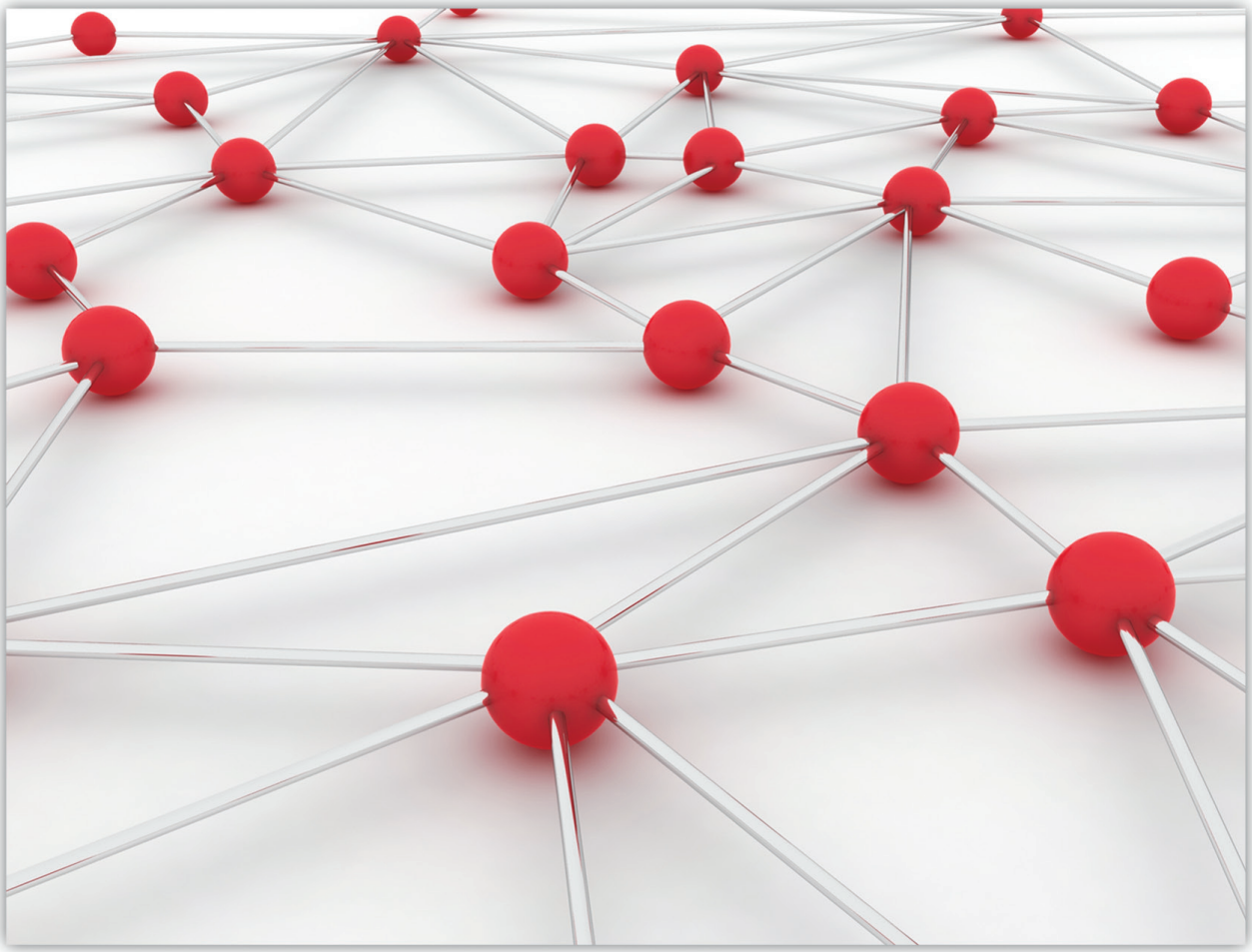
Wireless Sensor Networks

From Theory to Applications



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Contents

Preface

A wireless sensor network (WSN) is a simple low-cost approach that can be used in a distributed environment. A WSN is a group of distributed devices that could be employed to monitor physical and environmental conditions in real time. It is also used in the control of instruments, with the major benefit being that it provides efficient reliable communications via a wireless network. WSNs support the formation of connectivity independently in addressing and routing structures without much help from human beings. WSNs have certain traits of their own. The limitations of WSNs include power, low battery life, redundant data acquisition, low duty cycle, and many-to-one flows. New design methodologies could be adapted to overcome these limitations. Despite these problems, many WSN solutions are developed based on notions regarding wireless communication and environment. Moreover, it requires an enormous breadth of knowledge from a variety of disciplines such as electromechanical computers and communications.

There are many books on WSNs, mainly focused on beginners, which are already available in the market. A few books are available for advanced readers but they fail to provide comprehensive coverage. Hence, we thought of writing a book to fill this gap. However, because of the diverse richness and rapid development of the subject, we believe that only teamwork will yield good material for this hot topic. Consequently, we collected chapters from domain experts working on various subfields of WSNs around the globe and edited these chapters to develop this book. We approached CRC Press with our proposal on editing a book on the said topic during August 2011. CRC Press accepted our proposal and subsequently we announced the call for book chapters to various academic and industrial experts working on WSNs worldwide.

Forty-three expert teams submitted contributions from countries such as the United States, the United Kingdom, Canada, Mexico, Taiwan, Jordan, India, Iran, Italy, France, Egypt, Malaysia, Japan, Algeria, Saudi Arabia, Greece, Nigeria, Korea, and China. The materials presented in this book were reviewed by 36 reviewers and finally we accepted only 25 out of the 43 submissions based on the recommendations and comments from these reviewers.

This book is an edited volume prepared mainly for senior undergraduate and postgraduate students, researchers, scholars and academics, industrial researchers, and practicing engineers working in the field of WSNs and aiming to develop some genuine solutions for WSNs. We assume that the readers have some prior knowledge of computer networks, wireless communication, and basic electronics. The reader is provided with a concise list of references at the end of each chapter.

Organization of the Chapters

These 25 chapters are divided into seven parts, namely, Part I: Data Collection; Part II: Physical Layer and Interfacing; Part III: Routing and Transport Protocols; Part IV: Energy Saving Approaches; Part V: Mobile and Multimedia WSN; Part VI: Data Storage and Monitoring; and Part VII: Applications.

Data collection is a fundamental function provided by WSNs. How to efficiently collect sensing data from all sensor nodes, how to aggregate the collected data, and how to increase the coverage area are all critical to the performance of sensor networks. Part I addresses these issues and contains three chapters—one each on data collection, aggregation, and spatial coverage. Chapter 1 discusses data collection from different types of sensor networks. It starts with network models, communicative models, and related work. Later, this chapter focuses on data collection in random sensor networks. This chapter also elaborates data collection in arbitrary sensor networks under different categories. Chapter 2 gives a clear picture about data aggregation and data gathering in WSNs. This chapter deals with energy-efficient data aggregation protocols for a heterogeneous WSN. Various algorithms and protocols for data gathering and data aggregation are also discussed. Chapter 3 provides a survey of the various methods proposed for the estimation and optimization of spatial coverage of sensor networks. In addition, the chapter also concentrates on the state-of-the-art sensor networks and their related issues in terms of phenomena type of the environment and sensor as well as issues such as coverage communication and energy-saving problems.

Part II deals with physical layer and interfacing and also comprises three chapters. Chapter 4 deals with IEEE 802.15.4 WSNs. The architecture and functionalities of the ZigBee sensor networks are discussed. The IEEE 802.15.4 standard and the characteristics of 3-D terrains in WSNs are introduced. The performances of IEEE 802.15.4 WSNs in five artificial 3-D terrains are evaluated. A brief presentation on 3-D terrain visualization software is also available in this chapter. Chapter 5 is about multi-interface model. The idea is to exploit the heterogeneity of the interfaces available in modern devices in order to reduce energy consumption and prolong network lifetime. Several well-known combinatorial optimization problems are then reconsidered with respect to this new feature. Chapter 6 deals with the sensor bus architecture for a real-time WSN, and this applicability has been tested with three different sensor networks, which includes a real-world temperature sensor network from Texas Instruments. It has been integrated with the sensor bus to show its practical application in real-time temperature monitoring applications. Sun SPOT sensor networks, which generate random values using a Solarium emulator and a simulated sensor network, are also discussed.

Part III has five chapters on routing and transport protocols. Chapter 7 addresses the development of a specific framework for the computation of the network topology. Link layer performance is evaluated and the link level throughput and delay are defined. Routing performance is analyzed for IEEE 802.15.6. Chapter 8 focuses on the routing protocols that cover low energy adaptive clustering hierarchy (LEACH), C-LEACH, V-LEACH, N-LEACH, and PEGASIS, which are modified versions of the LEACH protocol. In addition to discussions on multihop routing in wireless ad hoc and sensor networks, a detailed survey on various connected dominating set construction techniques for ad hoc sensor networks is given in Chapter 9. This chapter also provides details on various network models used for virtual backbone construction. In Chapter 10, the authors discuss the different types of transport protocols in WSNs, and their guidelines performance metrics and congestion control mechanisms are shown. The existing transport protocols for WSNs are briefly reviewed and several problems in the existing protocols are also listed. Chapter 11 discusses energy-efficient MAC protocols for WSNs. It comprises radio energy consumption models, MAC

layer issues for WSNs design goals, energy trade-offs, and metrics. It also elaborates about the emerging MAC layer protocols such as Y-MAC, EM-MAC, and PIP.

Part IV has four chapters exclusively focusing on energy efficient methods in WSNs. Chapter 12 focuses on event monitoring and energy saving in the WSNs. Energy saving is accomplished using ultralight pulse switching protocol for resource-constrained sensors in event monitoring and target tracking applications. The joint MAC routing architectures for pulse switching with the hop angular and cellular event localization are also presented in this chapter. Chapter 13 explains about energy handling with the help of previous research findings and points out the major issues in energy conservation congestion control and avoidance in WSNs. Chapter 14 starts with the concept of cooperative multiple-input/multiple-output (MIMO) in WSNs and different forms of MIMO and its configurations. Then, the chapter focuses on energy consumption techniques, the energy model, and a complete study of the parameters that affect the system in various situations. The clustering algorithm, which is a kind of key technique used to reduce energy consumption in WSNs, is dealt with in Chapter 15. It details clustering requirement formation maintenance and the factors affecting clustering network architecture, etc. The focus is given to discussing the application of WSNs in watering for irrigation and effective usage of water in agriculture.

Part V is on mobile and multimedia WSNs and has three chapters. Chapter 16 focuses on GPS-free and anchor-free indoor localization schemes. This chapter also comprises information on works related to mobile sensor networks along with the proposed network model. A cognitive approach in mobile WSNs is addressed in Chapter 17. The chapter also describes the various challenges and design issues faced by MWSNs in addition to the major focus on cognitive radio-based WSNs. Chapter 18 introduces the acorrelation-based communication framework which leverages the spatial correlation of visual information in communication protocols for wireless multimedia sensor networks. A novel analytical spatial correlation model based on the projection geometry of camera sensors is provided in this chapter. It also provides a method for predicting the compression efficiency of correlated camera sensors, which is used to designed clustering and routing algorithms for multimedia sensor networks.

Data storage and monitoring are the themes of four chapters in Part VI. Distributed data storage and retrieval schemes using IPv6 in WSNs are discussed in Chapter 19. The state-of-the-art on distributed data storage techniques and current standard Internet of Things protocols are discussed. Then, a distributed data storage scheme called the low-complexity greedy mechanism is presented and analyzed. Chapter 20 deals with the monitoring mechanism for WSNs. This chapter introduces various monitoring mechanisms and their challenges. This chapter also provides solutions for those problems using a wireless distributed intrusion detection system. Building and orchestrating centralized remote management procedures for WSNs using the TinyOS platform and OpenRSM is dealt with in Chapter 21. It details the application development in TinyOS. This chapter also provides details for installing TinyOS remotely using web-based technologies such as HTML5, AJAX, and middleware, which provide platform-independent operations. Chapter 22 addresses the challenges for QoS support in WSNs. This chapter describes QoS performance metrics in WSNs at different levels. This chapter provides details on different types of services in WSNs and various mechanisms to achieve QoS in WSNs.

Most of the chapters that have been discussed thus far are oriented toward applications of WSNs in addition to their theoretical discussions. However, the last three chapters of this book in Part VI exclusively focus on the applications of WSNs. The ways and means to use the wireless body area networks (WBANs) in artificial eye vision is discussed in Chapter 23. Details about WBANs, which includes the system prototype and the data rates, are given. This is followed by discussions on the types of sensor benefits and challenges of WBANs, such as how WBANs can

be used in an artificial retina. Chapter 24 considers WSNs from a medical perspective. It presents an overview of the effect of WSNs on medical health care as well as highlighting the state-of-the-art in the applications of WSNs for tele–health care. Also, this chapter describes the challenges introduced by health care applications to WSNs. Chapter 25 deals with applying WSNs for monitoring various phenomena in different environmental fields. This chapter describes the challenges introduced by smart environmental monitoring applications of WSNs.

Acknowledgments

We are directly and indirectly indebted to a number of individuals who assisted in the preparation of the book. In particular, we are grateful to the 36 referees who performed the task of reviewing chapters and providing valuable suggestions, comments, and criticisms in improving the quality of the work. Our special thanks and congratulations are due to the authors of the 25 chapters for successfully submitting their work according to the recommendations of the reviewers. The support of CRC Press is really tremendous and is to be appreciated greatly. We are pleased to thank our colleagues for their cooperation in sharing our academic load during this work. We cannot find the right words to express our thankfulness to our family members for their love, prayers, and backing.

We are open to comments and criticisms from the readers in improving the quality of this book for future editions.

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