AS 6PE deployment, 419–421
 - interdepartment isolation, 162
 - interface ID (IPv6), 394
 - interface-level CEF, monitoring, 437–438
 - interior routing protocol, IPv6 configuration on Cisco IOS Software, 398–399
 - inter-MP-BGP session establishment (6PE), 405–407
 - internal routes, 270
 - exchange of between VPN sites, 273
- Internet, provisioning access, 259–260
 - CE routers with firewall functionality, 263
 - default routes, 260
 - firewall co-location, 261
 - hub-and-spoke topology with global routing table, 262
- interprovider connectivity, 296
 - back-to-back VRFs, 298–300
 - external Multiprotocol BGP, 306–314
 - Multihop MP-eBGP, 315–320
 - between route reflectors, 320–325
 - requirements, 297–298
 - route distribution across ASBR-ASBR links, 301–305

- IP addressing
 - 6PE (IPv6 provider edge router), 392, 400
 - designing with BGP confederations, 419
 - designing with BGP route reflectors, 415–418
 - inter-AS 6PE deployment, 419–421
 - inter-MP-BGP session establishment, 405–407
 - IPv6 datagram forwarding across MPLS backbone, 412–415
 - IPv6 route exchange between CE and PE routers, 401–404
 - labeled IPv6 MP-BGP prefixes, configuring, 407–411
 - route redistribution, 405–407
 - versus MPLS VPN, 392
- DHCP Relay, VPN support, 110–114
- IP multicast, 333
 - distribution trees, 334
 - in service provider environment, 343–345
 - MDT, mBGP updates, 361–364
 - multicast domains, state flags, 364–365
 - multicast forwarding, 338–339
 - mVPN case study, 367–386
 - PIM, 341
 - PIM Bi-Dir, 342
 - PIM DM, 342
 - PIM SM, 342
 - SSM, 342
 - RPF, 339–340
 - RPF checks, 360–361
 - shared trees, 336–337
 - source trees, 334–335
- ip vrf receive command, 198
- IPCP (Internet Protocol Control Protocol), 28
- IP-interarea routes, 151
- IPSec over MPLS, 264
- IPv4+Labels, 289–290
 - BGP next-hop exchange, 326–329
 - route filtering on CSC CE routers to PE router links, 291–293
- IPv6
 - 6PE, 400
 - designing BGP confederations, 419
 - designing with BGP route reflectors, 415–418
 - inter-AS 6PE deployment, 419–421
 - inter-MP-BGP session establishment, 405–407
 - IPv6 datagram forwarding across MPLS backbone, 412–415
 - labeled IPv6 MP-BGP prefixes, configuring, 407–411
 - route exchange between CE and PE routers, 401–404
 - route redistribution, 405–407
 - addressing, 394
 - dotted decimal notation, 396
 - interface ID, 394
 - BGP, configuring on Cisco IOS Software, 399–400
 - configuring on Cisco IOS Software, 398
 - deploying, 391, 393–394
 - interior routing protocol, configuring on Cisco IOS Software, 398–399
 - motivation for implementation, 389–390
 - neighbor discovery, 396
 - public address space, 396
 - routing, 397
- ISDN (Integrated Services Digital Network), dial-in access, 57–59
 - NAS/PE router configuration, 59–60
 - RADIUS server attributes, 60
 - SOHO router configuration, 61
 - verifying dial-in operation, 61
- IS-IS, PE-CE connectivity, 136
 - level 1 topology, 145, 149–150
 - level 1-2 topology, 141–144
 - level 2 topology, 147–148
 - requirements, 137–138
 - route propagation with Multiprotocol BGP, 139–140

- routing loop prevention, 151
- separation of VPN routing information, 138–139
- ISPs, connectivity between, 296–297
 - back-to-back VRFs, 298–300
 - Carrier's Carrier architecture, backbone connectivity, 271–279
 - dynamic routing between CSC PE/CE routers, 276–277
 - external route exchange, 277–279
 - internal route exchange, 273
 - static routing between CSC PE/CE routers, 274–275
 - external Multiprotocol BGP, 306–314
 - route types, 269–271
 - Multihop MP-eBGP, 315–325
 - requirements, 297–298
 - route distribution across ASBR-ASBR links, 301–305

K-L

- key chains, 233
- L2TP (Layer 2 Tunneling Protocol), 29–30
 - VPDNs, dial-in access, 40–56
- label exchange
 - between CSC PE and CE routers, 284–287
 - verifying, 436–437
- label spoofing, resistance to, 228–229
- LAC (Layer 2 Access Concentrator), 29
- large-scale service providers, Carrier's Carrier architecture
 - backbone connectivity, 271, 273–279
 - route types, 269–271
- Layer 2 services versus MPLS VPNs, 223–224
- LCP (Link Control Protocol), 27
 - authentication, 28
 - CHAP, three-way handshake, 29

- LDP (Label Distribution Protocol), 11
 - on PE-CE links, 280–283
 - label distribution between CSC PE and CE routers, 284–287
 - static default routes on CSC CE routers, 287–288
 - transport address usage, 283–284
 - transport address usage, 283
 - level 1 IS-IS topologies, deploying, 145, 149–150
 - level 1-2 IS-IS topologies, deploying, 141–144
 - level 2 IS-IS topologies, deploying, 147–148
- LFIB (label forwarding information base), 11
- LIB (label information base), 12
- limiting access
 - on extranet VPNs, 256, 259
 - to PE/CE circuits with access-lists, 252–256
- linking virtual router to MPLS VPN backbone, 182–195
- LSAs (link-state advertisements)
 - Advertising Router field, 124
 - controlling type generation at PE routers, 127–128
- LSDO, dial-out access, 62, 64
 - downloading static routes, 69–73
 - LAC/NAS configuration, 66
 - RADIUS attributes, 66
 - verifying VRF-aware LSDO operation, 67–69
 - VHG/PE router configuration, 64–65
- LSRs (label switch routers), 10–13
 - control plane operations, 12
- LSR-wide MPLS operation, verifying, 430–431

M

- maximum routes command, controlling routes injected into VRF, 242
- mBGP (multiprotocol BGP), MDT updates, 361–364
- MD5 key chains, 233
- MDT-Groups, 347

- MDTs, 352
 - Data-MDT, 355–359, 378–384
 - Default-MDT, 352, 355
 - multicast tunnel interfaces, 372–374
 - MTI, 359–360
 - SSM, 384–386
 - updates, 361–364
 - messages
 - Data-MDT joins, 357
 - DHCP, 36–37
 - RADIUS, 33–35
 - Miercom, comparison of Layer 2-based VPNs and MPLS VPNs, 223–224
 - monitoring
 - interface-level CEF, 437–438
 - OSPF processes inside VRF, 124–126
 - motivation for IPv6 implementation, 389–390
 - MPLS VPN Superbackbone, 120
 - MPLS-based VPNs, 9–10
 - access technology integration, 17
 - access via cable, 93–96
 - head-end PE router configuration, 96
 - verifying configuration, 98
 - access via DSL
 - configuring, 77–79
 - PPPoA, 82–85, 89–93
 - PPPoE, 86–93
 - RFC 1483 bridged encapsulation, 80–81
 - RFC 1483 routed encapsulation, 79
 - LSRs, 10–13
 - penultimate hop popping, 15
 - technologies involved, 14–16
 - MTI, 359–360
 - multicast domains, 346–348
 - state flags, 364–365
 - multicast forwarding, 338–339
 - multicast routing table entry, 340
 - multicast tunnel interfaces, 372–374
 - Multihop MP-eBGP, 315–320
 - between route reflectors, 320–325
 - Multiprotocol BGP
 - controlling routes injected into VRF, 245–247
 - EIGRP route propagation, 155–156
 - extended community attributes, CE-to-CE
 - Authentication Token, 240
 - multi-VRF functionality, configuring, 161–70
 - BGP, 174–178
 - OSPF, 170–174
 - mVPN architecture, 345–346
 - case study, 367–386
 - multicast domains, 346–348
 - mVRF, 348–350
 - PIM adjacencies, 351
 - mVPN forwarding
 - C-packets, 365–366
 - P-packets, 366
 - mVPN state flags, 364–365
 - mVRF, 348–350
 - PIM adjacencies, 376
 - routing entries, 377–384
- ## N
-
- NAS (network access server), 27
 - NAT, 202–204. *See also* PE-NAT
 - translation table, 202
 - neighbor authentication, 230–231
 - between PE routers, 235–236
 - on PE/CE circuits, 232–235
 - on P-networks, 236–237
 - neighbor discovery, IPv6, 396
 - network architecture
 - control plane
 - troubleshooting, 432
 - verifying label exchange, 436–437
 - verifying local TDP/LDP parameters, 433
 - verifying TDP/LDP Hello protocol, 433–434
 - verifying TDP/LDP session state, 435
 - customer control plane, 425

- data plane, 426
 - troubleshooting, 437–438
- point-to-point, 6–16, 23–24, 28–31, 34–40, 49, 51, 58, 63, 75–94, 100, 107, 112, 118–153, 163–165, 170–171, 175–179, 185–188, 197–207, 214, 226–239, 257–272, 277, 281, 287–306, 315, 317, 321, 324, 330, 335–336, 338–367, 379–380, 391–405, 416–432, 440–446
- provider control plane, 426
- network connections, figure icons for, xii

O

- ODAPs (on-demand address pools), 99–105
- off-net access to MPLS VPN, 25
 - features of Cisco IOS services, 25–26
- omitting leading zeroes in IPv6 address notation, 394
- OSPF (Open Shortest Path First)
 - authentication on CE routers, 234
 - controlling routes injected into VRF, 250
 - multi-VRF configuration, 170–174
 - PE-CE connectivity, 119
 - basic operation, 121–122
 - controlling LSA type generation, 127–128
 - extended community attribute (BGP), 126–127
 - monitoring processes inside VRF, 124–126
 - MPLS VPN Superbackbone, 120
 - process-id, 123
 - requirements, 120
 - router-id, modifying, 124
 - routing loop prevention, 129–130
 - sham-links, 120
 - VPN client backdoor links, 131–136
- overlapping circuit addresses, avoiding, 225
- overlapping VPN configuration on CE routers, 179–181
- overload NAT, 204
- oversized packets, troubleshooting, 438

P

- PAP, 28
- passive interfaces, 312
- PDBs (Protocol Descriptor Blocks), 126
- PE (provider edge) devices, 6
 - 6PE, 392
 - configuring, 400
 - designing with BGP confederations, 419
 - designing with BGP route reflectors, 415–418
 - inter-AS 6PE deployment, 419–421
 - inter-MP-BGP session establishment, 405–407
 - IPv6 datagram forwarding across MPLS backbone, 412–415
 - IPv6 route exchange between CE and PE routers, 401–404
 - labeled IPv6 MP-BGP prefixes, configuring, 407–411
 - route redistribution, 405–407
 - authentication between, 235–236
- PE/CE circuits
 - authentication, 232–235
 - limiting access with access-lists, 252–256
- PE-CE connectivity
 - EIGRP, 152
 - extended community attribute (BGP), 156–158
 - requirements, 152
 - route propagation with Multiprotocol BGP, 155–156
 - separation of VPN routing information, 153–155
 - VRF route types, 158–159

- IS-IS, 136
 - level 1 topology, 145, 149–150
 - level 1-2 topology, 141–144
 - level 2 topology, 147–148
 - requirements, 137–138
 - route propagation with Multiprotocol BGP, 139–140
 - routing loop prevention, 151
 - separation of VPN routing information, 138–139
- OSPF, 119
 - basic operation, 121–122
 - controlling LSA type generation, 127–128
 - extended community attribute (BGP), 126–127
 - monitoring processes inside VRF, 124–126
 - MPLS VPN Superbackbone, 120
 - process-id, 123
 - requirements, 120
 - router-id, modifying, 124
 - routing loop prevention, 129–130
 - sham-links, 120
 - VPN client backdoor links, 131–136
 - overlapping circuit addresses, 225
- PE-CE links, LDP, 280–283
 - label distribution between CSC PE and CE routers, 284–287
 - static default routes, 287–288
 - transport address usage, 283–284
- PE-NAT, 199
 - accessing common services, 205–208
 - common server VRF configuration, 209
 - configuring, 200–205
 - customer VRF configuration, 210–213
 - NAT pool configuration, 209
 - shared firewalls, 213–215, 217
- penultimate hop popping, 15
- per-VRF AAA, 105–110
- PIM, 341
 - adjacencies, 351, 376
 - PIM Bi-Dir, 342
 - PIM DM, 342
 - PIM SM, 342
 - SSM, 342
- PIM adjacencies, 351
- pinging
 - between CE routers, 440–441
- P-networks, 6
 - authentication, 236–237
- point-to-point architecture, 6–16, 23–24, 28–31, 34–40, 49, 51, 58, 63, 75–94, 100, 107, 112, 118–153, 163–165, 170–171, 175–179, 185–188, 197–207, 214, 226–239, 257–272, 277, 281, 287–306, 315, 317, 321, 324, 330, 335–336, 338–367, 379–380, 391–405, 416–432, 440–446
- P-packets, forwarding, 366
- PPP (point-to-point protocol), 27
 - L2TP, 29–30
 - LCP, 27
 - authentication, 28
 - CHAP, 29
- PPPoA, configuring MPLS VPN access via DSL, 82–85
- PPPoE, configuring MPLS VPN access via DSL, 86–88
- preventing routing loops
 - IS-IS 151
 - OSPF, 129–130
- private IP addresses, NAT, 202
- process-id value (OSPF), 123
 - selecting for VPN clients, 122
- propagation of MPLS VPN routes, troubleshooting, 448–449
- provider control plane, 426

provisioning

- Internet access, 259–260
 - CE routers with firewall functionality, 263
 - default routes, 260
 - firewall co-location, 261
 - hub-and-spoke topology with global routing table, 262
- OSPF VPN customers, 123

public address space

- IPv6 addresses, 396

R

RADIUS, 33, 35

- AV pairs, 35–36
- VSAs, 35–36

reachability of core networks, 226–227

redistribute bgp command, 140

redistribution, 119

- troubleshooting, 452–453

redundancy, dial backup for MPLS VPN access, 75–77

remote access

- DHCP, 36–37
- PPP, 27
 - L2TP, 29–30
 - LCP, 27–29

RADIUS, 33–35

- AV pairs, 35–36
- VSAs, 35–36

VPDNs, 31–33

remote access to MPLS VPN, 25

- features of Cisco IOS services, 25–26
- via cable, 93–96
 - head-end PE router configuration, 96
 - verifying configuration, 98

renumbering IPv6 addresses, 396

requirements for PE-CE connectivity

- EIGRP, 152
- IS-IS, 137–138
- OSPF, 120–122
 - process-id, 123
 - sham-links, 120

resistance to label spoofing, 228–229

- static labels, 230

revealing core network addresses, 228

RFC 1483 bridged encapsulation, configuring MPLS VPN access via DSL, 80–81

RFC 1483 routed encapsulation, configuring MPLS VPN access via DSL, 79

RFC 3107 support, 289–290

- route filtering on CSC CE routers to PE router links, 291

RIPv2

- authentication on CE routers, 233
- controlling routes injected into VRF, 243–244
- key chains, 233

route export, troubleshooting, 447–448

route import, troubleshooting, 450–451

route leaking, 151

route redistribution, 6PE, 405–407

router reflectors, configuring in 6PE deployment, 415–418

router-id (OSPF), modifying, 124

routers, 6PE, 392

routing, IPv6, 397

routing loops, preventing

- between IS-IS sites, 151
- between OSPF sites, 129–130

RPF (Reverse Path Forwarding), 339

RPF check, 360–361

S

secret keys, 29

Securing a Cisco Router whitepaper, 224

security, 224

- address space separation, 224–226
- authentication, CE-to-CE, 238–240
- comparing Layer 2-based VPNs and MPLS VPNs, 223–224
- core network visibility, 226–227
- neighbor authentication, 230–231
 - between PE routers, 235–236
 - on PE/CE circuits, 232–235
 - on P-networks, 236–237
- resistance to label spoofing, 228–229
 - static labels, 230

separation of EIGRP VPN routing information, 153–155

service providers

- connectivity between, 296–297
 - back-to-back VRFs, 298–300
 - external Multiprotocol BGP, 306–314
 - Multihop MP-eBGP, 315–325
 - requirements, 297–298
 - route distribution across ASBR-ASBR links, 301–305
- remote access services, 25

sham links, 17, 120

- configuring, 133–136

shared Internet access with default routes, 260

shared trees 336–337

show ip route vrf command, 444–445

show mpls interface command, 431

show vpdn session command, 53

sites, 6

source IP address as VRF selection criteria, 195–198

source trees, 334–335

SSM, 342, 384–386

state flags, 364–365

static default routes on CSC CE routers, 287–288

static labels, 230

static NAT, 203

static routing between CSC PE/CE routers, 274–275

structure of IPv6 addresses, 394

- interface ID, 394

T

TDP/LDP Hello protocol, verifying, 433–434

TDP/LDP session state, verifying, 435

three-way handshakes, 29

- CHAP, 28

traceroute command, revealing hidden core network addresses, 228

translation tables, 202

transport address usage, 283–284

troubleshooting

- control plane, 425, 432
 - verifying label exchange, 436–437
 - verifying local TDP/LDP parameters, 433
 - verifying TDP/LDP Hello protocol, 433–434
 - verifying TDP/LDP session state, 435
- data plane plane, 426
 - monitoring interface-level CEF, 437–438
 - oversized packets, 438
- egress CE-PE routing exchange, 444–445
- MPLS backbone, 427
 - verifying end-to-end LSP, 427–429
- MPLS VPN route propagation, 448–449
- MPLS VPN route redistribution, 452–453
- provider control plane operation, 426
- route export, 447–448
- route import, 450–451

tunneling

- GRE, creating links between adjacent routers, 182–195
- L2TP, 33
 - dial-in VPDN access, 40–56
- MDTs, 352
 - Data-MDT, 355, 357, 359

- Default-MDTs, 352, 355
- mBGP updates, 361–364
- MTI, 359–360
- multicast tunnel interfaces, 372–374
- VPDNs, 31–33

U-V-W-X-Y-Z

- unicast forwarding, 338

- UPDATE authenticator attribute (BGP), 240

- VCs (virtual circuits), 6

- verifying

- CEF operation, 429

- switching, 442

- connectivity between CE routers, 440–441

- dial-in access on VPDNs, 51–55

- end-to-end LSP, 427, 429

- label exchange, 436–437

- local TDP/LDP parameters, 433

- LSR-wide MPLS operation, 430–431

- MPLS VPN route propagation, 448–449

- TDP/LDP Hello protocol, 433–434

- TDP/LDP session state, 435

- VPDNs (virtual private dialup networks), 30–33

- dial-in access, 40–41

- aggregating remote user host addresses,
55–56

- configuring access between RADIUS
servers, 48–51

- NAS/LAC configuration, 42

- RADIUS server attributes, 43–48

- verifying dial-in, 51–55

- VHG/PE router configuration, 44–46

- VRF (virtual routing and forwarding)

- address space separation, 225

- back-to-back, 298–300

- controlling injected routes, 241–242

- with eBGP as PE/CE routing protocol,
247–249

- with OSPF as PE/CE routing protocol,
250

- with RIPv2 as PE/CE routing protocol,
243–247

- enabling multicast, 371

- monitoring OSPF processes, 124–126

- multi-VRF functionality

- BGP configuration, 174–178

- configuring, 161–170

- OSPF configuration, 170–174

- PE-NAT, 199

- accessing common services, 205–208

- common server VRF configuration, 209

- configuring, 200–205

- customer VRF configuration, 210–213

- NAT pool configuration, 209

- shared firewalls, 213–217

- selection based on source IP address, 195–198

- virtual routers, linking to MPLS backbone,

- 182–195

- VRF-aware support for DHCP Relay, 110–114

- VSAAs (vendor-specific attributes), 35–36

- whitepapers, Securing a Cisco Router, 224