



mobile communications series

Byeong Gi Lee
Sunghyun Choi

**BROADBAND
WIRELESS
ACCESS AND
LOCAL
NETWORKS:**

MOBILE

WiMAX

**AND
WiFi**



30806030

Broadband Wireless Access and Local Networks

Mobile WiMAX and WiFi

Byeong Gi Lee
Sunghyun Choi



**ARTECH
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BOSTON | LONDON
artechhouse.com

Library of Congress Cataloging-in-Publication Data

A catalog record for this book is available from the U.S. Library of Congress.

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library.

ISBN-13: 978-1-59693-293-7

Cover design by Yekaterina Ratner

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685 Canton Street

Norwood, MA 02062

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To our wives
Hyeon Soon Kang and Yoonjung Ryu

Preface

The recent trend of the convergence and diversification of data services and the growth of data traffic is truly phenomenal. The convergence of various different types of services (e.g., of voice, data, and video services), the convergence of conversational bidirectional services with distributive unidirectional services, the convergence of narrowband and broadband services, and the convergence of wireline and wireless services is now an established trend that is augmented by the convergence of user terminals. The growth of data traffic is exponential with the deep penetration of mobile wireless services, the popularization of music, video, and other forms of downloading and exchange, and the convergence of communications, entertainment, broadcasting, and financial services. The diversification of services has been driving a paradigm shift in communication services today toward *user-created content* (UCC). This grand trend has made the concept of *prosumers* (producers + consumers) a reality in the communication world and has brought other new terminologies into use as well, such as *motizens* (mobile citizens), *cyberlations* (cyber relations), and *digital natives*. In response, the Web has evolved to Web 2.0, with an increasing movement from Internet portal services to mobile Internet services.

Underlying the grand trend, and functioning as the enabler of the convergence, growth, and diversification of data services, is the *Internet protocol* (IP), which is a packet-mode technology designed to support the processing and transport of data in packets among different types of communication networks. Convergence of a diverse set of data services, for which circuit-mode technologies tried to offer a platform of service integration in the past, can now find a flexible and dependable platform in IP-based protocol stacks. The rapid growth of data services relies on the widely accepted means of processing and transport supported by IP-oriented technologies. The diversification of data services is also supported by IP technology with most emerging data services built upon IP.

The environment for data services now and in the near future is the Internet, or more generally, the networks using the IP. Originally developed for data communication among computers and terminals, IP has become a foundation of networking for all services in its short history of existence (only four decades). The key to today's success of IP technology is the omnipresence of Internet devices and IP's robust capability for realizing interoperability among many networks. The abundance of software that operates on top of IP is another strength of the IP technology. The secret behind the wide acceptance of IP was the simplicity of the IP. It was designed to support intermittent data communications among computers and terminals, based on *best effort* routing of packets in a variety of physical configurations, including bus, ring, and mesh. This simple protocol was generally considered

not sophisticated enough to support real-time services. It targeted academic research networks, supporting the limited world of computer professionals. Even after opening to the commercial world, IP for a long time covered only the data portion of the business world, as the simple skeleton of IP had to be augmented with many other protocols to accommodate the real-time multimedia part of the commercial world.

IP-based networking, with its (originally) modest goal and simple architecture, has spread to encompass the last meters of every computer network. IETF *requests for proposals* (RFPs), together with IEEE 802 PHY/MAC standards, contributed significantly to the wide penetration of IP to the customer end, strengthening reliability and capacity and reducing costs. IEEE 802.3 Ethernet, as the name predicted, has become an ether-like network, existing everywhere computers meet users. Its predominance in the local area was followed by IEEE 802.11 WiFi when the wireless technology became practical for end-user services. Over two decades, *carrier-sense multiple access with collision avoidance* (CSMA/CA)-based *wireless local area network* (LAN) technology has frequently replaced *CSMA with collision detection* (CSMA/CD)-based wireline LANs, establishing a truly ether-like presence in the air. Today laptop computers, *personal data assistants* (PDAs), and other user-carried devices are mostly equipped with the WiFi capability from the manufacturing stage. For personal area networks, Bluetooth is often the choice because of its very low power and cost.

On the other side of the communication world, there still exists circuit-mode communication technology with the star-topology network architecture. It was born with the invention of the telephone. Over 125 years, the telephone network has spread all over the world, covering all inhabited areas down to almost every residence. Throughout this long period of development and deployment, the copper-based telephone network became omnipresent but, in contrast, the service concentrated mainly on voice. Technology was developed with the spread of the telephone network, but the technology development was focused more on providing high-quality voice services by expanding the transmission distance, increasing the transmission capacity, and accelerating the switching speed, than on developing new protocols and architecture to accommodate new types of service. As a consequence, the central offices in the telephone network were filled with intelligent transmission, switching, and signaling devices, but the subscriber's telephone set has been providing the same function for more than 100 years. The main reason for this voice-centric development was probably the lack of visible demand for data services during that long development period of telephone networks. Even after data services began to grow, telephone service providers were not successful in migrating into the data service market for various reasons. The long tradition of voice-centric telephone service made it difficult to admit the importance and the potential growth of data services. The circuit-switched telephone network, with dumb end-user devices and central operation, was not well suited to effectively accommodate data services. The growth of data services was not fast enough to justify big investments for renovating the huge established telephone network and installing new data-centric equipment. Lacking a competitive option in the switched services of the telephone network, new IP-based networks (using, however, physical lines provided by the telephone carriers) were readily established and widely accepted among end data users.

Throughout the long development period of the telephone network and the comparatively short development period of computer networks, the two were living in quite different worlds, though the computer networks such as ARPANet used the leased lines of the telephone network for wide area networking. The circuit-based telco network served the large commercial voice market using telephone, and the packet-based research networks served the small computer-communication community with noncommercial operation. They maintained these totally different identities until data services began to indicate some potential growth in the 1980s and the Internet was opened to the commercial world in the 1990s. Around that time, there appeared the first attempt to combine circuit-based voice services with packet-based data services, based on circuit-mode technology. It was the first encounter of the two different worlds, which was made in the context of wireline networks. The second encounter came later in the arena of wireless networks with an effort to harmonize circuit-mode and packet-mode wireless services based on packet-mode (or IP) technology.

It was the *International Telecommunication Union* (ITU) CCITT, later renamed ITU-T, that initiated the first encounter. It standardized the *integrated services digital network* (ISDN) with the goal of integrating voice and data services on a circuit-based platform, and it advanced digitization, which had been successfully completed in the core network, down to the access network by digitizing subscriber lines. This visionary project, started at the turn of the 1980s, was followed by the standardization of the *broadband ISDN* (BISDN), which progressed in harmony with the standardization of optical transmission in the *synchronous optical network* (SONET) and the *synchronous digital hierarchy* (SDH). BISDN introduced a new technology for integrating voice, data, and other broadband services in the *asynchronous transfer mode* (ATM), which gracefully combines circuit switching with the packet format. Moreover, it supports distribution services in addition to conversational services, and real-time services in addition to nonreal-time services. As a services integration strategy, ATM was ideal in theory but less successful in reality because of its relative complexity and high overhead cost. Moreover, the deployment of broadband optical networks was not done in a timely manner. The promotion of ATM technology in the 1990s, ironically, aroused a strong reaction in the Internet world, stimulating it to strengthen the competitiveness of the Internet. It is worth noting that the ATM concept lives on in IP networks in the form of *multiprotocol label switching* (MPLS).

The second encounter between circuit-mode and packet-mode networks began recently in wireless communications, encouraged by the booming success of mobile wireless businesses. The circuit-mode wireline telephone network was succeeded by cellular mobile communications in two major streams—the GSM/WCDMA family harmonized in the *Third Generation Partnership Project* (3GPP) and the IS-95/cdma2000 family harmonized in 3GPP2. Both were rooted in circuit switching, with packet-mode hybridization introduced in the course of evolution. The competing streams penetrated wide area networks within most countries and expanded coverage through international roaming services. They were very successful in providing voice services and began to provide high-quality data services to mobile users with comparatively low data rates and comparatively high service charges.

At the same time, the packet-mode Ethernet LAN was followed by the WiFi WLAN, using CSMA/CA instead of CSMA/CD. It has been very successful in providing data device users with the last 50-m access service into a wired LAN. It provides very high data rates to *hot spot* users at very low cost, but service quality is often unpredictable, and both mobility support and coverage are limited. The harmonization of those wireless extensions of the telephone and computer networks, constituting a second encounter of those communication worlds, is taking several paths, one of which is the handoff of multimode devices between cellular mobile and WLAN networks and a second, more intense path is the development of Mobile WiMAX networks. Whereas the first attempt of integration was made by the ITU, this second attempt was made by the IEEE, specifically the IEEE 802.16e standard working group. In contrast to the first attempt that adopted circuit-mode and then ATM technology, which is midway between circuit and packet modes, this second attempt employs IP-packet technology as the common vehicle for harmonization. Mobile WiMAX was designed on an IP foundation, maintaining the spirit of support for an IP network level seen in all IEEE 802 standards, thereby realizing efficient deployment of all types of data services. For effective provision of real-time multimedia services, it adopted a connection-oriented approach, not the connectionless approach of WiFi. It was designed to be capable of providing high-rate, high-quality data services to mobile users in medium to wide areas at very reasonable service charges.

Mobile WiMAX is very new, with the first IEEE 802.16e standard published in 2006 and the first system development and commercial service launched in 2007 in Korea. Commitments to Mobile WiMAX service are being made in a large number of countries, and allocations of frequency spectrum for Mobile WiMAX services have been announced in many countries. Furthermore, Mobile WiMAX has been accepted as a viable technology for the *fourth generation* (4G) mobile communications and was recently adopted as an IMT-2000 standard by ITU-R. Mobile WiMAX is now a reality. It incorporates many strong technologies, such as *orthogonal frequency division multiple access* (OFDMA), *time-division duplexing* (TDD), *multi-input multi-output* (MIMO), *adaptive modulation and coding* (AMC), IP, and security features, that can be combined to produce high spectral efficiency and resilient channels, resulting in high-rate, low-cost, wide-area, mobile multimedia services. Singling out OFDMA, Mobile WiMAX is the first mobile wireless specification to adopt this technology. Everything is ready to realize the second encounter of the descendants of the traditional communication and computer worlds. It is the investment made by network operators that will dictate the success of this second attempt for a harmonious services integration.

This book introduces the network technologies adopted by Mobile WiMAX for the implementation of IP-based broadband mobile wireless access and the WiFi technologies that have steadily evolved for the past 10 years, establishing a firm foundation for IP-based wireless local network access. These access and local technologies have many things in common, most prominently that both are oriented toward IP traffic and standardized by IEEE 802 working groups. The book is organized in two parts separately addressing Mobile WiMAX and WiFi, plus a preliminary chapter to provide a common ground of discussions for the two network technologies.

For the Mobile WiMAX part, we collected the most recent experience and knowledge of the design and field engineers, especially from Samsung Electronics and the Korea Telecom (KT) Corporation, who have been involved in the first development and deployment of Mobile WiMAX systems in Korea (with the nickname of “WiBro,” an abbreviation for *wireless broadband*). The WiFi part is based on the extensive experience of one of the authors in IEEE 802.11 standards and on industry collaboration among Philips Electronics as a chip vendor, Samsung Electronics as a chip/system vendor, and KT as a service provider. The authors believe that understanding these two IP-oriented wireless network technologies will help readers deepen their insight into today’s wireless networks and enhance their competence and competitiveness in the design of future wireless networks.

Acknowledgments

This book was made possible thanks to the contributions of many colleagues in industry and academia who accumulated the most up-to-date and practical knowledge of Mobile WiMAX and WiFi networks through direct involvement in standardization, system development, and network deployment. In the particular case of Mobile WiMAX, we gratefully acknowledge the contributions and assistance of standards, design, and field engineers in Samsung Electronics, KT (Korea Telecom), and other companies.

First, we would like to thank those colleagues who contributed by writing some chapters or sections: Hyunpo Kim at KT (Chapters 1 and 10); Hyeonwoo Lee (Chapter 2), Euseok Hwang (Chapter 2), Hokyu Choi (Chapter 2), Dae Woo Lee (Chapter 2), Han-Seok Kim (Chapters 3 and 6), Jae Hwan Chang (Chapter 3), Seungjoo Maeng (Chapter 4), Myung-Kwang Byun (Chapter 4), Yonwoo Yoon (Chapter 4), Jaehee Cho (Chapter 4), Jinhan Song (Chapters 5 and 7), Inseok Hwang (Chapter 9), Eun Yong Kim (Chapter 9), and Jaekon Lee (Chapter 10), all at Samsung Electronics; Woojune Kim at Airvana (Chapter 3); Chung Gu Kang at Korea University (Chapters 5, 6, and 7); Pil Joong Lee at Pohang University of Science and Technology (POSTECH) (Chapter 8); and Hanbyul Seo (Chapters 2 and 7) and Hoojoong Kwon (Chapter 8 and 9) both at Seoul National University (SNU). We are especially indebted to those who dedicated a great deal of time and effort: Inseok Hwang, Chung Gu Kang, Han-Seok Kim, Woojune Kim, Seungjoo Maeng, and Jinhan Song.

We also thank the reviewers who helped improve the contents: Hyunpo Kim at KT (Chapters 1 and 10), Soon Young Yoon at Samsung Electronics (Chapters 1, 2, and 3), Chung Gu Kang at Korea University (Chapter 2), Dong Ho Cho at Korea Advanced Institute of Science and Technology (KAIST) (Chapters 3, 5, 6, and 7), Yong Hoon Lee at KAIST (Chapter 4), Jae Hyeong Kim at Posdata (Chapters 4, 9, and 10), Jae Hwan Chang at Samsung Electronics (Chapter 5), Saewoong Bahk at SNU (Chapters 5, 6, and 7), Dan Keun Sung at KAIST (Chapters 6, 7, 9, and 10), Seung Woo Seo at SNU (Chapter 8), Kwang Bok Lee at SNU (Chapter 9), Sunggeun Jin at SNU (Chapter 16), Youngsoo Kim at SNU (Chapter 18), Seongkwan Kim at SNU (Chapters 11, 16, and 18), Jeonggyun Yu at SNU (Chapters 11 and 14), Youngkyu Choi at SNU (Chapters 12 and 18), Hyewon Lee at SNU (Chapters 13 and 17), and Munhwan Choi at SNU (Chapters 13 and 15).

We are grateful to those who provided a comfortable environment and high-quality facilities to author the book: Seoul National University and the Research Institute of New Media and Communications at SNU. Byeong Gi Lee would like to thank Samsung Electronics, which offered an office for a year, and

two Buddhist temples, Cheon Kwan Sa and Ssang Bong Sa, which offered quiet rooms for stays of several weeks.

We would like to thank those who encouraged and supported the writing of this book in various ways: Ki Tae Lee, vice chairman; Woon Seob Kim, executive vice president; Young Ky Kim, executive vice president; Sei Jei Cho, senior vice president; and Soon Young Yoon, senior manager, of Samsung Electronics. Byeong Gi Lee would like to give special thanks to Ki Tae Lee, who arranged accommodations at Samsung Electronics during a sabbatical leave and supported the project in every aspect.

We would like to thank our graduate students at SNU for supporting the writing of this book by drawing figures, correcting typos, and doing other miscellaneous work: Seo Shin Kwak, Soo Min Koh, Joon Ho Lim, Seon Wook Kim, and Seung Han Ryu in the Telecommunications and Signal Processing (TSP) Laboratory and Okhwan Lee, Youngwoo Hwang, Minsoo Na, Heeyoung Lee, Changyeon Yeo, and Seungmin Woo in the Multimedia and Wireless Networking Laboratory (MWNL). Byeong Gi Lee would like to thank Kyung Hee Choi at Samsung Electronics for help in drawing the figures and Hojoong Kwon at the TSP Laboratory for helping out all miscellaneous works throughout the authoring process. Sunghyun Choi would like to thank both Seongkwan Kim and Dongmyoung Kim at the MWNL for taking care of all miscellaneous works.

Last, but not least, we deeply thank our wives, Hyeon Soon Kang and Yoonjung Ryu, whose love and support enabled us to accomplish this heavy authoring task while conducting our regular jobs at school and performing other work in the community.

Contents

Preface	xvii
Acknowledgments	xxiii
CHAPTER 1	
Preliminaries	1
1.1 Wireless Communication Channel Characteristics	2
1.1.1 Channel Gain	2
1.1.2 Fading	3
1.1.3 Channel Reinforcing Techniques	8
1.2 Frequency Spectrum for Wireless Communications	11
1.2.1 Frequency Spectrum for WiMAX	12
1.2.2 Frequency Spectrum for WiFi	16
1.3 Standardization History	20
1.3.1 IEEE 802.16/WiMAX Standardization	20
1.3.2 IEEE 802.11/WiFi Standardization	23
1.4 Mobile WiMAX Versus WiFi	30
1.4.1 Mobile WiMAX: Broadband Wireless Access Networks	30
1.4.2 WiFi: Wireless Local Area Networks	34
1.4.3 Similarities and Differences	39
References	40
Selected Bibliography	42
PART I	
Mobile WiMAX: Broadband Wireless Access Network	43
CHAPTER 2	
Introduction to Mobile WiMAX Networks	47
2.1 Key Network Technologies	49
2.1.1 Duplexing: TDD	50
2.1.2 Multiple Access: OFDMA	51
2.1.3 Coding and Modulation	53
2.1.4 Multiple Antennas	56
2.1.5 Bandwidth Management	58
2.1.6 Retransmission: HARQ	59
2.1.7 Mobility Management	60
2.1.8 Security Management	62
2.2 Protocol Layering	63

2.2.1	Service-Specific Convergence Sublayer	64
2.2.2	MAC Common Part Sublayer	65
2.2.3	Security Sublayer	66
2.2.4	Physical Layer	66
2.3	Network Architecture	68
2.3.1	Network Reference Model	68
2.3.2	Functional Entities	69
2.3.3	Reference Points	71
2.4	Mobile WiMAX Versus Cellular Mobile Networks	72
2.4.1	Evolution of Cellular Mobile Networks	72
2.4.2	Comparison of Mobile WiMAX and Cellular Mobile Networks	75
2.4.3	Mobile WiMAX to Cellular Mobile Network Interworking	78
	References	82
	Selected Bibliography	83

CHAPTER 3

	Network Initialization and Maintenance	85
3.1	Network Discovery	87
3.1.1	Scanning	88
3.1.2	Synchronization	88
3.1.3	Parameter Acquisition	88
3.2	Network Initialization	89
3.2.1	Initial Ranging	91
3.2.2	Basic Capabilities Negotiation	94
3.2.3	Authorization and Key Exchange	94
3.2.4	Registration	95
3.2.5	Establishing Connections	96
3.3	Connection Setup	96
3.3.1	Basic Connection Setup	96
3.3.2	QoS and Bandwidth Allocation	97
3.4	Nonconnected State	99
3.4.1	Sleep Mode	99
3.4.2	Idle Mode	100
3.5	Paging	100
3.6	Mobility	101
3.6.1	Nonconnected-State Mobility	102
3.6.2	Connected-State Mobility—Handover	102
3.7	Maintenance	103
3.7.1	Synchronization	104
3.7.2	Periodic Ranging	104
3.7.3	Power Control	105
	References	106
	Selected Bibliography	106

CHAPTER 4

	OFDMA PHY Framework	107
4.1	OFDMA Communication Signal Processing	107

4.1.1	Encoding and Modulation	108
4.1.2	Subcarrier Mapping and Transform	111
4.1.3	Transmit Processing	118
4.1.4	OFDMA System Parameters	122
4.2	Channel Coding and HARQ	124
4.2.1	Convolutional Code	124
4.2.2	Convolutional Turbo Code (CTC)	128
4.2.3	Hybrid ARQ	136
4.3	OFDMA Frame Structuring	139
4.3.1	OFDMA Slots and Bursts	139
4.3.2	OFDMA Frame	141
4.3.3	FCH and DL/UL MAPs	144
4.3.4	Burst Profiles	152
4.4	Subchannelization	156
4.4.1	DL PUSC	158
4.4.2	DL FUSC	160
4.4.3	UL PUSC	163
4.4.4	DL/UL AMC	165
	References	169
	Selected Bibliography	169

CHAPTER 5

MAC Framework	171
5.1 MAC Service-Specific Convergence Sublayer	171
5.1.1 Classification Functions	172
5.1.2 MAC SDU and CS PDU Formats	173
5.1.3 PHS Functions	175
5.2 MAC Common Part Sublayer	176
5.2.1 MAC CPS Functions	177
5.2.2 Addressing and Connections	179
5.2.3 MAC Management Messages	180
5.2.4 MAC PDU Formats	183
5.2.5 Construction and Transmission of MAC PDU	187
5.3 ARQ	188
5.3.1 ARQ Block Processing	188
5.3.2 ARQ Feedback	191
5.3.3 ARQ Operation	193
Reference	195
Selected Bibliography	195

CHAPTER 6

Bandwidth Management and QoS	197
6.1 Scheduling and Data Delivery Services	197
6.1.1 Scheduling Services	198
6.1.2 Data Delivery Services	202
6.2 Bandwidth Request and Allocation	203
6.2.1 Requests	203

6.2.2	Grants	204
6.2.3	Polling	204
6.3	QoS	205
6.3.1	Service Flows and Classes	207
6.3.2	QoS Messages and Parameters	208
6.3.3	QoS-Related Network Elements	210
6.3.4	Service Flow Setup/Release Procedures	213
6.3.5	Scheduling, CAC, and Policing	217
	References	219
	Selected Bibliography	219

CHAPTER 7

	Mobility Support	221
7.1	Cellular Concept	221
7.1.1	Intercell Interference Management	222
7.1.2	Handover Management	227
7.2	Handover Procedure	229
7.2.1	Network Topology Acquisition	230
7.2.2	Handover Execution	230
7.2.3	Soft Handover	234
7.3	Power Saving	236
7.3.1	Sleep Mode	236
7.3.2	Idle Mode	241
	References	247
	Selected Bibliography	248

CHAPTER 8

	Security Control	249
8.1	Fundamentals of Cryptography and Information Security	249
8.1.1	Cryptography	250
8.1.2	Encrypted Communication	251
8.1.3	Ciphers and Hash Functions	251
8.1.4	Practical Cryptographic Systems	255
8.1.5	Additional Security Components	258
8.1.6	Mobile WiMAX Security Overview	259
8.2	Security System Architecture	260
8.2.1	Security Association	261
8.2.2	Encapsulation	261
8.2.3	Authentication	262
8.2.4	Key Management	263
8.3	Key Management	264
8.3.1	PKMv1	265
8.3.2	PKMv2	267
8.3.3	State Machines for Key Exchange	272
	References	278
	Selected Bibliography	278

CHAPTER 9

Multiple Antenna Technology	281
9.1 Fundamentals of Multiple Antenna Technology	281
9.1.1 Multiple Antenna Techniques	282
9.1.2 Capacity of MIMO Channels	283
9.1.3 System Models	285
9.2 Open-Loop Technology	288
9.2.1 Transmit Diversity	289
9.2.2 Spatial Multiplexing	292
9.2.3 Mobile WiMAX Examples	295
9.3 Closed-Loop Technology	299
9.3.1 Precoding	300
9.3.2 Multiuser MIMO	303
9.4 MIMO Receiver Algorithms	305
9.4.1 Maximum Likelihood Detection	305
9.4.2 Linear Detection	306
9.4.3 Near-Optimal Algorithms	308
References	311
Selected Bibliography	313

CHAPTER 10

WiBro: The First Mobile WiMAX System	315
10.1 WiBro Network Configuration	316
10.1.1 WiBro Network Architecture	316
10.1.2 ASN-GW	317
10.1.3 RAS (or BS)	318
10.1.4 CSN Servers	319
10.2 WiBro System Requirements	319
10.2.1 Requirements on Radio Access	319
10.2.2 Requirements on Networks and Services	320
10.2.3 Requirements on ACR and CSN	321
10.2.4 Requirements on RAS	322
10.3 RAS System Design	322
10.3.1 RAS Architecture	323
10.3.2 RAS Functions	325
10.4 ACR System Design	327
10.4.1 ACR Architecture	327
10.4.2 ACR Functions	328
10.5 Access Network Deployment	333
10.5.1 Access Network Planning	334
10.5.2 RNP Case Studies	336
10.5.3 Access Network Implementation and Optimization	337
10.6 Other Network Elements Deployment	338
10.6.1 Core Network Planning	339
10.6.2 Servers and Other Elements	340
10.7 WiBro Services	341
10.7.1 Service Platform	341

10.7.2	Core Application Services	342
10.7.3	Other Major Services	345
	References	346
	Selected Bibliography	346

PART II

WiFi: Wireless Local Area Networks	349
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CHAPTER 11

Introduction to WiFi Networks	353
11.1 Network Architecture	356
11.1.1 Ad Hoc Network	357
11.1.2 Infrastructure Network	358
11.1.3 Distribution System (DS) and Extended Service Set (ESS)	359
11.2 Reference Model	360
11.3 Layer Interactions	361
11.3.1 MAC Message Types	362
11.3.2 Interaction Between MAC and PHY	362
11.3.3 Interaction Between MAC and IEEE 802.2 LLC	363
11.3.4 Interaction Between MAC and IEEE 802.1D MAC Bridge	365
11.4 Key Technologies	366
11.4.1 Multiple Access, Duplexing, and MAC	368
11.4.2 Multiple Transmission Rate Support	368
11.4.3 Power-Saving Schemes	369
11.4.4 Mobility Support	369
11.4.5 Access Control and Confidentiality Support	370
11.4.6 Spectrum and Transmit Power Management	370
11.4.7 Traffic Differentiation and QoS Support	370
References	371
Selected Bibliography	372

CHAPTER 12

PHY Protocols	373
12.1 IEEE 802.11 PHY Operations	373
12.1.1 Frame Transmission	373
12.1.2 Frame Reception	374
12.1.3 CCA Operations	375
12.2 IEEE 802.11a OFDM PHY in 5 GHz	376
12.2.1 Modulation and Coding Schemes	376
12.2.2 OFDM PLCP Sublayer	377
12.2.3 Physical Medium-Dependent (PMD) Operations	382
12.2.4 Reduced-Clock Operations	387
12.3 IEEE 802.11b HR/DSSS PHY in 2.4 GHz	387
12.3.1 PLCP Sublayer	388
12.3.2 Modulation Schemes	391
12.3.3 PMD Operations	393
12.4 IEEE 802.11g ER PHY in 2.4 GHz	396