

Index

Numerics

- 6PE, 354**
 - BGP features, 379
 - configuring, 358–361
 - similarities to MPLS VPN for IPv4, 357
 - verifying operation, 361–364
- 6VPE, 364**
 - BGP features, 379
 - comparing with MPLS VPN for IPv4, 366
 - configuring, 366–371
 - features of, 364
 - IPv6 Internet access, 377
 - RR, implementing, 378
 - supported features, 378
 - verifying configuration, 372–377

A

- AAL (ATM Abstraction Layer), 107**
- abbreviating IPv6 addresses, 332**
- address families, configuring, 191–192**
 - vpn4, 196
- addresses (IPv6), abbreviating, 332**
- adjacency table, 151, 351**
- adjusting**
 - LDP session keepalive timer, 73
 - metrics with autoroute announce, 319–320
- administratively down links, preventing with LDP Session Protection, 100**
- advertising label bindings, 77–81**
 - in UD mode, 78
 - label withdrawal, 81–83
- Advisory Notifications (LDP), 83**
- AF (assured forwarding), 459**
- aggregate labels, 131**

- aggregate operation, 47**
- applying table maps, 488–489**
- APS (automatic protection switching), 291**
- architecture of VPLS, 437–438**
- areas (OSPF), 215**
- ASICs (application-specific integrated circuits), 7, 147**
 - PSAs, 155–156
- ASN (autonomous system number), 179**
- ATM (Asynchronous Transfer Mode), 7**
 - AAL, 107
 - cells, 106
 - GFC field, 107*
 - interleaving, 132*
 - control VC, verifying, 115
 - Frame mode, configuring, 143–144
 - label advertisement, 111–114
 - control modes, 122–123*
 - LDP bindings, viewing, 118–119
 - LSRs, 109
 - aggregation, 131*
 - transit LSRs, 120*
 - VC-merge, 132, 135*
 - non MPLS-aware switches, 135–138
 - OAM cells, 576
 - OSPF neighborships, verifying, 114
 - overlay model, 107, 174
 - peer networks, 108
 - transporting across MPLS networks, 408
 - VCs, 111
- ATM AAL5, transporting across MPLS networks, 408–411**
- ATM cell relay, transporting across MPLS networks, 411–415**
 - packed cell relay mode, 414–416
 - single cell relay mode, 411–414

AToM (Any Transport over MPLS), 7, 21, 383

- architecture, 387
- configuring, 398–399
- control word, 393
 - functions of*, 394–397
 - placement of*, 394
- data plane, 387–388
- fragmentation and reassembly as potential
 - IETF draft topic, 581
- need for, 384
- OAM message mapping, 575–576
- packets, forwarding, 387
- pseudowire
 - status, signaling to remote PE*, 392
 - signaling*, 388
- QoS, implementing, 429–432
- supported Layer 2 protocols
 - ATM*, 408
 - ATM AAL5*, 408–411
 - ATM cell relay*, 411–415
 - Ethernet*, 416–424
 - Frame Relay*, 403–408
 - HDLC*, 402–403
 - PPP*, 403
 - QinQ*, 424–426
- tunnel label, 386

AToM Tunnel Selection feature, 426–429**attribute flags, 267****attributes**

- of MPLS TE links, 266
 - attribute flags*, 267
 - maximum reservable bandwidth*, 267
 - SRLG*, 268
 - sub-pool bandwidth*, 268
 - TE metric*, 267
- of MPLS TE tunnels, 268

authentication, configuring MD5 for LDP**sessions, 86****autonomous system override, 230–232****autoroute announce, 305**

- metrics, adjusting, 319–320

B**baby giant frames, 60, 511****backdoor links, 225–226****backup tunnels, SRLG, 302****bandwidth, configuring on MPLS****TE links, 256****benefits of MPLS, 6–8****BGP (Border Gateway Protocol)****6PE/6VPE, available features, 379****address families**

- configuring*, 191–192
- vpn4, configuring*, 196

capabilities

- displaying*, 190
- label advertisement capability*, 194–195

cost community, 223**extended communities**

- for EIGRP*, 221–222
- for OSPF*, 214–215
- SOO*, 235–237

extended community attributes, RT, 192**MPLS labels, advertising, 197****multiprotocol extensions, 189–191****prefixes, 32****route selection, 200****RRs, 197–199****VPNv4 routes, 193–194****BGP Multipath, 200****configuring, 201****criteria, 200–201****using multiple RDs, 203–204****bindings, 68. See also label bindings****blocking label requests, 130–131****BoS (Bottom of Stack) bit, 26****bottom label, 26****bound addresses, 78****building blocks****of MPLS TE, 253–255**

- best path selection*, 254
- forwarding traffic to TE tunnel*, 255
- link constraints*, 253–254
- TE information distribution*, 254–256, 259–266

of MPLS VPNs

- packet forwarding*, 187–188
- RD*, 179–180
- RTs*, 180–184
- VPNv4 route propagation*, 185–186
- VRF*, 176–179

Bytes Tag Switched column (LFIB), 517

C

C bit, 409

calculating shortest path

algorithms, 254

PCALC, 279

capabilities (BGP), 189–191

displaying, 190

label advertisement capability, 194–195

capability vrf-lite command, 243

carrying IPv6 over MPLS backbone, 352–353

C-bit, 389

CBTS (class-based tunnel selection), 309–310

CDP (Cisco Discovery Protocol), tunneling in VPLS, 446–447

CE (customer edge) routers, 14

Internet access, allowing, 237–240

management access, 243–245

VPN functionality, enabling, 241–242

CEF (Cisco Express Forwarding), 147–149, 351–352

adjacency table, 151–152

CEF table, 152–153

default load balancing mode, restoring, 158

distributed CEF, 154–155

IP packets, labeling, 161–162

load balancing, 156–159

labeled packets, 163–164

unequal cost, 159–161

need for, 149

PSAs, 155–156

troubleshooting, 164–167

cell packing, 414–416

cells, 106

GFC field, 107

interleaving, 132

central VRF sites, providing Internet access on CE routers, 240

characteristics

of MPLS TE links, 266

attribute flags, 267

maximum reservable bandwidth, 267

SRLG, 268

sub-pool bandwidth, 268

TE metric, 267

of MPLS TE tunnels, 268

of VPLS, 437

circuit emulation as potential IETF draft topic, 581

Cisco IOS Software

DiffServ tunneling models, implementing, 482–487

IP SLA, 558–561

MPLS ping

reply modes, 542

sending, 541–545

MPLS QoS rules, 462–465

TOS reflection, 462

classful routing, 333

classless routing, 333

clear cef table command, 167

CLR (Conservative Label Retention) mode, 38

commands

capability vrf-lite, 243

clear cef table, 167

debug ipv6 rip, 336–337

debug mpls lspv tlv, 548–549

debug mpls packet, 54

debug mpls packets, 511–513

domain-id ospf, 214

exact path, 514–516

interface mtu, 60

ip cef distributed, 155

ip route-cache, 148

ip route-cache flow, 518

ip rsvp bandwidth, 256

ip vrf forwarding, 177

ipv6 cef, 352

ldp maxhops, 126

logging host, 575

mpls ip, 111

mpls ip encapsulate explicit-null, 481

mpls ip propagate-ttl, 379

mpls ip ttl-expiration pop, 504–505

mpls ldp discovery transport-address, 74

mpls ldp maxhops, 126

mpls ldp neighbor targeted, 84

mpls mtu, 60, 397

mpls ping, 541

mpls traffic-eng router-id, 259

MQC for QoS, 475, 478–480

neighbor allowas-in, 232–233

no mpls ip propagate, 505–510

show ip bgp neighbors, 190

show ip bgp vpnv4, 193

show ip cache verbose flow, 518–520

show ip cef, 514

commands

- show ip cef exact-route, 159
- show isis database verbose, 263–264
- show mpls atm-ldp bindings, 118–119
- show mpls forwarding-table, 46–47, 155
- show mpls interfaces, 113
- show mpls interfaces detail, 516
- show mpls ip binding, 80, 120–121
- show mpls l2transport, 399
- show mpls ldp bindings, 91
- show mpls ldp discovery, 70
- show rtr collection-statistics, 560–561
- show tag-switching hardware-tag, 156
- traceroute, 495–496
 - TTL values, manipulating, 128–129*
- xconnect, 418

comparing

- 6VPE and MPLS VPN for IPv4, 366
- BGP speakers and RRs, 198
- IPv6 and IPv4, 331–332
- label lookup and IP lookup, 44, 46–49

configuring

- 6PE, 358–361
 - verifying configuration, 361–364*
- 6VPE, 366–371
 - verifying configuration, 372–377*
- AToM, 398–399
- BGP
 - address families, 191–192*
 - vpn4 address family, 196*
- BGP Multipath, 201
- EIGRP, 222
 - for IPv6, 345–346*
- extranets, RTs, 183–184
- forwarding adjacency, 307–309
- Frame mode ATM, 143–144
- IP SLA source and destination, 559–561
- IS-IS for IPv6, 342–344
- IS-IS on PE routers, 228–230
- Layer 2 protocols for encapsulation on AToM
 - ATM, 408*
 - ATM AAL5, 408–409*
 - ATM cell relay, 411–415*
 - Ethernet, 416, 418–424*
 - Frame Relay, 403–408*
 - HDLC, 402–403*
 - PPP, 403*
 - QinQ, 424–426*
- LDP Autoconfiguration, 92–93

- LDP advertisement control, 87–88, 90
- link protection on backup tunnels, 296–297
- MD5 authentication for LDP sessions, 86
- MP-BGP for IPv6, 348–350
- MPLS LDP-IGP Synchronization, 95–99
- MPLS TE
 - dual-TE metrics, 275–278*
 - for IS-IS, 262*
 - for OSPF, 259*
- MPLS TE tunnels
 - event-driven reoptimization, 275*
 - holding priority, 273–274*
 - manual reoptimization, 275*
 - path setup option, 269–273*
 - periodic reoptimization, 274–275*
 - setup priority, 273–274*
- MPLS-aware Netflow, 564
- MQC on EXP bits, 429–432
- Multi-VC TBR, 141
 - mapping CoS classes to LVCs, 142*
- OSPFv3, 339–342
- PE-CE routing protocols
 - OSPF, 209–213*
 - PE-CE routing, 208*
 - RIPv2, 208–209*
- RDs, 180
- RIPng, 335–336
- RTs, 180
- VPLS, 441–443
 - trunk ports, 449*
 - verifying configuration, 443–446*
- VRF, 177–179
- VRF-aware syslog, 575
- connected routes, 207**
- connectivity**
 - of pseudowires, verifying with VCCV, 555–558
 - testing
 - with MPLS, 536–539*
 - with MPLS LSP ping, 529–536*
 - return codes, 533
 - TLVs, 534
- context-based SNMP for MPLS VPN, 571–572**
- control modes for label advertisement, 122–123**
- control plane, 7**
 - LSCs, 138
- control VC, verifying on interfaces, 115**

control word, 393

- as potential IETF draft topic, 580
- function of
 - facilitate fragmentation and reassembly, 396–397*
 - facilitate load balancing, 396*
 - padding small packets, 394*
 - preserving sequence of transported frames, 395*
- placement of, 394

controlling LDP label advertisement, 87–90**CoS classes, mapping to LVCs, 142****cost community (BGP), 223****cost metric, 249, 311–320****CSPF (constrained SPF) algorithm, 254****D****Data Link Layer Protocol field, 27****data plane**

- label stack depth, troubleshooting, 493–494
- of AToM, 387–388
- of VPLS, 439–440

debug ipv6 rip command, 336–337**debug mpls lspv tlv command, 548–549****debug mpls packet command, 54, 511–513****debugging**

- MPLS LDP-IGP Synchronization, 99
- MPLS packets, 511–513

deploying MPLS TE, requirements, 252**DF (Don't Fragment) bit, 63****DHCPv6, 334****differences between IPv4 and IPv6, 333–334****DiffServ (Differentiated Services), 457–458**

- EXP bits, 462
- forwarding classes, 459–461
- recoloring packets, 472, 475
- ToS field, 459
- tunneling models, 466
 - advantages of, 469–471*
 - implementing, 472*
 - implementing in Cisco IOS Software, 482–487*
 - Pipe model, 467*
 - Short Pipe model, 467*
 - Uniform model, 468*

disabling TTL propagation on**PE routers, 379****discovering LSRs running LDP, 69–73****displaying**

- ATM LDP bindings, 118–119
- BGP peer capabilities, 190
- IS-IS database details, 263–264
- opaque LSA details, 260–261

disposing LSRs, 29**distance vector routing protocols and MPLS TE, 255****distributed CEF, 154–155****DLCI-to-DLCI, carrying Frame Relay across MPLS networks, 403–404****DoD (Downstream-on-Demand) label distribution mode, 38****DoD label advertisement, 116****domain-id ospf command, 214****Dot1q tunneling, 424–426**

- on H-VPLS, 450–452

down bit, 219–220**Downstream Label Distribution mode, 584****Downstream Mapping object, 536–538****dual-TE metrics, configuring on MPLS TE, 275–278****E****E bit, 409****eBGP, 230**

- autonomous system override, 230–232

eBGP Multipath, 200**echo requests**

- MPLS LSP ping, 529–530
 - Downstream Mapping, 536–538*
 - Errored TLVs TLV, 539*
 - packet format, 531*
 - Reply Modes, 532–533*
 - return codes, 533*
 - Target FEC Stack TLV, 534–536*
 - TLVs, 534*
 - with Router Alert label, 551*
- MPLS LSP traceroute, 545
 - sending/receiving with Cisco IOS Software, 546–551*
- MPLS ping information, 539–540
 - IP address ranges, specifying, 552–554*
- MPLS traceroute, IP address ranges, specifying, 554

EF (expedited forwarding), 459**egress LSRs, 29**

- egress NetFlow, 563**
- eiBGP Multipath, 200**
- EIGRP, 220**
 - backdoor links, 225–226
 - BGP extended communities, 221–222
 - configuring, 222
 - configuring for IPv6, 345–346
 - pre-bestpath POI, 223–224
 - verifying IPv6 configuration, 347–348
- elements of PW ID FEC TLV**
 - C-bit, 389
 - Group ID, 391
 - Interface Parameters, 392
 - PW ID, 392
 - PW Type, 390–391
- enabling**
 - LDP, 69
 - LDP Session Protection, 100, 103
 - VPN functionality on CE routers, 241–242
- encapsulation**
 - Layer 2, 27–28
 - of labeled packets, 27
- EoMPLS (Ethernet over MPLS), 416–424, 435**
- Errored TLVs TLV, 539**
- establishing**
 - LDP sessions, 73–74, 76
 - multiple LDP sessions between LSRs, 76
- Ethernet, transporting across MPLS networks, 416–424**
 - QoS, 490
- Ethernet**
- event-driven reoptimization of MPLS TE tunnels, configuring, 275**
- exact path command, 514–516**
- example of tracerouting in MPLS networks, 502**
- EXP (experimental) bits, 25, 462**
 - MQC, configuring, 429–432
- expiration of labeled packet TTL, 57–59**
- explicit NULL label, 51, 53**
- explicit path option, configuring on MPLS TE tunnels, 269–271**
- extended communities (BGP)**
 - for EIGRP, 221–222
 - for OSPF, 214–215
 - RT, 192
 - SOO, 235–236
- extended IS Reachability TLV, 261**

- extension headers, 331**
- external metric, 213**
- extranet VPN, 180**
- extranet RTs, configuring, 183–184**

F

- facility backup, 292**
- fast switching, 148**
- FCS retention as potential IETF draft topic, 581**
- features**
 - of 6VPE, 364
 - of BGP available on 6PE/6VPE, 379
- features supported on 6VPE, 378**
- FEC (Forwarding Equivalence Class), 30, 32**
 - bindings, 68
- fields in IPv6 header, 331–332**
- filtering incoming LDP label bindings, 90–91**
- flapping links, enabling LDP Session Protection, 100–103**
- flooding TE information, 264, 266**
- Flow Label header field (IPv6), 332**
- flows, tracking, 563–564**
- forwarding adjacency, 306–309**
- forwarding classes, 459–461**
- forwarding labeled packets**
 - IP lookup, comparing to label lookup, 44–49
 - LFIB, 35–36
 - load balancing, 49–50
 - with unknown labels, 51
- forwarding traffic**
 - with autoroute announce, 305
 - with CBTS, 309–310
 - with forwarding adjacency, 306–308
 - with PBR, 304–305
 - with static routing, 304
- fragmentation, 63**
 - avoiding with Path MTU Discovery, 63
 - MPLS MTU, 510–511
 - preventing, 510–511
- Frame mode ATM, configuring, 143–144**
- Frame Relay**
 - overlay model, 174
 - transporting across MPLS networks, 403–408
 - using DLCI-to-DLCI method, 403–405*
 - using FRoMPLS, 405–408*

FRR (Fast ReRouting), 19

- link protection, 292–295
 - configuring on backup tunnels,* 296–297
- multiple backup tunnels, 303
- node protection, 297
 - configuring on backup tunnels,* 299–301

SRLG, 302

functions of control word, 394

- facilitate fragmentation and reassembly, 396–397
- facilitate load balancing, 396
- padding small packets, 394
- preserving sequence of transported frames, 395

future of MPLS, 579

- new applications, 579
- new IETF draft topics
 - AToM fragmentation and reassembly,* 581
 - circuit emulation,* 581
 - control word,* 580
 - FCS retention,* 581
 - GMPLS,* 582
 - MPLS labeled multicast,* 584
 - OAM protocols,* 582–584

G**GFC field (ATM cells), 107****giant frames, 61****global routing table**

- providing Internet access on CE routers, 238–240
- providing Internet access on VPNs, 239–240

global unicast addresses, 333**GMPLS as potential IETF draft topic, 582****goals of MPLS OAM**

- accounting, 526
- control/data plane defects, detecting and diagnosing, 523–524
- LSP defects, detecting, 524
- management/MIBs, 526
- OAM interworking, 526
- path characterization, 525
- SLA measurement, 525

GRE (generic routing encapsulation)

tunnels, 12

Group ID, 391

H**HDLC, transporting across MPLS networks, 402–403****head end switch, 120****Hello interval (LDP messages), changing, 71**

for targeted LDP sessions, 84

Hello messages

discovering LSRs running LDP, 69–73

LDP

Hello interval, changing, 71

Hold time, changing, 71

history of MPLS, tag switching, 19–20**Hold time (LDP messages), 70**

changing, 71

holding priority of MPLS TE tunnels,

configuring, 273–274

hop count, enabling loop detection, 125–127**hub-and-spoke scenario, 233–235****H-VPLS (Hierarchical VPLS), 450**

with MPLS in access layer, 452

with QinQ, 450–452

I**iBGP Multipath, 200****ICMP**

“time exceeded” messages, 57

tracerouting MPLS networks, 498

IETF drafts, potential topics for, 580

AToM fragmentation and reassembly, 581

circuit emulation, 581

control word, 580

FCS retention, 581

GMPLS, 582

MPLS labeled multicast, 584

OAM protocols, 582–584

IGP labels, 187**IGPs**

over TE tunnels, calculating cost, 311–314, 365–320

synchronizing with LDP, 93–99

IGPs

- TE information distribution
 - requirements*, 255–256
 - via flooding*, 264–266

implementing

- DiffServ tunneling models, 472
- MPLS QoS in Cisco IOS Software, 482–487
- QoS in AToM, 429–432
- RR on 6PE/6VPE, 378

implicit NULL label, 51–52**imposing LSRs, 29****inband VCCV, 555****incoming LDP label bindings, filtering, 90–91****Independent LSP Control mode, 39, 123****ingress LSRs, 29–30****interface mtu command, 60****interface parameters, 392**

- verifying, 516

interleaving cells, 132**intermediate LSRs, 29****Internet access**

- on CE routers, 237
 - via central VRF site*, 240
 - via global routing table*, 238–240
- on VPNs, 238
- using 6VPE, 377

intranet VPN, 180**IntServ (Integrated Services), 457****inuse, 80****IP**

- least-cost routing principle, 249
- packets
 - labeling by CEF*, 161–162
 - prioritizing*, 458
 - tracerouting, 495–497

IP addresses of LSRs, advertising, 130**ip cef distributed command, 155****IP fast switching route cache, 148****IP headers, Router Alert option, 526–528****IP lookup versus label lookup, 44, 46–49****ip route-cache command, 148****ip route-cache flow command, 518****ip rsvp bandwidth command, 256****IP SLA, 558–559**

- source/destination, configuring, 559–561
- VRF-Aware, 561–562

ip vrf forwarding command, 177**IP-to-label forwarding case, 45****IPv4, comparing with IPv6, 331–334****IPv6**

- 6PE, 354
 - configuring*, 358–361
 - similarities to MPLS VPN for IPV4*, 357
 - verifying configuration*, 361–364
- 6VPE
 - configuring*, 366, 368–371
 - supported features*, 378
 - verifying configuration*, 372–377
- addresses, abbreviating, 332
- addressing, 332
- carrying in VPNs across MPLS backbone, 364
- CEFv6, 351–352
- EIGRP
 - configuring*, 345–346
 - verifying configuration*, 347–348
- extension headers, 331
- header fields, 331–332
- IS-IS
 - configuring*, 342–344
 - verifying configuration*, 344–345
- MP-BGP, configuring, 348, 350
- need for, 329–330
- OSPFv3, configuring, 339–342
- over MPLS backbone, 352–353
- packets, load balancing, 379
- RIPng, configuring, 335–336
- unspecified addresses, 333
- versus IPv4, 333–334

IPv6 + label, 356**ipv6 cef command, 352****IS-IS, 226–227**

- configuring for IPv6, 342–344
- database details, displaying, 263–264
- MPLS TE, configuring, 262
- PE router configuration, 228, 230
- TE extensions, 261–263
- up/down bit, 227
- verifying IPv6 configuration, 344–345

L**L2TPv3, transporting Layer 2 frames across PSN, 384–385****L2VPN Inter-Autonomous Networking, 431****L2VPN Pseudowire Switching, 432****label advertisement, 111–114**

- control modes, 122–123
- DoD, 116

- label advertisement capability (BGP), 194–195**
- label bindings**
 - advertising, 77, 79–81
 - in UD mode, 78*
 - label withdrawal, 81, 83*
 - incoming LDP, filtering, 90–91
 - inuse, 80
- label distribution, 32**
 - piggybacking, 33
 - running separate protocol, 34–35
 - with LDP, 35–36
- label distribution modes (LSRs), 38**
- label encoding, 110**
- label lookup versus IP lookup, 44, 46–49**
- label mappings, 68**
- label requests, blocking, 130–131**
- label retention modes (LSRs), 38**
- label space**
 - per-interface, 36–37
 - per-platform, 37
- label stacking, 26**
- label switching, 25**
- Label Switching Router Self-Test, 583**
- Label Withdraw messages, 392**
- label-aware ICMP, 498**
- labeled packets**
 - fragmentation, 63
 - labeling by CEF, 161–162
 - load balancing, 163–164, 515–516
 - MTU parameters, 59–60
 - baby giant frames, 60*
 - giant frames, 61*
 - MRU, 62–63*
 - SNAP header, 28
 - TTL behavior
 - expiry, 57–59*
 - IP-to-label/label-to-IP, 55*
 - label-to-label, 56*
- labels, 25**
 - IGP labels, 187
 - OAM Alert Label, 529
 - Router Alert Label, 528–529
 - on echo requests/replies, 551*
- label-switched bytes, verifying, 517**
- label-to-IP forwarding case, 45**
- label-to-label forwarding case, 45–46**
- LANE (LAN Emulation), 8**
- Layer 2 encapsulation, 27–28**
- Layer 2 frames, transporting across PSN, 384**
 - using L2TPv3, 384–385
- Layer 2 protocols, transporting across MPLS networks**
 - ATM, 408
 - ATM AAL5, 408–411
 - ATM cell relay, 411–415
 - Ethernet, 416–424
 - Frame Relay, 403–408
 - HDLC, 402–403
 - PPP, 403
 - QinQ, 424–426
- Layer 2 switches**
 - ATM, non MPLS-aware, 135–138
 - giant frames, handling, 61
- layers of OSI reference model, 28**
- LC-ATM (Label Switching Controlled-ATM) interfaces, 37**
 - LDP
 - loop detection, 125–130*
 - per-interface label space, 124*
- LDP (Label Distribution Protocol), 32, 67**
 - authentication, 86
 - autoconfiguration, 92–93
 - bindings, displaying, 118–119
 - bound IP addresses, 78
 - discovering on LSRs, 69–73
 - enabling, 69
 - for LC-ATM
 - loop detection, 125*
 - per-interface label space, 124*
 - Hello messages
 - Hello interval, changing, 71*
 - Hold time, 70–71*
 - IGP synchronization, 93–95
 - configuring, 95–99*
 - inbound label binding filtering, 90–91
 - label advertisement, controlling, 87–90
 - label bindings, advertising, 77–81
 - in UD mode, 78*
 - label withdrawal, 81–83*
 - label distribution, 34–35
 - maintenance, 73–76
 - notification messages, 83
 - session establishment, 73–76
 - multiple sessions, 76*
 - keepalive timer; adjusting, 72–73*
 - targeted sessions, 84–86*
 - transport IP address, changing, 74–76*
- LDP ID, 71**
- ldp maxhops command, 126**
- LDP Session Protection, enabling, 100–103**
- least-cost routing principle, 249**

LFIB (label forwarding information base), 34–36, 68

- Bytes Tag Switched column, 517

LIB (label information base), label bindings, 79–80**like-to-like functionality, 431****limiting**

- MAC addresses in VPLS, 454

- prefixes in routing table, 116

link admission control, 290**link manager, 290–291****link protection, 292–295**

- configuring on backup tunnels, 296–297

link-local unicast addresses, 333**link-state protocols**

- IS-IS, configuring MPLS TE, 262

- OSPF, configuring MPLS TE, 259

- TE information distribution

- IGP requirements, 255–256*

- TE, IS-IS extensions, 261–263*

- TE, OSPF extensions, 256, 259–261*

- via IGP flooding, 264–266*

LLR (Liberal Label Retention) mode, 38**load balancing, 250, 320, 552**

- in CEF, 156–159

- IPv6 packets, 379

- labeled packets, 49–50, 163–164, 514–516

- MPLS ping, specifying IP address ranges, 552–554

- MPLS TE solution, 251

- MPLS traceroute, specifying IP address ranges, 554

- unequal cost, in CEF, 159–161

Local Switching, 432**logging, Syslog, 573, 575****logging host command, 575****lookup methods, comparing IP lookup and**

- label lookup, 44–49

loop detection

- via hop count, 125–127

- via LDP, 125

- via Path Vector TLV, 129–130

loopback addresses, 333**LSAs (link-state advertisements), opaque, 256**

- displaying details, 260–261

LSCs (label switch controllers), 138**LSP (label switched path), 29–30****LSP control modes (LSRs), 39****LSP ping, 536–539****LSPs, MPLS TE tunnel, 252****LSPV (LSP verification), 540–541****LSRs (label switching routers), 29, 109**

- aggregation, 47, 131

- IP addresses, advertising, 130

- label distribution modes, 38

- label requests, blocking, 131

- label retention modes, 38

- LDP

- notification messages, 83*

- sessions, establishing, 73–76*

- targeted sessions, 84–86*

- LDP ID, 71

- LIB, 79

- LSP, 29–30

- control modes, 39*

- pop operation, 47

- running LDP, discovering, 69–73

- swap operation, 47

- transit LSRs, 120

- VC-merge, 132, 135

LVCs (label switched controlled virtual circuits), 111

- mapping to CoS classes, 142

- reducing number of, 144

- VPI/VCI range, changing, 116

M**MAC addresses, limiting in VPLS, 454****maintaining LDP sessions, 73–74, 76****management access on CE routers, 243–245****manipulating TTL values, 127****manual reoptimization of MPLS TE tunnels,**

- configuring, 275

mapping CoS classes to LVCs, 142**MD5 authentication, configuring on LDP**

- sessions, 86

measuring performance with IP SLA,

- 558–561

messages

- RSVP, 289

- syslog, severity levels, 573

- metrics**
 - adjusting with autoroute announce, 319–320
 - OSPF, propagating, 213
 - TE, 256
 - dual-TE metrics, configuring on MPLS TE, 275–278*
- MIBs, 564–570**
 - MPLS VPN MIBs, 572
- modifying**
 - LVCs, VPI/VCI range, 116
 - MPLS MTU parameters, 60
- moving MPLS QoS from PE to CE router, 480, 482**
- MP-BGP (Multiprotocol BGP), 67**
 - configuring for IPv6, 348–350
- mpls ip command, 111**
- mpls ip encapsulate explicit-null command, 481**
- mpls ip progagate-ttl command, 379**
- mpls ip ttl-expiration pop command, 504–505**
- MPLS labeled multicast as potential IETF draft topic, 584**
- MPLS labels, 25**
 - Data Link Layer Protocol field, 27
 - label stack, encapsulation, 27
 - label stacking, 26
 - Layer 2 encapsulation, 27–28
- mpls ldp discovery transport-address command, 74**
- mpls ldp maxhops command, 126**
- mpls ldp neighbor targeted command, 84**
- MPLS LDP Session Protection, enabling, 100, 103**
- MPLS LDP-IGP synchronization, 93–95**
 - configuring, 95–99
- MPLS LSP ping, 529–530**
 - Downstream Mapping, 536–538
 - Errored TLVs TLV, 539
 - packet format, 531
 - Reply Modes, 532–533
 - return codes, 533
 - Target FEC Stack TLV, 534–536
 - TLVs, 534
- MPLS LSP traceroute, 545**
 - sending/receiving with Cisco IOS Software, 546–551
- mpls mtu command, 60, 397**
- MPLS OAM (Operation and Maintenance), 523**
- MPLS packets, debugging, 511–513**
- MPLS payload, 36**
- MPLS ping**
 - echo request information, 539–540
 - IP address ranges, specifying, 552–554
 - LSPV, 540–541
 - sending with Cisco IOS Software, 541–545
 - reply modes, 542*
- MPLS QoS**
 - for Ethernet over MPLS, 490
 - rules, 462–465
- MPLS TE**
 - building blocks, 253–255
 - best path selection, 254*
 - forwarding traffic to TE tunnel, 255*
 - link constraints, 253–254*
 - TE information distribution, 254–266*
 - deployment requirements, 252
 - dual-TE metrics, configuring, 275–278
 - FRR
 - configuring on backup tunnels, 299–301*
 - link protection, 292–297*
 - multiple backup tunnels, 303*
 - node protection, 297*
 - IGP over TE tunnels, route calculation, 311–320
 - IS-IS, configuring, 262
 - link attributes, 266
 - attribute flags, 267*
 - maximum reservable bandwidth, 267*
 - SRLG, 268*
 - sub-pool bandwidth, 268*
 - TE metric, 267*
 - link manager, 290–291
 - load balancing, 320
 - local protection schemes, 291
 - need for, 249–251
 - on MPLS VPN networks, 321–323
 - VRF-to-TE tunnel routing, 324–325*
 - OSPF, configuring, 259
 - PCALC, 279
 - RSVP, 281
 - messages, 289*
 - packet forwarding, 281–282*
 - RRO, 282–284*
 - SE style, 288*
 - Session object, 284*
 - tunnels, configuring, 286–288*
 - source-based routing, 251

MPLS TE

- tunnels, 252
 - attributes*, 268
 - autoroute announce*, 305
 - between PE routers*, 321
 - CBTS*, 309–310
 - event-driven reoptimization*,
 - configuring*, 275
 - forwarding adjacency*, 306–309
 - holding priority*, *configuring*, 273–274
 - manual reoptimization*,
 - configuring*, 275
 - path setup option*, *configuring*,
 - 269–273
 - PBR*, 304–305
 - periodic reoptimization*, *configuring*,
 - 274–275
 - setup priority*, *configuring*, 273–274
 - static routing*, 304

MPLS traceroute, specifying IP address

ranges, 554

mpls traffic-eng router-id command, 259**MPLS VPN model**, 174–175**MPLS VPNs**

- backbone, 215
- connected routes, 207
- hub-and-spoke design, 233–235
- MIBs, 572
- OSPF
 - down bit*, 219–220
 - sham links*, 216–218
- packet forwarding, 204–206
- PE router requirements
 - packet forwarding*, 187–188
 - RD*, 179–180
 - RTs*, 180–184
 - VPNv4 route propagation*, 185–186
 - VRF*, 176–179
- PE-CE routing protocols
 - eBGP*, 230–232
 - EIGRP*, 220–226
 - IS-IS*, 226–230
- using MPLS TE, 321–323
 - VRF-to-TE tunnel routing*, 324–325

MPLS-aware Netflow feature, 518–519

configuring, 564

MPOA (Multiprotocol over ATM), 8**MQC (Modular QoS Command Line Interface)**, 139, 462

MPLS QoS commands, 475–480

MRU (maximum receive unit), 62–63**MTU (maximum transmission unit)**, 59–60, 510–511

- baby giant frames, 60
- giant frames, 61
- MPLS MTU values in MPLS backbone, 397
- MRU, 62–63

multicast addresses, 333**multiprotocol extensions, BGP**, 189–191**Multiprotocol Reachable NLRI attribute (BGP)**, 190**Multiprotocol Unreachable NLRI attribute (BGP)**, 190**Multi-Topology IS-IS, TLVs**, 343**Multi-VC TBR (Multi-Virtual Circuit Tagged Bit Rate)**, 139

- configuring, 141
- mapping CoS classes to LVCs, 142

Multi-VRF CE feature, 241–242**N****need for AToM**, 384**need for IPv6**, 329–330**need for VPLS**, 435–436**neighbor allowas-in command**, 232–233**nested LSP**, 30**Netflow**

- accounting, 563–564
- MPLS-aware, 518–520

network management, SNMP, 564

- context-based, 571–572
- MIBs, 564, 566, 568–570
- MPLS VPN MIBs, 572

NHOP bypass tunnel, 292**NNHOP (next-next-hop) backup tunnels**, 297**NNI (Network-Node Interface)**, 106**no mpls ip propagate-ttl command**, 505–510**node protection**, 297

- configuring on backup tunnels, 299–301

non MPLS-aware ATM switches, 135–138**notification messages (LDP)**, 83

O

OAM (Operation and Maintenance), 54

as potential IETF draft topic, 582–584
goals of

- accounting*, 526
 - control/data plane defects, detecting and diagnosing*, 523–524
 - LSP defects, detecting*, 524
 - management/MIBs*, 526
 - OAM interworking*, 526
 - path characterization*, 525
 - SLA measurement*, 525
- message mapping, 575–576

OAM Alert label, 51, 529

OIDs (Object Identifiers), 566

on-demand forwarding table, 148

opaque LSAs, 256

details, displaying, 260–261
TE LSA, 258

Ordered Control mode, 122

Ordered LSP Control mode, 39, 116

OSI reference model, 28

OSPF

areas, 215
BGP extended communities, 214–215
configuring, 209–211
down bit, 219–220
LSAs, 256
metric propagation, 213
MPLS TE, configuring, 259
neighborships on ATM links, verifying, 114
opaque LSAs, displaying details, 260–261
sham links, 216–218
TE extensions, 256, 259–261
VRFs, configuring, 211–213

OSPFv3, configuring, 339–342

out-of-band VCCV, 555

overlapping IP addressing, 175

overlay model, 10, 12, 107, 174, 249

overlay networks, 6, 107

P

packed cell relay (ATM), transporting across

MPLS networks, 414–416

packet forwarding, 204–206

as MPLS VPN requirement, 187–188

packets

FEC, 30–32
recoloring, 472, 475

Path MTU Discovery, 334, 510

avoiding fragmentation, 63

path setup option of MPLS TE tunnels, configuring, 269–273

Path Vector TLV, enabling loop detection, 129–130

PathErr messages (RSVP), 289

PathTear messages (RSVP), 289

payload

load balancing labeled packets, 49–50
MTU
baby giant frames, 60
giant frames, 61
MRU, 62–63

PBR, 304–305

PCALC (path calculation) algorithm, 254, 269, 279

PE (provider edge) routers, 14

AToM, configuring, 398–399

deploying MPLS VPN, requirements

packet forwarding, 187–188

RD, 179–180

RTs, 180–184

VPNv4 route propagation, 185–186

VRF, 176–179

in VPLS

CDP tunneling, 446–447

configuring, 441–443

STP tunneling, 447–449

TTL propagation, disabling, 379

VRF, configuring, 177–179

PE-CE routing protocols

eBGP, 230

autonomous system override, 230–232

EIGRP, 220

backdoor links, 225–226

BGP extended communities, 221–222

configuring, 222

pre-bestpath POI, 223–224

IS-IS, 226–230

OSPF

BGP extended communities, 214–215

configuring, 209–213

down bit, 219–220

metric propagation, 213

network design, 215

sham link, 216–218

RIPv2, configuring, 208–209

static routing, 208

peer networks, 108

peer-to-peer model, 175

- peer-to-peer VPN model, 12, 16
- per-destination load balancing in CEF, 156
- performance, measuring with IP SLA, 558–561
- per-interface label space, 36–37, 76
- periodic flooding of TE information, 264
- periodic reoptimization of MPLS TE tunnels, configuring, 274–275
- per-packet load sharing in CEF, 157
- per-platform label space, 37
- PHP (penultimate hop popping), 52, 379
- piggybacking, 33
- ping, 511
 - MPLS LSP ping, 529–530
 - Downstream Mapping*, 536–538
 - Errored TLVs TLV*, 539
 - packet format*, 531
 - Reply Modes*, 532–533
 - return codes*, 533
 - Target FEC Stack TLV*, 534–536
 - TLVs*, 534
 - MPLS ping
 - echo request information*, 539–540
 - LSPV*, 540–541
 - sending with Cisco IOS Software*, 541–545
- ping mpls command, 541
- Pipe tunneling model, 467
 - versus Short Pipe model, 470
- placement of control word, 394
- PLR (point of local repair), 292
- PLS-aware Netflow, 520
- PNNI (Private Network-Network Interface), 107
- pop operation, 47
- port-to-port FRoMPLS, 405–406
- PPP, transporting across MPLS networks, 403
- pre-bestpath POI for EIGRP, 223–224
- precedence bits, 459
- prefixes, limiting number of in routing table, 116
- pre-MPLS protocols, 5
- preventing fragmentation, 510–511
- prioritizing IP packets, 458
- private addressing scheme in MPLS VPN model, 175
- process switching, 147–148
- proliferation of MPLS, 584

- propagating OSPF metrics, 213
- providing management access on CE routers, 243–245
- PSA (Packet Switching ASIC), 155–156
- Pseudowire Associated Channel Header, 580
- pseudowire emulation edge-to-edge reference model, 385–387
- pseudowires, 385, 435, 437
 - connectivity, verifying with VCCV, 555–558
 - PW ID FEC TLV, 389
 - signaling in AToM, 388
 - status, sending to remote PE, 392
- PSNs, transporting Layer 2 frames, 384
 - using L2TPv3, 384–385
- PW ID, 392
- PW ID FEC TLV, 389
 - elements of
 - C-bit*, 389
 - Group ID*, 391
 - Interface Parameters*, 392
 - PW ID*, 392
 - PW Type*, 390–391
- PW Status TLV, 392
- PW Type, 390–391

Q

- QinQ
 - on H-VPLS, 450–452
 - transporting across MPLS networks, 424–426
- QoS
 - DiffServ, 458
 - experimental bits*, 462
 - forwarding classes*, 459–461
 - packets, recoloring*, 472, 475
 - Pipe tunneling model*, 467
 - Short Pipe tunneling model*, 467
 - ToS field*, 459
 - tunneling models*, 466, 469–472, 482–487
 - Uniform tunneling model*, 468
 - for Ethernet over MPLS, 490
 - implementing in AToM, 429–432
 - in MPLS networks, MPLS QoS rules, 462–465
 - in VPLS, 452–453

QoS

- moving from PE to CE router, 480–482
- MQC commands, 475, 478–480
- table-map feature, 487–489
- TOS reflection, 462

R

- R3 (Routing with Resource Reservation), 253**
- RD (route distinguisher), 179**
 - as MPLS VPN requirement, 179–180
- recoloring packets, 472, 475**
- reducing number of LVCs, 144**
- reoptimization, 274–275**
- requirements for MPLS TE deployment, 252**
- reserved labels, 51**
 - explicit NULL label, 53
 - implicit NULL label, 51–52
 - OAM Alert label, 54
 - Router Alert label, 53
- restoring CEF default load balancing mode, 158**
- ResvErr messages (RSVP), 290**
- ResvTear messages (RSVP), 289**
- RFC 1483, “Multiprotocol Encapsulation over ATM Adaptation Layer 5”, 8**
- RFC 3036, “LDP Specification”, 67**
- RFC 4379, “Detecting Multi-Protocol Label Switched (MPLS) Data Plane Failures”, 534**
- RIPng**
 - configuring, 335–336
 - multicast addresses, 336
- RIPv2, configuring, 208–209**
- route peering in VPLS, 454**
- route selection process (BGP), 200**
 - BGP Multipath, 200–201
 - using multiple RDs, 203–204
- Router Address TLV, 258**
- Router Alert label, 53, 528–529**
 - on echo requests/replies, 551
- router alert label, 51**
- Router Alert option, 526–528**
- router discovery in IPv6, 333**
- routing tables, 197–198**
 - lookup process, 6
 - prefixes, limiting number of, 116

RR (route reflectors)

- implementing on 6PE/6VPE, 378
- RR groups, 198–199

RRO (Record Route object), 282–284**RRR (Routing with Resource Reservation), 21****RSVP (Resource Reservation Protocol), 33, 279, 457**

- for MPLS TE, 281
 - messages, 289
 - packet forwarding, 281–282
 - RRO, 282–284
 - SE style, 288
 - Session object, 284
 - tunnels, configuring, 286–288

RT extended community attribute (BGP), 192**RTs (route targets), 180**

- as MPLS VPN requirement, 180–184
- configuring, 180

S

- scalability of MPLS VPN model, 175**
- SE (Shared Explicit) RSVP style, 288**
- service providers, carrying IPv6 over MPLS backbone, 352–353**
- Session object (RSVP), 284**
 - setup priority of MPLS TE tunnels, configuring, 273–274
- severity levels of syslog messages, 573**
- sham links, 211, 216–218**
- shim header, 27**
- Short Pipe tunneling model, 467**
 - versus Pipe model, 470
- shortest path selection, PCALC, 279**
- show ip bgp neighbors command, 190**
- show ip bgp vpnv4 command, 193**
- show ip cache verbose flow command, 518–520**
- show ip cef command, 514**
- show ip cef exact-route command, 159**
- show isis database verbose command, 263–264**
- show mpls atm-ldp bindings command, 118–119**
- show mpls forwarding-table command, 46–47, 155**

- show mpls interfaces command, 113
- show mpls interfaces detail command, 516
- show mpls ip binding command, 80, 120–121
- show mpls l2transport command, 399
- show mpls ldp bindings command, 91
- show mpls ldp discovery command, 70
- show rtr collection-statistics command, 560–561
- show tag-switching hardware-tag command, 156
- signaling protocols, RSVP, 279
 - for MPLS TE, 281–289
- single cell relay (ATM), transporting across MPLS networks, 411, 413–414
- SNAP (Subnetwork Access Protocol) header, 28
- SNMP, 564
 - context-based, 571–572
 - MIBs, MPLS VPN MIBs, 572
- SOO extended community, 235–237
- source-based routing, 19
 - MPLS TE, 251
- SRLGs (shared risk link groups), 268, 302
- stateless autoconfiguration, 334
- static routing, 304
 - configuring, 208
- STP, tunneling in VPLS, 447–449
- supported features on 6VPE, 378
- swap operation, 47
- switching
 - ASICs, 147
 - ATM switches, non MPLS-aware, 135–138
 - CEF
 - distributed CEF*, 154–155
 - IP packets, labeling*, 161–162
 - labeled packets, load balancing*, 163–164
 - load balancing*, 156–159
 - PSAs*, 155–156
 - troubleshooting*, 164–167
 - unequal cost load balancing*, 159–161
 - CEF switching, 149
 - adjacency table*, 151–152
 - CEF table*, 152–153
 - need for*, 149
 - fast switching, 148
 - process switching, 147

- synchronizing
 - LDP and IGP, 93–98
 - Syslog, 573, 575
- syslog (VRF-aware), configuring, 575

T

- T bit, 409
- table-maps, 487–488
 - applying, 488–489
- tag switching, 19–20
- tail end switch, 120
- Target FEC Stack sub-TLVs, 534–536
- Target FEC Stack TLV, 536
- targeted LDP sessions, 84–86
- TBR (Tagged Bit Rate)
 - configuring, 141–142
 - mapping CoS classes to LVCs, 142
- TDP (Tag Distribution Protocol), 33
- TE (traffic engineering). *See* MPLS TE
- TE LSAs, 258
- TE tunnels between PE routers, 321
- testing network connectivity with MPLS LSP ping, 529–539
 - return codes, 533
 - TLVs, 534
- TFIB (Tag Forwarding Information Base), 19
- “time exceeded” ICMP messages, 57
- TLVs (Type Length Values), 258
 - extended IS Reachability, 261
 - for Multi-Topology IS-IS, 343
 - IP option, Router Alert option, 527–528
 - PW ID FEC TLV, 389
 - PW Status TLV, 392
- top label, 26
- ToS field, 459
- TOS reflection, 462
- traceroute command, 495–496
- tracertouting
 - in MPLS networks, 499, 502
 - example*, 502
 - label-aware ICMP*, 498
 - no mpls ip progagate-ttl command*, 505–510
 - with broken links*, 503
 - IP networks, 495–497
 - TTL values, manipulating, 128–129

tracking network flows, 563–564

transit LSRs, 120

transport IP addresses, changing for LDP session establishment, 74, 76

transporting Layer 2 frames across PSN, 384
 using L2TPv3, 384–385

troubleshooting
 CEF, 164–167
 MPLS label stack depth, 493–494
 with ping, 511

trunk ports, configuring on VPLS, 449

TTL (Time To Live) bits, 26

TTL, 498
 behavior of labeled packets
 expiry, 57–59
 IP-to-label/label-to-IP, 55
 label-to-label, 56
 manipulating, 127
 propagation, disabling on PE routers, 379

tunnel label, 386

tunneling. *See also* tunnels
 CDP in VPLS, 446–447
 QinQ on H-VPLS, 450–452

tunneling models for DiffServ, 466
 advantages of, 469–471
 implementing, 482–487
 in Cisco IOS Software, 472
 Pipe model, 467
 Short Pipe model, 467
 Uniform model, 468

tunneling models (DiffServ)

tunneling STP in VPLS, 447–449

tunnels
 AToM Tunnel Selection feature, 426–429
 MPLS TE, 252
 attributes, 268
 autoroute announce, 305
 CBTS, 309–310
 event-driven reoptimization, configuring, 275
 forwarding adjacency, 306–309
 holding priority, configuring, 273–274
 manual reoptimization, configuring, 275
 path setup option, configuring, 269–273
 PBR, 304–305

periodic reoptimization, configuring, 274–275
setup priority, configuring, 273–274
static routing, 304

TVCs (Tag Switching controlled virtual circuits), 111

U

U bit, 409

UD (Unsolicited Downstream) label distribution mode, 38
 label bindings, advertising, 78

unequal cost load balancing in CEF, 159–161

UNI (User-Network Interface), 106

unicast routing
 EIGRP
 configuring for IPv6, 345–346
 verifying IPv6 configuration, 347–348
 IS-IS
 configuring for IPv6, 342–344
 verifying IPv6 configuration, 344–345
 MP-BGP, configuring for IPv6, 348–350
 OSPFv3, configuring, 339–342
 RIPng, configuring, 335–336

Uniform tunneling model, 468

unknown labels, 51

Unreserved Bandwidth, 256

unreserved labels, 54

unspecified addresses, 333

up/down bit, 227

Upstream Label Distribution mode, 584

V

VC IDs, 440

VCCV, 555–558

VC-Merge, 132, 135

VCs, 111

verifying
 6PE configuration, 361–364
 6VPE configuration, 372–377
 control VC on interfaces, 115
 EIGRP for IPv6 configuration, 347–348
 interface parameters, 516
 IS-IS for IPv6 configuration, 344–345

verifying

- label-switched bytes, 517
- MPLS TE configuration for OSPF, 259–260
- OSPF neighborships on ATM links, 114
- VPLS operation, 443–446

verifying connectivity of pseudowires with VCCV, 555–558**VFI (virtual forwarding instance), 439****viewing**

- ATM LDP bindings, 118–119
- BGP peer capabilities, 190

VLAN ID Rewrite, 418**VPI/VCi range, modifying, 116****VPLS (Virtual Private LAN Service), 383, 435**

- architecture, 437–438
- configuring, 441–443
- data plane, 439–440
- MAC addresses, limiting, 454
- need for, 434–436
- PE routers, 440
 - CDP tunneling, 446–447*
 - STP tunneling, 447–449*
- pseudowires, 437
- QoS, 452–453
- route peering, 454
- signaling, 440
- trunk ports, configuring, 449
- VC IDs, 440
- verifying configuration, 443–446

VPLS (Virtual Private LAN Switching), 21**VPNs, 10, 173**

- 6VPE, IPv6 Internet access, 377
- carrying IPv6 across MPLS backbone, 364
- Internet access, 238
- MPLS VPNs, 174

*backbone, 215**building blocks, 176–188**connected routes, 207**hub-and-spoke design, 233–235**packet forwarding, 204–206**private addressing scheme, 175**scalability of, 175*

overlay model, 10–12

peer-to-peer model, 12–14, 175

vpn4 address family, configuring, 196**vpn4 prefix, 179, 188****VPNv4 routes, 193–194**

route propagation as MPLS VPN

requirement, 185–186

selection process (BGP), 200

VPWS (virtual private wire service), 383**VRF (virtual routing/forwarding), 14**

as MPLS VPN requirement, 176–179

configuring, 177–179

VRF-aware IP SLA, 561–562**VRF-aware syslog, configuring, 575****VRF-Lite, 241–242****VRFs, 14**

OSPF, configuring, 211–213

RTs, configuring, 182

VRF-to-TE tunnel routing, 324–325**W-X-Y-Z****wild card label withdrawal, 391****withdrawing labels for advertisement, 81–83****xconnect command, 418**