

nonces, 704–705, 716–717
 non-persistent connections, 100–103, 198
 nonpreemptive priority queuing
 discipline, 643
 non-real-time applications, 92–93
 nonrepudiation and cryptographic
 techniques, 675
 nslookup program, 141–142
 N-way-unicast, 400–401

O

OBJECT IDENTIFIER data type, 766
 objects, 99, 103
 OC (Optical Carrier) standard link, 21
 odd parity schemes, 440
 offered load, 261
 OLT (optical line terminator), 16
 ONT (optical network terminator), 16
 Open-Shortest Path First. *See* OSPF
 Open Systems Interconnection model. *See*
 OSI model
 operational security, 673, 731–742
 Optical Carrier standard link. *See* OC
 standard link
 optical distribution network, 15–16
 optical line terminator. *See* OLT
 optical network terminator. *See* ONT
 options field, 235
 origin authentication, 363
 orthogonal frequency division multiplex-
 ing. *See* OFDM
 OSI (Open Systems Interconnection)
 model, 52–53
 OSPF (Open-Shortest Path First),
 366–367, 384, 388–390, 498
 LSAs (link-state advertisements), 405
 router authentication, 388–389
 OS vulnerability attacks, 740
 out-of-band, 117
 out-of-order segments, 236
 output buffers, 25
 output ports, 320–326
 packet queues, 327–331
 packet scheduler, 329
 processing, 326

output queue, 25
 overlapping fragments, 338
 overlay network, 154, 486

P

packet classification, 648–649
 packet delay, 35–44, 102, 635
 packet-discarding policy, 641
 packet filtering, 732, 737
 packet forwarding, 26–27
 packet loss, 25, 41–42, 91, 259, 613, 635
 error concealment, 620–621
 FEC (forward error correction),
 618–619
 interleaving, 618–620
 predicting imminent, 278
 recovering from, 213, 618–621
 packet marking, 638
 packet-radio networks, 62, 511
 packet repetition, 621
 packets, 4, 22
 average rate, 645
 bit errors, 207
 buffering, 218
 burst size, 646
 controlled flooding, 401–403
 cumulative acknowledgment, 222
 delays, 36–37
 delivering, 204–205
 destination, 35
 destination IP address, 158
 detecting loss, 212–215
 dropping, 41, 329
 duplicate, 210, 213–214
 duplicate ACKs, 211
 end-to-end delay, 612
 FIFO (first-in-first-out), 641–642
 format of, 5
 forwarding, 4, 308–310, 321–322, 649
 header fields, 55
 IP spoofing, 59–60
 jitter, 614
 moving between nodes, 52
 path, 35
 payload fields, 55

- peak rate, 646
- prefix destination address, 318
- priority queuing, 642–643
- processing delays, 36–37
- queuing delays, 25, 37, 39–42
- round-robin queuing, 643–644
- round-trip delays, 42–43
- routing, 308–310
- RTT (round-trip time), 102–103
- same priority class, 642
- sender's source address, 158
- sending, 24
- sending multiple, 218
- sequence numbers, 210, 218, 220
- sockets, 158
- source, 35
- source address, 162
- switching, 324–326
- tracing, 42–43
- transmitting, 213–214
- uncontrolled flooding, 401
- VC number, 315
- WFQ (weighted fair queuing), 644–645
 - what to do when loss occurs, 212–215
 - where queuing occurs, 327–331
- Packet Satellite, 511
- packet scheduler, 329
- packet sniffers, 58–59, 78
- packet-switched networks, 4, 25
 - ARPAnet, 61
 - comparing transmission and propagation delay, 38–39
 - delays, 35–39
 - end-to-end delays, 42–44
 - packet loss, 41–42
 - processing delays, 36–37
 - propagation delays, 37–38
 - queuing delays, 37, 39–42
 - sending packets, 28
 - transmission delays, 37
- packet switches, 4, 310
 - facilitating exchange of data, 6
 - link-layer switches, 22, 53, 310
 - output buffers, 25
 - routers, 22, 53, 310
 - store-and-forward transmission, 22, 24
- packet switching, 30–31
 - alternative to circuit switching, 60
 - forwarding tables, 26–27
 - packet loss, 25
 - queuing delays, 25
 - queuing theory, 60
 - routing protocols, 26–27
 - secure voice over military networks, 60
 - store-and-forward transmission, 22, 24
 - VC (virtual-circuit) approach, 267
- packet-switching networks, 62
- paging, 550
- parity checks, 440–442
- passive optical networks. *See* PONs
- passive spanning, 530
- passwords, 703, 710
- paths, 4, 365
 - least-cost, 365
 - multihop, 263–265
- payload fields, 55
- PBXs (private branch exchanges), 627
- PCM μ -law, 628–629
- PCM (pulse code modulation), 590
- PDU and SNMP applications, 776–777
- peak rate, 646
- peer, 34
- peer churn and DHTs (distributed hash tables), 155–156
- peering, 33
- peers, 86, 144–145
 - DHT, 155–156
 - file sharing, 145–151
 - torrent, 149
- peer-to-peer applications. *See* P2P applications
- per-connection QoS (Quality-of-Service)
 - guarantees, 634, 652–655
- per-connection throughput, 260
- perfectly reliable channel, 206–207
- Performance Management, 758, 763–764
- per-hop behavior. *See* PHB

- permanent address, 559
- persistent connections, 100–103
- persistent HTTP, 198
- personal area networks
 - Bluetooth, 544–545
 - Zigbee, 545–546
- PGP (Pretty Good Privacy), 678, 706, 709–711
- PHB (Per-hop behavior), 649–651
- physical address, 463
- physical layer, 50, 52–53
- physical media, 4
 - coaxial cable, 20
 - costs, 19
 - fiber optics, 20–21
 - guided media, 19
 - radio channels, 21
 - satellite radio channels, 21–22
 - twisted-pair copper wire, 19–20
 - unguided media, 19
- piconet, 544
- piggybacked acknowledgment, 237
- PIM (Protocol-Independent Multicast), 411–412, 584
- ping program, 353
- pipelined reliable data transfer protocols, 215–218
- pipelining, 218
 - persistent connections, 103
 - TCP (Transmission Control Protocol), 240
- plaintext, 675
- playback attacks, 703, 777
- playout delay, 614
- plug-and-play protocol, 346
- plug-and-play switches, 479–480
- PMS (Pre-Master Secret), 716
- points of presence. *See* PoPs
- point-to-point, 232
- point-to-point communication link, 434
- point-to-point links, 436, 445
- Point-to-Point Protocol. *See* PPP
- poisoned reverse, 377–378
- poisoning attack, 143
- policing disciplines, 645–648
- policing mechanisms, 640
- polling protocols, 459
- polls, 459
- polyalphabetic encryption, 678
- polynomial codes, 443
- PONs (passive optical networks), 15–16
- POP3 (Post Office Protocol-Version 3), 127–129
- POP3 server, 127, 129
- PoPs (points of presence), 33
- POP3 user agent, 128
- port-based VLAN, 483–484
- port numbers, 90, 158
 - addressing processes, 351
 - destination, 234
 - protocols, 90
 - source, 234
 - Web servers, 197–198
 - well-known, 192, 196
- port-based VLAN, 483–484
- port scanners, 196
- port scans, 196, 740
- positive acknowledgment. *See* ACK
- POST method, 104–105
- Post Office Protocol-Version 3. *See* POP3
- power management, 543–544
- P2P (peer to peer)
 - applications, 97–98
 - architecture, 86–88, 144–148
 - BitTorrent, 149–151
 - connection reversal, 352
 - DHTs (distributed hash tables), 145, 151–156
 - file distribution, 83, 88, 45–151
 - NAT, 351–352
 - Skype, 621–622
 - video streaming applications, 592
- PPP (point-to-point protocol), 434, 445
- PPstream, 87
- PPTV and P2P delivery, 611
- prefetching, 592
 - video, 596–597
- prefixes, 342, 344, 393
 - awareness of, 396–397
 - BGP attributes, 394

- forwarding table, 396–397
- gateway routers, 393
- Pre-Master Secret. *See* PMS
- prerecorded video, 591
- presentation layer, 53
- presentation service, 780
- Pretty Good Privacy. *See* PGP
- priority queuing, 642–643
- privacy
 - cookies, 108
 - proxy servers, 738
 - QQ, 623
 - Skype, 623
 - SSL (Secure Sockets Layer), 738
 - Web sites, 738
- private branch exchanges. *See* PBXs
- private CDNs (Content Distribution Networks), 603
- private key, 684–685, 693, 708
 - passwords, 710
- private networks, 66, 718
- processes, 88–90
 - communicating by sending messages to sockets, 157
 - communicating using UDP sockets, 158
 - connection sockets, 198
 - handshaking, 231
 - logical communication between, 186
 - sockets, 191
- processing delays, 36–37
- programming, event-based, 223
- propagation delays, 24, 36–39, 456
- proprietary network applications, 156–157
- Protocol-Independent Multicast. *See* PIM
- protocols, 5, 68
 - alternating-bit, 214
 - application-layer, 49–50
 - congestion-control, 9
 - defining, 7–9
 - hardware-implemented, 9
 - human analogy, 7–8
 - interior gateway, 384
 - Internet, 9
 - IP (Internet Protocol), 5
 - layering, 49–50
 - nonce, 704–705
 - packet sizes, 335
 - plug-and-play, 346
 - port numbers, 90
 - real-time interactive applications, 623–632
 - routing, 51–52
 - RTP, 623–626
 - SIP, 626–632
 - soft state, 408–409
 - SR (selective repeat), 223–230
 - stateless, 100
 - stop-and-wait, 209, 215, 217
 - TCP, 5
 - UDP, 5
 - transmission and receipt of messages, 7–8
 - transport-layer, 50
- protocol stack, 50
- provider, 32
- proxy servers, 106, 110, 738
- public key algorithm, 716
- public key certification, 697–699
- public-key cryptography, 708
 - digital signatures, 693–694
 - private key, 693
 - public key, 693, 697
 - secure e-mail system, 706–707
- public key encryption, 683–688
- public-key encryption algorithm, 687
- public keys, 684–685, 693, 706–708, 713–714
 - binding to particular entity, 697–698
 - certifying, 708
 - encryption/decryption algorithms, 684
- public key systems, 676
- pull protocol, 124
- pulse code modulation. *See* PCM (pulse code modulation)
- push protocol, 124
- PUT method, 105
- Python, 157, 160, 193