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Introduction

As everybody is undoubtedly aware, we are living in the midst of rapid information renovation and innovation. The changing world of information technology (IT) can be challenging or even frightening to all of us. For any IT engineer who stays out of the technological advancement for even a very short period of time, he/she will quickly find himself/herself an outsider to the technological transitions, with difficulty in understanding hundreds and thousands of new terminologies that are invented every year for newly emerging technologies.

In the last 30 years, the IT industries have witnessed two big waves of revolution, one being the invention of the Internet, and the other the wide applications of wireless technologies. The Internet technologies have for the first time in human history provided us with a high-speed information-dissemination infrastructure via its global optical fiber webs that cover virtually every corner of the world. If the time could be flashed back to 30 years earlier, people would have hardly believed that all the information contained in an enormous number of books in libraries can be accessed without going there personally. In addition, the readiness of two way data transactions on the Internet have triggered fundamental changes in many sectors of our life. For instance, intercontinental telephone calls will no longer be considered as a symbol of a lifestyle of luxury. Very soon everybody will be given the privilege that all voice telephone calls (either demotic or international) will be free of charge, thanks to the wide accessibility of the Internet throughout the world. The Internet operates on an all-IP based networking architecture, and thus the network level design and performance-ensuring mechanism play a critical role in all Internet-related applications. Table 1.1 shows the top 20 countries with most Internet subscribers in the world as recorded in 2005.[1]

On the other hand, the revolution of wireless technologies fuels the advancements in modern telecommunication systems through its cordless and mobile extension of wired networks, such as the Internet. Mobility is one of the most important characteristics of modern society. Everything and everyone are in motion. Therefore, the information-dispatching facilities should also be made available while people are on the move. The explosive increase in mobile cellular telephone services around the world has reflected the great demand for mobile communications. The availability of mobile cellular communications has exerted a strong influence on the lifestyle, the business models, as well as on the sense of value, distance, and time. The wireless technologies work on radio frequency (RF) to establish the data connection paths (or radio links) via electromagnetic radiation waves. The invisible RF air links connect users' end-terminals through *base stations* or *access points* with fixed or wired network infrastructures, such as the Internet. Therefore, the wireless technologies have a lot to do with the physical layer design and architecture.

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[1]It is amazing to note that China has contributed around 11% of the world's total Internet subscribers in 2005, and has become second only to the United States in terms of the percentage of the world's total Internet subscribers.

Table 1.1   Top 20 countries with most Internet subscribers in the world as recorded in 2005.

Country or region	Number of subscribers	Population in 2005	Penetration rate (%)	World percentage (%)
United States	202,888,307	296,208,476	68.5	21.6
China	103,000,000	1,282,198,289	7.9	11.0
Japan	78,050,000	128,137,485	60.9	8.3
Germany	47,127,725	82,726,188	57.0	5.0
India	39,200,000	1,094,870,677	3.6	4.2
United Kingdom	35,807,929	59,889,407	59.8	3.8
South Korea	31,600,000	49,929,293	63.3	3.4
Italy	28,610,000	58,608,565	48.8	3.0
France	25,614,899	60,619,718	42.3	2.7
Brazil	22,320,000	181,823,645	12.3	2.4
Russia	22,300,000	144,003,901	15.5	2.4
Canada	20,450,000	32,050,369	63.8	2.2
Spain	15,565,138	43,435,136	35.8	1.7
Indonesia	15,300,000	219,307,147	7.0	1.6
Mexico	14,901,687	103,872,328	14.3	1.6
Taiwan	13,800,000	22,794,795	60.5	1.5
Australia	13,784,966	20,507,264	67.2	1.5
Netherlands	10,806,328	16,316,019	66.2	1.2
Poland	10,600,000	38,133,891	27.8	1.1
Malaysia	9,513,100	26,500,699	37.9	1.1
Rest of the World	176,943,950	2,444,250,712	7.2	18.8
World total	938,710,929	6,420,102,722	14.6	100.0

The Internet in the absence of wireless technologies' support cannot offer the end users such convenience and readiness; while the wireless systems without the backup of the Internet infrastructure will limit its diversity in services and content. The combination of the Internet and wireless technologies will provide us access to information services at any time, in any place, and to any one. The combination of the Internet and wireless technologies has also created many challenging issues, such as the joint optimization of software and hardware implementations, cross-layer design for network solutions, all-IP wireless platforms, intelligent radios, and so on. Therefore, a modern wireless communication architecture can always be viewed from two different aspects: that is, the system level view, which is based mainly on the hardware and physical layer implementations on a local scale, and the network level, which is observed from the topological configuration and upper layer design on a global scale. We have observed a trend where wireless designs on the system and network levels come together. Investigations on both the system level (in a local scale) and the network level (in a global scale) helps to better understand any wireless communication entity of today.

This book was written in an effort to give the readers an up-to-date research reference containing almost all major technological advancements on both the system and the network levels that have happened in the last 20 years. The contents of this book can be divided into four major parts. We give a brief introduction for each part as follows.

1.1   Part I: Background Knowledge

The first part of this book was written by Professor Hsiao-Hwa Chen and it deals with the fundamentals and background knowledge of wireless communications. This part consists of only one chapter, that

is, Chapter 2, titled "Fundamentals of Wireless Communications," in which there are six sections altogether.

The first section introduces the theory of radio communication channels, which is part of the most important background knowledge needed to understand why and how a wireless communication system or network suffers various problems and bottlenecks when it works in a particular application scenario. The importance of the knowledge of the wireless channels lies in the fact that, no matter how advanced a future wireless communication system or network might be, we have to deal with the same set of problems associated with the radio propagation channels, such as delay spread, Doppler spread, coherent time, coherent bandwidth, and so on, which will always be there.

With the necessary information about radio channels, we can proceed to introduce various spread spectrum (SS) techniques in the second section. It has to be noted that the SS techniques are the basis of code division multiple access (CDMA) technology, which was first applied to the IS-95 standard [317−326] and has become the primary multiple access scheme chosen by almost all third generation (3G) mobile cellular systems, including CDMA2000 [345−359], WCDMA [425−431], TD-SCDMA [432−439], and so on. In this section, three major SS techniques are discussed, including direct sequence spread spectrum (DSSS), frequency hopping spread spectrum (FHSS), and time hopping spread spectrum (THSS) techniques. It is to be noted that the basic concepts of ultra-wideband (UWB) technologies are introduced while discussing the THSS, which has been applied to many emerging UWB systems, in particular, for those based on pulse position modulation (PPM). Nevertheless, it must be admitted that the most commonly used SS techniques are the DS and FH, rather than the TH technique. The wireless communication systems based on the SS techniques can often be called *wideband* wireless applications, in contrast to those that do not use the SS techniques.

It is amazing to note that the technological evolution happens so rapidly that used-to-be advanced technologies quickly become common background knowledge for all. In the late 1990s one of the coauthors of this book, Professor Hsiao-Hwa Chen, worked in the Telecommunications Laboratory, University of Oulu, Finland, which used to be the largest research group focusing on SS techniques in the whole of Europe. Then, most of the SS techniques had not been unclassified and there were very few publications on the SS techniques applied to civilian applications. The SS techniques were considered to be one of the most advanced know-hows at that time. Therefore, we had to resort to many technical reports and patents for reference information. Nowadays, knowledge of the SS techniques has become a must for all electrical engineers working in telecommunication areas.

Chapter 2 continues with the fundamentals of wireless communications to discuss the issues on multiple access technologies. Three major commonly used multiple access technologies are included in the discussions given in this section, namely, *frequency division multiple access* (FDMA), *time division multiple access* (TDMA), and CDMA technologies. Being different from CDMA, both FDMA and TDMA are always considered to be the traditional *narrow band* multiple access technologies. On the other hand, the CDMA technology was developed from the SS techniques and is often referred to as a *wideband* multiple access technology. As mentioned earlier, CDMA technology has become the main multiple access technology used in all major 3G mobile cellular standards owing to its relatively high bandwidth efficiency and robustness against time-dispersive frequency-selective fading and other external interferences. The first successful application of CDMA technology in commercial communication systems is IS-95A [317−326], which was developed by Qualcomm Inc., USA, and works based on DSSS techniques. The IS-95A system has been deployed in many countries in the world today and its reliability and stability have been confirmed from its long time operations in many countries. Now we have entered the era of 3G mobile communications. All major 3G systems operate on CDMA technologies with no exception, indicating the great popularity of these technologies. An interesting question arises: Can CDMA be still used as the primary multiple access technology in B3G wireless communications? Some people have suggested that the CDMA was

developed in the later 1980s and is suitable only for slow-speed, continuous-time traffic, and voice-centric applications. It has also been suggested that the current CDMA technologies may not be well suited for those applications where dominant traffic will carry high-speed, bursty, and data-centric services. To answer this challenging question, we have more discussions on this issue in Chapter 7 of this book.

The fourth section of Chapter 2 consists of three subsections, which are "Multiuser joint detection against MAI," "Pilot-aided CDMA signal detection," and "beam-forming techniques against cochannel interference." Obviously, all these three subsections deal with issues on how to suppress or eliminate the interferences. The *multiuser detection* (MUD) techniques used to be a very popular research topic a couple of years ago, due to the widespread application of CDMA technologies. As indicated by the title of the subsection, the MUD techniques are used only for overcoming the *multiple access interference* (MAI) problem. The MUD concept is smart in terms of the fact that it treats all MAI as a whole and proceeds with the detection through de-correlating the MAI components from the useful signals. Thus, it treats all signals, whether useful or not, as indispensable parts in the entire detection process. This entails a very high detection efficiency when compared to many other traditional interference suppression techniques, which treat unwanted signals individually as a component that should be suppressed as much as possible.

Pilot-added signal detection is another important issue covered in this subsection, where we introduce many useful conclusions from others' and our own research results. Pilot-added detection is used for overcoming the interferences introduced mainly by dispersive channels, where time dispersion (caused by multipath effect) and frequency dispersion (caused by Doppler effect) may exist individually or jointly. Unlike the MUD schemes, the pilot-added signal detection cannot solve the problems associated with MAI. Therefore, the pilot-added detection should always work along with the MUD to enable a wireless receiver with the capability to work successfully under various channel conditions. In this subsection, we summarize the experience gained in designing pilot-added detection schemes by the "three-same condition," which states that the pilot signal should be constructed at the same time, with the same frequency, and the same code as those used for data-carrying signals, to ensure an accurate estimation of the channel condition.

Section 2.4 ends with the subsection titled "Beam-forming techniques against cochannel interference." Actually, the beam-forming technique is a type of *aperture-synthesizing* technique, which uses multiple antennas to transmit or receive the same signal to achieve a certain array gain through narrowed beams. By using the beam-forming technique in transmitter (Tx) antennas we can pinpoint the transmitting signal to a particular directional angle to facilitate the signal reception at the receiver of interest.[2] On the other hand, we can also use receiver antenna beam-forming to reduce the cochannel interference coming from the angle-of-arrival outside the beam.[3] It has to be pointed out that the major difference between the traditional beam-forming techniques and the emerging multiple-in-multiple-out (MIMO) systems lies in the fact that the signals transmitted or received in multiple antennas in beam-forming techniques are exactly the same replicas (except for different delays), while those in a MIMO system are subject to different coding processes in different antennas to achieve spatial diversity gain or multiplexing capability.

The last three sections of Chapter 2 discuss the issues on "OSI reference model," "switching techniques," and "IP-based networking." Section 2.5 discusses an important concept on the Open System Interconnection (OSI) layered networking model. Section 2.6 concentrates on the discussions on two major network switching architectures, that is, circuit switching and packet switching, both of which play very important roles in wired and wireless networks. It is to be noted that circuit switching as a traditional switching technique has been revitalized recently because of its emerging applications in high-capacity fiber-optical trunk networks. Section 2.7 gives a brief introduction to IP-based

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[2]This is also called the *beam-steering* algorithm.
[3]This sometimes is also called the *null-steering* algorithm.

networking and its development, which has gained great attention due to its wide applications in the Internet-related applications and systems.

1.2 Part II: 3G Mobile Cellular Standards

The second part of this book covers the major 3G mobile cellular standards, including CDMA2000, WCDMA, and TD-SCDMA, which are discussed in Sections 3.1, 3.2, and 3.3, respectively, to form Chapter 3, which was written by Professor Hsiao-Hwa Chen.

As mentioned earlier, it is a great challenge to cover all these major 3G mobile cellular standards within the limited space available in this book, which also discusses many other up-to-date wireless technologies. Obviously, it is not desirable to give only a very brief introduction to each of them, as they also provide important information about the current state-of-the-art wireless technologies, which is the foundation for further discussions on more advanced beyond 3G (B3G) wireless technologies in this book. A relatively informative discussion on these important 3G systems will also be a useful reference to the readers. On the other hand, we are not allowed to spend too much of the space in this book to address the issues on 3G mobile cellular systems only. Therefore, we have to keep a very careful balance on the contents covered here. For this purpose, the discussions given in Chapter 3 have been made as informative as possible, while focusing mainly on their key technical features. Some detail specifications given in the long standard documentations have been omitted for conciseness of the discussions. Therefore, the discussions about the major 3G mobile cellular standards should not be considered complete as it is utterly impossible to condense a standard written in several thousands of pages into a section with only a few tens of pages.

The inclusion of the three major 3G mobile cellular standards, such as CDMA2000, WCDMA, and TD-SCDMA, takes into account the fact that they have been deployed in many countries in the world. The CDMA2000 is the standard that originated from the United States; whereas the WCDMA was the one proposed by Europe.[4] It is to be noted that the Japanese 3G system, ARIB WCDMA, bears a great similarity to the European 3G system, ETSI UMTS-UTRA. So, we do not discuss them individually in two different sections due to the limitation of space in this book. Instead, we put the two into the same section (i.e., Section 3.2), and their differences are discussed and explained in Section 3.2.2. In fact, ARIB has committed to make the Japanese 3G standard fully compatible with ETSI UMTS-UTRA system eventually, although there still are some differences in their specifications at the moment. At the time when this book was written, the roaming between Japanese 3G networks and European 3G networks has not been widely implemented.

Chapter 3 begins with the North American standard, or CDMA2000 standard, a 3G mobile cellular standard proposed by the TIA/EIA of the United States.[5] The discussion of CDMA2000 allows us to understand better how the evolutional change from 2G to 3G mobile cellular systems happens. The CDMA2000 technology is always referred to as the successor of its 2G solution, IS-95. CDMA2000 is one of the IMT-2000 candidate submissions to the International Telecommunication Union (ITU).

As early as 1985, ITU regulators had a vision that the future of mobile cellular systems would be multimedia – involving voice, video, and data services. Thus, in 1985 the ITU, the world's governing telecommunication body, began planning for the next generation digital cellular – "Future Public Land Mobile Telecommunications Systems" (FPLMTS) – later known as *IMT-2000*.[6] The goal of FPLMTS was to provide broadband multimedia wireless services via a single global frequency band

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[4]It is to be noted that the WCDMA standard was initially proposed by ETSI, Europe, and ARIB, Japan, jointly. Although there still are some minor differences in their network operations, both committed to make the standards fully compatible under the framework of 3GPP.

[5]The abbreviations of TIA and EIA stand for "Telecommunications Industry Association" and "Electronics Industry Association," respectively. Both the organizations are based in the United States.

[6]The abbreviation "IMT-2000" stands for "International Mobile Telecommunications in the year 2000," which would have been standardized in the year 2000 according to the ITU's vision of the 1990s. Unfortunately, the

IMT-2000 terrestrial
radio interfaces

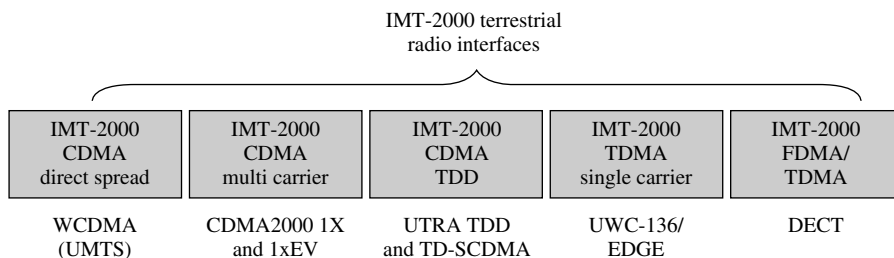| IMT-2000 CDMA direct spread	IMT-2000 CDMA multi carrier	IMT-2000 CDMA TDD	IMT-2000 TDMA single carrier	IMT-2000 FDMA/ TDMA
WCDMA (UMTS)	CDMA2000 1X and 1xEV	UTRA TDD and TD-SCDMA	UWC-136/ EDGE	DECT

Figure 1.1 Five radio interfaces for IMT-2000 standards as a part of the ITU-R M.1457 Recommendation.

allocation and standardized, interoperable technologies. The frequency range allocated would be around 2000 MHz.

The ITU requires that IMT-2000 (or 3G) networks, among other capabilities, deliver improved system capacity and spectrum utilization efficiency over the 2G systems and support data services at minimum transmission rates of 144 kbps in mobiles (outdoor) and 2 Mbps in fixed (indoor) environments. On the basis of these requirements, in 1999 ITU approved five radio interfaces for IMT-2000 standards as a part of the ITU-R M.1457 Recommendation. CDMA2000 is one of the five standards. It is also known by its ITU name *IMT-CDMA Multi-Carrier*. Figure 1.1 shows five radio interfaces for IMT-2000 standards as a part of the ITU-R M.1457 Recommendation, where WCDMA (Universal Mobile Telephone System (UMTS)) was submitted jointly by Europe and Japan, CDMA2000 1x and 1xEV was proposed by the United States, UTRA time division duplex (TDD), and TD-SCDMA were proposed by Europe and China, UWC-136 and EDGE were proposed by the United States, and DECT was submitted by Europe.

The development of the CDMA2000 standard was driven mainly by North American technology developers with an invested interest in the progression of IS-95, or its later version cdmaOne, as the global standard for next generation mobile cellular systems. The share for CDMA remains to be roughly same, if not reduced. Obviously, CDMA2000 is not a single standard in itself. From IS-95 (the 2G equivalent of Global System for Mobile Communication (GSM)) through CDMA2000 1xRTT, which increases the voice capacity of the former by approximately 40% and allows data transfer speeds up to a peak of 144 kbps, to CDMA2000 1xEV-DO, which has a theoretical bit rate of 2 Mbps, CDMA2000 1xEV-DO should be considered a full-fledged 3G standard.

CDMA2000 represents a family of technologies that includes CDMA2000 1x and CDMA2000 1xEV. CDMA2000 1x can double the voice capacity of cdmaOne (formerly known as *IS-95*) networks and can deliver peak packet data speeds up to 307 kbps in mobile environments. CDMA2000 1xEV includes the following:

- CDMA2000 1xEV-DO, which delivers peak data speeds of 2.4 Mbps and supports applications such as MP3 transfers and video conferences.

- CDMA2000 1xEV-DV, which provides integrated voice and simultaneous high-speed packet data multimedia services at speeds of up to 3.09 Mbps, which has already exceeded the peak data rate specified by IMT-2000 (or 3G) specifications.

1xEV-DO and 1xEV-DV are both backward compatible with CDMA2000 1x and cdmaOne. It is noted that the world's first CDMA2000 1x commercial system was launched by SK Telecom (Korea)

ITU's effort to reach a consensus on the IMT-2000 standard in the year 2000 was not successful because of obvious reasons.

in October 2000. Since then, CDMA2000 1x has been deployed in Asia, North and South America, and Europe, and it was estimated that the subscriber base is growing at 700,000 subscribers per day. CDMA2000 1xEV-DO was launched in 2002 by SK Telecom (Korea) and KT Freetel (Korea).

Section 3.1 discusses the CDMA2000 standard in a progressive way so that it is easy to understand for a person with a minimum background knowledge of wireless communications. Section 3.1 is made up of altogether 13 subsections, in which we give an introduction to the various technical aspects of the CDMA2000 standard. In order to make discussions up-to-date and consistent throughout Section 3.1, we concentrate on the CDMA2000 1xEV (or IS-856) standard based mainly on the specifications given in the following standard documentations [360–361]:

- CDMA2000 High Rate Packet Data Air Interface Specification, 3GPP2 C.S20024 Version 2.0, Date: October 2000.

- CDMA2000 High Rate Packet Data Air Interface Specification, 3GPP2 C.S20024-A, Version 1.0, Date: March 2004

the former of which is known as *Release 0* and the later is Revision A of CDMA2000 1xEV or IS-856 standard. There are also numerous references to CDMA2000 1xEV and their evolutional versions CDMA2000 1xEV-DO and CDMA2000 1xEV-DV, and readers may refer [360–367] for more information about them. In particular, the April 2005 issue of IEEE Communications Magazine has published a Special Issue on CDMA2000 1xEV-DV and seven papers appeared in this issue [368–374], which indicated that the CDMA2000 1xEV-DV will gain greater popularity around the world.

While focusing on the discussion on CDMA2000 1xEV, we also refer to the CDMA2000 1x standard from time to time in Section 3.1. Release 0 of the CDMA2000 1x standard [348–353] consists of the following 3GPP2 documents:

- C.S0001-0 Introduction to CDMA2000 Standards for Spread Spectrum Systems

- C.S0002-0 Physical Layer Standard for CDMA2000 Spread Spectrum Systems

- C.S0003-0 Medium Access Control (MAC) Standard for CDMA2000 Spread Spectrum Systems

- C.S0004-0 Signaling Link Access Control (LAC) Standard for CDMA2000 Spread Spectrum Systems

- C.S0005-0 Upper Layer (Layer 3) Signaling Standard for CDMA2000 Spread Spectrum Systems

- C.S0006-0 Analog Signaling Standard for CDMA2000 Spread Spectrum Systems

All final revisions (or Revision D) of CDMA2000 1x standard can be found in the reference list [359], given at the end of this book.

After having discussed CDMA2000 standards proposed by the United States, we will move on to Section 3.2, which covers the European 3G standard, the WCDMA system. The WCDMA is also one of the IMT-2000 candidate proposals, as shown in Figure 1.1, proposed by ETSI, Europe, and ARIB, Japan, jointly. The discussions given in Section 3.2 focus on the ETSI UMTS system; whereas the difference between European UMTS-FDD and Japanese ARIB WCDMA systems are explained, in particular, in Section 3.2.2 titled "ETSI UMTS versus ARIB WCDMA," to save space in this book. The conclusion will be drawn as a result from the comparison between ETSI UMTS-FDD and ARIB WCDMA that the two should be made fully compatible in mid-2003 under the time frame specified in UMTS Realease'99. [7] under the time frame specified in UMTS Release'99.

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[7]It has to be noted that some delay occurred in the compatibility time frame between the two, and up to the time when this book was written the roaming between Japanese and European 3G networks has not been widely implemented.

Japanese mobile services operator NTTDoCoMo launched the world's first commercial WCDMA network in 2001, although its operation was limited to only the great Tokyo area initially. When compared to the world's first CDMA2000 1x commercial system launched by SK Telecom (Korea) in October 2000, the NTTDoCoMo WCDMA system had suffered many technical problems during the initial phase of its services in Japan, including both its FOMA terminals[8] and networking. Even today, both Korea and Japan claim that they had the first 3G network in the world, and it is always a very tough issue as to who is number one if the two progress neck and neck in the development of new technologies. Nevertheless, the competition between Japan and Korea in the 3G mobile cellular communication field has been very serious for a long time. That is why many people really doubt the claim that Europe or the United States is the serious pusher for 3G development and standardization. Japan has been very worried for a long time about the fact that Korea has obtained the core CDMA intellectual property rights (IPRs) transfer from Qualcomm Inc., and consequently has grasped the know-hows in many key CDMA technologies. By following the United States's suit in developing its TDMA-based second-generation (2G) cellular technology, Japanese Digital Cellular (JDC) (which was not compatible with any of the 2G systems operating in the world), Japan virtually had no access to the lucrative world of the mobile cellar market. This sad experience made Japan determined to be a must-winner in the race for 3G technology, and motivated the country to work closely with Europe for developing the WCDMA technology. It seems that Japan has got the right bid, as clearly seen from its big share in terms of total WCDMA subscribers in the world. The number of 3G subscribers has so far topped more than 100 million, including four-million WCDMA users (mainly from Japan). With the growing maturity of WCDMA-related products and technology, its commercial-user networks are undergoing a dramatic development. Today, more than 70 3G/UMTS networks using WCDMA technology are operating commercially in 25 countries, supported by a choice of over 100 terminal designs from Asian, European, and US manufacturers.

The last section, Section 3.3, in Chapter 3 talks about the TD-SCDMA standard, which was proposed by China as one of the five IMT-2000 candidate proposals, as shown in Figure 1.1. Currently, very few books have covered the TD-SCDMA standard in their chapters related to 3G technologies. The importance of this Chinese-owned 3G standard will become clearer with the increase in the leverage weight of China's role in the world telecommunication market. China undoubtedly is the largest single market for mobile communications. The number of its mobile service subscribers surpassed the United States a few years ago, making it the most influential mobile cellular market in the world. It will be considered very silly if a mobile communication vendor/manufacturer has no presence in China today. Everybody wants to catch a bite of big China's mobile communication market. On the other hand, China clearly knows that it is stupid for its service providers to buy hundreds of thousands cellular equipments from outsiders with their hard-earned money. Even for those made-in-China equipments, they have to pay a large amount of loyalty fees to the foreign players due to the use of their IPRs. This harsh reality has motivated China to develop its own mobile communication standard in an effort to reduce or even eliminate the heavy reliance on these imported mobile cellular technologies.

However, the path toward the development of its own 3G system is not smooth either. The TD-SCDMA standard was proposed originally by CATT, which is one of the largest institutes[9] that specializes in telecommunication research in China. However, many people criticized the TD-SCDMA as standard lacks novelty technically and thus may still face a heavy licence fee payable to foreign companies even after its commercialization. It was also suggested that the TD-SCDMA used too many core technologies, such as power control (IS-95), RAKE receiver (IS-95), orthogonal variable spreading factor (OVSF) code for channelization (WCDMA), time division duplex (TDD) (UTRA-TDD), and so on, which are borrowed from Qualcomm as well as other companies.

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[8]The name "FOMA" is the abbreviation for "Freedom Of Mobile multimedia Access."

[9]CATT used to be a very large research institute that belonged to the former Ministry of Post and Telecommunications, China, and is now a privatized company specialized for mobile communications. For more information, please refer to the web site at http://www.catt.ac.cn.

Also, the use of TDD techniques has made it very hard to operate the TD-SCMA in a large cell, thus making it necessary for a service operator to have to offer a dual-system, one for small cells in cities and the other for large cells in the countryside or in suburb areas. This will not make sense economically for any operator. China, also being the largest free-market country, no longer suits the governing mode that worked before when centralized economy played a key role. Now, nobody even from the central government can order a mobile service provider to buy the equipments made only in China. The question then becomes who will care about TD-SCDMA if it does not work well technically. Maybe time will play its role in China again: TD-SCDMA needs some more time to get ready for its practical applications in China, and therefore the time when its 3G licences will be issued has become the focus of the world mobile cellular market now.

Observers widely expect that the Chinese government will make decisions on 3G licensing when it is certain that the homegrown TD-SCDMA is a viable option. However, analysts are urging China to roll out its 3G licensing soon. China cannot afford more delays in the licensing of 3G wireless communications telephony, they say. Delays could harm the development of the country's telecommunications industry, as they may be against the interests of the whole value chain. A clear timetable will help all players, both foreign and domestic, prepare resources planning, manufacturing, and research and development (R&D), they say.

According to current market expectations, China Mobile, the world's biggest mobile service carrier for a number of subscribers, would build a 3G system on the WCDMA standard, which is based on the GSM technology popular in Europe. China Unicom would build a system based on the CDMA2000 standard developed by Qualcomm Inc of the United States. For the homegrown TD-SCDMA system, all six domestic telecom operators are doing network trial tests based on the system. Analysts also expect that the major fixed-line operators China Telecom and China Netcom will receive licences, as will the two existing mobile operators, China Mobile and China Unicom. Some experts on TD-SCDMA predicted that if the 3G licences can be released in 2006, China's 3G mobile telecommunications revenue would likely reach 300 billion yuan (US$36 billion) in 2010. Revenue from 3G between 2005 to 2010 will accumulate to one trillion yuan (US$120 billion).

The discussions on TD-SCDMA in Section 3.3 span 12 subsections, dealing with various aspects of its technical features, including an overview of TD-SCDMA, frame structure, smart antenna applications, adaptive beam patterns, uplink synchronization control, intercell synchronization, baton handover, intercell dynamic channel allocation, flexibility in network deployment, and so on. In particular, we spend quite a bit of space to address the salient features of the TD-SCDMA technology, such as uplink synchronization control, baton handover, and so on. Before the end of Section 3.3, we also touch on the issue of the technical limitations of the TD-SCDMA, where we point out the possible technical problems that can arise when a TD-SCDMA system works on practical applications, as well as the global impact of TD-SCDMA technology.

We hope that the coverage of the TD-SCDMA standard in this book will be useful to those who are particularly interested in the TD-SCDMA technology as well as the Chinese 3G market.

1.3   Part III: Wireless Networking

The third part of this book is about wireless networks, which will be dealt with in two chapters, that is, Chapter 4, titled "Wireless Data Networks", and Chapter 5, titled "All-IP Wireless Networking". Both these chapters were written by Professor Mohsen Guizani.

In Chapter 4, we discuss wireless data networks. We cover all the different standards (including IEEE 802.11b, IEEE 802.11a, IEEE 802.11g, IEEE 802.15, IEEE 802.16, ETSI HIPERLAN and HIPERLAN/2, Japan's MMAC, etc.) and explain their purpose. Then, we discuss the architecture and functionality of the *MAC* sublayer. Next, we summarize the functionalities of *FHSS* and *DSSS*.

Then, we discuss security, authentication and Wired Equivalent Privacy (WEP). We conclude this chapter with a discussion on Bluetooth technologies and related security issues.

In Chapter 5, we discuss All-IP Wireless Networking, including mobile IP, IPv6 versus IPv4, Mobile IPv6, *wireless application protocol* (WAP), and few important routing protocols.

It is to be noted that the research on all-IP wireless is now very active around the world. Many new research topics are emerging everyday, such as voice over wireless local area networks (VoWLANs)[10], mobility support in heterogenous networking environment, security issues on all-IP wireless, and so on. Therefore, the discussions given in Chapter 5 only cover very fundamental knowledge for further research in this area.

Similar to discussions related to networking issues, Chapters 4 and 5 have a lot to do with the upper layer architecture/design of wireless networks. Obviously, to understand the discussions given in these chapters, it is desirable to gain enough knowledge on the *OSI* seven-layer model[11], which has been discussed in Section 2.5.

It should also be noted that the layered network architecture is a traditional network design methodology, which has been used extensively in many different wired and wireless communication systems/networks including all 1G to 3G mobile cellular standards and other networks, such as IEEE 802.11x WLANs. Because of the regularity in its modular structure, the OSI seven-layer model can help network designers to concentrate on the functionalities provided by each layer; while the interface between layers will be taken care of by the standard message exchange formality specified in the OSI-model. However, the reliance on extensive message exchanges happening in the boundaries of different layers results in long processing delays. This problem becomes even more acute where a wireless system is working in a high-speed burst-type traffic mode.

Motivated to solve this problem, a new concept called *cross-layer network design* approach has been proposed recently in an effort to greatly reduce the processing delay in the OSI layered model. The basic idea of cross-layer design is to achieve a global optimization design across different layers by tearing down the boundaries between different layers. In most cases, it might happen that the cross-layer design method is only applied to a few but not all layers. Because of the limited space, we will not elaborate more on the cross-layer design approach in this book.

1.4   Part IV: B3G and Emerging Wireless Technologies

The fourth (also the last) part of this book addresses the issues on B3G wireless communications and other emerging technologies, including Chapter 6, Chapter 7, Chapter 8, Chapter 9, and Chapter 10, which are titled "Architecture of B3G Wireless Systems", "Multiple Access Technologies for B3G Wireless", "MIMO Systems", "Cognitive Radio Technology", and "E-UTRAN: 3GPP's Evolutional Path to 4G", respectively. Chapter 6 was written by Professor Mohsen Guizani, and the other four chapters, that is, Chapters 7 to 10, were written by Professor Hsiao-Hwa Chen.

In Chapter 6, we concentrate on the architecture of B3G Wireless Systems. The discussion in this chapter includes spectrum allocation issues, high-speed data, multimode and reconfigurable platforms, ad hoc mobile networking, and satellite systems in B3G wireless. Since many issues are still in research labs, we conclude this chapter listing some challenging research topics of interest to our readers.

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[10]Voice over IP has been a research topic for some time; while *voice over wireless local area networks* (VoWLANs) is still a relatively new topic that emerged very recently. The main objective for VoWLANs research is to provide voice communications via any WLAN-compatible terminals, such as PDAs, notebook PCs, and so on.

[11]The OSI seven-layer architecture has become a standard layered architecture for any (either wired or wireless) network system. The seven layers in a downward order include "Application layer," "Presentation layer," "Session layer," "Transport layer," "Network layer," "Data link layer," and "Physical layer."

Chapter 7 titled "Multiple Access Technologies for B3G Wireless" consists of six sections, covering issues on various aspects of the multiple access technologies, which might be applied to futuristic B3G wireless communication systems. Section 7.1 gives a brief introduction on the required characteristics that a multiple access technology should have to suit the applications in B3G wireless. It is pointed out in the section that two major challenging issues have to be taken into account to architect future B3G wireless systems. One is the extremely high data rate that a B3G wireless system or network should provide to the subscribers when compared to that of the current 2G to 3G mobile cellular systems. The peak data rate in a future B3G system is suggested to be at least 500 Mbps. A field trial of a prototype 4G wireless system has been conducted very recently in the suburb area of Tokyo by NTTDoCoMo with a peak data transmission rate of about 1 Gbps being reached in its downlink transmission channels. This data transmission rate was achieved with a transceiver mounted in a slow moving vehicle that communicated with a base station without a constant line-of-sight path. The area where the field trial was conducted had a lot of high-rise buildings, and therefore it has to be considered as a very urbanlike environment with very rich multipath propagation components. This pioneer field test for a 4G system carried out by NTTDoCoMo has set up an example for the target data transmission rate for all futuristic B3G wireless systems. At such a high transmission rate, many new problems that are not visible in a slow-speed wireless communication system will surface, and even technically become a serious bottleneck to the whole wireless system design. Because of the relatively poor bandwidth efficiency in the currently available multiple access technologies (either FDMA, TDMA, or CDMA), it is simply impossible to provide all wireless subscribers with such a high data rate (i.e., about 1 Gbps). Some viable new technological solutions have to be found and tested thoroughly before they can be applied to future B3G wireless systems. It is indeed a tough but an interesting research topic.

Another critical issue that should be taken into account in designing or searching for B3G multiple access technologies is that the dominant traffic in future wireless channels will be virtually all burst-type owing to the wide use of all-IP wireless architecture in all future B3G systems. There will be no continuous transmissions originating from normal mobile subscribers, as it will be extremely wasteful in terms of bandwidth utilization. Continuous transmissions may happen only in some wireless trunk loops. Therefore, all subscribers will use high-speed packet-switched data transmission with a lot of on-and-off pauses in their transactions. The bursty nature of the B3G wireless communications will completely change the design philosophy of a wireless transceiver, which has to work at a very high speed to conduct channel estimation and signal detection on a packet basis, instead of on a frame basis as is the case with the current 2-3G wireless systems.[12] The high-speed bursty transmission in the B3G wireless systems has also made many currently available technologies obsolete and some new ones should be used to replace them. For instance, CDMA technology has been used in all current 3G mobile cellular standards, becoming a defacto standard multiple access technology for them. All 3G mobile standards were designed based basically on the circuit-switched traffic load with a relatively low peak transmission rate, typically below 2 Mbps. However, if the same CDMA technology was used in a 4G wireless system with a peak transmission rate being as high as 1 Gbps, big problems will definitely emerge. An obvious fact is that the conventional CDMA codes used in the 3G wireless systems were designed without considering at all their partial cross-correlation and partial auto-correlation functions, implying that an unprecedented high MAI and multipath interference (MI) will appear if a system needs to capture a lot of short bursts, each of which may contain only a small number of bits. Therefore, in this sense, the current CDMA technologies have to be greatly improved before they can be applied to any of the B3G wireless applications.

In Section 7.2 we introduce, in particular, a special issue titled "Multiple Access Technologies for B3G Wireless Communications," published in the 2005 February issue of the IEEE Communications Magazine [562], which was edited by both the authors of this book, Professor Hsiao-Hwa Chen and Professor Mohsen Guizani. This IEEE Communications Magazine special issue contains altogether

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[12]Here, we assume that each frame is always much longer than a packet.

eight papers contributed by very well known experts working in these areas worldwide, some of which have been included in the top 10 most popularly cited references in this particular research area in 2005. The significance of this special issue in the IEEE Communications Magazine [562] is also reflected in the timing of its publication, when the research community is working hard to start 4G wireless system design, and when multiple access technologies are always the core of its fundamental architecture. Also, the performance of a B3G wireless system will have very much to do with the multiple access technology it uses.

Section 7.3 is titled "Next Generation CDMA Technologies," whose focus has been indicated clearly in the title itself. As mentioned earlier, the current CDMA technologies are not suitable for B3G wireless applications, where high-speed bursty traffic will be dominant in the channels. This section tries to give possible answers to the questions, such as what the next generation CDMA technologies will look like and how to implement them, and so on. Several important aspects in innovating the current CDMA technologies have been addressed in Section 7.3. They include the design of better CDMA codes, the consideration of spreading and carrier modulation schemes[13], and so on. In particular, we introduce a new CDMA code design approach, namely, the Real Environment Adaptation Linearization (REAL) approach, as an effort to find some optimized CDMA codes with unique MAI-free and MI-free properties. In the REAL approach, a CDMA code set has been generalized as a generic complementary code set with its element code length, the flock size and set size being N, M, and K. If $M = 1$, the code becomes a normal unitary code, such as Gold codes, Walsh-Hadamard codes, OVSF codes, and so on. If $M > 1$, a complementary code is considered.

Two very important conclusions have been drawn from the discussions given in Subsection 7.3.5. The first conclusion is that it is impossible to implement an MAI-free and MI-free CDMA system if conventional unitary CDMA codes are used.[14] The second conclusion is that, theoretically speaking, such an MAI-free and MI-free CDMA system can only support maximum M users, where M is the flock size of the complementary codes used in this CDMA system. The two conclusions made in this subsection may guide us to search for more suitable CDMA codes for application in future CDMA-based B3G wireless communication systems. The significance of the REAL approach is that it is the first time in the history of the literature that the theory of the validity of the two aforementioned conclusions, telling us that we have to use complementary codes as the CDMA codes for the next generation CDMA technologies, is proven. Therefore, the complementary codes will become an essential part of the next generation CDMA technologies. Do not waste time in designing a CDMA-based B3G wireless system using any of the unitary codes.

Section 7.4 discusses multicarrier (MC) CDMA technology, which is another very popular air-interface architecture proposed recently, and has been found to have many applications in wireless systems. Intuitively, the MC-CDMA technologies were developed from single-carrier CDMA technologies. The major difference between a traditional single-carrier CDMA and MC-CDMA systems lies in the fact that the latter can take the advantage of transmitting multiple data streams in parallel via different carriers to make each subcarrier channel a flat fading channel. The errors caused in these subcarrier channels that coincide, deep fades in a frequency-selective fading channel and can be corrected via interleaving plus error-correction coding techniques, which have been widely used in many other wireless subsystems.

We introduce four major MC architectures in Section 7.4, including duplicated time-spreading MC-CDMA, duplicated frequency-spreading MC-CDMA, multiplexed time-spreading MC-CDMA, and multiplexed frequency-spreading MC-CDMA scheme. Their performances are compared in the section. It has to be noted that the importance of the MC-CDMA architecture has also been

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[13]In Subsection 7.3.3, we proposed a novel spreading modulation scheme, that is, offset stacking (OS) spreading modulation, for its possible application in next generation CDMA systems.

[14]Here, we define a unitary CDMA code as the one that works on a one-code-per-user basis. On the other hand, a complementary code works the other way: each user is assigned a flock (which is normally an even number) of element codes for CDMA purpose.

reflected in the fact that it is undoubtedly the foundation for another emerging technology, namely, the *orthogonal frequency division multiplex (OFDM) technology*, which is addressed in detail in Section 7.5.

Section 7.5 is dedicated to the discussions on OFDM technology, which has been given a lot of attention very recently because of its successful application in several commercial wireless systems, such as IEEE802.11a, IEEE802.11g, Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), and so on. As mentioned earlier, an OFDM scheme can be considered as an economical implementation of a MC system. One of the salient features of OFDM is its simplified base band implementation of parallel carrier modulation (via IFFT algorithm) and demodulation (via FFT algorithm) modules, which otherwise would have to be implemented by analogue components in a MC system. As both IFFT and FFT can be effectively realized using software solutions, it will make an OFDM module extremely flexible to fit into different applications with a different number of subcarrier channels by simply adjusting the number of FFT points.

It is noted that OFDM can use overlapped subcarriers to greatly improve its bandwidth efficiency because of the fact that it sends information by the combinations of tones (instead of a signal always occupying a certain bandwidth). Thus, the output from the IFFT unit will be a linear combination of multiple tones, depending on the input data patterns at the IFFT unit. Obviously, if there is only one single nonzero input with the rest being zero, the output signal from the IFFT unit will be a single sinusoidal waveform (or tone) at a certain frequency. Otherwise, a mixture of several sinusoidal waveforms (or tones) with different frequencies will be the result. Section 7.5 also addresses some implementation problems particularly associated with an OFDM system, such as cyclic prefix (CP) in Subsection 7.5.2, peak-to-average-power (PAPR) issues in Subsection 7.5.3, and Orthogonal Frequency Division Multiple Access (OFDMA) issues in Subsection 7.5.4, and so on. It has to be noted that OFDMA[15] is a rising star as a novel multiple access technology with a great potential for its possible application in future wireless communication systems.

Section 7.6 deals with the issues on UWB technology. In this section, in addition to the introduction of UWB technologies, we will also show how to use an analytical method to study a DS-CDMA UWB system, where both flat fading and frequency-selective fading channels will be taken into account.[16]

Chapter 8 titled "MIMO Systems" was written by Professor Hsiao-Hwa Chen. The MIMO system is a very important emerging technology, which was proposed initially in the later 1990s. The extreme importance of the MIMO technology has been reflected in the fact that it creates the "third" dimension of the diversity mechanism on top of the existing two, that is, frequency diversity (e.g., via MC transmission) and time diversity (e.g., via RAKE reception) techniques. It should be noted that only the MIMO system can provide such a spatial diversity gain to a wireless communication system without consuming other precious radio resources (such as the frequency and the time), which are nonreplaceable, of course with some price to pay in terms of complexity. This is partly the reason that some people call the MIMO technology as one of the most important technological breakthroughs in the wireless communications arena in the last 20 years.

There are two advantages in using MIMO technologies in a wireless communication system. One is it provides a scalable spatial diversity gain depending on the number of antennas used in the Tx and the receiver (Rx). This spatial diversity gain is obtained from the statistical independence existing in the channels over different Tx–Rx Rx antenna pairs, each of which can be viewed as an independent signal replica of others. Thus, combining these independent replicas can achieve substantially high

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[15]OFDMA treats frequency (or tone) and time as two signal spaces, different combinations of which can be assigned to different users in the same network for multiple access purpose. On the other hand, please note that OFDM is not a multiple access technology. Instead, similar to a MC scheme, OFDM can only provide multiplexing capability to a particular user.

[16]In the analysis that considers frequency-selective fading channels, a modified Saleh-Valenzuela (S-V) channel model will be used to fit a typical operational environment, such as an indoor channel.

diversity gain at a Rx without consuming any of the previous bandwidth resources, such as time and frequency. Another advantage that a MIMO system can exploit is its multiplexing capability provided through multiple transmission paths formed on different Tx–Rx antenna pairs, each of which can be considered as an independent data pipe. Thus, the use of more Tx–Rx antenna pairs will create more transmission paths in parallel, contributing to a great increase of the total data transmission rate in a particular point-to-point wireless air link. In fact, the advantage in the diversity gain and the multiplexing capability can be traded off to fit a particular application scenario. This is a very powerful leverage for a MIMO technology to offer, thus making it an indispensable part of future wireless communication systems. In Chapter 8, the theories on both spatial diversity and multiplexing schemes for a MIMO system are covered.

The MIMO technology has been treated as another focal point in this book, as clearly seen from the number of pages and the breadth of the topics it covers. In addition to the introduction to varied background knowledge of SISO, SIMO, MISO, and MIMO systems and the diversity versus the multiplexing capability in Sections 8.1, 8.2, and 8.3, we also provide an analytical example to evaluate the performance of a space–time block coded (STBC) CDMA system based on complementary codes, as explained in detail from Sections 8.4 to 8.8. The proposed complementary-coded STBC-CDMA scheme is the result of our very recent research activities. The purpose of this new scheme is to try to combine the desirable features of a MIMO system with the complementary-coded CDMA system with unique MAI-free and MI-free properties. This is a part of our effort to search for a suitable system architecture for futuristic B3G wireless communications. The results shown in Sections 8.4 to 8.8 have demonstrated that the STBC-CDMA system based on complementary codes is very promising in terms of its bit error rate performance, which can also be translated into capacity and bandwidth efficiency gains.

Chapter 9 covers the topic on "Cognitive Radio Technology," which is a new wireless technology proposed very recently as a solution to reuse the fallow spectrum that has not been fully used. The importance of the cognitive radio technology has been reflected in the remarks made by Ed Thomas, former Chief Engineer of the Federal Communication Commission (FCC): "If you look at the entire RF frequency up to 100 GHz, and take a snapshot at any given time, you'll see that only five to ten percent of it is being used. So there's 90 GHz of available bandwidth." This tells us that the utilization of the current radio spectrum is severely inefficient, and thus the cognitive radio can find its way to exploit the unused spectrum from time to time, as long as the vacancy appears in the spectrum.

In terms of its operation mode, cognitive radios are intelligent cell phones or smart radios that determine the best way to operate in any given channel situation. Instead of following a set of predefined protocols, as regular radios do, cognitive radios configure to their environment and their user's needs. Cognitive radios are similar to living creatures in that they are aware of their surroundings and understand their own and their user's capabilities and the governing social constraints. A radio's actions arise from a rational process that predicts probable consequences and remembers all of its failures and successes. The radios are treated like animals that learn to evolve over time with their changing environment. Basically, the cognitive engine is a brain that reads the radio's meters and turns the radio's knobs in order to get the desired outcome.

Cognitive radios can be applied to mainly two wireless application environments, one being the situation where cognitive radios should work on licensed bands, in which incumbent users are working; and the other being the environment where cognitive radios work on unlicensed bands. In the first situation, one or more cognitive radios should work with licensed primary users, which are never cooperative. In the first case, avoiding interference with these primary users while keeping reliable communications for cognitive radios, is the issue of concern. In the second scenario, it is possible to implement cognitive radios in all wireless terminals, which work in the same unlicensed bands. In this case a close cooperation among all cognitive radio terminals will be the key for successful operation of the cognitive radio network.

In this chapter, there are 11 sections, starting from the very basic concept of cognitive radio technology to various possible applications of cognitive radios in WPANs, WLANs, WMANs, WWANs, and WRANs. Several new IEEE 802 standards, such as IEEE 802.11h, IEEE 802.22, IEEE 802.16h, and so on, which are related to the applications of cognitive radio technologies, are introduced. We also introduce a few available cognitive radio products as examples in this chapter, to allow the readers to have a feeling about the real world of the cognitive radio.

Chapter 10 is titled "E-UTRAN: 3GPP's Evolutional Path to 4G"; "E-UTRAN" stands for Evolved UTRAN, which is a new technology owing to UTRA's long term evolution. E-UTRAN is also called *Super-3G* or simply 4G technology, and is still a technical standard under discussion in many 3GPP TSG RAN and SA Working Groups meetings. The primary targets for the development of 3GPP E-UTRAN are explained as follows.

To ensure competitiveness of the 3GPP systems in a time frame of the next 10 years and beyond, a long-term evolution of the 3GPP access technology needs to be considered. In particular, to enhance the capability of the 3GPP system to cope with the rapid growth in IP data traffic, the packet-switched technology utilized within 3G mobile networks requires further enhancement. A continued evolution and optimization of the system concept is also necessary in order to maintain a competitive edge in terms of both performance and cost.

Important parts of such a long-term evolution include reduced latency, higher user data rates, improved system capacity and coverage, and reduced overall cost for the operator. Additionally, it is expected that IP-based 3GPP services will be provided through various access technologies. A mechanism to support seamless mobility between heterogenous access networks, for example WLANs and 3GPP access systems, is a useful feature for future network evolution. In order to achieve this, an evolution or migration of the network architecture, as well as an evolution of the radio interface, should be considered. Architectural considerations will include end-to-end systems aspects, including core network aspects and the study of a variety of IP connectivity access networks (e.g., fixed broadband access).

In Chapter 10, there are in total eight sections, which cover the issues ranging from the organization of 3GPP TSG WGs for E-UTRAN, the origin of E-UTRAN, general technical features of E-UTRAN, introduction of E-UTRAN radio interface protocols, E-UTRAN physical layer aspects, and a summary remark. In this chapter, we include, in particular, a section (Section 10.7) to discuss a specific physical layer architecture design based on downlink and uplink FDD-OFDMA technology, which consists of many cutting-edge techniques.

It is noted that the coverage on the 3GPP E-UTRAN technology can be rarely seen in currently available books. Therefore, the information contained in this chapter is very timely and will be a useful reference to the people working in next generation wireless systems and networks.

1.5   Suggestions for Using This Book

As mentioned earlier, this book can be treated primarily as an up-to-date research reference, including many cutting-edge technologies for the people working in wireless communication systems and networks. In addition, this book can also be used as a teaching material to serve different teaching purposes, such as ordinary undergraduate/postgraduate courses in universities/colleges or short courses in professional training or continued education classes, and so on. In order to exploit maximum benefit from this book as either a supplementary teaching material (for undergraduate or postgraduate classes) or as the main text for a professional training course, we to provide some guidance in this section to the instructors who will conduct the lectures in the aforementioned courses.

There are a few paradigms for the course teaching to proceed, depending on the titles and the duration of the courses, as well as the background knowledge level of the attendees of the courses.

If the course is focused more on "Wireless Networks," we suggest that the instructors use the following chapters, that is, Chapters 2, 4 and 5, from this book to form the major part of the lecturing material, as shown in Figure 1.2(a).

If the course is concentrated mainly on "Wireless Communication Systems," we suggest that the flow diagram shown in Figure 1.2(b) should be used for the course teaching. On the other hand, if a course about "3G Mobile Cellular Communications" is given, the teaching flow diagram
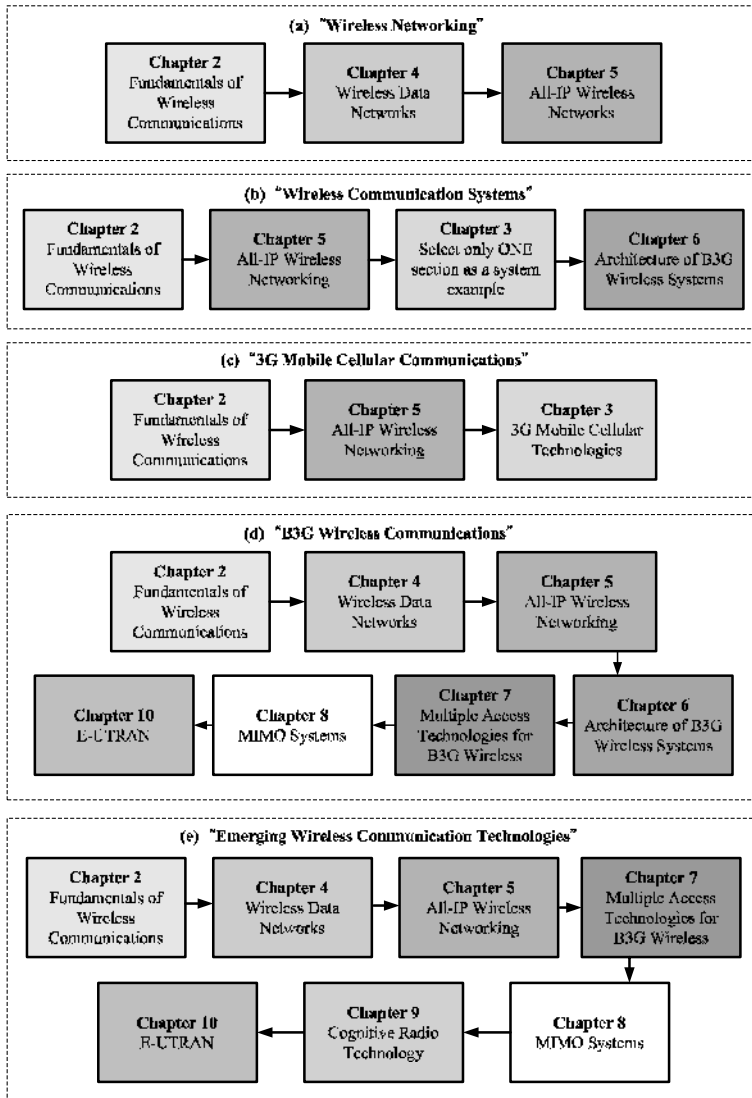

Figure 1.2 The teaching flow diagrams for different courses concentrated on (a) wireless networking, (b) wireless communication systems, (c) 3G mobile cellular communications, (d) B3G wireless communications, and (e) emerging wireless communication technologies.

shown in Figure 1.2(c) could be used. The book can also be used to conduct a teaching course on a more advanced level for senior postgraduate students. For instance, a course titled "B3G Wireless Communications" can be taught on the basis of the materials given in this book. An instructor can use the paradigm shown in Figure 1.2(d) to conduct the course in a time frame of one term. Another possible course using this book is "Emerging Wireless Communication Technologies," which can be taught within one semester by using the paradigm illustrated in Figure 1.2(e).

Therefore, it can be seen that this book can be used for teaching different courses for either undergraduate or postgraduate students in universities. It is also suitable for conducting many other different training classes dedicated to telecommunication engineers for continuing education purposes. Because of the time constraint, it is unfortunate that we could not provide exercise problems at the end of each chapter in this edition. This will be an important part when the next edition is brought out. We will, in particular, welcome any comments on how to use this book. The comments can be sent via email to either of the authors, Professor Hsiao-Hwa Chen (hshwchen@ieee.org), or Professor Mohsen Guizani (mguizani@cs.wmich.edu).