

Principles of Computer System Design

An Introduction

Complete Index

Jerome H. Saltzer

M. Frans Kaashoek

Massachusetts Institute of Technology

Version 5.0

Copyright © 2009 by Jerome H. Saltzer and M. Frans Kaashoek. Some Rights Reserved.

This work is licensed under a  Creative Commons Attribution-Non-commercial-Share Alike 3.0 United States License. For more information on what this license means, visit <http://creativecommons.org/licenses/by-nc-sa/3.0/us/>

Designations used by companies to distinguish their products are often claimed as trademarks or registered trademarks. In all instances in which the authors are aware of a claim, the product names appear in initial capital or all capital letters. All trademarks that appear or are otherwise referred to in this work belong to their respective owners.

Suggestions, Comments, Corrections, and Requests to waive license restrictions:
Please send correspondence by electronic mail to:

Saltzer@mit.edu

and

kaashoek@mit.edu

Complete Index of Concepts

Design principles and hints appear in *underlined italics*. Procedure names appear in CAPS. Page numbers in **bold face** are in the Glossary. Index entries for the Glossary and Problem Sets use Part II page numbers.

A

- abort 9–27, PS–1, GL–1
- absolute path name 68, 72, GL–1
- abstraction 22, GL–1
 - leaky 30
- accelerated aging 8–12
- access control list 11–74, GL–1
- access time 48
- ACK (see acknowledgment)
- acknowledgment 7–67, 7–77, 7–82, GL–1
- ACL (see access control list)
- ACQUIRE 225, 9–70
- action 53, 9–3, GL–1
- action graph PS–138
- active fault 8–4, GL–1
- ad hoc* wireless network 2, PS–69, PS–79
- adaptive
 - routing 7–49, GL–1
 - timer 7–69
- additive increase 7–96
- address
 - destination GL–8
 - in naming 51, 122, GL–1
 - in networks 7–46, GL–21
 - resolution protocol 7–105, GL–1
 - source GL–32
 - space 51, GL–1
 - virtual 206, 243, GL–36
- adopt sweeping simplifications* *xliv*, 40, 149, 160, 7–20, 8–8, 8–37, 8–51, 9–3, 9–29, 9–30, 9–47, 10–11, 11–16
- ADVANCE 276
- Advanced Encryption Standard (AES) 11–103
- adversary 11–6, GL–2
- advertise 76, 7–51, GL–2
- alias 72, GL–2
 - (see also indirect name)
- alibi 228
- all-or-nothing atomicity 89, 9–21, GL–2
- any-to-any connection 7–4, GL–2
- application protocol 7–23
- arbiter failure 229
- archive 9–37, GL–2
 - log 9–40
- ARP (see address resolution protocol)
- assembly 9
- associative memory 51
- asynchronous 55, 309, 7–7, GL–2
- at-least-once
 - protocol assurance 7–68, GL–2
 - RPC 170
- at-most-once
 - protocol assurance 7–71, GL–2
 - RPC 170
- atomic GL–2
 - action 89, 220, 9–3, GL–2
 - storage GL–2
- atomicity 9–3, 9–19, GL–2
 - all-or-nothing 89, 9–21, GL–2
 - before-or-after 46, 89, 9–54, GL–3
 - log 9–40
- attachment point (see network attachment point)
- authentication 11–20, GL–3
 - key 11–41
 - logic 11–86
 - origin 11–37, GL–22
 - tag 11–41, GL–3
- authoritative name server 179
- authorization 11–21, 11–73, GL–3
 - matrix 11–73

INDEX–1

- automatic rate adaptation 7-14, 7-93, GL-3
- availability 8-9, GL-3
- avoid excessive generality* *xliii*, 16
- avoid rarely used components* *xliii*, 8-51, 8-60, 11-148
- AWAIT 276
- B**
- backoff
 - exponential 7-70, GL-11
 - exponential random 9-78, GL-11
 - random 227
- backup copy 10-10, GL-3
- backward error correction 8-22, GL-3
- bad-news diode 38, GL-3
- bandwidth 7-37, GL-3
- bang-bang protocol 7-114
- base name 67
- batch 314, GL-3
- bathub curve 8-10
- be explicit* *xliii*, 8-7, 11-4, 11-10, 11-24, 11-26, 11-53, 11-55, 11-61, 11-67, 11-68
- before-or-after atomicity 46, 89, 9-54, GL-3
- Belady's anomaly 337
- best effort 7-14, GL-4
 - contract 7-21
- big-endian numbering 158
- BIND 63
- binding 27, 61, 62, GL-4
 - stable GL-32
 - user-dependent 74, GL-36
- bit error rate 7-38, GL-4
- bit stuffing 7-39, GL-4
- blast protocol 7-119
- blind write 9-49, 9-66, GL-4
- block 245
 - cipher 11-103
 - in UNIX[®] 93
- blocking read 9-11
- bootstrapping 223, 9-21, 9-43, 9-61, 9-80, GL-4
- bot 11-19
- bottleneck 300, GL-4
 - data rate 7-79
- bounded buffer 206
- broadcast 77, 7-45, 7-102, GL-4
- buffer overrun attack 11-22, 11-23
- burn in, burn out 8-11
- burst 7-7, GL-4
- bus 80
 - address 81
 - arbitration 81
- Byzantine fault 8-53, GL-4
- C**
- CA (see certificate authority)
- cache 51, 332, GL-4
 - coherence 10-4, GL-4
 - snoopy 10-8, GL-31
- capability 11-74, GL-4
- capacity 302, 322, GL-5
- careful storage 8-45
- carrier sense multiple access 7-100, GL-11
- cascading change propagation 11-105
- case-
 - coercing 128
 - preserving 128
 - sensitive 128
- CBC (see cipher-block chaining)
- cell 46
 - storage 9-31, GL-5
- certificate 11-56, GL-5
 - authority 11-56, GL-5
 - self-signed 11-92
- certify 11-11, GL-5
- checkpoint 9-51, GL-5
- checksum 7-10, 7-74, GL-5
- cipher 11-99, GL-5
- cipher-block chaining 11-105
- ciphertext 11-49, GL-5
- circuit
 - switch 7-9, GL-5
 - virtual 7-82, GL-36
- cleartext 11-38, GL-5
- client 155, 7-63, GL-5

- client/service organization 159, GL-5
 - clock algorithm 344
 - CLOSE 88
 - close-to-open consistency 192, GL-5
 - closure 68, GL-5
 - coding 8-21
 - coherence
 - cache 10-4, GL-4
 - read/write 46, GL-27
 - collision
 - Ethernet 7-100, GL-11
 - hash 11-33
 - name 124, GL-5
 - commit 9-27, GL-6
 - two-phase 9-84, GL-35
 - communication link 59, GL-6
 - commutative cryptographic transformation 11-153
 - COMPARE 75
 - compartment 11-81
 - compensation 10-31, GL-6
 - complete mediation* *xliv*, 11-5, 11-15, 11-18, 11-25, 11-136
 - complexity 10, GL-6
 - Kolmogorov 11
 - component 8
 - computationally secure 11-33
 - condition variable 276, PS-48
 - conditional failure rate function 8-14
 - confidentiality 11-49, GL-6
 - confinement 11-82, GL-6
 - conflict 10-19
 - confusion matrix 372
 - congestion 7-13, 7-87, GL-6
 - collapse 7-87, 7-88, GL-6
 - connection 7-7, GL-6
 - connectionless 7-8, GL-6
 - consensus 10-11, GL-6
 - the consensus problem 10-11
 - consistency GL-6
 - close-to-open 192, GL-5
 - eventual 10-3
 - external time 9-18
 - sequential 9-18
 - strict 10-3, GL-33
 - strong (see consistency, strict)
 - consistent hashing PS-90
 - constituent 9
 - constraint 10-2, GL-7
 - context 62, GL-7
 - context reference 63, 66, GL-7
 - continuous operation 8-35, GL-7
 - control point 7-89, GL-7
 - convergent encryption PS-191
 - cookie 11-124
 - cooperative multitasking 269
 - cooperative scheduling 269, GL-7
 - copy-on-write 326
 - covert channel 11-84, GL-7
 - critical section 220
 - cross-layer cooperation 7-91, 7-93
 - cryptographic
 - hash function 11-32, GL-7
 - key 11-39, GL-7
 - transformation 11-39, 11-99, GL-7
 - transformation, commutative 11-153
 - cryptography 11-22, GL-7
 - public key 11-40, GL-26
 - shared-secret 11-40, GL-31
 - CSMA/CD (see carrier sense multiple access)
 - cursor 88
 - cursor stability 10-30
 - cut-through 7-10, GL-7
- D**
- dally 314
 - dangling reference 130, GL-7
 - data integrity
 - in communications 7-73, GL-7
 - in security assurance 11-36, GL-7
 - in storage 10-15
 - data rate 7-4, GL-8
 - datagram 7-8
 - deadlock 221, 9-76, GL-8
 - decay 46, 8-41, GL-8
 - factor 7-70
 - set 8-42, GL-8
 - declassify 11-84

- decouple modules with indirection* *xliii*, 27, 106, 123, 173, 243, 286, 325, 7–110
- decrypt 7–86, 11–49, GL–8
- DECRYPT 11–49
- default context reference 66, GL–8
- defense in depth 8–3, 11–12
- delay 7–9, 7–98
 - processing 7–10, 7–98, GL–25
 - propagation 7–3, 7–10, 7–99, GL–25
 - queuing 7–11, 7–99, GL–26
 - transmission 7–10, 7–99, GL–34
- delayed authentication 11–157
- delegation forwarding 112
- demand
 - algorithm 339, GL–8
 - paging 346
- dependent outcome record 9–81
- design for iteration* *xliiii*, 37, 228, 8–8, 8–11, 8–15, 8–37, 11–4, 11–10, 11–26
- design principles* 40
 - adopt sweeping simplifications* *xliiii*, 40, 149, 160, 7–20, 8–8, 8–37, 8–51, 9–3, 9–29, 9–30, 9–47, 10–11, 11–16
 - avoid excessive generality* *xliiii*, 16
 - avoid rarely used components* *xliiii*, 8–51, 8–60, 11–148
 - be explicit* *xliiii*, 8–7, 11–4, 11–10, 11–24, 11–26, 11–53, 11–55, 11–61, 11–67, 11–68
 - complete mediation* *xliv*, 11–5, 11–15, 11–18, 11–25, 11–136
 - decouple modules with indirection* *xliiii*, 27, 106, 123, 173, 243, 286, 325, 7–110
 - design for iteration* *xliiii*, 37, 228, 8–8, 8–11, 8–15, 8–37, 11–4, 11–10, 11–26
 - durability mantra* *xliv*, 10–10
 - economy of mechanism* *xliv*, 11–16, 11–26
 - end-to-end argument* *xliiii*, 7–31, 8–49, 8–52, 9–79, 10–30, 11–16
 - escalating complexity principle* *xliiii*, 14
 - fail-safe defaults* *xliv*, 11–16, 11–24, 11–126
 - golden rule of atomicity* *xliv*, 9–26, 9–42
 - incommensurate scaling rule* *xliiii*, 33, 316, 7–91
 - keep digging principle* *xliiii*, 37, 8–8, 8–64, 11–126
 - law of diminishing returns* *xliiii*, 18, 305, 9–53
 - least privilege principle* *xliv*, 11–17, 11–24, 11–39, 11–79, 11–80, 11–81, 11–130
 - minimize common mechanism* *xliv*, 11–16, 11–141
 - minimize secrets* *xliv*, 11–15, 11–34, 11–39
 - one-writer principle* *xliv*, 212
 - open design principle* *xliiii*, 11–13, 11–39, 11–64, 11–140
 - principle of least astonishment* *xliiii*, 85, 89, 128, 205, 11–15, 11–138
 - robustness principle* *xliv*, 29, 8–15
 - safety margin principle* *xliv*, 24, 8–8, 8–16, 8–58
 - unyielding foundations rule* *xliv*, 20, 38, 288
- destination 7–8, 7–27, 7–46, GL–8
 - address GL–8
- detectable error 8–17, GL–8
- dictionary attack 11–34
- digital signature 11–44, GL–8
- dilemma of the two generals 9–90, GL–35
- diminishing returns, law of* *xliiii*, 18, 305, 9–53
- direct
 - mapping 346
 - memory access 83
- directory 65, GL–8
 - in UNIX[®] 97
- discipline
 - simple locking 9–72, GL–31
 - systemwide locking 9–70
 - two-phase locking 9–73, GL–35

- discovery
 - of maximum transmission unit 7-61, GL-19
 - of names 76
 - discretionary access control 11-74, 11-81, GL-8
 - dispatcher 262
 - distance vector 7-54
 - divide-by-zero exception 206
 - DMA (see direct memory access)
 - do action (see redo action)
 - domain
 - name 175
 - virtual memory 230, GL-8
 - Domain Name System
 - design of 175
 - eventual consistency in 10-5
 - fault tolerance of 8-36, 8-39
 - down time 8-9, GL-9
 - dry run 9-97
 - duplex 7-45, GL-9
 - duplicate suppression 7-17, 7-71, GL-9
 - durability 46, 8-39, GL-9
 - log 9-40
 - durability mantra* *xliv*, 10-10
 - durable storage 8-38, 8-46, GL-9
 - dynamic scope 68, GL-9
- E**
- earliest deadline first scheduling policy 360, GL-9
 - early drop 7-92, GL-9
 - echo request 7-60
 - economy of mechanism* *xliv*, 11-16, 11-26
 - element 9
 - elevator algorithm 361
 - emergent property 4, GL-9
 - emulation 208, GL-9
 - encrypt 7-86, 11-49, GL-9
 - ENCRYPT 11-49
 - encryption key 11-49
 - end-to-end GL-9
 - layer 7-25, 7-28, 7-62, GL-10
 - end-to-end argument* *xliii*, 7-31, 8-49, 8-52, 9-79, 10-30, 11-16
 - enforced modularity 153, GL-10
 - ENUMERATE 63
 - enumerate (in naming) 63, GL-10
 - environment GL-10
 - of a system 8
 - of an interpreter 53
 - reference 53
 - erasure 8-23, GL-10
 - ergodic 8-10, GL-10
 - error 8-4, GL-10
 - containment 8-2, 8-5, GL-10
 - correction 7-40, 8-2, 8-57, GL-10
 - detection 7-40, 8-2, GL-10
 - escalating complexity principle* *xliii*, 14
 - Ethernet 7-100, GL-11
 - event variable PS-45
 - eventcount 276, GL-11
 - eventual consistency 10-3, GL-11
 - EWMA (see exponentially weighted moving average)
 - exactly-once
 - protocol assurance 7-73, GL-11
 - RPC 171
 - exception 57, 206, 235, GL-11
 - divide-by-zero 206
 - illegal instruction 235
 - illegal memory reference 233
 - indirect 325
 - memory reference 231
 - missing-page 328, GL-19
 - permission error 233
 - TLB miss 253
 - explicit context reference 66, GL-11
 - explicitness 11-61, GL-11
 - exploit brute force* 301
 - exponential
 - backoff 7-70, GL-11
 - random backoff 9-78, GL-11
 - exponentially weighted moving average 355, 7-70
 - export 60, GL-11
 - external time consistency 9-18

F

fail-
 fast 8-5, 8-17, GL-11
 safe 8-17, GL-12
 secure 8-17, GL-12
 soft 8-17, GL-12
 stop 8-5, GL-12
 vote 8-27, GL-12
fail-safe defaults *xliv*, 11-16, 11-24,
 11-126
 failure 8-4, GL-12
 tolerance 8-16, GL-12
 false positive/negative 371
 fast start 7-114
 fate sharing 153
 fault 8-3, GL-12
 avoidance 8-6, GL-12
 tolerance 8-5, GL-12
 tolerance design process 8-6
 tolerance model 8-18
 FCFS (see first-come, first-served)
 FIFO (see first-in, first-out)
 file 87, GL-12
 in UNIX[®] 95
 memory-mapped 325
 pointer 88
 fingerprint 7-10, GL-12
 first-come, first-served scheduling policy 353,
 GL-12
 first-in, first-out page-removal policy 336,
 GL-12
 fixed
 timer 7-69
 window 7-78
 flooding 2, PS-75
 flow control 7-77, GL-12
 follow-me forwarding 112
 force 320, 9-53, GL-13
 forward
 error correction 8-21, GL-13
 secrecy 11-61, GL-13
 forwarder 7-9
 forwarding table 7-48, GL-13
 fragile name 121

fragment GL-13
 frame 7-6, 7-8, 7-37, GL-13
 freshness 11-61, GL-13
 full-duplex 7-45, GL-13

G

garbage collection 131
 gate (protected entry) 236, GL-13
 generality 15
 generated name 124, GL-13
 GET 50
 global name 75, GL-13
golden rule of atomicity *xliv*, 9-26, 9-42
 granularity 8, 9-71
 guaranteed delivery 7-14

H

half-duplex 7-45, GL-13
 Hamming distance 8-21, GL-13
 hard-edged 7-6
 hard error 8-5
 hard link 105
 hard real-time scheduling policy 359, GL-13
 hash function 125, GL-14
 hashed MAC 11-107
 hazard function 8-14
 header 7-26, GL-14
 heartbeat 8-54
 hierarchy 25, GL-14
 in naming 73
 in routing 7-56, GL-14
 high-water mark 9-65
hints 40
exploit brute force 301
instead of reducing latency, hide it 309
optimize for the common case 307, 334,
 9-39
separate mechanism from policy 331, 349,
 11-7, 11-84
 hit ratio 333
 HMAC (see hashed MAC)
 hop limit 7-54, GL-14
 hot swap 8-35, GL-14
 hyperlink 133

I

I/O bottleneck 316
 ICMP (see Internet control message protocol)
 idempotent 170, 7-18, 9-47, GL-14
 identifier 127, GL-14
 illegal instruction GL-14
 exception 235
 illegal memory reference exception 233
 IMS (see Information Management System)
 in-memory database 9-39
 incommensurate scaling 5, GL-14
incommensurate scaling rule *xliii*, 33, 316, 7-91
 incremental
 backup 10-18, GL-14
 redundancy 8-21
 indirect
 name 73, 104, GL-14
 indirection 27, 61, GL-14
 exception 325
 infant mortality 8-11
 information flow control 11-83
 Information Management System 9-100
 inode 95
 install 9-39, GL-15
instead of reducing latency, hide it 309
 instruction
 reference 53, GL-15
 repertoire GL-28
 integrity (see data integrity)
 intended load 7-88, GL-15
 interconnection 8
 interface 8
 interleaving 310, GL-15
 intermittent fault 8-5, GL-15
 International Organization for
 Standardization 7-30, GL-15
 Internet 7-32
 control message protocol 7-60
 protocol 7-32
 service provider 139
 interpreter 53, GL-15
 interrupt 53, 235, 283, GL-15
 invalidate 10-7, GL-15

invisible hand 7-98
 IP (see Internet protocol)
 ISO (see International Organization for
 Standardization)
 isochronous 7-6, GL-15
 isolation 220
 ISP (see Internet service provider)
 iteration 36

J

jitter 7-84, GL-15
 job 352, GL-15
 journal storage 9-31, GL-16

K

KDC (see key distribution center)
keep digging principle *xliii*, 37, 8-8, 8-64, 11-126
 kernel 238, GL-16
 mode 234, GL-16
 key (see cryptographic key)
 key distribution center 11-57, GL-16
 key-based cryptographic transformation
 11-41, GL-16
 Kolmogorov complexity 11

L

latency 49, 302, 8-5, GL-16
 latent fault 8-4, GL-16
law of diminishing returns *xliii*, 18, 305, 9-53
 layer
 bypass 79
 end-to-end 7-25, 7-28, 7-62, GL-10
 link 7-25, 7-34, GL-16
 network 7-25, 7-27, 7-46, GL-21
 layering 24, GL-16
 leaky abstraction 30
least astonishment principle *xliii*, 85, 89, 128, 205, 11-15, 11-138
least privilege principle *xliv*, 11-17, 11-24, 11-39, 11-79, 11-80, 11-81, 11-130

- least-recently-used page-removal policy 338, GL-16
 - least significant component 71
 - lexical scope (see static scope)
 - lightweight remote procedure call 238, PS-25
 - limited change propagation 11-100
 - limited name space 129, GL-16
 - link
 - in communications 59, GL-6
 - in naming 73, GL-16
 - in UNIX[®] 99
 - layer 7-25, 7-34, GL-16
 - soft (see indirect name)
 - symbolic (see indirect name)
 - list system 11-74, GL-16
 - little-endian numbering 158
 - livelock 222, 9-78, GL-16
 - locality of reference 334, GL-17
 - spatial 334, GL-32
 - temporal 334, GL-34
 - location-addressed memory 51
 - lock 218, 9-69, GL-17
 - compatibility mode 9-76
 - manager 9-70
 - point 9-72, GL-17
 - set 9-72, GL-17
 - lock-step protocol 7-75, GL-17
 - locking discipline
 - simple 9-72, GL-31
 - systemwide 9-70
 - two-phase 9-73, GL-35
 - log 9-39, GL-17
 - archive 9-40
 - atomicity 9-40
 - durability 9-40
 - performance 9-40
 - record 9-42
 - redo 9-50, GL-28
 - sequence number 9-53
 - undo 9-50, GL-28
 - write-ahead 9-42, GL-37
 - logical
 - copy 10-10, GL-17
 - locking 9-75, GL-17
 - lost object 130
 - LRPC (see lightweight remote procedure call)
 - LRU (see least-recently used)
- M**
- MAC
 - (see media access control address)
 - (see message authentication code)
 - magnetic disk memory 49
 - malware 11-19
 - Manchester code 7-36, GL-17
 - margin 8-20, GL-17
 - mark point 9-58, GL-17
 - marshal/unmarshal 157, GL-17
 - maskable error 8-18, GL-17
 - masking 8-2, 8-17, GL-18
 - massive redundancy 8-25
 - master 10-10, GL-18
 - maximum transmission unit 7-45, GL-18
 - mean time
 - between failures 8-9, GL-18
 - to failure 8-9, GL-18
 - to repair 8-9, GL-18
 - media access control address 126
 - mediation 11-73, GL-18
 - memory 45
 - associative 51
 - barrier 47
 - cell 46
 - location-addressed 51
 - manager 230, GL-18
 - manager, multilevel 325
 - manager, virtual 206, 243, GL-36
 - mapped file 325
 - mapped I/O 84, GL-18
 - random access 50, GL-26
 - transactional 9-69, GL-34
 - volatile/non-volatile 45, GL-21, GL-36
 - memory reference exception 231
 - memoryless 8-13, GL-18
 - message 59, 7-7, 7-33, GL-18
 - authentication 11-36, GL-18
 - authentication code 11-44, GL-19
 - representation 54

- message-sending protocol 7–63
 - message timing diagram 155
 - metadata 91, 120, GL-19
 - microkernel 240, GL-19
 - minimize common mechanism* *xliv*, 11–16, 11–141
 - minimize secrets* *xliv*, 11–15, 11–34, 11–39
 - mirror 10–9, GL-19
 - missing-page exception 328, GL-19
 - mobile host 7–118
 - modular sharing 116, GL-19
 - modularity 19
 - enforced 153, GL-10
 - soft 153, GL-32
 - module 9, 8–2, GL-19
 - monolithic kernel 238, GL-19
 - most-recently-used page-removal policy 340, GL-19
 - most significant component 72
 - MRU (see most-recently-used)
 - MTBF (see mean time between failures)
 - MTTF (see mean time to failure)
 - MTTR (see mean time to repair)
 - MTU (see maximum transmission unit)
 - MTU discovery 7–61, GL-19
 - multihomed 7–46, GL-19
 - multilevel
 - memory 324, GL-19
 - memory manager 325
 - multiple
 - lookup 73, GL-19
 - reader, single-writer protocol 9–76
 - register set processor PS-31
 - multiplexing 7–5, 7–42, 7–47, 7–64, GL-19
 - multiplicative decrease 7–96
 - multipoint 7–67, GL-19
 - multiprogramming 256
 - multitasking 256
 - Murphy's law 86
 - mutual exclusion 220
- N**
- N + 1 redundancy 8–35, GL-20
 - N-modular redundancy 8–26, GL-20
 - N-version programming 8–36, GL-20
 - NAK (see negative acknowledgment)
 - name 44, GL-20
 - base 67
 - collision 124
 - conflict 116, GL-20
 - discovery 76
 - fragile 121
 - generated 124, GL-13
 - global 75, GL-13
 - indirect 73, 104, GL-14
 - lookup, multiple 73, GL-19
 - opaque 121, GL-21
 - overloaded 120, GL-22
 - path GL-23
 - pure 120, GL-26
 - qualified 67, GL-26
 - resolution 62
 - resolution, recursive 71, GL-27
 - well-known 77, GL-36
 - name-mapping algorithm 62
 - name space 61, GL-20
 - limited 129, GL-16
 - unique identifier 64, GL-35
 - universal 62, GL-35
 - unlimited 129, GL-35
 - name-to-key binding 11–45, GL-20
 - namespace (see name space)
 - naming
 - authority 180
 - hierarchy 73, GL-20
 - network 72, GL-20
 - scheme 61, GL-20
 - NAT (see network address translation)
 - negative acknowledgment 7–71, 7–83, GL-20
 - nested outcome record 9–86
 - network 7–2, GL-21
 - address 7–46, GL-21
 - address translation 7–61
 - attachment point 65, 7–9, 7–27, 7–46, GL-21
 - layer 7–25, 7–27, 7–46, GL-21

- services access point GL-21
 - Network File System 184
 - NFS (see Network File System)
 - NMR (see N-modular redundancy)
 - non-blocking read 9-12
 - non-discretionary access control 11-74, 11-81, GL-21
 - non-preemptive scheduling 269, GL-21
 - non-volatile memory 45, GL-21
 - nonce 7-17, 7-71, GL-21
 - not-found result 64
 - NSAP (see network services access point)
- O**
- object 9, 60, GL-21
 - object-based virtual memory PS-51
 - occasionally connected 10-20
 - offered load 311, 7-88, GL-21
 - on-demand zero-filled page 326
 - one-time pad 11-99
 - one-writer principle* *xliv*, 212
 - opaque name 121, GL-21
 - OPEN 88
 - open design principle* *xliv*, 11-13, 11-39, 11-64, 11-140
 - operating system 78, 79, GL-21
 - OPT (see optimal page-removal policy)
 - optimal page-removal policy 337, GL-21
 - optimistic concurrency control 9-63, GL-21
 - optimize for the common case 9-45
 - optimize for the common case* 307, 334, 9-39
 - origin authenticity 11-37, GL-22
 - orphan 130
 - OSI (see International Organization for Standardization)
 - outcome record 9-32
 - overhead 302
 - overlay network 7-33, 3, PS-74
 - overload 311, GL-22
 - overloaded name 120, GL-22
 - overprovisioning 7-94
- P**
- packet 7-8, 7-33, GL-22
 - forwarding 7-9, GL-22
 - forwarding network 7-9
 - switch 7-9, GL-22
 - page 245, GL-22
 - fault (see missing-page exception)
 - map 245, GL-22
 - on-demand zero-filled 326
 - table 246, GL-22
 - page-map address register 247, GL-22
 - page-removal policy 329, GL-22
 - clock algorithm 344
 - direct mapping 346
 - first-in, first-out 336, GL-12
 - least-recently used 338, GL-16
 - most-recently used 340, GL-19
 - optimal 337, GL-21
 - random 345
 - pair-and-compare 8-33, GL-22
 - pair-and-spare GL-22
 - parallel transmission 7-35, GL-23
 - partition 8-34, 10-18, GL-23
 - password 11-31, GL-23
 - patch 17
 - path 7-48
 - name 75, GL-23
 - name, absolute 68, 72, GL-1
 - name, relative 72, GL-27
 - search 73, 75, GL-29
 - selection 7-51, GL-23
 - vector 7-51
 - payload 7-26, GL-23
 - peer-to-peer
 - design 164
 - network 3
 - pending 9-32, GL-23
 - performance log 9-40
 - permission error exception 233
 - persistent 46, GL-23
 - fault 8-5, GL-23
 - sender 7-67, GL-23
 - pessimistic concurrency control 9-63, GL-23
 - PGP (see protocol, pretty good privacy)

- phase encoding 7-36, GL-23
- phase-locked loop 7-36
- physical
 - address 243, GL-24
 - copy 10-10, GL-24
 - locking 9-75, GL-24
- piggybacking 7-77, GL-24
- pipeline GL-24
- PKI (see public key infrastructure)
- plaintext 11-38, 11-49, GL-24
- point-to-point 7-44, GL-24
- polling 273, GL-24
- port 7-64, GL-24
- precision (in information retrieval) 373
- preemptive scheduling 269, GL-24
- preparing 346, GL-24
- PREPARED
 - message 9-87
 - state GL-24
- presentation
 - protocol 7-23, 7-67, GL-24
 - service 7-29
- presented load (see offered load)
- preservation 8-40
- presumed commit 9-88
- preventive maintenance 8-12, GL-24
- pricing 7-97
- primary
 - copy 10-10, GL-24
 - device 331, GL-25
- principal 11-20, GL-25
- principle of escalating complexity* xliii, 14
- principle of least astonishment* xliii, 85, 89, 128, 205, 11-15, 11-138
- principles (see *design principles*)
- priority
 - inversion 358
 - scheduling policy 357, GL-25
- privacy 11-6, GL-25
- private key 11-40, GL-25
- probe 7-60
- procedure calling convention 150
- process 97, 248
- processing delay 7-10, 7-98, GL-25
- processor multiplexing 256
- producer and consumer problem 211
- program counter 56, GL-25
- progress 9-77, GL-25
- propagation delay 7-3, 7-10, 7-99, GL-25
- propagation of effects 4, GL-25
- protection 11-6, GL-25
 - group 11-76, GL-25
- protocol 7-21, GL-25
 - address resolution 7-105, GL-1
 - application 7-23
 - bang-bang 7-114
 - blast 7-119
 - bus arbitration 81
 - carrier sense multiple access 7-100, GL-11
 - challenge-response 11-64
 - Diffie-Hellman key agreement 11-68
 - Internet 7-32
 - internet control message 7-60
 - Kerberos 11-58
 - lock-step 7-75, GL-17
 - message-sending 7-63
 - multiplexing 7-42
 - Network File System 184
 - presentation 7-23, 7-67, GL-24
 - pretty good privacy 11-98
 - ready/acknowledge 7-35, GL-27
 - real-time transport 7-67
 - reliable message stream 7-66
 - request/response 7-66
 - routing 7-50
 - secure shell 11-46
 - secure socket layer 11-117
 - security 11-36, 11-54, GL-29
 - simple network time service 7-109
 - stream transport 7-82
 - transmission control 7-65
 - transport 7-23, 7-63, GL-34
 - transport layer security 11-116
 - two-phase commit 9-84, GL-35
 - user datagram 7-65
- proxy 7, 371

- pseudocode representation 54
 - pseudorandom number generator 11-101
 - public key 11-40, GL-25
 - cryptography 11-40, GL-26
 - infrastructure 11-93, 11-114
 - publish/subscribe 173, GL-26
 - pull 172
 - pure name 120, GL-26
 - purging 8-33, GL-26
 - push 172
 - PUT 50
- Q**
- quad component 8-26
 - qualified name 67, GL-26
 - quantum 356
 - quench 7-13, 7-91, GL-26
 - query 77
 - queuing delay 7-11, 7-99, GL-26
 - quorum 10-16, GL-26
 - quota 313
- R**
- race condition 215, GL-26
 - RAID 52, GL-26
 - RAID 1 8-47
 - RAID 4 8-24
 - RAID 5 8-67
 - RAM (see random access memory)
 - random
 - access memory 50, GL-26
 - backoff 227
 - backoff, exponential 9-78, GL-11
 - drop 7-92, GL-26
 - early detection 7-92, GL-26
 - number generator 11-99
 - page-removal policy 345
 - pseudorandom number generator 11-101
 - rate monotonic scheduling policy 360, GL-26
 - raw storage 8-42
 - RC4 cipher 11-101
 - READ 45
 - read and set memory 224, GL-27
 - read-capture 9-63
 - read/write coherence 46, GL-27
 - ready/acknowledge protocol 7-35, GL-27
 - real time 359, 7-84, GL-27
 - real-time
 - scheduling policy 359, GL-27
 - scheduling policy, hard 359, GL-13
 - scheduling policy, soft 359, GL-32
 - transport protocol 7-67
 - reassembly 7-8, GL-27
 - recall (in information retrieval) 373
 - RECEIVE 59
 - receive livelock 350
 - reconciliation 10-12, 10-19, GL-27
 - recovery 8-38
 - recursive
 - name resolution 71, GL-27
 - replication 8-27
 - RED (see random early detection)
 - redo
 - action 9-43, GL-27
 - log 9-50, GL-28
 - reduced instruction set computer 55
 - redundancy 8-2, GL-27
 - redundant array of independent disks (see RAID)
 - reference 60, GL-27
 - monitor 11-20
 - string 334, GL-27
 - register renaming 9-67
 - relative path name 72, GL-27
 - RELEASE 225, 9-70
 - reliability 8-13, GL-28
 - reliable
 - delivery 7-74, GL-28
 - message stream protocol 7-66
 - remote procedure call 167, GL-28
 - reorder buffer 9-67
 - repair 8-31, GL-28
 - repertoire 53, GL-28
 - replica 8-26, GL-28
 - replicated state machine 10-11, GL-28
 - replication GL-28
 - recursive 8-27

reply 155
 representations
 bit order numbering 158
 confusion matrix 371
 message 54
 pseudocode 54
 timing diagram 155
 Venn diagram 372
 version history 9–55
 wait-for graph 221
 repudiate GL-28
 request 155, GL-28
 request/response protocol 7–66
 resolution, name 62
 resolve GL-28
 RESOLVE 63
 response 155, GL-28
 restartable atomic region PS-34
 revectoring 8–46
 reverse lookup 64
 revocation 11–73
 RISC (see reduced instruction set computer)
 Rivest, Shamir, and Adleman cipher 11–109
robustness principle *xliv*, 29, 8–15
 roll-forward recovery 9–50, GL-28
 rollback recovery 9–50, GL-28
 root 72, GL-28
 in UNIX[®] 102
 round-robin scheduling policy 262, 356,
 GL-29
 round-trip time 7–67, GL-29
 estimation 7–69, 7–80
 route 7–9, 7–48
 router 7–9, 7–50, GL-29
 routing 7–48
 algorithm 7–49, GL-29
 protocol 7–50
 RPC (see remote procedure call)
 RSA (see Rivest, Shamir, and Adleman cipher)
 RSM (see read and set memory)
 RTP (see real-time transport protocol)

S

safety margin principle *xliv*, 24, 8–8, 8–16,
 8–58
 safety net approach 11–10
 safety-net approach 8–7
 scheduler 348, GL-29
 scheduling policy
 earliest deadline first 360, GL-9
 first-come, first-served 353, GL-12
 hard real-time 359, GL-13
 priority 357, GL-25
 rate monotonic 360, GL-26
 real-time 359, GL-27
 round-robin 262, GL-29, 356
 shortest-job-first 354
 soft real-time 359, GL-32
 scope 75, GL-29
 dynamic 68, GL-9
 lexical (see scope, static)
 static 68, GL-32
 search 73, GL-29
 in key word query 75
 in name discovery 76
 search path 73, 75, GL-29
 second-system effect 39
 secondary device 331, GL-29
 secrecy GL-29
 secure area GL-29
 secure channel 11–22, 11–116, GL-29
 Secure Socket Layer 11–117
 security 11–6, GL-29
 protocol 11–36, 11–54, GL-29
 seed 11–101
 segment
 of a message 7–8, 7–33, GL-30
 virtual memory 68, 253, 285, GL-30
 self-describing storage 365
 self-pacing 7–80, GL-30
 semaphore 276, 277, GL-30
separate mechanism from policy 331, 349,
 11–7, 11–84
 sequence coordination 211, 273, 9–13,
 GL-30
 sequencer 276, GL-30

- sequential consistency 9–18
- serial transmission 7–35, GL-30
- serializability PS-138
- serializable 9–18, GL-30
- server 157, GL-30
- service 155, 7–63, GL-30
 - time 311, 7–87
- session service 7–29
- set up 7–7, GL-31
- shadow copy 9–29, GL-31
- Shannon's capacity theorem 7–37
- shared-secret
 - cryptography 11–40, GL-31
 - key 11–40, GL-31
- sharing 60, 7–5, GL-31
- shortcut (see indirect name)
- shortest-job-first scheduling policy 354
- sign 7–86, 11–41, GL-31
- simple
 - locking discipline 9–72, GL-31
 - network time service protocol 7–109
 - serialization 9–54, GL-31
- simplex 7–44, GL-31
- simplicity 39
- single
 - event upset 8–5, GL-31
 - acquire protocol 220, GL-31
 - point of failure 8–63
 - state machine 10–13
- single-writer, multiple-reader protocol 9–76
- Six sigma 8–15
- slave 10–10, GL-31
- sliding window 7–79, GL-31
- slow start 7–95
- snapshot isolation 9–68
- snoopy cache 10–8, GL-31
- SNTP (see protocol, simple network time service)
- soft
 - error 8–5
 - link (see indirect name)
 - modularity 153, GL-32
 - real-time scheduling policy 359, GL-32
 - state 189, GL-32
- source 7–27, 7–46, GL-32
 - address GL-32
- spatial locality 334, GL-32
- speaks for 11–85, GL-32
- speculate 314, GL-32
- spin loop 212, GL-32
- SSH (see protocol, secure shell)
- SSL (see Secure Socket Layer)
- stability 46, GL-32
 - cursor 10–30
- stable
 - binding 64, GL-32
 - storage 45
- stack
 - algorithm 341, GL-32
 - discipline 150
 - pointer 56
- starvation 355, GL-32
- static
 - discipline 29
 - routing 7–49, GL-32
 - scope 68, GL-32
- station 7–50, 7–101, GL-33
 - identifier 7–101
- stop and wait (see lock-step protocol)
- storage 50, GL-33
 - atomic GL-2
 - careful 8–45
 - cell 46, 9–31, GL-5
 - durable 8–38, 8–46, GL-9
 - fail-fast 8–43
 - journal 9–31, GL-16
 - leak 130
 - raw 8–42
 - stable 45
- store and forward 7–14, GL-33
- stream 7–7, 7–33, GL-33
 - cipher 11–99
 - transport protocol 7–82
- strict consistency 10–3, GL-33
- strong consistency (see strict consistency)
- stub 167, GL-33
- subassembly 9
- submodule 9

- subsystem 9
 - supermodule 8-27, GL-33
 - supervisor call instruction 236, GL-33
 - SVC (see supervisor call instruction)
 - swapping 347, GL-33
 - sweeping simplifications
 - (see *adopt sweeping simplifications*)
 - symbolic link (see indirect name)
 - synonym 72, GL-33
 - system 8, GL-33
 - systemwide lock 9-70
- T**
- Taguchi method 8-16
 - tail drop 7-92, GL-33
 - TCB (see trusted computing base)
 - TCP (see transmission control protocol)
 - TDM (see time-division multiplexing)
 - tear down 7-7, GL-33
 - temporal
 - database 10-28
 - locality 334, GL-34
 - tentatively committed 9-82
 - test and set memory (see read and set memory)
 - thrashing 335, GL-34
 - thread 204, GL-34
 - manager 205, GL-34
 - threat 11-7, GL-34
 - insider 11-8
 - throughput 303, 323, GL-34
 - ticket system 11-74, GL-34
 - tiger team 11-27
 - time-division multiplexing 7-6
 - time domain addressing 10-28
 - time-sharing 256
 - time-to-live 10-6
 - timed capability 11-156
 - timer
 - adaptive 7-69
 - fixed 7-69
 - timing diagram 155, 156
 - TLB (see translation look-aside buffer)
 - TLB miss exception 253
 - TLS (see Transport Layer Security)
 - TMR (see triple-modular redundancy)
 - tolerance 23
 - tolerated error 8-18, GL-34
 - tombstone 7-72, GL-34
 - tracing garbage collection 131
 - trade-off 6
 - binary classification 7, 371
 - tragedy of the commons 7-93
 - trailer 7-26, GL-34, GL-36
 - transaction 9-3, 9-4, GL-34
 - transactional memory 9-69, GL-34
 - TRANSFER operation 9-5
 - transient fault 8-5, GL-34
 - transit time 7-9, GL-34
 - translation look-aside buffer 253
 - transmission
 - control protocol 7-65
 - delay 7-10, 7-99, GL-34
 - parallel 7-35, GL-23
 - serial 7-35, GL-30
 - transport
 - protocol 7-23, 7-63, GL-34
 - service 7-29
 - Transport Layer Security 11-116
 - triple-modular redundancy 8-26, GL-35
 - trusted
 - computing base 11-26, GL-35
 - intermediary 163, GL-35
 - TTL (see time-to-live)
 - tunnel (in networks) 7-33
 - two generals dilemma 9-90, GL-35
 - two-phase
 - commit 9-84, GL-35
 - locking discipline 9-73, GL-35
- U**
- UDP (see user datagram protocol)
 - UNBIND 63
 - undo
 - action 9-43, GL-35
 - log 9-50, GL-28
 - Uniform Resource Locator 133
 - unique identifier name space 64, GL-35
 - universal name space 62, GL-35

- universe of values 62, GL-35
 - unlimited name space 129, GL-35
 - untolerated error 8-18, GL-35
 - unyielding foundations rule* *xliv*, 20, 38, 288
 - upcall 7-27
 - URL (see Uniform Resource Locator)
 - useful work 302
 - user
 - datagram protocol 7-65
 - dependent binding 74, GL-36
 - mode 234, GL-36
 - utilization 302, GL-36
- V**
- valid construction 8-37, GL-36
 - validation (see valid construction)
 - value 62, GL-36
 - verify 7-86, 11-41
 - version history 9-30, GL-36
 - virtual
 - address 206, 243, GL-36
 - address space 206, 248
 - circuit 7-82, GL-36
 - machine 208, 290, GL-36
 - machine monitor 208, 290, GL-36
 - memory 206, 332
 - memory manager 206, 243, GL-36
 - memory, object-based PS-51
 - shared memory 326
 - virtualization 201, GL-36
 - virus 11-19
 - volatile memory 45, GL-36
 - voter 8-26, GL-36
- W**
- wait-for graph 221
 - WAL (see write-ahead log)
 - watchdog 8-54
 - waterbed effect 6
 - well-known
 - name/address 77, GL-36
 - port 7-64
 - window 7-78, GL-36
 - fixed 7-78
 - of validity 11-33
 - sliding 7-79, GL-31
 - wired down (page) 331
 - witness 7-10, 10-21, 11-48, GL-37
 - work factor 11-33
 - working
 - directory 67, GL-37
 - set 335, GL-37
 - worm 11-19
 - WRITE 45
 - write-ahead log 9-42, GL-37
 - write tearing 47, GL-2
 - write-through GL-37
- X**
- X Window System 162
- Y**
- yield (in manufacturing) 8-11
 - YIELD (thread primitive) 257