INDEX

Numerics

1+1 protection architecture (SDH), 254
4MD-xx.x cards, 336
10M-L1-xx.x/10M-xx.x service interface cards, 335
10T-L1-xx.x/10T-xx.x service interface cards, 335
32-Channel Wavelength Plan (100-GHz Spacing), ONS 15454 MSTP, 333
32DMX-O cards, 336
32MUX-O cards, 336
1550-nm loss-minimized fiber (ITU-T G.654), 72

A

A1 bytes (SDH), 225
A2 bytes (SDH), 225
access rings, 5
AD-1B-xx.x cards, 336
AD-1C-xx.x cards, 336
AD-2C-xx.x cards, 336
AD-4B-xx.x cards, 336
AD-4C-xx.x cards, 336
ADMs (add/drop multiplexers)
  linear ADMs, 419
    configuration, 356, 418–427, 508-517
    creating, 419–420
SDH (Synchronous Digital Hierarchy), 242–243
SONET, 176–177
Advanced MPLS Design and Implementation, 275
AIC-I cards, 720
AIS (alarm indication signal), 164
E1 signal format, 36
SDH, 237
superframes, 31
Alarm Browser, CTM (Cisco Transport Manager), 348–349
alarms
  AIS (alarm indication signal), 164
  E1 signal format, 36
  SDH, 237
  superframes, 31
  E1 signal format, 36–39
  ESF (extended superframe), 31–32
  SDH (Synchronous Digital Hierarchy), 235-236
  AIS (alarm indication signal), 237
  B1 errors, 238
  B2 errors, 238
  B3 errors, 238
  BIP-2 errors, 238
  LOF (loss-of-frame) alignment, 237
  LOP (loss-of-pointer) alignment, 237
  LOS (loss-of-signal) alarm, 237
  LSS (loss of sequence synchronization), 238
  OOF (out-of-frame) alignment, 237
  RDI (remote defect indication), 238
  REI (remote error indication), 237
  RFI (remote failure indication), 238
SDH (Synchronous Digital Hierarchy), 208
SF (superframe), 31–32
SONET, 140, 163
  AIS (alarm indication signal), 164
  B1 errors, 164
  B2 errors, 165
  B3 errors, 165
  BIP-2 errors, 165
  LOF (loss-of-frame) alignment, 163
  LOP (loss-of-pointer) state, 163
  LOS (loss-of-signal) alarm, 163
  LSS (loss of sequence synchronization), 165
  OOF (out-of-frame) alignment, 163
  RDI (remote defect indication), 164
  REI (remote error indication), 164
  RFI (remote failure indication), 164
A-law encoding, analog-to-digital conversion, 24
algorithms, fairness algorithm, RPRs (resilient packet rings), 292
amplifiers, WDM (wavelength-division multiplexing), 121–125
  distributed amplifiers, 124
  EDFAs (Erbium-Doped fiber amplifiers), 123
  hybrid amplifiers, 124
  RFAs (Raman fiber amplifiers), 124
analogue signals
digital signals, converting to, 21–24
electromagnetic interference (EMI), 21
  generating, 21
processing, 18-24
radio frequency interference (RFI), 21
reception, 21
AOTFs (acoustic optical tunable filters), optical
multiplexers, 117–118
applications, fiber-optics, 50
APS (automatic protection switching), 140, 157
SDH (Synchronous Digital Hierarchy), 253–255
SONET, 187–189
armored outside-plant cables, 58
arrayed waveguides, optical multiplexers, 115–116
asymmetrical delays, 198, 264
ATM, 275
ATM/SMDS, 3
A-to-Z provisioning, 429
attenuation
extrinsic attenuation, 66
fiber-optics, 64–67
intrinsic attenuation, 64
wavelengths, compared, 65
AU pointers, SDH (Synchronous Digital Overhead), 226
automatic protection switching (APS). See APS
(automatic protection switching)
automatically routed circuits, creating, 429–433
avalanche photodiodes, receivers, 127

B

B1 bytes (SDH), 225
B1 errors
SDH, 238
SONET, 164
B2 errors
SDH, 238
SONET, 165
B3 errors
SDH, 238
SONET, 165
background block error (BBE), E1 signal format, 36
Baird, John Logie, 49
band-separation method, WDM (wavelength
division multiplexing), 98
bandwidth
compounded growth matrix, 723
efficiency, improving, 10-11

management, RPRs (resilient packet rings),
spatial reuse, 292-293
normalized bandwidth calculations, 705
basic rate interface (BRI), ISDN, 39–40
BBE (background block error), E1 signal format, 36
BDCS (broadband digital cross-connect)
SDH (Synchronous Digital Hierarchy), 243–244
SONET, 178
Bell, Alexander Graham, 49
bend radius, fiber-optic cabling, 76–77
BERs (bit error rates), 127
bidirectional line-switched ring (BLSR). See BLSRs
(bidirectional line-switched ring)
bidirectional rings
SONET, 190–191
unidirectional rings, compared, 256–257
bidirectional traffic matrix, 703
bidirectional WDM, 96–98
band-separation method, 98
circulator method, 99
interleaving-filter method, 98–99
BIP, 157
BIP-2 errors
SDH, 238
SONET, 165
birefringence, 67
bit, 154
bit error rates (BERs), 127
bit errors, E1 signal format, 37
bit slips, E1 signal format, 37
bit-interleaved parity (BIP-24) bytes, 226
BITS Out references, 372
BLANK FMECs (front-mounted electrical
connections), 325
BLSR Ring Map Change dialog box, 399
BLSR Ring Map dialog box, 399
BLSR/MS-SPRing, implementing, 723
BLSRs (bidirectional line-switched rings), 6, 198-205
configuration, 356, 392–412
DCC terminations, creating, 395–396
K3 bytes, remapping, 397
linear ADMs, converting from, 423–427
nodes
adding, 404–406
failures, 201
removing, 407–409
ports, enabling, 396–397
provisioning, 397–400
subtending from, 417–418
trunk cards
installing, 394–395
moving, 409–412
upgrading, 400–402
UPSRs
subtending from, 415–416
subtending to, 414–415
Bragg resonance wavelengths, 107
BRI (basic rate interface), ISDN, 39–40
bridge group forwarding, configuration, 650–651
bridges
interface configuration, 643–645
SPRs, 279
byte stuffing, 224
cables (fiber-optic), 48
attenuation, 64–67
bend radius, 76–77
chromatic dispersion, 66–67
construction, 54–55
cross-phase modulation (XPM), 69
four-wave mixing (FWM), 69–70
glass fiber-optic cables, 55
interference, 64
jackets, 56
loose buffer cable plants, 76
minimum bend radius, 76
multifiber fiber-optic cables, 56–58
optical signal-to-noise ratio (OSNR), 68
PCS (plastic-clad silica) fiber-optic cables, 56
physics, 51–53
plastic fiber-optic cables, 55
polarization mode dispersion (PMD), 67–68
propagation modes, 58–63
self-phase modulation (SPM), 69
splicing, 75–76
stimulated Brillouin scattering (SBS), 70
stimulated Raman scattering (SRS), 70
submarine cable systems, 77
tensile loading, 76–77
termination, 48, 73–75
tight buffer cable plants, 76
calculations, normalized bandwidth calculations, 705
Call Reference Value (CRV) (1 or 2 octets) field (Q.931 header), 45
call setup, ISDN, 45
campus-to-central office (CO) traffic, 5
capacity planning, network design, 701–706
card view, CTC (Cisco Transport Controller), 342–343
CAS (channel-associated signaling), 26
case studies
multiservice metro optical SONET/SDH networks, 699–722
BLSR/MS-SPRing implementation, 723
capacity planning, 701–706
circuit provisioning, 722
delay analysis, 708–710
fiber plant analysis, 706–709
logical design, 712–716
design, 716–718
requirements analysis, 701
technology analysis, 710–712
upsizing, 723–730
SAN services, 731–732
C-band (conventional) optical frequency bands, WDM systems, 96
CCITT (Consultative Committee for International Telecommunications), 4
CCS (common channel signaling), 27
CDMA (code-division multiple access), 19
cell-switched data networks, 3
Change User dialog box, 366
channel banks, 26
TDM (time-division multiplexing), 47
channel spacing, WDM (wavelength division multiplexing), 99
channel-associated signaling, WDM (wavelength division multiplexing), 99
Chappe, Claude, 49
chirp, WDM transmitters, 111
cromatic dispersion compensation fiber-optics, 66–67
WDM (wavelength-division multiplexing), 134–136
Circuit Attributes dialog box, 433
Circuit Creation dialog box, 427, 433
Circuit Destination dialog box, 431
Circuit Name Search dialog box, 438
Circuit Source dialog box, 431
circuits, 428
  automatically routed circuits, creating, 429–433
  manually routed circuits, creating, 433–436
  monitor circuits, creating, 437–438
ONS 15454 circuits, searching for, 438–439
path traces, creating, 440–442
provisioning, 356, 428–444, 518–553
SNCP circuits, removing, 485
SONET DCC tunnels, provisioning, 442–444
unidirectional circuits, multiple drop creation, 436–437
UPSR circuits, editing, 439–440
Circuits on Span dialog box, 389
circuit-switched networks, 18, 25–26
  TDM (time-division multiplexing) signaling, 26–27
circulator method, WDM (wavelength division multiplexing), 99
circulators, optical multiplexers, 119
Cisco Transport Controller (CTC). See CTC (Cisco Transport Controller)
Cisco Transport Manager (CTM). See CTM (Cisco Transport Manager)
CLECs (competitive local-exchange carriers), 307
client software, CTM (Cisco Transport Manager), 345–346
  Alarm Browser, 348–349
  Domain Explorer, 346–347
  Network Map, 350–351
  Node View, 348–350
  Subnetwork Explorer, 347–348
clock slips, E1 signal format, 37
couplers, optical multiplexers, 119
cosmetic errors, E1 signal format, 37
code-division multiple access (CDMA), 19
collectors, access rings, aggregation, 5
COMET (Complete Optical Multiservice Edge and Transport), 306-307
common channel signaling (CCS), 27
Common Object Request Broker Architecture (CORBA), 206
communications systems, fiber-optics, 78
  receivers, 81–83
transmitters, 78–80
compensation, WDM (wavelength division multiplexing), 92,
133–134
competitive local-exchange carriers (CLECs), 307
Complete Optical Multiservice Edge and Transport (COMET), 306-307
compounded growth matrix, 723
configuration
  BLSRs (bidirectional line-switched rings), 356, 392-412
  linear ADMs
    SDH, 446, 508–517
    SONET, 356, 418-427
  MS-PRRing
    SDH, 485–502
    SONET, 446
  OSPF, 380–385, 474–478
  SNCP, SDH, 478–485
  subtending rings, 356, 413–418
  UPSR (unidirectional path-switched ring), 356–392
  DCC terminations, 387
console (CTC), 337
Consultative Committee for International Telegraph and Telephone (CCITT), 4
Control Panel, CTM (Cisco Transport Manager), 353
couplers, optical multiplexers, 119
core services, analog-to-digital conversions, 21–24
CoS (classes of service), RPRs (resilient packet rings), 291
circuit-switched networks, 18, 25–26
  DCC terminations, 387
  CREATE SDCCRTERMINATIONS dialog box, 387, 395, 415
  CREATE STATIC ROUTE dialog box, 379
Create User dialog box, 365
Create Virtual Link dialog box, 384
cross-connect systems, 428
  TDM (time-division multiplexing), 47
cross-phase modulation (XPM), fiber-optics, 69
CSU/DSU (channel service units/digital service units), TDM (time-division multiplexing), 46
CTC (Cisco Transport Controller), 306-307, 311, 336-338
  A-to-Z provisioning, 429
card view, 342–343
CTC console, 337
  default gateway, 377–378, 470
initial provisioning tasks
  SDH (Synchronous Digital Hierarchy), 447–449
  SONET, 357-359
multiple CTCs, static routes, 380–381
  network view, 340–342
  node view, 338–340
ONS nodes
  same IP subnet, 375–376
  searching for, 438-439
  separate IP subnet, 376
static routes, 473
CTM (Cisco Transport Manager), 306-307, 343-345
client software, 345–346
  Alarm Browser, 348–349
  Domain Explorer, 346–347
  Network Map, 350–351
  Node View, 348–350
  Subnetwork Explorer, 347–348
Control Panel, 353
NE Explorer, 351–353
customer demographics, design strategies, 697
customer rings, 5
customer service levels, design strategies, 697–698
customer service requirements, design strategies, 697
cutoff wavelengths, 61
CWDM (coarse wavelength-division multiplexing), 92, 100
  ITU grid, 92, 102–104
cyclic redundancy check (CRC) errors, E1 signal format, 38
D
D4 SF (superframe), 30
D5 ESF (extended superframe), 30
DACS (digital access and cross-connect system), 3, 26
  TDM (time-division multiplexing), 47
data communication channel/generic communication channel (DCC/GCC), AIC-I cards, 324
DBR (distributed Bragg reflector) lasers, WDM (wavelength-division multiplexing), 107–108
DCC/GCC (data communications channel/generic communication channel), AIC-I cards, 324
DCCs, 155, 226, 769
LDCCs (line DCCs), 442
SDCC (section DCC), 442
SONET DCC tunnels, provisioning, 442–444 terminations
  BLSR DCC terminations, creating, 395–396
  MS-SPRing, creating, 488–489
  UPSRs, configuration, 387
DCU (dispersion compensation module), 90
default gateway, CTC (Cisco Transport Console), 377–378
Define New Drop dialog box, 436
degraded minutes, E1 signal format, 38
delay analysis, network design, 708–710
Delete Circuit dialog box, 411
Delete User dialog box, 366
dense wavelength-division multiplexing (DWDM) infrastructures. See DWDM (dense wavelength-division multiplexing) infrastructures
  depressed-clad fiber, 61
descrambling techniques, 155
design strategies, 696
  customer demographics, 697
customer service levels, 697–698
customer service requirements, 697
  fiber infrastructure, 698
  parameters, 696
SANs, case study, 731-732
technology selection, 698–699
  vendor selection, 699
DFB (distributed feedback) lasers, WDM (wavelength-division multiplexing), 106–107

DGD (differential group delay), 67
dialog boxes
  BLSR Ring Map, 399
  BLSR Ring Map Change, 399
  Change User, 366
  Circuit Attributes, 433
  Circuit Creation, 427, 433
  Circuit Destination, 431
  Circuit Name Search, 438
  Circuit Source, 431
  Circuits on Span, 389
  Create Area Range, 384
  Create BLSR, 398
  Create DCC Tunnel Connection, 443
  Create Protection Group, 368
  Create SDCC Terminations, 387, 395, 415
  Create Static Route, 379
  Create User, 365
  Create Virtual Link, 384
  Define New Drop, 436
  Delete Circuit, 411
  Delete User, 366
  Edit Circuit, 437
  Edit Circuits, 436
  Upgrade BLSR, 401
dielectric jackets, fiber-optic cables, 57
differential group delay (DGD), 67
digital access and cross-connect system (DACS), 3, 26
digital loop carriers, SDH (Synchronous Digital Hierarchy), 245
digital signals, analog signals, converting from, 21–24
direct modulation, 111–112
dispersion, WDM (wavelength division multiplexing), 92, 133–134
  chromatic dispersion, 134, 136
  polarization mode dispersion, 136–138
  dispersion compensation module (DCU), 90
  dispersion-shifter fiber (ITU-T G.653), 71–72
distributed amplifiers, 124
distributed feedback (DFB), 107
diversity, SONET, 184–186
DLP (digital loop carriers), SONET, 179–180
Domain Explorer, CTM (Cisco Transport Manager), 346–347
double tagging, SPRs, 279
doubly clad fiber, 61
DPT (Dynamic Packet Transport), 275
RPRs (resilient packet rings), 288–290
DRI (dual-ring interconnect), 194–196, 260-261
drops, unidirectional circuits, creating for, 436–437
DS framing
  multiframing formats, 29–32
  T-carrier systems, 29
DS1 14-port cards, 720
DS1 signals, SDH (Synchronous Digital Hierarchy) multiplexing, 218
DS1/E1 FMECs (front-mounted electrical connections), 325
DS1-14 electrical cards, 314
DS1N-14 electrical cards, 314
DS2 signals, SDH (Synchronous Digital Hierarchy) multiplexing, 219
DS3 signals, SDH (Synchronous Digital Hierarchy) multiplexing, 220
DS3-12 electrical cards, 314
DS3-12E electrical cards, 315
DS3-N-12 electrical cards, 327
DS3N-12 electrical cards, 314
DS3N-12E electrical cards, 315
DS3XM-6 electrical cards, 315
dual-ring interconnect (DRI) architecture, 260–261
DWDM (dense wavelength-division multiplexing), 2, 13–16, 92, 101, 276
dynamic range, span analysis, 84
infrastructures, 306
ITU grid, 92, 102–104
lasers, 113
tunable lasers, 108–109

E

E1 bytes (SDH), 226
E1 FMECs (front-mounted electrical connections), 325
E1 signals, SDH (Synchronous Digital Hierarchy) multiplexing, 218–219
E-100 ports, provisioning, 566–567
E1000-2-G Ethernet cards, 318, 330
E100T-G Ethernet cards, 318, 330
E1-120NP FMECs (front-mounted electrical connections), 325
E1-120PROA FMECs (front-mounted electrical connections), 325
E1-120PROB FMECs (front-mounted electrical connections), 325
E1-42 electrical cards, 327
E1-N-14 electrical cards, 327
E2 orderwire bytes (SDH), 229
E3 signals SDH (Synchronous Digital Hierarchy) multiplexing, 219
E3/DS3 FMECs (front-mounted electrical connections), 325
E4 signals SDH (Synchronous Digital Hierarchy) multiplexing, 220
E-band (extended) optical frequency bands, WDM systems, 96
E-bit indication, E1 signal format, 38
EC1-12 electrical cards, 315
E-carrier system, 18, 32–34
alarms, 36, 38–39
CRC error checking, 36–37
errors, 36, 38–39
FAS (frame alignment signal), 34–35
MFAS (multi-frame alignment signal), 35–36
ECC (embedded communications channel), 155
echo cancellation, analog-to-digital conversions, 24
ECSA (Exchange Carriers Standards Association), 4
EDFAs (Erbium-Doped fiber amplifiers), 123
Edit Circuits dialog box, 436
editing
- protection groups, 369
- UPSR circuits, 439–440
users, 366
electrical card protection, 320, 331
electrical signals
SDH, 213–214
SONET, 140, 144–145
electromagnetic interference (EMI), analog signals, 21
embedded communications channel (ECC), 155
embedded operations channel (EOC), 155
encapsulation, Ethernet over SONET/SDH, 277
encoding analog-to-digital conversions, 23–24
Enterprise Systems Connection (ESCON), 3
environmental alarms, 720
EOC (embedded operations channel), 155
Erbium-Doped fiber amplifiers (EDFAs), 123
errored blocks, E1 signal format, 38
errored seconds (ES), E1 signal format, 38
ES (errored seconds), E1 signal format, 38
ESCNP mesh networks, SDH, 517–518
ESCON (Enterprise Systems Connection), 3
E-Series card ports, SPRs, 282
E-Series provisioning
- Ethernet over SDH, 556, 595–623
  - EtherSwitch point-to-point circuits, 597–603
  - EtherSwitch ports, 589–592
  - G1K-4 Ethernet ports, 587–589
  - hub-and-spoke Ethernet circuits, 607–611
  - MAC table information retrieval, 621
  - multicard EtherSwitch manual cross-connect, 615–618
  - ports, 596–597
  - RMON alarm thresholds creation, 622–623
  - single-card EtherSwitch manual cross-connect, 611–615
  - SPR (Shared Packet Ring), 603–606
  - STP (Spanning Tree Protocol) activation, 620–621
  - VLAN membership, 618–620
- Ethernet over SONET, 556, 565–584
  - E-100 ports, 566–567
  - EtherSwitch point-to-point circuits, 567–571
  - EtherSwitch SPR (shared packet ring), 571–574
  - hub-and-spoke Ethernet circuits, 574–577
  - MAC table information retrieval, 584
  - multicard EtherSwitch manual cross-connect, 579–581
  - RMON alarm thresholds, 584
  - single-card EtherSwitch manual cross-connect, 577–579
  - Spanning Tree Protocol activation, 582–584
  - VLAN membership, 581–582
ESF (extended superframe), 30–31, 171
alarms, 31–32
ESNCP (Extended SNCP) mesh networks, 446
Ethernet, 274–276
encapsulation, SONET/SDH, 11–12
GE (Gigabit Ethernet), 274–275
ML-series cards
accessing, 628–632
bridge group forwarding, 650–651
bridge interface configuration, 643–645
Fast Ethernet interface configuration, 634
IEE 802.1Q tunneling, 656–661
IOS command modes, 632–633
IP protocols, 672–673
Layer 2 tunneling, 656–658, 661–663
link aggregation, 663–664
POS channels, 664–667
POS interface configuration, 636–643
provisioning, 624–653, 655–669,
QoS, 673–674
RPR (resilient packet ring), 674–691
STP configuration, 645–650
switching database manager, 691–692
VACT (virtual concatenation), 691
VLAN configuration, 651–655
VRF lite, 667–669, 671
MSPPs (multiservice provisioning platforms), 274
RPRs (resilient packet rings), 274, 287–290
bandwidth management, 292–293
CoS (classes of service), 291
DPT (Dynamic Packet Transport), 288–290
fairness algorithm, 292
layer management, 303
MAC (Media Access Control), 294–303
OAM functions, 303
rerouting, 293–294
topology discovery, 290–291
traffic protection, 293–294
SONET/SDH, 556
SPRs (shared packet rings), 274, 277–281
design constraints, 281–282
E-Series card ports, 282
matching nodes, 286
ML-Series card ports, 283–285
Ethernet over SDH, 557
E-Series provisioning, 556, 595–623
EtherSwitch point-to-point circuits, 597–603
hub-and-spoke Ethernet circuits, 607–611
MAC table information retrieval, 621
multicard EtherSwitch manual cross-connect, 615–618
ports, 596–597
single-card EtherSwitch manual cross-connect, 611–615
SPR (Shared Packet Ring), 603–606
STP (Spanning Tree Protocol) activation, 620–621
VLAN membership, 618–620
G-Series provisioning, 556, 585–595
EtherSwitch circuits, 589–592
G1K-4 Ethernet ports, 587–589
manual cross-connect, 592–595
RMON alarm thresholds, creating, 622–623
Ethernet over SONET, 557
E-Series provisioning, 556, 565–584
E-100 ports, 566–567
EtherSwitch point-to-point circuits, 567–571
EtherSwitch SPR (switched packet ring), 571–574
hub-and-spoke Ethernet circuits, 574–577
MAC table information retrieval, 584
multicard EtherSwitch manual cross-connect, 579–581
RMON alarm thresholds, 584
single-card EtherSwitch manual cross-connect, 577–579
Spanning Tree Protocol activation, 582–584
VLAN membership, 581–582
G-Series provisioning, 556–565
G1K-4 manual cross-connect provisioning, 563–565
G1K-4 point-to-point circuit provisioning, 561–563
G1K-4 port provisioning, 560–561
point-to-point circuits, 559
EtherSwitch, 568
  point-to-point circuits, provisioning, 567–571, 597–603
  single-card EtherSwitch manual cross-connect, provisioning, 577–579
  SPR (shared packet ring), provisioning, 571–574
Exchange Carriers Standards Association (ECSA), 4
extended superframe (ESF), 171
external cavity tunable lasers, 109
external modulation, 112–113
external timing, SDH (Synchronous Digital Hierarchy), 212
external tunable lasers, 109
extra traffic, 194, 254
extrinsic attenuation, 66

F
F1 bytes (SDH), 226
F2 bytes (SDH), 231
F3 bytes (SDH), 232
Fabry Perot cavity filters, optical multiplexers, 117
fairness algorithm, RPRs (resilient packet rings), 292
FALM (frame alarm), E1 signal format, 38
far-end block error (FEBE), 159, 237
FAS (frame alignment signal), E1 signal format, 34–35, 38
Fast Ethernet, interface configuration, ML-Series cards, 634
FC connectors, fiber-optic cable termination, 73
FDM (frequency-division multiplexing), 19
FEBE (far-end block error), 159
FEC (forward error correction), WDM (wavelength-division multiplexing), 128–130
fiber Bragg grating, optical multiplexers, 115
fiber diversity, SDH (Synchronous Digital Hierarchy), 250–252
fiber infrastructure, design strategies, 698
fiber plant analysis, network design, 706–709
fiber routing
  SDH, 250–252
  SONET, 184–186
fiber-optics
  applications, 50
  attenuation, 64–67
  cables, 48
    bend radius, 76–77
    benefits of, 4
    construction, 54–55
    glass fiber-optic cables, 55
    jackets, 56
    minimum bend radius, 76
    multifiber fiber-optic cables, 56–58
    PCS (plastic-clad silica) fiber-optic cables, 56
    plastic fiber-optic cables, 55
    propagation modes, 58–63
    splicing, 75–76
    submarine cable systems, 77
    tensile loading, 76–77
    termination, 48, 73–75
  chromatic dispersion, 66–67
  communications systems, 78
    receivers, 81–83
    transmitters, 78–80
  cross-phase modulation (XPM), 69
  fiber span analysis, 83
    dynamic range, 84
    margin calculations, 84–86
    MMF span analysis, 86–88
    power budget, 84–86
    receiver sensitivity, 84
    SMF span analysis, 88–89
    transmitter launch power, 83–84
  fiber-span analysis, 48
  four-wave mixing (FWM), 69–70
  history of, 49–50
  interference, 64
  ITU-T G.651 (multimode fiber with 50-micron fiber), 71
  ITU-T G.652 (nondispersion-shifted fiber), 71
  ITU-T G.653 (dispersion-shifter fiber), 71–72
  ITU-T G.654 (1550-nm loss-minimized fiber), 72
  ITU-T G.655 (nonzero dispersion shifted fiber), 72
  loose buffer cable plants, 76
  optical signal-to-noise ratio (OSNR), 68

performance considerations, 53
physics, 51–53
polarization mode dispersion (PMD), 67–68
propagation, 48
self-phase modulation (SPM), 69
splicing, 48
stimulated Brillouin scattering (SBS), 70
stimulated Raman scattering (SRS), 70
tight buffer cable plants, 76
types, 48
fibers, nodes, connecting to, 495
fiber-span analysis, 48
Fibre Channel, 3
FICON (Fibre Connectivity), 3
filtering analog-to-digital conversions, 22
Force command, 389
four-fiber BLSRs, 202–204
upgrading to, 400–402
four-fiber MS-SPRing, upgrading to, 497–499
four-fiber rings
SONET, 191–193
two-fiber rings, compared, 257–259
four-way mixing (FWM), fiber-optics, 69–70
frame alarm (FALM), E1 signal format, 38
frame alignment signal (FAS).
See FAS (frame alignment signal)
Frame Relay, SONET/SDH, 3
frame-switched data networks, SONET/SDH, 3
framing
SDH (Synchronous Digital Hierarchy),
208, 220–221
higher-level framing, 208, 239–241
pointers, 223
STM-1 frames, 221–222
tributaries, 222–223
SONET, 140, 148–149
STS-N framing, 151–153
frequencies, E1 signal format, 38
frequency slicers, optical multiplexers, 120
frequency-division multiplexing (FDM). See FDM (frequency-division multiplexing)

G

G1 bytes (SDH), 231
G1K-4 Ethernet cards, 319, 330, 557

H

H4 bytes (SDH), 231
Hansell, Clarence W., 49
hardware-ready cards, 413, 503
high priority (Class A) class of service, RPRs (resilient packet rings), 291
high-density polyethylene (HDPE) jackets,
fiber-optic cables, 57
higher-level framing, SDH (Synchronous Digital Hierarchy), 208, 239–241
Hopkins, Harold H., 49
hub topologies
SDH, 247–248
SONET, 182
hub-and-spoke Ethernet circuit provisioning, 574–577
Ethernet over SDH, 607–611
hybrid amplifiers, 124

IDTs (integrated digital terminals), 179
IEEE 802.1Q tunneling, ML-Series cards, 656–661
ILECs (incumbent local-exchange carriers), 307
in-band FEC, WDM (wavelength-division multiplexing), 128
incumbent local-exchange carriers (ILECs), 307
initial provisioning tasks
SDH, 447
basic node information, 449–450
CTC (Cisco Transport Controller), 447–449
network information setup, 450–452
security, 452–457
users, 452–457
SONET, 357
basic node information, 359–360
CTC Cisco Transport Controller), 357–359
IP network setup, 361–362
SDH, 446
security, 362–366
users, 362–366
insertion loss, ONS 15216, 726
inside-plant cables, 57
installation
BLSR trunk cards, 394–395
MS-SPRing trunk cards, 486–488
trunk cards, 479–481
UPSR trunk cards, 386
integrated digital loop carrier (IDLC), 245
integrated digital terminals (IDTs), 179, 245
integrated platforms, benefits of, 4
Integrated Services Digital Network (ISDN).
See ISDN (Integrated Services Digital Network)
integration, TDM signals, SONET, 141–143
inter-exchange carriers (IXCs), interoperability standards, 4
interference, fiber-optics, 64
interleavers, optical multiplexers, 120
interleaving-filter method, WDM (wavelength division multiplexing), 98–99
internal timing
SDH (Synchronous Digital Hierarchy), 212
setting up, 464–466
SONET, 373–374
International Telecommunication Union
Telecommunication Standardization Sector (ITU-T), 4
Internet Protocol Security (IPSec), 275
intersymbol interference (ISI), 134
initial provisioning tasks, 356
intrinsic attenuation, 64
raylight scattering, 65
inventories, nodes, 356
SDH, 466–467
inventories, ONS 15454 nodes, 374–375
IOS command modes, ML-Series cards, 632–633
IP (Internet Protocol), 556
configuration, SDH (Synchronous Digital Hierarchy), 450–452
initial provisioning tasks, 361–362
ML-series cards
accessing, 628–632
bridge group forwarding, 650–651
bridge interface configuration, 643–645
configuration, 672–673
Fast Ethernet interface configuration, 634
Gigabit Ethernet interface configuration, 635
IEEE 802.1Q tunneling, 656–661
IOS command modes, 632–633
Layer 2 tunneling, 656–658, 661–663
link aggregation, 663–664
POS channels, 664–667
POS interface configuration, 636–643
provisioning, 624–682
QoS, 673–674
RPR (resilient packet ring), 674–691
STP configuration, 645–650
switching database manager, 691–692
VACT (virtual concatenation), 691
VLAN configuration, 651–655
VRF lite, 667–669, 671
OAM&P, SDH nodes, 356, 375–385
IP subnets, CTC (Cisco Transport Console) ONS nodes, 375–376
IPSec (Internet Protocol Security), 275
ISDN (Integrated Services Digital Network), 18, 39
BRI (basic rate interface), 39–40
call setup, 45
layer 1, 41–42
layer 2, 42–44
layer 3, 44–45
link layer establishment, 44
PRI (primary rate interface), 40–41
ISI (intersymbol interference), 134
isolators, optical multiplexers, 119
ITU grid, 92
WDM (wavelength-division multiplexing) systems, 102–104
ITU-T (International Telecommunication Union Telecommunication Standardization Sector), 4
ITU-T G.651 (multimode fiber with 50-micron fiber), 71
ITU-T G.652 (nondispersion-shifted fiber), 71
ITU-T G.652.C (low water peak nondispersion-shifted fiber), 71
ITU-T G.653 (dispersion-shifter fiber), 71–72
ITU-T G.654 (1550-nm loss-minimized fiber), 72
ITU-T G.655 (nonzero dispersion shifted fiber), 72
IXCs (inter-exchange carriers), interoperability standards, 4

L

lasing thresholds, 106
Layer 1 (ISDN), 41–42
Layer 2 (ISDN), 42–44
Layer 2 tunneling, ML-Series cards, 656–663
Layer 3 (ISDN), 44–45
Layer 3 (OSI model), 44
layers
RPRs, managing, 303
SDH, 208
multiplex section, 215
path layers, 215
photonic layer, 216
regenerator section layer, 216
SONET, 140, 146
line layer, 147
path layer, 146–147
photonic layer, 148
section layer, 147
L-band (long wavelength) optical frequency bands, WDM systems, 96
LC connectors, fiber-optic cable termination, 74
LDCCs (line data communications channels), 205, 442
leased lines
carrier perspective, 26
customer perspective, 25
LEDs, 79–80
legacy SONET/SDH, 6–7
Length (1 octet) field (Q.931 header), 44
line data communications channel (LDCC), 205
line DCCs (LDCCs), 442
line layer (SONET), 140, 147
line overhead (LOH), SONET, 155–159
line switching, SONET, 193–194
line timing, SDH, 212
linear add/drop architectures, 181

J-K

J0 bytes (SDH), 154, 225
J1 path traces, creating, 440–442
J1 user-programmable bytes (SDH), 230
J2 bytes (SDH), 233
jackets, fiber-optic cables, 56
jitter, 212
K1 bytes (SDH), 227
K2 bytes (SDH), 227
K3 bytes, remapping
BLSRs, 397
SDH, 490
Kao, Charles K., 49
Keck, Donald, 50
linear ADMs, 419
   BLSRs, converting to, 423–427
   configuration
   SDH, 446, 508–517
   SONET, 356, 418–427
   creating, 419–420, 509–510
   MS-SPRings, converting to, 514–517
   SNCP rings, converting to, 510–513
   UPSRs, converting to, 420–423
   linear characteristics, fiber-optics, 64–68
   line-terminating equipment (LTE), 147
   link aggregation, ML-Series cards, 663–664
   link budgets, span loss, 83
   link layer establishment, ISDN, 44
   Lockout command, 389
   LOF (loss-of-frame) alignment
   SDH, 237
   SONET, 163
   LOFS (loss of frame seconds), E1 signal format, 38
   logical design, networks, 712–716
   LOH (line overhead), SONET, 155–159
   loop timing, 145, 212
   loose buffer cables, cable plants, compared, 76
   LOP (loss-of-pointer) alignment (SDH), 237
   LOP (loss-of-pointer) state (SONET), 163
   LOS (loss of signal) alarm, superframes, 32, 163, 237
   LOSS (loss of signal seconds), E1 signal format, 38
   loss of frame seconds (LOFS), E1 signal format, 38
   low priority (Class C) class of service, RPRs (resilient packet rings), 291
   low water peak nondispersion-shifted fiber (ITU-T G.652.C), 71
   LSS (loss of sequence synchronization)
   SDH, 238
   SONET, 165
   LTE (line-terminating equipment), 147

MacChesney, John, 50
Mach-Zehnder interferometers, 118–119
Mandatory and Optional Information Elements (variable length) field (Q.931 header), 45
MANs (metropolitan area networks), building, technology options, 275
manual cross-connect provisioning, 563–565
manually routed circuits, creating, 433–436
margin calculations, span analysis, 84–86
master clocks, 145
matching nodes, 177
SPRs, 286
material absorption, intrinsic attenuation, 64
Maurer, Robert, 50
mechanical tunable lasers, 108–109
medium priority (Class B) class of service, RPRs (resilient packet rings), 291
medium-density polyethylene (MDPE) jackets, fiber-optic cables, 57
meshed topologies
   SDH, 249–250
   SONET, 184
Message Type (1 octet) field (Q.931 header), 45
MetroPlanner DWDM optical design software, 334
MFAL (multiframe alarm), E1 signal format, 38
MFAS (multiframe alignment signal), E1 signal format, 35–38
MIC-C/T/P FMECs (front-mounted electrical connections), 325
minimum bend radius, fiber-optic cables, 76
ML1000-2 Ethernet cards, 319
ML1000-2 Gigabit Ethernet cards, 330
ML100T-12 Ethernet cards, 319, 330
ML-Series cards
   12-port cards, 721
   accessing, 628–632
   bridge group forwarding, 650–651
   bridge interface configuration, 643–645
   Fast Ethernet interface configuration, 634
   Gigabit Ethernet interface configuration, 635
   IEEE 802.1Q tunneling, 656–661
   IOS command modes, 632–633
   IP protocols, 672–673
   Layer 2 tunneling, 656–663
   link aggregation, 663–664
   POS channels, 664–667
   POS interface configuration, 636–643
   provisioning, 624–680, 682

M1 bytes (SDH), 228
MAC (Media Access Control)
   information
   retrieval, 621
   retrieving, 584
   RPRs (resilient packet rings), 294–303
QoS, 673–674
RPR (resilient packet ring), 674–691
SPRs, 283–285
STP configuration, 645–650
switching database manager, 691–692
VACT (virtual concatenation), 691
VLAN configuration, 651–655
VRF lite, 667–671
MMF span analysis, fiber-optics, 86–88
modulators, WDM transmitters, 111–113
monitor circuits, creating, 437–438
MR-L1-xx.x/MR-1-xx.x service interface cards, 335
MRP-L1-xx.x/MRP-1-xx.x service interface cards, 335
MSOH (Multiplex Section Overhead), SDH, 226–229
MSP (multiplex section protection), 6
MSPP (multiservice provisioning platforms), 4, 8–12, 274–275
bandwidth efficiency, 10–11
Ethernet encapsulation, 11–12
provisioning, 12
QoS (quality of service), 11
signaling, 12
SDH, 245–246, 446
SONET, 180, 356–357
MS-SPRing (multiplex section-shared protection rings), 6, 264–271
configuration
SDH, 485–502
SONET, 446
DCC terminations, creating, 488–489
linear ADMs, converting from, 514–517
nodes
adding, 492–496
removing, 496–497
ports, activating, 488–489
provisioning, SDH, 490–492
traffic, switching, 493
trunk cards
installing, 486–488
moving, 500–502
upgrading, 497–499
MSTP (Multiservice Transport Platform), 694
MTP/MPO connectors, fiber-optic cable termination, 75
MT-RJ connectors, fiber-optic cable termination, 74
MTSE (Multiplex Section-Terminating Equipment), 215
mu-law encoding, analog-to-digital conversions, 24
multicard EtherSwitch manual cross-connect, provisioning, 579–581, 615–618
multifiber fiber-optic cables, 56–58
multiframe alarm (MFAL), E1 signal format, 38
multiframe alignment signal (MFAS) distant alarm, E1 signal format, 38
multiframing formats, DS framing, 29–32
multimode fiber with 50-micron core (ITU-T G.651), 71
multimode graded index, fiber-optic cables, 62–63
multimode step index, fiber-optic cables, 59–60
multiple drops, unidirectional circuits, creating for, 436–437
multiplex section (SDH), 215
multiplex section protection (MSP), 6
multiplex section switching, path switching, compared, 259–260
multiplex section-shared protection rings (MS-SPRing), 264–271
Multiplex Section-Terminating Equipment (MSTE).
See MSTE (Multiplex Section-Terminating Equipment)
multiplexed section protection rings (MS-SPRing). See MS-SPRing (multiplexed section protection rings)
multiplexing
ADM (add/drop multiplexers), 94, 176–177
characteristics, 92
CWDM (coarse wavelength-division multiplexing), 100
DWDM (dense wavelength-division multiplexing), 2, 13–16, 101, 306
FDM (frequency-division multiplexing), 19
linear ADMs
configuration, 418–427, 446
configurations, 508–517
MSP (multiplex section protection), 6
MS-SPRing (multiplex section protection ring), 6
MSTE (multiplex section-terminating equipment), 215
optical multiplexers, 113–121
acousto optical tunable filters, 117–118
arrayed waveguides, 115–116
circulators, 119
couplers, 119
Fabry Perot cavity filters, 117
fiber Bragg grating, 115
frequency slicers, 120
interleavers, 120
isolators, 119
Mach-Zehnder interferometers, 118–119
periodic filters, 120
TFFs (thin film filters), 114–115
SDH (Synchronous Digital Hierarchy), 216–220
SONET, 140, 174–175
TDM (time-division multiplexing), 2, 18–20, 694
analog signal processing, 20–24
circuit-switched networks, 26–27
E-carrier system, 32–39
network elements, 46–47
schematics, 19
SDH integration, 209–214
SONET/SDH, 3
statistical TDM, 20
synchronous TDM, 20
T-carrier system, 27–32
TM (terminal multiplexers)
SONET, 176
WDM (wavelength-division multiplexing), 92–96, 104–105
amplifiers, 121–125
bidirectional WDM, 96–99
channel spacing, 99
characteristics, 127–133
compensation, 133–134
dispersion, 133–138
ITU grid, 102–104
multiplexers, 113–121
need for, 93
optical frequency bands, 96
optical multiplexers, 113–121
optical-fiber media, 125
receivers, 125–127
schematic, 94
systems, 94
transmission impairments, 92, 127–133
transmitters, 106–113
unidirectional WDM, 96–97
multiservice metro optical SONET/SDH networks, case study, 699–722
BLSR/MS-SPRing implementation, 723
capacity planning, 701–706
circuit provisioning, 722
delay analysis, 708–710
fiber plant analysis, 706–709
logical design, 712–716
physical design, 716–718
requirements analysis, 701
technology analysis, 710–712
upscaleing, 723–730
multiservice provisioning platforms (MSPPs). See
MSPPs (multiservice provisioning platforms)
Multiservice Transport Platform (MSTP). See
MSTP (Multiservice Transport Platform)

N

N1 bytes (SDH), 232
N2 bytes (SDH), 233
NE Explorer, CTM (Cisco Transport Manager), 351–353
negative stuffing, 224
negative timing justification, 156
NEs (network elements), 140
SDH, 208
add/drop multiplexers, 242–243
BDCS (broadband digital cross-connect), 243–244
digital loop carriers, 245
MSPPs (multiservice provisioning platforms), 245–246
regenerators, 241
WDCS (wideband digital cross-connect), 244–245
SONET, 175
ADM (add/drop multiplexer), 176–177
BDCS (broadband digital cross-connect), 178
digital loop carriers, 179–180
MSPPs (multiservice provisioning platforms), 180
regenerator, 175
terminal multiplexers, 241–242
TM (terminal multiplexer), 176
WDCS (wideband digital cross-connect), 178–179
TDM (time-division multiplexing), 18, 46
channel banks, 47
cross-connect systems, 47
CSU/DSU, 46
DACS, 47
repeaters, 46
network management
SDH, 208, 271–272
SONET, 205–206
Network Map, CTM (Cisco Transport Manager), 350–351
network view, CTC (Cisco Transport Controller), 340–342
networks
design
capacity planning, 701–706
circuit provisioning, 722
delay analysis, 708–710
fiber plant analysis, 706–709
logical design, 712–716
physical design, 716–718
requirements analysis, 701
technology analysis, 710–712
design strategies, 696
customer demographics, 697
customer service levels, 697–698
customer service requirements, 697
fiber infrastructure, 698
parameters, 696
technology selections, 698–699
vendor selections, 699
new data flags, 224
node view, CTC (Cisco Transport Controller), 338–340, 348–350
nodes
BLSR
adding, 404–406
removing, 407–409
failures, BLSRs, 201
fibers, connecting to, 495
initial provisioning tasks, 359–360
inventories, 356, 374–375
IP networking
for OAM&P, 356
OAM&P, 375–385
MS-SPRing
adding, 492–496
removing, 496–497
multiple subtending rings, 413
SDH
basic information setup, 449–450
inventories, 466–467
IP networking for OAM&P, 446, 467–478
SNCP
adding, 483–484
removing, 484–485
static routes, 378–380, 470–473
UPSR, adding/removing, 388–392	nondispersion-shifted fiber (ITU-T G.652), 71
nonlinear characteristics, fiber-optics
cross-phase modulation (XPM), 69
four-wave mixing (FWM), 69–70
self-phase modulation (SPM), 69
stimulated Brillouin scattering (SBS), 70
stimulated Raman scattering (SRS), 70
nonzero dispersion-shifted fiber (ITU-T G.655), 72
normalized bandwidth, compounded growth matrix, 723
normalized bandwidth calculations, 705
northbound traffic, 308
O
O’Brien, Brian, 49
OAM functions, 303
OAM&P (operation, administration, maintenance, and provisioning), 375
IP networking, SDH nodes, 446, 467–478
ONS nodes, IP networking, 356, 375–385
O-band (original) optical frequency band, WDM systems, 96
OC12 IR/STM4 SH 1310 optical cards, 316
OC12 IR/STM4 SH 1310-4 optical cards, 316
OC12 IR/STM4-4 1310 optical cards, 316
OC12 LR/STM4 LH 1310 optical cards, 316
OC12 LR/STM4 LH 1550 optical cards, 316
OC192 IR/STM64 SH 1550 optical cards, 317
OC192 LR/STM64 LH 1550 optical cards, 317
OC192 LR/STM64 LH ITU DWDM optical cards, 318
OC192 SR/STM64 IO 1310 optical cards, 317
OC-192/STM64 1-Port cards, 720
OC-192/STM-64 ITU wavelengths, 724
OC3 IR/STM1 SH 1310-4 optical cards, 315
OC3 IR/STM1 SH 1310-8 cards, 720
OC3 IR/STM1 SH 1310-8 optical cards, 315
OC48 ERL/STM16 EH 100 GHz DWDM optical cards, 317
OC48 IR 1310 optical cards, 316
OC48 IR/STM16 SH AS 1310 optical cards, 316
OC48 LR 1550 optical cards, 317
OC48 LR/STM16 LH AS 1550 optical cards, 317
OC-N line rates, 149
ONS
  craft interface, initial provisioning tasks, 357–359
  nodes, initial provisioning tasks, 359–360
ONS 15100 series products, 308
ONS 15200 series products, 308
ONS 15300 series products, 309
ONS 15400 series products, 311–336
ONS 15454
  alarm interface controller (AIC-I), 314
  card protection, 320–321, 331–332
  circuits, searching for, 438–439
  cross-connect cards, 313, 323–324
  electrical cards, 314–315
  Ethernet cards, 318–319, 329–330
  FMECs (front-mounted electrical connections) cards, 325–326
  gateways, enabling, 377
  MSPP, 311–332
  MSTP, 332–336
  optical transmission elements, 335–336
  scalability, 729
  service interface cards, 335
  nodes
  CTC (Cisco Transport Console), 375–376
  inventories, 356, 374–375
  IP networking for OAM&P, 356, 375–385
  multiple subtending rings, 413
  static routes, 378–380
  optical cards, 315–317, 327–329
  OSPF configuration, 380–385, 474–478
  protection groups, provisioning, 366–369
  SAN (storage area networks) cards, 319–320, 330–331
  SDH security levels, 453
  SDH user idle times, 455
timing, 356, 370–374, 461–466
  Timing and Control (TCC2) cards, 313, 322–323
ONS 15500 series products, 309
ONS 15600 series products, 310
ONS 15800 series products, 310
OOF (out-of-frame) alarm, superframes, 31
OOF (out-of-frame) alignment
  SDH, 237
  SONET, 163
operation, administration, maintenance, and provisioning (OAM&P). See OAM&P (operation, administration, maintenance, and provisioning)
operations support system (OSS), 308
OPT-BST cards, 335
optical card protection, SDH, 331
optical frequency bands, WDM (wavelength division multiplexing), 96
optical interface layers, SONET, 140, 146–148
optical multiplexers, 113–121
  acousto optical tunable filters, 117–118
  arrayed waveguides, 115–116
  couplers, 119
  Fabry Perot cavity filters, 117
  fiber Bragg grating, 115
  frequency slicers, 120
  interleavers, 120
  isolators, 119
  Mach-Zehnder interferometers, 118–119
  periodic filters, 120
  TFFs (thin film filters), 114–115
optical protection, ONS 15454 cards, 320
optical signals
  SDH, 213–214
  SONET, 140, 144–145
optical signal-to-noise ratio, WDM (wavelength-division multiplexing), 130–133
optical signal-to-noise ratio (OSNR), fiber-optics, 68
optical transmission elements, ONS 15454 MSTP
  optical transmission elements, 335–336
optical-fiber media, WDM (wavelength-division multiplexing), 125
optical-power measurements, fiber-optics, 53
OPT-PRE cards, 335
OSC-CSM cards, 335
OSCM cards, 335
OSPF configuration, 380–385, 474–478
OSS (operations supprt system), 308
out-of-band FEC, WDM (wavelength-division multiplexing), 129
PAM (Pulse Amplitude Modulation), 23
parameters, network design strategies, 696
path layers (SONET), 140, 146–147
path layers (SDH), 215
path overhead (POH), SONET, 159–162
Path Protected Mesh Networking (PPMN), 250
path switching
  multiplex section switching, compared, 259–260
  SONET, 193–194
path traces, creating, 440–442
path-terminating equipment (PTE). See PTE
(path-terminating equipment)
payload pointers (SDH), 223
PCA (protection channel access), 194, 332
PCM (pulse code modulation), 19, 23
PCS (plastic-clad silica) fiber-optic cables, 56
PDH (plesiochronous digital hierarchy), 143, 210–211
periodic filters, optical multiplexers, 120
permanent virtual circuits (PVCs), 7
phase variation, 145, 212
photo-elastic effect, acoustic waves, 117
photonic layer (SDH), 216
photonic layer (SONET), 140, 148
photonic layer (SDH), 216
photonic layer (SONET), 140, 148
photondetector, invention of, 49
physical design, network design, 716–718, 722
photons, fiber-optics, 51–53
PINs (positive intrinsic negatives), 82, 126
plantribbon-cable systems, 56
plastic fiber-optic cables, 55–56
plesiochronous digital hierarchy (PDH). See PDH
(plesiochronous digital hierarchy)
POH (path overhead)
  SDH, 229–233
  SONET, 159–162
  VTs (virtual tributaries), 173–174
point of presence (POP) nodes, 3–5
pointers
  SDH, 223
  SONET, 156
point-to-multipoint topologies
  SDH, 247
  SONET, 181–182
point-to-point circuits, 561–563
Ethernet over SDH, 597–603
EtherSwitch point-to-point circuits, provisioning, 567–571
G-Series provisioning, 559
point-to-point topologies
  SDH, 246–247
  SONET, 181
polarization dependent loss (PDL), 68
polarization mode dispersion, WDM (wavelength-division multiplexing), 136–138
polarization mode dispersion (PMD), fiber-optics, 67–68
polarization mode dispersion compensation, WDM (wavelength-division multiplexing), 138
POP (point of presence) nodes, 3–5
population inversion, 106
ports
  BLSR, enabling, 396–397
  channels, 663
  enabling, 369
  E-Series, provisioning, 596–597
  MS-SPRing, activating, 488–489
  SNCP ports, enabling, 481–482
  UPSRs, enabling, 388
  VLAN membership, provisioning, 581–582
PoS (Packet over SONET), 275
  configuration, ML-Series cards, 664–667
  interface configuration, 636–643
positive intrinsic negatives (PINs), 82
positive stuffing, 224
power budget, span analysis, 84–86
PPMN (Pat-Protected Mesh Networks), 427–428
PRI (primary rate interface), ISDN, 40–41
primary reference source (PRS), 145
propagation, fiber-optics, 48
propagation modes, fiber-optic cables, 58
  multimode graded index, 62–63
  multimode step index, 59–60
  single-mode step index, 60–62
protection architectures
  SDH, 208
  SONET, 140, 187–189
protection channel access (PCA), 194
protection groups
  creating, 367–369
  deleting, 369
  editing, 369
provisioning, 356, 366–369
SDH, 457–461
protectional architectures, SDH, 253–255
Protocol Discriminator (1 octet) field (Q.931 header), 44
provisioning
A-to-Z provisioning, 429
BLSRs, 397–400
circuits, 356, 428–444
E-Series provisioning
Ethernet over SDH, 556, 595–623
Ethernet over SONET, 556, 565–584
G-Series provisioning
Ethernet over SDH, 556, 585–595
Ethernet over SONET, 556–565
initial provisioning tasks, 357
basic node information setup, 359–360
CTC (Cisco Transport Controller), 357–359
IP network setup, 361–362
security, 362–366
users, 362–366
initial provisioning tasks, 356
ML-Series provisioning, 624–682
MS-SPRing, 490–492
OAM&P (operation, administration, maintenance, and provisioning), 375
IP networking of ONS nodes, 375–385
ONS 15454 timing
SDH, 462–466
SONET, 37–372
PPMNs (Pat-Protected Mesh Networks), 427
protection groups, 356
SDH, 457–461
SONET, 366-369
SDH
circuits, 518–553
initial provisioning tasks, 447–457
MSPP, 446–447
SONET
DCC tunnels, 442–444
MSPP, 357
Proxy ARP, ONS 15454 gateways, enabling, 377
PRS (primary reference source), 145
PSTN (Public Switched Telephone Network), 4
PTE (path-terminating equipment)
SDH, 215
SONET, 147
Public Switched Telephone Network (PSTN), 4
pulling tensions, fiber-optic cables, 77
Pulse Amplitude Modulation (PAM), 23
pulse code modulation (PCM), 19, 23
PVCs (permanent virtual circuits), 7

Q-R
Q.931 headers (ISDN Layer 3), fields, 44
QoS (Quality of Service), 11
ML-Series cards, 673–674
quantization, analog-to-digital conversions, 22–23
radio frequency interference (RFI), analog signals, 21
Raman fiber amplifiers (RFAs), 124
raylight scattering, intrinsic attenuation, 65
RBOCs (Regional Bell Operating Companies), interoperability standards, 4
RDI (remote defect indication)
SDH, 238
SONET, 164
RDTs (remote digital terminals), 179
receivers
fiber-optic communications systems, 81–83
sensitivity, span analysis, 84
WDM (wavelength-division multiplexing), 125–127
avalanche photodiodes, 127
PIN photodiodes, 126
reception, analog signals, 21
Red CFA (carrier failure alarm), superframes, 32
regenerator section layer (SDH), 216
regenerators
SDH (Synchronous Digital Hierarchy), 241
SONET, 175
Regional Bell Operating Companies (RBOCs), interoperability standards, 4
REI (remote error indication)
SDH, 237
SONET, 164
remapping K3 bytes, 397, 490
remote digital terminals (RDTs), 179
remote fiber terminals (RFTs), 180, 245
repeaters, 175
TDM (time-division multiplexing), 46
requirements analysis, network design, 701
rerouting RPRs (resilient packet rings), 293–294
resilient packet ring (RPR). See RPR (resilient packet ring)
RFAs (Raman fiber amplifiers), 124
RFI (remote failure indication)
SDH, 238
SONET, 164
RFTs (remote fiber terminals), 180
SDH, 208, 248–271
SONET, 140, 189–190
  asymmetrical delay, 198
  bidirectional rings, 190–191
  BLSR (bidirectional line-switched rings), 198–205
  DRI (dual-ring interconnect), 194–196
  four-fiber rings, 191–193
  line switching, 193–194
  path switching, 193–194
  two fiber rings, 191–193
  unidirectional rings, 190–191
  UPSR (unidirectional path switched rings), 196–197
rings/architectures. See ring architectures
BLSRs, configuration, 392–412
MS-SPRing
  adding, 495–496
  DCC terminations, 488–489
  nodes, 492–497
  port activation, 488–489
  provisioning, 490–492
  trunk cards, 500–502
  upgrading, 497–499
SNCP trunk cards, installing, 479–481
subtending rings, 446, 502–508
configuration, 356, 413–418
UPSRs, configuration, 385–392
RMON alarm thresholds, creating, 584, 622–623
RPR over SONET/SDH, ML-series cards
  accessing, 628–632
  bridge group forwarding, 650–651
  bridge interface configuration, 643–645
  configuration, 674–691
Fast Ethernet interface configuration, 634
Gigabit Ethernet interface configuration, 635
IEEE 802.1Q tunneling, 656–661
IOS command modes, 632–633
IP protocols, 672–673
Layer 2 tunneling, 656–663
link aggregation, 663–664
POS channels, 664–667
POS interface configuration, 636–643
provisioning, 624–682
QoS, 673–674
STP configuration, 645–650
switching database manager, 691–692
VACT (virtual concatenation), 691
VLAN configuration, 651–655
VRF lite, 667–671
RPRs (resilient packet rings), 274287–288, 290
  bandwidth management, 292–293
  CoS (classes of service), 291
  DPT (Dynamic Packet Transport), 288–290
  fairness algorithm, 292
  MAC (Media Access Control), 294–303
  OAM functions, 303
  rerouting, 293–294
  topology discovery, 290–291
  traffic protection, 293–294
RSOH (Regenerator Section Overhead), SDH, 225–226
RSTE (Regenerator Section-Terminating Equipment), 216

S
S1 bytes (SDH), 228
sampling oscilloscopes, 127
SANs, case study, 731–732
S-band (short wavelength) optical frequency bands, 96
SC connectors, fiber-optic cable termination, 74
scaling up, optical networks, 723–730
Schultz, Peter, 50
scrambling techniques, 155
SDCC (section data communications channel), 205, 422
SDH (Synchronous Digital Hierarchy), 2-3, 208, 307
  alarms, 208, 235–236
    AIS (alarm indication signal), 237
    B1 errors, 238
    B2 errors, 238
point-to-point topology, 246–247
ring topology, 248–249
transport overhead, 224
AU pointers, 226
MSOH (Multiplex Section Overhead), 226–229
POH (path overhead), 229–233
RSOH (Regenerator Section Overhead), 225–226
SONET interworking, 233–235
secondary circuits, traffic monitors, creating, 437–438
section data communications channel (SDCC), 205, 442
section layer (SONET), 140, 147
section overhead (SOH), SONET, 154–155
section-terminating equipment (STE), 147
security, initial provisioning tasks
SDH, 452-457
SONET, 362-366
self-phase modulation (SPM), fiber-optics, 69
sensitivity curves, receivers, 82
service affecting, 409
service interface cards, ONS 15454 MSTP service interface cards, 335
service profile IDs (SPIDs), 44
SES (severely errored second), E1 signal format, 38
SF (superframe), 30–32
SH 1310-4 electrical cards, 328
shared packet ring (SPR). See SPR (shared packet ring)
shared protection, 201
signals, 12
analog signal processing, 18
analog-to-digital conversions, 21–24
CAS (channel-associated signaling), 26
CCS (common channel signaling), 27
electrical signals, 140, 144–145, 213–214
optical signals, 140, 144–145, 213–214
PAM (Pulse Amplitude Modulation), 23
PCM (Pulse Code Modulation), 23
TDM signals
SDH integration, 209–214
SONET, 140–143
SONET integration, 140
signal-to-noise ratio, WDM (wavelength-division multiplexing), 130–133
single points of failure, eliminating, 4
single-card EtherSwitch manual cross-connect, provisioning, 577–579
Ethernet over SDH, 611–615
single-mode dual-step index, fiber-optic cables, 60–62
SMF span analysis, fiber-optics, 88–89
SNCP (subnetwork connection protection), 6, 262, 446
circuits, removing, 485
configuration, SDH, 478–485
ESNCP (Extended SNCP) mesh networks, 446
linear ADMs, converting from, 510–513
nodes
adding, 483–484
removing, 484–485
ports, enabling, 481–482
ring traffic, switching, 482–483
subtending rings, 504
trunk cards, installing, 479–481
Snitzer, Elias, 49
SOH (section overhead), SONET, 154–155
SONET (Synchronous Optical Network), 2-3, 307
alarms, 140, 163
AIS (alarm indication signal), 164
B1 errors, 164
B2 errors, 165
B3 errors, 165
BIP-2 errors, 165
LOF (loss-of-frame) alignment, 163
LOP (loss-of-pointer) state, 163
LOS (loss-of-signal) alarm, 163
LSS (loss of sequence synchronization), 165
OOF (out-of-frame) alignment, 163
RDI (remote defect indication), 164
REI (remote error indication), 164
RFI (remote failure indication), 164
C2 byte values, 161
DCC tunnels, provisioning, 442–444
electrical signals, 140, 144–145
Ethernet, 556
Ethernet over SONET, 274, 557
E-Series provisioning, 556, 565–584
G-Series provisioning, 556–565
framing, 140, 148–149
STS-N framing, 151–153
initial provisioning tasks, 356
IP (Internet Protocol), 556
LTE (line-terminating equipment), 147
MSPP (multiservice provisioning platform), 356–357
multiplexing, 140, 174–175
multiservice metro optical SONET, case study, 699–722
NEs (network elements), 140, 175
ADM (add/drop multiplexer), 176–177
BDCS (broadband digital cross-connect), 178
digital loop carriers, 179–180
MSPPs (multiservice provisioning platforms), 180
regenerator, 175
TM (terminal multiplexer), 176
WDCS (wideband digital cross-connect), 178–179
network management, 205–206
OC-N line rates, 149
optical interface layers, 140, 146
line layer, 147
path layer, 146–147
photonic layer, 148
section layer, 147
optical signals, 140, 144–145
protection architectures, 140, 187
APS (automatic protection switching), 187–189
PTE (path-terminating equipment), 147
ring architecture, 189–190
asymmetrical delay, 198
bidirectional rings, 190–191
BLSR (bidirectional line-switched rings), 198–205
DRI (dual-ring interconnect), 194–196
four-fiber rings, 191–193
line switching, 193–194
path switching, 193–194
two-fiber rings, 191–193
unidirectional rings, 190–191
UPSR (unidirectional path switched rings), 196–197
ring architectures, 140
SDH (Synchronous Digital Overhead), 233–235
SPE, 150–151
standards, 4
STE (section-terminating equipment), 147
synchronization, 144–145
TDM signals
integration, 141–143
integration of, 140
TNM (Telecommunications Network Management) model, 140
topologies, 140, 180
diversity, 184–186
fiber routing, 184–186
hub topologies, 182
meshed topologies, 184
point-to-multipoint topologies, 181–182
point-to-point topologies, 181
ring topologies, 183
transport overhead, 153
LOH (line overhead), 155–159
POH (path overhead), 159–162
SOH (section overhead), 154–155
transit overhead, 140
VTs (virtual tributaries), 165–166
groups, 166–171
POH (path overhead), 173–174
superframes, 171–173
SONET/SDH (Synchronous Optical Network/Synchronous Digital Hierarchy), 2-7
DACS (digital access cross-connect systems), 3
DWDM (dense wavelength-division multiplexing), 13–16
legacy SONET/SDH, 6–7
MSPPs (multiservice provisioning platforms), 4, 8–12
bandwidth efficiency, 10–11
Ethernet encapsulation, 11–12
provisioning, 12
QoS (quality of service), 11
signaling, 12
Multiservice SONET/SDH, 3
southbound traffic, 308
span analysis, fiber-optics, 83
dynamic range, 84
margin calculations, 84–86
MMF span analysis, 86–88
power budget, 84–86
receiver sensitivity, 84
SMF span analysis, 88–89
transmitter launch power, 83–84
Spanning Tree Protocol (STP). See STP (Spanning Tree Protocol)
spatial reuse, RPRs (resilient packet rings), 292–293
SPE, 150–151
SPIDs (service profile IDs), 44
splicing fiber-optic cabling, 75–76
SPRs (shared packet rings), 274, 277
bridges, 279
design constraints, 281–282
E-Series card ports, 282
matching nodes, 286
ML-Series card ports, 283–285
double tagging, 279
Ethernet over SDH, 603–606
EtherSwitch provisioning, 571–574
STP model, 279
VLAN identifiers, 279
ss bits (SDH), 234
SSM (Synchronization Status Messaging), 370
ST connectors, fiber-optic cable termination, 74
static routes
CTCs, 473
multiple CTCs, 380–381
nodes, 470–473
static routes, ONS nodes, 378–380
statistical TDM, 20
STE (section-terminating equipment), 147
stimulated Brillouin scattering (SBS), fiber-optics, 70
stimulated emission, 106
stimulated Raman scattering (SRS), fiber-optics, 70
STM-1 frames (SDH), 221–222
STM1 SH 1310 optical cards, 328
STM16 EH 100-GHz DWDM electrical cards, 328
STM16 LH AS 1550 electrical cards, 328
STM16 SH AS 1310 electrical cards, 328
STM1E 1, FMECs (front-mounted electrical connections), 326
STM1E-12 electrical cards, 327
STM1SH 1310-8 electrical cards, 328
STM4 LH 1310 electrical cards, 328
STM4 LH 1550 electrical cards, 328
STM4 SH 1310 electrical cards, 328
STM64 LH 1550 electrical cards, 329
STM64 LH ITU DWDM electrical cards, 329
STM-N (Synchronous Transport Module-N), 213–214
Stoke’s low-wavelength waves, 70
STP (Spanning Tree Protocol)
configuration, 645–650
Ethernet ports, enabling, 582-584, 620–621
Stratum 3 (ST3) clocks, 370
stratum clock hierarchy, 146
STS-N framing, SONET, 151–153
submarine cable systems (fiber-optics), 77
subnetwork connection protection (SNCP). See SCP
(subnetwork connection protection)
Subnetwork Explorer, CTM (Cisco Transport Manager), 347–348
subtending rings, 5, 446, 502–508
configuration, 356, 413–418
superframes. See SF (superframe) and ESF
(extended superframe)
SVCs (switched virtual circuits), 7
switching traffic
MS-SPRing, 493
SNCP rings, 482–483
switching database manager, ML-Series cards, 691–692
switching protection, ONS 15454 cards, 320, 331
synchronization
SDH, 212–213
SONET, 144–145
Synchronization Status Messaging (SSM), 370
Synchronous Digital Hierarchy (SDH). See SDH
(Synchronous Digital Hierarchy)
Synchronous Optical Network (SONET). See SONET (Synchronous Optical Network)
synchronous TDM, 20
Synchronous Transport Module-N (STM-N). See STM-N (Synchronous Transport Module-N)

T

T-carrier system, 18, 27–29
DS framing, 29
DS multiframing formats, 29–32
TCC2 cards, 413, 503, 719
TDM (time-division multiplexing), 2, 18-20, 694
analog signal processing, 20–24
circuit-switched networks, 26–27
E-carrier system, 32–34  
alarms, 36, 38–39  
CRC error checking, 36–37  
errors, 36, 38–39  
FAS (frame alignment signal), 34–35  
MFAS (multiframe alignment signal), 35–36  
network elements, 18, 46  
channel banks, 47  
cross-connect systems, 47  
CSU/DSU, 46  
DACS, 47  
repeaters, 46  
schematics, 19  
SONET/SDH, 3  
statistical TDM, 20  
synchronous TDM, 20  
T-carrier system, 27–29  
DS framing, 29  
DS multiframing formats, 29–32  
TDM signals  
SDH integration, 208–214  
SONET integration, 140–143  
technology analysis, network design, 710–712  
Telecommunications Network Management (TNM).  
See TNM (Telecommunications Network Management)  
tensile loading, fiber-optic cabling, 76–77  
termination, fiber-optic cables, 48, 73-75  
TFFs (thin film filters), 114–115  
through timing, SDH, 212  
tight buffer cable plants, loose buffer cable plants, compared, 76  
time slot 16 AIS alarm, E1 signal format, 38  
time-division multiplexing (TDM). See TDM  
time-division multiplexing (time-division multiplexing)  
timing, ONS 15454 timing, 370-374  
SDH, 461–466  
SONET, 356  
timing references, 372  
TM (terminal multiplexers)  
SDH, 241–242  
SONET, 176  
TNM (Telecommunications Network Management), 140  
topologies, 2–7  
discoveries, RPRs (resilient packet rings), 290–291  

Multiservice SONET/SDH, 3  
SDH (Synchronous Digital Hierarchy), 2, 208, 246  
fiber diversity, 250–252  
fiber routing, 250–252  
hub topology, 247–248  
meshed topology, 249–250  
point-to-multipoint topology, 247  
point-to-point topology, 246–247  
ring topology, 248–249  
SONET (Synchronous Optical Network), 2, 140, 180  
diversity, 184–186  
fiber routing, 184–186  
hub topologies, 182  
meshed topologies, 184  
point-to-multipoint topologies, 181–182  
point-to-point topologies, 181  
ring topologies, 183  

traffic  
bidirectional traffic matrix, 703  
monitoring, secondary circuits, 437–438  
MS-SPRing, switching, 493  
northbound traffic, 308  
SNCP, switching, 482–483  
southbound traffic, 308  
unidirectional traffic matrix, 702  
UPSR traffic, switching, 389  
traffic protection, RPRs (resilient packet rings), 293–294  
transmitter launch power, span analysis, 83–84  
transceivers, 100  
transmission impairments, WDM (wavelength-division multiplexing), 92, 127–133  
FEC (forward error correction), 128–130  
optical signal-to-noise ratio, 130–133  

transmitters  
fiber-optic communications systems, 78–80  
WDM (wavelength-division multiplexing), 106  
chirp, 111  
distributed Bragg reflector lasers, 107–108  
distributed feedback lasers, 106–107  
modulators, 111–113  
tunable lasers, 108–109  
vertical cavity surface emitting lasers, 110–111
transport overhead
SDH, 224
  AU pointers, 226
  MSOH (Multiplex Section Overhead), 226–229
  POH (path overhead), 229–233
  RSOH (Regenerator Section Overhead), 225–226
  SONET interworking, 233–235
SONET, 140, 153
  LOH (line overhead), 155–159
  POH (path overhead), 159–162
  SOH (section overhead), 154–155
tributaries, SDH, 222–223
trunk cards
  BLSR trunk cards
    installing, 394–395
    moving, 409–412
    installing, 479–481
  MS-SPRing trunk cards
    installing, 486–488
    moving, 500–502
  UPSR trunk cards, installing, 386
  tunable lasers, WDM (wavelength-division multiplexing), 108–109
two-fiber BLSRs, upgrading, 400–402
two-fiber MS-SPRing, upgrading, 497–499
two-fiber rings
  four-fiber rings, compared, 257–259
  SONET, 191–193
upgrading
  BLSRs, 400–402
  MS-SPRing, 497–499
  optical networks, 723–730
UPSRs (unidirectional path-switched rings), 6, 356
  BLSRs
    subtending from, 414–415
    subtending to, 415–416
  configuration, 356
  circuits, editing, 439–440
  configuration, 385–392
  linear ADMs, converting from, 420–423
  nodes, adding/removing, 388–392
  ports, enabling, 388
  SONET, 196–197
  traffic, switching, 389
  trunk cards, installing, 386
user data channels (UDCs), AIC-I cards, 324
users
  creating
    SDH, 456
    SONET, 365
  deleting
    SDH, 457
    SONET, 366
  editing
    SDH, 457
    SONET, 366
  initial provisioning tasks, 362–366

U
UAS (unavailable seconds), E1 signal format, 38
U-band (ultra-long wavelength) optical frequency bands, WDM systems, 96
UDCs (user data channels), AIC-I cards, 324
unavailable seconds (UAS), E1 signal format, 38
unidirectional circuits, multiple drops, creating, 436–437
unidirectional path-switched ring (UPSR). See UPSR (unidirectional path-switched ring)
unidirectional rings
  bidirectional rings, compared, 256–257
  SONET, 190–191
unidirectional traffic matrix, 702
unidirectional WDM, 96–97
Upgrade BLSR dialog box, 401

V
V5 bytes (SDH), 232
VACT (virtual concatenation), ML-Series cards, 691
Van Heel, Abraham, 48–49
VC payload pointers (SDH), 224
VCSELs (vertical cavity surface emitting lasers), WDM (wavelength-division multiplexing), 110–111
vendors, selecting, 699
virtual tributaries (VTs). See VTs (virtual tributaries)
VLANs
  configuration, ML-Series cards, 651–655
Ethernet ports, provisioning for membership, 581–582
identifiers, SPRs, 279
membership, provisioning, 618–620
VRF lite, configuration, ML-Series cards, 667–671
VTs (virtual tributaries), 140
SONET, 165–166
groups, 166–171
POH (path overhead), 173–174
superframes, 171–173

WANs (wide area networks), building, technology options, 275
wavelength-division multiplexing (WDM).
See WDM (wavelength-division multiplexing)
wavelengths
attenuation, compared, 65
cutoff wavelengths, 61
OC-192/STM-64 ITU wavelengths, 724
WDCS (wideband digital cross-connect)
SDH, 244–245
SONET, 178–179
WDM (wavelength-division multiplexing), 92-96, 104-105
amplifiers, 121–125
distributed amplifiers, 124
EDFAs (Erbium-Doped fiber amplifiers), 123
hybrid amplifiers, 124
RFAs (Raman fiber amplifiers), 124
bidirectional WDM, 96–98
band-separation method, 98
circulator method, 99
interleaving-filter method, 98–99
channel spacing, 99
characteristics, 92, 127–133
compensation, 92, 133–134
CWDM (coarse wavelength-division multiplexing), 92, 100
dispersion, 92, 133–134
chromatic dispersion, 134–136
polarization mode dispersion, 136–138
DWDM (dense wavelength-division multiplexing), 92, 101
ITU grid, 102–104
multiplexers, 113–121
need for, 93
optical frequency bands, 96
optical multiplexers, 113–121
AOTFs (acousto optical tunable filters), 117–118
arrayed waveguides, 115–116
circulators, 119
couplers, 119
Fabry Perot cavity filters, 117
fiber Bragg grating, 115
frequency slicers, 120
interleavers, 120
isolators, 119
Mach-Zehnder interferometers, 118–119
periodic filters, 120
TFFs (thin film filters), 114–115
optical-fiber media, 125–127
receivers, 125–127
schematic, 94
systems, 94
transmission impairments, 92, 127–133
FEC (forward error correction), 128–130
optical signal-to-noise ratio, 130–133
transmitters, 106
chirp, 111
distributed Bragg reflector lasers, 107–108
distributed feedback lasers, 106–107
modulators, 111–113
tunable lasers, 108–109
vertical cavity surface emitting lasers, 110–111
unidirectional WDM, 96–97
XC10G cross-connect (XC) cards, 314, 323, 720
XCVT cross-connect (XC) cards, 313
XC-VXL-10G cross-connect (XC) cards, 323
XC-VXL-2.5G cross-connect (XC) cards, 324
Yellow CFA (carrier failure alarm), superframes, 32