Super 3G Technology Trends

Part 1: Super 3G Overview and Standardization Activities

Super 3G, which is now being studied as a means of making a smooth migration from 3G to 4G technology, will be explained in two parts. In this issue, Part 1 will cover the concept, requirements, and development scenario of Super 3G as well as current standardization activities. In the next issue, Part 2 will describe Super 3G technology in detail including the technology envisioned by current standardization efforts and specific technology proposed by DoCoMo.

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1. Introduction

In October 2001, DoCoMo launched a Third-Generation mobile communication (3G) service in Japan called "FOMA" based on the W-CDMA wireless-access system. Since then, new services and rate plans have been added, terminal functions and performance have been improved, and service areas have been expanded resulting in a dramatic jump in subscribers starting in 2003. As of July 2006, the number of FOMA subscribers in Japan had risen above 27 million, and the percentage of FOMA subscribers to all DoCoMo subscribers is now more than 52% reflecting a steady transition from 2G to 3G.

The international penetration of W-CDMA is also moving forward at a satisfactory pace. Up to 2003, the number of mobile communication carriers that had launched commercial services by W-CDMA was only a few, but the years since then have seen a rapid succession of W-CDMA offered by many carriers. To date, there are about 100 mobile communication carriers that offer 3G services using W-CDMA not only in Europe but in North America and Asia as well.

The maximum data rate of FOMA packet services offered by DoCoMo is currently 384 kbit/s, but the introduction of High Speed Downlink Packet Access (HSDPA)[*1] scheduled for 2006 will provide even higher speeds. Technical specifications for this new system call for a maximum downlink speed from a radio base station to a mobile terminal of about 14 Mbit/s. The HSDPA system is also expected to increase spectrum efficiency by 3 to 4 times that of the existing system thereby reducing cost per bit.

At the 3rd Generation Partnership Project (3GPP), which has been developing standard specifications for W-CDMA, technical specifications are nearly completed for High Speed Uplink Packet Access (HSUPA)[*2] that aims to raise the uplink speed to 5.7 Mbit/s. Short- and medium-term improvement of W-CDMA is also progressing well at 3GPP. However, on looking further out into the future, the need can be felt for a long-term vision, and to this end, DoCoMo proposed the "Super 3G" concept in 2004 to steer the evolution of 3G.

2. Super 3G Concept

2.1 Purpose of Super 3G

The "4G" mobile communication system of the future that will follow 3G is now being studied at the International Telecommunication Union-Radiocommunication sector (ITU-R), an organization devoted to standardizing wireless technology. In the current stage of these studies, discussions are being held to determine what frequency bands to use for 4G systems.

In short, 4G standardization activities are not yet at the stage where specific technical standards are being discussed. Nevertheless, specifications described in a framework recommendation[*3] are calling for data rates of 100 Mbit/s for high-speed mobility and 1 Gbit/s for low-speed mobility. DoCoMo is actively researching technology to meet these specifications, and field trials are already demonstrating rates of 100 Mbit/s for

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*1 HSDPA: A high-speed downlink packet transmission system based on W-CDMA. Maximum downlink transmission speed under the 3GPP standard is about 14 Mbit/s. HSDPA optimizes the modulation method and coding rate according to the reception conditions of the mobile terminal.

*2 HSUPA: A high-speed technology for the uplink based on W-CDMA. The 3GPP standard calls for a maximum uplink transmission speed of 5.7 Mbit/s. HSUPA optimizes the coding rate, spread factor, and transmit power according to radio-reception conditions at the base station.

*3 Framework recommendation: Organizational configuration for conducting a study; decides on procedures, etc.

high-speed mobility and 1 Gbit/s for low-speed mobility. A data rate of 2.5 Gbit/s in a low-speed mobility environment has also been demonstrated in field trials.

Three scenarios can be considered for deploying 4G as shown in **Figure 1**. Of these, DoCoMo reached the conclusion that the most optimal for introducing 4G in a smooth manner is scenario 3 that first enhances 3G and then constructs 4G on that enhancement. The concept of an enhanced version of 3G , called "Super 3G," was proposed by DoCoMo in the beginning of 2004.

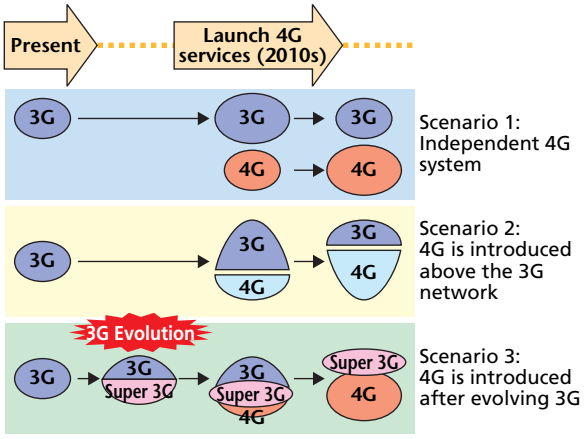


Figure 1 4G deployment scenarios

It has been considered that the introduction of HSDPA will enable 3G mobile communication systems based on W-CDMA technology to meet the demands of the market and remain competitive against other systems for a number of years. From here on, however, multimedia and ubiquitous traffic is expected to grow rapidly, and to support this traffic, technology must evolve based on a long-term perspective. This approach was well supported by many operators when DoCoMo proposed Super 3G (known as Long Term Evolution or Evolved UTRA and UTRAN in the standards) to 3GPP in 2004.

The purpose of Super 3G is not simply to migrate smoothly to 4G but also to maintain competitiveness over the long term by enhancing the W-CDMA 3G system (**Figure 2**). Super 3G will, of course, include the scope of 3G, and as for spectrum, it will use the frequency bands currently allocated to 3G plus those newly added for 3G use.

2.2 Super 3G Requirements

Super 3G will be required to provide low delay in addition to significantly faster data rates and improved spectrum effi-

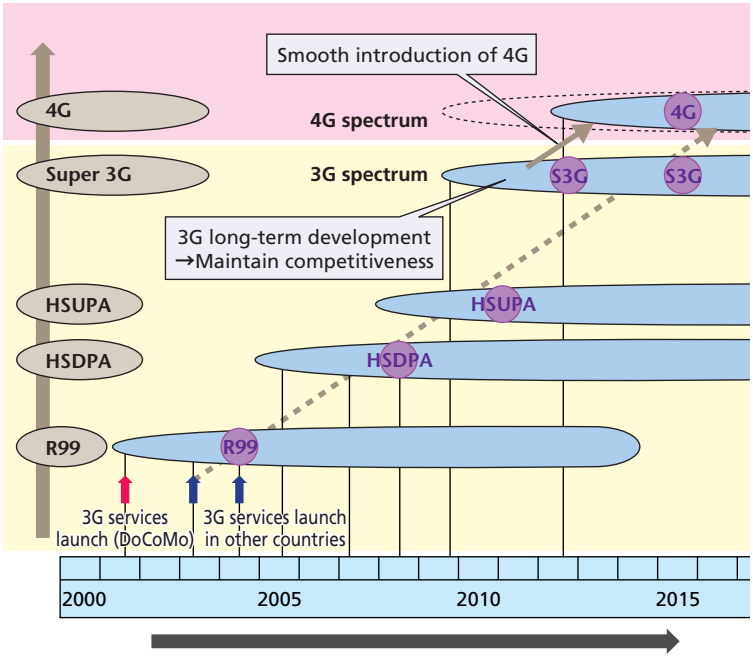


Figure 2 Super 3G concept

ciency[*4]. Achieving low delay will reduce the time required to establish calls, and reducing the time required for transferring data during a call will enable high-speed data transfer by a protocol like TCP/IP.

Though Super 3G is a system that adopts the 3G spectrum, it takes into account the potential for flexible operation by applying the 5-MHz and greater bandwidths used by W-CDMA. It is also assumed that the capital expenditure and operation expenses are to be reasonable for deployment of Super 3G. For these reasons, the development of Super 3G must aim to remove complexity in the radio network and mobile terminals and to construct a simple and inexpensive system.

2.3 Relationship with ITU-R

Discussions are now being held at ITU-R on the outlook for mobile communications of the future. In 2003, approval was given to Recommendation M.1645 entitled "Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000." This recommendation includes a graph depicting the relation between mobility and data rate (**Figure 3**). In the figure, IMT-2000 corresponds to 3G while the new capabilities of new system correspond to 4G.

It should be noted here that the terms "3G" and "4G" are not used in ITU-R. Although use of the name "4G" had been discussed, it has recently been decided that the term "IMT-Advanced" be adopted as ITU-R policy.

Referring again to Fig. 3, the scope of Super 3G and 4G is indicated by ellipses. As an extension of IMT-2000, Super 3G is included within the bounds of IMT-2000. In 4G, new spectrum with broadband capabilities is expected to be allocated to achieve higher data rates, while Super 3G will use the spectrum that includes the additional bands allocated for IMT-2000 use.

The M.1645 recommendation also envisions that the core network will accommodate a variety of interlinked access lines. These access lines will include W-CDMA and new wireless interfaces.

2.4 Super 3G Implementation Image

Super 3G, which will be using the 3G spectrum, will incorporate new technologies in the wireless access system with the aim of making a dramatic improvement in performance. Specifically, there is a view to adopting key technology elements like Orthogonal Frequency Division Multiplexing (OFDM)[*5] and Multiple Input Multiple Output (MIMO)[*6] in Super 3G. Furthermore, as delay is a major factor affecting frame structure in the radio interval, it must be given careful

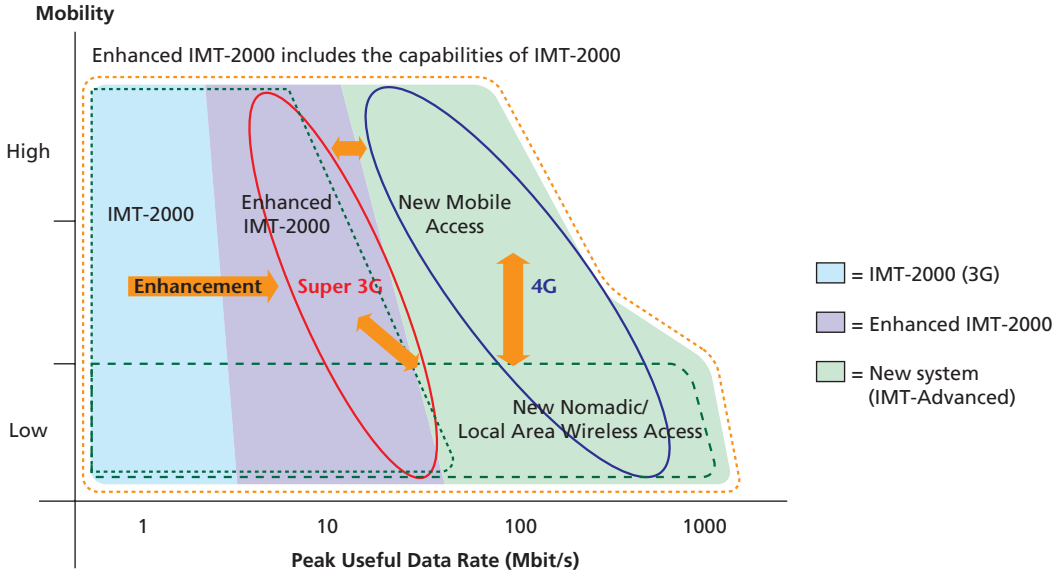


Figure 3 Relationship between Super 3G and Recommendation M.1645

*4 Spectrum efficiency: The number of data bits that can be transmitted per unit time and unit frequency band.

*5 OFDM: A digital modulation method which is known to be robust against multipath interference. High-speed data rate signals are converted to multiple low-speed narrow-band signals that are transmitted in parallel along the frequency axis. It allows transmission at a high frequency efficiency.

*6 MIMO: A technology for increasing data transmission speeds through the use of multiple antennas.

consideration at design time if the low-delay requirement of Super 3G is to be satisfied.

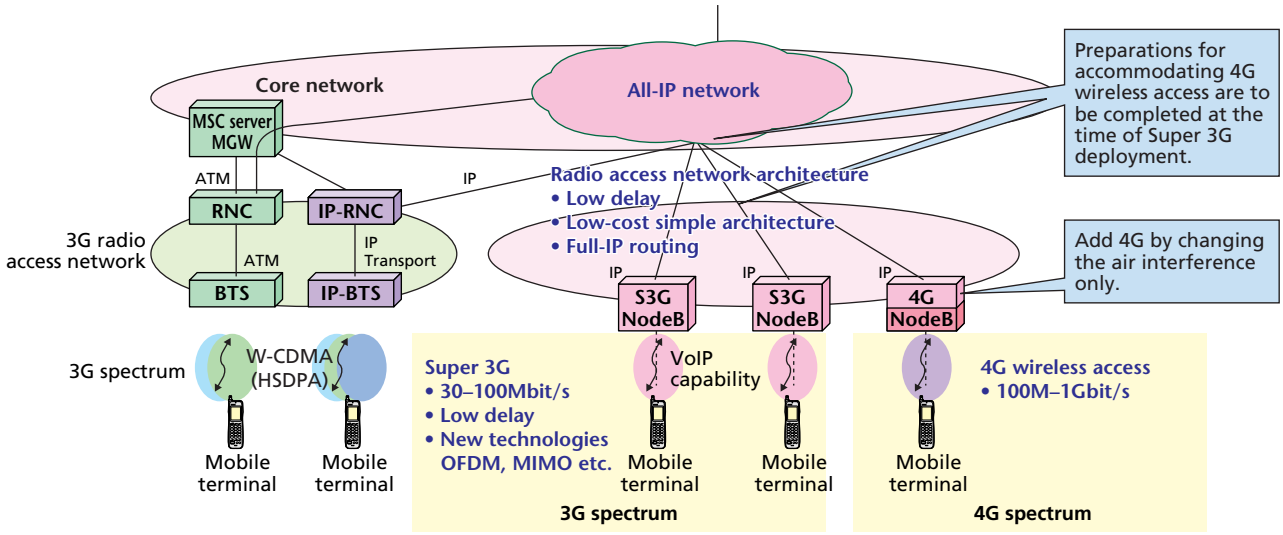
In this regard, a simple architecture that can achieve low delay and enable a low-cost network to be constructed should be adopted in the Radio Access Network (RAN). Various effective techniques can be considered here, such as channel-configuration simplification[*7] and signaling optimization[*8] to prevent the system from becoming complicated, and the decentralization of radio-resource control functions to base stations to reduce control delays.

Here, an All-IP network can be envisioned for the core network accommodating Super 3G wireless access, and technical specifications for this network are now being studied at 3GPP. If, when introducing an All-IP network to Super 3G, a configuration is adopted that can also accommodate 4G wireless access, the eventual deployment of 4G should progress in a smooth manner (**Figure 4** (a)).

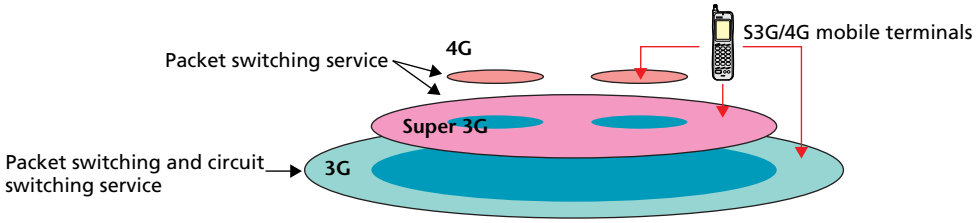
Super 3G, moreover, is not intended to replace the existing 3G system, and it is assumed that Super 3G terminals will be of the dual-mode type equipped with current 3G functions. The Super 3G coverage area will be deployed in a stepwise manner overlaying the 3G coverage area (Fig. 4(b)).

At the same time, Super 3G will target packet switching services. Although the current 3G network provides both circuit-switching services and packet-switching services, the plan is to have Super 3G use Voice Over IP (VoIP)[*9] on the packet network with the aim of achieving a network that can provide services equivalent to circuit-switching services while raising system efficiency.

However, whether or not to offer Super 3G as a service is



(a) Network migration scenario example



(b) Coverage example

BTS: Base Transceiver Station
RNC: Radio Network Controller
MSC: Mobile Switching Center (mobile communication control station)
MGW: Mobile GateWay (gateway server)
Node B: Base Station (3GPP name)

Figure 4 Network configuration example

*7 Channel-configuration simplification: Reducing channel types and inter-channel transition patterns by adopting a channel configuration optimized for packet transmission.

*8 Signaling optimization: Elimination of redundancies. Achieves high-speed and simplified signaling by reducing the number of signaling bits and sequences.

*9 VoIP: Technology for sending/receiving voice data on the IP network.

Table 1 Major requirements

Peak data rate		Downlink: 100Mbit/s, Uplink: 50Mbit/s
Delay	Control delay	less than 100 ms (idle state→active state) less than 50 ms (dormant state→active state)
	Transmission delay	5ms (one-way delay in RAN)
User throughput (compared with Rel. 6 HSDPA/HSUPA)	Cell-edge user throughput	2-3 times (Downlink), 2-3 times (Uplink)
	Average user throughput	3-4 times (Downlink), 2-3 times (Uplink)
Spectrum efficiency (compared with Rel. 6 HSDPA/HSUPA)		3-4 times (Downlink), 2-3 times (Uplink)
Frequency bandwidths		1.25, 2.5, 5, 10, 15, 20 MHz

Dormant: discontinues reception

being left to the discretion of each mobile communication carrier. It is not inevitable that Super 3G be offered as long as circuit-switching network facilities can be operated in an efficient manner. A complete migration from the current 3G system to Super 3G over the long term is also possible. In this way, a mobile communication carrier can decide whether to conduct operations solely on the basis of a packet network taking into account the cost of service development and communication facilities.

3. Standardization Activities

Recognizing the importance of studying the long-term development of the 3G system, a workshop called "3G RAN LTE (Long Term Evolution)" was held at 3GPP in November 2004. DoCoMo proposed the Super 3G concept at this workshop. The support of 26 companies was later obtained, and a proposal was made and agreed upon within 3GPP to begin a LTE study. In June 2006, a basic study that found Super 3G to be feasible had been nearly completed and a study on technical specifications was initiated. These specifications are scheduled to be completed in September 2007.

Various milestone targets have been prepared as part of a work procedure. First, a work plan and the configuration of technical reports are to be decided on and requirements agreed upon. Next, technical reports that gather together detailed concepts covering "functional split of RAN and core network," "radio interface protocol architecture," and "basic concept of physical layer" are to be completed and the basic study finalized.

In June 2005, a technical report covering requirements (TR25.913) was approved and a more detailed technical study at the working-group level was launched.

Table 1 shows major requirements agreed upon at 3GPP. A maximum data rate of 100 Mbit/s and a RAN transmission delay of no more than 5 ms represent high targets, and the values set for user throughput[*10] and spectrum efficiency are no less challenging. The maximum frequency bandwidth is expected to be 20 MHz, and bandwidths less than 5 MHz have been added considering application of Super 3G to frequency bandwidths used by Global System for Mobile communications (GSM)[*11] in Europe and other countries.

4. Conclusion

This article described the concept, requirements, and development scenario of Super 3G as well as current standardization activities at 3GPP. The next issue will describe proposed technology in more detail.

*10 Throughput: Effective amount of data transmitted without error per unit time.
*11 GSM: A Second-Generation mobile communication system used throughout the world, especially in Europe and Asia.