

Contents

1	Introduction	1
1.1	Background	1
1.2	Book Motivation and Contributions	3
1.2.1	Exploration Environment for Heterogeneous Tree-Based FPGA Architectures	5
1.2.1	Exploration of Tree-Based ASIF Architecture	5
1.3	Book Organization	6
2	FPGA Architectures: An Overview	7
2.1	Introduction to FPGAs	8
2.2	Programming Technologies	8
2.2.1	SRAM-Based Programming Technology	9
2.2.2	Flash Programming Technology	10
2.2.3	Anti-fuse Programming Technology	10
2.3	Configurable Logic Block	11
2.4	FPGA Routing Architectures	12
2.4.1	Island-Style Routing Architecture	14
2.4.2	Hierarchical Routing Architecture	19
2.5	Software Flow	24
2.5.1	Logic Synthesis	25
2.5.2	Technology Mapping	26
2.5.3	Clustering/Packing	27
2.5.4	Placement	32
2.5.5	Routing	36
2.5.6	Timing Analysis	38
2.5.7	Bitstream Generation	39
2.6	Research Trends in Reconfigurable Architectures	39
2.6.1	Heterogeneous FPGA Architectures	40
2.6.2	FPGAs to Structured Architectures	43
2.6.3	Configurable ASIC Cores	44

2.6.4	Processors Inside FPGAs	45
2.6.5	Application Specific FPGAs	45
2.6.6	Time-Multiplexed FPGAs	46
2.6.7	Asynchronous FPGA Architecture	46
2.7	Summary and Conclusion	47
3	Homogeneous Architectures Exploration Environments	49
3.1	Reference FPGA Architectures	50
3.1.1	Mesh-Based FPGA Architecture	50
3.1.2	Tree-Based FPGA Architecture	52
3.1.3	Comparison with Mesh Model	60
3.2	Architectures Exploration Environments	60
3.3	Architecture Description	61
3.3.1	Architecture Description of Tree-Based Architecture	61
3.3.2	Architecture Description of Mesh-Based Architecture	61
3.4	Software Flow	61
3.4.1	Logic Optimization, Mapping and Packing	62
3.4.2	Software Flow for Tree-Based Architecture	63
3.4.3	Software Flow for Mesh-Based Architecture	66
3.4.4	Timing Analysis	66
3.4.5	Area and Delay Models	67
3.5	Experimentation and Analysis	69
3.5.1	Architectures Optimization Approaches	69
3.5.2	Effect of LUT and Arity Size on Tree-Based FPGA Architecture	73
3.5.3	Comparison Between Homogeneous Mesh and Tree-Based FPGAs	75
3.6	FPGA Hardware Generation	77
3.6.1	FPGA Generation Flow	81
3.6.2	FPGA VHDL Model Generation	82
3.6.3	FPGA Layout Generation	83
3.7	Summary and Conclusion	84
4	Heterogeneous Architectures Exploration Environments	85
4.1	Introduction and Previous Work	85
4.2	Reference Heterogeneous FPGA Architectures	87
4.2.1	Heterogeneous Tree-Based FPGA Architecture	87
4.2.2	Heterogeneous Mesh-Based FPGA Architecture	90
4.3	Architecture Description	92
4.3.1	Architecture Description of Heterogeneous Tree-Based Architecture	92
4.3.2	Architecture Description of Heterogeneous Mesh-Based Architecture	95
4.4	Software Flow	96

4.4.1	Parsers	97
4.4.2	Software Flow for Heterogeneous Tree-Based Architecture	100
4.4.3	Software Flow for Heterogeneous Mesh-Based Architecture	101
4.4.4	Area Model	103
4.5	Exploration Techniques	103
4.5.1	Exploration Techniques for Heterogeneous Tree-Based Architecture	104
4.5.2	Exploration Techniques for Heterogeneous Mesh-Based Architecture	106
4.6	Experimentation and Analysis	108
4.6.1	Benchmark Selection	108
4.6.2	Experimental Methodology	110
4.6.3	Results Using Individual Experimentation Approach	111
4.6.4	Results Using Generalized Experimentation Approach	117
4.7	Heterogeneous FPGA Hardware Generation	121
4.8	Summary and Conclusion	122
5	Tree-Based Application Specific Inflexible FPGA	123
5.1	Introduction and Previous Work	123
5.2	Reference FPGA Architectures	125
5.2.1	Reference Tree-Based FPGA Architecture	125
5.2.2	Reference Mesh-Based FPGA Architecture	125
5.3	Software Flow	126
5.4	ASIF Generation Techniques	126
5.4.1	ASIF-Normal Partitioning/Placement Normal Routing	127
5.4.2	ASIF-Efficient Partitioning/Placement Normal Routing	128
5.4.3	ASIF-Normal Partitioning/Placement Efficient Routing	130
5.4.4	ASIF-Efficient Partitioning/Placement Efficient Routing	132
5.5	ASIF Area Model	132
5.6	Experimental Results and Analysis	133
5.6.1	Effect of Different ASIF Generation Techniques on Tree-Based Architecture	133
5.6.2	Effect of LUT and Arity Size on Tree-Based ASIF	138
5.6.3	Comparison Between Mesh-Based and Tree-Based ASIFs	142
5.6.4	Quality Analysis of Tree-Based ASIF	144
5.6.5	Quality Comparison Between Mesh-Based and Tree-Based ASIFs	146

5.7	ASIF Hardware Generation.	147
5.7.1	ASIF Generation Flow.	147
5.7.2	ASIF VHDL Model Generation	147
5.7.3	ASIF Layout Generation	150
5.8	Summary and Conclusion.	150
6	Tree-Based ASIF Using Heterogeneous Blocks	153
6.1	Reference Heterogeneous FPGA Architectures	153
6.1.1	Heterogeneous Tree-Based FPGA Architecture.	154
6.1.2	Heterogeneous Mesh-Based FPGA Architecture	154
6.1.3	Software Flow	155
6.2	Heterogeneous ASIF Generation Techniques.	155
6.3	Experimentation and Analysis.	156
6.3.1	Experimental Benchmarks	156
6.3.2	Effect of Different ASIF Generation Techniques on Heterogeneous Tree-Based ASIF	157
6.3.3	Effect of LUT and Arity Size on Heterogeneous Tree-Based ASIF	161
6.3.4	Comparison Between Heterogeneous Mesh-Based and Tree-Based ASIFs.	164
6.4	Quality Analysis of Heterogeneous Tree-Based ASIF	166
6.4.1	Quality Comparison Between Heterogeneous Mesh-Based and Tree-Based ASIF	168
6.5	Heterogeneous ASIF Hardware Generation.	168
6.6	Summary and Conclusion.	171
7	Conclusion and Future Lines of Research.	173
7.1	Summary of Contributions	173
7.1.1	Heterogeneous Tree-Based FPGA Exploration Environment.	174
7.1.2	Tree-Based ASIF Exploration.	174
7.1.3	FPGA and ASIF Hardware Generation for Tree-Based Architecture	176
7.2	Suggestions for Future Research	177
7.2.1	Datapath Oriented FPGA Architectures	177
7.2.2	Timing Analysis	178
7.2.3	Integrating ASIF Blocks in an FPGA Architecture	179
7.2.4	Further Optimizing the ASIF Generation	179
7.2.5	The Unexplored Parameters of Mesh-Based Architecture	180
	References	181