教育部高等教育司推荐
国外优秀信息科学与技术系列教学用书

无线与移动系统导论

（影印版）

INTRODUCTION TO WIRELESS AND MOBILE SYSTEMS

■ Dharma Prakash Agrawal
Qing-An Zeng

THOMSON

高等教育出版社
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前　言

20 世纪末，以计算机和通信技术为代表的信息科学和技术对世界经济、科技、军事、教育和文化等产生了深刻影响。信息科学技术的迅速普及和应用，带动了世界范围信息产业的蓬勃发展，为许多国家带来了丰厚的回报。

进入 21 世纪，尤其随着我国加入 WTO，信息产业的国际竞争将更加激烈。我国信息产业虽然在 20 世纪末取得了迅猛发展，但与发达国家相比，甚至与印度、爱尔兰等国家相比，还有很大差距。国家信息化的发展速度和信息产业的国际竞争能力，最终都将取决于信息科学技术人才的质量和数量。引进国外信息科学和技术优秀教材，在有条件的学校推动开展英语授课或双语教学，是教育部为加快培养大批高质量的信息技术人才采取的一项重要举措。

为此，教育部要求由高等教育出版社首先开展信息科学和技术教材的引进试点工作。同时提出了两点要求，一是要高水平，二是要低价格。在高等教育出版社和信息科学技术引进教材专家组的努力下，经过比较短的时间，第一批引进的 20 多种教材已经陆续出版。这套教材出版后受到了广泛的好评，其中有不少是世界信息科学技术领域著名专家、教授的经典之作和反映信息科学技术最新进展的优秀作品，代表了目前世界信息科学技术教育的一流水平，而且价格也是最优惠的，与国内同类自编教材相当。

这项教材引进工作是在教育部高等教育司和高教社的共同组织下，由国内信息科学技术领域的专家、教授广泛参与，在对大量国外教材进行多次遴选的基础上，参考了国内和国外著名大学相关专业的课程设置进行系统引进的。其中，John Wiley 公司出版的贝尔实验室信息科学研究中心副总裁 Silberschatz 教授的经典著作《操作系统概念》，是我们经过反复谈判，做了很多努力才得以引进的。William Stallings 先生曾编写了在美国深受欢迎的信息科学技术系列教材，其中有多种教材获得过美国教材和学术著作者协会颁发的计算机科学与工程教材奖，这批引进教材中就有他的两本著作。留美中国学者 Jiawei Han 先生的《数据挖掘》是该领域中具有里程碑意义的著作。由达特茅斯学院 Thomas Cormen 和麻省理工学院、哥伦比亚大学的几

位学者共同编著的经典著作《算法导论》，在经历了 11 年的锤炼之后于 2001 年出版了第二版。目前任教于美国 Massachusetts 大学的 James Kurose 教授，曾在美国三所高校先后 10 次获得杰出教师或杰出教学奖，由他主编的《计算机网络》出版后，以其体系新颖、内容先进而倍受欢迎。在努力降低引进教材售价方面，高等教育出版社做了大量和细致的工作。这套引进的教材体现了权威性、系统性、先进性和经济性等特点。

教育部也希望国内和国外的出版商积极参与此项工作，共同促进中国信息技术教育和信息产业的发展。我们在与外商的谈判工作中，不仅要坚定不移地引进国外最优秀的教材，而且还要千方百计地将版权转让费降下来，要让引进教材的价格与国内自编教材相当，让广大教师和学生负担得起。中国的教育市场巨大，外国出版公司和国内出版社要通过扩大发行数量取得效益。

在引进教材的同时，我们还应做好消化吸收，注意学习国外先进的教学思想和教学方法，提高自编教材的水平，使我们的教学和教材在内容体系上，在理论与实践的结合上，在培养学生的动手能力上能有较大的突破和创新。

目前，教育部正在全国 35 所高校推动示范性软件学院的建设和实施，这也是加快培养信息科学技术人才的重要举措之一。示范性软件学院要立足于培养具有国际竞争力的实用性软件人才，与国外知名高校或著名企业合作办学，以国内外著名 IT 企业为实践教学基地，聘请国内外知名教授和软件专家授课，还要率先使用引进教材开展教学。

我们希望通过这些举措，能在较短的时间，为我国培养一大批高质量的信息技术人才，提高我国软件人才的国际竞争力，促进我国信息产业的快速发展，加快推动国家信息化进程，进而带动整个国民经济的跨越式发展。

教育部高等教育司

二〇〇二年三月

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Preface

Wireless systems have been around for quite some time, and their obvious use in garage-door openers and cordless phones has gone unnoticed until recently. Their unique capability of maintaining the same contact number even if the user moves from one location to another has made them increasingly popular. Wireless telephones are not only convenient but are also providing flexibility and versatility. The introduction of affordably priced wireless and mobile telephones has made them attractive for the general population worldwide. Thus, the number of wireless phone subscribers and service providers has proliferated.

Wireless and mobile communications have found usefulness in areas such as commerce, education, and defense. According to the nature of a particular application, they can be used in home-based and industrial systems or in commercial and military environments. In a home-based system a central access point communicates with various appliances and controls them using a localized wireless node. This kind of system enables close coordination among appliances in the home (or industry) and achieves control over the home (or industry) access point using voice or a short message. To facilitate this, a consortium of companies is working on the Bluetooth project. There are many novel applications of such a wireless system—for example, a bracelet worn by a subscriber can constantly monitor body parameters and take action if needed (like informing the family physician about a health problem). However, the design and implementation of such a system brings with it a lot of important issues, such as standardization and infrastructure for Internet access, audio/video editing, and distributed decision-making software.

In a commercial system, the common issues are the range of the system, number of distribution infrastructure access points, number of users for each access point, and so on. For instance, we need to have several access points uniformly distributed in each floor of a factory so that users have continuous access to them. But this gives rise to problems such as appropriate coordination of channels between access points and channel bandwidth requirements. Any loss of information (voice or data packet) in wireless switching is unacceptable; hence care should be taken to ensure the reliable transmission and reception of information.

Wireless systems, such as the traditional infrastructure system, satellite system, or the more recent ad hoc networks formed by mobile users, have tremendous potential when used in defense applications. Ad hoc networks involve

information transfer in the peer-to-peer mode, but we have to deal with the problem of power consumption for a wide coverage area. Other problems involve channel allocation based on address, traffic types (voice, video, data, or audio), mobility pattern, and routing techniques.

The wireless technology also has influenced instructional infrastructure at many institutions. Carnegie Mellon University has taken the lead in creating a campus-wide wireless network. Steps have also been taken at the University of Cincinnati by installing wireless access points at several selected buildings and by enforcing a rule that all incoming engineering undergraduates have laptops with wireless capability. Similar phenomenon can be observed across the country at different organizations. Within engineering, computer, and information science disciplines, communication technology recently has advanced at an unparalleled speed. In particular, combinations of wireless communication and computer technologies have revolutionized the world of telecommunications. To explore and utilize this new technology, universities need to offer new courses and train students in the field so that they can continue their graduate work in this area. However, students in computer science and engineering (CSE) and electrical engineering (EE) are, at best, exposed to data communication, while wireless communication systems remain untouched; it is difficult to learn about wireless technology without having a substantial background in communications technology. On the other hand, EE students learn about radio frequency (RF) communication only; data communication and computing system issues and their correlation in nomadic, seamless computing remain untouched.

Although there are many books related to wireless and mobile communications, these books can be classified into two groups. The first group focuses on readers in the RF communication field, and the second covers only the general knowledge of data communication and is designed for sales agents and managers. The books in the first group require a detailed background in RF communication and signal processing and, therefore, are not suitable for students in CSE. Many recent texts emphasize microwave radar and sensor systems. However, books in the second group do not provide any depth in the data communication aspects of wireless technology. Many institutions do offer courses in the wireless and mobile networking area, primarily for graduate students, but then only as special topics. Most of these courses are EE types with many prerequisite EE courses. Thus, most undergraduate seniors in CSE are deprived of exposure to wireless and mobile communications. In addition, most existing books are tailored toward RF communications and antenna design aspects of the technology, making them difficult to use for CSE students.

Dharma Agrawal envisioned the need for this book when he spent all his sabbatical five years earlier with AT&T Laboratory. After joining the University of Cincinnati in the autumn of 1998, he started offering an introductory-level course in the wireless and mobile systems area to upper-level undergraduate and entering graduate students. Agrawal primarily used an old textbook, self-prepared notes, and some recent papers. Qing-An Zeng joined the University of Cincinnati in 1999 and helped organize the course. He noticed the need to develop class notes so that CSE students, with a limited communications

background, could understand the subject matter. This led to the foundation of this textbook. The designed course complements the RF communications background of EE students.

Creating such a unique instructional curriculum requires a great deal of effort. Planning such a text is a relatively difficult task because of the diverse background requirements. The limitations of most existing books and courses affects the wireless industries in the United States. Companies must train newly hired college graduates for a long time before they can get into the wireless industry. To the best of our knowledge, such an organized course has not been taught anywhere in the United States or the world. Teaching the introductory course strictly from research papers is difficult for the professor, which in turn causes students to learn the material inefficiently. Preparing systematic notes in this emerging area will enhance student training, increase the availability of well-educated personnel, shorten the new employee training period within industries, encourage students to do graduate work in this area, and allow nations to continue to advance the research in this technological field.

This book explains how wireless systems work, how mobility is supported, how infrastructure underlies such systems, and what interactions are needed among different functional components. It is not our intention to cover various existing wireless technologies, the chronological history behind their development, or the work being carried out, but to make EE and CSE students understand how a cell phone starts working as soon as you get out of an airplane. We have selected chapter topics that focus on qualitative descriptions and realistic explanations of relationships between wireless systems and performance parameters. The chapters are organized as follows:

Chapter 1: Introduction
Chapter 2: Probability, Statistics, and Traffic Theories
Chapter 3: Mobile Radio Propagation
Chapter 4: Channel Coding
Chapter 5: The Cellular Concept
Chapter 6: Multiple Radio Access
Chapter 7: Multiple Division Techniques
Chapter 8: Channel Allocation
Chapter 9: Mobile Communication Systems
Chapter 10: Existing Wireless Systems
Chapter 11: Satellite Systems
Chapter 12: Network Protocols
Chapter 13: Ad Hoc and Sensor Networks
Chapter 14: Wireless LANs and PANs
Chapter 15: Recent Advances

Mathematical formulations are needed in engineering and computer science work, and we include some of the important concepts so that students can appreciate their usefulness in numerous wireless and mobile systems. In all these applications, both security and privacy issues are important. Both ad hoc and

sensor networks are finding increased use in military and commercial applications, so detailed discussions are included. The introduction of the Bluetooth standard allows easy replacement of connector cables with wireless devices and is discussed in detail. Recent advances are covered in the last chapter, with emphasis on the research work being carried out in the wireless and mobile computing area, even though a comprehensive discussion is beyond the scope of this book. In the questions at the end of each chapter, special effort has been made to explore potential uses of the various technologies. Depending on availability of time (especially for undergraduates), students should be encouraged to use one of the simulators (ns, OPNET, or other stable simulators) to get a feel for overall system complexity. A list of possible group simulation projects is included as an Appendix B. The authors have tried such projects for several years and have found them highly effective in training students. Many undergraduates have also used them as their follow-up, year-long capstone design project.

This book is written both for academic institutions and for working professionals. It can be used as a textbook for a one-semester or a one-quarter course. The book also can be used for training current or new employees and could be adopted for short-term training courses. The chapters are organized to provide a great deal of flexibility; emphasis can be given to different chapters, depending on the scope of the course and the instructor's own interests or emphasis. The following are some suggestions for undergraduate students:

- For a one-quarter system, Chapter 15 can be skipped and the project could be optional for extra credit. Chapters 2, 10, 11, 13, and 14 can be covered in brief. Chapter 7 on modulation techniques could be skipped, as well.

- For a one-semester system, Chapter 15 can be skipped. Chapters 2 and 10 can be covered briefly, or Chapter 2 could be used for self-study and a simplified version of the project could be assigned.

In this textbook, we have tried to provide an overview of the basic principles behind wireless technology and its associated support infrastructure. We hope that we have been able to achieve our goal of helping students and others working in this area to have a basic knowledge about this exciting technology. Our efforts will not go to waste if we are able to accomplish this to some extent.

Dharma Prakash Agrawal
Qing-An Zeng
Cincinnati

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The authors welcome any comments and suggestions for improvements or changes that could be incorporated in forthcoming editions of this book. Please contact them at <dpa@ececs.uc.edu> and <qzeng@ececs.uc.edu>.

Dharma Prakash Agrawal
Qing-An Zeng
Cincinnati

Credits

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Figure 9.3 (p. 186) and Table 9.1 (p. 187): From "Beacon Signals: What, Why, How, and Where," by S. Gerasenko, A. A. Joshi, S. Rayaprolu, K. Ponnavaikko, and D. P. Agrawal, 2001. *IEEE Computer, 34,* pp. 108–110. Copyright ©2001 IEEE. Reprinted with permission.

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In memory of my parents, Shri Saryoo Prasad Agrawal and Shrimati Chandrakanta Bai Agrawal, who raised me affectionately and made me learn how to excel from a small unknown village.

—— Dharma Prakash Agrawal

To my wife, Min, and to our children, Yao and Andrew.

—— Qing-An Zeng

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