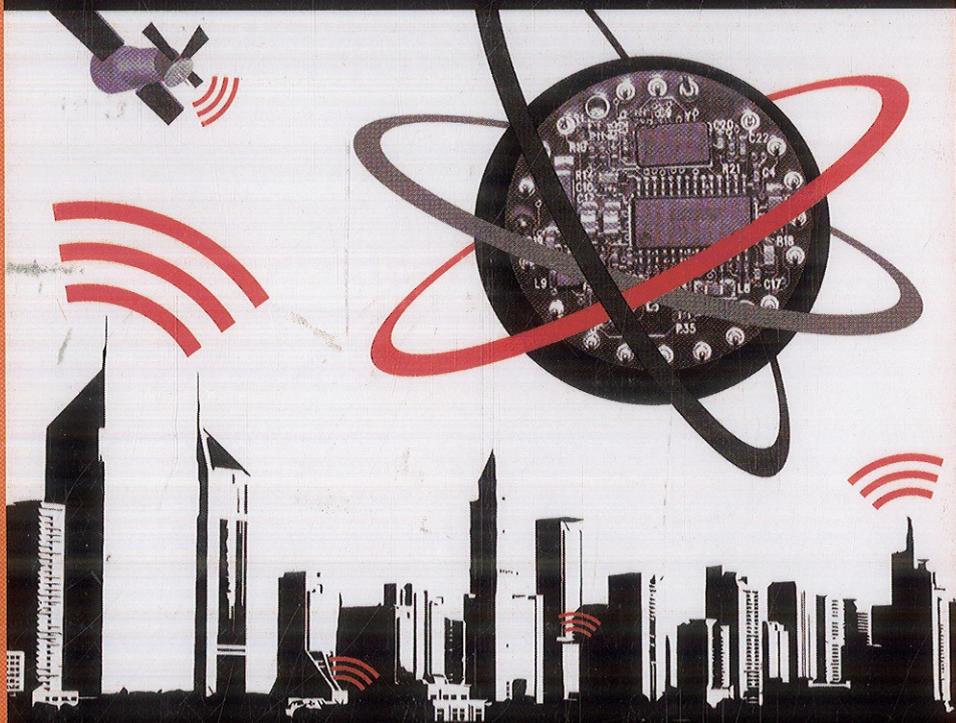


Fundamentals of Sensor Network Programming

APPLICATIONS AND TECHNOLOGY



S. SITHARAMA IYENGAR
NANDAN PARAMESHWARAN
VIR V. PHOHA
N. BALAKRISHNAN
CHUKA D. OKOYE

 WILEY

 IEEE
IEEE PRESS

Contents

PREFACE	xiii
FOREWORD	xvii
ACKNOWLEDGMENTS	xix
ABOUT THE AUTHORS	xxi
NOTATIONS AND ABBREVIATIONS	xxv
I OVERVIEW	
1 Introduction	3
1.1 Some Foundational Information	3
1.2 Next-Generation Sensor Networked Tiny Devices	5
1.3 Sensor Network Software	6
1.4 Performance-Driven Network Software Programming	8
1.5 Unique Characteristics of Programming Environments for Sensor Networks	10
1.6 Goals of the Book	10
1.7 Why TinyOS and NesC	10
1.8 Organization of the Book	10
1.9 Future Demands on Sensor-Based Software	12
Problems	12
References	14
2 Wireless Sensor Networks	15
2.1 Sensor Network Applications	17
2.2 Characteristics of Sensor Networks	20
2.3 Nature of Data in Sensor Networks	24
Problems	24
References	25
3 Sensor Technology	27
3.1 Sensor Level	27
3.2 Server Level	33

- 3.3 Client Level 36
- 3.4 Programming Tools 36
- Problems 37
- References 38

II BACKGROUND

4 Data Structures for Sensor Computing 41

- 4.1 Introduction to Sensor Computing 43
- 4.2 Communication Capabilities 46
- 4.3 General Structure of Programming 48
- 4.4 Details on Embedded Data Structures 51
- 4.5 Linked List 53
- 4.6 Importance of Graph Concepts in Sensor Programming 57
- 4.7 Graph and Trees 61
- 4.8 Trees 66
- 4.9 Graph Traversal 75
- 4.10 Connectivity 76
- 4.11 Planar Graphs 81
- 4.12 Coloring and Independence 83
- 4.13 Clique Covering 84
- 4.14 Intersection Graph 85
- 4.15 Defining Data Structure of Spanning Tree Protocols 86
- Problems 90
- References 91

5 Tiny Operating System (TinyOS) 92

- 5.1 Components of TinyOS 93
- 5.2 An Introduction to NesC 93
- 5.3 Event-Driven Programming 96
- Problems 97
- References 97

6 Programming in NesC 99

- 6.1 NesC Programming 99
- 6.2 A Simple Program 99
- Problems 108
- References 109

III SENSOR NETWORK IMPLEMENTATION

7 Sensor Programming 113

- 7.1 Programming Challenges in Wireless Sensor Networks 113

- 7.2 Sensing the World 119
- 7.3 Applications Using the Interface SplitControl 122
- Problems 129
- References 130

8 Algorithms for Wireless Sensor Networks 131

- 8.1 Structural Characteristics of Sensor Nodes 132
- 8.2 Distinctive Properties of Wireless Sensor Networks 134
- 8.3 Sensor Network Stack 135
- 8.4 Synchronization in Wireless Sensor Networks 138
- 8.5 Collision Avoidance: Token-Based Approach 144
- 8.6 Carrier Sensing Versus Decoding 148
- Problems 153
- References 154

9 Techniques for Protocol Programming 155

- 9.1 The Mediation Device Protocol 156
- 9.2 Contention-Based Protocols 158
- 9.3 Programming with Link-Layer Protocols 161
- 9.4 Automatic Repeat Request (ARQ) Protocol 161
- 9.5 Transmitter Role 161
- 9.6 Alternating-Bit-Based ARQ Protocols 163
- 9.7 Selective Repeat/Selective Reject 168
- 9.8 Naming and Addressing 170
- 9.9 Distributed Assignment of Networkwide Addresses 170
- 9.10 Improved Algorithms 177
- 9.11 Content-Based Addressing 179
- 9.12 Flooding 181
- 9.13 Rumor Routing 184
- 9.14 Tracking 188
- 9.15 Querying in Rumor Routing 189
- Problems 194
- References 194

IV REAL-WORLD SCENARIOS

10 Sensor Deployment Abstraction 197

- 10.1 Sensor Network Abstraction 197
- 10.2 Data Aggregation 198
- 10.3 Collaboration Group Abstractions 202
- 10.4 Programming Beyond Individual Nodes 205
- Problems 205
- References 206

11	Standards for Building Wireless Sensor Network Applications	207
11.1	802.XX Industry Frequency and Data Rates	207
11.2	ZigBee Devices and Components	208
11.3	ZigBee Application Development	210
11.4	Dissemination and Evaluation	212
	Problems	212
	References	214
12	INSPIRE: Innovation in Sensor Programming Implementation for Real-Time Environment	215
12.1	Motivation and Background	215
12.2	Software Microframework Requirements	236
	References	237
13	Performance Analysis of Power-Aware Algorithms	239
13.1	Introduction	239
13.2	Service Architecture	242
13.3	Approaches To WSN Programmability	248
13.4	Simulation Capabilities	249
13.5	Benchmarking	251
13.6	Conclusion	251
	Problems	252
	References	252
14	Modeling Sensor Networks Through Design and Simulation	253
14.1	Introduction	254
14.2	Why a New Simulator	254
14.3	Currently Available Simulators	255
14.4	Simulation Design	257
14.5	Implementation Details	261
14.6	Experimental Results	265
14.7	Final Comments	271
	Appendix	272
	Acknowledgments	275
	Problems	275
	References	275
15	MATLAB Simulation of Airport Baggage-Handling System	277
15.1	Introduction	277
15.2	Background	277
15.3	Proposed Architecture	283

15.4	Simulation Results and Discussion	283
15.5	Source Code	286
	Problems	295
	References	296
16	Security in Sensor Networks	297
16.1	Introduction	297
16.2	Security Constraints	297
16.3	Denial-of-Service Attacks in Multiple Layers	298
16.4	Some Well-Known Algorithms for Security Problems	302
16.5	Secure Information Routing	302
16.6	Security Protocols for Sensor Networks	303
16.7	Final Comments	303
	Problems	303
	References	304
17	Closing Comments	305
	Bibliography	307
	Index	313