Index

Absolute mode, for RTP header, 241
Access, with Carrier Ethernet, 110
Access control rules, 19
Access EPL Service attributes, 153–156.
   See also Ethernet private line (EPL)
Access EVPL Service attributes, 153–156.
   See also Ethernet Virtual Private Line (EVPL)
Access links, for Carrier Ethernet, 123, 124, 125, 126
Access-located PRC, 58
Access networks, xii, xiii. See also
   Copper access network service availability and, 222
   synchronization and, 34
Access points (APs)
   Ethernet protocol stack and, 116
   in ETH layer network, 118
Accuracy. See also Frequency accuracy with precision time protocols, 45–46
   in synchronization, 35–36, 39, 42, 43
AC reference model, 75. See also
   Attachment circuits (ACs)
Active EVC Status, ELMI protocol and, 249, 251
Active hubs, 17
Active LACP packet exchange mode, 104
Active Provider Edge (PE), multisegment pseudowire setup and, 78
Adaptation function headers, for
   CESoETH, 238–241
Adaptation functions, Ethernet protocol stack and, 117
Adaptation sink function, Ethernet protocol stack and, 117
Adaptation source function, Ethernet protocol stack and, 117
Adapter cards, 28
Adapters, 19
Adaptive methods
   in network synchronous operation, 54, 55
   packet network impairments and, 55–56
   stabilization period and, 56–57
Adaptive timing, 242
   IWF synchronization function and, 57
Address Family Identifier (AFI), in VPLS
   BGP NLRI, 355
Addressing modes, in OAM addressing, 194
Address learning, in LDP-based VPLS, 340–341
Address Withdraw message, in LDP-based VPLS, 341
Administrative domains, 188
Aggregation, with Carrier Ethernet, 110
Aggregation control, in link aggregation, 105
Aggregator, in link aggregation, 105
AIS frames, 194, 210–213. See also
   Alarm Indication Signal (AIS)
   Alarm generation, 190
AIS PDU, 210, 212. See also Protocol data units (PDUs)
AIS/RDI, 5, 184, 185. See also Remote Defect Indication (RDI) maintenance points and, 191–192 MPLS-TP data plane and, 328–329 AIS transmission, 210–213 AIS transmission period, 210 Alarm Indication Signal (AIS), 5, 244. See also AIS entries MPLS-TP data plane and, 328–329 Alarm propagation, in link OAM, 185 Alarm reporting, MPLS-TP data plane loopback and, 329 Alarms with CESoETH, 244–245 time/phase requirements for, 39 Alarm suppression locked signals and, 215 maintenance points and, 192 Allocated tokens, in CoS flow policing, 160 Aloha network, 14 American National Standards Institute (ANSI), 14 synchronization interface standards by, 36 “App Layer,” xii Application-CoS-priority mapping, with Carrier Ethernet, 168–177 Application requirements, synchronization-related, 35–39, 61 Application Services Layer, in Ethernet protocol stack, 114 APP to ETH Adaptation Function (EAF), 122–123 APS channels field values, with T-MPLS, 299. See also Automatic protection switching (APS) APS communication, protection switching triggers and, 93 APS frames, 94, 195 APS payload structure, with T-MPLS, 299–300 APS PDU format, for linear protection, 93–97. See also Protocol data units (PDUs) APS protection modes, 89 APS protocol, with T-MPLS, 299–300 APS signaling channel, automatic protection switching and, 88 APS-specific information protection switching control and, 93–94 table of code points and field values for, 95 Architectural standards, Carrier Ethernet, 111–113 Architecture. See also CES architecture; IEEE 802.1AB architecture; Linear protection architecture; Multisegment architecture; OAM architecture; Ring protection architecture Carrier Ethernet, 1, 3–4, 110–125 hierarchical VPLS, 349–353 MPLS-TE and pseudowire data plane, 304 MPLS-TP, 307–320 pseudowire, 65–72 of T-MPLS, 291–293 Assigning Company ID, in EVC ID, 133 Associated Channel Header (ACH), MPLS frame format and, 307 Asynchronous operation mode, 58–59 Asynchronous services, 52 Asynchronous Status, ELMI protocol and, 251 Asynchronous Transfer Mode (ATM), 2, 20. See also ATM entries Carrier Ethernet vs., 110 ATIS standards, 132, 133 ATM networks, synchronization and, 34–35. See also Asynchronous Transfer Mode (ATM) ATM protocols, PW demultiplexer layer and, 71 Atomic clock sources, synchronization and, 33 Attachment circuits (ACs) in hierarchical VPLS, 352 in LDP-based VPLS, 340–341 MPLS-TP architecture and, 308 in multisegment architecture, 74 in pseudowire architecture, 64–68 in pseudowire operations and maintenance, 82 in pseudowire security, 83–84 in VPWS, 352 Attachment Group Identifier (AGI), in LDP-based signaling, 346–347
Autodiscovery
- in BGP-based VPLS, 353–354
- in Ethernet PW data forwarding, 347
- in LDP-based VPLS, 342, 345
- in multi-AS VPLS, 358

Autokey cryptography, with NTPv4, 41

Automatically switched optical networks (ASONs), T-MPLS and, 290, 293

Automatic link aggregation, 104

Automatic protection switching (APS), 3, 86, 195. See also APS entries

Automatic protection switching entities, 87–88

Autonegotiation mechanism, 16

Autonomous system border router (ASBR), in multi-AS VPLS, 358–359

Autonomous systems (ASs), 13
- in BGP-based VPLS autodiscovery, 354
- on LDP-based VPLS discovery, 345
- in multi-AS VPLS, 358

Availability, 221–224
- service level agreements and, 164, 169, 170
- Availability attribute, 132, 162
- Average bandwidth limits, 177
- Averaging algorithms, 51

Backbone Core Bridge (BCB), 8–9, 274

Backbone destination address (B-DA, Backbone-DA), 8, 270, 271–272
- in IEEE 802.1ah frame format, 273

Backbone Edge Bridges (BEBs), 9, 273–276
- in PBB-TE network, 284

Backbone Networks, xii, xiii, 8
- service availability and, 222

Backbone POP MAC address, in provider backbone bridge network, 277

Backbone source address (B-SA, Backbone-S), 8, 270–272
- in IEEE 802.1ah frame format, 273

Backbone VLAN-ID (B-VID), 8. See also Virtual Local Area Networks (VLANs)
- in IEEE 802.1ah frame format, 271–272

Backup LSP, with T-MPLS networks, 296.
- See also Label switched paths (LSPs)

Bandwidth, 263
- achievable on twisted-pair wiring, 20
- with Carrier Ethernet, 109–110
- switches and, 19
- synchronization standards and, 40

Bandwidth constraints, on classes of service, 163

Bandwidth intense applications, 23

Bandwidth profile (BWP), 149
- with Carrier Ethernet, 177–180
- classes of service and, 164
- ENNI, 134
- policing parameters of, 160–161
- with VUNI/RUNI, 136–137

Bandwidth profile algorithm, 178

Bandwidth profile subinformation element, 253–256

Base stations (BSs), 236–237

Basic Ethernet. See Ethernet (ETH), basic

BB networks, spanning trees for, 274–275

B-component, in provider backbone bridge network, 276

Best master clock algorithm, IEEE 1588 and, 50

BGP Route Target community, 353–354.
- See also Border Gateway Protocol (BGP)

BGP update advertisement, 353

BGP update messages, in BGP-based VPLS signaling, 355

BGP VPLS, hierarchical, 359–360. See also Virtual Private LAN Services (VPLSs)

BGP VPLS operation, 357–358

Bidirectional 1:1 protection, with T-MPLS, 298, 300–301

Bidirectional connectivity, verifying, 203

Bidirectional EAPS, 88

Bidirectional end-to-end LSPs, T-MPLS and, 290. See also Label switched paths (LSPs)

Bidirectional forward detection (BFD), MPLS-TP OAM and, 320–321

Bidirectional linear protection architecture, 90–93
Bidirectional LSPs. See also Label switched paths (LSPs)
MPLS-TP data plane and, 310–311
MPLS vs. T-MPLS, 290
Bidirectional performance, testing, 229
Bidirectional point-to-point connections, MPLS-TP architecture and, 314
Bidirectional protection switching, 88
Bidirectional protection types, 95–96
Bidirectional T-MPLS LSPs, MPLS-TP and, 305. See also Label switched paths (LSPs)
Billing, time/phase requirements for, 39
Bit slips, 33
Bit stream, using clock signal from, 51
Bit stream payload, with pseudowires, 64–65
B-MAC address, in provider backbone bridge network, 275, 277
Border Gateway Protocol (BGP), 12–13. See also BGP entries
VPLS with, 353–360
Boundary clocks (BCs), 37
IEEE 1588 and, 50
Bridged Protocol Data Units (BPDUs), 131
ETH Layer Characteristic Information and, 121
within VPLS, 340
Bridged signal, 96
Bridge port model, 194
Bridge Relay Entity, 189
Bridges, 17–18, 25
automatic protection switching and, 88
maintenance points in, 190
switches for, 18
within VPLS, 339
in VPWS, 352
“Broadcast of unknown,” Carrier Ethernet and, 110
Broadcast service frames
Ethernet Virtual Connection and, 129
ETH Layer Characteristic Information and, 121
Broadcast video, protection for, 86
B-TAG backbone tag, in IEEE 802.1ah frame format, 273
B type Backbone Edge Bridge (B-BEB), 9, 274–276
Buffering, 37
Buffers in flow control, 161
packet network impairments and, 55
Building integrated timing supplies/sync supply units (BITS/SSU), 39. See also Sync supply units (SSUs)
timing technology with, 40
Bundling, OVCs and, 135
Burst mode, with NTPv4, 41
B-VID addresses, provider backbone transport and, 280
B-VLAN components, in provider backbone bridge network, 276
B-VLANs, 9. See also Virtual Local Area Networks (VLANs)
Cable for Gigabit Ethernet, 22
with Ethernet physical layer, 19
Cable integrity testing, 187
CA ENNI, color indicated in, 172. See also External Network–Network Interfaces (ENNI)
CA mode, 175
Canonical Format Indicator (CFI), in ETH Layer Characteristic Information, 118, 120
Capital expenditures (CAPEX), 262
with T-MPLS, 301
Carrier Ethernet (CE), xi–xii, xiii–xiv, 109–157
applications of, 109–110
bandwidth profile with, 177–180
circuit emulation for, 6–7, 234–246
ETH Layer Characteristic Information for, 117–121
ETH Layer functions for, 122–123
ETH links for, 123–125
IEEE 802.1AB for, 263, 264–270
interfaces for, 111–112, 125–138
local management interface for, 7–8, 247–261
MPLS-TP and, 303–332
network architecture of, 1, 3–4, 110–125
OAM&P with, 109, 114, 181–233
operations, administrations, and maintenance for, 5–6
protocol stack for, 114–117
provider backbone bridges for, 262, 270–278
provider backbone transport for, 8–9, 262, 263, 278–286
provider bridge technology in, 262–287
services with, 109–157
standards for, 111–113
synchronization and, 34
T-MPLS and MPLS-TP for, 9–11
testing in, 225–232
this book and, xiii–xiv
traffic management for, 4–5, 158–180
transport MPLS with, 288–302
Virtual Private LAN Services and, 11–13, 333–361
Carrier Ethernet 2.0 (CE 2.0), xi, xii
Carrier-Ethernet-based VPN service, 140.
See also Virtual Private Networks (VPNs)
Carrier Ethernet Networks (CENs), xiii
Carrier Ethernet OAM, 182
Carrier Ethernet Professional Certification Program, xii
Carrier Ethernet Virtual Circuits/Connectors (EVCs), 2–4
ELMI and, 7–8
Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
protocol, 2, 14–16
for Gigabit Ethernet, 22
CAS “ABCD” values, 243
CAT 5 cable, 22
CBS tokens, 177–179
CCM databases, 201. See also Continuity Check Messages (CCMs)
CCM frames, 94, 194, 198–199
with PBB-TE network, 285
CCM PDU format, 199, 200, 201. See also Protocol data units (PDUs)
CCM PDUs, TLVs for, 198–200
CCM period
of AIS frames, 210
locked signals and, 214
CCM transmission period, 199
in loss measurement, 219
CC-V packets, MPLS-TP data plane loopback and, 329. See also Continuity Check and Continuity Verification (CC-V)
CDMA2000 synchronization requirements, 37, 39
CE devices. See also CE equipment;
Customer Edges (CEs)
configuring and automatic provisioning of, 183
local management interface with, 247–248
Virtual Private Networks and, 335–336 in VPWS, 352
CE end-to-end signaling, in PWE3 maintenance reference model, 71–72
CE equipment, in MPLS-TP architecture, 312
Cell payload, with pseudowires, 64–65
Cell towers, in synchronization, 35–36
Cellular base station controller, synchronization and, 34
CE nodes, in MPLS-TP architecture, 312–314
Central offices (COs)
in harsh environmental conditions, 26
with NTP/SNTP, 42
CE–PE link, 13. See also Provider Edges (PEs)
CE router, 13
CES application, IEEE 1588 clocking in, 46–47. See also Circuit emulation service (CES)
CES architecture, 235
CES functional blocks, 237–238
CE signaling, 243
CES IWFs, 237–238. See also Interworking functions (IWFs)
CESoETH control word, 239–241. See also Circuit Emulation Services over Ethernet (CESoETH)
CESoETH data frames, 243
CESoETH service configuration, 245–246
CE-VLAN CoS preservations, 156. See also Virtual Local Area Networks (VLANs)
CE-VLAN ID/EVC Map IE ELMI message element, 252–253
CE-VLAN ID preservation, 156
CE-VLAN IDs
  Ethernet Virtual Connection and, 130–131
  with VUNI/RUNI, 137
CE-VLAN Tag (C-Tag), 1
  as CoS Identifier, 131
  in EP-LAN service, 140
  ETH Layer Characteristic Information and, 120
  UNI/EVC and, 130–131
CFM addresses, for provider backbone bridges, 270. See also Connectivity Fault Management (CFM)
CFM loopback, 206
CFM PDUs. See also Protocol data units (PDUs)
  MAID carried on, 192
  TLVs for, 196–198
Channel-associated signaling (CAS), 242–243
Channel Service Unit/Data Service Unit (CSU/DSU), User–Network Interface and, 127
Chassis ID TLV, in IEEE 802.1AB frame format, 268. See also TLVs (Type, Length, Value)
CheaperNet, 21
Chen, Nan, xii
Circuit emulation, 6–7
  Circuit emulation functions, 237–238
  Circuit Emulation over PSN (CESoPSN), 7. See also Packet switched networks (PSNs)
  Circuit emulation over PSN standard, 40
  Circuit emulation service (CES), 1, 6–7, 49, 53, 234–246. See also CES entries
  adaptation function headers for, 238–241
  applications of, 234–237, 246
  CESoETH defects and alarms and, 244–245
  CESoETH performance monitoring and, 245
  CESoETH service configuration and, 245–246
  circuit emulation functions with, 237–238
  payload convergence layer and, 70
  synchronization and, 35, 38, 241–242
  TDM application signaling and, 242–243
  timing technologies for, 40
  Circuit Emulation Services over Ethernet (CESoETH), 7, 234–246. See also CES0ETH entries
  Circuit switching, provider backbone transport and, 278
Class H CoS label, 4. See also Class of Service (CoS)
  bandwidth constraints and PCP and DSCP mapping under, 163
  PCP mapping and, 177
  performance parameters for, 162
  service level agreements for, 169–170
Classification, 158–159
  of VPLS packets, 338–339
Class L CoS label, 4
  bandwidth constraints and PCP and DSCP mapping under, 163
  bandwidth profile for, 164
  PCP mapping and, 177
  performance parameters for, 162
  service level agreements for, 169, 170
Class M CoS label, 4
  bandwidth constraints and PCP and DSCP mapping under, 163
  PCP mapping and, 177
  performance parameters for, 162
  service level agreements for, 169, 170
Class of Service (CoS). See also CoS entries;
  Three CoS model
  alarm indication signals and, 210
defined, 161
  frame delay measurement and, 225
  PCP and DSCP mapping and, 175
  in performance measurement, 215
  performance monitoring and, 217
  quality of service/congestion control and, 80
  service availability and, 222–223
  within VPLS, 339
Class of Service Identifier, 131–132, 135, 136
  with VUNI/RUNI, 137
Clear command, with T-MPLS, 300
Client-agnostic service, MPLS-TP as, 331
Client failure indication (CFI), MPLS-TP OAM and, 329–330
Client flow, in MPLS-TP architecture, 312
Client layer
  alarm indication signals and, 210
  in MPLS and T-MPLS networks, 292, 296
  MPLS-TP architecture and, 308–309
Client network protocol stack, MPLS-TP architecture and, 316
Client of the section layer, MPLS-TP data plane and, 310
Client packets, MPLS-TP architecture and, 314–316
Clock discipline algorithm, with NTPv4, 41
Clocking distribution, methods for, 51
Clocking methods, for synchronization, 54–55
Clock phase, in clocking information, 36–37
Clock QL, 36. See also Quality level (QL)
Clock recovery
  packet network impairments and, 55–56
  payload convergence layer and, 70
Clocks
  application requirements related to synchronizing, 35–39, 61
  basic principles of synchronizing, 33–35
  in CES synchronization, 241–242
  IWF synchronization function and, 57
  MPLS-TP and, 306
  network time protocols for, 40–43
  for NTP, 41
  precision time protocols for, 44–51
  stabilization period for, 56–57
  in Synchronous Ethernet networks, 51–61
Clock synchronization, 33
  frame delay measurement and, 225
  standards for, 36, 39–40, 61
CM parameter, 175. See also Color Mode (CM)
Coarse wave division multiplexing (CWDM), 25
Code points, for APS-specific information, 95
Collision, 15. See also Collisions
Collision detection, 15–16
  Ethernet II frames and, 29
  IEEE 802.3 frames and, 30
Collisions
  bridges and, 17–18
  switches and, 18
Color, PCP values for, 177
Color Forwarding, 156
Color identifiers, service level agreements and, 170–175
Color Mode (CM), in CoS flow policing, 160. See also CM parameter
Committed Burst Rate/Excess Burst Rate (CBR/EBR), User–Network Interface and, 128
Committed Burst Size (CBS)
  bandwidth profile and, 177–180
  in CoS flow policing, 160–161
Committed Information Rate (CIR)
  bandwidth profile and, 177–180
  in CoS flow policing, 160–161
Committed Information Rate/Excess Information Rate (CIR/EIR), User–Network Interface and, 128
Common channel signaling (CCS), 7, 242, 243
Common Object Request Broker Architecture (CORBA), in MPLS-TP network management, 320
Common spanning tree (CST), 270
Communication networks, traffic protection in, 86–87
Complete service testing, 231–232
Configurable availability threshold (Ca), 222
Configurable unavailability threshold (Cu), 222
Configuration attributes, in testing, 227
Congestion
  in performance measurement, 216
  PW demultiplexer layer and, 71
Congestion control, for pseudowires, 80–81
Conjoined Ethernet rings, 99
Connectionless trail, Ethernet protocol stack and, 115–117
Connectivity
  in hierarchical VPLS, 349–350
  in LDP-based VPLS, 340
Connectivity (cont’d)
MPLS vs. T-MPLS, 291
Connectivity check packets, with
T-MPLS, 298
Connectivity Fault Management (CFM), 6,
186–188
in automatic protection switching, 88
for provider backbone bridges, 270
Connectivity functions, Ethernet OAM,
182
Connectivity tests, loopback messages/replies and, 205
Connectivity verification (CV), MPLS-TP
OAM and, 330
Consecutive high loss interval, 162
Constant bit rate (CBR) services, 52–53
circuit emulation service as, 235–236
packet network impairments and, 55–56
Content-aware service, 40
Continental performance tier (PT3), 5. See
also Performance tiers (PTs)
service level agreements and, 168, 170
Continuity checks (CCs)
Ethernet, 183
MPLS-TP OAM and, 321, 326–327
Continuity Check and Continuity
Verification (CC-V), MPLS-TP OAM
and, 326–327
Continuity check/continuity verification
(CC/CV) messages, MPLS-TP OAM
and, 321, 326–327
Continuity Check Messages (CCMs), 6,
198–202. See also CCM entries
alarm indication signals and, 213
format octets for, 200
in loss measurement, 218–219
maintenance points and, 191
in 1:1 protection, 92
protection switching triggers and, 93
remote defect indication and, 213–214
in ring failure operation, 101
TLVs applicable for, 197
Control (C) bit, in LDP-based signaling,
347
Control Flags, in VPLS BGP NLRI, 356
Control frames, in provider backbone
bridge network, 278
Control parser/multiplexer, in link
aggregation, 105–106
Control plane(s)
in Ethernet protocol stack, 114
in MPLS-TP architecture, 317–320
MPLS-TP OAM and, 320
in multisegment architecture, 75–76
multisegment pseudowire setup and,
78–79
in PBB-TE network, 284
in provider backbone transport, 278
in T-MPLS networks, 291, 293
in User–Network Interface, 127
Control plane functions, in BGP-based
VPLS, 353
Control plane management, provider
backbone transport and, 280
Control-plane messages, 72
Control-plane security, 83–84
MPLS-TP support for, 331
Control-plane services, 72–74, 84
Control-plane switching, in pseudowire
operations and maintenance, 82
Control VLAN, in ring protection
architecture, 98. See also Virtual
Local Area Networks (VLANs)
Control words
in LDP-based VPLS discovery, 344
in PWE3 over an MPLS PSN protocol,
73–74
Copper, fiber vs., 26
Copper access network, 20
Copper ports, in link aggregation, 107
Core-located PRC, 57
Core MPLS networks, Virtual Private
Networks and, 335–336. See also
Multiprotocol label switching (MPLS)
Core networks, 262
Corporate networks, Carrier Ethernet in,
109–110
CoS flows, 4. See also Class of Service
(CoS)
in packet conditioning, 159–160
policing of, 160
queuing, scheduling, and flow control
in, 161
CoS identification, service level
agreements and, 170–175
CoS labels, CoS identification and,
170–175
CoS/Priority information, ETH Layer Characteristic Information and, 120
Coupling Flag (CF), 178
in CoS flow policing, 160
C-Tag PCP mapping, classes of service and, 163
Customer backbone ports (CBPs) with PBB-TE network, 284
in provider backbone bridge network, 276
Customer-DA, in IEEE 802.1ah frame format, 272. See also Destination addresses (DAs)
Customer Edges (CEs)
ELMI parameters and procedures and, 257–258
in Ethernet PW data forwarding, 347–348
ETH Layer functions and, 122
in hierarchical VPLS, 349–351
in MPLS-TP architecture, 311
in pseudowire architecture, 65–66
in PWE3 maintenance reference model, 71–72
PWE3 preprocessing and, 66
service providers and, 138
Virtual Private Networks and, 335–336
within VPLS, 339
in VPWS, 352
Customer-edge signaling, 7, 13
Customer equipment (CE), pseudowires and, 63
Customer frames, in VPLS encapsulation, 338
Customer premises, NTP/SNTP and, 42
Customer Premises Equipment (CPE) in network synchronous operation method, 54, 55
testing, 231–232
User–Network Interface and, 127
Customer-SA, in IEEE 802.1ah frame format, 272
Customer security, in provider backbone bridge network, 278
Customer VLAN-ID, in IEEE 802.1ah frame format, 272
Cut through switches, 18
Cyclic Redundancy Check (CRC), in ETH Layer Characteristic Information, 118
Data/control plane separation, with T-MPLS, 289–290
Data encapsulation, 25, 158, 158
Data field, in ETH Layer Characteristic Information, 117
Data format, for PTP over Ethernet, 45
Data forwarding, on Ethernet PWs, 347–348
Data frames, 243
Data Instance (DI), See DI IE ELMI message element
Data link layer, 25
bridges and, 17–18
LLDP over, 266
supporting pseudowires, 64, 69, 73–74
Data packets, as frames, 20
Data parsing, 158
Data pattern, in testing, 227
Data plane, 158
in Ethernet protocol stack, 114–115
in hierarchical BGP, 359–360
in MPLS-TP architecture, 310–311
in User–Network Interface, 127
Data plane loopback, MPLS-TP OAM and, 328–329
Data plane security, MPLS-TP support for, 331
Data services, MPLS developed for, 288
Data streams, with CESoETH, 234
Dedicated leased lines, Carrier Ethernet vs., 110
Defects, with CESoETH, 244–245
Delay, service level agreements and, 164
Delay measurement (DM), 6, 224
performance monitoring and, 217–218
Delay Measurement Message (DMM), 195
performance monitoring and, 217–218
in testing, 232
Delay Measurement Reply (DMR), 195
performance monitoring and, 217–218
in testing, 232
Delay_Req messages, in IEEE 1588 clocking, 46–47
Delay values, classes of service and, 164
Delay variation
IEEE 1588v2 and, 49
packet network impairments and, 55–56
Demarcation devices, 184–185
Demultiplexer (Demux), in BGP-based VPLS signaling, 355
Denial of service (DoS), 331
Denial-of-service attacks, 84
Dense Wavelength Division Multiplexing (DWDM), xiii
Destination address, ELMI protocol and, 248
Destination addresses (DAs). See also Backbone destination address (B-DA)
in Ethernet frames, 28
in IEEE 802.1AB frame format, 267
in loss measurement, 221
in OAM frames, 193
Destination MAC Address (DA), in ETH Layer Characteristic Information, 117, 119
Destination service access point (DSAP), 25
Destination/source MAC address (DA/SA), 195
Device under test (DUT), 228–229, 231
Diagnostics, in testing, 226
Diagnostic tests, loopback messages/replies and, 203–204
Differential global positioning system (DGPS), synchronization and, 33
Differential methods
IWF synchronization function and, 57
in network synchronous operation, 54
packet network impairments and, 55–56
Differential mode, for RTP header, 241
Differential timing, 242
synchronization and, 35, 54
Differentiated Services Code Point (DSCP). See also DSCP mapping color identification via, 172
as CoS Identifier, 131, 132, 171
Differentiated Services (Diff-Serv)
MPLS-TP data plane and, 311
T-MPLS and, 290
Digital Phase-Locked Loop (DPLL), with Synchronous Ethernet, 52
DI IE ELMI message element, 253, 255
Discard eligibility (DE), 172
Discovery
Ethernet, 183
in LDP-based VPLS, 342–345
in link OAM, 184–185
maintenance points and, 191
Distributed bonding, 21
Distributed dynamic control plane, 319
Distributed PRC strategy, for synchronization, 34
DIX Ethernet standard, 14
DIX (DEC, Intel, Xerox) frames, 27
format of, 29–30
SNAP and, 31
DMM frames, 195. See also Delay Measurement Message (DMM)
frame delay measurement and, 224–225
DMM PDU, in interframe delay variation measurement, 225–226. See also Protocol data units (PDUs)
DM OAM frames, frame delay measurement and, 224
DMR frames, 195. See also Delay Measurement Reply (DMR)
frame delay measurement and, 224–225
DMR PDU. See also Protocol data units (PDUs)
frame delay measurement and, 225
in interframe delay variation measurement, 225–226
DMR processing time
frame delay measurement and, 225
DNR state, revertive and nonrevertive modes and, 94, 96. See also “Do not revert” (DNR) request
Domain boundaries, in pseudowire security, 83
Domain hierarchy, in security, 232
Domain levels, maintenance and monitoring among, 188
Do Not Revert function, with T-MPLS, 301
“Do not revert” (DNR) request, 89. See also DNR state
Down MEP, 189. See also Maintenance end points (MEPs)
Drift, IEEE 1588 and, 50
Drop eligibility
as CCM attribute, 199
loopback messages/replies and, 204
in loss measurement, 220
in testing, 227
Drop eligible indicator (DEI), 164
color identification via, 172
Drop Eligible Indicator (I-DEI) field, in IEEE 802.1ah frame format, 273
DS1 robbed bit signaling, 242–243
DS1 services, CES as, 236
DSCP mapping, 175–177. See also Differentiated Services Code Point (DSCP)
classes of service and, 163–164
Dst field, 29
Dual-ended FLR measurement, 218, 220
dual-ended loss measurement, CCM frames and, 199
Dual homing, protection via, 352–353
Dying Gasp message, 184, 186, 232
Dynamic control-plane switching,
multisegment pseudowire setup and, 78–79
E1 circuits, synchronization and, 33–34. See also T1/E1 leased line
EAPS Function, protection switching control and, 93. See also Ethernet automatic protection switching (EAPS)
EBGP redistribution, in multi-AS VPLS, 359
EBS tokens, 177–179
ECMP load balancing, MPLS-TP data plane and, 311. See also Equal cost multiple path (ECMP)
ECMP option, 10
MPLS vs. T-MPLS, 291
Edge-to-edge services, 285–286
EEC-Option 1 function, 59–61
EEC-Option 2 function, 59–61
Egress bandwidth profiles (BWPs), 149, 156, 175
Egress Bandwidth Profile per ENNI CoS Identifier, 136
Egress Bandwidth Profile per EP, 136
Egress service frames, service availability and, 223
Egress UNI, in performance measurement, 216. See also User–Network Interface (UNI)
802.1QTag, in ETH Layer Characteristic Information, 117–119. See also IEEE 802 entries
E-LAN applications, 139. See also Ethernet local area network (E-LAN) services
Element Management System (EMS), 183 in MPLS-TP network management, 319–320
ELMI Check, 261. See also Ethernet local management interface (ELMI)
ELMI Ethertype, 248
ELMI framing structure, 248
ELMI message elements, 252–257, 258
ELMI (E-LMI) protocol, 183, 247–250
ELMI termination, 248
E-LSP (EXP Inferred LSP). See also Label switched paths (LSPs)
MPLS-TP and, 305
MPLS-TP data plane and, 311
Embedded Ethernet equipment clock (EEC), 59–61
Emulated Circuit De/Multiplexing Function (ECDX), 237, 238
Emulated Circuit Identifier (ECID), 238–239
in CESoETH configuration, 246
Emulation, of a native time service, 40. See also Pseudowire edge-to-edge emulation (PWE3)
Emulation modes, for CES, 235–236
Encaps type, in VPLS BGP NLRI, 356, 357
Encapsulated Customer Destination Address (C-DA) field, in IEEE 802.1ah frame format, 273–274
Encapsulated Customer Source Address (C-SA) field, in IEEE 802.1ah frame format, 274
Encapsulation, 20
data, 25
of LLDP messages, 266
MPLS-TP architecture and, 308–309
MPLS-TP G-ACh and, 317
MPLS-TP OAM and, 323
in provider backbone bridge network, 275, 276
with provider backbone bridges, 270 in pseudowires, 63
via payload convergence layer, 68–70
Virtual Private Networks and, 334
VPLS, 338
Encapsulation labels, MPLS-TP architecture and, 316
Encapsulation layer, supporting pseudowires, 63, 64
End-of-LLDPDU, in IEEE 802.1AB frame format, 268. See also Link layer discovery protocol data unit (LLDPDU)
End Point (EP) map, 135
End TLV, 197, 200. See also TLVs (Type, Length, Value)
End-to-end Carrier Ethernet, provider backbone transport in, 282–283
End-to-end Ethernet networks, 262
End-to-end Ethernet service, 181
End-to-end LSPs, MPLS-TP OAM and, 325–326. See also Label switched paths (LSPs)
End-to-end OAM, provider backbone transport and, 280. See also Operations, Administrations, and Maintenance (OAM) capabilities
ENNI attributes, of access EPL and EVPL services, 153–155. See also External Network–Network Interfaces (ENNIs)
ENNI service attributes, 152–153
Enterprise networks, Ethernet in, 109
Environmental conditions, harsh, 26–27
EPL across multiple networks, 152. See also Ethernet private line (EPL)
EP-LAN across multiple networks, 153
EP-LAN service, 140, 142
EP-LAN service attributes, 145–149
EPL attributes, of E-Line services, 145–146
EP-Tree EVC Service attributes, 151–152
EP-Tree service, 147
EP-Tree service attributes, 150–151
Equal cost multiple path (ECMP). See also ECMP entries with MPLS-TP, 304
with T-MPLS, 289–290
Equipment testing, 226
ERP control function, in ring failure operation, 101
Error detection mechanism, with PW demultiplexer layer, 71
ESMC information PDUs, 58. See also Protocol data units (PDUs)
ETH-AIS function, 190. See also Alarm Indication Signal (AIS)
ETH conditioning functions, 122
ETH Connection Function (ECF), 122, 123
Ethernet (ETH), xi, xii, xiii. See also Carrier Ethernet entries; ETH entries basic, 2, 14–32 bridges with, 17–18 CSMA/CD for, 15–16, 22 demand for, 32 described, 14 as dominant network technology, 1 embedded equipment clock in, 59–61 invention of, 14 physical layer of, 19–26 precision time protocols for, 44, 45 pseudowires in, 63 repeaters and hubs in, 16–17 as a service, 181 switches in, 18–19 synchronization and, 34 synchronization in, 36–37 temperature hardening of, 26–27
Ethernet II, SNAP and, 31
Ethernet II frames, 27 format of, 29–30
Ethernet Access services, 4
Ethernet adapter cards, 28
Ethernet addresses, 28–29
Ethernet AIS/RDI, 184–185. See also Alarm Indication Signal (AIS); Remote Defect Indication (RDI)
Ethernet alarm indication signal (ETH-AIS), 210–213
Ethernet automatic protection switching (EAPS), 87–88. See also EAPS Function
Ethernet-based access networks, hierarchical VPLS model using, 353
Ethernet-based transport networks, traffic protection in, 87
Ethernet CES, 234–246. See also Circuit emulation service (CES)
Ethernet Cloud Carrier access, 188
Ethernet continuity check (ETH-CC), 198, 212–213
Index

Ethernet Demarcation, User–Network Interface and, 127

Ethernet frames, 19–22, 27, 117–121
- in 1+1 protection, 89
- types and formats of, 27–32
- Virtual Private Networks and, 337

Ethernet Length/Type (EtherType), in ETH Layer Characteristic Information, 117, 119, 121. See also EtherType entries

Ethernet Length/Type/Subtype field, 184

Ethernet line (E-line, E-Line, E-LINE) services, 3, 8, 139, 140, 245, 262, 285–286
- attributes of, 143–145
- provider backbone transport and, 280
- T-MPLS and, 290

Ethernet line timing, 242

Ethernet links, maintenance points and, 190

Ethernet link trace (ETH-LT) function, 6, 206–209

Ethernet local area network (E-LAN) services, 3, 8, 139, 140, 262, 285–286
- T-MPLS and, 290

Ethernet local management interface (ELMI), 1, 7–8, 247–261
- applications of, 261
- message elements with, 252–257, 258
- messages with, 250–251
- OAM capabilities via, 5, 6
- protocol for, 247–250
- system parameters and procedures, 257–260
- UNI-C and UNI-N procedures with, 260–261

Ethernet locked signal (ETH-LCK), 214–215

Ethernet loopback (ETH-LB) function, 6, 202–205

Ethernet Loss Measurement (ETH-LM), 218–221

Ethernet MAC layer network, 3

Ethernet OAM capabilities, 1, 5–6, 182–183

Ethernet OAM PDU, protection switching control via, 93. See also Protocol data units (PDUs)

Ethernet over fibers, 20–22

Ethernet PHY (EFY) layer network, 3, 111. See also LAN PHY applications; WAN PHY applications MPLS-TP and, 304

Ethernet Ports, in EPSR domain, 97–98

Ethernet private line (EPL), 3, 128, 140–141, 146
- CES in, 236

Ethernet Private Tree (EP-Tree) services, 4

Ethernet Private Virtual Tree (EPV-Tree) services, 4

Ethernet protection, 86–108
- automatic protection switching entities in, 87–88
- future of, 108
- linear, 89–97
- link aggregation in, 102–107
- methods of, 86–87
- ring, 97–102

Ethernet Protection Switched Rings (EPSRs), 86, 97–99

Ethernet PWs, data forwarding on, 347–348. See also Pseudowires (PWs)

Ethernet remote defect indication (ETH-RDI), 213–214

Ethernet ring protection (ERP), 87

Ethernet service delivery, 138–140
- applications for, 139

Ethernet service providers (ESPs), with PBB-TE network, 284–285

Ethernet Services Layer, in Ethernet protocol stack, 114–115

Ethernet SOAM frame format, 195

Ethernet stack, 21

Ethernet standards, 27
- IEEE 1588v2 and, 49

Ethernet test (ETH-Test) function, 227

Ethernet transport network, layers in, 111

Ethernet Tree (E-Tree) services, 4, 139, 141–143, 285–286

Ethernet Virtual Connection and, 130

Ethernet Version 2 frames, 27
- format of, 29–30

Ethernet Virtual Circuits/Connectors (EVCs), xiii, 2, 3–4, 121, 122–124, 127, 128–130, 130–133, 196. See also EVC entries
Index

Ethernet Virtual Circuits/Connectors (EVCs) (cont’d)

alarm indication signals and, 213
bandwidth profile and, 179–180
CESoETH service configuration and, 245–246
as CoS Identifiers, 131
ECIDs and, 238–239
ELMI and, 7–8
ELMI protocol and, 247–251
ENNI and, 133–134
frame delay measurement and, 225
initiation of, 181
in link aggregation, 106
in loss measurement, 218
monitoring, 181
OAM bandwidth for, 232
in 1:1 protection, 92
in 1+1 protection, 90–91
operation of, 181
in packet conditioning, 159–160
PCP and DSCP mapping and, 175
in performance measurement, 215
performance monitoring and, 217
in security, 232
service availability and, 222–223
service level agreements and, 164, 166–168
service providers and, 138–139
in testing, 228, 231–232
with VUNI/RUNI, 136–138
Ethernet Virtual Private Line (EVPL), 3, 128, 140, 146
CES in, 236
EtherType. See also Ethernet Length/Type entries
in IEEE 802.1AB frame format, 267
in IEEE 802.1ah frame format, 271–272
EtherType subprotocol identifier, 29, 30, 31
EtherType values, for OAM frames, 193
ETH Flow Conditioning Function (EFCF), 122
ETH Flow Termination Function (EETF), 122–123
ETH Flow domains (EFDs), 3
in Ethernet, 111, 113
ETH Layer Characteristic Information, for Carrier Ethernet, 117–121
ETH Layer functions, for Carrier Ethernet, 122–123
ETH layer network, 114–115, 117–118
ETH links, for Carrier Ethernet, 123–125
ETH LND, in Ethernet, 114
ETH Provider Conditioning Function (EPCF), 122, 124
ETH-RDI frames, 213–214. See also Remote Defect Indication (RDI)
ETH Subscriber Conditioning Function (ESCF), 122
ETH to TRAN Adaptation Function (TAF), 122–123
ETSI-defined service classes, 176
ETY layer, 3
EVC attributes. See also Ethernet Virtual Circuits/Connectors (EVCs)
of EP-Tree and EVP-Tree services, 150–152
of Ethernet services, 143–145, 149
EVC frames, in packet conditioning, 159
EVC ID, 131, 132–133
EVC identifier subinformation element, 257–258
EVC map entry subinformation element, 257
EVC parameters subinformation element, 257–258
EVC performance attributes, 131–132
EVC Reference ID, ELMI protocol and, 252
EVC service code modifiers, 132–133
EVC service codes, 132
EVC services, 188
EVC Status, ELMI protocol and, 249
EVC Status IE ELMI message elements, 253–254
EVC Status IEs, ELMI protocol and, 251
Index

EVC status information, 183
EVC types, 132
EVPL across multiple networks, 152. See also Ethernet Virtual Private Line (EVPL)
EVP-LAN across multiple networks, 153
EVP-LAN service attributes, 145–149
EVP-LAN services, 140–142
EVPL applications, 139–141
EVP-Tree EVC Service attributes, 151–152
EVP-Tree service, 148
EVP-Tree service across multiple networks, 154
EVP-Tree service attributes, 150–151
Excess Burst Size (EBS) bandwidth profile and, 177–180
in CoS flow policing, 160–161
Excess Information Rate (EIR) bandwidth profile and, 177–180
in CoS flow policing, 160–161
EXP value, T-MPLS and, 290
Extension field, in ETH Layer Characteristic Information, 117, 119–120
External Clocking, synchronization and, 39
External neighbors, in multi-AS VPLS, 358
External Network–Network Interfaces (ENNIs), xiii, 3–4, 133–136
for Carrier Ethernet, 125–126, 262
CESoETH service configuration at, 245–246
CoS identification and, 170–175
in Ethernet, 111
link aggregation and, 103
in loss measurement, 218
in MPLS-TP architecture, 313
MPLS-TP control plane and, 319
in performance measurement, 215
protection switching at, 86
service availability and, 222
service providers and, 138
in testing, 231–232
for T-MPLS, 294
with VPLS, 360–361
with VUNI/RUNI, 136–137
External PBB-TE management/control plane, 284
External timing, 242
Facility Data Link (FDL), in performance monitoring, 245
Facility loopbacks, 187
Factory installed addresses, in Ethernet frames, 28
Failure conditions in link OAM, 184
link trace and reply messages and, 208
Failures alarm indication signals and, 210–213
APS detection of, 87–88
locked signals and, 214–215
1:1 protection against, 91–92
1+1 protection against, 90–91
performance monitoring and, 217
revertive and nonrevertive modes and, 94
ring protection switching and, 99–102
timer and, 96–97
Fast Ethernet, 21
described, 14–15
link aggregation and, 103
Fate sharing, MPLS-TP G-ACh and, 317
Fault detection, 190
Fault notification, maintenance points and, 191–192
Fault tolerance, with NTP, 41
FCAPS
MPLS frame format and, 307
MPLS-TP G-ACh and, 317
in MPLS-TP network management, 320
FCS error, UNI/EVC and, 130
FEC 128 pseudowire, multisegment pseudowire setup and, 78
FEC 129 pseudowire, multisegment pseudowire setup and, 78
FEC PW LDP messages, multisegment pseudowire setup and, 78–79
FEC TLV, in LDP-based signaling, 345–347. See also TLVs (Type, Length, Value)
Fiber, copper vs., 26. See also Fibers; Optical fibers
Fiber interface, between ENNI gateways, 134
Fiber ports, in link aggregation, 107
Fibers, Ethernet over, 20–22
Field values, for APS-specific information, 95
Filter implementation, stabilization period and, 56
Filtering database (FDB), in ring failure operation, 102
Filters, for classification function, 158
Five 9s (five nines) availability, 86, 221
Flags field, 201, 206–208, 212–213, 228
in OAM PDUs, 196
Floating point arithmetic, with NTPv4, 41
Flooding, 331
in LDP-based VPLS, 340–341
Flow control, in Carrier Ethernet, 161
Flow domain flow
  Ethernet protocol stack and, 115
  in ETH layer network, 118
Flow domains, in ETH layer network, 118
Flow forwarding function, in ring protection architecture, 98
Flow point pool (FPP), 3
  in Ethernet, 111, 113
Flow points (FPs)
  Ethernet protocol stack and, 116
  in ETH layer network, 118
Flows, 180
  Ethernet protocol stack and, 115
Flow termination functions, Ethernet protocol stack and, 116–117
Flow termination sink function, Ethernet protocol stack and, 116–117
Flow termination source function, Ethernet protocol stack and, 116–117
FLR-based availability, 224. See also Frame loss ratio (FLR)
FLR measurements, service availability and, 222, 224
Follow_up messages, in IEEE 1588 clocking, 46
Forced switch mode, 92
Forced Switch trigger, with T-MPLS, 301
40GBASE-CR4 Ethernet, 24
40GBASE-KR4 Ethernet, 24
40GBASE-LR4 Ethernet, 24
40GBASE-SR4 Ethernet, 24
40GBASE-X interfaces, 24
Forward (F) bit, in LDP-based VPLS, 341–342
Forwarders, PWE3 preprocessing and, 66–68
Forwarder Service Processing (FWRD), 66–67
Forward frames, IEEE 1588 and, 50
Forwarding
  in LDP-based VPLS, 340–341
  with MPLS-TP, 307
VPLS, 338–339
Forwarding behavior, of T-MPLS, 289
Forwarding database (FDB), in ring protection, 99–100
Forwarding Equivalence Class, MPLS frame format and, 306
Forwarding Information Base (FIB), 12
  within VPLS, 339, 340
Forwarding Model PBB-TE, 279–280
FPP links, in Ethernet, 111, 113
Fractional DS1 service, CES as, 236
Fragmentation
  payload convergence layer and, 70
  PW demultiplexer layer and, 70–71
Fragmentation (FRG) bits, in CESoETH control word, 240
Frame check sequence (FCS), 3, 238
  in ETH Layer Characteristic Information, 117, 121
Frame collection function, in link aggregation, 105
Frame delay (FD), service level agreements and, 165, 169–170
Frame Delay attribute, 132, 162
Frame delay measurements, 224–225
  types of, 224
Frame delay performance, service level agreements and, 164–165
Frame Delay Range (FDR), service level agreements for, 169–170
Frame Delay Range attribute, 132, 162
Frame delay range performance, service level agreements and, 165–166
Frame delay variation (FDV)
  frame delay measurement and, 225
  service level agreements and, 166–167
Frame distribution function, in link aggregation, 105
Index

Frame Error Ratio (FER), in performance monitoring, 245
Frame format(s)
  for MPLS-TP, 306–307
  for PBT, 9
  for provider backbone transport, 278
  for OAM&P, 193–198
Frame header evolution, 271
Frame Loss, 219, 220
Frame loss rate, testing, 229–231
Frame loss ratio (FLR). See also FLR entries
  with CESoETH, 244
  in loss measurement, 218–219, 221
  performance monitoring and, 217–218
  service level agreements and, 167–170
Frame Loss Ratio attribute, 132, 162
Frame Relay, Carrier Ethernet vs., 110
Frames, 19–22, 27
  in hierarchical VPLS, 350
  in link aggregation, 106
  in packet conditioning, 159
  in testing, 228–231
  types and formats of, 27–32
  Virtual Private Networks and, 337
  in VPLS encapsulation, 338
  in VPWS, 352
Frame sizes, in testing, 228
Frame structure, T-MPLS, 294–296
Free-running clocks, IWF synchronization function and, 57
Free-running networks, 51–52
Free run timing, 242
Frequency accuracy, of slave clocks, 59
Frequency error, stabilization period and, 56
Frequency synchronization, 37–38
FR protocols, PW demultiplexer layer and, 71
Full-duplex Ethernet operation, 16
Full Status Continued message/report with ELMI polling, 260–261
  ELMI protocol and, 251
Full Status message/report, with ELMI polling, 260–261
Full Status report type, ELMI protocol and, 251
Functional blocks, with Synchronous Ethernet, 53
Functional components, for CES, 237–238
G-Ach traffic, MPLS frame format and, 307. See also Generic Associated Channel (GACL, G-ACh)
Generalized FEC 128 pseudowire, multisegment pseudowire setup and, 78
Generalized ID FEC, in LDP-based signaling, 345–347
Generalized multiprotocol label switching (GMPLS), 10–11. See also GMPLS entries
  history of, 288
  MPLS-TP and, 304
  MPLS-TP control plane and, 319
  MPLS-TP protection switching and, 330
  provider backbone transport and, 280
Generic Associated Channel (GACL, G-ACh). See also G-Ach traffic
  MPLS-TP and, 304
  in MPLS-TP architecture, 317–318
  MPLS-TP control plane and, 319
  MPLS-TP OAM and, 321
  MPLS-TP security and, 331
Generic Associated Channel Label (GAL), MPLS-TP and, 304, 307
Gigabit Ethernet, 21–23, 119–120
  link aggregation and, 103
Gigabit Ethernet standards, 27
Gigabyte per second interface types, 23
Global performance tier (PT4), 5. See also Performance tiers (PTs)
  service level agreements and, 168, 170
Global positioning system (GPS)
  in network synchronous operation method, 54
  precision time protocols for, 44
  synchronization and, 33
GMPLS-controlled Ethernet label, provider backbone transport and, 280. See also Generalized multiprotocol label switching (GMPLS)
GMPLS protocols, T-MPLS and, 293
GPS timing technology, 40
Grandmaster Clock (GMC), 45–51
  synchronization and, 39
Group ID, in LDP-based signaling, 346
GSM synchronization requirements, 37
Guard timer, in linear protection, 96–97
Hairpin switching, 134–135
Half duplex Ethernet operation, 16
Handoff calls, synchronization and, 34
Hardware-NIC support, 39. See also
Network interface card (NIC)
Head end, automatic protection switching and, 87–88
Head-end bridge
in 1:1 protection, 91–92
in 1+1 protection, 89
protection switching triggers and, 93
Header(s)
in Ethernet frames, 27, 30–31
in MPLS frame format, 306
SNAP, 31
T-MPLS, 294–296
Heart-beat timer, 58
Heterogeneous systems, precision time protocols for, 44
Hierarchical BGP VPLS, 359–360
Hierarchical LSPs, MPLS-TP OAM and, 324–325. See also Label switched paths (LSPs)
Hierarchical time distribution, with
Synchronous Ethernet, 52
Hierarchical virtual private local area network service (H-VPLS), 12
Hierarchical VPLS (H-VPLS), 349–353. See also Virtual Private LAN Services (VPLSs)
High-level architecture, MPLS-TP, 308
High-level data link control (HDLC), MPLS-TP data plane and, 310
High loss interval attribute, 162
High speed roaming, synchronization and, 34
Hold-in range, of EEC clocks, 60
Hold-off timers, in linear protection, 96
Holdover performance, of EEC clocks, 60, 61
Holdover time, synchronization and, 34
Hub PWs, in hierarchical VPLS, 349. See also Pseudowires (PWs)
Hubs, 16–17
Hub/star configuration, for Ethernet, 14
IB type Backbone Edge Bridge (IB-BEB), 9, 274–276
ICMP Echo (Ping), 202
I-component, in provider backbone bridge network, 275–276
Identifying tags, in testing, 229
Idle cell stuffing, synchronization and, 34–35
IEEE 802.1AB architecture, 264–266
IEEE 802.1AB frame format, 267–270, 280
IEEE 802.1AB standard, 263–270
IEEE 802.1ad, ETH Layer Characteristic Information and, 121
IEEE 802.1ad links, 360–361
IEEE 802.1ag-2007 standard, 182–183
on addressing modes, 194
on LLC/SNAP frame format, 196–198
on service OAM, 186–188
terminology of, 192
IEEE 802.1ag standard, 264
for provider backbone bridges, 270, 282
IEEE 802.1ah frame format, for provider backbone bridges, 271–274
IEEE 802.1ah standard, 264
for provider backbone bridges, 270
IEEE 802.1P/Q, 109
IEEE 802.1Qay standard, 264
provider backbone transport and, 279
IEEE 802.1Q standard, ETH Layer Characteristic Information and, 120
IEEE 802.1Q tag, 30–31
IEEE 802.1 standards, used by PBB-TE, 280
IEEE 802.2 frame format, 30–31
SNAP and, 31–32
IEEE 802.2 LLC frame, 27. See also Logical link control (LLC) layer
IEEE 802.2 LLC/SNAP frame, 27. See also Subnetwork Access Protocol (SNAP)
IEEE 802.2 standards, 27
IEEE 802.3—2008 standard, 22
IEEE 802.3ad-based link aggregation, 102–107
LAGs and, 104–105
IEEE 802.3ae-2002 standard, 22
IEEE 802.3ah standard, 20–21, 182–183
for link OAM, 183, 186
IEEE 802.3 frame format, 29–30
IEEE 802.3 standards, 27
for Synchronous Ethernet networks, 51, 58
IEEE 802.3z standard, ETH Layer Characteristic Information and, 119
IEEE 802.5 standards, 27
IEEE 802 MAC client, for LLDP, 265–266
IEEE 802 standards, 14
  table of, 28
IEEE 1588, issues with, 51
IEEE 1588–2002 standard, 44
IEEE 1588–2008 standard, 44–45
IEEE 1588 precision time protocols (PTPs), 44–51, 61
IEEE 1588 protocol stack, 45
IEEE 1588v2, two-way synchronization methodology with, 49–50
IEEE 1588v2 protocol layer, timing technology with, 40
IEEE 1588v2 (PTPv2)-Layer-2-embedded OAM frames, 39
IEEE Ethernet standards, table of, 28
IEEE protocols, for Ethernet PBT, 8
IEEE Registration Authority, 28
IEEE standards, 181–183
IETF Entity MIB, IEEE 802.1AB frame format and, 269–270
IETF Interfaces MIB, IEEE 802.1AB frame format and, 270
IETF Physical Topology, IEEE 802.1AB frame format and, 269
IETF RFC4330 (NTPv4)-Layer-3-ToD information, 40. See also NTPv4 protocol layer; RFC entries
Independent VLAN learning (IVL) switches, provider backbone transport and, 279–280. See also Virtual Local Area Networks (VLANs)
Information element (IE) identifiers, ELMI protocol and, 249–250
Information fields, in IEEE 802.1AB frame format, 268
Ingress bandwidth profiles (BWPs), 149, 175
Ingress Bandwidth Profile per ENNI CoS Identifier, 136
Ingress Bandwidth Profile per OVC EP, 135. See also Operator Virtual Connections/Connectors (OVCs)
Ingress frames, in packet conditioning, 159
Ingress UNI, in performance measurement, 215–216. See also User–Network Interface (UNI)
In-service measurements, 217
Instance-tags (I-TAGs), in IEEE 802.1ah frame format, 272
Institute of Electrical and Electronics Engineers (IEEE), 14. See also IEEE entries
Interconnect, xi
Interface Parameters TLV, in LDP-based signaling, 346. See also TLVs (Type, Length, Value)
Interfaces. See also Ethernet local management interface (ELMI); External Network–Network Interfaces (ENNI); 40GABSE-X interfaces; Gigabyte per second interface types; Network interfaces; Network interface card (NIC); 100GABASE-X interfaces; PMA interfaces; Remote User–Network Interface (RUNI); 10GABASE-X fiber interfaces; User–Network Interface (UNI); User–Network Interface Tunnel Access (UTA); Virtual User–Network Interface (VUNI); WAN interface sublayer (WIS)
for Carrier Ethernet, 111–112, 125–138
for CES, 235, 237–238
T-MPLS, 293–294
Interface specifications, Carrier Ethernet, 111–112
Interface Status TLV, CCM frames and, 200. See also TLVs (Type, Length, Value)
Interframe delay variation (IFDV), service level agreements and, 165, 166–167, 169–170
Interframe Delay Variation attribute, 132, 162
Interframe delay variation measurements, 225–226
Internal Clocking, synchronization and, 37
Internal-Network Network Interface (I-NNI)
for Carrier Ethernet, 124–126
MPLS-TP control plane and, 319
service providers and, 138
Internal oscillator, stabilization period and, 56
Internal XO timing technology, 40
International Organization of Standards (ISO), 14
International Telecommunication Union (ITU). See ITU entries
Internet
Network Time Protocol with, 40–41
synchronization and, 33
Internet Engineering Task Force (IETF), 10. See also IETF entries
on application-CoS-priority mapping, 169
MPLS developed by, 288–289
MPLS, T-MPLS, and MPLS-TP and, 303–304
Internet Protocol (IP), with Virtual Private Networks, 333. See also IP entries
Internet Protocol Local Area Network Service (IPLS), MPLS-TP architecture and, 313
Internet Protocol Version 6 (IPv6), with NTPv4, 41
Interworking functions (IWFs). See also CES IWFs; IWF entries
circuit emulation service and, 235–236
synchronization and, 35
with Synchronous Ethernet, 52–55
Inverse multiplexing over ATM (IMA), 20–21
IP-based VPN service, 140. See also Internet Protocol (IP); IP VPNs; Virtual Private Networks (VPNs)
IP forwarding
MPLS frame format and, 306
with MPLS-TP, 305
IP functionality, MPLS-TP OAM and, 320
IP/MPLS networks, T-MPLS and, 289
IP/MPLS routing protocols, Virtual Private Networks and, 334
IP/MPLS standards, 11, 331
interoperability with T-MPLS, 301–302
with MPLS-TP, 304
Virtual Private Networks and, 336
IP/MPLS via Ethernet over T-MPLS network, 293
IP multicasting, precision time protocols based on, 44
IP network delay monitoring, time/phase requirements for, 39
IP networks. See also PWE3 over an IP PSN protocol structure
multisegment architecture and, 77
pseudowires in, 63
IP Packet Delay Variation (IPDV) application, 173–174, 176
IP Packet Errored Ratio (IPER) application, 173–174, 176
IP Packet Loss Ratio (IPLR) application, 173–174, 176
IP Packet Reordering Ratio (IPRR) application, 173–174
IP packets
MPLS-TP architecture and, 313
MPLS-TP data plane and, 310
IP Packet Transfer Delay (IPTD) application, 173–174, 176
IP service classes, 171–174
IP services, 140
IP standards, IEEE 1588v2 and, 49
IP transport service, in MPLS-TP architecture, 313–317
IP VPNs, in hierarchical BGP, 360. See also Virtual Private Networks (VPNs)
I-SID tag field, 8–9
Isolated physical clocks, 33
I-TAG service instance tag, in IEEE 802.1ah frame format, 273
ITU standards, 181
ITU Study Group 15, MPLS, T-MPLS, and MPLS-TP and, 303–304
ITU-T, 10
on application-CoS-priority mapping, 169–170
on maintenance entities, 188, 18
MPLS, T-MPLS, and MPLS-TP and, 303–304
MPLS-TP protection switching and, 3309
ITU-T layered network architecture, T-MPLS and, 293
ITU-T recommendations, for T-MPLS, 301
ITU-T Recommendation Y.1731, 182–183
on service OAM, 186–188
on testing, 226–228, 232
terminology of, 192
ITU-T Y.1711 standard, frame delay measurement and, 225
I type Backbone Edge Bridge (I-BEB), 9,
274–276
IWF-located PRC, 58. See also
Interworking function (IWF)
IWF synchronization function, 57

Jitter
IEEE 1588v2 and, 49–51
packet network impairments and, 56
service level agreements and, 164
Jitter buffer, with CESoETH, 244–245
Jitter buffer overrun, with CESoETH, 244
Jitter buffer underrun, with CESoETH,
244–245
Jitter generation, of EEC clocks, 60
Jitter requirements, synchronization and,
34–35, 40
Jitter values, classes of service and, 164
Joint Working Group (JWG), MPLS,
T-MPLS, and MPLS-TP and,
303–304

L2CP processing requirements, for
Ethernet services, 144, 146–148. See also Layer 2 entries
L2TPv3-PW, 78–79
in pseudowire operations and
maintenance, 81–82
L2 VPNs, 140. See also Virtual Private
Networks (VPNs)
Label blocks, in BGP-based VPLS
signaling, 355
Label distribution protocol (LDP), 11, 12.
See also LDP entries
MPLS-TP and, 304
multisegment pseudowire setup and,
78–79
in pseudowire security, 84
Virtual Private Networks and, 334
Label Edge Router (LER), 11
in MPLS-TP architecture, 311
MPLS-TP OAM and, 321, 323
Label For you (LFU), MPLS frame
format and, 307
Label mapping messages, in LDP-based
VPLS, 345
Labels
in MPLS frame format, 306–307
MPLS-TP architecture and, 316–317
Label space, T-MPLS and, 290
Label stack
MPLS frame format and, 306
MPLS-TP data plane and, 310
Label stack entry, MPLS-TP architecture
and, 309
Label stack using pseudowires, MPLS-TP
architecture for, 315
Label switched paths (LSPs), 9–10, 12.
See also LSP entries
MPLS, 288
with MPLS-TP, 305
MPLS-TP control plane and, 317–319
MPLS-TP data plane and, 310–311
MPLS-TP OAM and, 321, 323
MPLS-TP protection switching and, 330
with T-MPLS networks, 296
Label Switched Router (LSR), 11
MPLS-TP and, 307
in MPLS-TP architecture, 311
Label switching operations, MPLS-TP
data plane and, 311
LACPDUs, 104, 106. See also Link
aggregation control protocol (LACP);
Protocol data units (PDUs)
LACP frames, 104
LACP keys, 107
LACP packets, 104
LACP parameters, 106–107
LACP priority, 106
LACP timers, 107
LAN connectivity technology, Carrier
Ethernet as, 109. See also Local area
networks (LANs)
LAN PHY applications, 23–26. See also
Ethernet PHY (EFY) layer network
LAN segments, Virtual Private Networks
and, 334
LAN technology, Ethernet as, 2. See also
LAN connectivity technology
Index

Last Egress Identifier field, link trace and reply messages and, 209–210
Latency
  IWF synchronization function and, 57
  procedure for, 229, 230
  synchronization and, 37
Layer 1 networks, impact of packet network impairments on, 55
Layer 1 timing, 51
Layer 2 Control Protocol (L2CP) service frame, 131, 140, 171. See also L2CP processing requirements
  ETH Layer Characteristic Information and, 121
Layer 2 Info extended community
  in BGP VPLS operation, 357
  in VPLS BGP NLRI, 356
Layer 2 multipoint VPNs (VPLs), 11. See also Virtual Private Networks (VPNs)
Layer 2 point-to-point VPNs, 11
Layer 2 virtual connections, T-MPLS and, 288
Layer 3 multipoint VPN, 11. See also Virtual Private Networks (VPNs)
Layer network, T-MPLS, 291, 292
Layer Network Domain (LND) trail, in Ethernet, 111, 114
Layers
  in Ethernet transport network, 111
  in MPLS-TP architecture, 312
  with Virtual Private Networks, 333
L bit, in CESoETH control word, 239, 240
LBM frames, 194, 204–205. See also Loopback message (LBM)
LBM PDUs, 206–208. See also Protocol data units (PDUs)
LBR frames, 194, 204–205. See also Loopback reply (LBR)
LBR PDUs, 206–208. See also Protocol data units (PDUs)
LB sessions, 206
LCK (locked) condition, 214
  alarm indication signals and, 212
  LCK frames, 194, 214–215
    in testing, 227
  LCK messages, in testing, 227
  LCK PDU, 214. See also Protocol data units (PDUs)
  LCK transmission period, 214
LDP-based signaling, in LDP-based VPLS, 345–347. See also Label distribution protocol (LDP)
LDP-based VPLS, 12, 340–353
LDP MD5 authentication, in pseudowire security, 84
LDP notification message, in pseudowire operations and maintenance, 82
LDP signaling, in hierarchical VPLS, 349
“Leaf: UNIs, 141, 143. See also User–Network Interface (UNI)
Leaky bucket algorithms, 177–180
Leaky bucket method, in CoS flow policing, 160
Leased lines, Carrier Ethernet vs., 110
Length (LEN), in CESoETH control word, 240–241
Length field
  in IEEE 802.1AB frame format, 268
  in LDP-based VPLS, 341–342
Length/Type/Subtype field, 184
Level 1 label, in MPLS frame format, 306
Level m label, in MPLS frame format, 306
Light, in optical fibers, 20
Linear 1:1 protection architecture, 89, 91–92
Linear 1+1 protection architecture, 89–91
  APS PDU format for, 93–97
  triggers for, 89, 92–93
Linear protection architecture, 89–97
Linear protection switching, with T-MPLS, 296–297
Link aggregation, 102–107
  limitations of, 107
Link aggregation control protocol (LACP), 103–107. See also LACP entries
Link aggregation function, 105–106
Link Aggregation Groups (LAGs), 86, 102–104, 108
  objectives of, 104–105
Link aggregation sublayer, 103
LINK-DOWN control message, 99
Link Down events, in testing, 231–232
Link flows, Ethernet protocol stack and, 115
Link layer, MPLS-TP OAM and, 322
Index 385

Link layer discovery protocol data unit (LLDPDU)
IEEE 802.1AB frame format for, 267–270
transmission of, 266–267
Link Layer Discovery Protocol (LLDP), 263
defined, 264
ETH Layer Characteristic Information and, 119
IEEE 802.1AB architecture and, 264–266
principles of operation of, 266–267
Link layer functions, Ethernet OAM, 182
Link layer OAM capabilities, 5. See also Operations, Administrations, and Maintenance (OAM) capabilities
Link layer protocols, 264
Link monitoring OAM, 184
Link OAM, 183–187. See also Operations, Administrations, and Maintenance (OAM) capabilities
Links, in Ethernet, 111, 113–114
Link trace, 206–212
Ethernet, 183
maintenance points and, 191
Link trace messages (LTMs), 6, 206–212. See also LTM entries
TLVs applicable for, 197
Link trace replies (LTRs), 6, 206–212. See also LTR entries
TLVs applicable for, 197
Link Up events, in testing, 231–232
LKR packets, MPLS-TP data plane loopback and, 329
LLC protocol, 25. See also Logical link control (LLC) layer
LLC protocol header, 25
LLC/SNAP frame format, 196–198
LLDP agents, 265–267. See also Link Layer Discovery Protocol (LLDP)
LLDP components, 265–266
LLDP frames, 265
LLDP header, 266
LLDP information flow, 266
LLDP local system MIB, 266
LLDP messages, 266–267
LLDP MIB manager, 266
LLDP PDUs, 265. See also Link layer discovery protocol data unit (LLDPDU); Protocol data units (PDUs)
LLDP protocol, 267
LLDP receive module, 267
LLDP remote system MIB, 266
L-LSP (Label Only Inferred LSP). See also Label switched paths (LSPs)
MPLS-TP and, 305
MPLS-TP data plane and, 311
LMM frames, 195. See also Loss Measurement Message (LMM) in loss measurement, 220–221
LMM PDU, in loss measurement, 220–221. See also Protocol data units (PDUs)
LMR frames, 195. See also Loss Measurement Reply (LMR) in loss measurement, 220–221
LMR PDU, in loss measurement, 220–221. See also Protocol data units (PDUs)
Local area networks (LANs), 262
Carrier Ethernet for, 110
collision detection in, 15–16
Ethernet as, 1, 14
collision detection protocols, for, 44
User–Network Interface and, 127
Virtual Private Networks and, 334–335
Local offices, with NTP/SNTP, 42
Local TDM failure, CESoETH control word and, 239. See also Time-division multiplexing (TDM)
Local TDM failure modification bits, in CESoETH control word, 240
LOC defect, in loss measurement, 219
Lock Instruct (LKI) command, MPLS-TP data plane loopback and, 329–330. See also LCK entries
Lockout of Protection (LP), with T-MPLS, 300
Lock Reporting Function (LKR), MPLS-TP data plane loopback and, 329
LOF alarm, 244
Logical link control (LLC) layer, 25. See also IEEE 802.2 LLC entries; LLC entries
Logical protocol layering model, 63, 64
Long-service instance TAG, in IEEE 802.1ah frame format, 272, 273
Long-term average bandwidth limits, 177
Long-term averaging, 51
Loop avoidance, in ring failure operation, 102
Loopback(s), 187
Ethernet, 183
maintenance points and, 191
MPLS-TP data plane and, 328–329
Loopback control OAM PDU, 184–186.
See also Operations, Administrations, and Maintenance (OAM) capabilities;
Protocol data units (PDUs)
Loopback message (LBM), 202–208
TLVs applicable for, 197
Loopback reply (LBR), 202–208
TLVs applicable for, 197
Loop-based networks, traffic protection in, 86–87
Loop-free topology, in LDP-based VPLS, 342
Looping back frames, in testing, 231
Loop-timed/Line-Derived Clocking,
synchronization and, 39
Loss, service level agreements and, 164
Loss measurement(s), 6, 218–221
performance monitoring and, 217–218
Loss Measurement Message (LMM), 195
performance monitoring and, 217–218
in testing, 232
Loss Measurement Reply (LMR), 195
performance monitoring and, 217–218
in testing, 232
Loss of connectivity (LOC), protection
switching triggers and, 93
Loss of continuity (LOC) condition, 201, 212–213
Loss of frame alignment (LOF),
CESoETH control word and, 239
Loss of Frames (LOFs), 244
CESoETH control word and, 239–240
Loss of Frames State (LOFS)
CESoETH control word and, 239–240
in performance monitoring, 245
Loss of signal (LOS), 244
CESoETH control word and, 239
Low cost Ethernet, 262
LSP demultiplexer (Demux) label,
MPLS-TP architecture and, 314, 316.
See also Label switched paths (LSPs)
LSP layer, MPLS-TP OAM and, 322
LSP Maintenance Entity Group (LMEG),
MPLS-TP OAM and, 324
LSP merging option, MPLS vs. T-MPLS, 291
LSP mesh, Virtual Private Networks and, 336
LSP monitoring, MPLS-TP OAM and,
325–326
LSP protocol stack, MPLS-TP G-ACh
and, 317–318
LSP server, MPLS-TP architecture and,
314
LSP SPME MEG (LSMEG), MPLS-TP
OAM and, 324. See also Subpath
 Maintenance Element/Entity (SPME)
LTE, time/phase requirements for, 39
LTM egress identifier LTV, 208, 212. See also Link trace messages (LTMs)
LTM frames, 194, 208–212
LTM PDU, 208–212. See also Protocol
 data units (PDUs)
LTR frames, 194, 209–211. See also Link
 trace replies (LTRs)
LTR PDU, 208–211. See also Protocol
data units (PDUs)
MAC address aging, VPLS and, 339, 340.
See also Media access control (MAC)
MAC addresses, 3, 13, 28, 121, 146, 182,
184, 195
bridges and, 17–18
dual homing protection and, 353
ECIDs and, 238–239
in Ethernet PW data forwarding, 348
Ethernet Virtual Connection and,
129–130
frame delay measurement and, 225
in hierarchical VPLS, 350
on LDP-based VPLS discovery,
344–345
in link aggregation, 106
link trace and reply messages and,
208–209
LLDP and, 267
loopback messages/replies and, 203–206
in loss measurement, 220
maintenance points and, 191
MPLS-TP architecture and, 313
in OAM addressing, 194
in provider backbone bridge network, 275, 277–278
for provider backbone bridges, 270–271, 274
provider backbone transport and, 280
in ring failure operation, 102
switches and, 19
in testing, 227
Virtual Private Networks and, 333, 336–337
VPLS and, 339–341
in VPWS, 352
MAC address learning. See also MAC learning
in LDP-based VPLS, 340–341
VPLS and, 339–340
MAC-client sublayer, 25
MAC control protocol, 16
MAC flooding, 263
MAC header, in IEEE 802.1ah frame format, 271
MAC-in-MAC encapsulation, 8
with provider backbone bridges, 270
MAC layer functions, 237
MAC (ETH) layer network, in Ethernet, 111, 113
MAC-layer packets, bridges for transferring, 17
MAC learning, Carrier Ethernet and, 110. See also MAC address learning
MAC sublayer, 25–26
Maintenance, maintenance domains in, 188
Maintenance Association Identifier (MAID), 192
as CCM attribute, 199
Maintenance Associations (MAs), 192–193, 196. See also MA–MD level mapping; Short MA Name with PBB-TE network, 284–285
in security, 232
Maintenance Communication Channel (MCC), 195. See also Management Communication Channel (MCC)
Maintenance domain name formats, 192–193
Maintenance domains (MDs), 187–188, 192, 196, 211. See also MA–MD level mapping; MD entries
Maintenance end points (MEPs), 6, 187–190. See also MEG End Point (MEP); MEP entries
alarm indication signals and, 210–213
CCM frames issued by, 198–199
frame delay measurement and, 224–225
link trace and reply messages and, 206–209
locked signals and, 214–215
loopback messages/replies and, 202–206
in loss measurement, 219–221
MPLS-TP client failure indication and, 330
MPLS-TP data plane loopback and, 328–329
MPLS-TP OAM and, 321–328
with PBB-TE network, 285
performance monitoring and, 218
protection switching triggers and, 93
remote defect indication and, 213
in ring failure operation, 101–102
in testing, 227
Maintenance entities (MEs), 188–190, 192
MPLS-TP OAM and, 321–323
Maintenance Entity Groups (MEGs), 188–190. See also MEG entries
alarm indication signals and, 210, 213
MPLS-TP data plane loopback and, 328–329
MPLS-TP OAM and, 321–324
remote defect indication and, 213
Maintenance intermediate points (MIPs), 6, 187–190
alarm indication signals and, 210
CCM frames and, 199
functions of, 191
link trace and reply messages and, 209
locked signals and, 215
Index

Maintenance intermediate points (MIPs) (cont’d)
  loopback messages/replies and, 203–206
  in loss measurement, 218
MPLS-TP client failure indication and, 330
MPLS-TP data plane loopback and, 328–329
MPLS-TP OAM and, 321–324, 328
  in testing, 227
Maintenance point functions, 191
Maintenance points (MPs), 6, 187–188, 190–193
  link trace and reply messages and, 208–209, 211
  loopback messages/replies and, 202–206
  in security, 232
  terminology mapping for, 192
Maintenance reference model, pseudowires and, 71–72
Malformed frames, with CESoETH, 244
MA–MD level mapping, 189. See also
  Maintenance Associations (MAs); Maintenance domains (MDs)
Management Communication Channel (MCC), MPLS-TP G-ACh and, 317.
  See also Maintenance Communication Channel (MCC)
Management entities, 188
Management information bases (MIBs), 264
  IEEE 802.1AB frame format and, 269–270
Management plane
  in Ethernet protocol stack, 114
  with T-MPLS, 290
  in User–Network Interface, 127
Management specifications, Carrier Ethernet, 111–113
Manual Switch (MS) trigger, with T-MPLS, 301
Manual switch mode, 92
Manycast mode, with NTPv4, 41
Marker response, in link aggregation, 105
Martini encapsulation, Virtual Private Networks and, 334
Master clocks, in precision time protocols, 44–51
Master node
  in EAPS ring, 87
  in EPSR domain, 98
  in ring failure operation, 99–101
  in ring protection, 99–100
Master port model, 194
Master-slave strategy/hierarchy
  for synchronization, 34, 42, 44–51
  for Synchronous Ethernet, 51–53
MAU Transport Termination, in performance measurement, 215
Maximum time interval error (MTIE), of EEC clocks, 60
Maximum time interval error/time deviation (MTIE/TDEV) frequency, 40
Maximum Transmission Unit (MTU), in VPLS BGP NLRI, 356–357
M bits, in CESoETH control word, 240
MCC frames, 195
MD connectivity, unintended, 198–199.
  See also Maintenance domains (MDs)
MD level
  in security, 232
  in testing, 227
MD Name, 192–193
MDSFN, time/phase requirements for, 39
Mean Frame Delay (MFD) attribute, 132, 162
Mean frame delay performance, service level agreements and, 166, 169–170
Measurement bins, in performance measurement, 216–217
Measurement methodologies, Carrier Ethernet, 111, 113
Measurements, types of, 217
Media access control (MAC), 25, 158. See also Ethernet MAC layer network;
  MAC entries
  link aggregation and, 102–107
  in ring failure operation, 102
Media Attachment Unit (MAU), 215
Medium access control rules, 19
MEF FM 1A recommendations, 189. See also Metro Ethernet Forum (MEF)
MEF specifications, xiii
Carrier Ethernet, 111–113
MEF standards, 181
MEG connectivity, unintended, 198–199.
See also Maintenance Entity Groups (MEGs)
MEG End Point (MEP), 190–193, 196.
See also MEP entries
in OAM addressing, 193–194
MEG ID, as CCM attribute, 199–201
MEG level(s), 189
as CCM attribute, 199
locked signals and, 214–215
in loss measurement, 219–220
maintenance points and, 192
in testing, 227
MEG Level field, in OAM PDUs, 196
MEN-bound IWFs. See also Metro Ethernet Networks (MENs)
CESoETH control word and, 239–241
in performance monitoring, 245
synchronization and, 241–242
MEP IDs, 192–193. See also Maintenance end points (MEPs); MEG End Point (MEP)
as CCM attribute, 199, 201
MEP types, 189
Merged LSPs, MPLS-TP and, 307. See also Label switched paths (LSPs)
Mesh networks, traffic protection in, 86–87
Message Type ELMI message element, 252
Metcalfe, Robert, 14
Metro Ethernet, 110
Metro Ethernet Backhaul, CES in, 236–237
Metro Ethernet Forum (MEF), xi, xii. See also MEF Specifications
on application-CoS-priority mapping, 169
Carrier Ethernet and, 109
on CES IWF, 236
on classes of service, 162
Ethernet Virtual Connection and, 128
EVC ID and, 132
on maintenance entities, 188, 192
on performance tiers, 168
User–Network Interface and, 128
Metro Ethernet Networks (MENs), 2, 6, 8, 53–55, 121. See also MEN entries
attributes of, 138
Carrier Ethernet vs., 262
defects caused by, 244
ECIDs and, 238–239
ELMI parameters and procedures and, 257–258
ELMI protocol and, 247
ENNI and, 134
Ethernet Virtual Connection and, 129–130
ETH Layer functions and, 122
link aggregation and, 103
OVC and, 134
in performance measurement, 215–216
protocol stack for, 114
security for, 232
service providers and, 138
synchronization in, 36–37
TDM pseudowire over Ethernet and, 235–236
User–Network Interface and, 127
with VUNI/RUNI, 137–138
Metro Ethernet services, 108
Metro Ethernet technology, 180
Metro performance tier (PT1), 5. See also Performance tiers (PTs)
service level agreements and, 168–169
Metropolitan Area Networks (MANs), xiii
Carrier Ethernet for, 110
Ethernet and, 1
MIB objects, 266. See also Management information bases (MIBs)
Mid-band Ethernet services, 21
Mileage-based SLAs, with Carrier Ethernet, 168
Minimum one-way delay, service level agreements and, 166
Minimum pull-in range, of EEC clocks, 60
Misconfiguration, MPLS-TP security and, 331
Misconnection control-plane service and, 72
with CESoETH, 244
Mismerge condition, 198–199, 201–202
Mobile applications
service classes for, 176
synchronization and, 35–36
Mobile Backhaul, 36, 39–40
Mobile networks, synchronization in, 36–37
Modifier bits, in CESoETH control word, 240
Monitoring
  maintenance domains in, 188
  MPLS-TP and, 308
  MPLS-TP OAM and, 321, 325–328
MP configuration information, in loss measurement, 220
MPLS core, 263. See also Multiprotocol label switching (MPLS)
MPLS data plane, 310
MPLS Fast ReRoute (FRR) capability, T-MPLS and, 290
MPLS forwarding, MPLS-TP and, 307
MPLS frame format, 306
MPLS labels, 306
  Virtual Private Networks and, 334
MPLS label size, 239
MPLS label stack, MPLS-TP architecture and, 316
MPLS label switched paths (LSPs), 288.
  See also Label switched paths (LSPs)
MPLS LND, in Ethernet, 114
MPLS networks, Virtual Private Networks and, 335–336
MPLS PW label. See PW MPLS label
MPLS-TP LSPs, 307–308. See also Label switched paths (LSPs)
MPLS-TP nodes, MPLS-TP security and, 331
MPLS Traffic Engineering (MPLS-TE) data plane architecture, 304
MPLS-Transport Profile (MPLS-TP), 301, 303–332. See also Multiprotocol label switching (MPLS); Multiprotocol label switching transport profile (MPLS-TP)
  architecture of, 307–320
  frame format for, 306–307
  future of, 331
  history and uses of, 303–306
  OAM for, 303, 320–330
  protection switching supported by, 330
  security with, 331
MPLS tunnels, Virtual Private Networks and, 336–337
MRP protocols, 148
MS Delay, 47, 48
MS-Time_Difference, 47, 48–49
MSTP control plane, in PBB-TE network, 284. See also Multiple Spanning Tree Protocol (MSTP)
Multi-AS VPLS, 358–350
Multicast addresses, 194
Multicast bandwidth, switches and, 19
Multicast DAs, 194. See also Destination addresses (DAs)
Multicast DA usage, 194–195
  in testing, 227
Multicast ETH-LB, 203, 204–206
Multicast frames, with ETH-LB request information, 205
Multicasting, precision time protocols based on, 44
Multicast LTM, 209. See also Link trace messages (LTMs)
Multicast service frame, ETH Layer Characteristic Information and, 121
Multi-CoS, 180
Multidirectional point-to-point transport paths, MPLS-TP OAM and, 323
Multihop EBGP redistribution, in multi-AS VPLS, 359
Multimode fiber, 20
Multimode fiber ports, in link aggregation, 107
Multipair technologies, 21
Multiple AC to multiple PW forwarding, 66, 68. See also Attachment circuits (ACs); Pseudowires (PWs)
Multiple CEs, Virtual Private Networks and, 333. See also Customer Edges (CEs)
Multiple CE-VLAN IDs, Ethernet Virtual Connection and, 130. See also Virtual Local Area Networks (VLANs)
Multiple Classes of Service (Multi-CoS), xi
Multiple ESR domains, 98–99
Multiple PBT domains, end-to-end Carrier Ethernet connections with, 282–283. See also Provider backbone transport (PBT)
Multiple Spanning Tree Protocol (MSTP), for provider backbone bridges, 270. See also MSTP control plane
Multiple VPLS services, in LDP-based VPLS discovery, 344. See also Virtual Private LAN Services (VPLSs)
Multiplexed UNI, User–Network Interface and, 128. See also User–Network Interface (UNI)
Multiplexer, in link aggregation, 105
Multiplexing, 140
  CES architecture with, 235
  PW demultiplexer layer and, 70–71
Multipoint EVC, performance monitoring and, 217. See also Ethernet Virtual Circuits/Connectors (EVCs)
Multipoint-to-multipoint EVCs, 129–130 frame loss ratio for, 168 service providers and, 138–139
Multipoint-to-Multipoint EVC status, ELMi protocol and, 249, 251
Multipoint-to-multipoint LSPs, MPLS-TP data plane and, 311. See also Label switched paths (LSPs)
Multipoint-to-multipoint VC availability, 223–224
Multipoint-to-point LSPs, MPLS-TP data plane and, 311. See also Label switched paths (LSPs)
Multipoint VPNs, 333. See also Virtual Private Networks (VPNs)
Multipoint VPN services, 336
Multiprotocol label switching (MPLS), 10, 263, 285–286, 288. See also PWE3 over an MPLS PSN protocol structure; Transport MPLS
MPLS-TP vs., 303
multisegment pseudowire setup and, 78 in pseudowire operations and maintenance, 81–82
pseudowires and, 63 in T-MPLS networks, 291–293
T-MPLS vs., 290–291
virtual private LAN services and, 11–13
Virtual Private Networks and, 333
Multiprotocol label switching transport profile (MPLS-TP), 1, 9–11. See also MPLS-Transport Profile (MPLS-TP)
Multiproviders Ethernet service delivery, 275
Multisegment architecture, pseudowires in, 74–77
Multisegment pseudowire (MS-PW), 74, 76, 84 in MPLS-TP architecture, 312, 314
MPLS-TP OAM and, 324–325 in pseudowire security, 83 quality of service/congestion control and, 80–81 resiliency and, 80 setup mechanisms for, 77–79
Multisegment setup mechanisms, for pseudowires, 77–79
Multiservice provisioning platforms (MSPPs), 288
Multitenant unit (MTU)
dual homing protection and, 352–353 in hierarchical VPLS, 349–351 in VPWS, 352
Multivendor interoperability, 264
Nanokernel implementation, with NTPv4, 41
Native data units, encapsulation via payload convergence layer, 68–70
Native Service Processing (NSP), 66–68
Native services, 234
Native time service, emulation of, 40
NE counters, in performance measurement, 216. See also Network Edge (NE); Network elements (NEs); Network errors
Network administration, maintenance domains in, 188
Network clocks
IWF synchronization function and, 57 with Synchronous Ethernet, 52
Network Edge (NE)
local management interface with, 247
OAM bandwidth for, 232 in security, 232
Network edge signaling, 7 in performance measurement, 215–216
Network elements (NEs), MPLS-TP and, 304
Network errors, 263
Network flow, Ethernet protocol stack and, 115–116
Network gateway, with NTP/SNTP, 42
Network interface card (NIC), 21. See also Hardware-NIC support
  MAC addresses of, 28
Network Interface Device (NID),
  User–Network Interface and, 127
Network interfaces, 4
Network layer, PBB-TE and, 263
Network-layer clients, MPLS-TP architecture for, 315
Network layering, MPLS-TP architecture and, 308–309
Network-layer protocols, MPLS-TP architecture and, 316
Network Layer Reach-ability Information (NLRI), 13
Network management
  MPLS-TP architecture and, 319–320
  performance measurement in, 215–217
  T-MPLS, 291
Network Management Support, LAGs and, 105
Network Management System (NMS), 10–11, 183
  MPLS-TP and, 304
  MPLS-TP control plane and, 317–319
  MPLS-TP data plane loopback and, 329
  in MPLS-TP network management, 320
  in performance measurement, 216
  in security, 232
Network management systems, 264
Network–network interface (NNI)
  in MPLS-TP architecture, 312, 313
  for T-MPLS, 293–294
Network node interfaces, for T-MPLS, 294
Network operation center (NOC),
  MPLS-TP and, 304
Networks, xiii
  synchronization among, 33–62
  testing, 231–232
  T-MPLS and, 288–290
  T-MPLS and MPLS-TP for, 9–11
Network service layers, in MPLS and T-MPLS networks, 292
Network-synchronous clocking methods, 51
Network-synchronous operation, IWF synchronization function and, 57
Network synchronous operation method, 54–55
Network technologies, 1. See also Transport technologies
  Network Time Protocol (NTP), 40–44
  New VC Status, ELMI protocol and, 249, 251
  No Customer Addresses (NCA) field, in IEEE 802.1ah frame format, 273
Nodes
  in MPLS-TP architecture, 312
  MPLS-TP security and, 331
  synchronization and, 34–35
  Noise generation, of EEC clocks, 60
  Noise tolerance bounds, of EEC clocks, 60
  Noise transfer bounds, of EEC clocks, 60–61
Nonmultiplexed UNI, User–Network Interface and, 128. See also User–Network Interface (UNI)
Non-PBT provider domains, end-to-end Carrier Ethernet connections with, 283
Nonrevertive 1:1 protection, 92
Nonrevertive 1+1 protection, 89–90
Nonrevertive modes
  APS PDU format and, 94
  in ring failure operation, 101
  with T-MPLS protection, 298–299
Nonrevertive protection switching, 89
No Request (NR) state, 88
  with T-MPLS, 299, 301
Not Active EVC Status, ELMI protocol and, 249, 251. See also Ethernet Virtual Circuits/Connectors (EVCs)
Novell’s nonstandard IEEE 802.3 frame, 27
NTPv3, NTPv4 vs., 41. See also Network Time Protocol (NTP)
NTPv4, features of, 41
NTPv4 protocol layer, timing technology with, 40. See also IETF RFC4330 (NTPv4)-Layer-3-ToD information
OAM addressing, 193–198. See also Operations, Administrations, and Maintenance (OAM) capabilities
OAM architecture, 190
OAM bandwidth, 232
OAM discovery, 184–185
OAM flow, 189
OAM frames, 193–198
  frame delay measurement and, 224
  in loss measurement, 218–219, 221
  maintenance points and, 190–192
OAM functionality, provider backbone transport and, 279
OAM functions, 183
  with MPLS-TP, 304–305, 308–309, 320–331
  MPLS-TP control plane and, 317–319
  MPLS-TP G-ACh and, 317
  with T-MPLS, 300
OAM functions for proactive monitoring, MPLS-TP and, 325–328
OAM hierarchy, MPLS-TP OAM and, 322–325
OAM messages, in testing, 227–228
OAM methodology, T-MPLS and, 293
OAM monitoring, MPLS-TP and, 325–328
OAM packets, MPLS-TP data plane loopback and, 328–329
OAM process operating boundaries, 182
OAM protocol data units (OAM PDUs), 184–186
  bandwidth for, 232
  Continuity Check Messages in, 198–202
  format of, 196
  in security, 232
OAM protocols, 181
OAM requirements, Carrier Ethernet, 111–113
OAM test frames, performance monitoring and, 217–218
Offset, IEEE 1588 and, 50
On-demand measurements, 217
1:1 protection architecture, 89, 91–92
  protection types in, 95–96
  with T-MPLS, 296, 298
100BASE-CX Ethernet, 22
100BASE-T Ethernet, 21
100BASE-T2 Ethernet, 21
100BASE-T4 Ethernet, 21
100BASE-TX Ethernet, 20–21
100GBASE-CR10 Ethernet, 24
100GBASE-ER4 Ethernet, 24
100GBASE-LR4 Ethernet, 24
100GBASE-SR10 Ethernet, 24
100BASE-X interfaces, 24
1-phase protocol, with T-MPLS, 300
1+1 protection architecture, 89–91, 93
  protection types in, 95–96
  with T-MPLS, 296–298
1000BASE-BX10 Ethernet, 23
1000BASE-CX Ethernet, 22–23
1000BASE-KX Ethernet, 23
1000BASE-LH Ethernet, 23
1000BASE-LX10 Ethernet, 23
1000BASE-LX Ethernet, 23
1000BASE-PX10-D Ethernet, 23
1000BASE-PX10-U Ethernet, 23
1000BASE-PX20-D Ethernet, 23
1000BASE-PX20-U Ethernet, 23
1000BASE-SX Ethernet, 22–23
1000BASE-T Ethernet, 20, 22–23
1000BASE-ZX Ethernet, 23
One_Way_Delay, 48–49
One-way delay measurement (1DM)
  frames, 195
  frame delay measurement and, 224–225
  performance monitoring and, 217–218
One-way delay measurements (1DMs), 225
One-way FLR measurement, 218. See also Frame loss ratio (FLR)
One-way frame delay, 164–166, 224–225
One-way frame delay range performance metric, 166
One-way IFDV measurements, 225
One-way mean frame delay (MFD)
  performance metric, 166
One-way protocols, LLDP as, 267
OpCode field
  loopback messages/replies and, 206–208
  in OAM PDUs, 196–197
Open Shortest Path First (OSPF, OSPF-TE), 12
  Virtual Private Networks and, 337
Operational expenditures (OPEX), 262
  with T-MPLS, 301
Index

Operation modes, asynchronous and synchronous, 58–59
Operations, Administrations, and Maintenance (OAM) capabilities, xiii, 1, 5–6, 10, 263. See also OAM entries
ENNI and, 134
ETH Layer functions and, 123
failure detection via, 88
MPLS-TP and, 320–330
T-MPLS and, 289–290
Operations, Administrations, Maintenance, and Provisioning (OAMP) capabilities
availability and, 221–224
with Carrier Ethernet, 109, 114, 181–233
Continuity Check Messages in, 198–202
Ethernet alarm indication signal in, 210–213
Ethernet locked signal in, 214–215
Ethernet remote defective indication in, 213–214
frame delay measurements and, 224–225
functions and standards for, 181–183
interframe delay variation measurements and, 225–226
link OAM, 183–187
link trace and reply messages in, 206–212
loopback and reply messages in, 202–208
loss measurements for, 218–221
maintenance entities in, 188–190
maintenance point in, 190–193
need for, 233
OAM addressing and frame format for, 193–198
OAM bandwidth, 232
performance measurements for, 215–217
performance monitoring in, 217–218
security and, 232
service OAM, 186–188
for testing, 225–232
with T-MPLS, 301
Operations and maintenance (OAM), of pseudowires, 81–83. See also Operations, Administrations, and Maintenance (OAM) capabilities
Operator Support System (OSS), 183
Operator Virtual Connections/Connectors (OVCs), 3–4
alarm indication signals and, 213
CESoETH service configuration and, 245–246
ENNI and, 134–136
in loss measurement, 218
in performance measurement, 215
service availability and, 222
in testing, 231
with VUNI/RUNI, 136–138
Optical fibers
for Gigabit Ethernet, 22
types of, 20
Optical transport network (OTN), MPLS-TP and, 304. See also OTN networks
Optional TLVs, in IEEE 802.1AB frame format, 268–269. See also TLVs (Type, Length, Value)
Organizationally specific TLVs, in IEEE 802.1AB frame format, 269. See also TLVs (Type, Length, Value)
Organizational unique identifier (OUI), 28
Organization-specific slow protocol (OSSP), 58
OriginMAC address, link trace and reply messages and, 209
OSI layer, end-to-end Carrier Ethernet connections and, 282
OTN networks, impact of packet network impairments on, 55. See also Optical transport network (OTN)
Out-of-order delivery, control-plane service and, 72–73
Out-of-sequence frames, with CESoETH, 244
Out-of-service diagnostic tests, loopback messages/replies and, 203
Out-of-service ETH-Test, locked signals and, 214
Out-of-service measurements, 217
Out-of-service testing, 229
Out-of-service throughput testing, MPLS-TP OAM and, 328
OVC attributes. See also Operator Virtual Connections/Connectors (OVCs)
of access EPL and EVPL services, 155–156
Color Forwarding and, 156
OVC End Point (OEP, OVC EP), 134–135
OVC EP attributes, of access EPL and EVPL services, 155–156
OVC EP Identifier, 135
Packet-based clocking methods, 51–52
Packet conditioning, 4, 158–159
Packet corruption, control-plane service and, 72–73
Packet error ratio, packet network impairments and, 56
Packet forwarding, MPLS-TP and, 308
Packet loss
control-plane service and, 72–73
MPLS-TP and, 305
Packet loss ratio, packet network impairments and, 56
Packet network impairments, impact on synchronization, 55–56
Packet networks
clocking methods for synchronization in, 54
precision time protocols for, 45
synchronization and, 34–35
timing distribution via time stamps in, 53
Packet payload, with pseudowires, 64–65
Packet payload, with pseudowires, 64–65
Packet payload, with pseudowires, 64–65
Packet payload, with pseudowires, 64–65
Packet streams, IWF synchronization function and, 57
Packet switched network (PSN), 303. See also PSN entries
in multisegment architecture, 74–77
Pseudowires and, 63
PW demultiplexer layer and, 71
Packet transfer delay, packet network impairments and, 55–56
Padding, in ETH Layer Characteristic Information, 117
Parameters, for ELMI, 257–260
Parser, in link aggregation, 105
Partially Active EVC Status, ELMI protocol and, 249, 251. See also Ethernet Virtual Circuits/Connectors (EVCs)
Passive LACP packet exchange mode, 104. See also Link aggregation control protocol (LACP)
Passive Provider Edge (PE), multisegment pseudowire setup and, 78
Path layer, in Ethernet, 111
Path Segment Tunnels (PSTs), MPLS-TP OAM and, 321–322
PAUSE, 16
PAUSE control, 161
Pause Threshold, 161
Payload
control-plane service and, 72–74
in Ethernet frames, 27
in IEEE 802.1ah frame format, 272
Payload-agnostic service, 40
Payload-aware emulations, synchronization and, 37
Payload convergence layer, 68–70, 73–74
Payload size, in CESoETH configuration, 245
Payload type mismatch, control-plane service and, 72
Payload types, with pseudowires, 64–65
PBB model, provider backbone transport and, 279. See also Provider backbone bridges (PBBs)
PBB protocol, 264
PBB-TE networks, provider backbone transport in, 284–286. See also Provider backbone bridging traffic engineering (PBB-TE)
PBB-TE protocols, 280
PBB-TE topology, 284
PBB-TE trunks, 284–285
PB networks, spanning trees for, 274–275. See also Provider Bridged Networks (PBNs)
PBT domain, 278. See also Provider backbone transport (PBT)
PBT–MPLS interworking, 285–286
PBT packets, 279
PBT-TE protection, 279
PBT tunnels, 263, 278–279
PCP mapping, 175–177, classes of service and, 163–164. See also Priority Code Point (PCP)
PCP values, for color, 177
PDH networks, impact of packet network impairments on, 55. See also T-MPLS-over-plesiosynchronous digital hierarchy (PDH, MoP)
PDH timing requirements, synchronization and, 35
PE devices. See also Provider Edges (PEs) in hierarchical VPLS, 312, 314–315
Virtual Private Networks and, 336, 337
PE discovery, Virtual Private Networks and, 337
PE discovery/signaling, 12
PE equipment failure, dual homing protection against, 352–353
Peer MPs, loopback messages/replies and, 202–206. See also Maintenance points (MPs)
PE nodes, in MPLS-TP architecture, 312, 314–315
Penultimate Hop Popping (PHP), 10. See also PHP option with MPLS-TP, 304–305
MPLS-TP data plane and, 311
with T-MPLS, 289–290
Performance, synchronization and, 34
Performance measurements, 6, 215–217
Performance monitoring, 217–218
of CESoETH, 245
MPLS-TP OAM and, 321
Performance tiers (PTs), service level agreements and, 5, 168–170
Per-Hop Behavior (PHB). See PHB mapping
Periodicity of AIS frames, 210
of LCK frame transmission, 215
Periodic measurements, 217
Periodic polling process, for ELMI, 260
Permanent Virtual Circuit (PVC), Ethernet Virtual Connection and, 128
PE routers, 13. See also Provider Edge (PE) routers within VPLS, 339
Phase error, stabilization period and, 56
Phase locked loop (PLL) process, 40
Phase synchronization, 37–39
PHB mapping, classes of service and, 163
PHP option, MPLS vs. T-MPLS, 291. See also Penultimate Hop Popping (PHP)
Physical access security, for Metro Ethernet, 232
Physical clocks, 33
Physical coding sublayer (PCS), 26
Physical (PHY) layer, 19–26
in Ethernet, 111
failure detection via, 88
in MPLS and T-MPLS networks, 292, 296
MPLS-TP OAM and, 322
sublayers of, 26
supporting pseudowires, 64, 69, 73–74
with Synchronous Ethernet networks, 51–52
timing technology with, 40
Physical layer local area network (LAN), 14
Physical medium, 19
Physical medium attachment (PMA), 26
Physical medium-dependent (PMD) sublayer, 26
Pipe tunnel mode, 290
Plesiochronous clocking methods, 51
PMA interfaces, 26
Points of Presence (PoPs), with Carrier Ethernet, 110
Point-to-multipoint EVC, 130. See also Ethernet Virtual Circuits/Connectors (EVCs)
service providers and, 138–139
Point-to-multipoint LSPs, MPLS-TP data plane and, 310–311. See also Label switched paths (LSPs)
Point-to-multipoint multicast, MPLS-TP and, 305
Point-to-multipoint services, with PBB-TE network, 284
Point-to-point constant bit rate service, circuit emulation service as, 235
Point-to-point Ethernet connections, Maintenance Entity Group for, 188
Point-to-point EVCs, 129. See also Ethernet Virtual Circuits/Connectors (EVCs)
  frame loss ratio for, 168
  performance monitoring and, 217
  service level agreements for, 169–170
  service providers and, 138–139
Point-to-point EVC status, ELM1 protocol and, 249
Point-to-point LSPs. See also Label switched paths (LSPs)
  MPLS-TP and, 307
  MPLS-TP data plane and, 310–311
Point-to-point services, with PBB-TE network, 284
Point-to-point VPNs, 333. See also Virtual Private Networks (VPNs)
Police, 160–161
Policing, in Carrier Ethernet, 160–161
Policing function, MPLS-TP OAM and, 323
Polling Counter, for ELM1, 259
Polling Timer, for ELM1, 258–259
Polling Verification Timer, for ELM1, 259
Port-based Carrier Ethernet services, 139
Port ID TLV, in IEEE 802.1AB frame format, 268. See also TLVs (Type, Length, Value)
Port-level testing, 186
Port priority, 107
Ports, 133. See also Customer backbone ports (CBPs)
  in EPSR domain, 97–98
  Ethernet protocol stack and, 115
  flow control on, 161
  in LAGs, 103–104
  in link aggregation, 106–107
as maintenance points, 190
  in testing, 231–232
Port Status TLV, CCM frames and, 200.
  See also TLVs (Type, Length, Value)
Power failures, Dying Gasp message during, 184, 186
Preamble, in ETH Layer Characteristic Information, 117, 119
Preamble field, in Ethernet II frame, 29–30
Precision time protocols (PTPs), 2, 44–51, 61
data format for, 45
IEEE 1588 and, 50
Prefix
  for classification function, 158
  in EVC ID, 132
Preprocessing (PREP) functionality, 66–67
Primary clock signal, synchronization and, 33–34
Primary LSP, with T-MPLS networks, 296. See also Label switched paths (LSPs)
Primary reference clock (PRC), 2, 33–34
IEEE 1588v2 and, 49
in synchronization, 57–58
with Synchronous Ethernet, 52–54
Priority
  in loss measurement, 220
  in testing, 227
Priority Code Point (PCP)
  color identification via, 172
  ETH Layer Characteristic Information and, 120
Priority Code Point (PCP, I-PCP) field, 131, 171
  in IEEE 802.1ah frame format, 273
Priority of frame as CCM attribute, 199
  loopback messages/replies and, 204
Proactive DM, MPLS-TP OAM and, 328.
  See also Delay measurement (DM)
Proactive LM, MPLS-TP OAM and, 325–328
Proactive OAM frames, protection switching control and, 93. See also Operations, Administrations, and Maintenance (OAM) capabilities
Procedures, for ELMI, 257–260
Promiscuous mode, of Ethernet adapter cards, 28
Protected LSPs, MPLS-TP architecture and, 309. *See also* Label switched paths (LSPs)
Protecting entities
  in 1:1 protection, 91–92
  in 1+1 protection, 89–91
Protection
  via dual homing, 352–353
  with Ethernet, 2–3
  with T-MPLS, 296–301
Protection channels, automatic protection switching and, 87
Protection entity
  automatic protection switching and, 87–88
  revertive and nonrevertive modes and, 94
Protection operation mode, with T-MPLS, 298–299
Protection paths, in automatic protection switching, 88
Protection State Coordination (PSC) mechanism, MPLS-TP support for, 330
Protection switches, forcing, 88
Protection switching, 86, 300–301
  importance of, 108
  MPLS-TP OAM and, 327
  MPLS-TP support for, 330
  in ring protection, 99–102
  types of, 89, 95–96
Protection switching control, via Ethernet OAM PDU, 93
Protection switching triggers, 89, 92–93
Protection switching types, with T-MPLS, 300
Protocol data units (PDUs), 6. *See also* ESMC information PDUs
  ELMI parameters and procedures and, 258
  in Ethernet, 114
  ETH Layer Characteristic Information and, 119
  ETH Layer functions and, 123
  frame delay measurement and, 225
  payload convergence layer and, 68–70
  performance monitoring and, 217–218
  protection switching triggers and, 93
  in pseudowire architecture, 66
  in pseudowire operations and maintenance, 81
  pseudowires and, 63
  in pseudowire security, 83
  PW demultiplexer layer and, 70–71
  in testing, 227–228
Protocol layers, supporting pseudowires, 63–64
Protocols
  Ethernet, 182–183
  MPLS vs. T-MPLS, 290–291
  for PBB-TE, 280
  for T-MPLS, 289
Protocol stack, for Carrier Ethernet, 114–117
Protocol stack reference model, 63–64, 67
  MPLS-TP G-ACh and, 317–318
Protocol Version ELMI message element, 252
Provider Backbone Bridge Edge, 277. *See also* Provider Backbone Edge Bridge (PBE)
Provider Backbone Bridge Network (PBBN), 9, 273, 274–278, 284
Provider backbone bridges (PBBs), 1, 8–9, 262, 270–278. *See also* PBB entries
  IEEE 802.1ah frame format for, 271–274
  operation and applications of, 270–271, 287
  principles of operation of, 274
  in provider backbone bridge network, 274–278
Provider backbone bridging traffic engineering (PBB-TE), 263, 278. *See also* Forwarding Model PBB-TE; PBB-TE entries
Provider Backbone Core Bridges (PBCBs), provider backbone transport and, 281–282
Provider Backbone Edge Bridge (PBE), 271, 274
  in end-to-end Carrier Ethernet connections, 282
Index

Provider backbone transport and, 281–282
Provider backbone transport (PBT), 1, 8–9, 262–263, 278–286
in end-to-end Carrier Ethernet, 282–283
implementation of, 281
operation and applications of, 278–280, 287
in PBB-TE network, 284–286
in PBT–MPLS interworking, 285–286
principles of operation of, 280–282
underlying protocols for, 263–264
uses of, 287
Provider bridge (PB) frames, 8
Provider Bridged Networks (PBNs), 276.
See also PB networks
Provider bridges (PBs), 262
Provider bridge technology, in Carrier Ethernet, 262–287
Provider Edge (PE) routers, 11–13. See also PE routers
in MPLS-TP architecture, 311
Provider Edges (PEs), 84
in BGP-based VPLS autodiscovery, 354
in BGP-based VPLS signaling, 354–355
in BGP VPLS operation, 357–358
in Ethernet access networks, 353
in Ethernet PW data forwarding, 347–348
in hierarchical VPLS, 349–353
in LDP-based signaling, 345
in LDP-based VPLS, 340–342
in LDP-based VPLS discovery, 342–345
in pseudowire architecture, 65–68
in PWE3 maintenance reference model, 71–72
PWE3 preprocessing and, 66
supporting pseudowires, 63
Virtual Private Networks and, 335–337
within VPLS, 339–340
in VPLS BGP NLRI, 356
in VPWS, 352
Provider link state bridging (PLSB), provider backbone transport and, 280
Provider Network Port(s), 9
Provider (P) router, 11
Provider VLANs (P-VLANs). See also Virtual Local Area Networks (VLANs)
in Ethernet access networks, 353
in hierarchical VPLS, 351
Provisionable hold-off timer, 96
Pseudowire (PW) data plane architecture, 304
Pseudowire (PW) routers, in MPLS-TP architecture, 312
in MPLS-TP architecture, 312
Pseudowire edge-to-edge emulation (PWE3), 84. See also PWE3 entries
MPLS-TP control plane and, 317–319
in multisegment architecture, 76–77
Pseudowire Emulation Edge-to-Edge (PW3), 2, 63, 84
MPLS, T-MPLS, and MPLS-TP and, 303–304
Pseudowires (PWs), 1, 2, 12–13, 63–85, 234. See also PW entries
advantages of, 84
applications of, 63
architecture of, 65–72
congestion control for, 80–81
data forwarding on, 347–348
control plane services for, 72–74
in hierarchical VPLS, 349–353
data forwarding on, 347–348
in LDP-based signaling, 345–347
in LDP-based VPLS, 340–343
in LDP-based VPLS discovery, 342–345
MPLS frame format and, 307
MPLS-TP architecture and, 308, 313–314
MPLS-TP control plane and, 317–319
MPLS-TP data plane and, 310
MPLS-TP G-ACh and, 317–318
MPLS-TP protection switching and, 330
in multisegment architecture, 74–77
multisegment setup mechanisms for, 77–79
operations and maintenance of, 81–83
payload types with, 64–65
protocol layers supporting, 63–64
provider backbone transport and, 280
quality of service with, 80–81
resiliency with, 80
Pseudowires (PWs) (cont’d)
  security of, 83–84
  T-MPLS and, 288
Pseudowire tunnels, in PBT–MPLS
  interworking, 285–286
PSN convergence layer, 63–64, 69,
  73–74. See also Packet switched
  network (PSN)
PSN Layer, 71
PSN TE tunnels, in multisegment
  architecture, 77
PSN tunnels
  in multisegment architecture, 76
  in pseudowire architecture, 65–66
  in pseudowire security, 83
  in PWE3 maintenance reference model,
    71–72
  quality of service/congestion control
    and, 80
PTP frames, IEEE 1588 and, 50. See also
  Precision time protocols (PTPs)
PTP protocol, IEEE 1588 and, 50
  PTPv2, 44–45
Public-key cryptography, with NTPv4, 41
Pull-out range, of EEC clocks, 60
PW associations, in LDP-based VPLS
  discovery, 344. See also Pseudowires
  (PWs)
PW demultiplexer (Demux) label,
  MPLS-TP architecture and, 314
PW demultiplexer layer, 63–64, 69,
  70–71, 73–74
PWE3 control-plane services, 72–74
  See also Pseudowire edge-to-edge
  emulation (PWE3)
PWE3 encapsulation layer, 68–70
PWE3 maintenance reference model,
  71–72
PWE3 Network Reference Model, 67
PWE3 over an IP PSN protocol structure,
  73
PWE3 over an MPLS PSN protocol
  structure, 73–74
PWE3 preprocessing, in pseudowire
  architecture, 66–68
PWE3 protocol stack reference model,
  63–64
PWE3 signaling protocols, in
  multisegment architecture, 77
PW encapsulation layer, 68–70
PW forwarder, in MPLS-TP architecture,
  312
PW Grouping LTV, in LDP-based
  signaling, 346
PWid FEC elements, in LDP-based
  signaling, 345–347
PW labels, in LDP-based VPLS
  discovery, 344
PW layer, MPLS-TP OAM and, 322
PW link failure, dual homing protection
  against, 352–353
PW Maintenance Entity Group (PMEG),
  MPLS-TP OAM and, 324
PW MPLS label. See also Multiprotocol
  label switching (MPLS)
  multsegment pseudowire setup and, 78
  in pseudowire operations and
  maintenance, 82
PW over LSP monitoring, MPLS-TP
  OAM and, 325–326. See also Label
  switched paths (LSPs)
PW packets, in LDP-based VPLS
  discovery, 344
PW-PDUs. See Protocol data units (PDUs)
PW/PE maintenance, in PWE3
  maintenance reference model, 71–72
PW segments, resiliency with, 80
PW server layer, MPLS-TP architecture
  and, 308
PW setup, as control-plane service, 72
PW signaling, in multisegment
  architecture, 77
PW SPME MEG (PSMEG), MPLS-TP
  OAM and, 324. See also Subpath
  Maintenance Element/Entity (SPME)
PW switching
  multsegment architecture and, 74–77
  in pseudowire operations and
  maintenance, 82
PW switching interprovider reference
  model, 76
PW switching provider edge (S-PE),
  74–76
  multsegment pseudowire setup and,
    77–79
PW switching reference model, 75
PW teardown, as control-plane service,
Index

PW tunnels, in LDP-based VPLS discovery, 344
PW type, in LDP-based signaling, 347
Q-in-Q hierarchy, 8, 270
Q-in-Q networks, 121
QoS classes, 172. See also Quality of service (QoS)
QoS metrics, 263
QoS queues, in packet conditioning, 159–160
Qualified learning, within VPLS, 339–340
Quality level (QL). See also Clock QL of synchronization, 34
of system clocks, 58–59
Quality of service (QoS), 158, 177
with Carrier Ethernet, 110, 262
in end-to-end Carrier Ethernet connections, 282
MPLS-TP data plane and, 311
with pseudowires, 80–81
T-MPLS and, 290
Quality of service (QoS) attribute, 138
Queuing, 4
in Carrier Ethernet, 161
Quiet time, collision detection and, 16
Radio network controllers (RNCs), 236–237
Rapid Spanning Tree Protocol (RSTP), 86–87, 97
R-APS messages, timer and, 96–97. See also Automatic protection switching (APS)
R-APS PDUs, in ring failure operation, 102. See also Protocol data units (PDUs)
R bit, in CESoETH control word, 239–240
RDI field, 213. See also Remote Defect Indication (RDI)
Real Time Protocol (RTP), 43
Real Time Transport Control Protocol (RTCP), 43
Real-time transport protocol (RTP), 241
in CESoETH configuration, 246
Reassembly service, PW demultiplexer layer and, 71
Receive Time Stamp, frame delay measurement and, 224–225
Reconfiguration, 51
Recovery, of clocking information, 36–40
Recovery schemes, MPLS-TP protection switching and, 330
Recursive transport layer, in MPLS and T-MPLS networks, 292
Redundancy, in traffic protection, 86–87
Reference clock in network synchronous operation method, 54
for NTP, 41
Reference source selection mechanism, for Synchronous Ethernet, 58
Reference timing signal, 34
with Synchronous Ethernet, 52
Regional performance tier (PT2), 5. See also Performance tiers (PTs)
service level agreements and, 168–169
Reliability, Carrier Ethernet, 262
Reliability attribute, 138
Remote Authentication Dial-In User Service (RADIUS), 12
in LDP-based VPLS discovery, 344
Virtual Private Networks and, 337
Remote Defect Indication (RDI), 5, 213–214. See also AIS/RDI; Report discovered information (RDI)
Remote end MAC address discovery, 182
Remote Loss of Frames (LOFs), CESoETH control word and, 239–240
Remote terminals (RTs), in harsh environmental conditions, 26
Remote User–Network Interface (RUNI), 4, 136–138
Repeaters, 16–17
bridges and, 17
Report discovered information (RDI), 267
MPLS-TP data plane and, 328–329
Report Type IE ELMI message element, 252
Requested signal, 96
Research, on transport technologies, xiii–xiv
Reserved 1 (Res1) field, in IEEE 802.1ah frame format, 273
Reserved 2 (Res2) field, in IEEE 802.1ah frame format, 273
Resiliency, with pseudowires, 80
Resilient Packet Ring (RPR), 87
Resource Reservation Protocol–Traffic Engineering/Extension (RSVP-TE), 12
in LDP-based VPLS discovery, 344
MPLS-TP and, 304
Virtual Private Networks and, 337
Return path reference model, 322
Reverse Request function, with T-MPLS, 301
Revertive 1:1 protection, 92
Revertive modes
APS PDU format and, 94
in ring failure operation, 100–101
timer and, 96
with T-MPLS protection, 298–299
Revertive protection switching, 89
RFC 1242, on testing, 228
RFC 2544, on testing, 225–231
RFC 2764, on VPLS, 333
RFC 4364, on LDP-based VPLS discovery, 344
RFC 4761, on VPLS, 333–334
RFC 4762
on LDP-based VPLS discovery, 344
on VPLS, 334
Ring-based networks, traffic protection in, 87
RING-DOWN FLUSH-FBD message, 99
Ring failure condition, 98
Ring failure operation, 100
Ring-fault operation, 99
Ring links, 97–98, 101
Ring nodes, 97–98, 101
Ring ports, 97–98, 101
Ring protection architecture, 97–102
Ring Protection Link (RPL), 97–98, 101
Ring protection switching, with T-MPLS, 296
Rooted-multipoint EVCs, 130. See also Ethernet Virtual Circuits/Connectors (EVCs)
frame loss ratio for, 168
service providers and, 138–139
“Root” UNIs, 141, 143. See also User–Network Interface (UNI)
Round-trip delay (RTD), 224
Round-trip IFDV measurement, 225
Route reflectors (RRs)
in BGP-based VPLS autodiscovery, 354
in BGP-based VPLS signaling, 355
in hierarchical BGP, 359–360
Routers, IEEE 1588 and, 50. See also Autonomous system border router (ASBR); CE router; PE routers; Provider Edge (PE) routers; Provider (P) router; Pseudowire (PW) routers; Switching Provider Edge (S-PE) routers; Terminating Provider Edge (T-PE) router
Router types, in MPLS-TP architecture, 311–312
Route Target (RT), 13
in BGP-based VPLS, 353–354
Route tracing, MPLS-TP OAM and, 329–330
Routing, with VPLS, 11–13
Routing protocols, Virtual Private Networks and, 334–335
RPL Owner. See also Ring Protection Link (RPL)
in ring failure operation, 100, 101
in ring protection architecture, 98
RT format, 354. See also Route Target (RT)
RTP header, 243
in CESoETH control word, 240–241
RxFcB field, 199, 200, 218–219
RxFCl field, 220–221
RxFCl counter, in loss measurement, 218–220
S bit, MPLS-TP architecture and, 309
Scalability
Carrier Ethernet, 110, 262–263
Ethernet, 1, 8–9
maintenance points and, 191
NTP, 41
Scalability attribute, 138
Scheduling, in Carrier Ethernet, 161
SDH networks, impact of packet network impairments on, 55. See also Synchronous digital hierarchy (SDH)
Seamless edge-to-edge services, 285–286
Section layers, MPLS-TP data plane and, 310
Section Maintenance Entity Group (SMEG), MPLS-TP OAM and, 324
Security for Metro Ethernet, 232
MPLS-TP support for, 331
in provider backbone bridge network, 278
of pseudowires, 83–84
VPLS, 360
Segment Number, in EVC ID, 133
Selector, automatic protection switching and, 88
Selector bridge, with T-MPLS, 298
Sender ID TLV. See also TLVs (Type, Length, Value)
CCM frames and, 200
link trace and reply messages and, 209
loopback messages/replies and, 206
Sequence Numbers (SNs)
in CESoETH control word, 241
for ELMI, 259
Sequence Numbers IE ELMI message element, 252
Sequencing function, 70
Sequencing layer, 69–70, 73–74
Serial Number, in EVC ID, 133
Server layers
alarm indication signals and, 210, 212
MPLS-TP data plane and, 310
Server MEPs, 190
MPLS-TP OAM and, 323
Server stack, MPLS-TP architecture and, 316
Service access points (SAPs), 31
Service availability. See Availability
Service classes
ETSI-defined, 176
3G traffic, 175
Service clock
in network synchronous operation method, 54
with Synchronous Ethernet, 53
Service Code, in EVC ID, 132
Service Code Modifier, in EVC ID, 132
Service end points, circuit emulation service and, 235
Service frame disposition, UNI/EVC and, 130
Service frames, 3
color of, 172, 175
ETH Layer Characteristic Information and, 121
ETH Layer functions and, 122
frame delay for, 164–165
in loss measurement, 218
performance monitoring and, 217
in provider backbone bridge network, 278
service availability and, 223
Service frame transparency, UNI/EVC and, 130
Service functions, Ethernet OAM, 182
Service instance identifier (I-SID)
in provider backbone bridge network, 276–277
for provider backbone bridges, 270
provider backbone transport and, 282
Service Instance Identifier (I-SID) field, in IEEE 802.1ah frame format, 273–274
Service interfaces, in MPLS-TP architecture, 312–313
Service labels, MPLS-TP architecture and, 316–317
Service layer, PBB-TE and, 263
Service layer OAM capabilities, 5. See also Operations, Administrations, and Maintenance (OAM) capabilities
Service Level Agreements (SLAs), xiv, 5, 84, 181, 262
availability in, 221
within Carrier Ethernet, 110, 164–168
mileage-based, 168
with MPLS-TP, 304
in performance measurement, 215
performance monitoring for, 217
for service OAM, 187
Service Level Specifications (SLSs) performance monitoring and, 217
for service OAM, 187
Service LSP (SvcLSP) demultiplexer (Demux) label, MPLS-TP architecture and, 316. See also Label switched paths (LSPs)
Service LSP switching, MPLS-TP architecture for, 315
Service management, with provider backbone transport, 263
Service management attribute, 138
Service network partitioning, 190
Service node interface (SNI), for Carrier Ethernet, 124–125
Service OAM (SOAM), 186–188. See also Operations, Administrations, and Maintenance (OAM) capabilities; SOAM entries
Service providers (SPs)
Carrier Ethernet and, 109
in LDP-based VPLS discovery, 344–345
multisegment architecture and, 77 pseudowires and, 63
Virtual Private Networks and, 333
Service provider VLANs (S-VLANs), 189. See also Virtual Local Area Networks (VLANs)
Service specifications, Carrier Ethernet, 111–113
Service tag (S-Tag), 172
as CoS Identifier, 131
in Ethernet access networks, 353
ETH Layer Characteristic Information and, 120–121
Service testing, complete, 231–232
Service type, in CESoETH configuration, 245
Setup of PW, as control-plane service, 72. See also Pseudowires (PWs)
Shim header, in MPLS frame format, 306
Shortest path bridging (SPB), with PBB-TE network, 284
Short MA Name, 192–193. See also Maintenance Associations (MAs)
Short-pipe tunnel mode, 290
Short-service instance TAG, in IEEE 802.1ah frame format, 272
Signal amplification, 16
Signal degrade (SD)
APS detection of, 87–88
protection switching triggers and, 93 timer and, 96
Signal Degrades, with T-MPLS, 301
Signal fail condition, MPLS-TP data plane loopback and, 329
Signal Fail trigger, with T-MPLS, 301
Signal failure (SF)
APS detection of, 87–88
in ring failure operation, 100–101
protection switching triggers and, 93 timer and, 96
SignalFall condition, 202
Signaling, 354
in BGP-based VPLS, 354–355
failure indication via, 88
in hierarchical VPLS, 349
in LDP-based VPLS, 345–347
in PWE3 maintenance reference model, 71–72
Virtual Private Networks and, 337
Signaling Communication Channel (SCC), MPLS-TP G-ACh and, 317
Signaling frames, 243
Simple Network Management Protocol (SNMP), 17, 266. See also SNMP agents maintenance points and, 191–192
for provider backbone bridges, 271
Simple Network Time Protocol (SNTP), 40, 42, 44
Simple point-to-point service, PWE3 preprocessing and, 66–67
Single domains, end-to-end Carrier Ethernet connections with, 282–283
Single-ended FLR measurement, 218, 220
Single EVC Asynchronous Status, ELMI protocol and, 251. See also Ethernet Virtual Circuits/Connectors (EVCs)
Single-mode fiber, 20
Single-mode fiber ports, in link aggregation, 107
Single rate three color marking (SRTCM), in CoS flow policing, 160
Single-segment pseudowire (SS-PW)
MPLS-TP architecture for, 314
in pseudowire operations and maintenance, 81
quality of service/congestion control and, 80
64/65-octet encapsulation, 20
Slave clock accuracy, with NTP/SNTP, 42–43
Slave clocks
EEC, 60
frequency accuracy of, 59
in precision time protocols, 44–45, 46–51
Sliding windows, service availability and, 222–223
SM Delay, 47–48
SM_Time_Difference, 48–49
SNC protection, with T-MPLS, 301
SNMP agents, IEEE 802.1AB frame format and, 269–270. See also Simple Network Management Protocol (SNMP)
SOAM frame format, 195. See also Service OAM (SOAM)
SOAM PDUs, 190. See also Protocol data units (PDUs)
SOAM tools/procedures, 233
SOAM traffic, 190
in security, 232
somethingChangedLocal() procedure, 266
SONET cross-connect, PWE3 preprocessing and, 66. See also Synchronous Optical Network (SONET)
SONET paths, maintenance points and, 190
SONET/SDH. See also Synchronous digital hierarchy (SDH)
Carrier Ethernet and, 110
MPLS-TP and, 303–304
Source address (SA). See also Backbone source address (B-SA)
in Ethernet frames, 28
in IEEE 802.1AB frame format, 267
Source Attachment Individual Identifier (SAII), in LDP-based signaling, 346–347
Source clocks, IWF synchronization function and, 57
Source MAC (S-MAC) addresses (SAs). See also Media access control (MAC) in ETH Layer Characteristic Information, 117, 119
within VPLS, 339–340
Source MEPs, MPLS-TP OAM and, 327. See also Maintenance end points (MEPs)
Source service access point (SSAP) header, 25–26, 32
Spanning Tree Protocol (STP), 86–87, 97, 270. See also Multiple Spanning Tree Protocol (MSTP); Rapid Spanning Tree Protocol (RSTP); STP frames alarm indication signals and, 210
Carrier Ethernet and, 110
ETH Layer Characteristic Information and, 119
maintenance points and, 192
provider backbone transport and, 280
Virtual Private Networks and, 334
Spanning trees provider backbone transport and, 280 with provider backbone bridge, 274–275
SP bridge, 12
SP domains in pseudowire security, 83
Split horizon in hierarchical VPLS, 350
Split horizon rule, 339, 342
SP network, 12. See also Service providers (SPs); Switched paths (SPs)
Spoke PWs, in hierarchical VPLS, 349–352. See also Pseudowires (PWs)
SSRC value, in CESoETH configuration, 246
Stabilization period IWF synchronization function and, 57
in synchronization, 56–57
Stack, 21. See also Label stack entries;
LSP protocol stack; MPLS label stack; Protocol stack entries; PWE3 protocol stack reference model;
Server stack
Stack (S) field, in MPLS frame format, 306
S-Tag. 1
S-tagged ENNI, 135. See also External Network–Network Interfaces (ENNIs)
S-Tag PCP mapping, classes of service and, 163
Standalone synchronization equipment (SASE), 39
timing technology with, 40
Standardized Multi-CoS, xi. See also
Class of Service (CoS)
Standardized services attribute, 138
Standards
Carrier Ethernet, 111–113
Ethernet, 181–183
for service OAM, 186–188
synchronization, 36, 39–40, 61
StarLAN 1BASE5 Ethernet, 19
Star networks, traffic protection in,
86–87
Start frame delimiter (SFD), 3
in ETH Layer Characteristic
Information, 117
Star topology, 17
Static configuration, in pseudowire
security, 83
Static control-plane switching,
multisegment pseudowire setup and,
78–79
Static link aggregation configuration, 107
Static MPLS-TP, 304. See also
MPLS-Transport Profile (MPLS-TP)
Station and Media Access Control
Connectivity Discovery, 264
Status Counter, for ELMI, 259
STATUS ENQUIRY messages, 7, 8
ELMI protocol and, 249–251, 258–261
STATUS messages, 7
ELMI protocol and, 249–251, 259–261
Status monitoring, as control-plane
service, 72
Stochastic fluctuations, 51
Store and forward switches, 18
STP frames, in provider backbone bridge
network, 278. See also Spanning Tree
Protocol (STP)
Stratum-1 servers, with NTP, 41–42
Stratum-2 servers, with NTP, 41–42
Stratum-3 servers, with NTP, 41–42
Stratum-4 servers, with NTP, 42
Stratum clocking, accuracy requirements
for, 36
Stratum levels, in synchronization, 36
Structure-agnostic emulation, 242
Structure agnostic TDM over packet
(SAToP) standard, 7, 40. See also
Time-division multiplexing (TDM)
with CESoETH, 234–235
Structure-aware emulation, 242–243
Structured bit stream payload, with
pseudowires, 64–65
Structured emulation mode, CES in,
236
Subinformation element identifiers, ELMI
protocol and, 249, 250
Sublayer trail termination functions, with
T-MPLS, 300
Subnetwork Access Protocol (SNAP), 25.
See also IEEE 802.2 LLC/SNAP
frame
frame format with, 31–32
Subnetwork connection protection, with
T-MPLS, 300
Subpath Maintenance Element/Entity
(SPME)
MPLS-TP control plane and, 319–320
MPLS-TP OAM and, 321–325
Subscriber flows, Ethernet Virtual
Connection and, 130
Subsequent Address Family Identifier
(SAFI)
in BGP VPLS operation, 357
in VPLS BGP NLRI, 355
Suffix, in EVC ID, 133
Suspect flag, in performance
measurement, 216
S-VID (S-VLAN-ID) tag field, 8. See also
Virtual Local Area Networks
(VLANs)
S-VID mapping, in provider backbone
bridge network, 276–277
S-VLAN components, in provider
backbone bridge network, 276–277. See also Virtual Local Area Networks
(VLANs)
S-VLAN IDs, 135
with VUNI/RUNI, 137
S-VLANs, 9
Switched paths (SPs), 12
Switches, 18–19
IEEE 1588 and, 50
in provider backbone transport,
278
with Synchronous Ethernet, 52
Switching
MPLS-TP OAM and, 325–326
multisegment pseudowire setup and, 78–79
in pseudowire operations and maintenance, 82
resiliency and, 80
in ring protection architecture, 98
in VPWS, 352
Switching point PE TLV (SP-PE TLV), 79. See also TLVs (Type, Length, Value)
in pseudowire operations and maintenance, 82–83
Switching provider edge (S-PE), 74–76
multisegment pseudowire setup and, 77–79
in pseudowire operations and maintenance, 81–82
in pseudowire security, 83–84
resiliency and, 80
Switching Provider Edge (S-PE) routers in MPLS-TP architecture, 311–312
MPLS-TP OAM and, 324–325
Switch ports, 19
Synchronization, 33–62
application requirements related to, 35–39, 61
basic principles of, 33–35, 61
with Carrier Ethernet, 110
in circuit emulation service, 241–242
clocking methods for, 54–55
Ethernet and, 2
frame delay measurement and, 225
impact of packet network impairments on, 55–56
network time protocols for, 40–43, 61
precision time protocols for, 44–51, 61
primary reference clock in, 57–58
stabilization period in, 56–57
standards for, 36, 39–40, 61
in Synchronous Ethernet networks, 51–61
Synchronization computation, 47
Synchronization (SYNC, sync, Sync) messages, 44–45
in IEEE 1588 clocking, 46–47
Synchronization function IWF, 57
packet network impairments and, 56
with Synchronous Ethernet, 52
Synchronization packets, IEEE 1588v2 and, 49
Synchronization status messaging (SSM), 58
Synchronous digital hierarchy (SDH), 10. See also SDH networks; SONET/SDH
Synchronous Ethernet operation modes with, 58–59
primary reference clock in, 57–58
timing technology with, 40
Synchronous Ethernet-Layer-1-embedded timing information, 39
Synchronous Ethernet (SyncE) networks, 2
synchronization in, 51–61
Synchronous operation mode, 58–59
Synchronous Optical Network (SONET), 5, 10, 25–26, 263. See also SONET entries
MPLS and, 288
pseudowires and, 65
Synchronous residual time stamp (SRTS), 35
in network synchronous operation method, 54
Sync supply units (SSUs), 53. See also Building integrated timing supplies/sync supply units (BITS/SSU)
Synthetic Loss Message (SLM), performance monitoring and, 218
Synthetic Loss Reply (SLR), performance monitoring and, 218
Synthetic OAM test frames, performance monitoring and, 217. See also Operations, Administrations, and Maintenance (OAM) capabilities
System clocks, 59
quality level of, 58–59
System priority, 107
Systems, synchronization among, 33–62
T1 circuits, synchronization and, 33–34
T1/E1 leased line. See also E1 circuits
PW demultiplexer layer and, 70–71
timing technology with, 40
Index

T1/T3 leased lines, 84
  pseudowires and, 63
Tag Control Identifier (TCI), in ETH Layer Characteristic Information, 118. See also TCI field
Tag Control Information (TCI), 31
Tag Protocol Identifier (TPID), 30–31
ETH Layer Characteristic Information and, 120, 121
Tags, in VPLS encapsulation, 338
Tail end
  automatic protection switching and, 88
  in 1:1 protection, 91–92
  in 1+1 protection, 89
  protection switching triggers and, 93
Tandem Connection Monitoring (TCM), MPLS-TP OAM and, 321–322
Tandem connections, MPLS-TP OAM and, 321–322
Target Attachment Individual Identifier (TAII), in LDP-based signaling, 346, 347
Targeted Label Distribution Protocol (T-LDP), MPLS-TP control plane and, 319
TargetMAC address, link trace and reply messages and, 208–209
Target switching time, with T-MPLS, 301
TCI field, ETH Layer Characteristic Information and, 120. See also Tag Control Identifier (TCI)
TDD mode, synchronization and, 39
TDM application signaling, 242–243. See also Time-division multiplexing (TDM)
TDM-based services, synchronization and, 35, 38
TDM Bit Rate, in CESoETH configuration, 245
TDM-bound IWFs
  CESoETH control word and, 239–240
  frame loss detection by, 244
  in performance monitoring, 245
  synchronization and, 241–242
TDM circuit emulation, 49
TDM circuits, in testing, 232
TDM circuit/service emulation, synchronization and, 37
TDM data, with CESoETH, 234
TDM end systems, in network synchronous operation method, 54–55
TDM line timing, 241
TDM networks, synchronization in, 33–35
TDM pseudowire over Ethernet, 235
TDM service
  synchronization standards and, 40
  with Synchronous Ethernet, 53
TDM service emulation, 235
TDM Service Processor (TSP), for CES, 237
TDM/SONET, 236–237
TDM transport, with CESoETH, 234
TDM virtual private line, 236
TD-SCDMA, time/phase requirements for, 39
Teardown of PW, as control-plane service, 72. See also Pseudowires (PWs)
Technology. See GPS timing technology;
Internal XO timing technology; LAN connectivity technology; LAN technology; Metro Ethernet technology; Multipair technologies;
Network technologies; Provider bridge technology; Timing technologies; Transport technologies
Telecom operators, 49
Telecom service providers, xii
Temperature hardening, 26–27
10BASE2 Ethernet, 19, 21
10BASE5 Ethernet, 19
10BASE-F Ethernet, 21
10BASE-T Ethernet, 19–21
10GBASE-ER Ethernet, 22, 24
10GBASE-EW Ethernet, 22, 24
10GBASE-LR Ethernet, 22, 24
10GBASE-LX4 Ethernet, 22, 24
10GBASE-R Ethernet, 25–26
10GBASE-SR Ethernet, 22, 24
10GBASE-SW Ethernet, 22, 24
10GBASE-T Ethernet, 22
10GBASE-W Ethernet, 26
10GBASE-X Ethernet, 25–26
10GBASE-X fiber interfaces, 24
10PASS-TS Ethernet, 20
Terabit Ethernet, 23
Terminal loopbacks, 187
Terminating PEs (T-PEs), 76–77
MPLS-TP OAM and, 323, 324–325
multisegment pseudowire setup and, 77–79
in pseudowire operations and maintenance, 81–83
in pseudowire security, 83–84
quality of service/congestion control and, 80–81
resiliency and, 80
Terminating Provider Edge (T-PE) router, in MPLS-TP architecture, 311–312
Termination flow points (TFPs)
Ethernet protocol stack and, 115–116
in ETH layer network, 118
Test frames, 228
Testing, 225–232
Test methodologies, Carrier Ethernet, 111, 113
Test packets, MPLS-TP OAM and, 328
Test signal (TST), 227–228. See also TST entries
ThinNet, 21
Third Generation Partnership Project (3GPP), synchronization and, 38
Three CoS model, 161–164
3G Traffic Service Classes, 175
3-phase protocol, with T-MPLS, 300
Threshold counters, in performance measurement, 216
Threshold crossing alerts (TCAs), 181
Throughput, testing, 229–230
Throughput testing, MPLS-TP OAM and, 328
Time, synchronization and, 35, 39
Time deviation (TDEV), of EEC clocks, 60
Time distribution, synchronization and, 35
Time-of-day (ToD)
in clocking information, 36–37
synchronization and, 38
Time-of-day clock synchronization, performance monitoring and, 218.
See also TOD master Clock sync accuracy
Time/phase distribution, 49
Timers
in linear protection, 96–97
in LLDPDU transmission, 266
Time sources, with NTP, 41
Time stamps, 53
in CESoETH configuration, 246
IEEE 1588v2 and, 49
in interframe delay variation measurement, 226
with NTP/SNTP, 42
synchronization and, 35
Timestamp values, 243
Time synchronization, 37–39
Time to live (TTL), with MPLS-TP, 305.
See also TTL PW label
Time to live (TTL) field
link trace and reply messages and, 208–209
in MPLS frame format, 306
T-MPLS and, 290
Time-to-Live (TTL) TLV, in IEEE 802.1AB frame format, 268. See also TLVs (Type, Length, Value)
Timing, MPLS-TP and, 306
Timing clock recovery algorithm, IEEE 1588v2 and, 49
Timing distribution, packet network impairments and, 55–56
Timing distribution networks, 34
Timing layer, 69, 73–74
Timing recovery
in network synchronous operation method, 54
with Synchronous Ethernet, 53–54
Timing references, stabilization period and, 56
Timing technologies, for circuit emulation services, 40
TLV Offset, protection switching control and, 93
TLV Offset field, in OAM PDUs, 196
TLVs (Type, Length, Value)
- for CCM PDUs, 198–200
- for CFM PDUs, 196–198
- in LDP-based signaling, 345–347
- in LDP-based VPLS, 341, 342
- for LLDP, 267–269
T-MPLS networks, 296–301. See also
- Transport MPLS (T-MPLS)
T-MPLS-over-ETH (MoE), 294
T-MPLS-over-optical transport hierarchy (OTH, MoO), 294–295
T-MPLS-over-plesiosynchronous digital hierarchy (PDH, MoP), 294–295
T-MPLS-over-resilient packet ring (RPR, MoR), 294
T-MPLS tunnels, 296–297
TOD master Clock sync accuracy, with
- NTP/SNTP, 42–43. See also
- Time-of-day entries
Token leaky bucket algorithms, 177–180
Token rates, in CoS flow policing, 160
- Tokens, in flow control, 161
Top label, in MPLS frame format, 306
Toy, Mehmet, xiv
Traffic Class, MPLS frame format and,
- 306
Traffic data, MPLS-TP OAM and, 321
Traffic-engineered provider backbone bridging. See Provider backbone bridging traffic engineering (PBB-TE)
Traffic engineering (TE), 8, 262–263
Traffic management, 4–5
- in Carrier Ethernet, 158–180
Traffic measurements, in performance measurement, 215
Traffic paths, MPLS-TP protection switching and, 330
Traffic unit groupings, Ethernet protocol stack and, 115
Traffic units, 94
Trailer, in Ethernet frames, 27
Trails, Ethernet protocol stack and, 115
Trail termination, automatic protection switching and, 88
Trail termination functions, with T-MPLS, 300
Trail termination point (TTP), in Ethernet, 114
"Tran Layer," xii
- for Carrier Ethernet, 123–126
- Transient response, of EEC clocks, 60, 61
- Transit delay, IEEE 1588v2 and, 49
- Transit nodes
- in EAPS ring, 87
- in ring failure operation, 99–100
- Transmission, of LLDPDU, 266–267
- Transmission channels, automatic protection switching in, 87
- Transmission links, synchronization and, 35
- Transmission time stamps, with
- NTP/SNTP, 42
- Transmit Time Stamps, frame delay measurement and, 224–225
- Transparent clocks, 37
- IEEE 1588 and, 50
- Transparent LAN service (TLS), Virtual Private Networks and, 333
- Transparent switches, IEEE 1588 and, 50
- Transport
- with Carrier Ethernet, 110
- of clocking information, 36–37
- Transport (Trans) LSP demultiplexer (Demux) label, MPLS-TP architecture and, 316. See also Label switched paths (LSPs)
- Transport Alert Label, MPLS frame format and, 307
- Transport connections, T-MPLS and, 289
- Transport Control Protocol (TCP), bandwidth profile and, 179
- Transport entities, Ethernet protocol stack and, 115
- Transport facility testing, 226
- Transport label, in MPLS frame format, 306
- Transport layers
- for LLDP, 265
- maintenance points and, 190
- in MPLS and T-MPLS networks, 292
- Transport LSP, MPLS-TP architecture and, 317. See also Label switched paths (LSPs)
- Transport MPLS (T-MPLS), 1, 9–11,
- 288–302. See also Multiprotocol
label switching (MPLS); T-MPLS entries
advantages and future of, 301–302
architecture of, 291–293
frame format/structure of, 294–296
history and uses of, 288–290
interfaces and, 293–294
MPLS-TP vs., 303
MPLS vs., 290–291
networks with, 296–301
protection with, 296–301
Transport Multiplexing Function (TMF),
for Carrier Ethernet, 124–125
Transport path layer, in MPLS-TP architecture, 312, 316
Transport paths, MPLS-TP OAM and,
321–323
Transport Service Instance, in MPLS-TP architecture, 312–313
Transport Services Layer
in Ethernet protocol stack, 114
in MPLS-TP architecture, 312, 316
Transport technologies. See also Network technologies
for access and backbone networks, xiii
Carrier Ethernet and, xii
research on, xiii–xiv
Triggers, for linear protection, 89,
92–93
True time, for NTP, 41
Trunk layer, T-MPLS, 296
Trunk links, for Carrier Ethernet, 123–126
TST frames, 195. See also Test signal (TST)
TST OAM PDU, in testing, 227–228. See also Operations, Administrations, and Maintenance (OAM) capabilities;
Protocol data units (PDUs)
TTL PW label, in pseudowire operations and maintenance, 82. See also Pseudowires (PWs); Time to live (TTL) entries
Tunneling, 263
Tunnel LSPs, 12. See also Label switched paths (LSPs)
Virtual Private Networks and, 334–335
Tunnel modes, 290
Tunnels, 4
in hierarchical VPLS, 349–350
MPLS-TP architecture and, 308–309
in multisegment architecture, 76–77
in provider backbone bridge network, 276–278
in provider backbone transport, 278
pseudowires and, 63
in pseudowire security, 83
with VUNI/RUNI, 137
Tunnel topology, in LDP-based VPLS, 341–342
Twisted-pair wiring, 19
bandwidth achievable on, 20
2BASE-TL Ethernet, 20–21
2-phase protocol, with T-MPLS, 300
Two rate three color marking (TRTCM) in CoS flow policing, 160
Two-way FD measurements, 225
Two-way frame delay, 224–225
Two-way synchronization methodology, 49–50, 52
TxFCb field, 199–200, 218–221
TxFCf field, 199–200, 218–220
TxFCI counter, in loss measurement, 218–220
Type code, in Ethernet II frame, 29
Type field
in IEEE 802.1AB frame format, 268
in LDP-based VPLS, 341, 342
Type values, for TLVs, 198
UDP/IP-Port: 42, 123. See also User Datagram Protocol (UDP)
Unavailability, 222
UnexpectedMEG condition, 201
UnexpectedMEP condition, 199, 202
UnexpectedPeriod condition, 202
UNI attributes. See also User–Network Interface (UNI)
of access EPL and EVPL services, 153–155
in CE-VLAN ID and CoS preservations, 156
of E-Line services, 143–145
of EP-Tree and EVP-Tree services, 150
Unicast bandwidth, switches and, 19
Unicast DA usage, 194–195. See also Destination addresses (DAs)
in testing, 227
Unicast destination MAC address, frame delay measurement and, 225
Unicast ETH-LB, 203–205
Unicast flow, in ETH layer network, 118
Unicast LBM frames, 204
Unicast LBR frames, 204
Unicast MAC address, in testing, 227. See also Media access control (MAC)
Unicast service frames
   Ethernet Virtual Connection and, 129–130
   ETH Layer Characteristic Information and, 121
UNI-C function
   for Carrier Ethernet, 124–125, 127–128
   ELM1 protocol and, 247–248, 251, 258–261
   in MPLS-TP architecture, 312
   service availability and, 222
Unidirectional 1+1 trail protection, with T-MPLS, 298–300
Unidirectional EAPS, 88. See also Ethernet automatic protection switching (EAPS)
Unidirectional linear protection architecture, 90–91
Unidirectional LSPs, MPLS-TP data plane and, 310–311. See also Label switched paths (LSPs)
Unidirectional MEs, MPLS-TP OAM and, 323. See also Maintenance entities (MEs)
Unidirectional point-to-point connections, MPLS-TP architecture and, 314
Unidirectional point-to-point transport paths, MPLS-TP OAM and, 323
Unidirectional protection switching, 88
Unidirectional protection types, 95–96
Uniform tunnel mode, 290
UNI frames, in packet conditioning, 159
UNI ID, 133
UNI identifier subinformation element, 257
UNI interface, for T-MPLS, 293
UNI-N function
   for Carrier Ethernet, 124–125, 127–128
   ELM1 protocol and, 247–248, 251, 258–261
   in MPLS-TP architecture, 312
UNI pairs, performance monitoring and, 217
UNI port speeds, 133
UNI service code modifiers, 133
UNI service codes, 133
UNI Status IE ELM1 message element, 253. See also Ethernet local management interface (ELMI)
UNI tunnel access (UTA), 136–137
UNIX operating system, NTP with, 41
Unknown (U) bit, in LDP-based VPLS, 341–342
Unknown packets, on LDP-based VPLS discovery, 345
Unqualified learning, within VPLS, 339
Unstructured emulation mode, CES in, 235–236
Untagged service frames, 171
Up MEP, 189. See also Maintenance end points (MEPs)
Upstream network failure conditions, 58
User data, in ETH Layer Characteristic Information, 117–119
User Datagram Protocol (UDP), 209. See also UDP/IP-Port: 123
User IDs, 232
User–Network Interface (UNI), 3–4, 140–141
   bandwidth profile and, 179–180
   for Carrier Ethernet, 124–125
   CES in, 236
   CESoETH at, 234
   CESoETH service configuration at, 245–246
   CoS identification and, 170–175
   ELM1 and, 7–8
   ELM1 protocol and, 247–248
   ENNI and, 133–134
   in Ethernet, 111
   Ethernet Virtual Connection and, 128–133
   ETH Layer functions and, 122
   frame delay performance and, 164–168
   in loss measurement, 218
   in MPLS-TP architecture, 312–313
   in packet conditioning, 159–160
   in performance measurement, 215–216
   performance monitoring and, 217
Index

413

protection switching at, 86
service availability and, 222–223
service providers and, 138
in testing, 231
types of, 128
User–Network Interface Tunnel Access (UTA), 4
UTC time base, 46

Value change status, in LLDPDU transmission, 267
Value field, in IEEE 802.1AB frame format, 268
Value range, for classification function, 158
VC labels, in hierarchical VPLS, 350. See also Virtual connection (VC) LSPs
VE IDs. See also Virtual private local area network service edge (VE)
in BGP VPLS operation, 357–358
in multi-AS VPLS, 359
Version field, in OAM PDUs, 196
Video on demand, protection for, 86
Virtual circuit connectivity verification (VCCV) functions, 79
MPLS-TP G-ACh and, 317–318
in pseudowire operations and maintenance, 81
Virtual connection (VC) LSPs, 12. See also Label switched paths (LSPs); VC labels
Virtual Local Area Networks (VLANs), 9, 109. See also VLAN entries
in link aggregation, 106
in packet conditioning, 159
provider backbone transport and, 279
in ring protection architecture, 97–98, 100, 102
Virtual Private Networks and, 334, 339–340
Virtual Private LAN Services (VPLSs), 333–361. See also Virtual private local area network service (VPLS); VPLS entries
advantages of, 337–338
applications and functionality of, 333–338, 361
BGP, 353–360
components of, 337
data plane of, 338–340
ENNI and, 360–361
hierarchical, 349–353
hierarchical BGP, 359–360
LDP-based, 340–353
multi-AS, 358–359
security in, 360
Virtual private local area network service (VPLS), 1, 11–13. See also Virtual Private LAN Services (VPLSs)
advantages of, 13
Virtual private local area network service edge (VE), 12. See also VE IDs; VPLS edge (VE)
Virtual Private Multicast Service (VPMS), MPLS-TP architecture and, 313
Virtual Private Networks (VPNs), 11, 140, 263
MPLS-based, 333
Virtual Private Routed Networks (VPRNs), 333
Virtual Private Wire Service (VPWS), 352
MPLS-TP architecture and, 313
Virtual User–Network Interface (VUNI), 4, 136–138
Virtual wire, 6
VLAN-based Carrier Ethernet services, 139. See also Virtual Local Area Networks (VLANs)
VLAN Identifier (VLAN ID, VID) in ETH Layer Characteristic Information, 118, 120
in provider backbone bridge network, 275
provider backbone transport and, 280, 281
with PBB-TE network, 284–285
VLAN ID filtering, in ring failure operation, 102
VLAN tag, 172
ETH Layer Characteristic Information and, 120
UNI/EVC and, 130
Voice over IP (VoIP), protection for, 86
VPLS BGP NLRI, 355–357. See also Border Gateway Protocol (BGP); Network Layer Reach-ability Information (NLRI); Virtual Private LAN Services (VPLSs)
VPLS-capable networks, 335
VPLS code module, 336
VPLS domains, 345
VPLS edge (VE), 339. See also VE IDs; Virtual private local area network service edge (VE)
VPLS encapsulation, 338
VPLS identifier, in Ethernet PW data forwarding, 347
VPLS operation, 357–358
VPLS packets, VPLS data plane and, 338–339
VPLS single-bridge domain, 335
VPLS-to-VPLS connections, in multi-AS VPLS, 358

Wait to Restore function, with T-MPLS, 301
Wait to Restore state, with T-MPLS, 299
Wait-to-restore (WTR) timer, 89
in linear protection, 96–97
revertive and nonrevertive modes and, 94, 96
in ring failure operation, 100
Wander generation bounds, of EEC clocks, 60
Wander requirements, synchronization and, 34–35
WAN interface sublayer (WIS), 25. See also Wide Area Networks (WANs)
WAN PHY applications, 23, 25–26. See also Ethernet PHY (EFY) layer network

Wave Division Multiplexing (WDM), MPLS-TP and, 304
WCDMA synchronization requirements, 37, 39
Wide Area Networks (WANs), xiii. See also WAN interface sublayer (WIS)
Carrier Ethernet for, 110
Ethernet and, 1
synchronization among, 34
User–Network Interface and, 127
WiMAX, synchronization and, 38–39
Windows operating systems, NTP with, 41
Working channels, automatic protection switching in, 87
Working entities automatic protection switching and, 87–88
in 1:1 protection, 91–92
in 1+1 protection, 89–91
protection switching triggers and, 93
revertive and nonrevertive modes and, 94
Working paths, in automatic protection switching, 88
WTR period, 96. See also Wait to Restore entries

XAU1 (10-Gb Ethernet attachment unit interface), 26
XSBI (10-Gb Ethernet 16-bit interface), 26