Overview of Global Standardization of IMT-2000 and Its Evolution

●Eisuke Fukuda ●Akishige Noda ●Mamoru Higuchi

(Manuscript received June 3, 2002)

The fundamental objective of the standardization activities for International Mobile Telecommunication 2000 (IMT-2000) is to develop a globally unified standard to facilitate mobile multimedia services and global circulation of mobile terminals. To achieve this, the International Telecommunication Union (ITU) has been making extensive efforts over a long period. Also, technical forums such as the 3rd Generation Partnership Project (3GPP) and the 3GPP2 have been carrying out the pertinent practical work in close cooperation with other entities such as the Internet Engineering Task Force (IETF), the GSM Association (GSMA), and IPv6 Forum.

This paper presents an overview of the global standardization activities for IMT-2000 and describes some of the contributions that Fujitsu has made during the standardization activities. Sections 1 to 3 describe the background of the 3GPPs. Sections 4 to 6 describe the scope and objectives of the 3GPPs, their organization, the specifications they have released, and the harmonization activities in the two groups. Section 7 describes Fujitsu's activities in the standardization process, and Section 8 looks at new features for enhancing the performance of systems beyond IMT-2000.

1. Introduction

NTT DoCoMo,Inc. is now providing nationwide commercial services with a Wideband Code Division Multiple Access (W-CDMA) system, taking the global lead in deployment of 3rd generation mobile systems. Meanwhile, KDDI has also started cdmaOne and J-Phone has announced its commercial W-CDMA service to be launched within 2002. The successful deployment of the W-CDMA and cdmaOne systems is due to the enormous time and effort spent not only for research and development of their equipment but also the contentious but constructive discussions that have taken place in the standardization process for more than one and a half decades.

The most fundamental requirement for standardization of IMT-2000 is to create a standard that provides capabilities to facilitate worldwide roaming and mobile multimedia applications as defined in Recommendation ITU-R M.1455,[1] "Key Characteristics for the IMT-2000 Radio Interfaces." In order to meet these requirements, the ITU[2] has been playing a centripetal role in creating harmonized recommendations backed up by practical work carried out in parallel by such technical forums as the 3GPPs,[3),4] which comprise regional standard development organizations (SDOs) in Europe, North America, and Asia. This centripetal role has led to the creation of five radio interfaces that are referred to as family members of IMT-2000 as defined in Recommendation ITU-R M.1457,[5] "Detailed Specifications of the Radio Interfaces of IMT-2000."

Among the five family members, W-CDMA is categorized as a CDMA Direct Sequence (CDMA-DS) and cdmaOne is categorized as a CDMA Multi-Carrier (CDMA-MC). Both of these members have been allocated a spectrum of

120 MHz in Japan, and consequently Fujitsu has been making continuous technical contributions to these two systems. This paper mainly focuses on standardization activities for the CDMA-DS and CDMA-MC systems.

Because of the many abbreviations in this paper, an explanation of these abbreviations is given in **Table 1** for better readability.

2. History of standardization of IMT-2000

The overall history of the standardization of IMT-2000 is shown in **Table 2** in chronological order from the perspective of three regional standardization activities as well as those in the ITU. The dawn of the standardization process can be traced back to the middle of the 1980s, when

Table 1
Abbreviation.

1XEV DO	1X Evolution Data Only
1XEV DV	1X Evolution Data and Voice
3G	3rd Generation
3GPP	3rd Generation Partnership Project
3GPP2	3rd Generation Partnership Project 2
ACTS	Advanced Communication Technologies and Services
AMC	Adaptive Modulation and Coding
ANSI	American National Standards Institute
ARIB	Association of Radio Industries and Businesses
ATDMA	Advanced TDMA Mobile Access
CBC	Cell Broadcast
CDMA	Code Division Multiple Access
CDMA-DS	CDMA Direct Sequence
CDMA-MC	CDMA Multi-Carrier
CODIT	Code Division Testbed
CPM	Conference preparatory meeting
CR	Change Request
CWTS	China Wireless Telecommunication Standard group
DECT	Digital Enhanced Cordless Telecommunications
EDGE	Enhanced Data rate for GSM Evolution
EIA	Electronic Industries Alliance
ETSI	European Telecommunications Standards Institute
FCS	Fast Cell Selection
FDD	Frequency Division Duplex
FMA	FRAMES Multiple Access
FPLMTS	Future Public Land Mobile Telecommunications System
FRAMES	Future Radio Wideband Multiple Access System
GLR	Gateway Location Register
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
GSMA	GSM Association
GTP	GPRS Tunneling Protocol
HARQ	Hybrid Automatic Repeat Request
HRPD	High Rate Packet Data
HSDPA	High Speed Downlink Packet Access
IETF	Internet Engineering Task Force
IMS	IP Multimedia Subsystem
IMT-2000	International Mobile Telecommunication 2000
IP^2	IP-based IMT Platform
IPR	Intellectual Property Rights
IPv6	Internet Protocol Version 6
ISD	International Standard Development Sub-committee
ITU-R	International Telecommunication Union, Radiocommunication Sector
ITU-T	International Telecommunication Union, Telecommunication Standardization Sector
LCS	Location Services
MAP	Mobile Application Part
mITF	Mobile IT Forum
MPHPT	Ministry of Public Management, Home Affairs, Posts and Telecommunications
MVCE	Mobile VCE (Virtual Centre of Excellence in Mobile and Personal Communications)
ODMA	Opportunity Driven Multiple Access
OFDM	Orthogonal Frequency Division Multiple Access
OHG	Operators Harmonization Group
PDNR	Preliminary Draft New Recommendation
RACE	Research of Advanced Communication Technologies in Europe
RAN	Radio Access Network
RCR	Research and Development Center for Radio Systems
Rel	Release
REVAL	ITU-R Recommendation on Evaluation
RSEL	ITU-R Recommendation on Selection Procedure

Table 1
Abbreviation (Continued).

RSPC	ITU-R Recommendation on Specification of IMT-2000
RTT	Radio Transmissions Technologies
SDO	Standards Development Organization
SMG	Special Mobile Group
SSDT	Site Selection Diversity Transmission
T1	Committee T1
T1P1	Technical Subcommittee T1P1
TDD	Time Division Duplex
TDMA-SC	TDMA Single Carrier
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
TG8/1	Task Group 8/1
TIA	Telecommunications Industry Association
TSG	Technical Specification Groups
TSG-SA	TSG Service and System Aspects
TSG-T	TSG Terminals
TTA	Telecommunications Technology Association
TTC	Telecommunication Technology Committee
UE	User Equipment
UMTS	Universal Mobile Telecommunication System
URL	Uniform Resource Locator
UTRA	UMTS Terrestrial Radio Access/Universal Terrestrial Radio Access
UTRAN	Universal Terrestrial Radio Access Network
UWC-136	Universal Wireless Communications-136
VoIP	Voice Over Internet Protocol
WARC	World Administrative Radio Conference
WCDMA	Wideband CDMA
WCDMA-N/A	North American WCDMA
WG	Working Group
WIMS CDMA	Wireless Multimedia and Messaging Services WCDMA
WP	Working Party
WRC	World Radiocommunication Conference
WTDMA	Wideband TDMA
WWRF	Wireless World Research Forum

IMT-2000 used to be called in the ITU-R by its former name of "Future Public Land Mobile Telecommunications System" (FPLMTS).

It was not until the early 1990s that practical work was commenced when a dedicated task group, TG8/1, was established in the ITU-R and the World Administrative Radio Conference 92 (WARC'92) allocated a 230 MHz bandwidth for IMT-2000 between 1885 and 2025 MHz and between 2110 and 2200 MHz. At the same time, Japan established the FPLMTS Study Committee under the RCR, which was the predecessor organization of the Association of Radio Industries and Businesses[6] (ARIB). Also at this time, the European region established the Universal Mobile Telecommunication System Ad Hoc (UMTS Ad Hoc) in the European Telecommunications Standards Institute[7] (ETSI), where two programs, CODIT and ATDMA, were being developed as possible evolutions from the Global System for Mobile Communications (GSM) within the RACE II project.

Since both administrators and the industries of all participating countries strongly anticipated a globally unified standard for IMT-2000 to allow global circulation of terminals, the ITU-R requested each regional SDO to make proposals for Radio Transmissions Technologies (RTTs). In response, each regional SDO, including the ARIB, commenced research in the middle 1990s to seek for the best RTT for IMT-2000 and many other organizations, including Fujitsu, actively started R&D and field experiments to find the most promising RTT for proposal to the ITU-R.

Between 1996 and 1998, many companies and organizations made proposals to their regional SDOs, and Fujitsu proposed a W-CDMA with a chip rate of 4.096 Mcps to the ARIB and ETSI. In 1998, the ITU-R announced that 10 RTTs had been proposed for the terrestrial components of IMT-2000 (**Table 3**), resulting in a somewhat chaotic situation in the selection process for a unique RTT for IMT-2000. However, the concept of "a family" was introduced to harmonize all of these proposals by merging them into five family members. The five family members are CDMA-DS;

Table 2
Overall history of IMT-2000 standardization.

Year	Fujitsu's Activities	ITU (ITU-R/ITU-T)	Europe (ETSI)	Japan (ARIB/TCC)	US (TIA/T1) and other regions
1985		• SG8 IWP8/13 established in ITU CCIR for initial study of FPLMTS.			
1986					
1987					
1988			• ETSI established. • RACE I program started.		
1989					
1990			• UMTS Ad Hoc established.		
1991		• ITU-R TG8/1 established.			
1992	• Commenced initial study of FPLMTS.	• WARC'92 allocated 230 MHz for IMT-2000 in 2 GHz band: - 1885 to 2025 MHz - 2110 to 2200 MHz	• RACE Ⅱ started with CODIT and ATDMA.		
1993	• Conducted experiment on propagation characteristics.			• FPLMTS study committee established in RCR.	• TIA TR46 established.
1994	• Proposed WCDMA to ARIB for RTT of FPLMTS.			• 24 candidates for RTT of FPLMTS were proposed.	
1995	• Conducted field experiment using WCDMA air interface.	• RSEL and REVAL completed.	• ACTS started. FRAMES project was set up.	• RCR changed its name to ARIB. • Evaluation of RTT candidates.	
1996	• Prototyping of WCDMA.		• Two harmonized modes were defined as UMTS candidates: - FMA1 WTDMA - FMA2 WCDMA	• Merging process was conducted to consolidate as WCDMA FDD and TDD.	
1997	• Proposed WCDMA concept to ETSI, resulting in creation of α-concept group.	• FPLMTS was renamed to IMT-2000. • Study of introduction of family concept was started.	• Five concept groups were formed: - α-concept WCDMA - β-concept OFDM - γ-concept WTDMA - δ-concept TDMA/CDMA - ε-concept ODMA • In MVCE, the Core-1 Program was formally commenced for new technology development for next-generation mobile communication systems.	• WCDMA was selected for FDD and TDD operation as a unique proposal to ITU-R TG8/1.	
1998	• Presented experimental results to ETSI SMG2.	• 10 candidates for terrestrial component and 6 candidates for satellite component were approved.	• ETSI decided to select WCDMA for UTRA FDD band and WTDMA/CDMA for TDD band. • 3GPP inaugurated with ETSI, ARIB, TTC, TTA, and T1 in December. • UTRA was proposed to 3GPP.	• WCDMA was proposed to ITU-R TG8/1.	• TR45.5 submitted to ITU-R cdma2000 based on IS-95. Proposal is similar to CDMA1 proposal from TTA. • TR46.1 submitted to ITU-R WIMS CDMA. • T1P1 submitted to ITU-R WCDMA-N/A. Proposal has commonality with WCDMA proposal from ARIB and ETSI. • WCDMA-N/A and WIMS WCDMA are merged into WP-CDMA and submitted to ITU-R. • TTA submitted CDMA 1 and CDMA 2. CDMA 1 is similar to proposals from ETSI and ARIB. CDMA 2 is similar to proposal cdma2000.
1999	• Elected as an official of 3GPP TSG RAN WG4.	• IPR concerns about CDMA technology were resolved. • "Family of systems" concept was defined in Q.1701 (framework for IMT-2000 networks). • Network and terminal functions for support of IMT-2000 services were identified in Q.1711 (network functional model for IMT-2000).	• Work in ETSI SMGs on UTRA transferred to 3GPP. • The first set of specifications of UTRA, Rel-99 was released in December. • Core-2 program started in MVCE.	• ISD established to work with 3GPPs. • Report on introduction of IMT-2000 was submitted by Telecommunications Technology Council of MPT Japan.	• 3GPP2 inaugurated. • CWTS in China joined 3GPP and proposed TD-SCDMA. • OHG studied the possibility of harmonizing between CDMA-DS (WCDMA) and CDMA-MC (cdma2000). This resulted in the chip rate being changed to 3.84 Mcps for CDMA-DS and to 3.6864 Mcps for SDMA-MC.

Table 2
Overall history of IMT-2000 standardization (Continued).

Year	Fujitsu's Activities	ITU (ITU-R/ITU-T)	Europe (ETSI)	Japan (ARIB/TCC)	US (TIA/T1) and other regions
1999		• Extensive harmonization activities result in merging of RTTs into 5 IMT-2000 family members: - CDMA-DS (WCDMA) - CDMA-MC (cdma2000) - CDMA-TDD (TD-SCDMA) - TDMA-SC (UWC-136) - FDMA/TDMA (DECT) • IMT.RKEY (key parameters of IMT-2000) approved.			
2000	• Continued to work with 3GPP and 3GPP2 to stabilize specifications. • Proposed SSDT to 3GPP RAN. • Hosted several 3GPP meetings.	• IMT.RSPC (M.1457) detailed specification of five IMT-2000 family members were approved by RA2000. • WRC2000 identified additional frequency bands for IMT-2000: - 806 to 960 MHz - 1710 to 1885 MHz - 2500 to 2690 MHz • Discussions about vision of systems beyond IMT-2000 were started.	• A tremendous amount of CRs were discussed and approved by 3GPP to stabilize Rel99 specifications.	• Based on the report from the Telecommunications Technology Council, the relevant legislation process was completed. • ISD works closely with 3GPPs. • A vision of systems beyond IMT-2000 was proposed to ITU-R WP8F.	
2001	• Elected as officials of TSG-RAN, RAN4, SA2 and T1 of 3GPP, and 3GPP2 TSG-P. • Presented a scenario for UTRAN Future Evolution workshop of 3GPP. • Presented OFDM as a possible candidate for future evolution. • Drafted PDNR on measurement uncertainty, global circulation, and spurious emissions for ITU-R WP8F.	• CDMA2000 1X-DO (HDR) and HSDPA were approved for inclusion in the revised version of M.1457. • Discussions of vision of systems beyond IMT-2000 were continued.	• 3GPP released Rel4. • WWRF was founded to formulate visions for future strategic research directions.	• MITF was founded to study 4th generation mobile communication systems led by MPMHPT. • A vision of systems beyond IMT-2000 was proposed to ITU-R WP8F. • IP^2 was established in TTC to study a future IP-based core network.	
2002		• Preparations were made for CPM about vision of systems beyond IMT-2000.	• 3GPP released Rel5. • Long-term evolution ad hoc meeting is established.	• Contributions are made to ITU-R WP8F for CPM.	

Table 3
Proposals of terrestrial components for IMT-2000.

	Proposal	Description	Source
1	CDMA Ⅰ	Multiband Synchronous DS-CDMA	South Korea TTA
2	CDMA Ⅱ	Asynchronous DS-CDMA	South Korea TTA
3	cdma2000	Wideband CDMA (IS-95)	USA TIA TR-45.5
4	DECT	Digital Enhanced Cordless Telecommunications	ETSI Project (EPDECT)
5	NA: W-CDMA	North American-Wideband CDMA	USA T1P1-ATIS
6	TD-SCDMA	Time-Division Synchronous CDMA	China Academy Telecommunications Technology
7	UTRA	UMTS Terrestrial Radio Access	ETSI SMG2
8	UWC-136	Universal Wireless Communications	USA TIA TR-45.3
9	W-CDMA	Wideband CDMA	Japan ARIB
10	WIMS W-CDMA	Wireless Multimedia and Messaging Services Wideband CDMA	USA TIA TR-46.1

CDMA-MC; CDMA-TDD (Time Division Duplex), which is sometimes referred to as TD-SCDMA (Time Division Synchronous Code Division Multiple Access); TDMA-SC (TDMA Single Carrier); and FDMA/TDMA.

Regarding CDMA-DS, CDMA-TDD, and CDMA-MC, it was suggested that practical development of the relevant technical specifications be mandated to two technical forums of the 3GPP and 3GPP2 and that the ITU-R provide in its recommendations hyperlinks by which each specification can be reached. Fortunately, the 3GPP and 3GPP2 successfully completed the first set of global specifications at the end of 1999, resulting in the best use of the specifications for commercial deployment in Japan and worldwide.

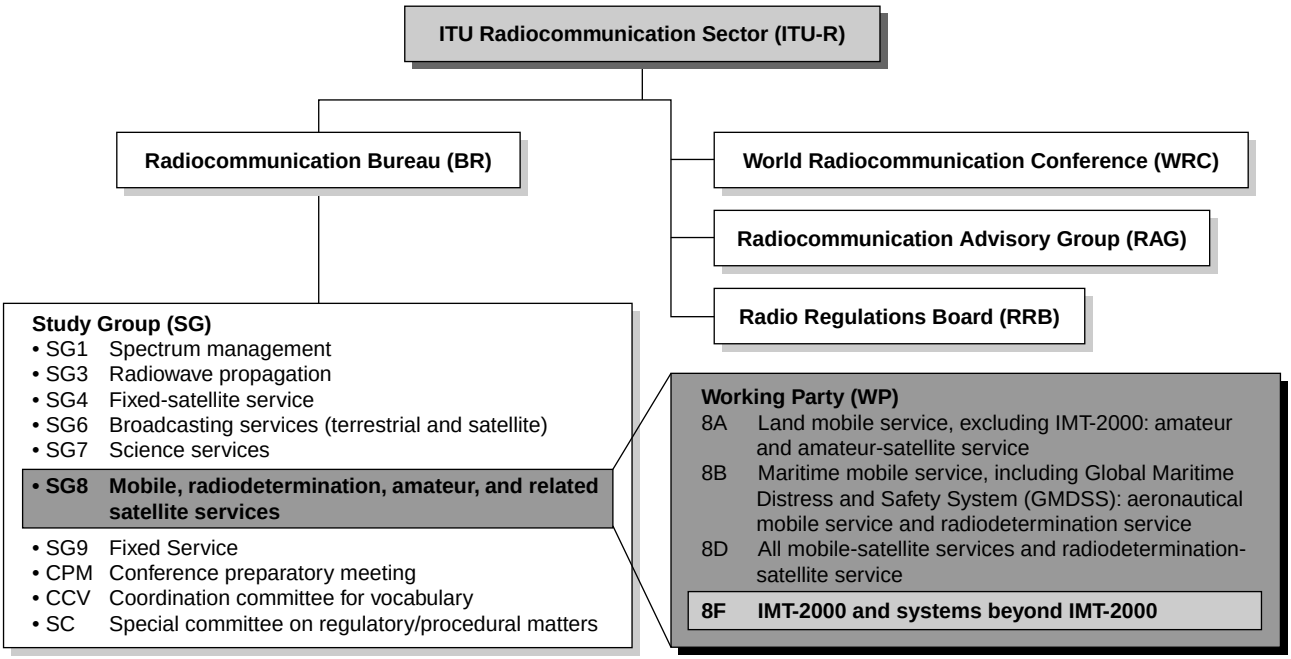


Figure 1
Organization of ITU-R.

3. Framework of standardization in the ITU

Successful development of specifications of IMT-2000 would not have been achieved without the extensive and substantial harmonization activities performed by the ITU with its centripetal force and ability to achieve a global consensus. In particular, the ITU-R and ITU-T are the main bodies that produce recommendations for IMT-2000. The ITU-R is responsible for creating recommendation related to radio transmission aspects (**Figure 1**). The Working Party 8F (WP8F) under an umbrella of SG8 of the ITU-R has been especially active in creating all of the international standards and recommendations of IMT-2000. Regarding regulatory issues such as frequency allocation and its re-farming for the IMT-2000 spectrum, the World Radio communication Conference (WRC) is held every three years to provide solutions that are based on global consensus.

On the other hand, the ITU-T is studying other aspects of the core network of IMT-2000.[8),9)] Specifically, the SG3 is creating a recommendation on tariffs and accounting principles, and the SG11 is creating signaling requirements and protocols (**Figure 2**). In addition, the Special Study Group "IMT-2000 and Beyond," has been established to investigate service and interface requirements for IMT-2000 and beyond, application and interworking of IMT-2000 systems, and harmonization and convergence of IMT-2000 systems.

Figure 3 shows the relations between the ITU and technical forums such as the 3GPPs and regional SDOs. As can be seen, there is a circular process in which the practical work of specifications development is carried out in the 3GPPs. The outcome of this work is submitted in the form of hyperlink references to the ITU through the member SDOs of the 3GPPs, and the SDOs adopt the relevant recommendations for their regional use.

4. 3GPP

In April 1998, the ARIB and Telecommunication Technology Committee (TTC) of Japan had a preliminary meeting with the ETSI in Sophia

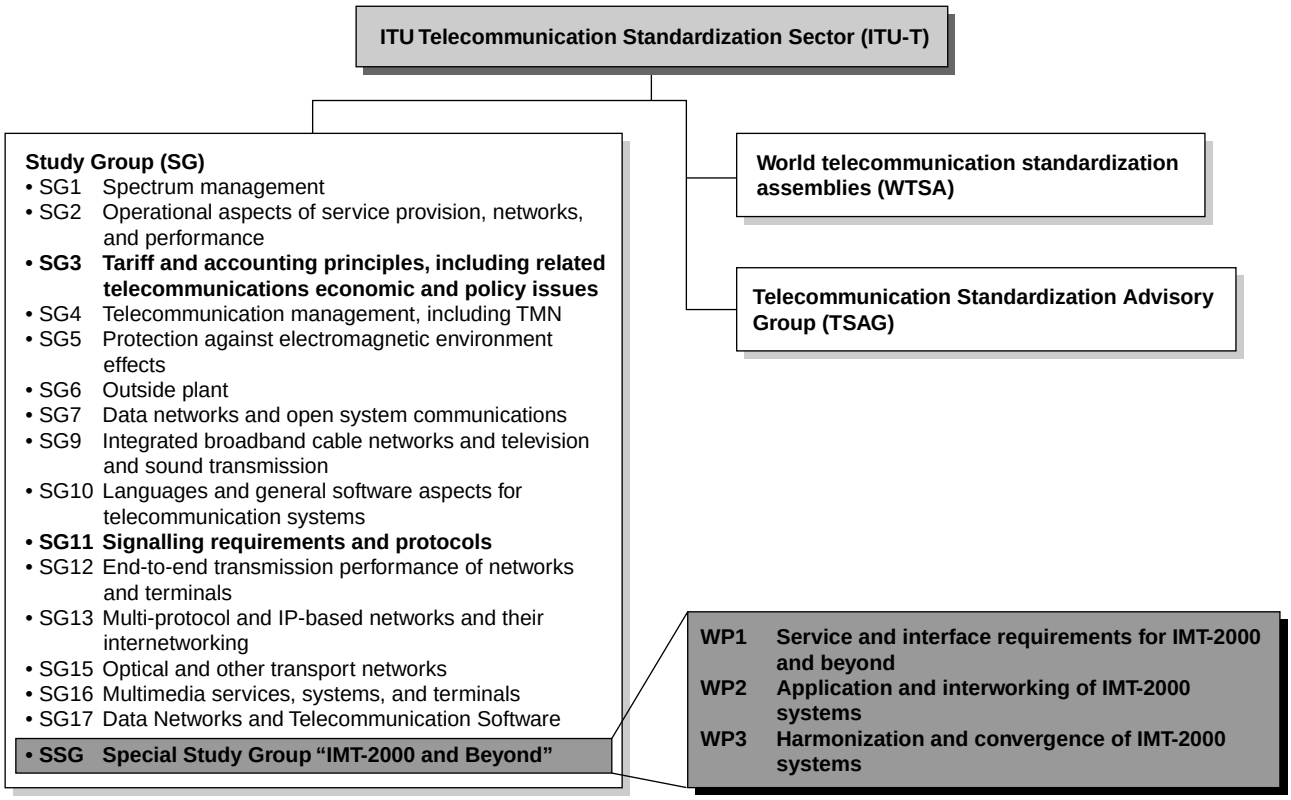


Figure 2
Organization of ITU-T.

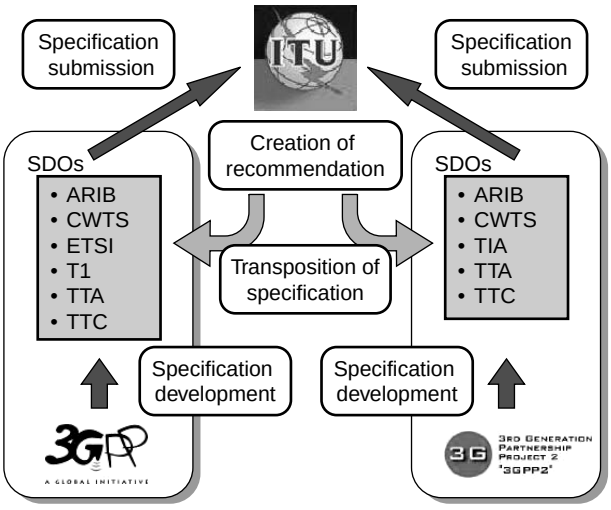


Figure 3
Relations between standardization entities.

Antipolis, France to discuss how global standardization work on the 3rd generation mobile system should proceed. Then, Committee T1 (T1) of the US and the Telecommunications Technology Association (TTA) of Korea joined the meeting and these four SDOs started substantial discussions on how the standardization work should fulfill the requirements of the mobile market, users, vendors, and operators. Through their discussions, a collaborative agreement regarding the partnership project for the 3rd generation mobile system was reached with the ARIB, ETSI, T1, TTA, TTC, and China Wireless Telecommunication Standard group (CWTS) of China. This agreement led to the inauguration of the 3GPP in 1998 with these six SDOs as signatories.

4.1 Scope and objectives

The original scope of the 3GPP was to provide globally applicable technical specifications for the 3rd generation mobile system based on an enhanced GSM core network and UTRA (Universal Terrestrial Radio Access) using W-CDMA FDD

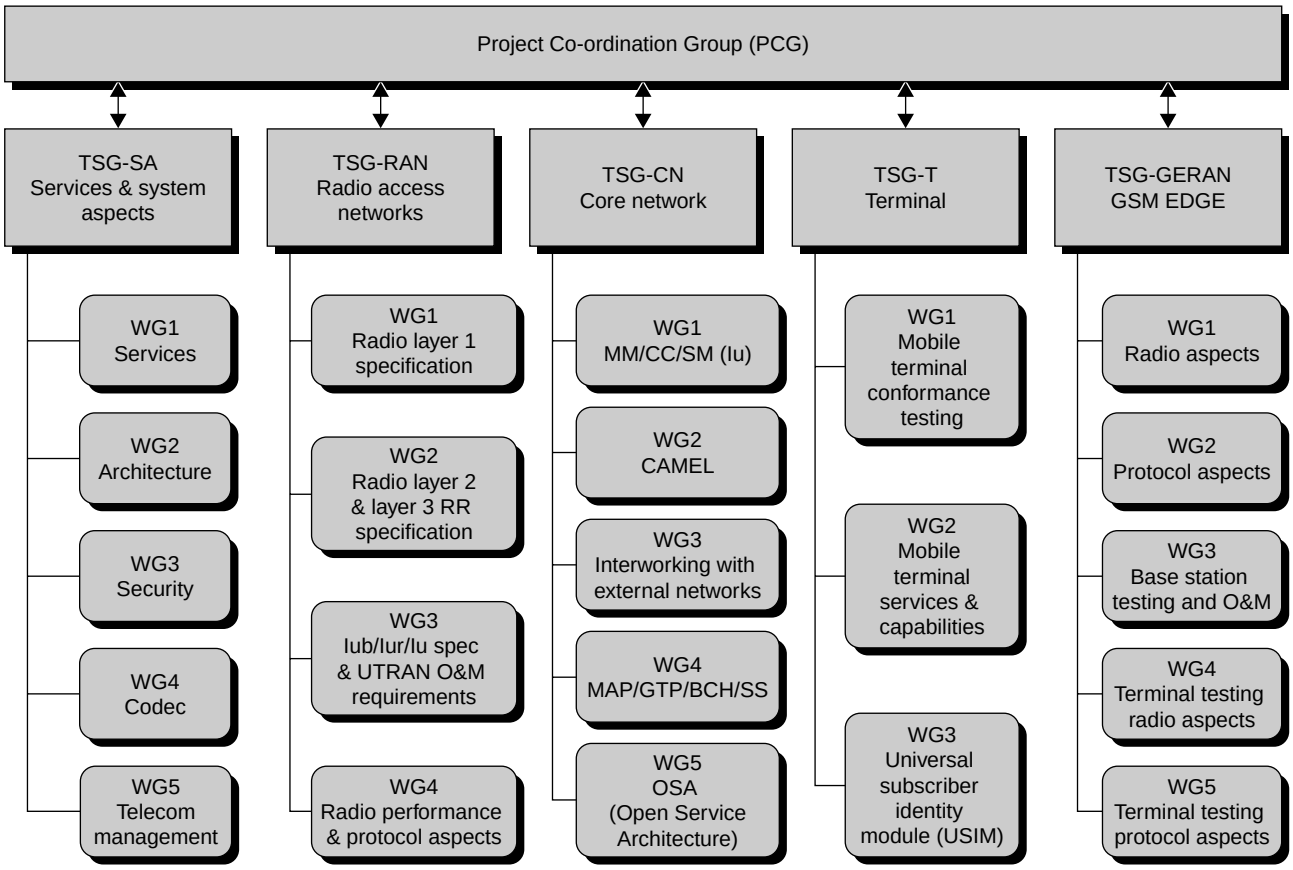


Figure 4
Structure of 3GPP.

and TDD.[10] The scope was later expanded to maintenance and development of GSM-related technical specifications, including enhancements of GSM radio access technologies such as GPRS and EDGE. This expansion was done to ensure handover between UMTS and GSM, which was an essential requirement in Europe.

The objective of the 3GPP was to develop a set of global specifications for UTRA to facilitate global circulation of mobile terminals and it is responsible for the creation of a basic specification of standards to which all SDOs refer and are endorsed as regional standards by the ITU-R.

4.2 Organization

1) Partner and member

The 3GPP consists of partners and individual members. A partner is categorized as either an Organizational Partner (OP) or a Market Representation Partner (MRP). The OPs include six SDOs: ARIB, CWTS, ETSI, T1, TTA, and TTC. The MRPs include the GSM Association[11] and the UMTS Forum,[12] both of which represent the European mobile market and industry. The OPs retain authority to define, publish, and set regional standards, while the MRP identifies consolidated views of mobile market requirements. The individual members are tasked with making technical contributions within the scope of the 3GPP in close cooperation with other entities such as the Internet Engineering Task Force[13] (IETF) and IPv6 Forum.[14]

2) Organizational structure

The structure of the 3GPP is shown in **Figure 4**. It consists of the Project Co-ordination Group (PCG) and five Technical Specification Groups (TSGs). The PCG handles high-level management of programs, and the TSGs cover a wide

Table 4
Categories of 3GPP specification documents.

"aa" in TS/TR	Category
21	Requirements
22	Service Aspects
23	Technical realization
24	Signalling protocols (UE to Core Network)
25	Radio Access aspects
26	Codec
27	Related to DATA applications
28	Signalling protocols (RNS to CN)
29	Core Network Signalling Protocols (MAP, GTP, etc…)
30	Program management (Project Plan, Work Item, etc…)
31	SIM/UIM/UICC
32	Charging and OAM&P (Operations, Administration, Maintenance & Provisioning)
33	Security
34	Test Specifications
35	Algorithms (encryption, authentication, etc.)

Table 5
Release and version numbers of 3GPP specification documents.

Version field	Meaning
x	0: Draft 1: Presented to TSG for information (specification estimated by prime responsible group to be at least 60% stable) 2: Presented to TSG for approval (specification estimated by prime responsible group to be at least 80% stable) 3 or greater: Approved by TSG and under change control; the value indicates the Release (x = 3: Release 99, x = 4: Release 4, x = 5: Release 5)
y	Under change control "y" changes are only made when the TSG approves one or more Change Requests.
z	Incremented each time a purely editorial change is made.

Table 6
Main features defined in 3GPP specification sets.

Release '99	Release 4	Release 5
December 1999	March 2001	March 2002
• Basic capability of UTRA (W-CDMA FDD) • UTRAN architecture (Iu/Iur/Iub interfaces and protocols) • UMTS AMR (Adaptive Multi-Rate codec for UMTS) • Enhanced Call Control • GLR (Gateway Location Register) • Advanced QoS for UMTS (4 QoS classes were defined, as "Conversation," "Streaming," "Interactive," and "Background")	Features in Rel99 plus: • UTRA (W-CDMA-TDD) • UTRAN architecture (TDD part of Iu/Iur/Iub interfaces and protocols) • Transport and Control Separation in CS CN domain • Introducing 1.28 Mcps TDD mode • LCS (Location Service)	Features in Rel4 plus: • IMS (IP Multimedia service Subsystem) • HSDPA (High Speed Data Packet Access) • End to End QoS • Extended Transparent End-to-End Packet Switched Mobile Streaming Applications • Wideband AMR • Security Enhancements • Intra Domain Connection of RAN Nodes to Multiple CN Nodes

range of technical areas, including service & system aspects (TSG-SA), radio access networks (TSG-RAN), the core network (TSG-CN), terminals (TSG-T), and the GSM/EDGE radio access network (TSG-GERAN).

4.3 Specification document

The 3GPP yields two deliverable types of documents: Technical Specifications (TSs) and Technical Reports (TRs). Individual TSs and TRs are identified according to the following numbering schemes:

TS/TR aa.bbb version x.y.z,

where "aa" indicates the category of the specification (**Table 4**), "bbb" is the document number, and "x.y.z" indicates the release and version numbers (**Table 5**).

4.4 Enhancement of features (Rel99/Rel4/Rel5)

Table 6 shows the main features defined in the three major specification sets that the 3GPP has so far released: Release-99, Release-4, and Release-5. Release-99 includes the basic capabilities and functionalities of UMTS. In Release-4, one of the new features was contributed by CWTS

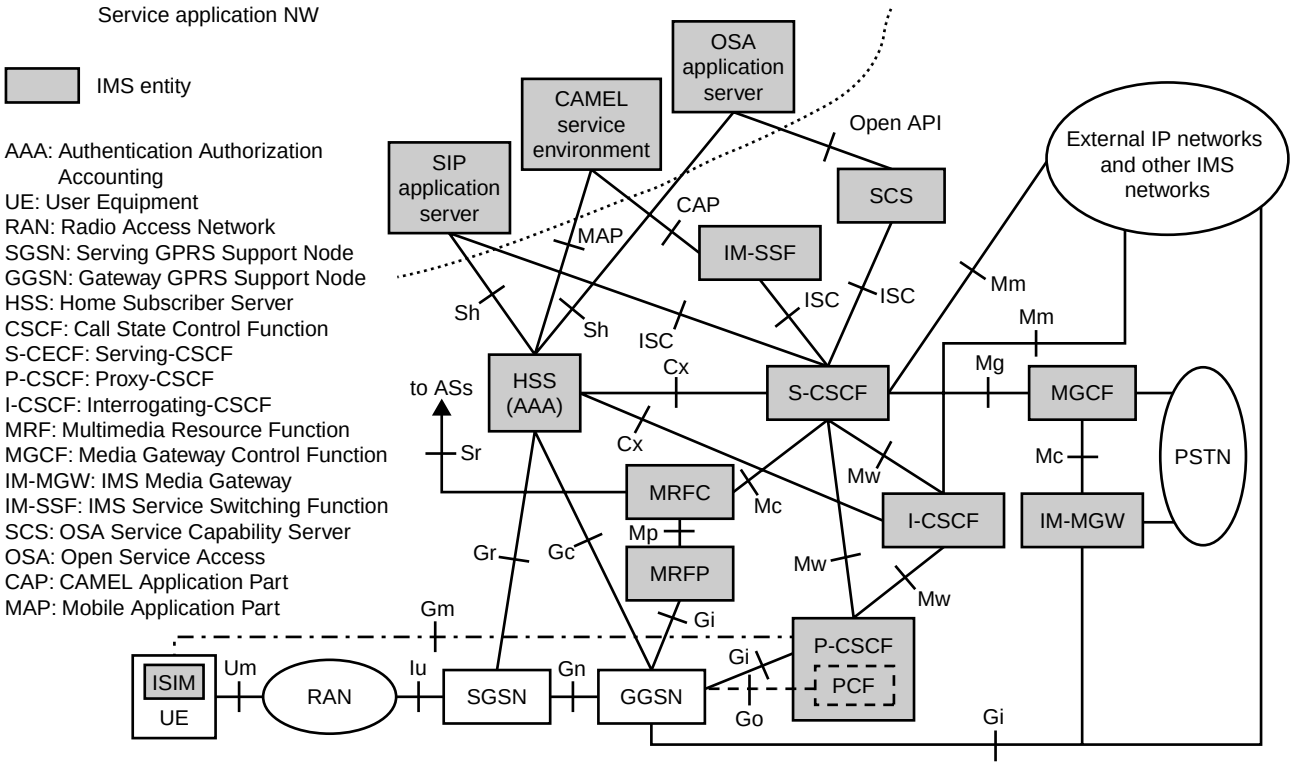


Figure 5
Architecture of IP multimedia subsystem (IMS).

of China and incorporated as W-CDMA TDD.

In March 2002, most of Release-5 was frozen and the IP Multimedia Subsystem (IMS) as shown in **Figure 5** was incorporated to enable the operation of cost-effective and high-quality IP-based multimedia services, including VoIP. The IMS adds new features to IP-based services, for example, security, content-based charging, and location related-services.[15] These new features help operators to quickly and flexibly find new sources of revenue that are not available in existing circuit-switched services and packet-switched services.

In addition, a significant improvement in radio access technology called High Speed Data Packet Access (HSDPA) was included to improve the throughput of downlink packet transmission to 8 Mb/s. HSDPA provides this improvement because it uses Adaptive Modulation and Coding (AMC), Hybrid ARQ (HARQ), and Fast Cell Selection (FCS) technologies.

4.5 Enhancement of features toward Release-6

Now that Release-5 is almost completed, the 3GPP is moving toward the next release, Release-6, to further improve performance and to enhance capabilities. Some of the new features that are on the table are Multimedia Broadcast Multicast Service (MBMS), interworking between Wireless LAN (WLAN) and UMTS, and Orthogonal Frequency Division Multiple Access (OFDM).

Study of MBMS as an enhanced form of Cell Broadcast (CBC) with a larger message size has been started. MBMS may pioneer a new service which allows broadcast of multimedia messaging and video/music streaming capabilities as one of its major applications. The interworking between WLAN and UMTS has been identified as one of the keys for providing flexibility when accessing multiple radio resources and for providing service mobility between WLAN and the 3G system in various mobile environments. Initial work has

been started under the TSG SA, and the first draft on its architecture has already been completed.

Orthogonal Frequency Division Multiple Access (OFDM) is being studied as a radio access technology which may drastically increase data rates by using a large number of orthogonal frequencies that are mutually spaced apart. Because of its potential for realizing high-bit-rate data transfer, an OFDM feasibility study that will complete its initial phase in 2003 is about to be started. It is also foreseen that OFDM could be a promising candidate for what is called the 4th generation mobile system.

5. 3GPP2

5.1 Scope and objectives

Immediately after the 3GPP was inaugurated in Europe, the 3GPP2 was established as a counterpart of the CDMA-MC camp supporting the ANSI/TIA/EIA-41 and IS-95 specifications. The 3GPP2 specifies an air interface based on a cdmaOne technology called IS-95 and the cdma2000 interface, which is an evolved form of the IS-95 interface, to increase capacity and allow faster data communication. It also specifies a core network based on an ANSI-41 specification developed to support cellular and cdmaOne networks. Furthermore, the 3GPP2 is studying an IP-based core network for IMT-2000 to support various kinds of communications. The 3GPP2's relationship with the ITU-R is similar to the one between the 3GPP and the ITU-R. The 3GPP2 is responsible for developing technical specifications to which each SDO refers and are endorsed as regional standards by the ITU-R.

5.2 Organization

1) Partners and members

Like the 3GPP, the 3GPP2 also has Organizational Partners (OPs) and Market Representation Partners (MRPs) in addition to individual members who make technical contributions. The OPs include ARIB, CWTS, TIA, TTA, and TTC. The CDMA Development Group (CDG), Mobile Wireless Internet Forum (MWIF), and IPv6 Forum are included as MRPs.

2) Organizational structure

The 3GPP2 has a structure similar to that of the 3GPP (**Figure 6**). It has five Technical Specification Groups (TSGs) for corresponding technical areas, led by the Steering Committee (SC). Coverage of technical areas of the 3GPP2 is also similar to that of the 3GPP, including the service capability requirements (TSG-S), interfaces between the radio access network and core network (TSG-A), functions and interfaces between the cdma2000 infrastructure and user terminal equipment for the radio access part (TSG-C), Internet and IP multimedia core network (TSG-P), and core network internal interfaces for call associated and non-call associated signaling (TSG-N).

5.3 Specification document

Each TSG issues a set of specifications based on its study. The structure of these specifications is organized and issued by each TSG. Unlike the 3GPP, no particular numbering scheme is applied to the specification documents.

In 1999, IS-2000 Release-0 was defined as the first step toward an IMT-2000 system based on cdmaOne technology to support the following features:

1) Quick power control for the downlink traffic channel,
2) turbo coding,
3) transmission diversity, and
4) a high-speed supplemental channel for up to 144 kb/s data communication.

In 2000, Release-A was issued to enhance data communication services supporting the following:

1) A multi carrier mode with 3x,
2) a high-speed supplemental channel for up to 2 Mb/s data communication,
3) a high-speed control channel, and
4) simultaneous data and voice communication.

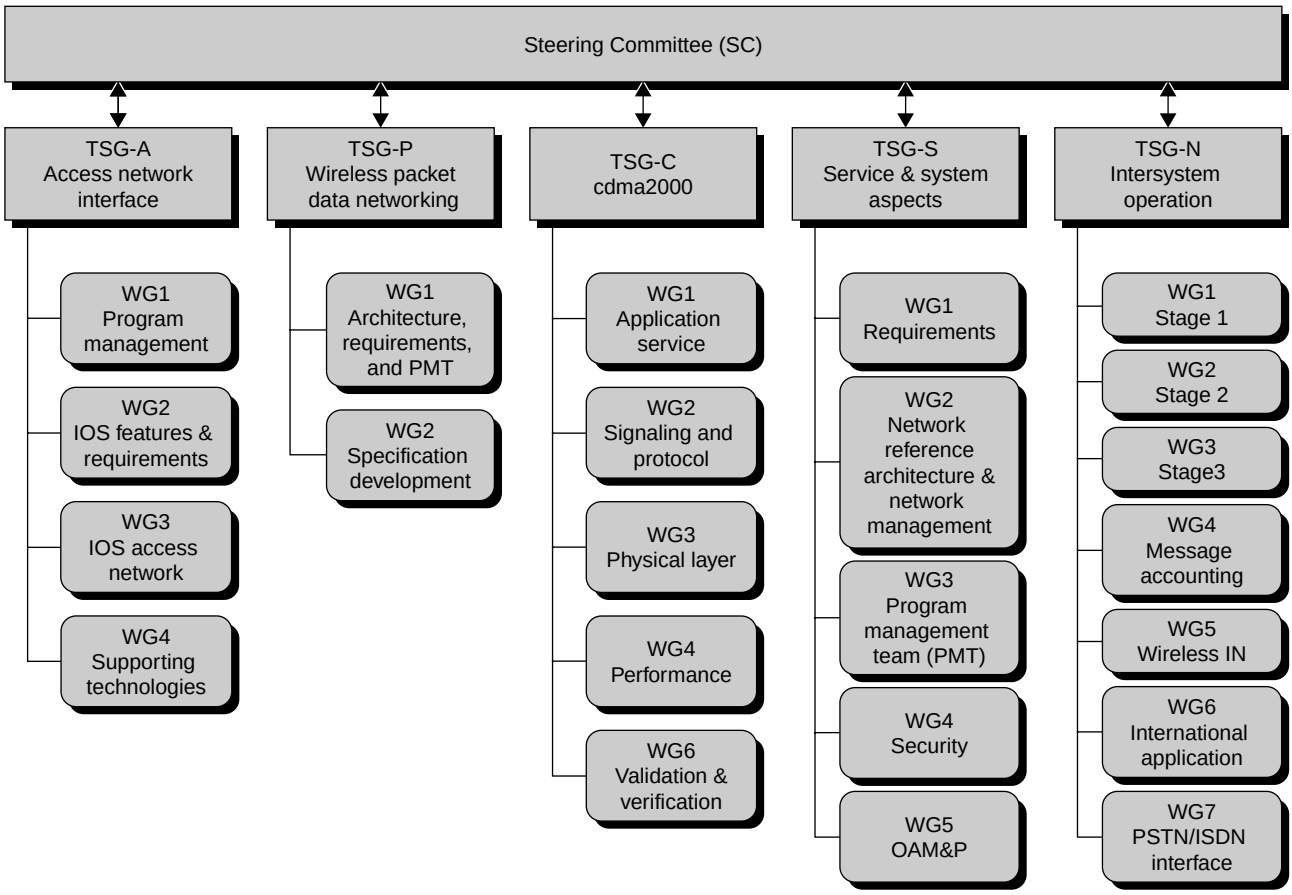


Figure 6
Structure of 3GPP2.

5.4 Enhancement of features

The 3GPP2 has also been working to enhance its capability. Typical new features for this purpose include 1XEV DO, 1XEV DV, and support of IP multimedia services.

In the fourth quarter of 2000, a specification for High Rate Packet Data (HRPD) was issued to enhance downlink data communication. HRPD, which is sometimes called 1XEV DO (1X Evolution Data Only), allows mobile terminals to easily access an IP network thorough a high-speed data communication link that is dedicated for mobile data services and made separate from the radio access network for voice communication (hence the "Data Only" in the name). It has been reported that an average data throughput of from 600 to 900 kb/s was obtained. Because 1XEV DO was devised for data communication only, another radio channel was required for speech communication, which led to the development of 1XEV DV (1X Evolution Data and Voice). To support multimedia services, it is necessary to provide simultaneous speech and data communication using the same carrier frequency. This is achieved by separately setting the transmission powers of the data and speech channels.

One of the key objectives for advanced future mobile wireless networks is to support voice communication over an IP network. Due to bandwidth limits, it is not easy to efficiently support a VoIP feature over the current IMT-2000 air interface. The 3GPP2 is considering voice signal transmission using existing air channels and conversion to IP packets at both the terminal and network sides. This method is called 0-byte header compression and was devised to solve the bandwidth problems of VoIP over the air.

6. Harmonization activities in the 3GPPs

The 3GPP and 3GPP2 have sought for an adequate network architecture for provisioning IP based multimedia services, and the 3GPPs have consequently developed architectures that have a high degree of commonality. In April 2002, the first IP core network harmonization workshop was held in Toronto to find ways to harmonize the 3GPP with the 3GPP2, where it drafted recommendations to the 3GPPs to harmonize their IP based core networks. During the workshop, the 3GPP produced IMS while the 3GPP2 produced Multi Media Domain (MMD), and both of these sets of recommendations have been endorsed by the 3GPPs. Afterwards, a new study on interoperability between IP-based core networks and WLAN systems was initiated in the 3GPP TSG-SA, and Fujitsu has contributed to this study.

7. Fujitsu's activities in the standardization process

In 1993, in the early stage of R&D for IMT-2000, Fujitsu commenced studies on CDMA. In those studies, Fujitsu conducted field experiments using a frequency band of 2 GHz to determine whether the CDMA air interface was a candidate RTT for proposal to the ITU-R. Based on the experimental results, Fujitsu proposed a W-CDMA with a chip rate of 4.096 Mcps to the ARIB in 1994 and to the ETSI in 1997. Through discussions within the group, Fujitsu agreed to change the chip rate to 3.84 Mcps for harmonization with other proposals.

In the first stage of the establishment of the 3GPP, Fujitsu contributed a great deal by making proposals regarding its structure and working procedures and decided to send some officials to the forum. As one of the representatives of ARIB and TTC, Fujitsu has also helped to create the requisite amendments to the scope of the 3GPP. Fujitsu has also actively contributed to the development of the technical specifications of, for example, the MAP/GTP enhancement for GPRS, the protocol between the UE and core network, GLR, development of the Iu/Iur/Iub interface, SSDT in UTRAN, and the charging aspects of MBMS.

In parallel with these activities, Fujitsu has been a long-time participant in the ITU-R and ITU-T, making not only technical contributions to promote stabilization of technical recommendations but also strategic contributions to ensure that recommendations comply with Japanese laws under the guidance of the Ministry of Public Management, Home Affairs, Posts and Telecommunications.

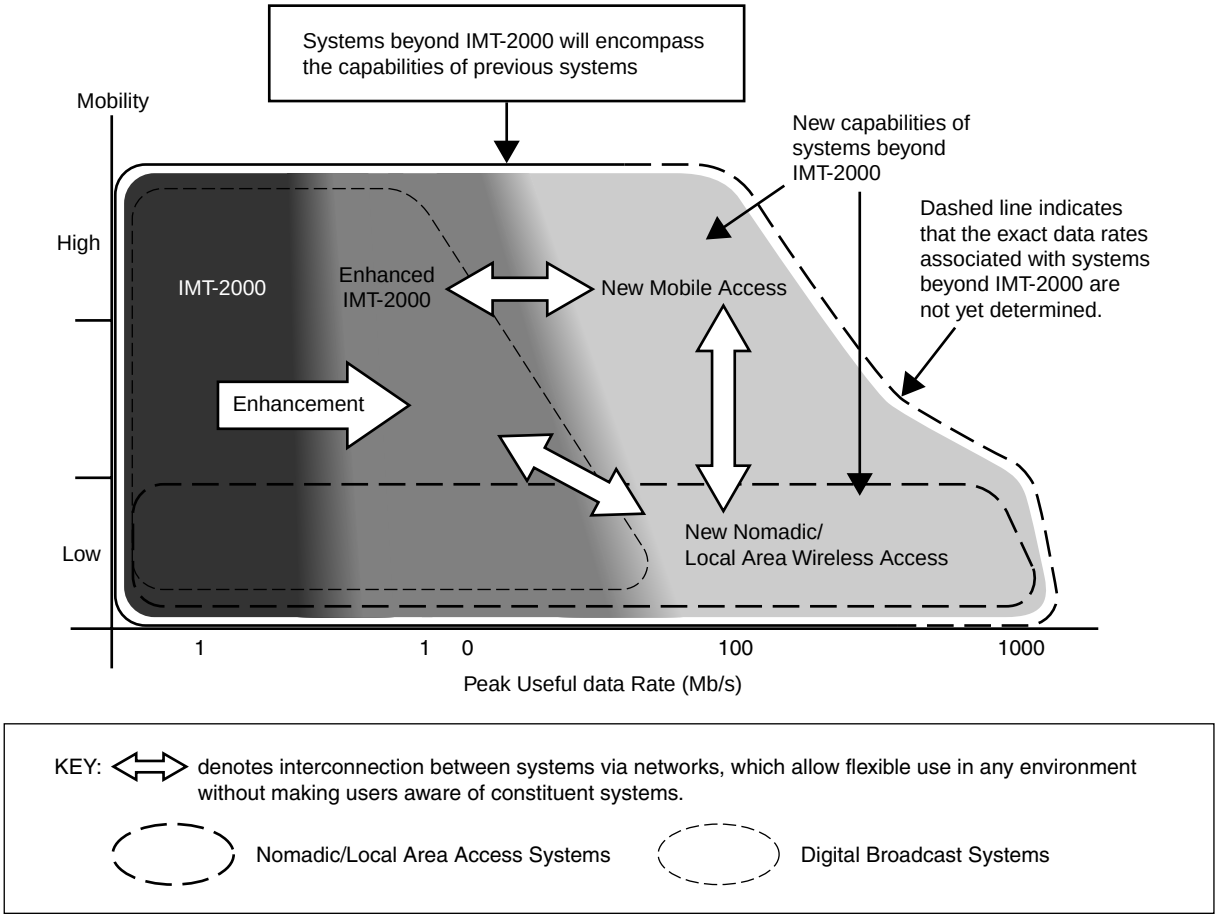
8. Enhancements and evolution of IMT-2000

8.1 Evolution of IMT-2000

As mentioned in the previous sections, the first sets of IMT-2000 specifications, based on Release-99 developed by the 3GPP and Release-0 by the 3GPP2, have been produced in the form of Recommendation ITU-R M.1457. However, there have been further demands such as faster data rates for users and an IP-based multimedia subsystem to enhance the performance and capability of current IMT-2000 systems. These demands have encouraged the ITU-R to revise the current M.1457 to include new features such as HSDPA, LCS, IMS, 1XEV-DO, and 1XEV-DV. Continuous and regular revision in the ITU-R is being carried out for technical enhancement within the scope of IMT-2000.

8.2 Systems beyond IMT-2000

Having seen that the specifications for the first releases of IMT-2000 systems have been completed, the ITU-R has undertaken studies on the future development of IMT-2000 and systems beyond IMT-2000 to cope with the need for enhancements of technical capabilities, the range of available services, and the breadth of applications. The capabilities of systems beyond IMT-2000 were intensively discussed in the



Dark shading indicates existing capabilities, medium shading indicates enhancements to IMT-2000, and the lighter shading indicates new capabilities of systems beyond IMT-2000.

The degree of mobility as used in this figure is described as follows: Low mobility covers pedestrian speed, and high mobility covers high speed on highways or fast trains (60 km/h to ~250 km/h, or more).

Figure 7
Capabilities of IMT-2000 and systems beyond IMT-2000.
Source: RECOMMENDATION ITU-R M.1645, Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000

ITU-R WP8F and are illustrated in **Figure 7**, which came from the ITU-R document, "Preliminary Draft New Recommendation (PDNR): Vision, framework and overall objectives of the future development of IMT-2000 and of systems beyond IMT-2000."

The systems beyond IMT-2000 may include new radio access capabilities and a new core network (probably an IP-based network) to be realized around 2010. Progress has been accelerated by extensive contributions from Japan in line with the activities of the mITF[16] to promote the "new-generation mobile communication system." Similar discussions to those held in the ITU-R WP8F have just been started in the 3GPPs as well as in academic bodies such as the MVCE[17] in the UK and the WWRF[18] in Europe, and we can expect them to result in another phase of harmonization.

9. Conclusion

This paper presented a comprehensive overview of the global standardization activities for IMT-2000 in the ITU and 3GPPs and described some related activities of Fujitsu. The standardization process of IMT-2000 took more than a

decade because of temporary technical turmoil in certain stages. However, owing to extensive efforts by the ITU as well as the 3GPPs, a global consensus has fortunately been reached, resulting in a harmonized standard that will make it easier to improve mobile services around the globe and encourage the industry for the future.

Since IMT-2000 has just been commercialized and the industry is about to step into another stage to stimulate the mobile market, new standardization work needs to be commenced for the system beyond IMT-2000, which is expected to provide more sophisticated services to meet the further demands of the wireless community.

Fujitsu has a long history of experience in research and development backed up by its expertise in information processing, communication, and devices for IMT-2000. By drawing on this experience and expertise, we will continue to contribute to the global standardization of not only IMT-2000 but also the systems that will come after it.

References

1) ITU-R Recommendation M.1455: Key characteristics for the International Mobile Telecommunications-2000 (IMT-2000) radio interfaces.
2) *http://www.itu.int/*
3) *http://www.3gpp.org/*
4) *http://www.3gpp2.org/*
5) ITU-R Recommendation M.1457: Detailed specifications of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000).
6) *http://www.arib.or.jp/english/index.html*
7) *http://www.etsi.org/*
8) ITU-T Recommendation Q.1701: Framework for IMT-2000 networks.
9) ITU-T Recommendation Q.1711: Network functional model for IMT-2000.
10) Harri Holma and Antti Toskala: W-CDMA for UMTS revised edition. John Wiley & Sons, Inc., 2001.
11) *http://www.gsmworld.com/*
12) *http://www.umts-forum.org/*
13) *http://www.ietf.org/*
14) *http://www.ipv6forum.org/*
15) *http://www.openmobilealliance.org/*
16) *http://www.mitf.org/index_e.html*
17) *http://www.mobilevce.com/index2.htm*
18) *http://www.wireless-world-research.org/*

Eisuke Fukuda received the B.S. degree in Electrical Engineering from Tohoku University, Sendai, Japan in 1979. He then joined Fujitsu Laboratories Limited, where he was engaged in research and development of terrestrial radio communication systems, and later, of mobile communication systems, including the PDC system and W-CDMA system for IMT-2000. After working for Fujitsu Europe Telecom R&D Centre Ltd. in the UK from 1996 to 1999, he moved to the 3G Standardization Promotion Department of Fujitsu Limited. He has been the vice chair of the TSG-RAN of the 3GPP since 2001 and is a member of the Institute of Electronics, Information, and Communication Engineers (IEICE) of Japan.

E-mail: efukuda@jp.fujitsu.com

Akishige Noda received the M.S. degree in Information Engineering from Shinshu University, Nagano, Japan in 1982. He then joined Fujitsu Limited, Kawasaki, Japan, where he was engaged in various development projects, including facsimile communication systems and the X25 packet, PHS, and PDC systems. Since 1998, he has been working on standardization for IMT-2000. Since 2001, he has been vice-chair of the TSG-SA WG2. He is currently active in the TSG-SA WG2 and TSG-CN of the 3GPP.

E-mail: aki.noda@jp.fujitsu.com

Mamoru Higuchi received the M.S. degree in Electronics Engineering from Osaka University, Osaka, Japan in 1980. He then joined Fujitsu Limited, Kawasaki, Japan, where he has been engaged in software development for communication systems. He was vice chair of the TSG-P of the 3GPP2 from February 2001 to March 2002. He is a member of the Institute of Electrical and Electronics Engineers (IEEE) and the Institute of Electronics, Information and Communication Engineers (IEICE) of Japan.

E-mail: mamoru.higuchi@jp.fujitsu.com