

**Numbers**

4B/5B encoding, 82–83  
6-BONE, 696  
10Base2, 118  
10Base5, 117  
10baseT, 117  
802.11, 137–43  
802.11i, 625–26  
authentication server use, 626  
EAP, 625  
personal mode, 625  
802.15.1, 136–37  
802.16, 143–44  
802.17, 131–33  
802.5 protocol, 127, 128  
addresses, 130  
token ring, 129  
token ring frame format, 130

**A**

Abstract channels, 16  
Abstract Syntax Notation One (ASN.1), 551–52  
*Accept* operation, 33  
Access control, 587  
Access points (AP), 140  
connected to distribution network, 141  
scanning, 141  
AC coefficients, 563  
Acknowledgments, 102  
Active queue management, 489  
Adaptive retransmission, 403–7  
implementation, 406–7

Jacobson/Karels algorithm, 405–6  
Karn/Partridge algorithm, 404–5  
original algorithm, 403–4  
*See also* Transmission Control Protocol (TCP)  
Adaptive video coding, 572–74  
Additive increase multiplicative decrease (AIMD), 474–77  
defined, 476  
packets in transit, 476  
Addresses  
802.5, 130  
anycast, 328  
broadcast, 120  
care-of, 291  
Ethernet, 120–21  
flat, 248  
global, 248–50  
hierarchical, 248  
home, 291  
IP, 248–50, 319–24  
MAC, 253  
multicast, 120, 331–32  
unicast, 120, 321–24  
Addressing problem, 232  
subnets, 300  
Address Resolution Protocol (ARP), 208, 256–58  
ATMARP, 256–58  
defined, 255  
goal, 255  
packer format, 255, 256  
proxy, 292

server, 258  
tables, 255  
Address translation, 254–58  
Ad hoc networks, 135  
Admission control, 509–10  
action coordination, 691–92  
defined, 507  
dependencies, 509  
off-path, 691  
policing versus, 510  
policy and, 510  
with session control protocol, 691  
Advanced Encryption Standard (AES), 593  
Advertised window, 394, 397, 409  
Aggregation points, 149  
Akamai, 714  
Aloha, 116  
Anycast address, 328  
Any source multicast (ASM), 331  
Application Level Framing (ALF), 430  
Application processing, 693  
Application programmer, 6  
Application programming interfaces (APIs), 31–33  
defined, 31  
protocol-to-protocol interface versus, 37  
Applications, 4–6, 640–728  
bandwidth requirements, 49  
delay requirements, 49  
elastic, 500  
electronic mail, 643–50

Applications (*continued*)  
interactive, 426  
multimedia, 426, 678–93  
name service, 657–66  
network management, 666–68  
overlay networks, 693–719  
performance needs, 48–50  
real-time, 500  
streaming, 426  
summary, 719–20  
traditional, 642–68  
Web Services, 668–78  
World Wide Web, 650–56  
Application-specific protocols, 441–42  
Architecture tags, 548  
Area border routers (ABRs), 316, 317  
Assured forwarding (AF) PHB, 518–22  
RIO, 518–20  
WRED, 520–21  
*See also* Per-hop behaviors (PHBs)  
Asymmetric digital subscriber line (ADSL), 75, 77  
Asynchronous protocols, 419  
Asynchronous transfer mode (ATM), 167, 195–208  
adaptors, 219  
available bit rate (ABR), 521, 522  
cell format, 199–200  
cell payload, 199  
cells, 195–200  
cell size, 196–99  
constant bit rate (CBR), 521, 522  
defined, 179, 195  
in DSL access networks, 219  
header, 208  
in LAN, 206–9  
physical layers, 206–8  
QoS, 521–23  
segmentation/reassembly, 200–205  
service classes, 521–22  
signaling, 195  
switches, 205, 218, 347–48  
unspecified bit rate (UBR), 521, 522  
variable bit rate – nonreal-time (VBR-nrt), 521, 522  
variable bit rate – real-time (VBR-rt), 521, 522  
virtual paths, 205–6  
ATM Adaptation Layer (AAL), 200  
AAL3/4, 201–3  
AAL5, 203–5  
defined, 200  
ATMARP, 256–58  
defined, 257  
LIS, 257  
server, 257  
At-most-once semantics, 418  
Attacks  
ciphertext only, 590  
denial-of-service, 632–33, 716  
known plaintext, 590  
man-in-the-middle, 612  
replay, 587, 604  
suppress-replay, 604–5  
Audio, streaming, 4  
Audio applications example, 501–3  
playback buffer, 502  
playback point, 502, 505  
playback time, 501  
variability of delay, 502  
Authentication, 802.11, 625–26

Availability, 587  
Available bit rate (ABR), 521, 522  
Average queue length, 487 computation, 488–89  
over time, 492  
use of, 489  
weighted, 490

**B**

Backbone networks, 322  
Backdoor, 630  
Bandwidth, 40–44  
bit transmission, 41  
common availability, 73  
defined, 40  
downstream, 76  
example, 40  
I/O bus, 209  
latency relationship, 47, 48  
memory, 69  
requirements, 42  
specification, 45

TCP, 482  
UDP, 439  
Baseline wander, 80  
Batcher network, 218  
Baud rates, 80–81  
Beacons, 149  
Berkeley Software Distribution (BSD), 275  
Best-effort delivery, 236, 237  
Best-effort services, 507  
B frames, 566, 567  
combination, 574  
compression, 568–69  
macroblocks, 568  
Bidirectional PIM (BiDIR-PIM), 341–43  
advantages, 343  
defined, 341  
domains and, 342–43  
operation, 342  
trees, 341  
Big-endian form defined, 544  
illustrated, 545  
Binary Synchronous Communication (BISYNC) protocol, 84–85  
frame format, 84–85  
sentinel characters, 85  
Bind operation, 32  
Bit-by-bit round-robin, 471  
Bit pipe, 18  
Bit rates, 80–81  
Bit stuffing, 88  
BitTorrent, 710–14  
benefits, 710–11  
connections, 712  
defined, 710  
fairness, 713–14  
good behavior, 713–14  
peers, 711  
swarms, 711  
.torrent file, 711–12  
tracker, 712–13  
*See also* Peer-to-peer networks  
Block ciphers, 591

Bluetooth, 79, 136–37  
channels, 136  
defined, 136  
Business-to-business (B2B), 669  
**C**  
Cables, 72–73  
defined, 72  
thick-net, 117  
thin-net, 117  
types, 73  
*See also* Links  
Cable TV (CATV), 76–77  
Cache Arrouting Protocol (CARP), 718  
Canonical intermediate form, 546–47  
Canonical name (CNAME) concept, 434, 436, 437  
Care-of address, 291  
Carrier sense multiple access (CSMA) networks, 64  
CCMP, 626  
Cell phone technologies, 145–47  
base stations, 146  
CDMA, 146  
cells, 145  
GPRS, 146  
handoff, 145  
TDMA, 146  
UMTS, 146–47  
Cells, 195–96  
format, 199–200  
payload, 199  
queues of, 197  
size, 196–99  
Cell switching, 195–208  
cell format, 199–200  
cells, 195–200  
cell size, 196–99  
physical layers, 206–8  
segmentation/reassembly, 200–205  
virtual paths, 205–6  
Centralized forwarding, 296  
Certificate revocation list (CRL), 603

Certification authorities (CAs), 601–2  
defined, 601  
tree-structured hierarchy, 602  
Challenge-response protocol, 606  
Channels abstract, 16  
abstraction, 417  
Bluetooth, 136  
concurrent logical, 115  
defined, 15  
functionality, 18  
message stream, 17  
piconet, 136, 137  
as pipes, 15  
request/reply, 17  
RTT, 45  
Character stuffing, 85  
Checksum, 93  
Internet, 94–95  
UDP, 383  
Cipher block chaining (CBC), 591–92  
defined, 591  
illustrated, 592  
Ciphers block, 591  
defined, 589  
public-key, 593–95  
symmetric-key, 591–93  
Ciphertext only attack, 590  
Circuit-switched networks, 8  
Classless interdomain routing (CIDR), 303–6, 357  
defined, 303  
function, 304  
notation, 304  
prefix length, 306  
route aggregation, 304, 305  
Clear to Send (CTS) frame, 140  
Client–nonce, 620  
Clients  
Kerberos, 609  
name resolution, 664  
in network software implementation, 33–35  
Constant logical channels, 115  
Congested switches, 14, 167  
Congestion, 178–79  
Congestion avoidance DEChit, 486–87  
defined, 486  
mechanisms, 486–99  
RED, 487–93  
source-based, 493–99  
TCP Vegas, 494–99  
Congestion control additive increase multiplicative decrease (AIMD), 474–77  
behavior, 480  
congestion window, 474–77  
DCE-RPC, 425  
defined, 385, 458  
elements, 457  
equation-based, 522–24  
fast recovery, 485  
fast retransmit, 483–85  
flow control versus, 458  
maximum segment size (MSS), 475  
mechanisms, evaluating, 497–98  
quick start, 482, 483  
routing versus, 459  
slow start, 477–83  
strategy, 475–76  
TCP, 474–85  
TCP-friendly, 523, 524  
Connectionless flows, 460–61  
Connectionless networks, 169  
characteristics, 171–72  
defined, 169  
Connection-oriented approach, 170  
Connectivity, 7–10  
challenges, 10  
clouds, 9  
links, 7–10  
nodes, 7–10  
requirement, 7  
Consistent hashing, 706, 718  
Constant bit rate (CBR), 521, 522  
Constrained shortest path first (CSPF), 351  
Content distribution networks, 714–19  
Akamai, 714  
client request distribution, 716  
commercial, 715  
components, 715

defined, 714  
flash crowd, 715  
network proximity, 716  
policies, 717–19  
redirectors, 715–16  
server surrogates, 714  
system throughput, 716  
URL rewriting, 716  
*See also* Peer-to-peer networks  
Controlled load service, 506  
Control status register (CSR), 67–68  
Conventions, naming, 663–64  
Conversion strategies, 546–47  
canonical intermediate form, 546–47  
receiver-makes-right, 546, 547  
*See also* Presentation format  
Core-based trees (CBT), 342–43  
Counter mode, 591  
Counting semaphore, 109  
Count to infinity problem, 273  
Crossbar switch, 215  
Crypanalysts, 590  
Cryptographic hash function, 596  
Cryptographic tools, 589–98  
authenticators, 595–98  
public-key ciphers, 593–95  
symmetric-key ciphers, 591–93  
*See also* Security  
Cyclic redundancy check (CRC), 85  
calculation, 96  
calculation with polynomial long division, 99  
calculation with shift register, 101  
common polynomials, 101  
error detection, 92  
protection, 96

**D**

Data  
defined, 542  
encoding/decoding, 544  
end-to-end, 542–85

integrity, 587  
multimedia, 542–43  
presentation format, 542,  
    544–57  
tagged, 547–48  
untagged, 547–48  
Data compression. *See*  
    Compression  
Data Encryption Standard (DES),  
    591–92  
Datagram forwarding, 250–54  
algorithm, 251  
illustration, 171  
in IP, 250–54  
Datagrams, 169  
defined, 170  
IP, 241  
ID, delivery, 236–37  
source routing in, 182  
Data manipulation, 543  
Data types, 545–46  
complex, 546  
flat, 545–46  
DC coefficient, 563  
DCP–RPC, 419, 422–26  
at-most-once call semantics, 423  
fragmentation and reassembly support, 424  
fragmentation and selective acknowledgments, 425  
implementation, 422–23  
message exchange, 423  
request/reply transactions, 424  
very large message support, 425  
*See also* Remote Procedure Call (RPC)  
DCT phase, 562–63  
DECbit, 486–87  
Decompression, 557  
Decryption, 589  
Delay  
buffers as source, 214  
example distribution of, 503  
propagation, 42, 44  
queuing, 690

queuing, 42  
ratio of throughput to, 465  
variability, 502  
*See also* Quality of Service (QoS)  
Digital Data Communication Message Protocol (DDCMP), 84  
defined, 86–87  
frame format, 87  
Digital Network Architecture (DNA), 486  
Digital signatures, 597  
Digital Signature Standard (DSS), 597  
Digital subscriber line (xDSL), 75, 207  
Direct link networks, 64–165  
encoding, 79–84  
error detection, 92–101  
Ethernet, 116–24  
framing, 84–91  
hardware building blocks, 66–79  
reliable transmission, 101–15  
rings, 124–33  
summary, 147–49  
wireless, 133–47  
Direct memory access (DMA), 68, 209  
Direct providers, 322  
Direct sequence spread spectrum, 78  
Distance Vector Multicast Routing Protocol (DVMRP), 332–34, 700  
Diffe-Hellman key agreement, 605, 611–13  
fixed, 612  
lack of authentication, 612  
parameters, 613  
DiffServ, 516–22  
applications benefiting from, 519–20  
code points (DSCPs), 517  
defined, 516  
as middle ground, 525  
queuing, 690

DiffServ (*continued*)  
quiet success, 518–21  
*See also* Quality of Service (QoS)  
Digital Data Communication Message Protocol (DDCMP), 84  
defined, 86–87  
frame format, 87  
Digital Network Architecture (DNA), 486  
Digital signatures, 597  
Digital Signature Standard (DSS), 597  
Digital subscriber line (xDSL), 75, 207  
Direct link networks, 64–165  
encoding, 79–84  
error detection, 92–101  
Ethernet, 116–24  
framing, 84–91  
hardware building blocks, 66–79  
reliable transmission, 101–15  
rings, 124–33  
summary, 147–49  
wireless, 133–47  
Direct memory access (DMA), 68, 209  
Direct providers, 322  
Direct sequence spread spectrum, 78  
Distance Vector Multicast Routing Protocol (DVMRP), 332–34, 700  
Diffe-Hellman key agreement, 605, 611–13  
fixed, 612  
lack of authentication, 612  
parameters, 613  
DiffServ, 516–22  
applications benefiting from, 519–20  
code points (DSCPs), 517  
defined, 516  
as middle ground, 525  
queuing, 690

Domains  
areas, 316  
routing, 267, 307  
Drop probability, 488  
Dual-fiber rings, 131  
Dual-stack operation, 322  
Duplicate ACK, 484, 485  
Dynamic Host Configuration Protocol (DHCP), 259–62  
defined, 259  
goal, 260  
IP address assignment, 260  
messages, 260  
packet format, 261  
relay agent, 261  
server, 259, 260

**E**

Early random drop, 488  
Edge routers, 349

UDP, 382–84  
Enterprise application integration (EAI), 669  
Equation-based congestion control, 522–24  
Error correcting codes (ECC), 92, 99  
Error detection, 92–101  
CRC, 92, 96–101  
error correction versus, 100  
Internet checksum, 94–95  
problem, 64  
two-dimensional parity, 93–94  
Ethernet, 116–24  
adaptor, 117  
addresses, 120–21  
bridging, 167  
defined, 116  
experience with, 123–24  
frame format, 119–20  
hubs, 118  
media access control (MAC), 119  
physical properties, 116–19  
repeaters, 117, 118  
roots, 116  
switches, 207  
transceiver, 117  
transmitter algorithm, 121–23  
use, 124  
Exact match algorithm, 346  
Exercises  
applications, 722–28  
direct link networks, 151–65  
end-to-end data, 579–85  
end-to-end protocols, 443–55  
foundation, 55–63  
interNetworking, 360–79  
network security, 634–38  
packet switching, 221–31  
resource allocation and  
    congestion control, 527–40  
solutions, 729–42  
Expedited forwarding (EF) PHB, 517  
Explicit congestion notification (ECN), 488–89

**F**

Fabrics, 210, 214–18  
banyan, 216, 217  
crossbar, 215  
function, 211  
scalable, 214  
self-routing, 215–17  
shared bus, 214–15  
shared memory, 215  
Fair queuing (FQ), 469–74  
bit-by-bit round-robin, 471  
defined, 470  
example illustration, 472  
fairness, 470  
implementation, 472  
weighted (WFQ), 473–74

work-conserving, 472  
*See also* Queuing  
Fair resource allocation, 466–67  
Fast Fourier transform (FFT), 562  
Fast recovery, 485  
Fast retransmit, 483–84  
Fast, 483  
defined, 483  
duplicate ACKs, 484, 485  
function, 483–84  
trace of TCP with, 485  
*See also* Congestion control  
FDDI token ring, 124, 130–31  
802.5 versus, 130  
token rotation time (TRT), 130  
*See also* Token rings  
Feedback  
explicit, 463  
implicit, 463  
resource allocation, 462–63  
Fiber Distributed Data Interface (FDDI) protocols, 28–29,  
    65, 124, 240  
packets, 240  
packet size, 195  
*See also* FDDI token ring  
File Transfer Protocol (FTP), 26,  
    27  
Fine-grained QoS, 505  
Firefox web browser, 651  
Firewalls, 626–30  
defined, 626  
demilitarized zone (DMZ), 627–28  
filtering, 628  
level 4 switches, 628  
stateful, 629  
stateless, 629  
strengths and weaknesses, 629–30  
zones of trust, 627  
First-in-first-out (FIFO), 13, 467,  
    468–69  
defined, 468  
illustrated, 468  
priority queuing, 469  
problem, 469

Forward search algorithm, 281  
(continued)  
RED thresholds, 490  
as scheduling discipline, 468  
tail drop, 468, 469  
*See also* Queuing  
Fish networks, 350  
Fixed Diffe-Hellman, 612  
Flash crowd, 715  
FLASH format, 570  
Flat data types, 545–46  
Flood-and-prune protocols, 332  
Flow control  
congestion control versus, 458  
defined, 385  
support, 114  
Flows  
connectionless, 460–61  
defined, 460, 507  
with equal average rates, 509  
multiple, passing through  
    router, 461  
one-hop, 466  
types, 566–69  
quantitative guarantees of QoS,  
    462  
Framing, 84–91  
byte-counting approaches, 86–87  
clock-based, 89–91  
HDLC, 87–88  
PPP, 84–87  
problem, 64, 84  
sentinel-based approaches, 84–86  
SONET, 89–91, 182  
Frequency division duplexing (FDDI), 144  
Frequency-division multiplexing (FDM), 12  
Frequency hopping, 78  
Full-duplex links, 72

**G**

Forwarding equivalence class (FEC), 347  
Forwarding tables, 170, 252–53  
example rows, 267  
routing tables versus, 266–67  
with subnetting, 302

Gateways, 9  
Generalized MPLS (GMPLS), 350  
example rows, 267  
routing tables versus, 266–67  
with subnetting, 302

General Packet Radio Service (GPRS), 146

Global addresses, 248–50  
Global Internet, 297–329  
Globally unique identifiers, 170  
Global unicast addresses, 321–24  
Gnutella, 703–5  
defined, 703  
example topology, 704  
QUERY message, 703, 704  
software, 703  
*See also* Peer-to-peer networks  
Graphical interchange format (GIF), 542, 560–61  
8-bit color images, 560–61  
compression ratios, 561  
Guaranteed service, 506

**H**

H.323, 687–88  
defined, 687  
H.245 protocol, 688  
network devices, 687  
terminals, 688  
Half-duplex links, 72  
Handoff, 145  
Handshake protocol, 619–21  
Hashed message authentication code (HMAC), 598  
Hashing  
consistent, 706, 718  
modulo, 718  
Hash tables, 705  
Headers  
blocks, 673  
defined, 24  
prediction, 494  
Head-of-line blocking, 213, 214  
Heterogeneity, 232, 254, 356  
Hidden node problem, 139  
Hierarchical aggregation, 254  
High-Level Data Link Control (HDLC), 87–88  
bit stuffing, 88  
defined, 87–88  
frame format, 88

High Performance Parallel Interface (HiPPI), 15

**I**

- Internetworking (*continued*)
  - MPLS, 343–56
  - multicast, 329–43
  - routing, 266–97
  - service model, 236–48
  - simple, 232–66
- Internetworks
  - defined, 234
  - illustrated, 235, 236
  - as network of networks, 234
  - tunnels through, 264
- Interpacket gap, 50
- Intradomain routing, 267
  - defined, 267
  - integration, 313–15
  - See also Routing*
- I/O bus, 69, 209
- IP addresses
  - anycast, 328
  - global unicast, 321–24
  - IPv6, 319–24
  - multicast, 330
  - notation, 321
  - not specifying, 35
  - space exhaustion, 304
  - variable-length prefix match, 306
- See also Addresses*
- IP Security (IPsec), 622–25
  - ESP format, 624
  - transport mode, 623
  - tunneled mode, 623
- See also Security*
- IP tunnels, 263–366
  - contacting routers with, 265
  - defined, 263
  - downside, 266
  - illustrated, 264
  - IPv6, 318–29
    - 128-bit address space, 319
    - address assignment, 323
    - address notation, 321
    - address prefix assignment, 320
    - address space allocation, 320–21
    - advanced routing capabilities, 328–29
  - autoconfiguration, 326–28
  - deployment, 358
  - fragmentation extension header, 326
  - global unicast addresses, 321–24
  - historical perspective, 318–19
  - IPv4 transition to, 322–23
  - MLD, 331
  - NAT, 327–29
  - packet format, 324–26
  - packet header, 325
  - provider-based unicast address, 324
  - routing, 319–20
  - stateless autoconfiguration, 327
- See also Internet Protocol (IP)*

**J**

- Jacobson/Karels algorithm, 405–6
- clock and, 406
- introduction, 405
- new approach, 405–6
- problem, 405
- JavaScript Object Notation (JSON), 677
- Jitter, 50
- Joint Photographic Experts Group. *See JPEG compression*
- JPEG compression, 542, 561–66
  - block diagram, 561
  - color images, 565–66
  - control, 566
  - DCT phase, 562–63
  - defined, 561–62
  - encoding phase, 564–65
  - phases, 561–62
  - quantization phase, 563–64
- See also Compression*

**K**

- Karn/Partridge algorithm, 404–5
- Kerberos, 608–11
  - authentication illustration, 610
- authentication server (AS), 610
- clients, 609
- defined, 608
- Key predistribution, 599–604
  - public keys, 599–601
  - symmetric keys, 604
- Kilo (K), 45
- Known plaintext attack, 590

**L**

- Label switching routers (LSRs),
  - 347
  - ATM switches functioning as, 348
  - defined, 347
  - edge routers and, 349
- LAN emulation (LANE), 207
- LAN emulation configuration server (LECS), 209
- Last-mile links, 74–77
  - ADSL, 75–76, 77
  - CATV, 76–77
  - ISDN, 75
  - POTS, 74
  - VDSL, 76, 77
- See also Links*
- Latency, 40–44
  - bandwidth relationship, 47, 48
  - components, 42
  - defined, 40
  - measurement, 41–42
  - memory, 70
  - perceived, 43
  - pipe length and, 44
  - propagation delay, 42
  - queuing delays, 42
  - speed-of-light, 42
  - TCP, 438
  - UDP, 438
  - unit transmission time, 42
- Layering
  - examples, 20
  - features, 20–21
- Learning bridges, 184–87
  - illustrated, 184
  - implementation, 185–87

Index 795

Leased lines, 73–74  
**L**empel-Ziv (LZ) compression, 560–61  
 Length tags, 548  
 Lightweight Directory Access Protocol (LDAP), 663  
 Link Control Protocol (LCP), 86  
 Links, 7–10, 71–79  
     attributes, 71–72  
     baud rate, 80–81, 82  
     cable, 72–73  
     defined, 7  
     efficient utilization, 198  
     full-duplex, 72  
     half-duplex, 72  
     implementation, 71  
     last-mile, 74–77  
     leased line, 73–74  
     media, 71  
     multiple-access, 7  
     network adaptors, 67  
     point-to-point, 7  
 SONET, 89, 91  
     wireless, 77–79  
 Link-state packets (LSPs), 277–78  
     defined, 277  
     flooding of, 279  
     generation avoidance, 279  
     information, 277–78  
     sequence numbers, 279  
     time to live, 280  
 Link-state routing, 269, 277–86  
     defined, 277  
     example network, 282  
     LSPs, 277–78  
     OSPF, 283–86  
     reliable flooding, 277–80  
     route calculation, 280–83  
     routing table, 282  
     See also Routing  
**L**isten operation, 33  
 Little-endian form  
     defined, 544  
     illustrated, 545  
 Load balancing, 284  
 Local area networks (LANs), 14  
     ATM in, 206–9  
     designated bridges, 189  
     extended, 184, 188  
     shared-media, 183  
     switches, 183–94  
     switching, 167  
 Localization, 149  
 Local loop, 75  
 Local traffic, 309  
 Logical IP subnet (LIS), 257  
 Lossless compression  
     algorithms, 559–61  
     defined, 558  
     delta encoding, 560  
     dictionary-based methods, 560–61  
     differential pulse code modulation (DPCM), 559–60  
 Lempel-Ziv (LZ), 560–61  
 run length encoding (RLE), 559  
     See also Compression  
 Lossy compression  
     algorithms, 557–58  
     defined, 557  
     See also Compression  
**M**  
 Macroblocks, 567, 568  
 Mail readers, 646, 649  
 Main profile MPEG-2 stream, 571, 572  
 Management information base (MIB), 643  
     defined, 667  
     groups, 667  
     variables, 668  
 Manchester encoding, 82  
 Man-in-the-middle attack, 612  
 Many-to-many communication, 330  
 Markup languages, 553–57  
 Master key, 607  
 Maximum transmission unit (MTU), 240  
 MBone, 265  
 Measured performance, 41  
 Media access control (MAC), 119  
     address, 253  
     token ring, 127–28  
 Media gateway (MG), 577  
 Mega (M), 45  
 Memory bandwidth, 69  
 Memory latency, 70  
 MEMS (Microelectromechanical Systems), 183  
 Mesh networks, 135  
 Message authentication code (MAC), 597–98  
 Message buffers, 39  
 Message digest, 596  
 Message Digest 5 (MD5), 597  
 Message exchange patterns (MEPs), 671  
 Messages  
     ciphertext, 589  
     defined, 69  
     DHCP, 260  
     example data structure, 40  
     incoming/outgoing, copying, 39  
     SDP, 682, 693  
     SIP session, 685  
     tagged, 547–48  
 Message stream channels, 17  
 Message Stream Protocol (MSP), 22  
 Metropolitan area networks (MANs), 14  
     RPR in, 132  
     WiMAX, 143  
 Middleware, 657  
 MIME, 643–45  
     image types, 644  
     messages, 645  
     pieces, 644  
 Mobile IP, 289–94  
     foreign agent, 291  
     home agent, 291  
     route optimization, 293–94  
     security challenges, 294  
 Mobile networks, 294  
 Mobility agents, 291

Modulation, 71  
 Modulo hashing scheme, 718  
 Mores, 149  
 Motion compression, 575–76  
 Motion estimation, 569  
 Motion-JPEG, 575  
 Moving Picture Experts Group.  
     *See* MPEG  
 MP3, 575–76  
     compression ratios, 576  
     quantization tables, 576  
 MPEG, 566–75  
     computation expense, 570  
     defined, 566  
     effectiveness, 569–70  
     encoding, 569  
     frame types, 566–69  
     groups of pictures (GOP),  
         572–73  
     main profile, 571, 572  
     motion estimation, 569  
     performance, 569–70  
     stream packetizing, 574  
     stream decoding, 567  
     transmitting over a network,  
         571–75  
     video stream format, 571  
 MPEG-4, 570  
 Multicast, 329–43  
     addresses, 120, 330, 331–32  
     any source (ASM), 331  
     backbone, 265  
     defined, 10  
     distribution trees, 332  
     end-system, 697–700  
     frames, 192  
     implementation, 192  
     interdomain, 338–39  
     protocol fate, 341–43  
     protocol-independent (PIM),  
         334–38  
     receiver-driven layered (RLM),  
         574  
     routing, 332–43  
     source-specific (SSM), 331, 340  
     using, 330  
 Multicast backbone (MBone),  
     696  
 Multicast Listener Discovery  
     (MLD), 331  
 Multicast Open Shortest Path  
     First (MOSPF), 341–42  
 Multicast Source Discovery  
     Protocol (MSDP), 338–39  
     defined, 338  
     information broadcast, 338–39  
     operation, 339  
     peer RP, 339  
 Multihomed AS, 309  
 Multimedia applications, 426,  
     678–93  
     call control, 687–88  
     H.323, 687–88  
     resource allocation, 688–93  
 SDP, 680–82  
 session control, 679–86  
 SIP, 682–86  
     *See also* Applications  
 Multiparty conferencing tool, 426  
 Multiple-access links, 7  
 Multiple access with collision  
     avoidance (MACA), 140  
 Multiplexing, 25–26  
     defined, 11  
 DWDM, 180–81  
 FDM, 12  
     multiple logical flows, 11  
 SONET support, 90  
     statistical, 12  
 STDM, 12  
 Multiprotocol label switching  
     (MPLS), 233, 343–56  
     applications, 354  
     defined, 343–44  
     deployment, 354–55  
     destination-based forwarding,  
         344–50  
     exact match algorithm, 346  
     explicit routing, 350–51  
     forwarding equivalence class  
         (FEC), 347  
     generalized (GMPLS), 350  
     header, 353  
 label forwarding mechanism,  
     346  
 labels, 347, 355  
 label swapping, 351  
 label switching routers (LSRs),  
     347  
 layer, 348  
 routers, 344  
 tunnels, 352–56  
 VPNs, 352–56  
 Multistation access unit (MSAU),  
     126

**N**

Nagle's algorithm, 402–3  
 Name resolution, 663–66  
     client query, 664  
     example illustration, 665  
     *See also* Domain name system  
         (DNS)  
 Name servers, 659–63  
     hierarchy illustration, 660  
     levels, 661–62  
     resource records, 661, 662  
     zones, 659, 660  
     *See also* Domain name system  
         (DNS)  
 Namespace, 657  
 Naming conventions, 663–64  
 Napster, 702, 703  
 N-bit chipping code, 78  
 Needham-Schroeder  
     authentication protocol,  
         608, 609  
 Negative acknowledgments  
     (NAK), 107

**N**  
**Nethostbyname** utility, 33–34  
 Network adaptors, 67  
     block diagram, 68  
     design issues, 68  
     frames, 68–69  
     links, 67  
 Network address translation  
     (NAT), 327–29, 358  
     anycast address, 328  
     boxes, 328, 329

- defined, 327
- popularity, 329
- Network architectures, 3, 19–30
  - defined, 19
  - encapsulation, 24–25
  - Internet, 28–30
  - layering, 20–24
  - multiplexing/demultiplexing, 25–26
- OSI, 26–28
- protocols, 20–24
- Network Data Representation (NDR), 553
- Network designers, 6
- Network-induced jitter, 50
- Network model, 458–62
- Network provider, 7
- Networks
  - applications, 4–6
  - backbone, 322
  - building blocks, 2
  - connectionless, 171–72
  - connectivity, 7–10
  - CSMA, 64
    - defined, 2
    - direct link, 64–165
    - Ethernet, 116–24
    - FDDI, 240
    - fish, 350
  - generality, 2
  - as graphs, 268–69
  - growth, 50–51
  - high-speed, 46–48
  - interconnection, 10
  - mobile, 294
  - overlay, 693–719
  - packet-switched, 459
  - performance, 40–50
  - as pipes, 45
  - requirements, 6–19
  - resource sharing, 11–14
  - routing, 124–33
  - security, 586–638
  - sensor, 148–49
  - support for common services, 14–19
  - switched, 8
- virtual circuit, 172–79
- wireless, 133–47
- Network software
  - example application, 33–36
  - implementing, 30–40
  - sockets, 31–33
- Next Generation IP (IPng), 357
- Next hop router, 251
- NFS (Network File System), 16
- Nodes, 7–10, 66–71
  - addresses, 9
  - aggregation points, 149
  - cluster head, 149
  - defined, 7
  - exposed, problem, 139
  - failure, 149
  - hidden, problem, 139
  - illustrated, 8
  - leaf set, 708
  - mobility, 142
  - source, 10
- Nonforgeability, 588
- Nonrepudiation, 587
- Nonreturn to zero inverted (NRZI) encoding, 81–82
- Nonreturn to zero (NRZ)
  - encoding, 80–81
  - baseline wander, 80
  - clock recovery, 80–81
  - defined, 80
  - illustrated, 81
- NSFNET backbone, 298

defined, 22  
illustrated example, 23  
running switches, 169  
SunRPC/ UDP, 420

**Protocol-independent multicast (PIM),** 334–38  
bidirectional (BIDIR-PIM), 341–43  
defined, 334  
dense mode (PIM-DM), 334  
designated router (DR), 335  
operation, 336  
sender-specific state, 337  
shared trees, 335, 337  
source-specific multicast (PIM-SSM), 340  
source-specific trees, 335, 338  
sparse mode (PIM-SM), 334

**Protocols**  
application-specific, 441–42  
asynchronous, 419  
defined, 21  
family, 32  
implementation issues, 37–39  
interoperation, 23  
services, 31  
specifications, 23  
synchronous, 419  
*See also* specific protocols

**Protocol stacks, 23**

**Protocol-to-protocol interface, 37**

**Proxy ARP, 292**

**Pseudocode, 383**

**Pseudowire emulation, 352**

**Public-key authentication protocols, 606–7**

**Public-key certificates, 600**

**Public-key ciphers, 593–95**  
ElGamal, 595  
RSA, 594–95  
speed, 595

**Public key infrastructure (PKI), 600**

**Public keys, 593**  
authentication with, 595  
predistribution, 599–601

Q

Q2931, 195  
**Quality of service (QoS)**, 499–524  
application requirements, 500–505  
ATM, 521–23  
coarse-grained, 505  
defined, 14, 500  
differentiated service, 500  
emerging approaches, 524  
equation-based control, 522–24  
fine-grained, 505  
integrated services, 500  
multiple, 462  
quantitative guarantees, 505  
RPR support, 132  
RSVP, 505, 510–12  
virtual circuit networks, 505

**Quantization**  
equation, 563–64  
phase, 563–64  
table, 564

**Queuing**  
DiffServ, 690  
disciplines, 467–74  
fair (FQ), 469–74  
FIFO, 467, 468–69  
priority, 469  
weighted fair (WFQ), 521–22

**Quick start, 482, 483**

R

**Random early detection (RED),** 487–93  
average queue length computation, 487  
DECT versus, 488  
deployment in Internet, 488  
drop probability function, 487  
early random drop, 488  
with explicit feedback, 488

1

Q.2931, 195

**Quality of service (QoS),**

- 499–524

application requirements,

- 500–505

ATM, 521–23

coarse-grained, 505

defined, 14, 500

differentiated services, 516–22

emerging approaches, 524–25

equation-based congestion control, 522–24

fine-grained, 505

integrated services, 506–16

multiple, 462

quantitative guarantees, 462

RPR support, 132

RSVP, 505, 510–13

virtual circuit network, 178

**Quantization**

- equation, 563–64
- phase, 563–64
- table, 564

**Queueing**

- DifFserv, 690
- disciplines, 467–74
- fair (FQ), 469–74
- FIFO, 467, 468–69
- priority, 469
- weighted fair (WFQ), 473–74, 521–22

Quick start, 482, 483

**R**

Random early detection (RED), 487–93

average queue length computation, 488–89, 490

DECBit versus, 488

deployment in Internet, 492

drop probability function, 491

early random drop, 488

with explicit feedback scheme, 488

queue length thresholds, 489, 492

random nature, 492

weighted (WRED), 520–21

*See also* Congestion avoidance

Rate-based design, 411, 463

Real-time applications, 500

adaptability, 504–5

audio example, 501–3

distinguishing characteristic, 500

intolerant, 503–4

loss tolerance, 503

QoS requirements, 500–505

taxonomy, 503–5

tolerant, 503–4

**Real-time Transport Control Protocol (RTCP),** 430, 433–37

in best-effort networks, 688

block statistics, 435–36

canonical name (CNAME)

- concept, 434, 436, 437
- defined, 433
- functions, 433–34
- packet contents, 434–35
- packet types, 434
- reporting frequency, 435
- reports, 435
- sender report, 435
- source description packet, 436
- traffic, 435

**Real-time Transport Protocol (RTP),** 381, 426–37

**Application Level Framing (ALF),** 430

contributing source (CSRC), 433

details, 429–33

formats, 430

header format, 430–33

header format illustration, 431

packets, padding, 432

payload, 430, 431

playback buffer, 428

- Overlay nodes, programming, 696
- Overlays, 693–719
  - content distribution, 714–19
  - end system multicast, 697–709
  - layered on physical networks, 694
  - multicast tree embedded in, 697
  - multiple, 693
  - osification and, 695–96
  - peer-to-peer, 702–14
  - resilient, 701–2
- RON, 701–2
- routing, 695–702
  - routing overlays, 695–702
  - structured, 705–10
- See also Applications*

1

- Packet exchange diagrams, 103–4
- Packets
  - classifying, 513–15
  - contention, 167
  - defined, 13
  - failures at, 18
  - FDDI, 240
  - FIFO, 13
  - fixed-length, 197
  - forwarding, 19
  - fragmented, 242
  - IP format, 237–39
  - link-state (LSRs), 277–78
  - RTCPC, 434
  - RTP; padding, 432
  - size, 212, 295
  - unfragmented, 242
  - variable-length, 196
- in virtual circuit networks, 175
- Packer scheduling
  - algorithms, 515
  - defined, 507, 513
  - details specification, 514
- Packets per second (PPS) rate, 212
- Packet-switched networks, 459
  - defined, 8
- Performance, 40–50
  - application needs, 48–50
  - bandwidth, 40–44
  - delay × bandwidth product, 44–46
  - high-speed networks, 46–48
  - latency, 40–44
  - measured, 41
  - mobile networks, 294
  - MPEG, 569–70
  - switch, 211–14
- Per-hop behaviors (PHBs), 517
  - assured forwarding (AF), 518–22
  - expedited forwarding (EF), 517
- Periodic updates, 271–72
- Permanent virtual circuits (PVCs), 175
- P frames, 566, 567, 574
- Piconet, 136, 137
- Playback buffer, 428
  - illustrated, 502
  - operation, 502
- Playback point, 502, 505
- Playback time, 501
- Point-to-point links, 7
- Point-to-Point Protocol (PPP), 84–87

**800 Index**

Real-time Transport Protocol  
 (RTP), *continued*  
 profiles, 430, 432  
 protocol stack using, 427  
 requirements, 428–29  
 standard protocols, 430  
 synchronization source (SSRC),  
 433

Reassembly IP, 248

Receiver-driven layered multicast  
 (RLM), 574

Receiver-makes-right, 546, 547

Redirectors, 715–16

RED with In and Out (RIO),  
 518–20

defined, 518

drop possibilities, 518

effectiveness, 520

packet marking, 519

packet order, 520

Relays, 126

Reliability, 18–19

Reliable byte stream, 384–411

Reliable flooding, 277–80

defined, 277

design goals, 279

illustrated, 279

*See also* Link-state routing

Remote method invocation  
 (RMI), 412

Remote Procedure Call (RPC),  
 381, 411–26

acknowledgments, 416

at-most-once semantics, 418

channel abstraction, 417

components, 413

DCE-RPC, 422–26

functions, 414

fundamentals, 412–19

identifiers, 414–16

implementations, 419–26

layer, 414–15

mechanism illustration, 413

Open Network Computing  
 (ONC), 419

recurrent challenges, 415

reliability, 418

reliable, timeline, 416, 417

SunRPC, 420–22

as synchronous protocols, 419

timeline, 412

timeouts, 416

zero-or-more semantics, 418

*See also* End-to-end protocols

Reno algorithm, 494, 495

Repeaters, 181

defined, 117

illustrated, 118

Replay attack, 587, 604

Request/reply channels, 17

Request/reply Protocol (RRP),  
 22

communication with peers, 22

demultiplexing key, 26

Request to Send (RTS) frame,  
 140

Reservation-based design, 462–63

Resilient Overlay Network  
 (RON), 701–2

defined, 702

scaling, 702

Resilient Packet Ring (RPR),  
 131–33

buffer insertion, 132

counterrotating optical fiber  
 rings, 132

in MANs, 132

QoS support, 132

Resource allocation

defined, 458

effective, 464–66

elements, 457

evaluation criteria, 464–67

fair, 466–67

feedback-based, 462–63

host-centric, 462

issues, 458–67

for multimedia applications,  
 688–93

problem, 456

rate-based, 463

reservation-based, 462–63

router-centric, 462

taxonomy, 462–64

Policies, 717–19  
 Policing, 510  
 Polynomial arithmetic modulo 2,  
     97  
 Port Mapper, 421  
 Ports  
     buffering function, 213  
     communication, 211  
     input, 210, 212  
     output, 210  
     switch, 210–4  
 Post Office Protocol (POP), 649  
 P-persistent algorithm, 121  
 Presentation format, 542, 544–57  
 ASN.1, 551–52  
 conversion strategy, 546–47  
 data types, 545–46  
 encoding/decoding, 544  
 examples, 549–53  
 NDR, 553  
 stubs, 548–49  
 tags, 547–48  
 taxonomy, 545–49  
 XDR, 549–51  
 XML, 553–57  
*See also* Data  
 Pre-shared key (PSK) mode, 625  
 Pretty Good Privacy (PGP),  
     602–3, 613–15  
 confidentiality, 613  
 defined, 602  
 key signing parties, 603  
 message preparation steps, 614  
 sender authentication, 613  
*See also* Secure systems  
 Priority queuing, 469  
 Private key, 593  
 Processes, 37  
 Process models, 37–39  
     process-per-message, 37–38  
     process-per-protocol, 37, 38  
 Profiles, 675–76  
 Programmed I/O (PIO), 68  
 Propagation delay  
     defined, 44  
     speed-of-light, 42  
 Protocol graphs

bottleneck, 459  
 contacting with tunnels, 265  
 defined, 9  
 designated (DR), 335  
 edge, 349  
 implementation, 294–97  
 label switching (LSRs), 347  
 MPLS-enabled, 344  
 multiple flows passing through, 461  
 next hop, 251  
 PIM-SM, 334  
 running OSPF, 284  
 running RIP, 277  
 sender-specific state, 337  
 soft state, 510  
 switches versus, 253  
 Routing, 266–97  
     behavior, monitoring, 289–90  
     congestion control versus, 459  
     defined, 9, 171  
     distance vector, 269–77  
     distributed nature, 269  
     domains, 267, 307  
     forwarding versus, 266  
     interdomain, 306–15  
     intradomain, 267  
     IPv6, 319–20  
     link state, 269–86  
     metrics, 286–89  
     for mobile hosts, 289–94  
     multicasts, 332–43  
     network as graph, 268–69  
     optimality, 318  
     OSPF, 283–86  
     policies, 307  
     RIP, 275–77  
     source, 179–83  
     through banyan network, 217  
     triangle, 293  
 Routing areas, 316–18  
 defined, 316  
 illustrated, 316  
 Routing Information Protocol (RIP), 275–77  
 defined, 275  
 example network running, 276  
 packet format, 276  
*See also* Distance-vector routing  
 Routing overlays, 695–702  
 Routing tables, 170  
     BGP, 315  
     distance-vector routing, 270, 271  
     example rows, 267  
     forwarding tables versus, 266–67  
     link-state routing, 282  
     unicast, 333  
 RSA (Rivest, Shamir, and Adleman), 594–95  
 Run length encoding (RLE), 559  
 Runt frames, 122

**S**

Satellite communication, 147  
 Satphones, 147  
 Scalability, 515–16  
 Scanning, 141  
 Schemas, XML, 555  
**Sdr** defined, 6  
 Secure Hash Algorithm (SHA-1), 597  
 Secure HTTP (SHTTP), 618–19  
 Secure Shell (SSH), 615–17  
     defined, 615  
     port forwarding, 617  
     protocols, 616  
     SSH-CONN, 616, 617  
     SSH-TRANS, 616  
 Secure Socket Layer (SSL), 618, 619  
 Secure systems, 613–26  
     802.11, 625–26  
     IPsec, 622–25  
     PGP, 613–15  
 SSH, 615–17  
 Security, 586–638  
     authentication protocols, 604–13  
     authenticators, 595–98  
     cryptographic tools, 589–98  
*See also* Internet Protocol (IP)

firewalls, 626–30  
 key predistribution, 599–604  
 mobile networks, 294  
 transport layer, 618–22  
 wireless, 625–26

Security parameter index (SPI), 623  
 Segmentation and reassembly (SAR), 200–205, 295  
 Segments, 388, 398  
 Selective acknowledgments, 107, 409  
 Self-certifying certificates, 601  
 Self-clocking solution, 402  
 Self-routing fabrics, 215–16  
     defined, 215–16  
     illustrated, 217  
     scalability, 216–17  
*See also* Fabrics  
 Semantic gap, 19  
 Sender-specific state, 337  
 Sensor networks, 148–49  
 Scanning, 141  
 Separation of concerns, 115  
 Server-nonce, 620  
 Servers, 32  
     ARP, 258  
     authentication, 626  
     backend, 714  
     defined, 17  
     DHCP, 259, 260  
     name, 659–63  
     in network software implementation, 35–36  
     surrogates, 714  
*See also* Clients  
 Service classes, 506  
 Service interfaces  
     defined, 21  
     illustrated, 22  
 Service model, 236–48, 461–62  
     best effort, 236, 237  
     datagram delivery, 236–37  
     fragmentation and reassembly, 239–42  
     implementation, 242–48  
     packet format, 237–39  
*See also* Congestion control  
 Smart dust, 149  
 SOAP  
     defined, 670, 672–73  
     faults, 675  
 Simple Internet Protocol Plus (SIPP), 319  
 Simple Mail Transfer Protocol (SMTP), 29, 642, 646–48  
     client, 648  
     example, 647–48  
     server, 648  
     sessions, 647  
 Simple Network Management Protocol (SNMP), 289, 642, 666–68  
     client, 668  
     defined, 666  
     MIB, 667  
 Single probability calculations, 96–97  
 Sliding window, 105–15  
     algorithm, 105–8  
 Source-based congestion avoidance, 493–99  
*See also* Multiplexing

Steering, 132  
 Stop-and-wait algorithm, 102–5  
     defined, 102  
     shortcoming, 104  
     timeline, 104  
 Storage area networks (SANs), 15  
 Store-and-forward, 9  
 Streaming applications, 426  
     audio, 4  
     video, 4  
 Structured overlays, 705–10  
     consistent hashing, 706  
     defined, 705  
     distributed hash tables (DHTs), 707, 710  
     nodes, 707–9  
     objects, locating, 710  
     probabilistic bound, 710  
*See also* Overlays; Peer-to-peer networks  
 Stub AS, 309  
 Stubs, 348–49  
 Subnet mask, 300  
 Subnet number, 300  
 Subnetting, 299–303  
     defined, 299  
     example, 301  
     forwarding table, 302  
     multiple subnets, 303  
     scalability solution, 303  
 Subscriber stations, 143  
 SunRPC, 419, 420–22  
     defined, 420  
     header formats, 421  
     implementation, 420  
     protocol graph, 420  
     semantics, 422  
     two-tier identifiers, 420  
*See also* Remote Procedure Call (RPC)  
 Supress-replay attack, 604–5  
 Swarms, 711  
 Switched networks  
     circuit-switched, 8  
     illustrated, 8  
     packet-switched, 8, 9

Switched virtual circuits (SVCs), 173  
 Switches  
     ATM, 205, 218, 347–48  
     bridges versus, 252  
     buffers as delay source, 214  
     congested, 14, 167  
     contention problem, 167  
     crossbar, 215  
     defined, 9  
     Ethernet, 207  
     fabrics, 210, 211, 214–18  
     implementation, 208–18  
     input port, 210, 212  
     LAN, 183–94  
     link connection, 169  
     optical, 181–82  
     packer, 166  
     performance, 208–18  
     ports, 210–14  
     protocol graph running, 169  
     queues, 196  
     router versus, 253  
     shared bus, 214–15  
     shared memory, 215  
     star topology, 168  
     with three input/output ports, 169  
 throughput, 211–14  
 workstation as, 210  
*T*

Tags, 547–48  
     architecture, 548  
     defined, 547  
     length, 548  
     type, 548  
 Tahoe algorithm, 495  
 TCP-friendly congestion control, 523, 524  
 TCP/IP architecture. *See also* Internet architecture  
 TCP Vegas, 494–99  
     calculations, 496–97  
     congestion avoidance, 496  
     congestion window decrease, 499  
     current sending rate, 497  
     intuition behind, 495  
     multiplicative decrease, 499  
     race of congestion-avoidance mechanism, 499  
 Thick-net, 117  
 Thin-net, 117  
 Threads, 37  
 Three-way handshake, 390–91  
     defined, 390  
     timeline, 391  
*See also* Transmission Control Protocol (TCP)  
 Throughput. *See* Bandwidth  
 Ticket-granting server (TGS), 610  
 Time division duplexing (TDD), 144  
 frames out of phase, 91

Time division multiple access (TDMA), 146  
 Timelines, 103–4  
 reliable RPC, 416, 417  
 RPC, 412  
     for sliding window algorithm, 105  
     for stop-and-wait, 104  
     three-way handshake, 391  
 Timestamp, 408  
 Time to live (TTL), 280, 386  
 Token holding time (THT), 127  
 Timestamp, 124  
 Token rings  
     FDDI, 124, 130–31  
     frame format, 130  
     IBM, 124  
     MAC, 127–29  
     maintenance, 129–30  
     relay, 126  
 Token rotation time (TRT), 130  
 Traceroute tool, 290  
 Traditional applications, 642–68  
 Traffic  
     confidentiality, 586  
     local, 309  
     modeling, 213  
     RTCP, 435  
     transit, 308, 309  
 Trailers, 24  
 Transit AS, 309  
 Transit traffic, 308, 309  
 Transmission Control Protocol (TCP), 4, 29, 384–411  
     adaptive retransmission, 403–7  
     advertised window, 394, 397, 409  
     alternative design choices, 410–11  
     as byte-oriented protocol, 387–90  
     byte stream management, 388, 407  
     byte stream support, 384  
     congestion control, 385, 477–85  
     connection establishment/termination, 390–94  
     connections, 385, 389, 407  
     defined, 384  
     effective window, 397  
     end-to-end issues, 385–87  
     explicit connection establishment phase, 385  
     explicit setup/teardown phases, 411  
     extensions, 408–9  
     faster, 481–83  
     flow control, 385, 396–99  
     header format, 388  
     header length, 441  
     push operation, 408  
     receiver buffer, 395  
     record boundaries, 407–8  
     reliability through retransmission, 442  
     reliable and ordered delivery, 395–96  
     Reno, 494, 495  
     for request/reply applications, 410  
     round-trip latencies, 438  
     sawtooth pattern, 477  
     segment format, 387–90  
     segments, 388, 398  
     selective acknowledgments, 409  
     send buffer, 395  
     state-transition diagram, 391–94  
     Tahoe, 494, 495  
     three-way handshake, 390–91  
     throughput, 482  
     timeout mechanism, 408  
     timestamp, 408  
     transmission trigger, 400–403  
     Vegas, 494–99  
     as window-based protocol, 411  
     window size requirement, 400  
     wraparound protection, 399–400  
 Uniform resource identifiers (URIs), 654–55, 684  
 Uniform Resource Locators (URLs), 4, 654–55, 716  
 Universal Mobile Telecommunications System (UMTS), 146–47  
 Unmarshalling, 544  
 Unreliable service, 237  
 Unspecified bit rate (UBR), 521, 522  
 User Datagram Protocol (UDP), 29, 260, 382–84  
     checksum, 383  
     defined, 382  
     header format, 382

length field, 383  
 message queue, 384  
 pseudohander, 383  
 round-trip latencies, 438  
 throughput, 439  
*See also* End-to-end protocols  
 User-network interface (UNI), 199

**V**

Variable bit rate – nonreal-time (VBR-nrt), 521, 522  
 Variable bit rate – real-time (VBR-rt), 521, 522  
 Vat tool, 426  
 defined, 6  
 newer versions, 427  
 user interface, 427  
 Vegas algorithm, 494–99  
 calculations, 496–97  
 congestion avoidance, 496  
 congestion window decrease, 499  
 current sending rate, 497  
 intuition behind, 495  
 multiplicative decrease, 499  
 race of congestion-avoidance mechanism, 499  
 Very high rate digital subscriber line (VDSL), 76, 77  
**Vic**, 5–6  
**Video**  
 application classes, 5  
 compression, 566–70  
 interactive, 5  
 streaming, 4  
 Videoconferencing, 5  
 Video-on-demand, 5  
 Virtual circuit identifiers (VCIs), 173, 205  
 Virtual circuit networks ATM, 179  
 packets in, 175  
 QoS, 178  
 source routing in, 182  
 Virtual circuits (VC), 172

permanent, 173  
 switched, 173  
 table entries, 174  
**Virtual circuit switching**, 170, 172–79  
 buffer allocation, 177  
 characteristics, 177  
 connection setup, 172, 173  
 data transfer, 172  
 use of, 218  
**Virtualization**, 702  
 Virtual LANs (VLANs), 193  
 backbone, 193  
 header, 194  
**Virtual paths**, 205–6  
 example, 206  
 identifier (VPI), 205, 206  
**Virtual private networks (VPNs)**, 179, 262–63  
 defined, 262–63  
 illustrated, 264  
 implementation, 694  
 MPLS, 352–56  
**Viruses**, 630  
 Voice over IP (VOIP), 52, 426, 689

**W**

Wavelengths, 71  
**Wb**, 6  
**Web Services**, 668–78  
 defined, 670  
 REST, 676–78  
 SOAP, 670–76  
*See also* Applications  
**Web Services Description Language (WSDL)**  
 defined, 670  
 documents, 672  
 message exchange patterns (MEPs), 671  
 multiple bindings, 672  
 operation model, 671  
 parts, 671–72  
 as standard, 675  
 use, 671

Weighted fair queuing (WFQ), 473–74, 521–22  
**Weighted RED (WRED)**, 520–21  
**Wide area networks (WANs)**, 14, 15  
**Withdrawn routes**, 312  
**Work-conserving queuing**, 472  
**Workstations**  
 architecture, 67  
 as packet switches, 210  
**Worldwide Interoperability for Microwave Access. *See* WiMAX**  
**X**

XML, 553–57  
 defined, 554  
 namespaces, 556–57

Wrapping, 132  
**WS-I Basic Profile**, 676  
**WS-I Basic Security Profile**, 676

**X**

XML, 553–57  
 defined, 554  
 namespaces, 556–57

**Z**

Zero-or-more semantics, 418  
**Zones**, 659, 660

Schema Definition (XSD), 555, 556  
 schemas, 555  
 syntax, 554