

Preface

The field of wireless sensor networks continues to evolve and grow in both practical and research domains. More and more wireless sensor networks are being used to gather information in real life applications. It is common to see how this technology is being applied in irrigation systems, intelligent buildings, bridges, security mechanisms, military operations, transportation-related applications, etc. At the same time, new developments in hardware, software, and communication technologies are expanding these possibilities. As in any other technology, research brings new developments and refinements and continuous improvements of current approaches that push the technology even further.

Looking toward the future, the technology seems even more promising in two directions. First, a few years from now more powerful wireless sensor devices will be available, and wireless sensor networks will have applicability in an endless number of scenarios, as they will be able to handle traffic loads not possible today, make more computations, store more data, and live longer because of better energy sources. Second, a few years from now, the opposite scenario might also be possible. The availability of very constrained, nanotechnology-made wireless sensor devices will bring a whole new world of applications, as they will be able to operate in environments and places unimaginable today. These two scenarios, at the same time, will both bring new research challenges that are always welcome to researchers.

Book Origin and Overview

This book is the result of more than six years of research in wireless sensor networks. This research involved investigating new techniques for localization and localization services, energy-efficient MAC, network, and transport layer protocols, and more recently, topology control, the main topic of the book. Not surprisingly, although the book emphasizes topology control, it also includes background information on communication protocols for wireless sensor networks.

The book is divided in three parts. Part I consists of six chapters containing general information about wireless sensor networks, communication protocols, and topology control. Chapter 1 is an introductory chapter that describes the architec-

ture of a generic wireless sensor device and network architectures. The chapter ends with the motivation for these types of networks describing the possible application domains and the challenges that still remain. Chapter 2 describes the most important aspects of the physical layer as they relate to wireless sensor networks. This is not a typical chapter on physical layer communication technologies; instead, it includes needed information about signal propagation models, energy dissipation models, error generation models in wireless networks, and sensing models, all of them of utmost importance in the design and evaluation of wireless sensor networks. Chapter 3 is about the Data Link Layer of the communication protocol stack, and as such, includes the Medium Access Control protocols for energy efficient access of the wireless media and Logical Link Control protocols for flow and error control. The topic of routing for wireless sensor networks is included in Chapter 4 where the most important routing protocols are surveyed and explained. Chapter 5 is devoted to transport layer protocols for wireless sensor networks. Protocols for applications with different reliability requirements are explained along with a discussion about the need of congestion control and the use of TCP and UDP in wireless sensor networks. Finally, Chapter 6 introduces the reader to the topic of topology control and provides the road map for the rest of the book. In this chapter, the reader is presented with the motivations for topology control, its challenges, and general design guidelines. A formal definition of topology control is presented along with a discussion about where in the communication protocol stack this function should be implemented. Lastly, a new taxonomy of topology control is presented that includes the concept of topology construction (currently known as topology control), and for the first time, the concept of topology maintenance.

Part II of the book is devoted to what we call Topology Construction, or techniques that, given a set of nodes, build a reduced topology to save energy while preserving important network characteristics, such as network coverage and connectivity. Chapter 7 discusses those topology construction mechanisms that build the reduced topology by controlling the transmission power of the nodes. Chapter 8 includes those techniques that build reduced hierarchical topologies. The last chapter of Part II is Chapter 9, which includes hybrid topology construction techniques for the first time.

The third and last part of the book, is about Topology Maintenance, a concept that had never been formally defined as part of topology control. Chapter 10 introduces the topic and includes general information about topology maintenance that applies to all three remaining chapters, such as design issues, topology maintenance triggering criteria, and radio synchronization. Chapter 11 introduces topology maintenance static techniques and includes a performance evaluation of global static techniques in sparse and dense networks. Chapter 12 is about topology maintenance dynamic techniques, and it also includes a performance evaluation of both global and local dynamic techniques in sparse and dense networks. Finally, Chapter 13, which ends Part III of the book, includes topology maintenance hybrid techniques and their performance evaluation, and two sections where all topology maintenance techniques described in this part of the book are further evaluated and compared.

Intended Audience

The book is intended for graduate students, professors, researchers, and industry professionals interested in wireless sensor networks. The book can be used as a reference book in a graduate class on wireless sensor networks, or as the main book in an advanced, research oriented course on the same topic with emphasis on topology control. The Atarraya simulator is an excellent teaching aid for explaining difficult concepts in a graphical way, and an invaluable tool for experimentation and the assignment of research-oriented projects for the class.

Resources

Appendix A is another important contribution of this book. It describes the structure of the Atarraya simulator in detail. Atarraya is a Java-based simulation tool developed for teaching and researching topology control topics in wireless sensor networks. We hope that you use the tool as much as we have in your classes and in your research. As a Java-based tool, it is easily understandable and expandable, so you can include new topology control mechanisms as well as other aspects of wireless sensor networks, such as new propagation models, error models, etc. Atarraya comes with a graphical user interface that can be used to visualize the effect of applying topology control algorithms in a class or demonstration. All experimental-based figures included in the book were generated with Atarraya.

Atarraya, which is copyrighted under the GNU license agreement, can be downloaded for free from <http://www.csee.usf.edu/~labrador/Atarraya>.

Acknowledgments

We are very grateful to Hillary Wade, who spent a tremendous amount of time revising and making suggestions about the manuscript. We would also like to thank the staff of Springer for their support during all the phases of the book. Finally, we want to acknowledge our own families for their patience, support, and understanding during all these months of continuous, hard work.

About the Authors

Miguel A. Labrador received the M.S. in Telecommunications and the Ph.D. degree in Information Science with concentration in Telecommunications from the University of Pittsburgh, in 1994 and 2000, respectively. Since 2001, he has been with the University of South Florida, Tampa, where he is currently an Associate Professor in the Department of Computer Science and Engineering. Before joining USF, he worked at Telcordia Technologies, Inc., NJ, in the Broadband Networking Group of the Professional Services Business Unit. He has more than fifteen years of industry experience in the Telecommunications area. His research interests are in design

and performance evaluation of computer networks and communication protocols for wired, wireless, and optical networks, energy-efficient mechanisms for wireless sensor networks, bandwidth estimation techniques, and location-based services. He has published more than 50 technical and educational papers in journals and conferences devoted to these topics. Dr. Labrador has served as Technical Program Committee member of many IEEE conferences and is currently member of the Editorial Board of Computer Communications and the Journal of Network and Computer Applications, Elsevier Science. He served as Secretary of the IEEE Technical Committee on Computer Communications (TCCC), Chair of the IEEE VTC 2003 Transport Layer Protocols over Wireless Networks Symposium, and guest editor of the special issue of Computer Communications on "Advanced Location-Based Services". Dr. Labrador is a senior member of the IEEE Communications Society, and member of the ACM SIGCOMM, ASEE, and Beta Phi Mu honor society.

Pedro M. Wightman received his B.S. in Systems Engineering from the Universidad del Norte, in Barranquilla, Colombia, in 2004. He received his M.S. in Computer Science from the University of South Florida in 2007, where he is a Ph.D. candidate in the department of Computer Science and Engineering. Pedro worked as a part-time assistant professor at the Universidad del Norte during 2004 and 2005. In 2005 he was selected to participate in the National Program of Young Researchers in Colombia, sponsored by the Colombian Institute of Science and Technology, Colciencias. In 2005, he was selected by the Universidad del Norte to participate in the Teaching Formation Program which gave him the opportunity to enroll in the University of South Florida to pursue his doctorate degree in Computer Science and Engineering. His research interests are in the development of energy efficient protocols for wireless sensor networks, topology construction and topology maintenance protocols. He is also interested in the design and implementation of communication platforms with an emphasis on virtual reality chat rooms and distance learning applications. Mr. Wightman has published technical papers in peer-reviewed conferences related to the areas previously mentioned. He is a member of the IEEE Communication Society, and co-founder of CommNet, the Communication Networks Group at USF.

Tampa,
October 2008

Miguel A. Labrador
Pedro M. Wightman