# Table of contents


- **Preface** (p. vii)
- **Acknowledgements** (p. xiii)
- **Chapter 1 Fundamental Concepts in Fault Tolerance and Reliability Analysis** (p. 1)
- **1.1 Introduction** (p. 1)
- **1.2 Redundancy Techniques** (p. 4)
- **1.2.1 Hardware Redundancy** (p. 5)
- **1.2.1.1 Passive (Static) Hardware Redundancy** (p. 5)
- **1.2.1.2 Active (Dynamic) Hardware Redundancy** (p. 6)
- **1.2.1.3 Hybrid Hardware Redundancy** (p. 7)
- **1.2.2 Software Redundancy** (p. 9)
- **1.2.2.1 Static Software Redundancy Techniques** (p. 9)
- **1.2.2.2 Dynamic Software Redundancy Techniques** (p. 10)
- **1.2.3 Information Redundancy** (p. 12)
- **1.2.3.1 Error Detecting Codes** (p. 14)
- **1.2.3.2 Error Correcting Codes** (p. 18)
- **1.2.3.3 SEC-DED Codes** (p. 20)
- **1.2.3.4 CRC Codes** (p. 26)
- **1.2.3.5 Convolution Codes** (p. 27)
- **1.2.4 Time Redundancy** (p. 29)
- **1.2.4.1 Permanent Error Detection with Time Redundancy** (p. 30)
- **1.3 Reliability Modeling and Evaluation** (p. 33)
- **1.3.1 Empirical Models** (p. 34)
- **1.3.2 The Analytical Technique** (p. 34)
- **1.4 Summary** (p. 42)
- **References** (p. 42)
- **Chapter 2 Fault Modeling, Simulation and Diagnosis** (p. 44)
- **2.1 Fault Modeling** (p. 44)
- **2.2 Fault Simulation** (p. 51)
- **2.3 Fault Simulation Algorithms** (p. 52)
- **2.3.1 Serial Fault Simulation Algorithm** (p. 52)
- **2.3.2 Parallel Fault Simulation** (p. 53)
- **2.3.3 Deductive Fault Simulation** (p. 54)
- **2.3.4 Concurrent Fault Simulation** (p. 57)
- **2.3.5 Critical Path Tracing** (p. 57)
- **2.4 Fault Diagnosis** (p. 59)
- **2.4.1 Combinational Fault Diagnosis** (p. 59)
- **2.4.2 Sequential Fault Diagnosis Methods** (p. 61)
- **2.5 Summary** (p. 64)
- **References** (p. 64)
- **Chapter 3 Error Control and Self-Checking Circuits** (p. 66)
- **3.1 Error-Detecting/Error-Correcting Codes** (p. 67)
- **3.2 Self-Checking Circuits** (p. 81)
- **3.3 Summary** (p. 92)

- **References** (p. 92)
- **Chapter 4 Fault Tolerance in Multiprocessor Systems** (p. 94)
- **4.1 Fault Tolerance in Interconnection Networks** (p. 95)
- **4.2 Reliability and Fault Tolerance in Single Loop Architectures** (p. 104)
- **4.3 Introduction to Fault Tolerance in Hypercube Networks** (p. 108)
- **4.4 Introduction to Fault Tolerance in Mesh Networks** (p. 120)
- **4.5 Summary** (p. 125)
- **References** (p. 126)
- **Chapter 5 Fault-Tolerant Routing in Multi-Computer Networks** (p. 127)
- **5.1 Introduction** (p. 127)
- **5.2 Fault-Tolerant Routing Algorithms in Hypercube** (p. 131)
- **5.2.1 Depth-First Search Approach** (p. 131)
- **5.2.2 Iterative-Based Heuristic Routing Algorithm** (p. 135)
- **5.3 Routing in Faulty Mesh Networks** (p. 140)
- **5.3.1 Node Labeling Technique** (p. 140)
- **5.3.2 A FT Routing Scheme for Meshes with Non-Convex Faults** (p. 141)
- **5.4 Algorithm Extensions** (p. 147)
- **5.4.1 Multidimensional Meshes** (p. 147)
- **5.4.2 Faults with f-Chains** (p. 148)
- **5.5 Summary** (p. 149)
- **References** (p. 149)
- **Chapter 6 Fault Tolerance and Reliability in Hierarchical Interconnection Networks** (p. 152)
- **6.1 Introduction** (p. 152)
- **6.2 Block-Shift Network (BSN)** (p. 154)
- **6.2.1 BSN Edges Groups** (p. 155)
- **6.2.2 BSN Construction** (p. 156)
- **6.2.3 BSN Degree and Diameter** (p. 158)
- **6.2.4 BSN Connectivity** (p. 158)
- **6.2.5 BSN Fault Diameter** (p. 159)
- **6.2.6 BSN Reliability** (p. 160)
- **6.3 Hierarchical Cubic Network (HCN)** (p. 161)
- **6.3.1 HCN Degree and Diameter** (p. 162)
- **6.4 HINs versus HCNs** (p. 163)
- **6.4.1 Topological Cost** (p. 163)
- **6.5 The Hyper-Torus Network (HTN)** (p. 166)
- **6.6 Summary** (p. 170)
- **References** (p. 170)
- **Chapter 7 Fault Tolerance and Reliability of Computer Networks** (p. 172)
- **7.1 Background Material** (p. 173)
- **7.2 Fault Tolerance in Loop Networks** (p. 174)
- **7.2.1 Reliability of Token-Ring Networks** (p. 175)
- **7.2.2 Reliability of Bypass-Switch Networks** (p. 176)
- **7.2.3 Double Loop Architectures** (p. 176)
- **7.2.4 Multi-Drop Architectures** (p. 178)
- **7.2.5 Daisy-Chain Architectures** (p. 178)

- **7.3 Reliability of General Graph Networks** (p. 180)
- **7.3.1 The Exact Method** (p. 180)
- **7.3.2 Reliability Bounding** (p. 185)
- **7.4 Topology Optimization of Networks Subject to Reliability & Fault Tolerance Constraints** (p. 188)
- **7.4.1 Enumeration Techniques** (p. 189)
- **7.4.1.1 Network Reliability** (p. 195)
- **7.4.2 Iterative Techniques** (p. 199)
- **7.5 Maximizing Network Reliability by Adding a Single Edge** (p. 204)
- **7.6 Design for Networks Reliability** (p. 204)
- **7.7 Summary** (p. 205)
- **References** (p. 206)
- **Chapter 8 Fault Tolerance in High Speed Switching Networks** (p. 208)
- **8.1 Introduction** (p. 208)
- **8.2 Classification of Fault-Tolerant Switching Architectures** (p. 212)
- **8.3 One-Fault Tolerance Switch Architectures** (p. 213)
- **8.3.1 Extra-Stage Shuffle Exchange** (p. 213)
- **8.3.2 Itoh Network** (p. 214)
- **8.3.3 The B-Tree Network** (p. 215)
- **8.3.4 Benes Network** (p. 216)
- **8.3.5 Parallel Banyan Network** (p. 217)
- **8.3.6 Tagle & Sharma Network** (p. 218)
- **8.4 Two-Fault Tolerance Switch Architectures** (p. 219)
- **8.4.1 Binary Tree Banyan Network** (p. 219)
- **8.5 Logarithmic-Fault Tolerance** (p. 220)
- **8.5.1 RAZAN** (p. 220)
- **8.5.2 Logical Neighborhood** (p. 222)
- **8.5.3 Improved Logical Neighborhood** (p. 223)
- **8.6 Architecture-Dependent Fault Tolerance** (p. 224)
- **8.7 Summary** (p. 226)
- **References** (p. 226)
- **Chapter 9 Fault Tolerance in Distributed and Mobile Computing Systems** (p. 229)
- **9.1 Introduction** (p. 229)
- **9.2 Background Material** (p. 231)
- **9.3 Checkpointing Techniques in Mobile Networks** (p. 236)
- **9.3.1 Minimal Snapshot Collection Algorithm** (p. 237)
- **9.3.2 Mutable Checkpoints** (p. 239)
- **9.3.3 Adaptive Recovery** (p. 241)
- **9.3.4 Message Logging Based Checkpoints** (p. 243)
- **9.3.5 Hybrid Checkpoints** (p. 244)
- **9.4 Comparison** (p. 245)
- **9.5 Summary** (p. 247)
- **References** (p. 247)
- **Chapter 10 Fault Tolerance in Mobile Networks** (p. 249)
- **10.1 Background Material** (p. 249)

- **10.2 More on Mutable Checkpoint Techniques in Mobile Networks** (p. 251)
- **10.2.1 Handling Mobility, Disconnection and Reconnection of MHs** (p. 252)
- **10.2.2 A Checkpointing Algorithm Based on Mutable Checkpoints** (p. 253)
- **10.2.3 Performance Evaluation** (p. 261)
- **10.3 Hardware Approach for Fault Tolerance in Mobile Networks** (p. 265)
- **10.4 Summary** (p. 273)
- **References** (p. 273)
- **Chapter 11 Reliability and Yield Enhancement of VLSI/WSI Circuits** (p. 276)
- **11.1 Defect and Failure in VLSI Circuits** (p. 276)
- **11.2 Yield and Defect Model in VLSI/WSI Circuits** (p. 279)
- **11.3 Techniques to Improve Yield** (p. 284)
- **11.4 Effect of Redundancy on Yield** (p. 286)
- **11.5 Summary** (p. 288)
- **References** (p. 288)
- **Chapter 12 Design of Fault-Tolerant Processor Arrays** (p. 291)
- **12.1 Introduction** (p. 291)
- **12.2 Hardware Redundancy Techniques** (p. 294)
- **12.3 Self-Reconfiguration Techniques** (p. 317)
- **12.4 Summary** (p. 321)
- **References** (p. 322)
- **Chapter 13 Algorithm-Based Fault Tolerance** (p. 326)
- **13.1 Checksum-Based ABFT for Matrix Operations** (p. 327)
- **13.2 Checksum-Based ABFT Error Handling** (p. 330)
- **13.3 Weighted Checksum Based ABFT** (p. 331)
- **13.4 ABFT on a Mesh Multiprocessor** (p. 332)
- **13.5 Checksum-Based ABFT on a Hypercube Multiprocessor** (p. 334)
- **13.6 Partition-Based ABFT for Floating-Point Matrix Operations** (p. 336)
- **13.7 Summary** (p. 339)
- **References** (p. 339)
- **Chapter 14 System Level Diagnosis-I** (p. 341)
- **14.1 Background Material and Basic Terminology** (p. 342)
- **14.2 System-Level Diagnosis Models** (p. 347)
- **14.3 Diagnosable Systems** (p. 352)
- **14.4 Diagnose-Ability Algorithms** (p. 358)
- **14.4.1 Centralized Diagnosis Systems** (p. 359)
- **14.4.2 Distributed Diagnosis Systems** (p. 365)
- **14.5 Summary** (p. 372)
- **References** (p. 373)
- **Chapter 15 System Level Diagnosis-II** (p. 378)
- **15.1 Diagnosis Algorithms for Regular Structures** (p. 378)
- **15.2 Regular Structures** (p. 379)
- **15.3 Pessimistic One-Step Diagnosis Algorithms for Hypercube** (p. 380)
- **15.4 Diagnosis for Symmetric Multiple Processor Architecture** (p. 383)
- **15.5 Summary** (p. 394)
- **References** (p. 394)
- **Appendix** (p. 397)

- **Chapter 16 Fault Tolerance and Reliability of the RAID Systems** (p. 400)
- **16.1 Introduction** (p. 401)
- **16.2 Redundancy Mechanisms** (p. 403)
- **16.3 Simple Reliability Analysis** (p. 411)
- **16.4 Advanced RAID Systems** (p. 413)
- **16.5 More on RAIDS** (p. 418)
- **16.6 Summary** (p. 423)
- **References** (p. 423)
- **Chapter 17 High Availability in Computer Systems** (p. 426)
- **17.1 Introduction** (p. 426)
- **17.2 Tandem High Availability Computers at a Glance** (p. 430)
- **17.3 Availability in Client/Server Computing** (p. 438)
- **17.4 Chapter Summary** (p. 440)
- **References** (p. 440)