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

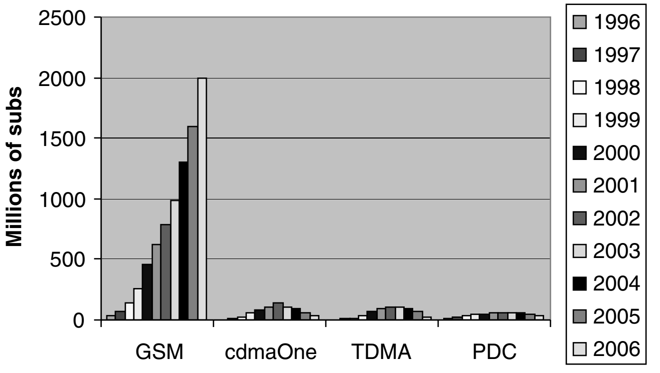

Figure 1.1 Evolution of 2G technologies.

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.

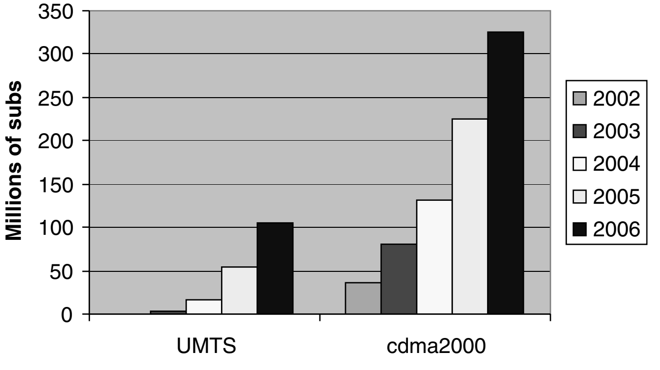

Figure 1.2 3G subscriber evolution.

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

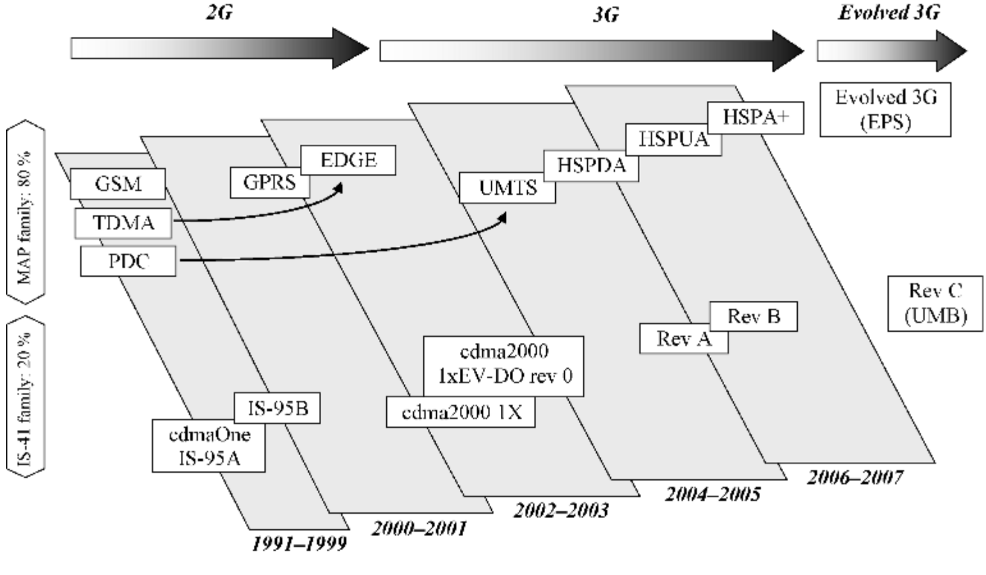

Figure 1.3 Evolutionary path of 2G and 3G technologies.

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.

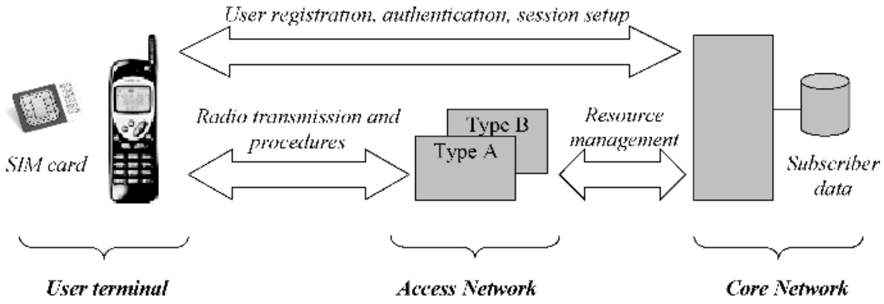

Figure 1.4 A simplified view of cellular communication systems.

- **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

GSM/UMTS and cdma2000 specifications. For illustration purposes, the two following major points are highlighted:

- User modules put in the terminal such as USIM (Universal Subscriber Identity Module) for UMTS or R-UIM (Removable User Identification Module) for cdma2000 have lots of similarities in terms of data organization and management process.
- The all-IP architecture evolution introduced in both UMTS and cdma2000 under different names – IMS (IP Multimedia Subsystem) for UMTS and MMD (MultiMedia Domain) for cdma2000 – are very close to each other in terms of architecture and underlining concepts. Besides, both IMS and MMD make use of SIP (Session Initiation Protocol) to set up communication sessions.

In the following sections, more details are provided about the main steps of the MAP and IS-41 evolutionary paths.

1.2.3 The MAP Technologies

This section briefly describes the technologies part of the MAP family. Figure 1.5 compares the typical user data throughput for each of them.

(i) GSM

The well known GSM (Global System for Mobile communications) entered into commercial service in 1991. This technology uses a TDMA/FDMA (Time Division Multiple Access/ Frequency Division Multiple Access) radio multiplexing scheme and GMSK (Gaussian Minimum Shift Keying) radio modulation. In its early days, GSM was only providing a voice service, SMS (Short Message Service) and low-rate circuit-switched data at 9.6 Kb/s.

(ii) GPRS

GPRS (General Packet Radio Service) is an evolution of GSM, designed for packet data communication. Based on the same GMSK modulation, GPRS provides, however, better user

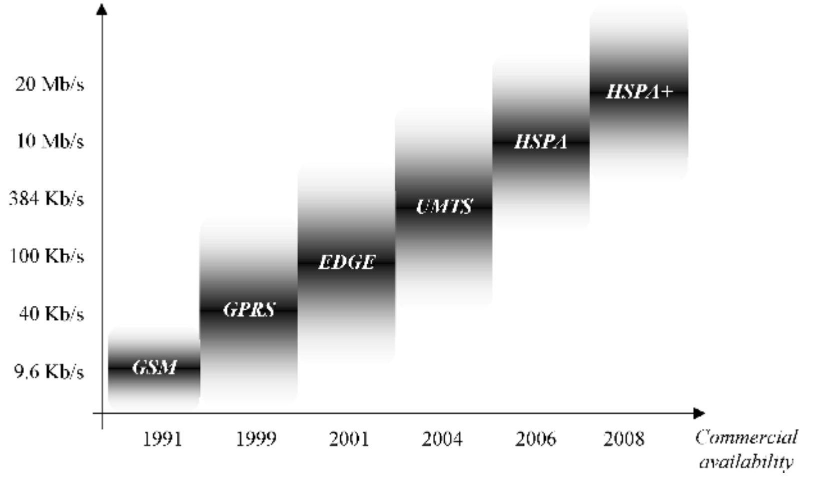

Figure 1.5 Typical downlink user data throughput of MAP systems.

rate by providing the least robust but fastest coding scheme (theoretical maximum bit rate is around 20 Kb/s per radio time slot) and the possibility to aggregate several radio slots for data transmission.

This system was intended to be more suitable and efficient for packet data applications, as it relies on sharing a set of radio channels among several terminals, for both uplink and downlink transmission.

(iii) EDGE

EDGE (Enhanced Data rates for GSM Evolution) introduces the 8-PSK (8 Phase Shift Keying) modulation, providing increased data rate. Using the fastest coding scheme, EDGE provides a maximum theoretical bit rate of around 50 Kb/s per radio time slot.

When combined with GPRS, it is possible to aggregate several EDGE-coded radio slots to increase the peak data rate for packet applications.

(iv) UMTS

UMTS (Universal Mobile Telecommunications System) is based on a standard developed by the 3GPP (3rd Generation Partnership Project), commercially launched in 2001 in Japan – under the name of FOMA (Freedom of Mobile Multimedia Access) – and 2003 in other countries. UMTS supports two variants: a FDD mode, being the most deployed, and a TDD mode, mainly supported for the Chinese market.

UMTS relies on the CDMA (Code Division Multiple Access) multiplexing scheme using a high chip rate direct spread sequence. In its first form, UMTS/FDD advantages were limited to increased data rates (up to 384 Kb/s per user on a single channel), the possibility of simultaneous packet and circuit applications, and improved roaming capabilities.

A theoretical maximum bit rate of 2 Mb/s over dedicated channels has been defined within the specification, but has never been deployed as such in commercial networks.

UMTS is often presented as the 3G evolution of GSM networks. Although the UMTS radio interface is completely different from the GSM/EDGE one, a lot of architectural concepts and procedures have been inherited from GSM. From a practical perspective, this can be expressed as follows:

- UMTS SIM cards are backward-compatible with GSM, meaning that a UMTS SIM can be inserted in a GSM phone, so that the SIM owner can benefit from services available under the GSM coverage.
- The MAP protocol of UMTS networks is an evolution of the GSM MAP as well as the packet and circuit session protocol being used between the terminal and the network. Although new elements and procedures have been defined in 3G, they rely on the same basis of concepts and principles.
- Specific network and user terminal procedures have been defined within the standard to ensure seamless mobility between GSM and UMTS, for both packet and circuit applications.

(v) HSDPA

HSDPA (High Speed Downlink Packet Access) is a UMTS enhancement, commercially available at the end of 2005.

The aim of HSDPA is to increase user throughput for packet downlink transmission (from network to mobile). For this purpose, new modulation has been introduced – 16 QAM (Quadrature Amplitude Modulation) – allowing a theoretical peak rate of 14.4 Mb/s (using the lowest channel protection algorithm). At first, 1.8 or even 3.6 Mb/s was expected as a realistic user experience.

From a radio interface perspective, HSDPA is based on a shared radio scheme and real time (every 2 ms) evaluation and allocation of radio resources, allowing the system to quickly react to data bursts. In addition, HSDPA implements a HARQ (Hybrid Automatic Repeat Request) which is a fast packet retransmission scheme located in the Base Station as close as possible to the radio interface. This allows fast adaptation to a change in radio transmission characteristics.

(vi) HSUPA

HSUPA (High Speed Uplink Packet Access) is the equivalent of HSDPA for uplink (from terminal to network) packet transmission.

HSUPA actually implements the same sort of techniques already used by HSDPA, such as a HARQ packet retransmission scheme providing low latency packet repetition between the terminal and the base station, and a reduced transmission time interval of 2 ms. However, unlike HSDPA, HSUPA is not based on a complete shared channel transmission scheme. Each of the HSUPA channels is actually a dedicated channel with its own physical resources. The actual resource sharing is provided by the Base Station, which allocates transmission power for uplink HSUPA transmission based on resource requests sent by terminals.

In theory, HSUPA can provide up to 5.7 Mb/s, using the top-level mobile category and larger transmission resources than can be allocated to a single terminal.

HSUPA may be combined with HSDPA – the association of the two is often referred to as HSPA (High Speed Packet Access) – so that data sessions can benefit from an increased data rate for both uplink and downlink.

As described in the following chapters, it is interesting to note that Evolved 3G makes use of techniques similar to HSDPA and HSUPA for transmission over the radio interface. The main difference is that those techniques are integrated from the early beginning of the definition of the Evolved 3G new interface and are applicable to all data-transmission flows. From a historical perspective, HSDPA and HSUPA have been added on top of a UMTS radio access initially designed for high bit rate, dedicated and circuit-oriented transmission.

(vii) HSPA+

High Speed Packet Access Plus, also known as ‘HSPA Evolution’, is an enhancement of HSDPA and HSUPA technologies, and intends to provide a fully 3G backward-compatible evolution step, until Evolved UMTS systems are available. HSPA+ is intended to be commercially available in 2008.

It is expected that HSPA+ will be as efficient as Evolved UMTS within the typical 5-MHz WCDMA channel bandwidth, thanks to a number of technical evolutions, including the use of MIMO (Multiple Input Multiple Output) and higher-order modulations (like 64 QAM in downlink and 16 QAM in uplink) for radio transmission and reception. Architectural evolutions are also envisaged to reduce data-transmission latency.

HSPA+ has to be considered as an optional and intermediate step between current HSPA and Evolved UMTS networks, intended to provide increased performance in a 3G backward-compatible way. This offers operators an opportunity to smoothly upgrade their networks and benefit from HSDPA enhancement until Evolved UMTS networks actually become commercially available.

1.2.4 The IS-41 Technologies

The IS-41 technology family contains lots of evolutions. For clarity, Figure 1.6 describes the various versions of cdma2000 standard, in relation to the names used in public and press communications.

As opposed to the MAP standard family, North American CDMA technology has been thought of in terms of a backward-compatible evolutionary path, starting from 2G IS-95 to 3G cdma2000.

The 3G cdma2000 main branch leads to 1xEV-DV (Evolution Data and Voice), which is probably never going to be available commercially on a large scale. The other 1xEV-DO branch (Evolution Data Optimized) is already in service and provides an enhanced user rate. This will eventually lead to the Revision C, which is the cdma2000 equivalent of Evolved UMTS.

The rest of this section briefly describes the technologies part of the IS-41 family. Figure 1.7 compares the typical user data throughput for each of them.

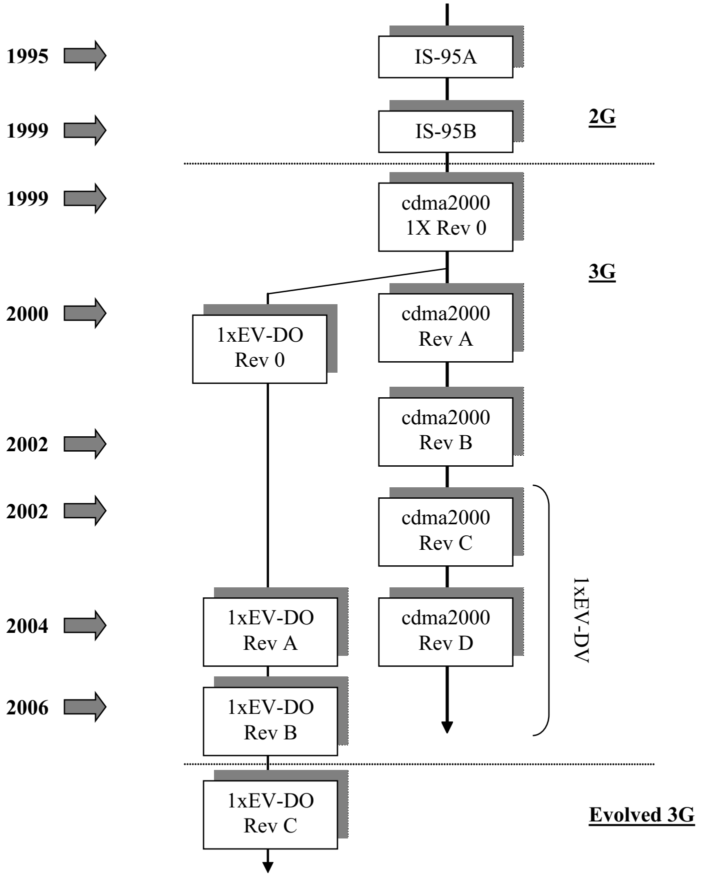

Figure 1.6 IS-41 standard family publication dates.

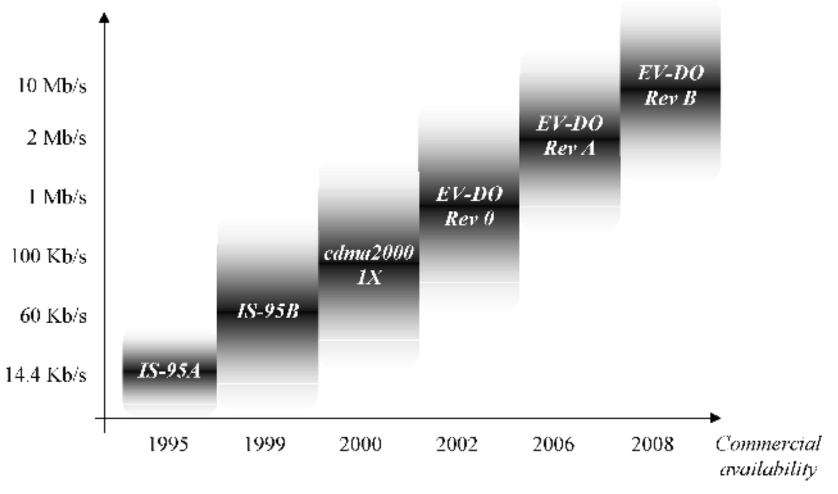

Figure 1.7 Typical downlink user data throughput of IS-41 systems.

(i) cdmaOne (IS-95A)
cdmaOne is the brand name of the first CDMA cellular system, deployed in September 1995, initially based on IS-95A North American standards. This system provides voice services as well as circuit-switched data up to 14.4 Kb/s.

This system was mostly deployed in North and Latin America, as well as other countries, such as South Korea and Australia. This system provided a similar grade of service as the GSM technology which was delivered at that time in other parts of the world.

(ii) cdmaOne (IS-95B)
IS-95B is a standard evolution of IS-95A systems, first deployed in September 1999, offering simultaneous voice and packet data services up to 115 Kb/s (maximum theoretical bit rate).

(iii) cdma2000 1X
cdma2000 1X – commercially deployed in October 2000 – is the first 3G system derived from the IS-95 technology. The cdma2000 standard has been developed by 3GPP2 (3rd Generation Partnership Project 2) and is part of approved radio interfaces for IMT-2000. (Please refer to the section on standard organizations for further details.)

As opposed to the GSM/UMTS transition, the cdma2000 radio interface has been specified as an evolution of the already existing CDMA-based 2G IS-95 standards. This can be seen in many parts of the radio interface definition, such as the structure of the common radio channel or the carrier spacing (the cdma2000 1.25-MHz carrier spacing is inherited from the IS-95 standard). This provides the reason why cdma2000 systems have been commercially available around 3 years before 3G UMTS systems.

The '1X' name comes from the fact that this system relies on a single 1.25-MHz carrier, as opposed to multi-carrier transmission schemes making use of three 1.25-MHz carriers. The 3X MC (or Multi-Carrier) scheme was only referred to as an IMT-2000 candidate technology, but has never been deployed in this form.

Initially, cdma2000 1X was able to provide voice services as well as up to 307 Kb/s downlink packet data and 153 Kb/s on the uplink on a single 1.25-MHz carrier.

More details about the physical layer of this system can be found in document C.S0002, 'Physical Layer Standard for cdma2000 Spread Spectrum Systems', published by the 3GPP2 consortium.

From that initial cdma2000 1X version, two branches have emerged. The first one is based on the evolution of the 1X specifications, leading to the 1xEV-DV (Evolution Data and Voice) and providing a high bit rate as well as simultaneous voice and data services in a fully backward-compatible way with 1X systems. The second branch, known as 1xEV-DO (for 'Evolution Data Only', which was eventually renamed 'Data Optimized'), provides improved data transmission as an overlay technology.

Eventually, EV-DV development was stopped, due to the lack of interest from operators and manufacturers.

(iv) cdma2000 1xEV-DO Revision 0

The 1xEV-DO (Evolution Data Optimized) has been in commercial service since the end of 2002.

This evolution allows the operator to provide simultaneous voice and high-speed packet data at the cost of an additional 1.25-MHz carrier. For that reason, a 1xEV-DO requires terminals to support multi-mode radio interface, in order to be fully backward-compatible with 1X and IS-95 technologies.

EV-DO Revision 0 introduces new 8-PSK and 16-QAM modulations, and is able to provide theoretical peak data speeds of 2.4 Mb/s on the downlink and 153 Kb/s on the uplink.

More information about Revision 0 additions can be found in document C.S0024-0, 'cdma2000 High Rate Packet Data Air Interface Specification', published by the 3GPP2 consortium.

(v) cdma2000 1xEV-DO Revision A

Commercially available in 2H2006, the Revision A objective was to improve the lack of real Quality of Service for packet data transmission and limited uplink capabilities of Revision 0.

As a result, Revision A systems are able to deliver theoretical peak data speeds of 3.1 Mb/s on the downlink and 1.8 Mb/s on the uplink. Moreover, packet prioritization schemes and more robust algorithms for uplink transmission have also been introduced.

More information about Revision A additions can be found in document C.S0024-A, 'cdma2000 High Rate Packet Data Air Interface Specification', published by the 3GPP2 consortium.

(vi) cdma2000 1xEV-DO Revision B

Revision B standard evolution was published in the first half of 2006 for planned commercial availability in 2008. Its main objective is to improve multimedia experience and packet-based delay-sensitive application performance in general.

This evolution introduces a new 64-QAM modulation scheme as well as a multi-carrier transmission scheme. Thanks to these new radio capabilities, Revision B systems will be able to deliver theoretical peak rates of 73.5 Mb/s in the forward link (from network to terminal) and 27 Mb/s in the reverse link (from terminal to network) through the aggregation of 15 1.25-MHz carriers within 20 MHz of bandwidth.

(vii) cdma2000 1xEV-DO Revision C

Revision C, currently under development, is the equivalent of the 3GPP Evolved UMTS. This new step in the EV-DO standard family is also known as UMB (Ultra Mobile Broadband).

It is planned that this evolution will support flexible and dynamic channel bandwidth scalability from 1.25 MHz up to 20 MHz and will be backward-compatible with Revisions A and B.

As for Evolved UMTS, Revision C is oriented towards 'all over IP' service support over a high-speed packet radio interface.

More information about Revision A additions can be found in document C.S0084-000, 'Overview for Ultra Mobile Broadband (UMB) Air Interface Specification', published by the 3GPP2 consortium.

1.3 Standards and Organizations

The development and introduction of worldwide technology cannot be achieved without global standard organizations.

This section describes the structure of the main standard organizations and support bodies involved in future system definition, in an attempt to shed some light on the jungle of acronyms, terms and initiatives emerging around 3G and its evolution.

1.3.1 The Role of ITU

The ITU (International Telecommunication Union), as a worldwide telecommunication standard body, played a key role in 3G definition.

(i) ITU and the IMT-2000 Framework

The IMT-2000 framework (International Mobile Telecommunications 2000) was initially launched by the ITU (International Telecommunication Union), in order to define 3G system and evolution for heterogeneous 2G technologies (Figure 1.8). This was felt the best way to define a common basis for performance, global access and seamless mobility requirements.

The IMT-2000 framework not only aims at defining international standards for 3G, but also cares about frequency spectrum issues, technical specifications for radio and network components, as well as regulatory aspects.

As a result of the call for the submission of candidate IMT-2000 radio interfaces, up to 16 candidates as Radio Access Technologies (RAT) have been proposed by various Regional Standard Organizations. The proposals were related to the terrestrial radio interface, as well as satellite systems. In 1999, a decision was eventually made by IMT-2000 to only accept five of them, as described in document M.1457, 'Detailed Specifications of the Radio Interfaces of International Mobile Telecommunications – 2000', published by the IUT:

- **CDMA DS** (Direct Spread): this corresponds to the FDD mode of UMTS.
- **CDMA MC** (Multi Carrier): this corresponds to the cdma2000 system family.
- **CDMA TDD**: this corresponds to the TDD mode of UMTS. As in UMTS/TDD specifications, the two variants are represented: the low chip rate mode (1.6-MHz bandwidth) and the high chip rate mode (5-MHz bandwidth).

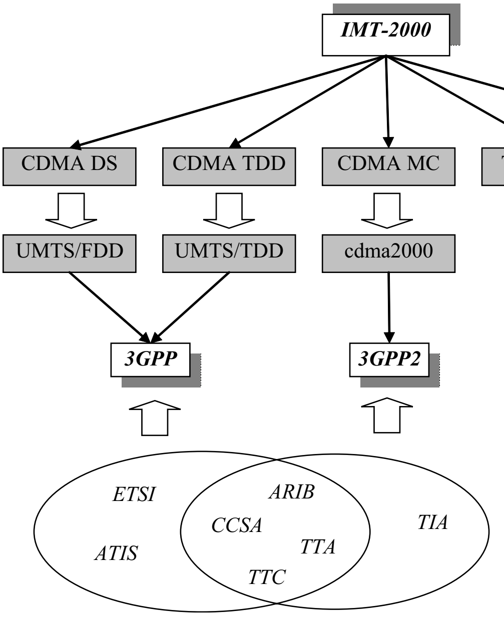

Figure 1.8 3G technologies and standard bodies.

- **TDMA SC** (Single Carrier): this access technology is based on 2G GSM/EDGE interface evolution.
- **FDMA/TDMA**: this corresponds to a high bit rate and packet data evolution of 2G DECT standard (Digital European Cordless Telephone).

Although ITU documents describe five technologies for use in the IMT-2000 terrestrial radio interface, only the CDMA-based first three systems have gained momentum within the industry.

The definition of those three radio systems was eventually handled by two 3G cross-country standardization bodies further described in this chapter: the 3GPP and the 3GPP2.

(ii) The IMT-Advanced Evolution
IMT-Advanced is a concept from the ITU for mobile communication systems with capabilities which go further than that of IMT-2000. IMT-Advanced was previously known as 'systems beyond IMT-2000'. The initial objective of ITU is to enable the commercial availability of IMT-Advanced compliant systems as early as 2011.

1.3.2 3G Cross-Country Standardization Bodies

The concept of 'cross-country organization' emerged in 1998, resulting from IMT-2000 activities. This was felt as the best way to ensure worldwide 3G adoption and success.

Table 1.2 List of regional organizations involved in 3GPP and 3GPP2.

ARIB	Association of Radio Industries and Businesses	Japan
ATIS	Alliance for Telecommunications Industry Solution	North America
CCSA	China Communications Standards Association	China
ETSI	European Telecommunication Standard Institute	Europe
TIA	Telecommunications Industry Association	North America
TTA	Telecommunications Technology Association	Korea
TTC	Telecommunications Technology Committee	Japan

As a result of IMT-2000's call for candidate 3G radio access technologies, two parallel consortiums were created in early 1999: the 3GPP (3rd Generation Partnership Project) and the 3GPP2 (3rd Generation Partnership Project 2), both aiming at producing technical specifications for third-generation mobile systems.

The decision process within these two organizations is driven by the consensus (or by votes in exceptional cases in which consensus is not reached), and a lot of care is given to maintaining as much as possible the balance between regions in the process of attribution of chairman seats of the various technical working groups.

The main difference between the two is that 3GPP is promoting UMTS (Universal Mobile Telecommunications System) – the 3G evolution from the GSM/MAP system family – whereas 3GPP2 is focusing on IS-41 technology evolution.

3GPP and 3GPP2 consortiums involve lots of different organizations like terminal and network manufacturers, the main network operators, all of them representing the various regional standard bodies listed in Table 1.2. The role of the regional organizations listed in this table is to promote locally unified standards and may include product testing and certification. Their scope of activity is not limited to cellular communication and may also include satellite communication, broadcasting systems, private mobile radio systems, etc.

The regional organizations involved in 3GPP are ARIB, ATIS, CCSA, ETSI, TTA and TTC. The regional organizations involved in 3GPP2 are ARIB, CCSA, TIA, TTA and TTC.

1.3.3 The Structure of 3GPP

As the focus of this book is Evolved UMTS, more details are provided about the 3GPP structure and associated working groups (Figure 1.9).

The technical part of the 3GPP consortium is composed of four groups or TSG (Technical Specification Groups):

- **SA** (Services and system Aspects), which is responsible for the overall architecture and service definition.
- **RAN** (Radio Access Networks), which is responsible for the features, interfaces and protocols of the Access Network.
- **CT** (Core Network and Terminals), which is responsible for Core Network specific protocols and end-to-end protocols for call control and session management.
- **GERAN** (GSM EDGE Radio Access Network), which is responsible for the evolution of the GSM/EDGE-based Radio Access Network. As described in previous sections, UMTS

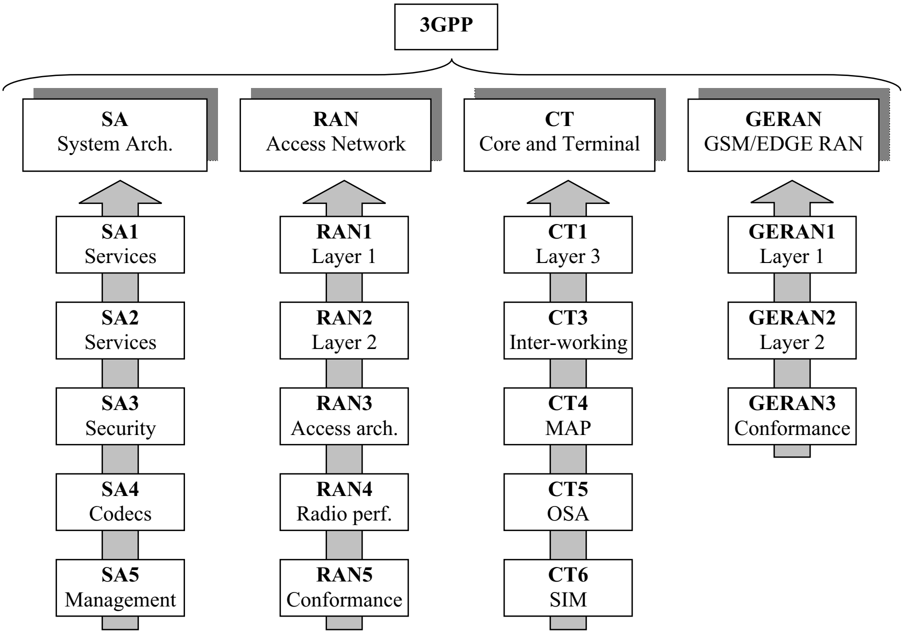

Figure 1.9 The structure of 3GPP.

inheritance from GSM technology is quite significant from a Core Network and Service perspective. This is the reason why this TSG, initially part of the ETSI, was eventually moved to the 3GPP organization in late 2000.

Each of these groups is composed of different working groups (or WG), each of them having responsibility for an area of work requiring a specific level of expertise.

The SA TSG (Services and system Aspects) is composed of the following groups:

- **SA1** is in charge of high-level service and feature requirements. SA1 produces specific documents (called Stage 1 specifications) focused on system and service capabilities and used as a baseline by other groups.
- **SA2** has the responsibility of defining network architecture and the features to be supported by the network entities, based on the stage 1 documents provided by SA1. SA2 produces Stage 2 specifications, which are used as inputs by groups in charge of detailed interface specifications.
- **SA3** is the security group of 3GPP. Its role is to set up security requirements for the overall system, and produce specifications for security algorithms to be applied in the network.
- **SA4** works on the specification of speech, audio, video and multimedia codecs applicable to circuit and packet-based applications.
- **SA5** is focused on network management. SA5 has the responsibility of specifying the architecture, procedures and interface-related issues of network management, including charging, configuration and performance management, inventory, etc.

The RAN TSG (Radio Access Networks) is composed of the following groups:

- **RAN1** is responsible for the definition of the physical (Layer 1) interface of the UTRAN Access Network. This includes the specification of the radio modulation, channel coding, physical layer measurements, etc.
- **RAN2** works on the radio interface protocols used on top of the physical layer. This includes Layer 2 protocols for data transmission as well as the signalling procedures related to radio interface such as radio resource allocation, handover management, etc.
- **RAN3** is in charge of overall UTRAN architecture. This includes the definition of interfaces between entities of the Access Network, as well as the specification of the UTRAN transport network.
- **RAN4** is responsible for the RF conformance aspects of UTRAN and produces test specifications for radio network and terminal equipment regarding RF transmission and reception performance.
- **RAN5** works on radio interface conformance test specifications. RAN5 produces test specifications, based on RAN4 documents, and signalling procedures defined by other groups such as RAN2.

The CT TSG (Core Network and Terminals) is composed of the following groups:

- **CT1** has the responsibility of specifying Layer 3 protocols, being used between the Core Network and terminals to set up communication sessions for circuit, packet and IMS-based applications.
- **CT3** is in charge of the inter-working between 3GPP networks and external packet or circuit networks. This includes signalling or protocol inter-working, as well as possible user plane data adaptation.
- **CT4** is in charge of supplementary service definitions (such as SMS or Call Transfer) as well as the specification of interfaces and protocols between Core Network elements such as the MAP.
- **CT5** works on UMTS OSA (Open Service Access) and produces Application Programming Interfaces to facilitate UMTS service definition and creation.
- **CT6** is in charge of the definition of the format of the Subscriber Identity Module (SIM). This includes the specification of SIM card data content, format and organization, as well as interfaces between the SIM card and external entities.

The GERAN TSG (GSM EDGE Radio Access Network) is composed of the following groups:

- **GERAN1** (the RAN1 equivalent) is responsible for the definition of the physical interface of the GSM/EDGE Access Network.
- **GERAN2** (the RAN2 equivalent) works on the radio interface protocols defined on top of the physical layer.
- **GERAN3** is in charge of conformance test specification for the GERAN access network.

In the scope of 'Evolved UMTS', the structure of 3GPP will not change. All existing TSG and most of their Working Groups will extend their scope in order to cover Evolved UMTS requirements and specifications.

1.3.4 The NGN Evolution

NGN (Next Generation Networks) is a new broad term which refers to emerging network architectures. Briefly, NGN is a concept of converged architecture which natively supports a wide range of services, such as:

- Conversational services (person-to-person communications or voice call).
- Messaging (email, short or multimedia message exchange).
- Content-on-demand (streaming, video on demand, broadcast, multicast).

Beyond this very general and high-level statement, there are actually two main ideas behind NGN. All information is transmitted via packets with a strong support of Quality of Service mechanisms ensuring that the end-to-end service-level agreement is reached. This mandates that the packet transport network is aware of the Quality of Service requirements and supports all the needed features to control and enforce them.

The second principle relates to the decoupling of service and transport layers, allowing them to be offered separately and to evolve independently. This clear separation between services and transport should allow the provision of new services independently from the access technology and transport type.

NGN standardization is actively going on in parallel within two major standardization bodies:

- The Global Standard Initiative (GSI) within the ITU-T.
- The TISPAN technical body (Telecommunication and Internet converged Services and Protocols for Advanced Networking) within the ETSI.

Through a large number of working groups, the two standardization bodies study and define technical aspects of NGN, such as the general architecture, Quality of Service support, network management, signalling protocols, migration from existing network architectures towards NGN, etc.

Initially, NGN has a focus on fixed access such as ADSL. However, wireless access will also be considered in a second step as normal evolution.

It is interesting to note that Evolved UMTS is actually moving in the same direction as NGN. As described in Chapter 2, Core Network simplification introduced by the Evolved UMTS Packet Core is completely in line with NGN objectives. In some respects, IMS already answers parts of the NGN requirements in providing a common framework for the support of a large set of services, from interactive data services to Quality of Service-constrained voice or streaming applications.

For illustration purposes, Figure 1.10 presents the TISPAN NGN overall architecture, as described in specification 282 001, 'NGN Functional Architecture Release 1', from the ETSI. The picture shows a clear separation of the transport and service parts of the network, represented by the dotted horizontal line.

The main purpose of the Transport Layer is to provide IP connectivity to the end-user under the control of Network Attachment and Admission Control subsystems. In principle, these two subsystems are independent from the transport technology used below the IP network layer, so this model is suitable for any type of fixed or wireless access.

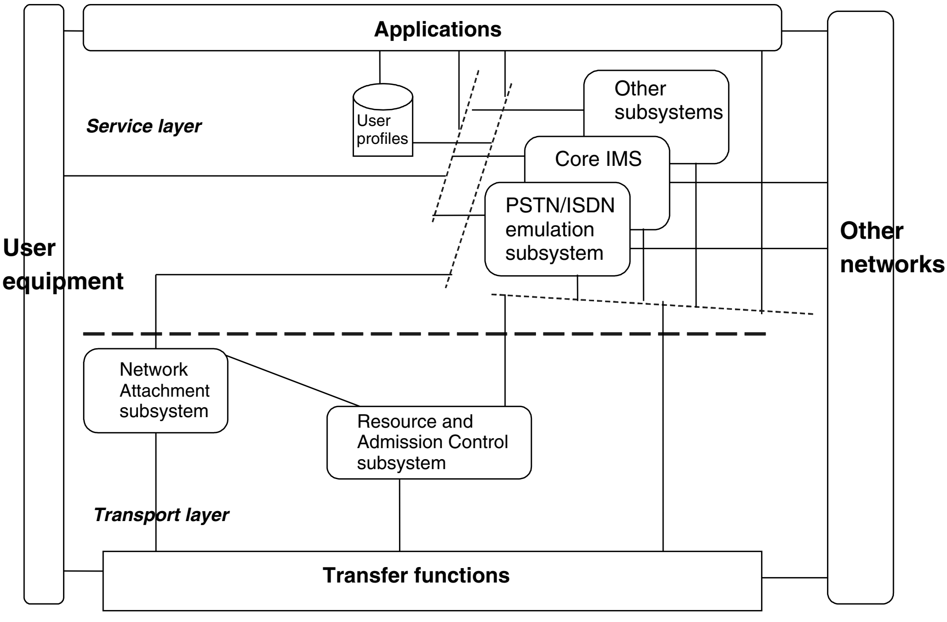

Figure 1.10 TISPAN NGN overall architecture (source: ETSI ES 282 001).

The Service part is represented as an integrated layer supporting applications, user profile management and IMS (IP Multimedia Subsystem) elements. The 'Core IMS' of the NGN is actually a subset of the full 3GPP IMS architecture and re-uses the same principles in terms of SIP-based session signalling and call servers as well as multimedia resource and gateway functions. In addition, the Service Layer also provides access to other networks such as the legacy PSTN (Public Switched Telephony Network).

In addition to basic communication session support, TISPAN NGN has also specified a complete framework for supplementary services, similar to those proposed for circuit-switched speech, and supported by a wireline and wireless legacy circuit infrastructure. This point is further described in Chapter 6.

In order to avoid the development of diverging IMS architectures and services, it was agreed in June 2007 to migrate all TISPAN activity within 3GPP under a new framework known as 'Common IMS'. 'Common IMS' is therefore an extension of 3GPP IMS activity handled by the SA (System Architecture) group, enabling IMS services not only for wireless networks (legacy mobile cellular and WLAN networks) but also for packet cable and fixed networks. Common IMS is part of Release 8 of the 3GPP standard.

1.3.5 The NGMN Initiative

NGMN (Next Generation Mobile Networks) is an initiative led by a group of mobile operators, including NTT DoCoMo, Vodafone, Orange, T-Mobile, China Mobile, Sprint and KPN. The objective of NGMN is to provide a vision for 3G technology evolution for commercial availability planned in 2010. NGMN expects the standardization phase of the next generation to be completed by the end of 2008, so that the trial phase can start in 2009. NGMN is not a competitor to ITU or any other cross-country standardization body. It rather intends to complete and support the work handled by the standardization committees and to make sure that future systems will meet the needs of mobile operators and their customers.

Not surprisingly, the target NGMN performance requirements in terms of data rate, latency and spectrum efficiency are aligned with Evolved UMTS (as described in Chapter 2). The same goes for the overall architecture concepts supported by NGMN, which is based on a Packet Switched Core Network together with an evolved high-speed radio interface.

On the service side, NGMN initiative and Evolved UMTS also share the same interest on three key subjects:

- **Efficient Always-On support:** as most of the new services (such as 'Presence' or 'Push-To-Talk') require the end-user to be 'always connected'.
- **Seamless mobility between systems:** this applies not only to voice calls, but also to all other services. In principle, no interruption or drop in performance should be experienced by end-users when changing systems.
- **Efficient Support of Broadcast and Multicast:** this requirement is a consequence of the growing interest of operators and customers in mobile broadcasting technologies such as DVB-H.

The NGMN initiative is technology-independent, as it actually considers all 3G system migration including UMTS as well as the cdma2000 1xEV-DO family.

Figure 1.11 describes the high-level architecture envisaged by NGMN. It is planned that future systems will support all kinds of services and ultimately integrate all the circuit and packet-switched services through one unique Packet Core network domain. As we will see in Chapter 2, the convergence of all services on a common packet-based network architecture is also a key concept of Evolved UMTS.

For more information about the NGMN initiative, please consult http://www.ngmn-cooperation.com/.

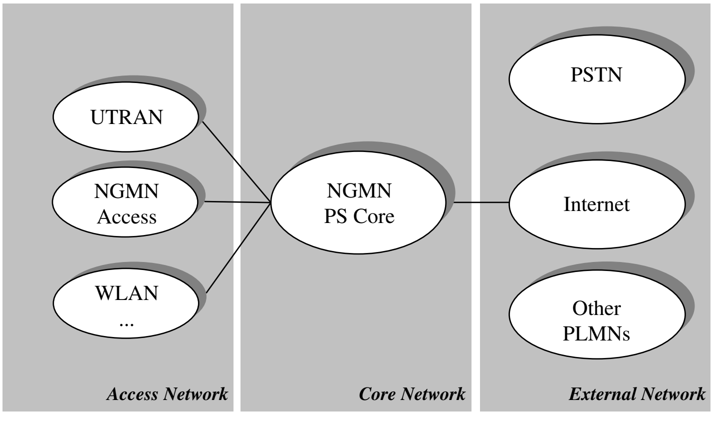

Figure 1.11 High-level NGMN system architecture.

1.4 Spectrum

The radio spectrum is the most critical resource in radio communication systems, making frequency regulation and allocation a complex issue:

- **A scarce resource:** because of physics laws, the amount of spectrum that can actually be used for mobile (possibly high-speed) and high bit rate applications is quite limited. The lower part of the spectrum (starting at 400 MHz) is already overcrowded with digital, analogue, public and military applications. The upper part of the spectrum, above 2 GHz, offers more possibility for extensions and high bit rate-demanding applications, at the cost of a shorter cell range because the propagation loss increases with the frequency.
- **Lack of harmonization:** because of the history of and disparities in regulation rules, spectrum allocation is not consistent between countries. This complicates worldwide system spectrum definition.

Coming back to cellular system history, GSM (the most popular 2G technology) was initially built to work on a single 900-MHz frequency band. The way it was introduced in the core specifications of GSM left quite limited possibilities for extension to other frequency bands. However, as GSM became largely accepted, the need for additional frequencies appeared as a requirement to support the increasing number of customers and operators. GSM was therefore modified to be able to support other frequencies on the request of specific countries, first in the 1800 and 1900-MHz bands, and then in the 450, 480 and 850-MHz bands.

When 3G and IMT-2000 emerged, a lot of attention was paid to the issue of spectrum allocation. One of the key IMT-2000 objectives was to allow global mobility, seamless service access and increased user experience. This was felt as difficult to achieve without a minimum level of spectrum harmonization. For that reason, the decision was made at the WARC-92 (World Administrative Radio Conference of 1992) to identify 230 MHz of spectrum on a worldwide basis for the operation of IMT-2000 networks. This amount of spectrum was shared in two bands:

- 1885–2025 MHz.
- 2110–2200 MHz.

In a second step, and because the WARC-92 spectrum studies were based on the assumption of low bit rate services, the need for additional frequency was raised during the WRC-2000 (World Radiocommunication Conference of 2000). In order for the IMT-2000 to be able to cope with upcoming multimedia services, three additional new bands have been defined, adding close to 500 MHz of spectrum to the initial WARC-92 allocation:

- 806–960 MHz.
- 1710–1885 MHz.
- 2500–2690 MHz.

The IMT-2000 does not specify the way the spectrum is used. This point is left for decision to the local regulator. In Europe, this activity is under the European Radiocommunications

Committee (ERC)'s responsibility, within the CEPT (European Conference of Postal and Telecommunications Administrations).

Figure 1.12 represents an overview of the spectrum allocated to IMT-2000 in comparison with existing communication systems currently using those frequencies in Europe.

Regarding 3G frequencies, the spectrum is shared between the three following technologies:

- UMTS/FDD (Frequency Division Duplex), which mandates paired spectrum allocation: one band for uplink (UL) transmission (from terminal to network) and one band for downlink (DL) transmission (from network to terminal).
- UMTS/TDD (Time Division Duplex), which is designed for unpaired spectrums. Uplink and downlink transmissions are therefore using the same frequencies at different times.
- MSS (Mobile Satellite Services), which is the satellite component of IMT-2000.

In any case, and as opposed to GSM, one improvement point is that UMTS specifications are flexible enough to accommodate a large range of frequencies (theoretically from 0 to 3276.6 MHz).

Figure 1.12 also represents 2G technologies overlapping the IMT-2000 spectrum. As 2G technologies will start to decline, spectrum can therefore easily be re-allocated to IMT-2000 systems. The major 2G systems subject to spectrum re-use are:

- The GSM technology, in the 900 and 1800-MHz bands (Figure 1.12 includes the Primary as well as the Extended GSM 900 band), working in FDD mode and requiring paired spectrum.
- The DECT system (Digital European Cordless Telephone), working in TDD unpaired spectrum.

At this point in time, the spectrum for systems beyond IMT-2000 is not yet identified. This will be a subject for the WRC-07 conference, being held at the end of 2007.

1.5 The Evolution of UMTS

The need for 3G long-term evolution studies was stated at the end of 2004 within the 3GPP, in order to maintain the competitive position of UMTS-based technologies for the future. It was therefore decided to launch feasibility on overall system architecture and access network evolution, with an objective to finalize core specifications by mid-2007.

1.5.1 1st Evolution Driver: The Move towards Data Applications

As described above, initial 2G systems were built for circuit-switched applications – voice being the main one, and low-rate circuit-switched data being supported as well. As the World Wide Web became a reality, 2G systems evolved towards packet data. This was not a complete system redesign, as packet data network architecture was defined as an add-on to existing networks – meaning increased costs for deployment and operation.

Within Evolved UMTS networks, all communication streams will be considered as packet data, allowing converged and simplified network architectures.

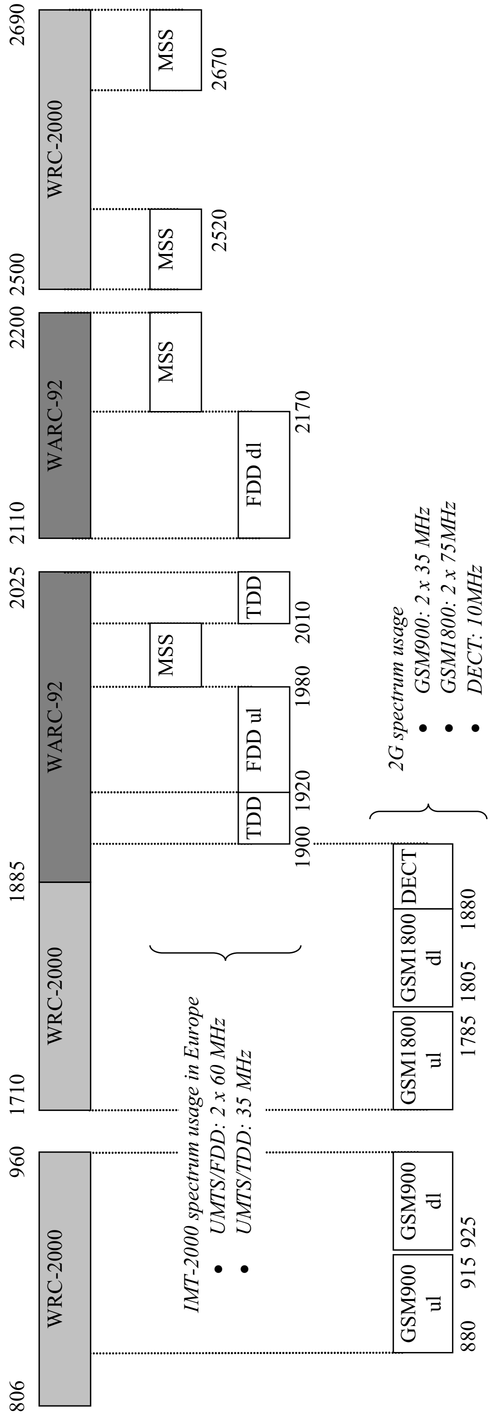

Figure 1.12 Overall cellular spectrum overview.

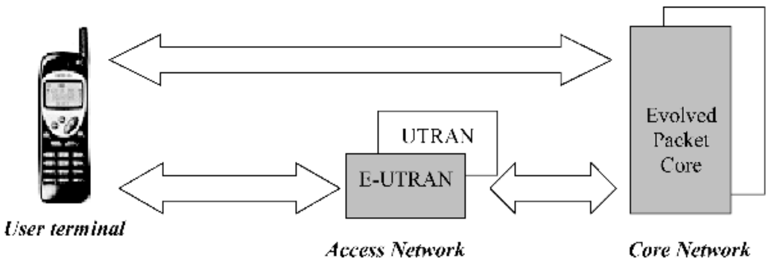

Figure 1.13 Towards 'Evolved UMTS' networks.

1.5.2 2nd Evolution Driver: Enhanced Radio Interface Capabilities

Over the past few years, fixed Internet access capabilities have been improving, from the 56-Kb/s V90 modem-based access to 10-Mb/s ADSL and 100-Mb/s fiber access, enabling new services and much better user experience. As a consequence, it is not surprising that wireless communication systems are also moving towards increased capabilities and performances, so that the Quality of Service for existing and new services is kept acceptable when used over the radio interface.

1.5.3 What Will Change Within the Network?

The evolution of UMTS consists of two parts (Figure 1.13):

- The Core Network evolution – as a consequence of the global move towards packet data applications. The Evolved Packet Core network (or EPC) aims to provide a converged framework for packet-based real-time and nonreal-time services.
- The Access Network – existing UMTS access network, also named as UTRAN (Universal Terrestrial Radio Access Network) is evolving towards E-UTRAN (for Evolved-UTRAN) so as to offer high-data-rate, low-latency and packet-optimized radio access technology. This implies a new radio interface, new protocols and also new access network architecture, as further described in this book.

Some vocabulary

The ***E-UTRAN*** Access Network (for Evolved UTRAN) is often referred to as LTE (for Long Term Evolution) in 3GPP reports and specifications, which was the initial name given to the 3G/UTRAN evolution study item.

Similarly, on the Core Network side, the evolution towards Evolved Packet Core, or ***EPC***, is referred to as SAE (for System Architecture Evolution).

The Evolved UMTS, which is basically the concatenation of the E-UTRAN access network and EPC Core Network, is referred to as ***EPS*** (Evolved Packet System) in 3GPP standard documents.

1.5.4 What is Described in this Book?

The technical details of UMTS evolution are further described, through the following chapters:

- **Chapter 2** provides an overview of 'Evolved UMTS'. The major blocks and concepts are described, as an introduction to the in-depth view presented in the following chapters.
- **Chapter 3** is dedicated to the physical radio layer, as being a disruption with existing 2G (TD/FDMA) or 3G (CDMA) systems.
- **Chapter 4** is dedicated to the network architecture. Major blocks are presented – Access and Core – as well as the main protocol layers and Transport Network.
- **Chapter 5** aims at presenting the steps and procedures being implemented throughout the life of the terminal (from power-on to mobility in ACTIVE mode).
- **Chapter 6** describes the main services built on top of 'Evolved UMTS', focusing on how the service is implemented over the architecture.

All through this book, lots of references are provided to standards and specifications, so that the reader willing to dig into a specific area can refer to the right document.

1.6 Links and Documents

1.6.1 Useful Web Sites

Here is a list of Web sites which may be consulted for further information:

- **http://www.3gpp.org/** This is the homepage of the 3GPP consortium. Lots of information can be found here, from details on technical working groups to technical specifications. Access to technical documents is free of charge.
- **http://www.3gpp2.org/** This is the homepage of the 3GPP2 consortium. Access to 3GPP2 specifications is free of charge.
- **http://www.rfc-editor.org/** The RFC Editor is the publisher of the IETF RFC documents and is responsible for the final editorial review. All the IETF RFC mentioned in this book can be found here, free of charge.
- **http://www.openmobilealliance.org/** This link points to the home page of the OMA (Open Mobile Alliance). Specifications of services presented in Chapter 6 of this book can be accessed from this link, free of charge.
- **http://www.itu.int/home/imt.html** This address points to the IMT-2000 page hosted by the ITU. General information about IMT-2000 can be found here. In most cases, access to ITU documents is subject to charging.

1.6.2 Evolved UMTS Specifications

(i) The 3GPP Standard Releases

As for many standard committees, 3GPP work is organized into releases. This allows the different groups to work on future evolutions and still allow corrections and bug tracking on

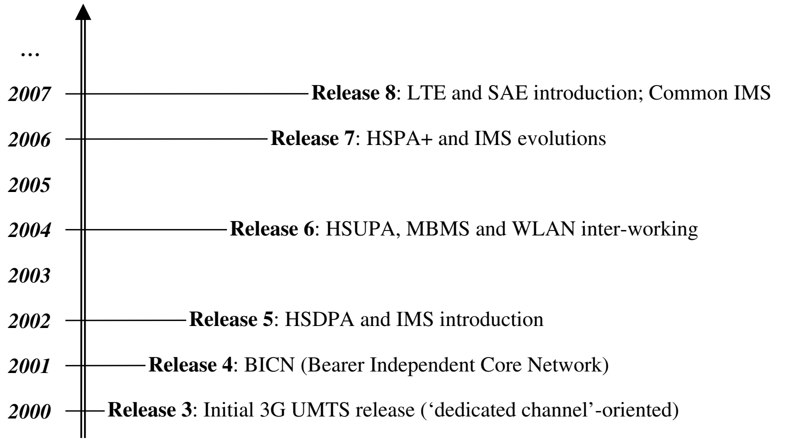

Figure 1.14 3GPP standard releases.

previous stable versions. Each manufacturer (either on the network or on the terminal side) has the flexibility to implement any version it prefers. In principle, specification progress is backward-compatible, meaning that a given version includes all the basic and optional features which were defined in all previous versions (except in some rare cases of 'option pruning', where useless features are withdrawn from the standard).

Figure 1.14 represents all 3G standard releases supported by the 3GPP. The picture is limited to 3G and post-3G evolutions and does not include GERAN versions of the standard.

Each version actually contains a great number of new features. The picture only shows the main ones. E-UTRAN and complete Evolved Packet Core definition are actually part of Release 8 of the 3GPP standard. The completion of all protocols and messages is planned for the end of 2007.

(ii) The Main Documents

This section describes all the main 3GPP specifications related to Evolved UMTS, all available from the 3GPP homepage.

The following documents are maintained by the SA2 3GPP group. They specify overall network architecture (including Access and Core parts) as well as general procedures such as network attachment, session setup and mobility:

- 23.401, 'GPRS Enhancements for E-UTRAN Access'.
- 23.402, Architecture Enhancements for Non-3GPP Accesses'.

These documents are maintained by the RAN1 3GPP group. They specify the physical layer of the E-UTRAN radio interface:

- 36.201, 'LTE Physical Layer: General Description'.
- 36.211, 'Physical Channels and Modulation'.
- 36.212, 'Multiplexing and Channel Coding'.
- 36.213, 'Physical Layer Procedures'.
- 36.214, 'Physical Layer Measurements'.

These documents are maintained by the RAN2 3GPP group. They specify the layer 2 and E-UTRAN control protocols supported by the E-UTRAN radio interface:

- 36.300, 'E-UTRAN Overall Description: Stage 2'.
- 36.302, 'E-UTRAN Services Provided by the Physical Layer'.
- 36.304, 'User Equipment (UE) Procedures in Idle Mode'.
- 36.306, 'User Equipment (UE) Radio Access Capabilities'.
- 36.321, 'Medium Access Control (MAC) Protocol Specification'.
- 36.322, 'Radio Link Control (RLC) Protocol Specification'.
- 36.323, 'Packet Data Convergence Protocol (PDCP) Specification'.
- 36.331, 'Radio Resource Control (RRC) Protocol Specification'.

These documents are maintained by the RAN3 3GPP group. They specify the interfaces and procedures supported by interfaces between network nodes of E-UTRAN:

- 36.401, 'E-UTRAN Architecture Description'.
- 36.410, 'S1 General Aspects and Principles'.
- 36.411, 'S1 Layer 1'.
- 36.412, 'S1 Signalling Transport'.
- 36.413, 'S1 Protocol Specification'.
- 36.414, 'S1 Data Transport'.
- 36.420, 'X2 General Aspects and Principles'.
- 36.421, 'X2 Layer 1'.
- 36.422, 'X2 Signalling Transport'.
- 36.423, 'X2 Protocol Specification'.
- 36.424, 'X2 Data Transport'.

In addition to those specifications, 3GPP also produces a number of Technical Reports, which record working assumptions and agreements until actual specifications are made available:

- 24.801, '3GPP System Architecture Evolution: CT WG1 Aspects'.
- 29.804, 'CT WG3 Aspect of 3GPP System Architecture Evolution'.
- 29.803, '3GPP System Architecture Evolution: CT WG4 Aspects'.
- 32.816, 'Telecommunication Management; Study on Management of LTE and SAE'.
- 32.820, 'Telecommunication Management: Study on Charging Aspects of 3GPP System Evolution'.
- 33.821, 'Rationale and Track of Security Decisions in LTE/SAE'.