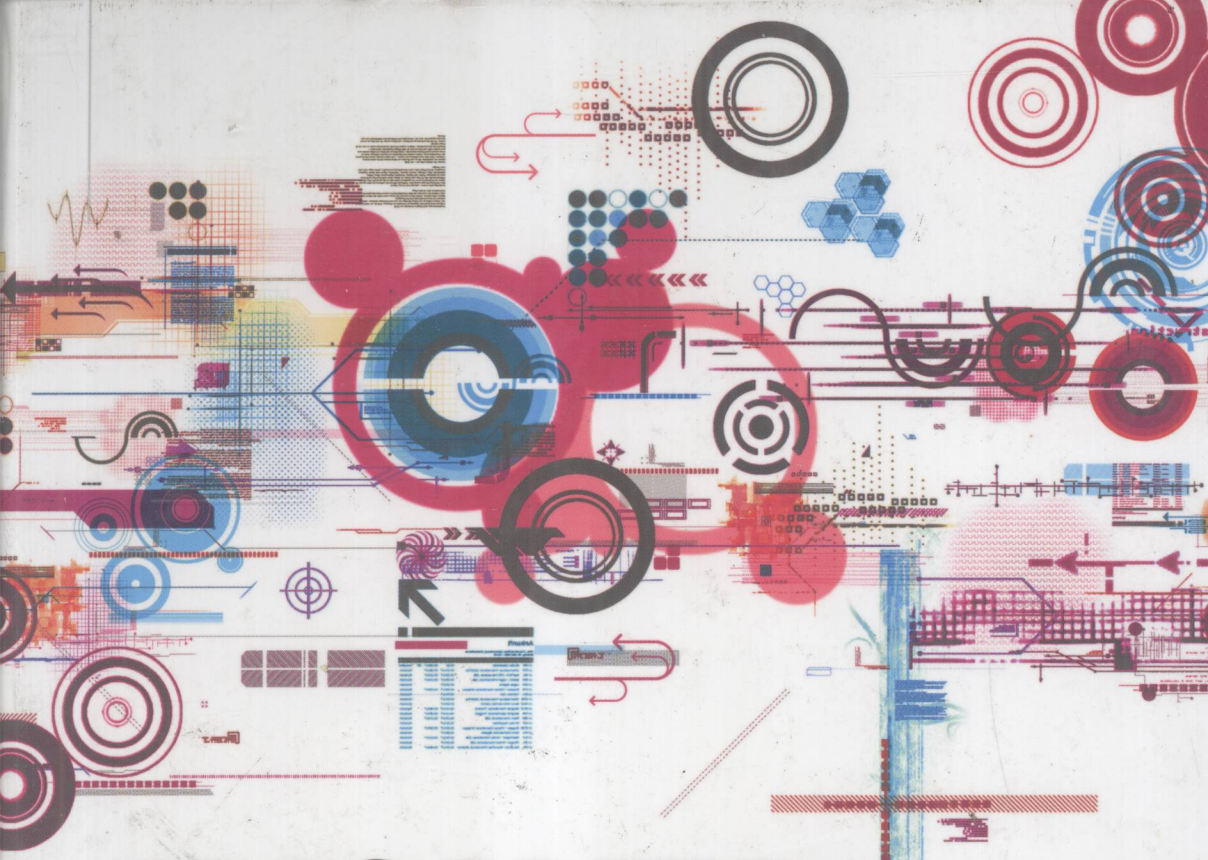

EVOLVED PACKET SYSTEM (EPS)

The LTE and SAE Evolution of 3G UMTS

Pierre Lescuyer | Thierry Lucidarme

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THE LTE AND SAE EVOLUTION OF 3G UMTS

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Erratum

Please note on page 170, the following should appear:

The author of chapter 3 acknowledges the following contributions.

Myung, Lim, Goodman (2006), *Peak-to-Average Power Ratio of Single Carrier FDMA Signals with Pulse Shaping.* Proc. of the IEEE PIMRC, Sept. 2006 pp. 1-5
For 3.2.6 equations 3.23 to 3.31 p 88-89 and three last lines after equation (3.31).

Pokhariyal, Monghal, Pedersen, Mogensen, Kovács, Rosa, Kolding (2007), *Frequency Domain Packet Scheduling Under Fractional Load for the UTRAN LTE Downlink.* VTC Spring: pp. 699-703
For 3.7.14 paragraph (i) p 147 and 4 first lines p 148 Figure 3.50.

Li, Feng, Zhong, *Inter-cell Interference Mitigation based on IDMA*. IEEE C802.16m-07/115r1, Tsinghua University
For 3.7.16 paragraph (i) and (ii) pp. 154-155

Meyer, Wiemann, Renfors, Torsner, Jung-Fu Cheng (2006), *ARQ Concept for the UMTS Long-Term Evolution*, Vehicular Technology Conference, 2006. VTC-2006 Fall. IEEE 64th Volume, Issue: Sept. 2006 pp. 1-5.
For 3.7.13 paragraph (i) pp. 143-144

Bossert, Huebner, Schuehlein, Haas, Costa, *On Cyclic Delay Diversity in OFDM Based Transmission Schemes.* http://whitepapers.techrepublic.com.com/whitepaper.aspx?docid=291148

3GPP Technical Report 25.814, Version 7.1.0, *Physical Layer Aspects for Evolved UTRA*, Sept. 2006.

EVOLVED PACKET SYSTEM (EPS)

Preface

With more than two billion customers, there is no doubt that 2G GSM and 3G UMTS cellular technologies are a worldwide success, adopted by most countries and network operators. The 3G UMTS technology has significantly evolved since the first declination. The first release of the standard, published in 1999, was mostly oriented towards dedicated channel allocation, and circuit-switched service support. Later on, the standard evolved to high-speed packet radio interface for downlink transmission (HSDPA for High Speed Downlink Packet Access) and uplink transmission HSUPA as a clear orientation towards IMS (IP Multimedia Subsystem) and IP-based services.

EPS (Evolved Packet System) represents the very latest evolution of the UMTS standard. EPS is also known by other acronyms related to technical study items being worked on at 3GPP standard committees: **LTE** (Long Term Evolution), which is dedicated to the evolution of the radio interface, and **SAE** (System Architecture Evolution), which focuses on Core Network architecture evolution.

Although still a 3G-related standard, EPS proposes a significant improvement step, with a brand new radio interface and an evolved architecture for both the Access and the Core Network parts. The two major disruptions brought by EPS are:

- **Improved performances** – characterized by a spectrum efficiency which is twice as large as HSDPA/HSUPA.
- **A packet-only system** – resulting in a unified and simplified architecture.

EPS is specified as part of the 3GPP family and, from that perspective, EPS will benefit from the same ecosystem that made the success of GSM and UMTS technologies. In addition, it is believed that technical and architectural evolutions brought by EPS prefigure future 4G networks (also known as IMT-Advanced networks).

This book presents the EPS evolution, as introduced in Release 8 of the 3GPP standard. It is not a substitute to the 3GPP standard, and advanced readers willing to dig into any specific domain of EPS are encouraged to consult the 3GPP specification documents which are referenced, when appropriate, through the different chapters.

The objective here is rather to provide a comprehensive system end-to-end vision of EPS, from the radio interface to the service level, including network architecture, radio protocols, as well as subscriber and session management. As EPS was not thought of as a completely new and standalone technology, the authors have also tried to show the inheritance and relations with 2G GSM and early 3G UMTS in terms of ground principles and technical aspects.

The technical content of this book is based on early documents and standards available at the time of writing. For that reason, the view presented here might be slightly different from the actual reference standard. This should, however, be constrained to very limited parts or specific details of this book.

Contents

1

Introduction

This chapter is an introduction to the evolution of UMTS systems, also known as EPS (Evolved Packet System). It provides a picture of current wireless and cellular communications, as an introduction to the requirements and motivations for Evolved 3G systems, which are the subject of the next chapter.

This chapter presents the following elements:

- A brief history of digital cellular systems, from 2G to the latest 3G evolutions.
- The evolution of the subscriber base.
- The various organizations which are supporting 3G and Evolved 3G system specifications.
- An overview of the spectrum usage.
- A list of Web links and documents directly connected to Evolved UMTS.

1.1 Wireless World Picture

Wireless cellular communication is certainly one of the major evolutions provided to the telecommunication world, experiencing an exponential growth from the early 1990s.

Wireless communication systems started to emerge in the mid-1980s, first based on so-called 1G (first-generation) analogue technologies like AMPS (Advanced Mobile Phone System) in the United States or NMT (Nordic Mobile Telephone) in Northern Europe. Those systems have evolved to 2G (second-generation) digital radio – providing robustness and better spectral efficiency – and, ultimately, to 3G, so as to offer global mobility and improved end-user experience over a wide range of services.

The unprecedented success of wireless communication has multiple business repercussions, by developing the potential for voice traffic and added-value services like Instant text and Voice Messaging, Multimedia Messaging (MMS), high-value content delivery or streaming, location-based services, etc.

As of mid-2006, there were:

- 2.3 billion mobile subscribers worldwide.
- 1.8 billion GSM mobile subscribers – GSM represented a 78% market share of cellular subscribers.

Evolved Packet System (EPS) P. Lescuyer and T. Lucidarme

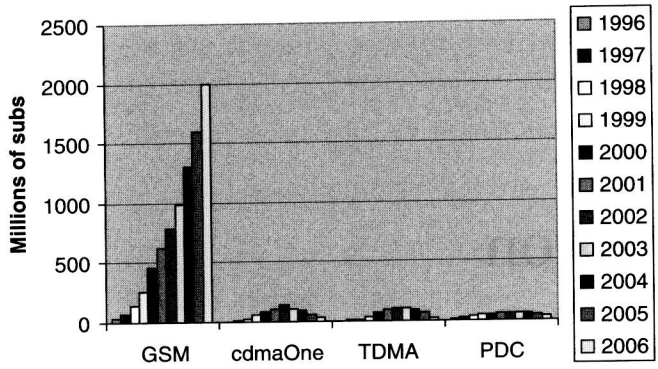

Figure 1.1 Evolution of 2G technologies.

Figure 1.1 describes the evolution of the main 2G technologies during the past few years:

- **GSM** (Global System for Mobile communications), originated from Europe and worldwide deployed.
- **cdmaOne**, corresponding the IS-95 North American standard. This technology is mainly used in Asia-Pacific, North and Latin America.
- **TDMA** (Time Division Multiple Access), corresponding to the IS-136 North American standard, mostly used in North America. This system is also called D-AMPS (Digital Advanced Mobile Phone System), as it is an evolution to AMPS, an analogue 1G cellular system.
- **PDC** (Personal Digital Cellular), the 2G standard developed and used exclusively in Japan.

It can be observed that TDMA and PDC started to decline rapidly as 3G cdma2000 and UMTS technologies became commercially available. This is true especially in Japan, where UMTS was commercially offered at the end of 2001 under the commercial name of FOMA (Freedom of Mobile Multimedia Access), and in North America, where 2G EDGE (Enhanced Data rates for GSM Evolution) and 3G cdma2000 services were been released at the end of 2000. The same also applies to cdmaOne networks, which progressively migrated towards early cdma2000 3G technology in 2002.

However, although new services like video-telephony and content streaming have been proposed as 3G started to be commercial, GSM and cdmaOne have continued to grow substantially along with first 3G network deployments, thanks to the remaining potential of voice services.

Figure 1.2 presents the 3G subscriber evolution from 2002 to 2006 for the two main 3G systems being deployed worldwide: the UMTS (Universal Mobile Telecommunications System) and the cdma2000. This figure shows that the cdma2000 is ahead of UMTS over this period of time in terms of subscribers. This can be explained by the fact that cdma2000 was released at the end of 2000 – earlier than UMTS, which only reached commercial availability in 2003. However, because of the GSM subscriber base prevalence, it can be expected that UMTS will follow the GSM trend within the next few years.

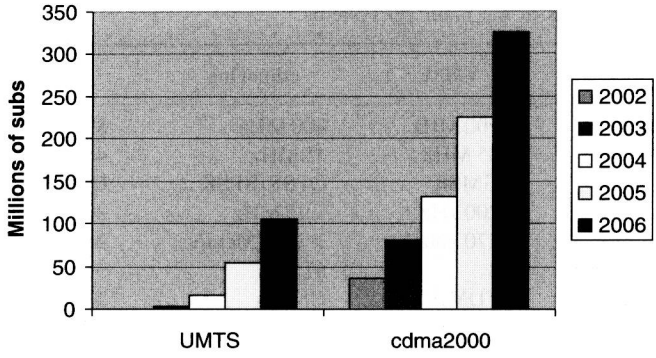

Figure 1.2 3G subscriber evolution.

1.2 About Technologies

This section provides an overview of the main 2G and 3G technologies, their evolutions, and how they relate to each other. At first glance, the picture represented by Figure 1.3 contains lots of different systems, but most of them actually fall into two main families: the 'MAP' and the 'IS-41'. In mid-2006, MAP (Mobile Application Part) systems were adopted by 80% of the subscriber base, while the IS-41 family captured the remaining 20%.

Most of the networks which were using PDC and TDMA moved towards MAP systems (Japan PDC was replaced by UMTS in 2001 and most of the TDMA networks have been

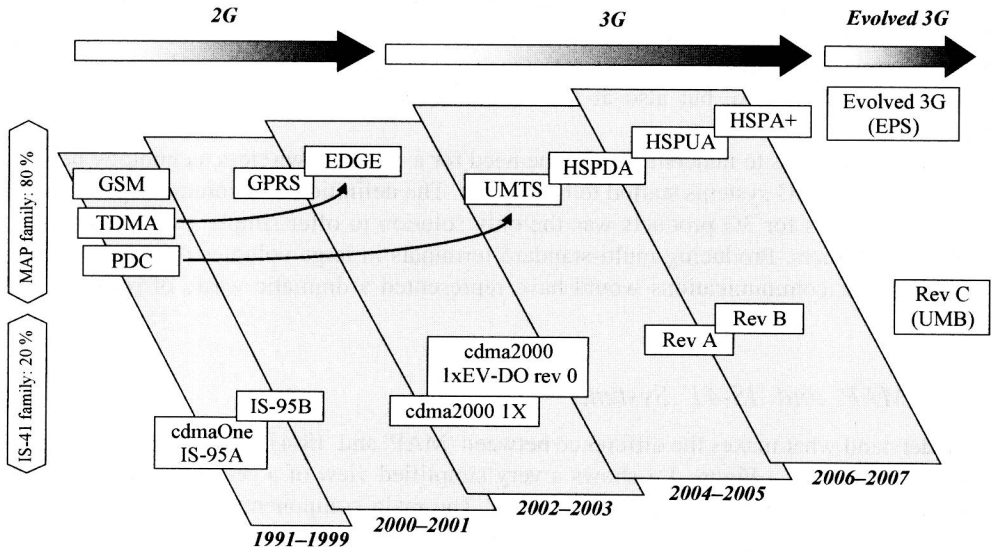

Figure 1.3 Evolutionary path of 2G and 3G technologies.

Table 1.1 Core parameters of the main 2G systems.

	GSM	cdmaOne	TDMA	PDC
Initial frequency band	900 MHz	800 MHz	800 MHz	900 MHz
Duplex separation	45 MHz	45 MHz	45 MHz	130 MHz
Modulation	GMSK	QPSK/BPSK	QPSK	QPSK
RF carrier spacing	200 kHz	1.25 MHz	30 kHz	25 kHz
Carrier modulation rate	270 kbits/s	1.2288 Mchip/s	48.6 kbits/s	42 kbits/s
Traffic channel per carrier	8	61	3	3
Access method	TDMA	CDMA	TDMA	TDMA
Initial data rate	9.6 kbits/s	14.4 kbits/s	28.8 kbits/s	4.8 kbits/s
Speech codec algorithm	RPE-LTP	CELP	VSELP	VSELP
Speech rate	13 kbits/s	13.3 kbits/s	7.95 kbits/s	6.7 kbit/s

upgraded to 2G EDGE). This is the reason why PDC and TDMA systems are considered in this picture as being part of the MAP family, although not being MAP technologies as such.

Both 3G standard family systems are moving towards Evolved 3G technologies. On the MAP side, Evolved 3G systems are known as EPS (Evolved Packet System), described in this book. The IS-41 standard family will move towards cdma2000 Revision C, also known as UMB (Ultra Mobile Broadband).

1.2.1 Heterogeneous 2G Systems

This section provides a very brief description of the main 2G systems' initial characteristics. Table 1.1 highlights the main differences between the four leading 2G technologies, not only in terms of radio basic parameters (such as radio modulation, carrier spacing and radio channel structure), but also at the service level (initial data rate and voice-coding scheme).

This table helps us to understand why the need for a common wireless technology became obvious once the 2G systems started to be popular. The definition of a common specification and product basis for 3G products was the only solution to offer simple global mobility to wireless customers. Producing multi-standard terminals in large volumes only for covering public cellular communications would have represented a dramatic waste of resource and energy.

1.2.2 'MAP' and 'IS-41' Systems

To understand what makes the difference between 'MAP' and 'IS-41' – the two main families of cellular systems – Figure 1.4 shows a very simplified view of a cellular communication system that all 2G and 3G systems comply to. The main components are:

- **The end-user terminal**, generally associated to an integrated circuit card containing subscriber-related information such as identifiers, security keys, etc.

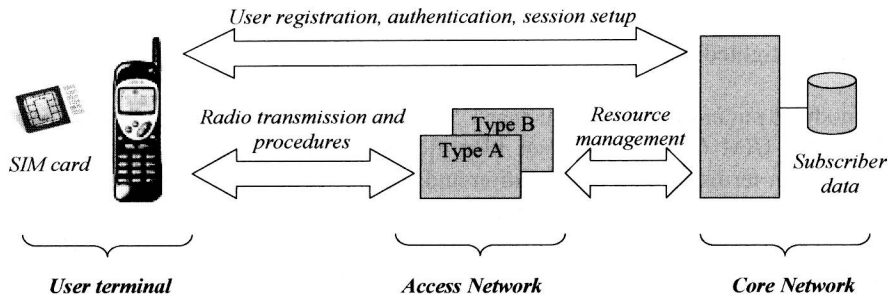

Figure 1.4 A simplified view of cellular communication systems.

- **The Access Network part**, which is responsible for radio-specific related tasks like secure and reliable transmission over the radio interface, radio resource management, handling of radio mobility procedures (this includes radio measurement processing as well as the handover decision process), etc.
- **The Core Network part**, which is responsible for end-to-end session setup, subscriber data management (this later includes authentication, authorization and billing), inter-working with external packet and circuit-switched networks, etc.

As pointed out before, the cellular systems can be distributed into two categories: the 'MAP' one and the 'IS-41' one. The difference between the two is not really about radio interfaces. Of course, radio interfaces are different between the two families, but this happens anyway within a given system, because of technological evolutions. These evolutions usually provide added value, such as better protection over radio transmission errors, increased bit rate, better radio resource usage efficiency, etc. These improvements often require the terminal manufacturers to design multi-mode terminals able to cope with new modulations or new data-coding schemes.

The major differences between those two families actually reside in the two following points:

- **The handling and management of user identities and subscription data** – this refers to the way customers are identified, and how these identities are stored in both network and user terminals.
- **The network procedures** – GSM and other technologies derived from GSM rely on the MAP (Mobile Application Part) protocol, whereas cdmaOne and cdma2000 rely on a completely different IS-41 North American standard. MAP and IS-41 are end-to-end protocols used between the terminal and the Core Network, and also between Core Network entities, for the purpose of user registration and authentication, call or data session setup, mobility management, and management of user subscription data.

In the past, systems from the two families used to be quite different and incompatible. However, as in recent evolutions of the standards, lots of effort has been made to reduce the gap and define synergies between MAP and IS-41 systems, for the benefit of R&D effort and product simplification. This can be observed at many levels when looking into latest detailed