

Principles of Wireless Sensor Networks

Wireless sensor networks are an emerging technology with a wide range of applications in military and civilian domains. The book begins by detailing the basic principles and concepts of wireless sensor networks, including information gathering, energy management, and the structure of sensory nodes. It proceeds to examine advanced topics, covering localization, topology, security, and evaluation of wireless sensor networks, highlighting international research being carried out in this area. Finally, it features numerous examples of applications of this technology to a range of domains, such as wireless, multimedia, underwater, and underground wireless sensor networks. The concise but clear presentation of the important principles, techniques and applications of wireless sensor networks makes this guide an excellent introduction for anyone new to the subject, as well as an ideal reference for students, practitioners and researchers.

Mohammad S. Obaidat, recognized around the world for his pioneering and lasting contributions to several areas, including wireless sensor networks, green ICT, wireless and wired networks, performance evaluation of computer systems and networks, and information and network security, is a Professor of Computer Science at Monmouth University, New Jersey, USA. He is the editor-in-chief or editor of many international journals, and has authored over 30 books and over 600 technical papers to date. He has received numerous awards, including a Nokia Research Fellowship, Distinguished Fulbright Scholar Award, McLeod Founder's Award, SCS Presidential Award, and SCS Modeling & Simulation Hall of Fame Award and Best Paper awards in many conferences. He served as SCS President, Advisor to the President Philadelphia University, and Chair of the Department of Computer Science and Software Engineering at Monmouth University. He is a Fellow of the IEEE and the SCS. He has chaired numerous international conferences all over the world and has been invited to give keynote speeches in international conferences. He served as an IEEE Computer Society Distinguished Speaker and is now serving as an ACM and SCS Distinguished Lecturer/speaker.

Sudip Misra is an Associate Professor at the Indian Institute of Technology, Kharagpur. He has authored over 180 scholarly research papers and has edited 6 books. He was awarded the Canadian Government's prestigious NSERC Post-Doctoral Fellowship and the Humboldt Research Fellowship in Germany.

“The book covers the main aspects regarding modern wireless sensor networks, touching hardware and software platforms, networking architectural organization, and communication protocols and applications. It includes treatment of important issues like localization and tracking, topology management, performance evaluation, security, mobility, and multimedia, as well as of two challenging environments ... underwater and underground.

“The material blends theory and applications, and is presented in a form suitable for students, researchers and practitioners. It provides a comprehensive overview and perspective of the field.”

Franco Davoli
University of Genoa

Principles of Wireless Sensor Networks

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To Our Families

Contents

	<i>Preface</i>	<i>page xv</i>
1	Introduction to wireless sensor networks	1
	1.1 Background	1
	1.2 Components of a wireless sensor node	3
	1.3 Classification of sensor networks	5
	1.4 Characteristics of wireless sensor networks	6
	1.5 Challenges of wireless sensor networks	8
	1.6 Comparison between wireless sensor networks and wireless mesh networks	10
	1.7 Summary	11
	References	12
2	Inside a wireless sensor node: structure and operations	14
	2.1 Limitations in wireless sensor networks	14
	2.2 Design challenges	17
	2.3 Hardware architecture	18
	2.4 Operating systems and environments	20
	2.5 Examples of sensor nodes	22
	2.6 Effect of infrastructure on the performance evaluation of WSNs	23
	2.7 MEMS technology	25
	2.8 Hardware platforms	26
	2.8.1 System-on-chip (SoC) sensor nodes	26
	2.8.2 Augmented general-purpose personal computers (PCs)	26
	2.8.3 Dedicated sensor nodes	27
	2.9 Software platforms	27
	2.10 Summary	27
	References	28
3	Wireless sensor network applications: overview and case studies	30
	3.1 Target detection and tracking	30
	3.1.1 Energy	32
	3.1.2 Dependability	33

viii	Contents	
	3.1.3 Complexity	33
	3.1.4 Recognition of the target perturbations to the environment (phenomenology)	34
	3.1.5 Sensing selection	35
	3.2 Contour and edge detection	35
	3.2.1 Consecutive extremum search	36
	3.2.2 Sensor grouping and contour point finding	37
	3.2.3 Contour line creation	37
	3.3 Types of applications	38
	3.3.1 Environmental applications	38
	3.3.2 Health care applications	38
	3.3.3 Manufacturing process control	39
	3.3.4 Intelligent and smart home	39
	3.3.5 Homeland security	39
	3.3.6 Underwater applications	39
	3.3.7 Agriculture	44
	3.3.8 Military applications	44
	3.4 Summary	45
	References	45
4	Medium access in wireless sensor networks	48
	4.1 Medium access control in wireless networks	48
	4.1.1 S-MAC: An energy-efficient protocol	50
	4.1.2 L-MAC: a light-weight medium access protocol	55
	4.1.3 Dynamic scheduling MAC protocol	57
	4.1.4 Energy-efficient QoS-aware medium access (Q-MAC) protocol	60
	4.1.5 Energy-efficient application aware medium access protocol	62
	4.1.6 Location-aware access control protocol	63
	4.1.7 An energy-efficient MAC approach for mobile wireless sensor networks	64
	4.1.8 O-MAC: a receiver-centric power management protocol	65
	4.1.9 PMAC: an adaptive energy-efficient MAC protocol for wireless sensor networks	66
	4.1.10 T-MAC	68
	4.1.11 BMAC protocol	69
	4.2 MAC issues in wireless sensor networks	70
	4.3 Summary	72
	References	73
5	Routing in wireless sensor networks	76
	5.1 Fundamentals of routing and challenges in WSNs	76
	5.2 Network architecture-based routing protocols for wireless sensor networks (WSNs)	80

	Contents	ix
5.2.1	Multi-hop flat routing	81
5.2.2	Hierarchical/cluster-based routing schemes	86
5.2.3	Location-based routing schemes	92
5.3	WSN routing protocols based on the nature of operation	96
5.3.1	Query-based routing approach	96
5.3.2	Multipath routing schemes	96
5.3.3	Coherent and non-coherent processing	97
5.3.4	Quality-of-service (QoS)-based routing schemes	98
5.3.5	Negotiation-based routing schemes	99
5.4	Summary	100
	References	101
6	Transport protocols for wireless sensor networks	105
6.1	Transport protocol requirements for WSNs	105
6.1.1	Performance metrics	105
6.2	Internet transport protocols and their suitability for use in WSNs	107
6.3	Existing transport protocols for WSNs	108
6.3.1	Classification	108
6.3.2	Congestion and flow control-centric protocols	108
6.3.3	Reliability-centric protocols	119
6.3.4	Other protocols	129
6.4	Summary	131
	References	131
7	Localization and tracking	134
7.1	Localization	135
7.1.1	Distance estimation techniques	136
7.1.2	Time difference of arrival (TDOA)	137
7.1.3	Angle of arrival (AOA), digital compasses	139
7.1.4	Localization algorithms	140
7.2	Target tracking	158
7.2.1	Single target tracking	159
7.2.2	Multi-target tracking	166
7.3	Summary	167
	References	168
8	Topology management and control	172
8.1	Topology management	172
8.2	Taxonomy of topology management	173
8.2.1	Topology discovery	173
8.2.2	Sleep cycle management	176
8.2.3	Clustering	182

8.3	Topology control	190
8.3.1	Network coverage	190
8.3.2	Network connectivity	193
8.4	Summary	195
	References	195
9	Performance evaluation of wireless sensor networks	200
9.1	Background information	200
9.2	Wireless sensor networks (WSNs) modeling	202
9.3	Simulation models	206
9.4	Modeling the behavior of sensors and sensor networks	209
9.4.1	Self-organization	210
9.4.2	Cooperative algorithms	211
9.4.3	Security mechanisms	211
9.4.4	Energy-aware requirement	212
9.5	Simulation tools for wireless sensor networks (WSNs)	212
9.6	Performance metrics	216
9.7	Fundamental models	217
9.7.1	Traffic model	217
9.7.2	Energy models	218
9.8	Summary	218
	References	219
10	Security issues in wireless sensor networks	222
10.1	Background	222
10.1.1	Software updating in WSNs	225
10.2	Limitations in WSNs	227
10.3	Security requirements in WSNs	228
10.4	Vulnerabilities and attacks specific to wireless sensor networks (WSNs)	231
10.5	Physical attacks on WSNs	233
10.6	Recent security issues in WSNs	235
10.7	Secure protocols for wireless sensor networks	236
10.7.1	SPINS	236
10.7.2	TinySec	237
10.7.3	LEAP	237
10.8	Denial of service (DoS) in WSNs and related defenses	238
10.9	Summary	242
	References	243
11	Wireless mobile sensor networks	248
11.1	Coverage and mobile sensors	249
11.1.1	Voronoi diagram-based approaches	250

11.1.2	Virtual force-based approaches	255
11.1.3	Grid-based approach	257
11.1.4	Event coverage	258
11.2	Network lifetime improvement	263
11.2.1	Predictable and controllable mobile sink	263
11.2.2	Predictable but uncontrollable mobile sink	265
11.2.3	Unpredictable and uncontrollable sink	268
11.2.4	Mobile relays and data mules	275
11.3	Summary	279
	References	280
12	Wireless multimedia sensor networks	282
12.1	Network applications	282
12.1.1	Multimedia surveillance	282
12.1.2	Traffic management	283
12.1.3	Advanced health care	283
12.1.4	Environmental monitoring	283
12.1.5	Industrial process control	284
12.1.6	Virtual reality	284
12.2	Challenges in WMSN	284
12.2.1	Resource constraints	284
12.2.2	Variable channel capacity	285
12.2.3	Multimedia coding technique	285
12.2.4	Redundancy removal	285
12.2.5	QoS requirements	286
12.3	Different architecture of WMSNs	286
12.3.1	Traditional WSN architecture	287
12.3.2	Heterogeneous, single-tier, clustered architecture	287
12.3.3	Heterogeneous, multiple-tier architecture	288
12.3.4	Integrated architecture	289
12.4	Comparison of different architectures	290
12.5	Multimedia sensor node architecture	290
12.6	Existing sensor node platforms	291
12.6.1	Panoptes	292
12.6.2	Cyclops	293
12.6.3	SensEye	294
12.7	Communication layers	295
12.7.1	Physical layer	295
12.7.2	Link layer	298
12.7.3	Network layer	304
12.7.4	Transport layer	307
12.7.5	Application layer	310
12.7.6	Cross-layer issues	313

xii	Contents	
	12.8 Summary	314
	References	314
13	Underwater sensor networks	319
	13.1 Characteristics, properties, and applications of UWSNs	321
	13.2 Underwater physics and dynamics	323
	13.3 UWSN design: communication model and networking protocols	329
	13.3.1 UWSN components	329
	13.3.2 UWSN architecture	331
	13.3.3 Localization services	332
	13.3.4 UWSN protocol design	336
	13.4 Summary	343
	References	343
14	Wireless underground sensor networks	348
	14.1 Applications	349
	14.1.1 Soil property monitoring	349
	14.1.2 Environment monitoring	350
	14.1.3 Border surveillance	350
	14.1.4 Mining safety vigilance	350
	14.1.5 Infrastructure monitoring	351
	14.1.6 Location determination	351
	14.2 Challenges in designing WUGSNs	351
	14.2.1 Underground communication channel design	352
	14.2.2 Topology design	352
	14.2.3 Power consumption	352
	14.2.4 Antenna design	353
	14.2.5 Environmental hazards	354
	14.3 Network architecture	354
	14.3.1 Topologies for WUGSNs buried underground	354
	14.3.2 Topologies for WUGSNs deployed in mines and tunnels	357
	14.4 Communication architecture	357
	14.4.1 Physical layer	357
	14.4.2 Data link layer	358
	14.4.3 Network layer	359
	14.4.4 Transport layer	360
	14.4.5 Cross-layer design	360
	14.4.6 Extremely opportunistic routing	361
	14.4.7 Underground opportunistic routing protocol	362
	14.5 Wireless underground channels	362
	14.5.1 Wireless underground channel properties	363
	14.6 Effects of soil properties on wireless underground channels	365
	14.6.1 Volumetric water content	365

	Contents	xiii
14.6.2	Soil composition	366
14.6.3	Density of soil	366
14.6.4	Size of soil particles	366
14.6.5	Soil temperature	366
14.6.6	Operating frequency	366
14.7	Underground channel models	366
14.7.1	Communication channels for WUGSNs buried underground	367
14.7.2	Communication channels for WUGSNs deployed in mines and tunnels	368
14.8	Summary	369
	References	369
	<i>References</i>	371
	<i>Subject index</i>	405

Preface

Overview and goals

Small low-cost devices powered with wireless communication technologies along with the sensing capabilities are instrumental in the inception of *wireless sensor networks* (WSNs). Recent years have witnessed a sharp growth in research in the area of WSNs. The characteristics of such distributed networks of sensors are that they have the potential for use in various applications in both the civilian and military fields. Enemy intrusion detection in the battlefield, object tracking, habitat monitoring, patient monitoring, and fire detection are some of the numerous potential applications of sensor networks. The ability of an infrastructure-less network setup with minimal reliance on network planning, and the ability of the deployed nodes to self-organize and self-configure without the association of any centralized control are the smart features of these networks. Leveraging the advantages of these features, the network setup is swift in challenging scenarios such as emergency, rescue, or relief operations. The smart features also enable continuous operation of the network without any intervention in case of any failure.

Along with the above-mentioned attractive features possessed by sensor networks, there are several challenges which hinder hassle-free, autonomous, and involuntary operation of these networks. Some of the challenges are attributed to issues relating to scalability, quality-of-service (QoS), energy efficiency, and security. The protocols should be light-weight enough to be suitable for these networks, which consist of small-sized sensor nodes with limited computation power. Sensor networks are often deployed in large-scale and are expected to function through years. Clearly, battery power is an issue in such cases, and can be achieved with the help of energy-efficient or energy-aware protocols. Finally, QoS is also an issue for applications which demand prompt responses.

There exists vast literature on various issues and dimensions of WSNs. This book attempts to provide a comprehensive guide on fundamental concepts, challenges, problems, trends, models, and results in the areas of WSNs. This book has been prepared keeping in mind that it needs to prove itself to be a valuable resource dealing with both the important core and the specialized issues in the areas. We have attempted to offer a wide coverage of topics. We hope that it will be a valuable reference for students, instructors, researchers and practitioners. We believe this is a particularly attractive feature of this book, as the limited selection of books available on sensor networks are written primarily for academicians/researchers. We have attempted to make this book useful for both the academics and the practitioners alike.

Organization and features

The book is broadly divided into three sections – the first part discusses the basics of WSNs, the second part focuses on the networking aspects and protocols of WSNs, and the third part deals with the advanced issues and topics such as localization, topology management, security, modeling, and simulation. There are 14 chapters in the book, of which the first part has three chapters, the second part has three chapters, and the third part has eight chapters.

In the first part, we provide an introduction to WSNs to the readers in Chapter 1. In this chapter, we provide an up-to-date treatment of the fundamental techniques, applications, taxonomy, and challenges of such networks. We also explain the basic components of a wireless sensor node, and classify the sensor networks. Finally, we discuss the differences between WSNs and wireless mesh networks and RFID systems.

Chapter 2 elaborates on components, structure, and operations of a wireless sensor node. We discuss the limitations and the design challenges of WSNs. The hardware architecture and the operating systems of a sensor node are discussed with examples of sensor nodes. This chapter also includes the effects of the infrastructure on the performance evaluation of WSNs. We also discuss the MEMS technology used to manufacture low-power inexpensive sensor nodes.

Chapter 3 reviews the major WSNs applications to various areas including environmental monitoring, health care, intelligent and smart home, homeland security, underwater applications, agriculture and greenhouse monitoring, and military applications.

Chapter 4 is dedicated to discussions about medium access control (MAC) in WSNs. We first discuss the problems of the traditional MAC schemes. In this chapter, the major MAC schemes for WSNs are discussed in detail.

In Chapter 5, we review the aspects, related advantages, and disadvantages, as well as challenges, of routing in WSNs. We classify the existing routing schemes into various categories, and explain a few schemes from each of the categories.

Chapter 6 deals with the transport protocols and quality-of-service (QoS) issues of the WSNs. We first address the transport protocol requirements for WSNs, and discuss the applicability of the Internet transport protocol in WSNs. Finally, the transport protocols are classified into various categories, and schemes from each of the categories are discussed.

Chapter 7, the first chapter of the third part of the book, presents the localization and target tracking schemes of WSNs. First, we discuss the basics of localization and the various distance estimation techniques. Next, the taxonomy of the existing localization schemes is presented with a few schemes from each category investigated in detail. Similarly, the target tracking schemes are also classified into various categories, and we discuss a few existing schemes as well.

In Chapter 8, the aspects and importance of topology management and control are discussed. A taxonomy of the existing schemes is also presented. Finally, we present a few existing schemes from each of the categories.

In Chapter 9, we provide an up-to-date treatment of the techniques that can be used to evaluate the performance of WSN systems. We discuss modeling and simulation techniques for WSNs, which are important when performance evaluation of these networks is needed. The performance metrics and fundamental models associated with performance evaluation are also discussed.

Chapter 10 discusses the security issues related to WSNs. We present a comprehensive study of the challenges, vulnerabilities, attacks, existing solutions, and then compare the major security techniques related to WSNs.

Chapter 11 presents the issues and aspects related to mobile wireless sensor networks. The authors investigate various issues such as coverage, connectivity, and deployment in mobile WSNs.

In Chapter 12, the authors discuss another variant of WSNs named wireless multimedia sensor networks (WMSNs). The challenges and specific applications of WMSNs are also discussed. This chapter also includes the network and node architecture and the communication layers of WMSNs.

Chapter 13 presents the underwater counterpart of WSNs. It is named as Underwater Sensor Networks (UWSNs). We present the challenges and characteristics of UWSNs, and the underwater physics and dynamics associated with UWSNs. The UWSN sensor nodes, their components, the network architectures, and few localization services are also studied in this chapter. We go through each layer of the protocol stack for UWSNs, and briefly discuss the schemes related to each layer.

Chapter 14 deals with another variant of WSNs, the Wireless Underground Sensor Networks (WUGSNs). The applications, challenges, network architectures of WUGSNs are presented. We also shed some light on the protocol stack, communication channels, and routing schemes for such networks.

Target audience

The book is written primarily for the student community. This includes students of all levels – those being introduced to these areas, those with an intermediate level of knowledge of the topics, and those who are already knowledgeable about many of the topics. In order to achieve this goal, we have attempted to design the overall structure and content of the book in a manner that makes it useful at all learning levels.

The secondary audience for this book is the research community, which includes researchers working in academia, industry, or government. To meet the specific needs to this audience group, most chapters of the book also have a section in which attempts have been made to provide directions for future research.

Finally, we have also taken into consideration the needs of those readers, typically from the industry, and those practitioners who wish to gain insight into the practical significance of the topics, i.e. how the spectrum of knowledge and the ideas are relevant for real-life workings of sensor networks.

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