Contents

1 Introduction 1
1.1 Motivation 2
1.2 Contribution 3
1.3 Related Work 4
1.4 Term Definitions 5
1.4.1 Models and Performance Evaluation 5
1.4.2 Parallel System Architecture 6
1.4.3 Distributed System Architecture 7
1.4.4 Network Architecture 8

2 Characteristics of Network Architectures 11
2.1 Switching Techniques 11
2.1.1 Circuit Switching 11
2.1.2 Packet Switching 12
2.2 Traffic Patterns 14
2.2.1 Distribution in Space 14
2.2.2 Distribution in Time 15
2.3 Wired Network Architectures 21
2.3.1 Basic Classifications 22
2.3.2 Bus 23
2.3.3 Mesh 23
2.3.4 Torus 25
2.3.5 Ring 25
2.3.6 Star 26
2.3.7 Tree 27
2.3.8 Hypercube 27
2.3.9 Crossbar 28
2.3.10 Multistage Interconnection Network 30
2.3.11 Switching Fabric 46
2.3.12 Dynamic Networks versus Static Networks 46
2.4 Wireless Network Architectures 47

2.4.1 Basics in Wireless Transmission 48
2.4.2 Cellular Networks 52
2.4.3 Ad-hoc Networks 54
2.5 Network-on-Chip Architectures 55
2.5.1 Origin and Use 56
2.5.2 Particular Characteristics 58
2.5.3 Topologies 60
2.6 Network Reconfiguration 62
2.6.1 Reconfiguration Types and Levels 63
2.6.2 Dynamic Reconfiguration 64
2.6.3 Reconfigurable Hardware Architectures 67

3 Performance Evaluation 73
3.1 Numerical Simulation 74
3.1.1 Statistics 75
3.1.2 Acceleration 82
3.2 Markov Chains 85
3.2.1 Markov Process 86
3.2.2 Discrete Time Markov Chain 86
3.2.3 Continuous Time Markov Chain 90
3.2.4 Solution Methods 93
3.3 Petri Nets 99
3.3.1 Basic Petri Nets 99
3.3.2 Stochastic Petri Nets 102

4 Model Engineering 107
4.1 Model Development 107
4.1.1 Simulation Model 111
4.1.2 Mathematical Model 115
4.2 Complexity Reduction 116
4.2.1 Simulation 116
4.2.2 Mathematical Model 118
4.3 Automatic Model Generation 126
4.3.1 Rule Design 126
4.3.2 Generating Systems of Equations 128
4.3.3 Generator Design 131

5 Application: Cellular Network 133
5.1 USAIA Framework 134
5.2 Petri Net Model 137
5.2.1 Initialized Mobile Nodes 138
5.2.2 Real-time Traffic 142
5.2.3 Entire Model 146
5.3 Model Engineering and Performance 147
5.3.1 Model Development and Complexity Reduction 148

5.3.2 Modeling Power 148

6 Application: Multistage Interconnection Network 153
6.1 Simulation: Petri Nets 153
6.1.1 Full Petri Net Model 154
6.1.2 Iterative Petri Net Model 158
6.1.3 Multicast Probabilities 161
6.2 Simulation: *MINSimulate* 165
6.2.1 Simulator Engineering 166
6.2.2 Features 169
6.3 Mathematical Model: Complexity Reduction 172
6.3.1 Symmetries 172
6.3.2 Multiple State Spaces 184
6.3.3 Fixed Point Iteration 189
6.4 Mathematical Model: Automatic Model Generation 192
6.4.1 Rule Design 192
6.4.2 Generating and Solving the Equations 209
6.4.3 Changing the Model 210
6.5 Model Engineering and Performance 215
6.5.1 Comparison of the Modeling Techniques 215
6.5.2 Model Capabilities 218

7 Concluding Remarks 219

References 223

Index 239