Abstract

An overview of third-generation wireless personal communications is presented, and the challenges to meet its demands are examined. At the ITU level, the third generation is known as IMT-2000.[1] In Europe, the third generation of wireless personal communications is known as UMTS. Special attention has been paid in giving a brief description of the research and development, standardization, and regulatory activities. The UMTS Terrestrial Radio Access (UTRA) concept is presented. The different ACTS projects involved in making UMTS a success are introduced.

An Overview of Third-Generation Wireless Personal Communications: A European Perspective

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In 1980 the mobile cellular era started. Mobile communications has experienced enormous growth during the last ten years. First-generation mobile systems such as AMPS, TACS, and NMT using analog transmission for speech services were introduced in the early '80s. Second-generation systems, which use digital transmission, were introduced in the late 1980s. Global System for Mobile Communications (GSM), Personal Digital Cellular (PDC), IS-136, and IS-95 are second-generation systems. The services offered by these systems cover speech and low-bit-rate data. The second-generation systems will further evolve toward third-generation systems to offer more advanced services such as medium-bit-rate (up to 100 kb/s) circuit- and packet-switched data. These evolved systems are referred to as *generation 2.5*.

From Digital Bearers to a Multiservice Platform

New innovative services, in particular broadband multimedia, will form the basis for true third-generation systems. Third-generation systems will offer seamless wireless access to mass market multimedia. Rather than offer standardized digital bearers for specific services, third-generation systems will provide a service platform for future, not yet defined services.

Objectives and Challenges of Third-Generation Wireless Systems

The driving force and main design objective for third-generation systems has been high-bit-rate services. Third-generation systems should be able to offer at least 144 kb/s (preferably 384 kb/s) for high-mobility users with wide-area coverage and 2 Mb/s for low-mobility users with local coverage. The high-bit-rate services together with the lack of spectrum motivate the development of more spectrum-efficient radio technologies [1–3].

Technical Challenges

The goal of UMTS/IMT-2000 is to support a large variety of services, most of which are not known yet, over a large variety of radio conditions. The Universal Mobile Telecommunications Services/International Moble Telecommuncia-tions in the year 2000 (UMTS/IMT-2000) air interface has to be able to cope with variable, asymmetric data rates with different quality of service requirements (bit error ratio, delay) (i.e., multimedia services with bandwidth on demand). An efficient packet access protocol is also essential in order to transfer bursty real-time and non-real-time data. The challenge is to achieve the required flexibility without overwhelming complexity in the network and terminals.

High and low rate users, with different quality of service requirements, will coexist in the network. Radio resource management algorithms need to guarantee the required quality for all users in a fair manner. A flexible allocation of the radio resources for packet-type services with unpredictable bit rates, taking into account asymmetric data transmission, is an essential requirement for third-generation networks. Furthermore, manual network planning for a network with varying load and different services would be an enormous task. Therefore, automatic network planning capabilities are of crucial importance.

IMT-2000 is building on backward compatibility to second-generation networks. Dual-mode terminals will facilitate deployment of third-generation networks according to market demand starting from high-bit-rate coverage islands. An obvious challenge is how to build dual-mode terminals without increasing the terminal cost too much.

Easy-to-use terminals and simple user interfaces with, for example, voice recognition capability appeal far more to the ordinary user than complex acronyms related to a new technology. In particular, the success of wireless data products will depend on the development of attractive, easy-to-use terminals, which would increase users' productivity.

[1] *Previously IMT-2000 WAS called Future Public Land Mobile Telecommunication Systems (FPLMTS).*

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Market Aspects

The most important success factor for third-generation wireless systems will be the existence of a mass market. The basis for the UMTS/IMT-2000 market will be the existing GSM market, covering GSM, GSM1800, and GSM1900 systems. GSM will offer speech, and low- and medium-bit-rate data. The current number of GSM users is over 70 million and is expected to increase manyfold by 2000. GSM and its enhancements can fulfill the needs of speech and low-rate data services even up to 100 percent penetration in most countries. Therefore, the UMTS/IMT-2000 market, especially in the beginning of its life cycle, will concentrate on high-bit-rate multimedia and packet data services, complementing the services offered by GSM. Possible spectrum congestion in GSM networks can be relieved by migrating heavy data users into UMTS.

There are considerable differences between the several market estimates for mobile users. The UMTS Forum has predicted that there will be 1.7 billion mobile users by 2010. This is 20 percent of the world's user population. The UMTS Forum also estimates that 45 percent of mobile users will use high-speed data services by 2010. It is clear, however, that there is no single right figure for the IMT-2000 market. The market for mobile multimedia services will depend on several factors. The market analysis group in the UMTS Forum has conducted a study that analyzed four different market scenarios for the mobile multimedia market [4]. These scenarios give an indication of the factors that will determine third-generation market development. Table 1 shows the number of mobile and multimedia users in 2005 for the different scenarios.

In scenario 1 (slow evolution), mobile multimedia development is slow, characterized by limited applications, and high service and terminal prices due to unsuccessful liberalization and fragmented standards.

In scenario 2 (business-centric), mobile multimedia takes off in the business sector but not in the consumer sector, because there is a lack of innovation in consumer applications.

In scenario 3 (sophisticated mass market), a mass market for mobile multimedia has emerged. Terminals and applications have large sets of features and can be customized for personal needs. However, user interfaces are still rather complicated, being suitable for IT-literate users.

In scenario 4 (commoditised mass market), a real mobile multimedia mass market has emerged quickly and comprises both business and consumer users. The main difference from the previous scenario is availability of simple user interfaces and cheaper spectrum.

Scenario	Mobile users (penetration, %)	Multimedia users
1. Slow evolution	82 M (22)	7.5 million
2. Business-centric	82 M (22)	9 million
3. Sophisticated mass market	123 M (35)	19 million
4. Commoditized mass market	140 M (40)	27 million

Table 1. *The estimated number of mobile and multimedia users in Europe in 2005 [4].*

Spectrum Regulation

Fundamentally, regulatory matters are national issues. However, in some cases regional and global harmonization of regulations and policy issues is desirable [5]. Areas where common regulations might be required are licensing, services, provisioning, interconnection, infrastructure, frequencies, numbering, security, and policies [5]. With regard to a radio access system, the most important regulatory areas are spectrum coordination and licensing.

The process of obtaining frequencies can be divided into three phases: identification of spectrum, allocating the spectrum for specific purposes, and licensing the spectrum. Since the identified spectrum is usually already used for some other purpose, it needs to be cleaned of existing users before it can be used for a new purpose. Therefore, proactive long-term planning is required to ensure the availability of spectrum when required.

The International Telecommunication Union (ITU) plays an important role in spectrum regulation. The Radio Regulations (RRs) of ITU are updated in World Administrative Radio Conferences (WARCs). The next WARC is scheduled for 1999. The national regulators are not bound to follow the ITU guidelines for spectrum allocation. However, the ITU RRs form a tool to encourage national regulators to do so in order to achieve global harmonization of spectrum [5]. The IMT-2000 spectrum was identified in the year 1992 by WARC92 as a result of the ITU studies on IMT-2000. These studies indicated that the minimum spectrum for IMT-2000 should be 230 MHz. Figure 1 illustrates the use of the IMT-2000 frequencies in different regions.

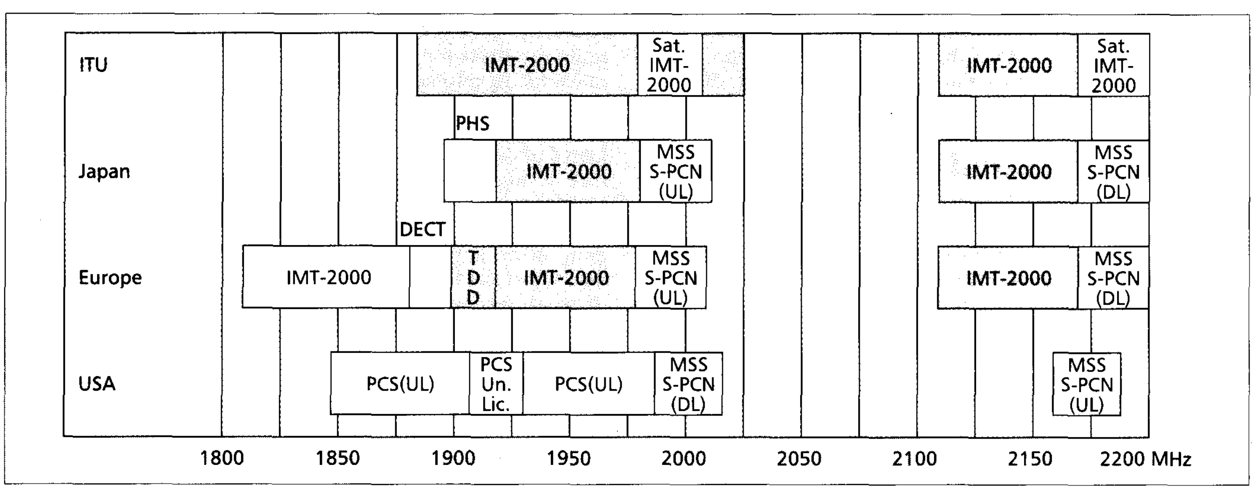
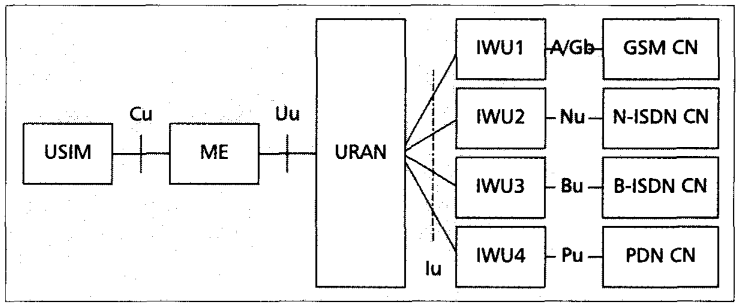


Figure 1. *IMT-2000 frequency allocations.*

In general, Europe follows ITU Recommendations for spectrum issues. Europe-wide harmonization is carried out by the Conférence Européenne des Postes et Télécommunications (CEPT). In addition, the European Commission can issue directives to create harmonized frequency allocations for specific technologies. Examples of such directives are GSM in 1987 and DECT in 1991. Recently, the Commission has published its proposed UMTS Decision, which sets in place timescales and actions for national licenses and spectrum harmonization by 2000 [6]. The European Radiocommunications Committee (ERC) of CEPT makes decisions which usually form the basis for harmonized spectrum designations. CEPT has designated most of the IMT-2000 spectrum for UMTS with the adoption of the ERC Decision on UMTS, which identifies a total of 155 MHz of spectrum for terrestrial UMTS services with an additional 60 MHz set aside for UMTS satellite services [7].

The UMTS Forum, established based on the UMTS Task Force report [8], has played an important role in developing the regulatory framework, including spectrum aspects, for UMTS [9].



■ **Figure 2.** *General UMTS architecture (figure adapted from [14]).*

Third-Generations Standards Take Shape

The work on IMT-2000 was initiated by the ITU in 1986 [1]. Recently, the third-generation standardization has advanced toward concrete specifications.

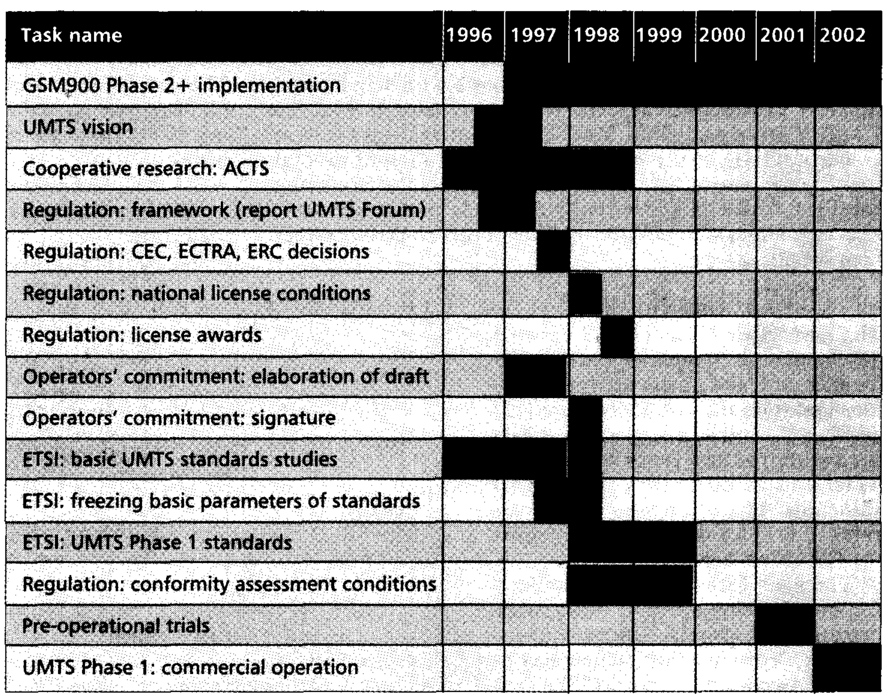
Focus on Radio

Main regional standards bodies have already decided the preferred radio technology for IMT-2000 [2]. The fast development in recent years has been due to the Japanese initiative. In the beginning of 1997, the Association for Radio Industry and Business (ARIB), a standardization body responsible for Japan's radio standardization, decided to proceed with detailed standardization of wideband code division multiple access (CDMA). The technology push from Japan accelerated standardization in Europe and the United States. During 1997, the Japanese and European wideband CDMA proposals were consolidated; the common air interface is now commonly referred as WCDMA. In January 1998, the strong support for WCDMA led to its selection as the UMTS terrestrial air interface scheme for frequency-division duplex (FDD) frequency bands in the European Telecommunications Standards Institute (ETSI). The selection of WCDMA has also been backed by the Asian and American GSM operators.

In the United States, the Telecommunications Industry Association (TIA) TR45.5 committee, responsible for IS-95 standardization, adopted a framework for WCDMA backward-compatible with IS-95, cdma2000 (also known as Wideband cdmaOne), in March 1998. TIA TR45.3, responsible for IS-136 standardization, adopted a time-division multiple access (TDMA)-based third-generation proposal, Universal Wireless Communications (UWC)-136, based on the recommendation from UWCC in February 1998. UWC-136 proposes modulation enhancement to the existing 30 kHz 136-channel (136+) and complementary wider-band TDMA carriers with bandwidths of 200 kHz and 1.6 MHz (136 HS). The 200 kHz carrier, 136 HS (vehicular/outdoor) has the same parameters as the GSM Enhanced Data Rates for GSM Evolution (EDGE) concept described later in this article, and provides medium bit rates up to 384 kb/s. Korea is still considering two wideband CDMA technologies, one similar to WCDMA and the other to cdma2000.

The Evolution of Second-Generation Systems

Based on evolution studies in ETSI and ITU, it has been recognized that third-generation systems will evolve from the second-generation systems. This has been the basis for the ITU IMT-2000 family of systems concept [10]. In ETSI, the UMTS will be standardized based on evolution from GSM and integrated services digital network (ISDN). This is facilitated by the Generic Radio Access Network (GRAN) concept [11]. Recently, extensive work to specify the GSM-based UMTS core network has started in ETSI, with wide participation from different regions.



■ **Table 2.** *The UMTS schedule [12].*

	Old UMTS	New UMTS
Core idea	Integration of all existing and new services into one new universal network	1. Focus on innovative new services 2. Support of GSM services
Partner networks	Broadband ISDN	Intranets and Internet
Introduction	Migration from existing networks	Evolution from GSM and ISDN networks
Roaming Mobility management	New development INAP-based	Evolution of GSM roaming, MAP-based
	Standardization of IMT-2000 as one monolithic standard in ITU	IMT-2000 family in ITU based on ANSI, ETSI, ARIB/TTC standards

■ **Table 3.** *UMTS focus (Source: ETSI Web site, http://www.etsi.fr).*

UMTS Standardization in ETSI

In ETSI, the UMTS standardization work started in 1991. The Special Mobile Group (SMG) technical committee has overall responsibility for UMTS standardization. Subtechnical committee SMG1 is responsible for UMTS service aspects, SMG2 is responsible for the specification of UMTS generic radio access, SMG3 for GSM core network evolution, and SMG12 for overall UMTS architecture. The UMTS time schedule for standardization, regulation, and implementation is given in Table 2.

The New UMTS Focus

To meet market needs, the UMTS focus was changed in 1997. Table 3 illustrates the basic features of the "old" and "new" UMTS. At the beginning of 1997, a consensus on the UMTS concept had been reached. The main technical choices, including the air interface and core network principles, were agreed upon. Furthermore, the regulatory framework for licensing and spectrum allocation is in place. All these factors contribute positively to the planned finalization of UMTS basic standards by 2000 and start of commercial operation by 2002.

Generic Service Capabilities

Subtechnical committee SMG1 is responsible for standardization of UMTS service aspects. Wide participation from the UMTS Forum and GSM MoU Third Generation Interest Group (3GIG) in the work of SMG1 has been of crucial importance. Currently, UMTS service principles are being specified. The leading concept is to standardize generic service capabilities with different quality of service classes rather than specific services.

UMTS Network Aspects

The basic idea of the UMTS network development is to separate the development of core and access networks. This idea builds on the GRAN concept [11]. The benefit is that it leaves freedom in the future for new types of products, which utilize different core network solutions. The interested reader can refer to [13] for different views about the GRAN concept.

The main focus of UMTS standardization will be on a UMTS radio access network (URAN) that can be connected to one core network, which may be based on GSM, narrowband ISDN (N-ISDN), broadband ISDN (B-ISDN), or packet data networks (PDNs) through interworking units (IWUs), as depicted in Fig. 2. The UMTS air interface will be an open and well-specified standard (Uu interface). Furthermore, the Iu interface specifies the interface between URAN and core networks, and Cu interface terminal equipment and the UMTS subscriber identity module (USIM).

As shown in Fig. 3, the first implementations of GRAN will be based on the integration of URAN and the GSM/UMTS core network, evolved from the GSM core network by integrating new third-generation capabilities. The evolved GSM network elements are referred to as 3G MSC and 3G SGSN.

In this scenario the MSC still provides interworking with ISDN, but is capable of handling multiple simultaneous calls from/to the same mobile terminal (i.e., the MSC can provide *n* x 64 kb/s services). This multicall capability may also be introduced to the GSM system along with the 2+ feature EDGE.

The interface between the 3G MSC and 3G SGSN, Gs', is an evolved version of the corresponding Gs interface in GSM phase 2+, and could provide improved coordination of packet- and circuit-switched services.

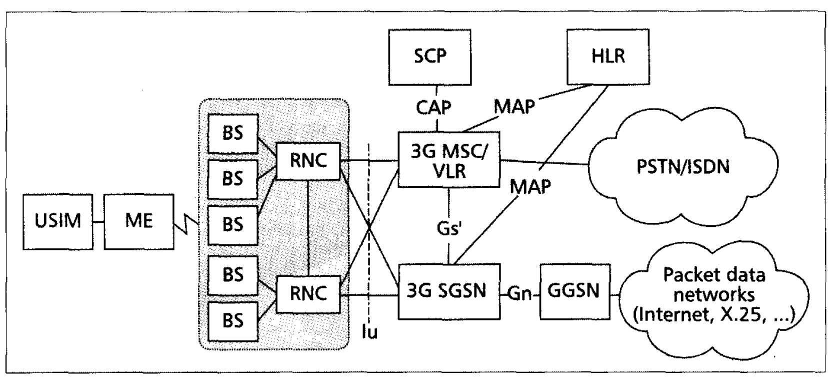
Customized Applications for Mobile Network Enhanced Logic (CAMEL) and the GSM Mobile Application Part (MAP) are also subject to evolution [15]. The purpose of CAMEL is to provide a mechanism for supporting services consistently and independent of subscriber location [15]. It is based on intelligent network (IN) principles and can be used to provide operator-specific services for roaming users. CAMEL is the basis for the UMTS virtual home environment (VHE) concept, which would facilitate full transparency of offered services regardless of the network to which the user is currently attached.

UMTS Radio Access

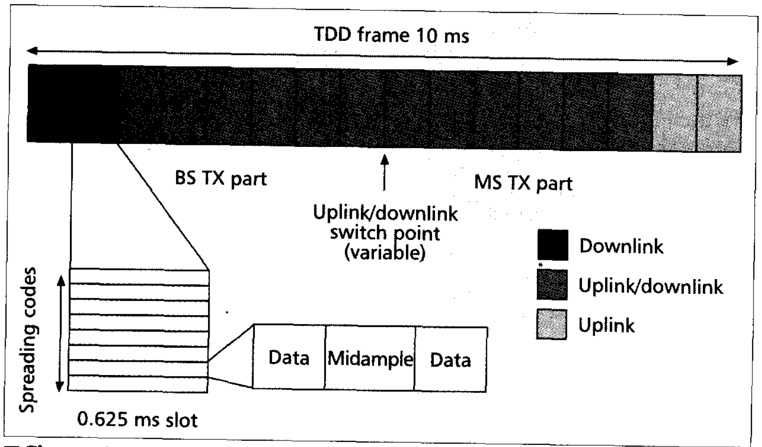
The Consensus on UTRA

The definition process of UMTS Terrestrial Radio Access (UTRA) was started in the UMTS workshop held in December 1996. The main milestones of the process are presented below:

- M1 6/97: Definition of a limited number of UTRA concepts based on the proposed access technologies or combinations of them
- M2 12/97: Selection of one UTRA concept



■ **Figure 3.** *One possible scenario where URAN is connected to an evolutionary GSM core network; 3G MSC/VLR and 3G SGSN provide Iu interface.*



■ **Figure 4.** *An example TDD frame structure.*

- M3 6/98: Definition of key technical aspects of the UTRA (including carrier bandwidth, modulation, channel coding, channel types, frame structure, access protocols, channel allocation and handover mechanisms, cell selection mechanisms, etc.)

Several air interface concepts were submitted to the UTRA evaluation process [2, 3]. The submitted air interface concepts were grouped into five different concept groups. The Future Radio Wideband Multiple Access Systems (FRAMES) wideband CDMA concept, FRAMES Multiple Access 1 (FMA1) [16], and three wideband CDMA schemes from Japan were submitted into the Alpha group. The Beta group evaluated FRAMES FMA1 without spreading [16] together with some other TDMA ideas. Two orthogonal frequency-division multiplexing (OFDM) concepts were submitted into the Gamma group. The Delta group evaluated FMA1 with spreading, which has also been called the TD-CDMA scheme. The Epsilon group considered opportunity-driven multiple access (ODMA), which is a relay technology in principle applicable to all multiple access schemes.

In the concept group evaluation process, the FMA2 proposal was considered together with the wideband CDMA schemes from Japan. At the same time, the Coordination Group (CG) in ARIB had discussions on the harmonization of different CDMA proposals. These two efforts led to the harmonization of the parameters for ETSI and ARIB wideband CDMA schemes [17]. The main parameters of the current scheme are based in the uplink on FMA2 and in the downlink on ARIB wideband CDMA. Also, contributions from other proposals and parties have been incorporated to further enhance the concept. In January 1998, ETSI SMG reached a consensus agreement on the UTRA concept [18]:

- In the paired band (FDD) of UMTS the system adopts the radio access technique formerly proposed by the WCDMA group.
- In the unpaired band (time-division duplex — TDD) the UMTS system adopts the radio access technique proposed formerly by the TD-CDMA group.
- In implementing this solution, ETSI SMG members pursue, together, the specification of UMTS with the objective of providing low-cost terminals, ensuring harmonization with GSM and providing FDD/TDD dual-mode-operation terminals.

Consequently, technical work was initiated to achieve a fully integrated UTRA concept. In April 1998, the FDD and TDD modes were harmonized to have the same chip rate, frame length, and number of slots per frame.

UMTS FDD-WCDMA

UTRA WCDMA is a network-asynchronous CDMA scheme [19]. Its main parameters are listed in Table 4. The WCDMA concept is based on the ETSI and ARIB wideband CDMA proposals; the main parameters in the uplink are from the ETSI proposal, originally developed in the FRAMES project; the main parameters in the downlink are from the ARIB concept. The following new capabilities characterize WCDMA:

- Wide bandwidth and chip rate
- Provision of multirate services
- Packet data
- Complex spreading
- A coherent uplink using a user-dedicated pilot
- An additional pilot channel in the downlink for beamforming
- Seamless interfrequency handover
- Fast power control in the downlink, and
- Optional multiuser detection

Channel bandwidth	5, 10, 20 MHz
Downlink RF channel structure	Direct spread
Chip rate	4.096/8.192/16.384 Mchips/s
Rolloff factor	0.22
Frame length	10 ms/20 ms (optional)
Spreading modulation	Balanced QPSK (downlink) Dual-channel QPSK (uplink) Complex spreading circuit
Data modulation	QPSK (downlink) BPSK (uplink)
Coherent detection	User dedicated time multiplexed pilot (downlink and uplink), Common pilot in downlink
Channel multiplexing in uplink	Control and pilot channel time multiplexed I and Q multiplexing for data and control channel
Multirate	Variable spreading and multicode
Spreading factors	4–256 (4.096 Mchips/s)
Power control	Open and fast closed loop (1.6 kHz)
Spreading (downlink)	Variable-length orthogonal sequences for channel separation, Gold sequences for cell and user separation
Spreading (uplink)	Variable-length orthogonal sequences for channel separation, Gold sequence 2^{41} for user separation (different time shifts in I and Q channel, cycle 2^{16} 10 ms radio frames)
Handover	Soft handover Interfrequency handover

■ **Table 4.** *WCDMA parameters.*

UMTS TDD

In the UMTS TDD mode, a wideband CDMA carrier with a chip rate of 4.096 Mchips/s is divided between the uplink and downlink in time. The frame length is as in UTRA FDD, currently 10 ms, and the number of time slots per frame is 16. Figure 4 shows an example TDD frame structure with one switching point for uplink/downlink separation within a frame. Another option under study is multiple switching points. As shown, a burst consists of three parts (data block — midamble — data block). The TDD mode uses quadrature phase shift keying (QPSK) data modulation and currently employs a fixed spreading factor. In addition, a variable spreading factor is under study.

Enhanced Data Rates for GSM Evolution

The EDGE concept adds a new, more spectrum-efficient modulation method to the GSM 200 kHz carrier. This facilitates provision of third-generation services within the existing frequency bands, where the introduction of the new wideband CDMA air interface would not be possible. The parameters of the EDGE proposal are listed in Table 5.

In addition to the originally proposed modulation schemes, quaternary offset quadrature amplitude modulation (Q-O-QAM) and binary offset QAM (B-O-QAM), other modulation schemes — continuous phase modulation (CPM) and 8-PSK — are currently under evaluation in order to select the most optimum modulation for EDGE.

The EDGE multirate scheme is based on a variable slot, code, and modulation structure. EDGE data services are shown in Table 6. Depending on user requirements and channel conditions, a suitable combination of modulation, coding, and number of data slots is selected. 136 HS can offer packet-switched as well as both transparent and nontransparent circuit-switched data services. Asymmetric data rates are provided by allocating different numbers of time slots in the uplink and downlink. For packet-switched services the RLC/MAC protocol provides fast medium access via a reservation-based medium access scheme, supplemented by selective automatic repeat request (ARQ) for efficient retransmission.

Duplex method	FDD
Carrier spacing	200 kHz
Modulation	Q-O-QAM B-O-QAM GMSK
Gross bit rate	722.2 kb/s (Q-O-QAM) 361.1 kb/s (B-O-QAM) 270.8 kb/s (GMSK)
Payload	521.6 kb/s (Q-O-QAM) 259.2 kb/s (B-O-QAM) 182.4 kb/s (GMSK)
Frame length	4.615 ms
Number of slots	8
Coding	Convolutional 1/2, 1/4, 1/3, 1/1 ARQ
Frequency hopping	Optional
Dynamic channel allocation	Optional

■ **Table 5.** *EDGE parameters.*

The European Research Program

The driving force behind European third-generation development has been the European Commission funded research programs Research of Advanced Communication Technologies in Europe (RACE) and Advanced Communication Technologies and Services (ACTS) [20–22]. Their value lies in producing technical results for standardization, but most of all in bringing together different parties from industry and academia, and thus fueling technical innovation and building consensus for successful UMTS development.

Within the current EU program ACTS (1995–1998) several projects aimed at contributing to UMTS system development have been set up. These projects cover service aspects, advanced mobile station and base station technologies, as well as radio and network aspects.

UMTS services are considered in the following projects: MOMENTS (Mobile Media and ENTertainment Services), MULTIPORT, MICC, UMPTIDUMPTI, and ON THE MOVE. The FIRST (Flexible Integrated Radio Systems Technology) project is studying advanced mobile station technologies, including software radio. The TSUNAMI project is studying advanced base station technologies. The FRAMES project has developed an air interface concept (FMA)[16], which formed the basis for the UMTS air interface [2]. The WAND project has developed a broadband access concept providing data rates up to 20 Mb/s. RAINBOW (Radio Access Independent Broadband On Wireless) studies core network aspects. STORMS (Software Tools for the Optimization of Resources in Mobile Systems) is addressing the complex issue of radio network planning for the UMTS network. Security issues are considered by the ASPECT and EXODUS projects. For more detailed information on these projects, see [22].

Service name	Code rate	Modulation	Gross rate	Radio interface rate
ECS-1	0.51	Q-O-QAM	65.2 kb/s	33.0 kb/s
ECS-2	0.63	Q-O-QAM	65.2 kb/s	41.0 kb/s
ECS-3	0.74	Q-O-QAM	65.2 kb/s	48.0 kb/s
ECS-4	1	Q-O-QAM	65.2 kb/s	65.2 kb/s
ECS-5	0.35	B-O-QAM	32.4 kb/s	11.2 kb/s
ECS-6	0.45	B-O-QAM	32.4 kb/s	14.5 kb/s
ECS-7	0.52	B-O-QAM	32.4 kb/s	16.7 kb/s
ECS-8	0.70	B-O-QAM	32.4 kb/s	22.8 kb/s

■ **Table 6.** *Overview of data services for EDGE (note: only single time slot rates shown).*

Conclusions

The development of the third-generation wireless system UMTS/IMT-2000 has reached a stage where it can now be emphatically said that the objective of today's communication engineers to achieve a global communications village, which was yesterday's myth (before 1970), will be tomorrow's reality (by 2000). UMTS/IMT-2000 will convert the already shrinking world into a global village. The objective of UMTS/IMT-2000 is seen as being the ultimate goal of today's communication engineers, to provide communication services from any person to any person in any place at any time without any delay in any form through any medium by using one pocket-sized unit at minimum cost with acceptable quality and security through using a personal telecommunication reference number.

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Biographies

TERO OJANPERÄ [M] (tero.ojanpera@research.nokia.com) received his M.Sc. degree from the University of Oulu, Finland, in 1991. From 1991 to 1992 he worked for Nokia Mobile Phones as a research engineer. From 1992 to 1995 he led a radio systems research group concentrating on CDMA, GSM WLL, and U.S. TDMA in Nokia Mobile Phones, Oulu, Finland. From 1994 to 1995 he was also a project manager in wideband CDMA concept development within Nokia. Later, this concept formed the basis for the FRAMES Wideband CDMA. From 1995 to 1997 he was a research manager in Nokia Research Center, Helsinki, Finland, heading the third-generation radio research program within Nokia. During 1996 he was also leader of a work package in the FRAMES project, responsible for the selection of the FRAMES Multiple Access (FMA) scheme. FRAMES Wideband CDMA was the basis for the UMTS WCDMA concept in ETSI. From 1994 to 1997 he was a Nokia representative on UMTS radio interface issues to ETSI SMG5 and SMG2 standardization committees. From August 1997 to August 1998, he worked as a principal engineer at Nokia Research Center, Irving, TX. Since September 1998 he has been with Nokia Telecommunications, Finland, as head of research, radio access systems. He is the author of a book, *Wideband CDMA for Third Generation Mobile Communications* (Artech House, 1998). He has also authored several conference papers and chapters in two books, *Wireless Communications: TDMA vs. CDMA* (Kluwer, 1997) and *GSM: Evolution towards 3rd Generation* (Kluwer, 1998).

RAMJEE PRASAD (r.prasad@its.tudelft.nl) has been with the Telecommunications and Traffic Control Systems Group, Delft University of Technology (DUT), The Netherlands, since February 1988. He is head and program director of the Center for Wireless Personal Communications, International Research Center for Telecommunications Transmission and Radar (IRCTR), where he is involved in the area of wireless personal and multimedia communication (WPMC). He is currently involved in the European ACTS FRAMES project as a project leader of DUT. He has published over 300 technical articles and three books: *CDMA for Wireless Personal Communications* (Artech House), *Universal Wireless Personal Communications* (Artech House), and (as co-author) *Wideband CDMA for Third Generation Mobile Communications* (Artech House). His current research interests are in the areas of packet communications, multiple access protocols, adaptive equalizers, spread-spectrum CDMA systems, and multimedia communications. He is coordinating editor and one of the editors-in-chief of a Kluwer international journal, *Wireless Personal Communications*, and also a member of the editorial boards of other international journals, including *IEEE Communications Magazine*. He is conference chair of the 50th IEEE Vehicular Technology Conference (VTC '99 Fall) to be held in Amsterdam, The Netherlands, September 19–22, 1999.