

## SUBJECT INDEX

---

- A\*, 182
- Accuracy, 222
- Active wait, 243
- Adjacency, 201
- Adjacency list, 44
- Adjacency matrix, 44
- Agglomeration, 23, 120, 138
- ALAP (as-late-as-possible), 98
- Algorithm, 51
- Allocated level, 99, 107
- $\alpha$  field, 159, 214, 249
- $\alpha|\beta|\gamma$  classification, 158
- $\alpha|\beta|\gamma$  notation, 214, 249
- AltVec, 8, 154, 156
- Ancestor, 43
- Annotation, 183
- Antidependent, 53
- Application, 22, 24
  - area, 27
  - specification, 22
- Architecture, *see* Parallel architecture
- Array, 32
  - dimension, 34
  - element, 32
- Array processors, 55, 61, 67, 127
  - systolic, 62
  - wavefront, 61
- ASAP (as-soon-as-possible), 98
- Assignment
  - spatial, 23, 75
  - temporal, 23, 75
- Asymptotic notation, 44
- Asynchronous, 60
- Atomic instruction, 49
- Attribution of start times, 118
  
- Bandwidth, 12
- $\beta$  field, 159, 214, 249
- BFS, *see* Breadth first search
- Bin packing, 139
  
- BINPACKING, 89, 165
- Bisection width, 13
- Blocking wait, 243
- Bottom level, 95, 107
  - computation, 96
- Branching, 49
- Breadth first search (BFS), 46
  - algorithm, 46
  - complexity, 46
- Breeding, 170
- Broadcast, 21
- Bubble scheduling and allocation (BSA), 149, 158, 191, 200
- Buffer size, 202
- Bus, 11, 22, 193
  
- C-SCHED, 211
- Cache, 76
- Cache effect, 76
- CASCH, 183
- CCR, *see* Communication to computation ratio
- CFG, *see* Control flow graph
- CG, *see* Computation graph
- Chess, 38
- Child, 43
- Chromosome, 171–177
  - direct representation, 173–174
  - encoding, 172
  - fittest, 181
  - indirect representation, 172–173
  - node list, 172, 176
  - pool, 171
  - processor allocation, 172, 176
  - representation type, 174–175
- Clan, 138
- Classic model, 76
- Cluster, 120
  - assignment, 139–140
  - linear, definition, 124
  - merge, 121

- Cluster of workstations, 11, 37, 195
- Clustering, 119–141
  - algorithms, 121–124
  - contention model, 220, 221
  - definition, 120
  - dynamic sequence, 137–138
  - initial, 121
  - linear, 124–128
    - algorithm, 127–128
    - bound, 125
    - contention model, 221
    - definition, 124
    - example, 128
  - list scheduling, 135–138
    - contention model, 221
  - node duplication, 138–139
  - nonlinear, 124
  - performance, 141
  - principle, 121–122
  - scheduling on processors, 141
  - single edge, 128–135
    - contention model, 221
    - example, 131
  - to scheduling, 139–141
- Code generation, 267
- Common buffer, 230
- Communication, 32, 49
  - concurrent, 76, 87, 188, 209
  - conflict, 19
  - contention, *see* Contention
  - cost, 50, 68, 77, 163, 247
    - definition, 50
    - function, 77
    - network model, 203
  - cost free, 76, 81, 87
  - delay, 75, 77, 247–248
  - device, 231
  - distance, 57
  - high, 105
  - interiteration, 33, 56, 64–65
  - interprocessor, 29, 76
  - intraiteration, 33, 56, 64–65
  - intraprocessor, 76
  - layer, 232, 245
  - local, 76
  - low, 105
  - medium, 105
  - network, *see* Network
  - nonuniform, 58
  - overhead, 28
  - packet based, 235
  - port, 189
  - processor, 191
  - processor involvement, 228, 268
  - remote, 76
  - resources, 76
  - serialize, 228
  - speed, 28
  - subsystem, 76, 87, 222, 231, 239
  - time, on link, 203
  - uniform, 58
  - without costs, 86
- Communication sensitive data flow graph (CS-DFG), 61
- Communication to computation ratio, (CCR), 104–105, 107, 180
  - definition, 105
- Comparison criteria, 50
- Compile time, 74
- Compiler, 53, 70
- Completion time, 163
- Complexity, 44
  - analysis, 43
  - notational convention, 44
- Computation, 49
  - cost, 50, 68, 77, 163
    - definition, 50
    - function, 77
  - heterogeneous processors, 155
  - cyclic, 32, 55–56, 63, 68
  - iterative, 32, 51, 56, 58, 68
  - regular, 32, 55
  - regularity, 27
  - type, 27, 51, 55, 58, 61, 63
  - uniform, 61
- Computation graph (CG), 61
- Computing node, 10
- Concurrency, 24
  - degree of, 24
    - average, 24
    - maximum, 24
  - inherent, 24
- Conservative, 34, 58
- Contention, 11, 76, 78, 187–188
  - awareness, 188–192, 209, 211
    - undirected topology graph, 190
  - end-point, 189, 192, 195, 196
  - free, 187, 196
  - network, 189, 192, 193
- Contention aware scheduling, 209–215
  - basics, 209–211
  - clustering, 220–221
  - experimental results, 221, 223
  - heuristic, 216, 223
  - list scheduling, *see* List scheduling, contention aware

- NP-completeness, 214–215
  - priority schemes, 219
- Contention model, 209–210
- Control flow, 49, 70
- Control flow graph (CFG), 49, 70
- Control structure, 29, 50
- Control unit, 8
- Convex Exemplar, 20
- Coordinate system, 53
- Cost
  - communication, *see* Communication, cost
  - computation, *see* Computation, cost
  - uniform, 50
- Cost matrix, 156
- CP, *see* Critical path; Path, critical
- CP/MISF (critical path/most immediate successors first), 117
- Cray
  - J90, 9
  - T3D, 11, 198–199
  - T3E, 11, 17, 198–200, 222, 231
- Cray-1, 8
- Critical path, 93, 107
  - allocated, 107
  - computed, 99
  - node, 93
- Crossbar, 11, 18
  - routing, 18
- Crossover, 171, 177–179
  - node list, 178–179
  - permutation, 178
  - processor allocation, 177
  - single-point, 177
  - two-point, 177
- CU, *see* Control unit
- Cycle, 42, 58
  - simple, 42
  - subpath, 42
- DAG, *see* Directed acyclic graph
- Data
  - flow, 7
  - stream, 7, 51
- Data flow graph (DFG), 61
- Data flow language, 61
- Data item, 60
  - initial, 60
- Data parallel, 8, 188
- Data rate, 196, 197, 207
- Data ready time (DRT), 79
  - contention model, 217
  - cost free communication, 87
  - involvement-contention model, 258
  - node duplication, 151
- Data-driven execution model, 60–61
- Deadline, 105, 159
- Deadlock handling, 202
- Decision problem, 82
- Decomposition
  - data, 25
  - exploratory, 25, 26
  - hybrid, 25
  - recursive, 25
  - speculative, 25, 27
- Decomposition techniques, 25–27
- Degree, 41
  - in-, 41
  - mean, 14
  - out-, 41
- Delay, 12, 57, 58, 64, 66, 77, 210
- Dependence, 29
  - analysis, 23, 24, 29–36, 51
  - anti-, 31, 52, 86
  - control, 29, 35–36, 49, 70
  - cycle, 58
  - data, 29–32, 52
  - direction vector, 35
  - distance, 33
  - distance vector, 34, 53, 66
  - elimination, 31
  - false, 31
  - flow, 30, 52, 64, 86
  - in scheduling, 32
  - iteration, 33, 54
  - intraiteration, 33, 54
  - local, 55
  - loops, 32–35, 53
  - nonuniform, 53
  - output, 31, 52, 86
  - real, 31, 64
  - relation, 23, 51
  - structure, 27, 35, 50–51
  - test, 35
  - uniform, 33, 53
- Dependence graph, 51–55
  - computer representation, 55
  - conservative, 55
  - definition, 51
  - iteration, *see* Iteration dependence graph
  - pictorial representation, 53
  - true, 55
- Dependent
  - anti-, 30
  - control, 35
  - flow, 30, 53
  - output, 31, 53

- Depth first search (DFS), 46
  - algorithm, 47
  - complexity, 46
- Descendant, 43
- DFG, *see* Data flow graph
- DFS, *see* Depth first search
- DG, *see* Dependence graph
- Direct memory access (DMA), 231
- Directed acyclic graph (DAG), 2, 40, 47, 62
  - maximum number of edges, 45
- Distance vector, *see* Dependence, distance vector
- Distributed memory, *see* Memory, distributed
- Divide-and-conquer, 25
- DLS, *see* Dynamic level scheduling
- DMA, *see* Direct memory access
- Dominant sequence, 132–135
  - definition, 132
- DRT, *see* Data ready time
- DSC, *see* Dynamic sequence clustering
- DSH, *see* Duplication scheduling heuristic
- Duplex
  - full, 189, 193
  - half, 192, 193
- Duplication scheduling heuristic (DSH), 138, 153
- Dynamic level scheduling (DLS), 115, 118, 158, 190
- Dynamic sequence clustering (DSC), 137
- Earth Simulator, 9
- Eccentricity, 13
- (E)CPFD ((economical) critical path fast duplication), 149, 153
- Edge, 40
  - counter directed, 193
  - directed, 41
  - finish time, 78, 247
    - contention model, 210
    - cost free communication, 87
  - finish time on link, 203
  - finish time on processor, 253
    - provisional, 253
  - incident on, 41
  - order
    - dynamic, 132
    - static, 130–131, 144
  - parallel, 57
  - selection, 134
  - start time on link, 203
  - start time on processor, 240
  - undirected, 41
  - weight, 50, 57, 62, 210, 247
- Edge scheduling, 203–209, 240, 246
  - aligned, 205
  - concept, 190
  - condition, 208
    - causality, 204
    - on a processor, 245
  - definition, 208
  - heterogeneous links, 208
  - involvement-contention, 246
  - nonaligned, 205
  - on a processor, definition, 245
  - on route, 204–208
  - order, 211, 217, 254
  - packet view, 206
  - provisional, 252
- Edge zeroing, 123–124
  - implicit, 124, 129
  - multiplicity, 124
    - edge, 124, 128
    - node, 124, 135
    - path, 124, 127
- Efficiency, 222
- Elitism, 176, 181
- Embedded systems, 154
- Encoding
  - permutation, 172
  - value, 172
- End technique, 109–111
  - definition, 110
  - optimal, 110
- Estimated parallel time (EPT), 123
- ETF (earliest time first), 115, 118
- Evaluation, 171
- Evolution, 170, 177
- Execution
  - order, 23, 52
  - self-timed, 60
  - time, 155
    - average, 155
- Fast Fourier transform (FFT), 38
- Feasibility, 55
- Feasible, 106. *See also* Schedule, feasible
- FG, *see* Flow graph
- FIFO, *see* First in first out
- Finish time, *see* Edge; Node; Processor
- Finish time minimization, 157
- First in first out, 46, 60
- Fitness function, 171, 176–177
  - definition, 176
- Flow control, 202

- Flow graph (FG), 56–62
  - definition, 57
  - feasible, 58
  - to iteration DG, 66
  - to task graph, 64–65
- Flynn's taxonomy, 7–9, 25
- Forest, 160
  - opposing, 160
- Fully connected processors, 76, 188
  
- GA, *see* Genetic algorithm
- $\gamma$  field, 163
- Gantt chart, 81
- Gap, 12
- Gap elimination, 253
- Gene, 172
- Generalization, 164
- Generation, 170
- Genetic algorithm (GA), 170–182
  - basics, 171–172
  - complexity, 181
  - involvement-contention model, 261
  - node duplication, 186
- Genetic involvement-contention scheduling (GICS), 261
- Grain packing, 138
- Grained, 55
  - coarse, 25, 101
  - fine, *see* Grained, small
  - medium, 25
  - small, 25
- Granularity, 24, 49, 51, 55, 101–105, 107, 165
  - coarse, 163, 165
  - weak, 101–103, 107
- Graph, 40–73
  - acyclic, 42, 58, 62
  - basic concepts, 40–49
  - bipartite, 162
  - chain(s), 91, 160
  - computer representation, 43–45, 51
  - conversion, 64
  - dense, 45
  - dependence, *see* Dependence graph
  - directed, 41, 47
    - maximum number of edges, 45
  - directed acyclic, *see* Directed acyclic graph
  - elementary algorithms, 46–49
  - flow, *see* Flow graph
  - fork, 83, 160
  - fork-join, 106, 161
  - harpoon, 161
  - interval-ordered, 162
  - join, 160
  - model, 40, 49
  - parallel, 162
  - path, *see* Path
  - pictorial representation, 41
  - send, *see* Graph, fork
  - series, 162
  - series-parallel, 161
  - size, 51, 55, 63
  - sparse, 45
  - subgraph, 70
  - task, *see* Task graph
  - topology, *see* Topology graph
  - transformation, 64
  - undirected, 41
    - maximum number of edges, 45
  - undirected topology, *see* Undirected topology graph
- Gray code, 17
- Greedy algorithm, 113
  
- H-SCHED, 156
- Heap, 115
- Heterogeneity
  - communication network, 188
  - consistent, 156, 197
  - functional, 154, 191
  - inconsistent, 156, 197
  - link, 197
  - uniform, 156
  - unrelated, 156
- Heterogeneous processors, 154–159, 181
- Hierarchical graph, 70
- Hitachi S-3600, 8
- HLF (highest level first), 117
- HLFET (highest level first with estimated times), 117
- Homogeneous system, 55, 76
- Hop, 190, 199–200
- HP SuperDome series, 11, 19, 20
- HPF, 232
- Hypercube, 17
  - dimension, 17
- Hyperedge, 194
  - adjacency, 201
- Hypergraph, 194
- Hypertool, 183
  
- IBM
  - Blue Gene/L, 11, 17, 21, 231
  - RS/6000 SP-SMP, 19–20
  - SP-2, 199, 231, 234
- IC-SCHED, 249

- Idle, 146, 149
- Idle time interval, 208, 244
- if-statement, 35, 49
- ILP, *see* Integer linear program
- Index, 32
  - bound, 58
  - variable, 30
  - vector, 34
- Insertion into gaps, 254
- Insertion scheduling heuristic (ISH), 138, 149
- Insertion technique, 145–149
  - definition, 148
  - end technique, 148
- Instance, 34, 53, 58, 59
- Instruction
  - flow, 7
  - stream, 7, 51
- Integer linear program (ILP), 138, 182
- Integer programming, 35
- Intel Paragon, 11, 17, 195
- Intel Pentium, 8
- Interiteration, *see* Communication; Dependence
- Intermediate node, 20
- Intermediate representation, 55
- Intraiteration, *see* Communication; Dependence
- Intree, 153, 160
- Involvement, 187, 229, 238, 249
  - characteristic, 232–236
  - direct, 233
  - function, 245
  - length, 233
  - type, 229, 232
- Involvement scheduling, 238–250
  - algorithmic approaches, 257
  - causality condition, 242
  - edge scheduling, *see* Edge scheduling
  - experimental results, 263
  - genetic algorithm, 261
  - heuristic, 229, 232, 257, 264
  - list scheduling, *see* List scheduling, involvement-contention
  - node-edge order, 242
  - nonaligned, 243
  - NP-completeness, 248, 250
  - order overhead-involvement, 242
  - priority schemes, 260
  - two-phase, 261
- Involvement-contention model, 238
  - homogeneous system, 240
  - task graph, 247
- ISH, *see* Insertion scheduling heuristic
- Iteration, 32, 57, 64
  - number of, 58, 68
  - space, 55
- Iteration dependence graph, 53–55
  - computer representation, 55
  - dimension, 53, 66
  - granularity, 55
  - irregular, 53
  - projection, 66
  - regular, 54
  - to flow graph, 66
- Iteration-driven execution model, 57
- Iterative
  - block, 27
  - kernel, 64
- Iterative data-flow program, 61
- Iterative task graph (ITG), 61
- KNAPSACK, 89
- LAN (local area network), 37, 195
- Latency, 12, 199
- Leaf node, 20
- Level bound, 97
- Linear algebra, 27
- Link, 13, 190, 196
  - directed, 193, 196
  - heterogeneous, 207
  - multidirectional, 196
- Link set, 196
- List scheduling, 108–119
  - clustering, *see* Clustering, list scheduling
  - contention aware, 216, 218–220
    - complexity, 219
    - example, 218
  - dynamic priorities, 114–115
    - complexity, 114–115
  - example, 111
  - involvement-contention, 257, 261
    - complexity, 261
    - example, 259
    - with processor allocation, 262
  - node insertion, 148–149
    - complexity, 149
  - simple, 108
    - complexity, 112
    - with processor allocation, 119
    - involvement-contention, 262
- Load balance, 180
- Load balancing, 139
- LogGP, 237

- LogP, 12, 189, 228, 235–237
  - generalized, 237
  - scheduling, 238
- Lookahead technique, 137
- Loop, 32–35, 49, 53, 56
  - body, 32, 54, 64–65
  - double, 34, 54
  - instance, 32
  - kernel, 32, 54, 65
    - double, 34
  - nest, 34, 54
  - stride, 35
  - transformation, 55
- Makespan, 80
- Mapping, 23, 51, 61, 75, 118, 120, 254
  - load minimization, 140
  - wrap, 140
- Mapping heuristic (MH), 190
- Massively parallel processors (MPP), 11
- Matrix–vector multiplication, 25, 27
- MCP, *see* Modified critical path
- MD, *see* Mobility directed
- Meander, 183
- Meiko CS-2, 231
- Memory
  - access policy, 9, 11
  - access time, 9
  - architecture, 9–11
  - centralized, 9
  - concurrent access, 11–12
  - distributed, 9
  - exclusive access, 12
  - hierarchy, 10
  - local, 10, 13
  - location, 9
  - organization, 9, 11
  - remote, 10
  - shared, 9
- Memory architecture, 51
- Memory bank, 20
- Mergesort, 79, 115, 140
- Mesh, 15
  - acyclic, 15
  - bisection width, 17
  - cyclic, 15
  - degree, 15
  - diameter, 15
  - dimension, 15
  - grid, 15
  - linear, 15
  - ring, 15
  - torus, 15
  - wrapped, 15
- Message, 193
  - long, 237
  - size, 13
- Message passing, 9
  - architecture, 10, 76
- Message passing interface (MPI), 222, 231
- MH, *see* Mapping heuristic
- MIMD, *see* Multiple instruction multiple data
- MISD, *see* Multiple instruction single data
- MMX, 8
- Mobility directed (MD), 139, 149
- Model
  - asynchronous, 13
  - synchronous, 12
- Modified critical path (MCP), 117, 137
- MPI, *see* Message passing interface
- MPP, *see* Massively parallel processors
- Multigraph, 57
- Multiple instruction multiple data (MIMD), 8, 69
- Multiple instruction single data (MISD), 7
- Multiprocessor
  - centralized shared-memory, 9
  - distributed memory, 10
  - distributed shared-memory, 10
- Mutation, 170–171, 179–180
  - node list, 180
  - processor allocation, 179–180
  - swap, 179–180
- NEC SX-6, 9
- Network, 13–22
  - binary tree, 20, 195
  - blocking, 15, 19
  - butterfly, 19
  - capacity, 13, 237, 238
  - cost free, 86
  - degree, 13
  - diameter, 13
  - dimension, 15, 17
  - direct, 13
  - dynamic, 18–22, 194
    - properties, 21
  - fat tree, 21
  - fully connected, 14, 209, 220
  - grid, 15
  - hardware costs, 14
  - hypercube, 17
  - indirect, 13, 18
  - interface, 189, 195
  - linear, 15
  - mesh, 15
  - model, 192–202

- Network (*continued*)
  - modular topology, 18
  - multistage, 19
  - nonblocking, 15, 18
  - omega, 19
  - ring, 15, 193
  - star, 214, 220
  - static, 13–18
    - properties, 16
  - subtopology, 18
  - topology, 13, 187
  - torus, 15
  - tree, 20
  - type, 13
  - vertex, 196
- Node, 49. *See also* Vertex
  - branch, 49
  - fictive, 147
  - finish time, 77
    - heterogeneous processors, 155
  - free, 109
    - definition, 109
    - partially, 137
  - grain, definition, 101
  - input, 49
  - level, 95
    - computation, 96
    - computing, 99
    - examples, 99
  - order, 119
    - optimal, 85, 111
  - ordering, 130
  - out-degree, 152
  - output, 49
  - priority, 115–118
    - dynamic, 114, 117–118
    - start times, 117
    - static, 114–117
    - tie(s), 116–117, 142
  - ready, 117, 119
  - redundant, 154
  - root, 160
  - sink, 93
  - source, 93
  - start time, 75
    - duplication, 151
  - strictness, 49, 52, 58, 60, 78
  - type, 49
  - weight, 50, 62
- Node duplication, 150–154
  - clustering, 138–139
  - contention model, 226, 227
  - heuristic, 153–154
    - primary candidate, 152
    - redundant node removal, 154
- Node order anomaly, 151–152
- Node-processor pair, 114
- Nonbacktracking, 124
- Nonblocking, 243, 246, 264
- Nonuniform, 33
- Nonuniform memory access (NUMA), 10, 76
- NP-complete, 82
  - strong sense, 83
  - weak sense, 84
- NP-completeness, 82
  - strong sense, 84
  - weak sense, 84, 106
- NUMA, *see* Nonuniform memory access
- Offspring, 171
- One-port model, 189, 196, 214
- One-sided, 229–230
- OpenMP, 232
- Operator, 171
- Optimality criterion, 163
- Orchestration, 23, 120, 138
- OREGAMI, 183
- Outtree, 153, 160
- Overhead, 12, 232, 239, 249
  - function, 245
  - length, 233
- Overlap, 78, 231
- Packet, 199
  - dropping, 202
- Parallax, 183
- Parallel
  - computation, 49
  - time, 222
- Parallel architecture, 7–13, 51
- Parallel computer, 7
- Parallel programming, 22
- Parallel random access machine (PRAM), 12
- Parallel system, 7, 11. *See also* Target
  - parallel system
    - consistent, 156
    - dedicated, 76, 86
    - inconsistent, 156
    - uniform, 156
    - unrelated, 156
- Parallelism, 24, 49
  - inherent, 24
- Parallelization, 22–24
  - hardware-oriented, 61
  - loop, 53



- manual, 28
  - process, 23–24
  - technique, 28
  - tool, 182
- Parallelizing compiler, 28, 31, 53, 55
- Parent, 43
- Partial order, 23, 52
- Partial representation, 55
- Partially connected processors, 181
- PARTITION, 84, 106
- 3-PARTITION, 83
- Partitioning
  - input data, 25
  - intermediate data, 25
  - output data, 25
- Passive wait, 246
- Path, 41
  - bottom, 95, 100
  - contains, 41
  - critical, *see* Critical path
  - cycle, *see* Cycle
  - length, 42, 248
    - allocated, 93, 117
    - computation, 92
    - in task graph, 92
    - with overhead, 248
  - level, 97
  - shortest, 46
  - simple, 42
  - subpath, 42
  - top, 96, 100
- PE, *see* Processing element
- Perfect shuffle, 19
- Performance bottleneck, 22
- Point-to-point, 193
- Polynomial time, 82
- Population, 170, 171
  - initial, 176
  - size, 176
- PowerPC, 8
- PRAM, *see* Parallel random access machine
- Precedence constraint, 22, 52, 160
- Precedence order, 31, 52, 78
- Precedence relation, 160
- Predecessor, 42
- Preemption, 105, 159
- Preemptive, 76, 87
- Problem
  - instance, 159
  - type, 159
- Processing element (PE), 8
- Processing node, 20
- Processing speed, 155
- Processor, 9, 13, 189, 196
  - active, 230
  - allocation
    - definition, 75
    - optimal, 85
  - available, 85, 90
  - dedicated, 76, 87
  - dual, 197
  - environment, 159
  - functional capability, 154
  - heterogeneous, *see* Heterogeneous processors
  - idle, 146
  - involvement, *see* Involvement
  - number, 28, 159
    - fixed, 159
    - unlimited, 85, 89, 159
  - passive, 231
  - physical, 120
  - speed, 154
  - used, 86, 90
    - definition, 80
  - virtual, 120, 191
- Processor allocation, 75, 118, 261
  - node duplication, 151
- Processor finish time, 80
- Processor heterogeneity, 154–155
- Processor network, 13, 21
- Program, 22
  - execution, 50
  - feasible, 58, 59, 62
    - definition, 52
    - lemma, 52
  - formulation, 28
  - input, 63
  - linear, 32
  - model, 49
  - transformation, 51, 55
- Programming
  - message passing, 11, 77
  - model, 11–13, 51
  - paradigm, 11–13, 29
  - shared memory, 11
  - technique, 24
- Projection, 59, 66
  - linear, 67, 127
- PVM, 232
- PYRROS, 183
- Queue, 46, 60
  - priority, 115
- r-SCT, 163
- Retiming, 61

- Reachable, 43
- Real time, 154
- Real time system, 191
- Reassignment, 31
- Receive, 11
- Receiving, 12
- Recursive algorithm, 46
- Reduction, 164
  - graph, 164
- Regularity, 51
- Reordering, 53
- Reproduction, 177–180
- Rescheduling, 149, 254
- Root node, 20
- Round robin, 166
- Route, 18, 200, 204
- Routing, 198, 202
  - adaptive, 198
  - algorithm, 198, 200
    - complexity, 201
  - cut-through, 199
  - delay, 199, 200
  - dimension ordered, 201
  - minimal, 201
  - nonadaptive, 198
  - static, 198
  - store-and-forward, 199, 209
- Runtime, 74
- Safeguard, 179
- Scalability, 11
- Scalable coherent interface (SCI), 17, 193
- Scalar, 32
- SCHED, 83
- SCHED-C0, 89
- Schedule
  - accuracy, 222
  - compaction, 253
  - condition
    - data ready time constraint, 80
    - exclusive processor allocation, 77
    - link constraint, 202
    - precedence constraint, 78, 151
  - definition, 75
  - example, 81–82, 87–88
  - execution time, 222
  - feasible, 79
  - implicit, 122–123
  - length, 80
  - optimal, 82
  - partial, 92, 109
- Scheduling, 23, 24, 51, 61
  - communication contention in, 187–226
  - complexity, 158–170
    - heterogeneous processors, 170
    - with communication costs, 82–86, 165–168
    - with node duplication, 168–170
    - without communication costs, 88–92, 165
  - condition, 147
  - contention aware, *see* Contention aware scheduling
  - direct, 251
  - dynamic, 74
  - entering edges, 251
  - framework, 74
  - fundamentals, 74–76
  - heterogeneous processors, 157–158
    - heuristic, 157–158
  - involvement, *see* Involvement scheduling
  - list, *see* List scheduling
  - node, involvement-contention model, 247
  - NP-completeness, 83, 85
    - contention model, 211
    - heterogeneous processors, 156
    - involvement-contention model, 248
    - unlimited number of processors, 85
    - without communication costs, 89
  - optimal, unlimited processors, 90
  - phase two, 119
  - problem, 82
    - general, 75
  - process, 82
  - static, 74
  - tool, 182
  - trade-off, 82
  - two-phase, 118
    - with communication costs, 76–86
    - with processor allocation, 118–119, 254
    - without communication costs, 86–92
- SCI, *see* Scalable coherent interface
- Scientific computing, 25
- SCT, *see* Small communication time
- Seed, 176
- Selection, 171, 180–181
  - roulette wheel, 181
  - tournament, 180
- Self-loop, 41
- Send, 11
- Sending, 12
- Sequent NUMA-Q, 11
- Sequential computer, 7
- Sequential implementation, 22
- Sequential order, 49, 91
- Sequential program, 28
- Sequential programming, 22

- Sequential time, 81
- SFG, *see* Signal flow graph
- SGI Origin, 11, 17, 19, 230
- Shared memory, *see* Memory, shared
  - get, 230
  - put, 230
- Signal flow graph (SFG), 61
- Signal processing, 27, 55
- SIMD, *see* Single instruction multiple data
- Simulated annealing, 170
- Single instruction multiple data (SIMD), 8, 25, 55
- Single instruction single data (SISD), 7
- Single processor, 22
- Single program multiple data (SPMD), 9, 55, 69
- SISD, *see* Single instruction single data
- Slot, 147
- Small communication time (SCT), 163
- SMP, *see* Symmetric multiprocessors
- Software layer, 231
- Software pipelining, 54, 61
- sp-graph, *see* Graph, series-parallel
- Speed, 155
  - relative, 156
- Speedup, 222
- SPMD, *see* Single program multiple data
- SSE, 8, 154, 156
- Start time, *see* Edge; Node; Processor
- Start time minimization, 111–114
- Start time order, 78
- Statement, 30, 32, 35, 49, 51, 53
  - conditional, 29, 50
- Steps of refinement, 121
- Stochastic search, 170
- Subscript, 34
  - function, 55
- Subtask, 22
- Subtask decomposition, 23–29, 138
- Successor, 42
- Sun Enterprise, 11
  - 3500, 221
  - 10000, 11, 19–20
- Sun Fire E25K, 19–20
- Survival of the fittest, 171, 180
- Switch, 13, 18, 194–195, 197
  - implicit, 14, 195
  - internal, 18
  - vertex, 194, 197
- Switching
  - circuit, 199
  - packet, 199
  - strategy, 199
- Symmetric multiprocessors (SMP), 9
- Synchronization, 11, 60
- Synchronous, 61
- Target parallel system, 28, 76
  - classic model, 76
  - contention model, 209
  - cost free communication, 86
  - heterogeneous processors, 155
  - involvement-contention model, 238
- Target system, 50
- Task, 22, 30, 49
  - characteristic, 159
  - independent, 160
- Task duplication, 163
- Task graph, 2, 40, 62–69
  - bottom of, 96
  - contention model, 210
  - costs, 158
  - definition, 62
  - granularity, 101
  - involvement-contention model, 245, 247
  - kernel, 65, 66
  - limitations, 68
  - motivations, 68
  - properties, 92–105
  - sample, 62
  - scheduled, definition, 132
  - simplified, 62
  - structure, 158
  - to dependence graph, 64
  - top of, 96
  - unrolled, 65
  - weak granularity, definition, 102
- Task Grapher, 183
- Task interaction graph (TIG), 70
- Task scheduling, *see* Scheduling
- TCG, *see* Temporal communication graph
- TCP/IP, 229, 231
- Technique, 51
- Temporal communication graph (TCG), 70
- Thinking Machines CM-5, 11
- Third party, 229
- Thread, 49
- TIG, *see* Task interaction graph
- Token, 60
- Top level, 95, 107
  - computation, 96
- Topological order, 47, 52, 78, 89
  - definition, 47
  - lemma, 47
- Topological sort algorithm, 48
- Topology, star, 223

Topology graph, 192–197

  breath first search, 201

  definition, 196

  shortest path, 201

  symmetric, 220

Tree, 160

Triplet, 83

Two-sided, 229

Unit communication time (UCT), 163

Unit execution time (UET), 153, 163

Uniform memory access (UMA), 9, 76

Undirected topology graph, 189

Unfolding, 59, 61

Unrolling, 59, 65

  partial, 66

Variable

  array, 32

  boolean, 36

  input, 55

  renaming, 31

  reuse, 31

Vector

  architecture, 8

  machine, 8

  processor, 8

Vertex, 40

  adjacent, 41, 201

  degree, *see* Degree

  destination, 41

  distance, 13, 46

  entry, 43

  exit, 43

  origin, 41

  relationships, 42

    in cycle, 43

  sink, 43

  source, 43

Virtual edge, definition, 132

VLSI, 55, 61, 67, 127

von Neumann model, 7, 12

Wrap around, 20

Zero-copy, 234