1

Introduction

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1.1 WCDMA in Third-Generation Systems

Analog cellular systems are commonly referred to as first-generation systems. The digital systems, such as Global System for Mobile Communications (GSM), PDC, cdmaOne (IS-95) and US-TDMA (IS-136), are second-generation systems. These systems have enabled voice communications to go wireless in many of the leading markets, and customers are also increasingly finding value in other services, such as text messaging and internet access, which are starting to grow rapidly.

Third-generation systems are designed for multimedia communication: with these, person-to-person communication can be enhanced with high-quality images and video, and access to information and services on public and private networks will be enhanced by the higher data rates and new flexible communication capabilities of third-generation systems. This, together with the continuing evolution of the second-generation systems, will create new business opportunities not only for manufacturers and operators, but also for the providers of content and applications using these networks.

In the standardisation forums, Wideband Code Division Multiple Access (WCDMA) technology has emerged as the most widely adopted third-generation air interface. Its specification has been created in the 3rd Generation Partnership Project (3GPP), which is the joint standardisation project of the standardisation bodies from Europe, Japan, Korea, the USA and China. Within 3GPP, WCDMA is called Universal Terrestrial Radio Access (UTRA) Frequency Division Duplex (FDD) and Time Division Duplex (TDD), the term WCDMA being used to cover both FDD and TDD operations.

Throughout this book, the chapters related to specifications use the 3GPP terms UTRA FDD and TDD, the others use the term WCDMA. This book focuses on the WCDMA FDD technology. The WCDMA TDD mode and its differences from the WCDMA FDD mode are presented in Chapter 17, including a description of TD-SCDMA. UTRA is the radio access part of the Universal Mobile Telephone System (UMTS) network.

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1.2 Spectrum Allocations for Third-Generation Systems

Work to develop third-generation mobile systems started when the World Administrative Radio Conference (WARC) of the International Telecommunications Union (ITU), at its 1992 meeting, identified the frequencies around 2 GHz that were available for use by future International Mobile Telephony 2000 (IMT-2000) mobile systems, both terrestrial and satellite. Within the IMT-2000 framework, five air interfaces are defined for third-generation systems, based on either CDMA or TDMA technology, as described in Chapter 3. The original target of the third-generation process was a single global IMT-2000 air interface. In practice, the third-generation systems are closer to this target than were second-generation systems, since WCDMA has clearly turned out to be the most dominant IMT-2000 standard in commercial deployments. The same WCDMA air interface is deployed in Europe, Asia, Australia, in North and South America and in Africa.

Most of the WCDMA deployments use the identified IMT-2000 spectrum around 2 GHz: 1920–1980 MHz for uplink and 2110–2170 MHz for downlink. This spectrum is in IMT-2000 use in Europe, Asia (including Japan and Korea) and in Brazil. The first licences for that spectrum were granted in Finland in March 1999, followed by Spain in March 2000. No auction was conducted in Finland or in Spain. Also, Sweden granted the licences without auction in December 2000. However, in other countries, such as the UK, Germany and Italy, an auction similar to the US Personal Communication Services (PCS) spectrum auctions was conducted.

WCDMA will also be deployed in the existing second-generation frequency bands that were also identified for IMT-2000 in WRC-2000 and are currently used by GSM or cdma. That approach is called *refarming*. The WCDMA deployment in the USA started by refarming WCDMA to the existing cellular bands at 850 MHz and to the PCS band at 1900 MHz, since there were no new frequencies available for WCDMA deployment. A new frequency band was auctioned in the USA in 2006. This band, the so-called Advanced Wireless Services (AWS) band, is located at 1700 MHz for uplink and at 2100 MHz for downlink. WCDMA deployment at that band has already started. The AWS band uplink happens to be within the GSM1800 uplink band and the downlink is within the UMTS downlink band.

WCDMA refarming to GSM bands has also started in Europe and in Asia. The GSM900 band is attractive, since a lower frequency can provide better coverage than the IMT-2000

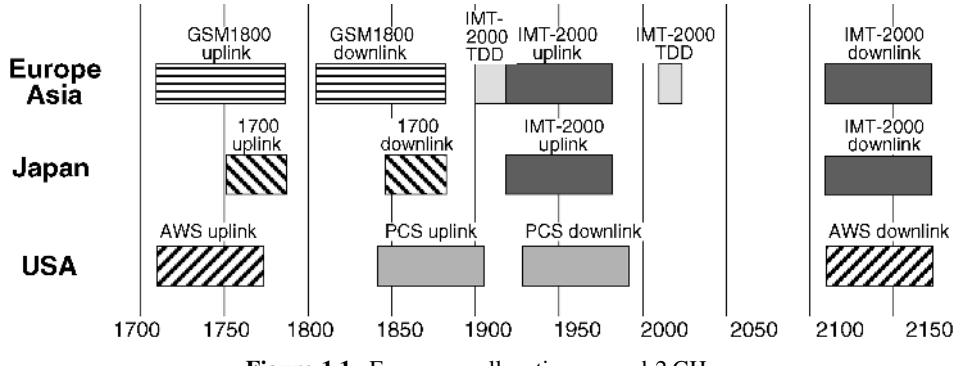

Figure 1.1. Frequency allocation around 2 GHz

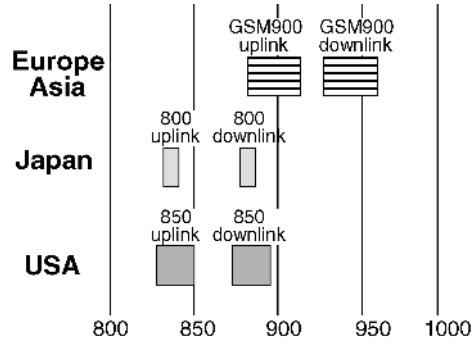

Figure 1.2. Frequency allocation around 800–900 MHz

band at 2 GHz. The coexistence of GSM and WCDMA in the same frequency band needs to be taken into account in the network planning. This is considered in Section 8.6.

The new IMT-2000 band around 2.6 GHz with a total 190 MHz spectrum will soon be available for the deployment of IMT-2000 and other mobile systems. In Europe, the spectrum includes 2×70 MHz for FDD systems and 50 MHz in the middle gap that could be used, for example, for TDD. The same 2.6 GHz spectrum is also available for mobile usage, including IMT-2000, in the USA. The band is already licensed and is likely to be used for TDD deployments due to the operator spectrum being more in line with the TDD arrangement.

The IMT-2000 mobile spectrum around 2 GHz is presented in Figure 1.1, around 800–900 MHz in Figure 1.2 and at 2.6 GHz in Figure 1.3. The WCDMA system is specified in 3GPP for all the frequency bands shown in these figures.

There are further frequencies where WCDMA specification and deployment are also considered, including the 700 MHz band in USA, the 2.3 GHz (Wireless Communication Services (WCS) band in the USA and part of the existing broadcast frequencies between 400 and 700 MHz.

1.3 Requirements for Third-Generation Systems

The second-generation systems were built mainly to provide speech services in macro cells. To understand the background to the differences between second- and third-generation systems, we need to look at the new requirements of the third-generation systems, which are listed below:

- Bit rates up to 2 Mbps;
- Variable bit rate to offer bandwidth on demand;

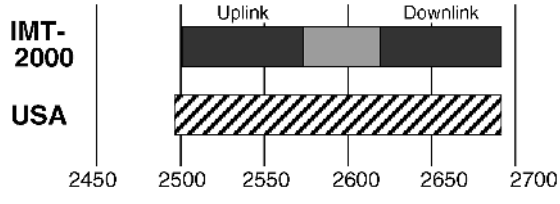

Figure 1.3. Frequency allocation around 2.6 GHz

Table 1.1. Main differences between WCDMA and GSM networks

	WCDMA/HSPA	GSM/EDGE
Carrier spacing	5 MHz	200 kHz
Frequency reuse factor	1	1–18
Frequency diversity	5 MHz bandwidth gives multipath diversity with Rake receiver	Frequency hopping with frequency diversity
Power control frequency	Up to 1500 Hz	Up to 2 Hz
Circuit and packet switched protocols	Same protocols in radio network	Different protocols
Packet scheduling and retransmission control	In base station (HSPA)	In base station controller
Network architecture	Flat architecture with two network elements in user plane (HSPA Release 7)	Four network elements in user plane
MIMO	2×2 MIMO in downlink	–
Downlink modulation	QPSK, 16QAM, 64QAM (HSPA Release 7)	GMSK, 8PSK

- Multiplexing of services with different quality requirements on a single connection, e.g. speech, video and packet data;
- Delay requirements from delay-sensitive real-time traffic to flexible best-effort packet data;
- Quality requirements from 10% frame error rate to 10^{-6} bit error rate;
- Coexistence of second- and third-generation systems and inter-system handovers for coverage enhancements and load balancing;
- Support of asymmetric uplink and downlink traffic, e.g. web browsing causes more loading to downlink than to uplink;
- High spectrum efficiency.

Table 1.1 lists the main differences between WCDMA/High Speed Packet Access (HSPA) and GSM/Enhanced Data Rates for GSM Evolution (EDGE) networks. The differences reflect the new requirements of the third-generation systems. For example, the larger bandwidth of 5 MHz is needed to support higher bit rates. HSPA Release 7 has also added a Multiple Input Multiple Output (MIMO) multi-antenna solution and higher order modulation 64QAM to support even higher data rates. HSPA pushes more functionalities to the base station and allows flat architecture, which improves the efficiency and the Quality of Service (QoS) capabilities for packet services.

1.4 WCDMA and its Evolution

European research work on WCDMA was initiated in the European Union research projects CODIT [1] and FRAMES [2] and within large European wireless communications

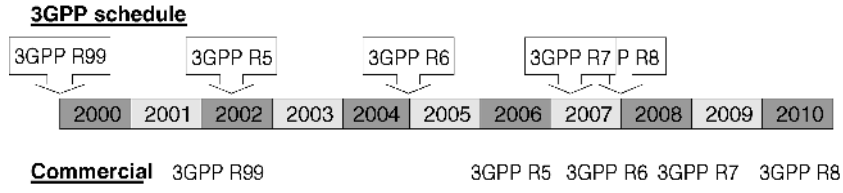

Figure 1.4. Standardisation and commercial operation schedule for WCDMA and its evolution

companies at the start of the 1990s [3]. Those projects also produced WCDMA trial systems to evaluate link performance [4] and generated the basic understanding of WCDMA necessary for standardisation. In January 1998 the European standardisation body ETSI decided upon WCDMA as the third-generation air interface [5]. Detailed standardisation work has been carried out as part of the 3GPP standardisation process. The first full set of specifications was completed at the end of 1999, called Release 99. The first commercial network was opened in Japan during 2001 for commercial use in key areas, and in Europe at the beginning of 2002 for the pre-commercial testing phase and for commercial use during 2003.

3GPP specified important evolution steps on top of WCDMA: HSPA for downlink in Release 5 and for uplink Release 6. The downlink solution, High Speed Downlink Packet Access (HSDPA) was commercially deployed in 2005 and the uplink counterpart, High Speed Uplink Packet Access (HSUPA), during 2007. Further HSPA evolution is specified in 3GPP Release 7, and its commercial deployment is expected by 2009. HSPA evolution is also known as HSPA+.

3GPP is also working to specify a new radio system called Long-Term Evolution (LTE), where the target for finalizing 3GPP standardization is during 2007. Release-7 and -8 solutions for HSPA evolution will be worked in parallel with LTE development, and some aspects of LTE work are also expected to reflect on HSPA evolution. HSPA, its evolution and LTE are covered in this book. The schedule for 3GPP standardization and for commercial deployment is illustrated in Figure 1.4.

The peak data rate evolution for WCDMA is illustrated in Figure 1.5. WCDMA Release 99 in theory enabled 2 Mbps, but in practice gave 384 kbps. HSPA in Release 5 and Release 6 pushes the peak rates to 14 Mbps in downlink and 5.7 Mbps in uplink. HSPA evolution in Release 7 brings a maximum 28 Mbps in downlink and 11 Mbps in uplink. LTE will then further push the peak rates beyond 100 Mbps in downlink and 50 Mbps in uplink by using a 20 MHz bandwidth.

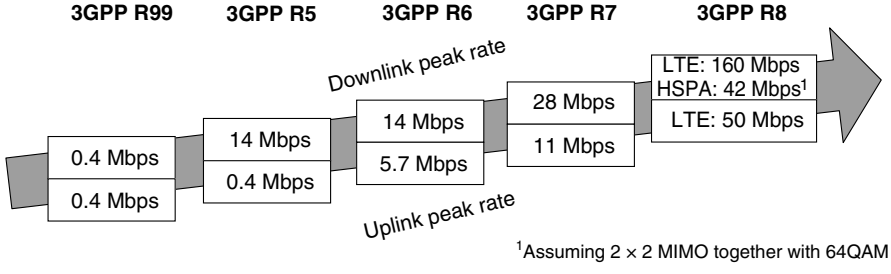

Figure 1.5. Peak data rate evolution for WCDMA

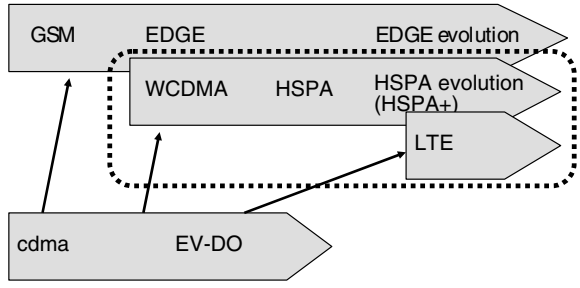

Figure 1.6. System evolution

1.5 System Evolution

GSM and WCDMA together account for 85% of the global mobile subscriptions, and their share keeps increasing. WCDMA is designed for coexistence with GSM, including seamless handovers and dual-mode handsets. Most of WCDMA networks are deployed on top of the existing GSM network. GSM, EDGE and EDGE evolution can be efficiently deployed together with WCDMA and its evolution. In the same way, LTE is designed for coexistence with GSM and WCDMA.

The cdma2000 market share globally in terms of mobile subscribers has been decreasing since 2004 and is currently slightly above 10%. A number of major cdma operators are turning to GSM/WCDMA for voice evolution to get access to the benefits of the large and open GSM/WCDMA ecosystem and economics of scale for low-cost mobile devices. The cdma data solution EV-DO is currently deployed commercially. For further data evolution a number of cdma operators are looking for HSPA or Worldwide Interoperability for Microwave Access (WiMAX) in the short term and 3GPP LTE in the long run.

The high-level system evolution is illustrated in Figure 1.6.

Looking back at the history of GSM, we note that, since the opening of the first GSM network in July 1991 (Radiolinja, Finland), several countries have reached more than 80% cellular phone penetration and the global GSM subscriber count exceeded 2 billion in 2006 – 15 years after the opening of the first network. The global cellular phone penetration currently stands at over 40%, with more than 1 million new GSM subscribers signing every day. Early GSM experiences showed that growth rates were very high once there were small-sized attractive terminals available with low power consumption. WCDMA is foreseen to follow the same trend. It took 7 years for GSM to reach 100 million subscribers and less than 6 years for WCDMA. Currently, there are more than 150 commercial WCDMA networks with more than 130 million subscribers.

Second-generation systems could already enable voice traffic to go wireless; now third-generation systems face the challenge of making a new set of data services go wireless as well.

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