

Contents

Abstract	xiii
List of Symbols/Abbreviations	xv
1 Introduction	1
1.1 Background	1
1.2 Static and Dynamic Task Graphs	3
1.3 Motivation	4
1.4 Contributions of this work	6
1.4.1 Hybrid Scheduling of Dynamic Task Graphs with Limited Duplication	7
1.4.2 Online Scheduling of Dynamic Task graphs with Communication and Contention	8
1.4.3 Slack Distribution in Dynamic Task Graph Schedules for Power Reduction	9
1.5 Thesis organization	10
2 Literature Survey	11
2.1 Introduction	11
2.2 Multiprocessor System on Chip Architectures	12
2.3 Taxonomy of the scheduling problems	14
2.4 Scheduling to Minimize Makespan	16
2.4.1 Static Task Graph Models	16
2.4.1.1 A Few Important Classical Methods	17
2.4.1.2 Basics of List scheduling Algorithms	17
2.4.1.3 Important List Scheduling Based Heuristics	18
2.4.1.4 Task Duplication	21
2.4.1.5 Clustering Based Heuristics	21
2.4.1.6 Communication Structure and Contention	23
2.4.1.7 Code Memory Constraints	24
2.4.2 Dynamic Task Graph Models	25
2.4.2.1 Conditional Task Graphs	25
2.4.2.2 Tasks with Unpredictable Execution behavior	26
2.4.3 Online Scheduling	30
2.4.4 Miscellaneous	31
2.5 Scheduling to Optimize Power Consumption	31
2.5.1 Introduction of DVS	31

2.5.2	Energy Model	32
2.5.3	Static Power Management	32
2.5.3.1	The Relaxed Deadline Problem	32
2.5.3.2	The Task Stretching Problem	33
2.5.3.3	Mapping and Scheduling Methods	35
2.5.4	Dynamic Power Management	36
2.5.4.1	Path Based Algorithms	36
2.5.4.2	Greedy Algorithms	37
2.5.4.3	Other Approaches	38
2.5.5	Miscellaneous	39
2.6	Conclusion	40
3	Hybrid Scheduling of Dynamic Task Graphs with Limited Duplication	43
3.1	Introduction	43
3.2	Motivational Example	45
3.3	Models, Notations and Definitions	48
3.3.1	Task Graph Model	48
3.3.2	Processor model	49
3.3.3	Derived Task graph Notations	49
3.3.4	Static Scheduling Notations	50
3.3.5	Online Scheduling Notations	51
3.4	Proposed Three Phase Strategy	51
3.4.1	Task Mapping	52
3.4.1.1	Phase-I: Initial Task Mapping	52
3.4.1.2	Phase-II: Selective Code Duplication	54
3.4.2	Phase-III : Online Scheduler	61
3.4.2.1	Online scheduler without deadline guarantee	61
3.4.2.2	Online Scheduling with hard deadline	62
3.4.3	Complexity and Overhead	64
3.4.3.1	Selective code duplication	64
3.4.3.2	Online Scheduler	65
3.5	Experimental results	67
3.5.1	Conditional task graph with nodes of fixed execution time	67
3.5.1.1	Setup	67
3.5.1.2	Experiments	67
3.5.1.3	Results	68
3.5.2	Unconditional task graph with unpredictable execution time	71
3.5.2.1	Setup	72
3.5.2.2	Experiments	72
3.5.2.3	Results	72
3.5.3	Combined Results	73
3.5.4	Computation time and Overhead Results	74
3.6	Summary	76

4 Online Scheduling of Dynamic Tasks with Communication and Contention	79
4.1 Introduction	79
4.2 Motivational Example	81
4.3 Models, Notations and Definitions	84
4.3.1 Task Graph Model	84
4.3.2 Processor model	85
4.3.3 Scheduling Notations	85
4.4 Proposed Online Scheduling	86
4.4.1 Global Scheduler Modeling	86
4.4.2 Scheduling under broadcast model	87
4.4.3 Scheduling under point-to-point model	87
4.4.4 Illustration of the Algorithm using an example	90
4.4.5 Complexity and Overhead	92
4.5 Experimental results	94
4.5.1 Random Conditional task graphs	94
4.5.1.1 Setup	94
4.5.1.2 Experiments	95
4.5.1.3 Results	95
4.5.2 Random Unconditional variable execution task graphs	98
4.5.2.1 Setup	98
4.5.2.2 Experiments	99
4.5.2.3 Results	99
4.5.3 Experiments on Benchmark task graphs	100
4.5.4 Computation time and Overhead Results	102
4.6 Summary	103
5 Slack Distribution in Dynamic Task Graph Schedules for Power Reduction	105
5.1 Introduction	105
5.2 Motivational Example	108
5.3 System model	111
5.4 Proposed DVS Strategy	113
5.4.1 Offline Analysis	114
5.4.1.1 Series combination	114
5.4.1.2 Parallel combination	116
5.4.2 Future Workload and Future Slack Computation	120
5.4.3 Illustration with an Example	121
5.4.4 Online Strategy	122
5.4.5 Complexity	123
5.5 Experimental Results	123
5.5.1 Setup	123
5.5.2 Experiments	124
5.5.3 Results	124
5.5.3.1 Equally Dynamic Tasks	124
5.5.3.2 Variable number of dynamic tasks	125

5.5.3.3 Effect of conditions and number of processors	125
5.5.3.4 Benchmark Applications	129
5.6 Summary	129
6 Conclusions and Future Work	131
6.1 Contributions of this work	131
6.2 Work in Progress	133
6.2.1 Restricted Online Scheduling with Memory and Time Constraints	133
6.2.2 Intra-DVS with expected energy minimization	134
6.3 Future Directions	134
6.3.1 Heterogeneous Multiprocessor Models	135
6.3.2 Data Memory Constraints	135
6.3.3 Data communication within task execution	136
6.3.4 DVS with ABB	136
List of Publication/Communications	139
References	139
A Random Task Graph Generation	153
A.1 Random Unconditional DAG Generation	153
A.2 Random Conditional Task Graph Generation	154