Wireless Sensor Networks

Principles and Practice

Fei Hu • Xiaojun Cao

Wireless Sensor Networks

Principles and Practice

常州大学山书馆
藏书章

FEI HU • XIAOJUN CAO

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business
AN AUERBACH BOOK

MATLAB® is a trademark of The MathWorks, Inc. and is used with permission. The MathWorks does not warrant the accuracy of the text or exercises in this book. This book's use or discussion of MATLAB® software or related products does not constitute endorsement or sponsorship by The MathWorks of a particular pedagogical approach or particular use of the MATLAB® software.

Auerbach Publications
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

© 2010 by Taylor and Francis Group, LLC
Auerbach Publications is an imprint of Taylor & Francis Group, an Informa business

No claim to original U.S. Government works

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number: 978-1-4200-9215-8 (Hardback)

This book contains information obtained from authentic and highly regarded sources. Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, please access www.copyright.com (http://www.copyright.com/) or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of users. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

Library of Congress Cataloging-in-Publication Data

Hu, Fei, 1972-
Wireless sensor networks : principles and practice / Fei Hu and Xiaojun Cao.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-4200-9215-8 (alk. paper)
1. Wireless sensor networks. I. Cao, Xiaojun, 1972- II. Title.

TK7872.D48H82 2009
681'.2--dc22 2009044545

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the Auerbach Web site at
http://www.auerbach-publications.com

Wireless Sensor Networks

Principles and Practice

OTHER TELECOMMUNICATIONS BOOKS FROM AUERBACH

Broadband Mobile Multimedia: Techniques and Applications
Yan Zhang, Shiwen Mao, Laurence T. Yang, and Thomas M Chen
ISBN: 978-1-4200-5184-1

Carrier Ethernet: Providing the Need for Speed
Gilbert Held
ISBN: 978-1-4200-6039-3

Cognitive Radio Networks
Yang Xiao and Fei Hu
ISBN: 978-1-4200-6420-9

Contemporary Coding Techniques and Applications for MobileCommunications
Onur Osman and Osman Nuri Ucan
ISBN: 978-1-4200-5461-3

Converging NGN Wireline and Mobile 3G Networks with IMS: Converging NGN and 3G Mobile
Rebecca Copeland
ISBN: 978-0-8493-9250-4

Cooperative Wireless Communications
Yan Zhang, Hsiao-Hwa Chen, and Mohsen Guizani
ISBN: 978-1-4200-6469-8

Data Scheduling and Transmission Strategies in Asymmetric Telecommunication Environments
Abhishek Roy and Navrati Saxena
ISBN: 978-1-4200-4655-7

Encyclopedia of Wireless and Mobile Communications
Borko Furht
ISBN: 978-1-4200-4326-6

IMS: A New Model for Blending Applications
Mark Wuthnow, Jerry Shih, and Matthew Stafford
ISBN: 978-1-4200-9285-1

The Internet of Things: From RFID to the Next-Generation Pervasive Networked Systems
Lu Yan, Yan Zhang, Laurence T. Yang, and Huansheng Ning
ISBN: 978-1-4200-5281-7

Introduction to Communications Technologies: A Guide for Non-Engineers, Second Edition
Stephan Jones, Ron Kovac, and Frank M. Groom
ISBN: 978-1-4200-4684-7

Long Term Evolution: 3GPP LTE Radio and Cellular Technology
Borko Furht and Syed A. Ahson
ISBN: 978-1-4200-7210-5

MEMS and Nanotechnology-Based Sensors and Devices for Communications, Medical and Aerospace Applications
A. R. Jha
ISBN: 978-0-8493-8069-3

Millimeter Wave Technology in Wireless PAN, LAN, and MAN
Shao-Qiu Xiao and Ming-Tuo Zhou
ISBN: 978-0-8493-8227-7

Mobile Telemedicine: A Computing and Networking Perspective
Yang Xiao and Hui Chen
ISBN: 978-1-4200-6046-1

Optical Wireless Communications: IR for Wireless Connectivity
Roberto Ramirez-Iniguez, Sevia M. Idrus, and Ziran Sun
ISBN: 978-0-8493-7209-4

Satellite Systems Engineering in an IPv6 Environment
Daniel Minoli
ISBN: 978-1-4200-7868-8

Security in RFID and Sensor Networks
Yan Zhang and Paris Kitsos
ISBN: 978-1-4200-6839-9

Security of Mobile Communications
Noureddine Boudriga
ISBN: 978-0-8493-7941-3

Unlicensed Mobile Access Technology: Protocols, Architectures, Security, Standards and Applications
Yan Zhang, Laurence T. Yang, and Jianhua Ma
ISBN: 978-1-4200-5537-5

Value-Added Services for Next Generation Networks
Thierry Van de Velde
ISBN: 978-0-8493-7318-3

Vehicular Networks: Techniques, Standards, and Applications
Hassnaa Moustafa and Yan Zhang
ISBN: 978-1-4200-8571-6

WiMAX Network Planning and Optimization
Yan Zhang
ISBN: 978-1-4200-6662-3

Wireless Quality of Service: Techniques, Standards, and Applications
Maode Ma and Mieso K. Denko
ISBN: 978-1-4200-5130-8

AUERBACH PUBLICATIONS
www.auerbach-publications.com
To Order Call: 1-800-272-7737 • Fax: 1-800-374-3401
E-mail: orders@crcpress.com

此为试读，需要完整PDF请访问：www.ertongbook.com

To Fei's family—*Fang* and *Gloria* .....

To Matt's family .....

Preface

Wireless sensor networks (WSNs) are one of the hottest topics of research in today's era of information explosion. The latest advances in science and engineering have paved the way for employing the low-power, low-cost WSN, which provides a high order of spatial and effective resolution for an ever-increasing number of applications, such as infrastructure protection and security, surveillance, healthcare, habitat/environment monitoring, food safety, and smart energy. Although the use of WSNs has many advantages over traditional networking techniques and sensing methods in the aforementioned applications, it also poses many challenging issues and optimization problems in the design of network architectures, protocols, and algorithms. To resolve these challenges despite constraints on available energy, bandwidth, memory space and computing power, high rates of node failure and data loss, adverse communication environments, and unique application requirements, significant efforts have been made in the academia and industry.

Although some books on sensor networks have been published recently, most (if not all) of them are not suitable to be used as textbooks due to the limited number of topics covered or to the nature of editorial collections. This textbook attempts to comprehensively discuss all the major technologies, standards, topics, and developments in sensor networks. It covers almost all aspects that readers need to know to enter this burgeoning field, including hardware design, medium access control, routing schemes, transport protocols, OS support, middleware, data management, localization, synchronization, security, actuator/underwater/video sensor networking, power control, and sensor simulations.

This textbook makes complicated concepts easy to understand through interesting examples and WSN applications. In addition, it has exercises, assignments, and detailed case studies that help readers understand the contents and then apply their knowledge in designing their own applications or for solving real-world problems. We have also included some practical sensor network design cases such as medical applications.

Targeted Audiences

This book is ideal for senior college students or first-year graduate students who are majoring in computer engineering, electrical engineering, or computer science. It is also an excellent reference book for sensor network designers, researchers, and engineers who wish to fully exploit WSN technology, and for government employees who wish to use WSNs to enhance homeland security.

Scope of This Book

Because we target both engineering and science students, we have covered both hardware and software topics in this textbook. This book, which consists of 18 chapters, is organized in the following manner:

	Chapter 1. Introduction (WSN overview; basic network concepts)
Computer engineering knowledge	**Chapter 2.** Hardware (micro-sensors with microcontrollers and radio)
Network protocol stack	**Chapter 3.** MAC layer (neighborhood wireless transmission)
	Chapter 4. Routing layer (find an optimal source-to-end path)
	Chapter 5. Transport layer (loss recovery, congestion control)
Computer science knowledge	**Chapter 6.** Operating system (such as TinyOS)
	Chapter 7. Middleware (hide networking details for programmers)
	Chapter 8. Sensor data management
Advanced WSN topics	**Chapter 9.** Localization (also called calibration; very useful)
	Chapter 10. Clock synchronization (correct clock drifts in sensors)
	Chapter 11. Security (countermeasure WSN attacks)

(continued)

Special sensor networks	**Chapter 12.** Wireless actor and sensor networks (with mobile actors)
	Chapter 13. Underwater sensor networks (using acoustic; not RF)
	Chapter 14. Video sensor networks
Miscellaneous	**Chapter 15.** Energy models and low-energy design
	Chapter 16. WSN simulators
Case studies	**Chapter 17.** WSN for tele-healthcare applications
	Chapter 18. WSN for light control

What Can Be Covered in a Course

For a One-Semester (15 Weeks) Course: The following table is our suggested time allocation plan among different topics. Instructors should adjust their teaching plan based on students' feedback and learning practices.

Time Length	*Teaching Topics*	*Chapters*
2 weeks	WSN basics; sensor hardware (for computer science major, the hardware part can be shortened)	Chapters 1 and 2
2 weeks	MAC layer (teach at least two MAC schemes, emphasizing "energy-saving" design)	Chapter 3
2.5 weeks	Routing layer (teach proactive/reactive routing schemes, emphasizing "scalable" design)	Chapter 4
1.5 weeks	Transport layer (teach both "reliable end-to-end transmission" and "congestion control")	Chapter 5
1 week	Operating system; middleware (for computer science major, 2 weeks may be used)	Chapters 6 and 7
1 week	Sensor data management (for computer science major, 2 weeks may be used)	Chapter 8
1 week	Sensor localization; time synchronization (for PhD/MS students, 2–3 weeks may be used)	Chapters 9 and 10

(continued)

(continued)

Time Length	*Teaching Topics*	*Chapters*
1 week	WSN security (Teach μTESLA, Key pre-distribution)	Chapter 11
1.5 weeks	Special sensor networks (especially underwater WSN)	Chapters 12 through 14
0.5 week	Energy models; WSN simulators	Chapters 15 and 16
1 week	Case studies	Chapters 17 and 18
Total: 15 weeks	In each chapter, teach both math principles and concrete design cases. Leave some topics for after-class reading assignments.	

Note that some time should also be allocated for class labs.

For a One-Quarter (10 Weeks) Course:

Time Length	*Teaching Topics*	*Chapters*
1.5 weeks	WSN basics; sensor hardware	Chapters 1 and 2
1 week	MAC layer (emphasizing "energy-saving" design)	Chapter 3
1.5 weeks	Routing layer (teach proactive/reactive routing schemes; emphasizing "scalable" design)	Chapter 4
1 week	Transport layer (teach both "reliable end-to-end transmission" and "congestion control")	Chapter 5
0.5 week	Operating system; middleware (for computer science major, 1.5 weeks may be used)	Chapters 6 and 7
0.5 week	Sensor data management (for computer science major, 1.5 weeks may be used)	Chapter 8
1 week	Sensor localization; time synchronization (for PhD/MS students, 2–3 weeks may be used)	Chapters 9 and 10

(continued)

Time Length	*Teaching Topics*	*Chapters*
0.5 week	WSN security (Teach μTESLA, Key pre-distribution)	Chapter 11
1 week	Special sensor networks (especially underwater WSN)	Chapters 12 through 14
0.5 week	Energy models; WSN simulators	Chapters 15 and 16
1 week	Case studies	Chapters 17 and 18
Total: 10 weeks	In each chapter, teach both math principles and concrete design cases. Leave some topics for after-class reading assignments.	

For computer engineering majors, Chapter 2 (sensor hardware) is important. This chapter may be allocated more time as it would require a detailed study. For computer science majors, Chapters 6 through 8 (OS, data management) should be covered in more details.

Some chapters, such as Chapters 8 through 10 (localization, synchronization, and security), may be assigned to PhD/MS students as term paper topics (i.e., the students are required to explore this topic in more detail and submit a research paper based on their investigations). Chapters 17 and 18 could be used as projects for senior students.

While teaching, the use of survey-like PowerPoint® slides is not recommended in class as this book covers WSN topics in detail. Instructors should select good design examples to elaborate certain concepts. For instance, when studying MAC layers, at least one of the MAC schemes (such as S-MAC) should be taught in detail.

Math principles are extremely important to WSN design. Therefore, if any chapter has some good math models, they should be studied carefully. These math principles should especially be emphasized for PhD/MS students.

MATLAB® is a registered trademark of The MathWorks, Inc. For product information, please contact:

The MathWorks, Inc.
3 Apple Hill Drive
Natick, MA 01760-2098 USA
Tel: 508 647 7000
Fax: 508-647-7001
E-mail: info@mathworks.com
Web: www.mathworks.com

此为试读，需要完整PDF请访问：www.ertongbook.com

Acknowledgments

Dr. Xiaojun Cao has contributed about one fifth of the contents of this book, and the remaining text has been written by Dr. Fei Hu. We wish to express our gratitude to all those who have helped us during the preparation of this book. Students in the Department of Electrical and Computer Engineering at the University of Alabama, Tuscaloosa, have helped to edit some figures and math equations. They have also helped to edit some of the content. We are grateful to Rahul Mallampati for helping us revise the content, edit some figures, and format the text in Microsoft Word®. Thanks also to Barnali Chakrabarty and the staff at Auerbach Publications who have provided us continuous support during the writing effort.

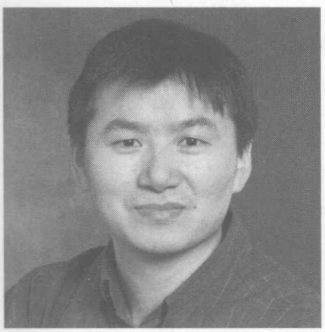
A final note: Much of the content and concepts of the textbook are based on existing research efforts from the literature that we cannot list here specifically. We would like to particularly express our appreciation to those authors who have published excellent materials on WSNs.

Disclaimer

As the purpose of this textbook is to explain the latest concepts on wireless sensor network (WSN) design in a textbook format to train students and engineers, we would like to make it clear that this book is not meant for publishing innovative research ideas. Although we have tried our best to provide due credit to all publications cited in this book, there could still be some errors. We would like to sincerely thank all the authors who have published WSN materials that have been cited by us. Any errors or questions on the content of this book can be addressed to us (Fei Hu: fei.hu@ieee.org or Matt Cao: cao@cs.gsu.edu); we will correct the errors and thus improve this textbook in future editions.

Authors

Fei Hu is currently an associate professor in the Department of Electrical and Computer Engineering at the University of Alabama (main campus), Tuscaloosa. His research interests include sensor networks, wireless networks, network security, and their applications in biomedicine. His research has been supported by the U.S. National Science Foundation, Cisco, Sprint, and other sources. He received his PhD in 1999 in signal processing from Tongji University, Shanghai, China, and in 2002 in electrical and computer engineering from Clarkson University, New York. He received his BS and MS in telecommunication engineering from Shanghai Tiedao University, China, in 1993 and 1996, respectively.



Xiaojun Cao is currently an assistant professor in the Department of Computer Science at Georgia State University, Atlanta. He received his BS from Tsinghua University, Beijing, China, and his MS from the Chinese Academy of Sciences, Beijing, China. In June 2004, he received his PhD in computer science and engineering from the State University of New York at Buffalo. Dr. Cao's research has been sponsored by the U.S. National Science Foundation, IBM, and Cisco's University Research Program. He is a recipient of the NSF CAREER Award, 2006–2011. His research interests include modeling, analysis, and protocol/algorithm design of communication networks. Important among these are optical networking, waveband switching, optical burst switching, mobile ad hoc networks, sensor networks and security, and optical wireless communications.

Contents

此为试读，需要完整PDF请访问：www.ertongbook.com