Contents

Preface 8

Chapter 1: Wireless Telecommunications Systems and Networks **11**
1.1 The History and Evolution of Wireless Radio Systems *12*
1.2 The Development of Modern Telecommunications Infrastructure *16*
1.3 Overview of Existing Network Infrastructure *24*
1.4 Review of the Seven-Layer OSI Model *25*
1.5 Wireless Network Applications: Wireless Markets *31*
1.6 Future Wireless Networks *33*
Questions and Problems *33*

Chapter 2: Evolution and Deployment of Cellular Telephone Systems **34**
2.1 Different Generations of Wireless Cellular Networks *35*
2.2 1G Cellular Systems *37*
2.3 2G Cellular Systems *50*
2.4 2.5G Cellular Systems *53*
2.5 3G Cellular Systems *54*
2.6 4G Cellular Systems and Beyond *59*
2.7 Wireless Standards Organizations *60*
Questions and Problems *61*

Chapter 3: Common Cellular System Components **63**
3.1 Common Cellular Network Components *64*
3.2 Hardware and Software Views of the Cellular Network *76*
3.3 3G Cellular System Components *78*
3.4 Cellular Component Identification *78*
3.5 Call Establishment *83*
Questions and Problems *87*

Chapter 4: Wireless Network Architecture and Operation **88**
4.1 The Cellular Concept *89*
4.2 Cell Fundamentals *90*

4.3 Capacity Expansion Techniques *95*
4.4 Cellular Backhaul Networks *103*
4.5 Mobility Management *105*
4.6 Radio Resources and Power Management *112*
4.7 Wireless Network Security *114*
Questions and Problems 115

Chapter 5: GSM and TDMA Technology **116**
Part I GSM System Overview 117
5.1 Introduction to GSM and TDMA *117*
5.2 GSM Network and System Architecture *120*
5.3 GSM Channel Concept *126*
Part II GSM System Operations 137
5.4 GSM Identities *137*
5.5 GSM System Operations (Traffic Cases) *138*
5.6 GSM Infrastructure Communications (Um Interface) *157*
Part III Other TDMA Systems 165
5.7 North American TDMA *165*
Questions and Problems 170

Chapter 6: CDMA Technology **171**
Part I CDMA System Overview 172
6.1 Introduction to CDMA *172*
6.2 CDMA Network and System Architecture *177*
Part II CDMA Basics 186
6.3 CDMA Channel Concept *186*
6.4 CDMA System (Layer 3) Operations *198*
Part III 3G CDMA 211
6.5 IS-95B, cdma2000, and W-CDMA *211*
Questions and Problems 218

Chapter 7: Cellular Wireless Data Networks—2.5 and 3G Systems **219**
7.1 Introduction to Mobile Wireless Data Networks *220*
7.2 CDPD, GPRS, and EDGE Data Networks *221*
7.3 CDMA Data Networks *233*
7.4 Evolution of GSM and NA-TDMA to 3G *235*
7.5 Evolution of CDMA to 3G *238*
7.6 SMS, EMS, MMS, and MIM Services *242*
Questions and Problems 244

Chapter 8: Wireless Modulation Techniques and Hardware **246**
8.1 Transmission Characteristics of Wireline and Fiber Systems *247*
8.2 Characteristics of the Air Interface *248*
8.3 Wireless Telecommunications Coding Techniques *255*
8.4 Digital Modulation Techniques *260*
8.5 Spread Spectrum Modulation Techniques *264*
8.6 Ultra-wideband Radio Technology *266*
8.7 Diversity Techniques *266*
8.8 Typical GSM System Hardware *269*
8.9 Typical CDMA System Hardware *277*
8.10 Subscriber Devices *279*
Questions and Problems 281

Chapter 9: Wireless LANs/IEEE 802.11x **283**
9.1 Introduction to IEEE 802.11x Technologies *284*
9.2 Evolution of Wireless LANs *284*
9.3 IEEE 802.11 Design Issues *287*
9.4 IEEE 802.11 Services—Layer 2: Overview *291*
9.5 IEEE 802.11 MAC Layer Operations *295*
9.6 IEEE 802.11 Layer 1: Details *301*
9.7 IEEE 802.11a/b/g—Higher Rate Standards *307*
9.8 IEEE 802.11i—Wireless LAN Security *314*
9.9 Competing Wireless Technologies *318*
9.10 Typical WLAN Hardware *319*
Questions and Problems *322*

Chapter 10: Wireless PANs/IEEE 802.15x **323**
10.1 Introduction to IEEE 802.15x Technologies *324*
10.2 Wireless PAN Applications and Architecture *325*
10.3 IEEE 802.15.1 Physical Layer Details *332*
10.4 Bluetooth Link Controller Basics *333*
10.5 Bluetooth Link Controller Operational States *341*
10.6 IEEE 802.15.1 Protocols and Host Control Interface *346*
10.7 Evolution of IEEE 802.15 Standards *350*
Questions and Problems *357*

Chapter 11: Broadband Wireless MANs/IEEE 802.16x **359**
11.1 Introduction to WMAN/IEEE 802.16x Technologies *359*
11.2 IEEE 802.16 Wireless MANs *362*
11.3 IEEE 802.16 MAC Layer Details *364*
11.4 IEEE 802.16 Physical Layer Details *368*
11.5 IEEE 802.16a Physical Layer Details for 2–11 GHz *375*
11.6 IEEE 802.16 Common System Operations *390*
Questions and Problems *395*

Chapter 12: Broadband Satellite and Microwave Systems **396**
12.1 Introduction to Broadband Satellite and Microwave Systems *396*
12.2 Line-of-Sight Propagation *399*
12.3 Fundamentals of Satellite Systems *402*
12.4 Broadband Satellite Networks *408*
12.5 Broadband Microwave and Millimeter Wave Systems *416*
Questions and Problems *418*

Chapter 13: Emerging Wireless Technologies **420**
13.1 Introduction to Emerging Wireless Technologies *420*
13.2 New and Emerging Air Interface Technologies *422*
13.3 New Wireless Network Implementations *428*
13.4 IEEE 802.20/Mobile Broadband Wireless Access *433*
13.5 Satellite Ventures and Other Future Possibilities *434*
Questions and Problems *435*

Index *436*

Preface to Indian Edition

AUDIENCE

Today, the telecommunications industry continues to implement new technologies in an effort to provide high-bandwidth, high-speed data transmission capabilities to the consumer. In the end, a combination of sophisticated wireline, fiber-optic, and wireless technologies will most likely be deployed by this industry to satisfy consumer demand. The technology of choice for a particular situation will be dictated by both economic considerations and marketplace preferences. ***Introduction to Wireless Telecommunications Systems and Networks*** provides a comprehensive, broad-based coverage of the fundamental aspects of the most popular forms of wireless telecommunications systems and the emerging wireless technologies used to extend the reach of the wired public or private data network.

This text is written primarily for either the two- or four-year college-level student who is studying the technical aspects of wireless systems and networks. The text can also be used to help readers gain a deeper understanding about the fundamental operations of wireless technologies used by professionals and technicians involved in a technical-support segment of this field. Readers will also gain knowledge about other popular technologies in this and the next generation of wireless telecommunications systems and networks. Lastly, the text serves as a good reference for those who simply need to know more about the fundamentals of present-day wireless telecommunications systems.

APPROACH

Introduction to Wireless Telecommunications Systems and Networks will provide the reader with a detailed look at two basic wireless industry segments: the wireless cellular industry and the industries that produce products that provide wireless extensions to wired IEEE 802.x data networks and wireless connectivity to the Internet. Coverage includes GSM and CDMA cellular systems, 3G cellular, and IEEE standards-based wireless LANs, PANs, and MANs. Additionally, a chapter is included that addresses the relatively poor transmission quality of the air interface and the techniques used to overcome this shortcoming, a chapter on broadband satellite and microwave systems, and another chapter that takes a look at emerging wireless air interface and network technologies that will be incorporated into the next generations of wireless systems.

This text is unique in that it provides coverage of both major cellular wireless technologies (GSM and CDMA), provides the reader with a clearly defined path for the migration from these technologies to 3G cellular, addresses the technical aspects of the air interface and the special technologies used to achieve high data rates and combat bit errors, and lastly, provides a comprehensive coverage of all three IEEE 802.xx wireless network technologies and includes information about mobile satellite technology.

Writing a text that covers all of these topics provides an opportunity to point out similarities between systems and to contrast systems where appropriate. The broad coverage of wireless topics will provide the reader with the comprehensive overview needed to see the big picture of where various wireless technologies and systems are applicable or not. It is also this author's opinion that in the long term these major wireless industry segments will eventually morph into one industry that offers ubiquitous high-speed wireless network access.

ORGANIZATION

There are two major technology areas that are covered in this book. The first seven chapters deal with the rapidly expanding cellular wireless industry. Coverage includes an introduction and review of modern telecommunications infrastructure, a short history and review of wireless communications, the evolution of the cellular telephone system, an introduction to common cellular network components, the cellular concept, GSM and CDMA wireless cellular systems, and coverage of cellular wireless data networks. With cellular wireless systems now covered, Chapter 8 takes a step back and examines the wireless channel or so-called 'air interface'. The effect that a relatively poor-quality channel has on wireless system hardware and the steps needed to provide high-quality radio links are examined. New digital modulation techniques and other esoteric encoding methods used to mitigate detrimental wireless propagation effects are presented in this chapter and also set the stage for the newer wireless systems introduced in the next four chapters that make use of these new technologies. To wrap up the topic of cellular wireless, typical GSM and CDMA system hardware is presented as the last topic in this chapter.

The next three chapters deal with the rapidly evolving IEEE standardized wireless extensions to LANs, PANs, and MANs. IEEE 802.11, 802.15, and 802.16 are each covered in their own chapter with varying levels of detail. The last two topics are so new that only a limited number of products have been introduced into the marketplace. However, it is this author's contention that these technologies will each play an increasingly larger role in the future of wireless data access and transfer. For the sake of completeness, Chapter 12 provides an overview of yet another impending wireless technology: broadband satellite systems. Finally, the last chapter provides a brief glimpse into the emerging technologies that will shape the wireless systems and networks of the future.

FEATURES

1. The text is written from a systems perspective with very few detailed system block diagrams.
2. The mathematics used in the text is limited to algebra, the use of dBs, and various exponentials making this text suitable for use at the two-year college level. The topic coverage has been chosen to provide the reader with the necessary fundamental concepts and theories needed to understand the operation of cellular wireless systems, broadband satellite technology, and the IEEE standards-based wireless LANs, PANs, and MANs extension technologies.
3. This text is almost totally devoid of any detailed circuit diagrams. Almost all the topics that are presented in this text are basic fundamental wireless system and network concepts and therefore they transcend the changing technology that may be used to implement them over the course of time. Today, one must deal with these systems from a block diagram point of view—the same approach

taken by this work. It is the author's belief and observation that the field and support technician of today and the future will be primarily tasked with the evaluation of system operation and the possible reconfiguration of programmable hardware/ system functions more often than the repair of this hardware. This text was written with this is mind.

4. In summation, the style of presentation used in this text closely resembles how the author presents and demonstrates this material in a classroom setting—at a systems level. It is the author's belief that this text will be helpful to the student that desires to learn about the basic operation of the wireless networks and systems presented here.

ACKNOWLEDGEMENTS

The Author and Cengage Delmar Learning would like to thank the following reviewers:

Herm Braun, DeVry University, Denver, CO

Shakti Chatterjee, DeVry University, Columbus, OH

Felton Flood, DeVry University, Arlington, VA

Mohammad Jalali, DeVry University, Long Beach, CA

ABOUT THE AUTHOR

Gary Mullett is a longtime faculty member at Springfield Technical Community College in Springfield, Massachusetts. For the past decade he has been actively involved in the field of telecommunications as a consultant and codirector of the National Science Foundation, Advanced Technology Education, National Center for Telecommunications Technologies located at Springfield Technical Community College. A principal figure in the implementation of the pace-setting Verizon NextStep Program, he has spent many years as a consultant to local industry. Additionally, the author has spent over thirty years teaching students about his favorite subjects—fundamental and advanced wireless communications topics.

Wireless technology has been a special passion of this author since he was a small child and used to spend time listening to the family's vacuum tube, short-wave receiver. This passion translated into several engineering degrees in microwave and radar technology and years of working and teaching in this field. The author can only hope that his passion for this subject matter shows through to the readers of this text and translates into an informative and easily understandable work.