Progress of 3G Evolution Technology Standardization

Abstract:
The challenges brought by broadband wireless access technologies to cellular mobile communication technologies speed up the study and standardization of 3G evolution technologies that support higher data rates. Both the 3GPP and the 3GPP2 have launched research programs on the study and standardization of the emerging 3G evolution technologies. The Long Term Evolution (LTE) program of 3GPP has made progress in key technical indexes of air interface, wireless network architecture and high-level protocols. At the same time, the Air Interface Evolution (AIE) program of 3GPP2 has made study achievements in the formulation of air interface standards for Layer 2 and upper layers, as well as for the physical layer.

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Mobile communications have been growing fastest in the telecommunications industry of China over the years 2001-2005 (the 10th 5-year Plan Period of China). New technologies are advancing and market requirements become higher. Besides, the R&D and industrialization breakthroughs have been made in the Chinese proprietary Time Division-Synchronous Code Division Multiple Access (TD-SCDMA) standard and technology. Therefore, it is a great strategic significance for China to keep mobile technologies' sustainable developments and get the upper hand in the new round of technological and standard competition.

1 Background and Service Requirements of 3G Evolution Technology Standardization

In recent years, the challenges brought by the Broadband Wireless Access (BWA) technology to cellular mobile communications technology have speeded up the research and standardization of 3G evolution technologies that support faster transmission. Since the end of 2004, the international standard bodies, 3GPP and 3GPP2, have both launched the study and standardization programs for the emerging 3G evolution technologies[1-3].

1.1 3GPP Long Term Evolution (LTE) Program

High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) are introduced into 3GPP R6 (Release 6). As a response to the "threat" of BWA technologies like WiMAX, 3G cellular technology is working on higher-competitive wireless access interfaces and network architecture solutions. The 3GPP has set down the development direction, roadmap and key technical requirements for Enhanced 3G (E3G). The technical scheme of E3G was expected to come out in March 2006 and all E3G specifications will be fulfilled in June 2007. So far, 3GPP has proposed the following design objectives for E3G system service capabilities:

(1) Data Rates and Spectrum Efficiency

The peak rate is 100 Mb/s for downlink and 50 Mb/s for uplink (corresponding system bandwidth is up to 20 MHz, spectrum efficiency is 5 b/s/Hz for downlink and 2.5 b/s/Hz for uplink). Paired and unpaired spectrum allocation is supported.

(2) Latency

The system design is targeted at packet domain service to support real-time-based services and reduce latency of radio networks. Most available indexes have been obtained according to the QoS requirements for various real time services such as Voice over IP (VoIP). Moreover, the system reduces control-plane state-shift latency to improve users' network service experience. At the user data plane, the on-air unidirectional latency is smaller than 5 ms, while the latency for user's idle-to-active change is smaller than 100 ms at the control plane.

(3) Coverage and Mobility

When a cell's coverage radius is less than 5 km, all performance requirements for LTE should be satisfied, and the cell coverage capability within 30 km be

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supported. However, some performance loss is allowed. The evolution system should support terminal mobility within the entire system, optimize services for low-speed mobile subscribers, and provide high-speed mobility.

(4) Multimedia Broadcast Multicast Service (MBMS)

The E3G evolution system should enhance its support for MBMS to help integrate the asymmetric MBMS with bidirectional services and fulfill the application of MBMS on asymmetric frequency bands.

1.2 3GPP2 Air Interface Evolution (AIE) Program

3GPP2 has also launched E3G research work. The CDMA2000 AIE focuses on higher data rates, lower latency, enhanced QoS, and backward compatibility.

The CDMA2000 AIE aims at:

- Increasing user throughput at the cell edge
- Increasing voice capacity as compared with CDMA2000 1X
- Increasing the peak data rates and system capacity to reach a forward peak data rate of 100 Mb/s–1 Gb/s and backward peak rate of 50 Mb/s in the long term
- Supporting 20 MHz bandwidth allocation (in the unit of 1.25 MHz)
- Improving spectrum efficiency, reducing system latency, and fulfilling less terminal power consumption
- Improving cell coverage
- Remaining compatibility in the near future

To fulfill these objectives, meet requirements of different market stages and make technology R&D less complex, 3GPP2 initially decided to split the CDMA2000 AIE program into two phases. Phase One aims at the multi-carrier CDMA2000 air interface, with a purpose of speeding up the marketing process and meeting market demand for the near future. It uses CDMA2000 1× EV-DO and combines multiple CDMA2000 1× EV-DO carriers to offer higher packet data rates. This phase was fulfilled and the results would be published in March 2006. Phase Two is aiming at enhanced CDMA2000 and will be completed in June 2007.

2 3G Evolution Technologies and Network Architecture

2.1 Progress of 3GPP LTE Program

So far, the 3GPP LTE program has made the following achievements:

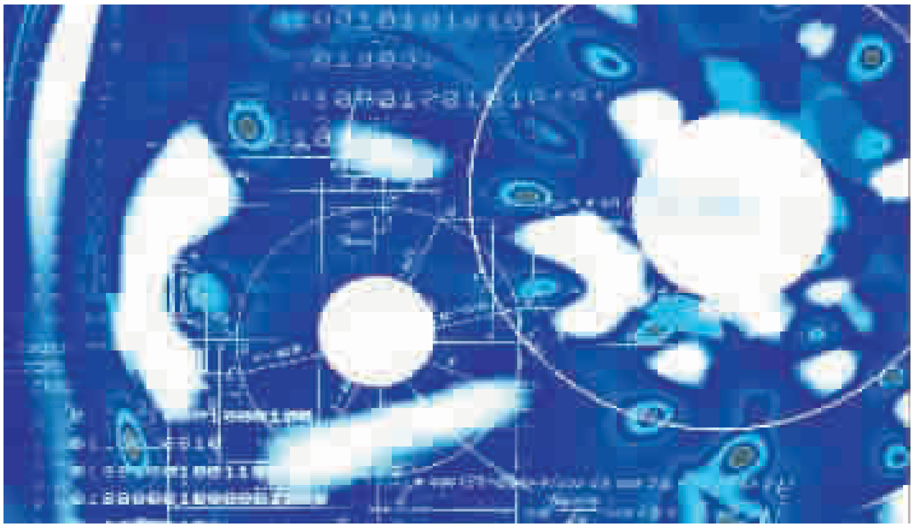
- As for multiple access at the physical layer, Orthogonal Frequency Division Multiple Access (OFDMA) for downlink and Single Carrier-Synchronous Frequency Division Multiple Access (SC-SFDMA) for uplink are used.
- When the coexistence requirements of TDD system are taken into consideration, the Time Division Duplex (TDD) frame structure of the evolution system and its compatibility with TD-SCDMA system are specified for design of uplink/downlink OFDMA parameters (such as sub-carrier spacing) and radio frame structure.
- Macro diversity technology is not used.
- Progress is made in research of downlink pilot channel, uplink channel multiplexing, uplink synchronization mechanism, Hybrid Automatic Repeat Request (HARQ), and random access.
- Preliminary performance evaluation is given, which shows great performance improvement of the E3G system as compared with a 3G system.
- Transmission channels and physical channels for radio access network are specified.
- Two-layer data retransmission mechanism is adopted.

2.1.1 Key Technical Indexes of Air Interface

(1) Multiple Access

At the meeting held in June 2005, 3GPP finished collecting proposals on multiple access solution and settled down on six candidate solutions, four of which were based on OFDM technology. The four OFDM-based candidate proposals differ from each other in respects of Frequency Division Duplex (FDD) and TDD, and in the uplink multiple access modes. Since the peak-to-average power ratio (PAPR) of conventional OFDM signals tends to increase power consumption of the terminal and amplifier cost, quite some companies suggest Single Carrier-Frequency Division Multiple Access (SC-FDMA) solution for uplink while OFDMA is fixed for downlink. There are two more CDMA-based multiple access modes that are multi-carrier solutions evolved from current 3G Wideband CDMA and TD-SCDMA standardized by 3GPP. The 3GPP evolution system will adopt "OFDMA as the downlink multiple access technique and SC-FDMA as the uplink multiple access technique". As an assumption for further study, this decision will apply to both FDD and TDD modes. Another request approved in this meeting was that 3GPP LTE should support TD-SCDMA frame structure to guarantee the evolution of TD-SCDMA system.

The MC TD-SCDMA and the MC WCDMA as the CDMA-based proposals will be evolving within the 3G framework of Universal Mobile Telecommunications Systems (UMTS), such as following the



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R7 standards. The bandwidth will however be restricted to less than 5 MHz.

(2) Macro Diversity

Whether uplink macro diversity should be adopted not only has a direct impact on the selection of physical layer solution, but also involves several important issues, such as air interface high-layer protocol and evolution system architecture. Of all candidate proposals for physical layer access, only two are based on multi-carrier CDMA while others use OFDM technology for multiple access solution, which is essentially different from the current 3G scenario that employs CDMA multiple access mechanism. Furthermore, the evolution system will use adaptive mechanisms such as HARQ and time-frequency scheduling to play down the role of macro diversity (macro diversity has been widely applied in the 3rd generation CDMA system). A show of hands took place in 3GPP Radio Access Network (RAN) Plenary 30, with a clear majority against using uplink macro-diversity as a working assumption for LTE system.

2.1.2 Radio Network Architecture

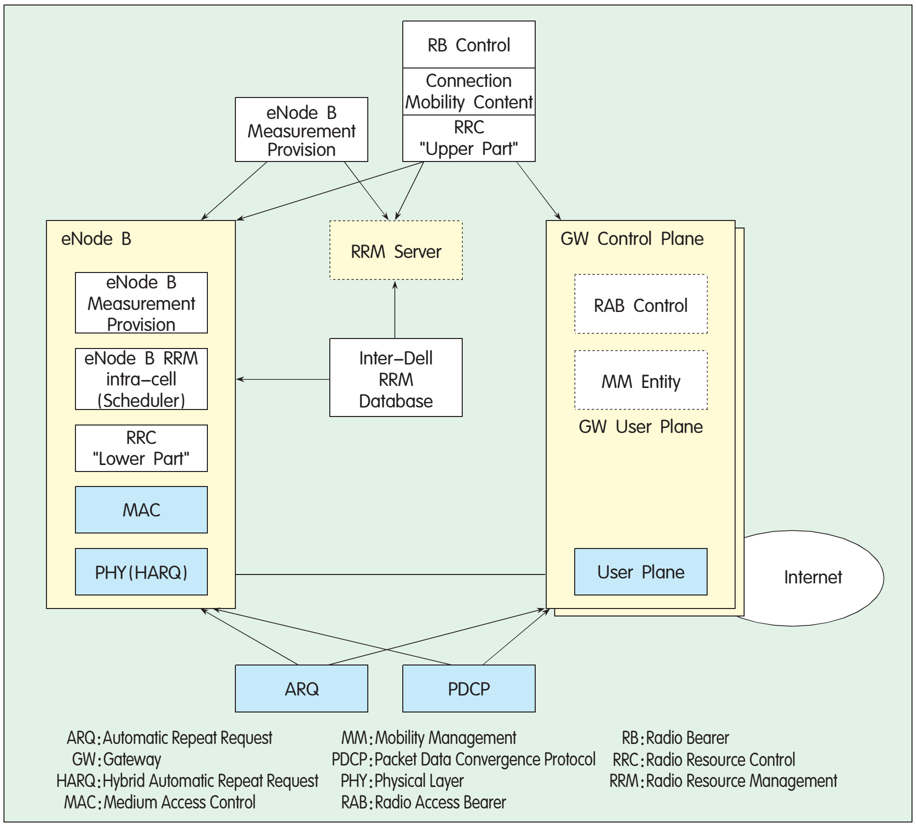
For the control and user planes of RAN, some potential solutions have presented themselves as a result of convergence of a wider range of proposals. Future development work will roll out on the basis of these proposals.

At the user plane, high-layer Automatic Repeat Request (ARQ) mechanism is added to LTE besides the MAC layer HARQ. The destination node and functions of this ARQ are not decided yet. Two current schemes are:

- Both HARQ and high-layer ARQ terminate at Node B.
- HARQ terminates at Node B while high-layer ARQ terminates at network elements above Node B.

At the control plane, 3 schemes are possible depending on the positions of LTE Idle and LTE Radio Resource Control (RRC) Active:

- Both LTE Idle and LTE RRC Active terminate at Node B.
- Both LTE Idle and LTE RRC Active terminate at network elements above Node B.
- LTE RRC Active terminates at Node B while LTE Idle terminates at network elements above Node B.



▲Figure 1. Schematic diagram of 3GPP LTE network architecture.

At the same time, 3GPP LTE has reached some largely agreed conclusions on the overall network architecture and distribution of management functions of radio resource, and specified these conclusions as the start of the study.

In the 3GPP LTE network architecture, a radio network comprises two types of network nodes: the base stations and the LTE gateway. Figure 1 shows the functional entities of the network nodes.

In Figure 1, the yellow logic nodes in continuous lines have been agreed on while those in dotted lines are pending for consensus. Those functional entities with white and blue background stand for the control plane and user plane functions. Those entities in continuous lines inside the nodes are established and have defined relationship with the logic nodes. Those entities with their existence established yet their relationship with logic nodes not defined are in continuous lines and placed outside the nodes, but an arrow is drawn to indicate their possible positions. Those entities with uncertain existence are put in dotted lines.

Issues and problems to be clarified and solved in the follow-up study are:

- Should the LTE gateway be split into the user plane and the control plane or not?
- Should the high-layer ARQ be placed in the base station or LTE gateway?
- For RRC functionality fulfilled by "the RRC upper part" and "the RRC lower part", what functions are to be fulfilled by "the RRC upper part" and "the RRC lower part" respectively and specifically? What solutions should be employed for better encryption and intactness protection?
- Detailed RRC message structure
- Should UE measurement configuration be put in "the RRC upper part" or "the RRC lower part"?

2.2 Progress of 3GPP2 AIE Program

The 3GPP2 AIE program breaks into two phases.

The Working Group (WG) 2 and WG 3 are responsible for Phase 1. The WG 2 formulates standards for Layer 2 and higher layers of the air interface, while the

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WG 3 makes standards for the air interface physical layer. Before that, WG2 used to focus on Radio Link Protocol (RLP) design, DSC/ACK/DRC channel, and FTCMAC/RTCMAC design. The WG 3 and WG 2 have now fulfilled the physical layer and high-layer text proposals respectively and planned to publish Phase 1 standards in the first half of year 2006.

The technical requirements for Phase 2 are still in discussion. In the meeting held in October 2005, WG 3 settled down on the basic roadmap for Phase 2. That is to establish the final technical requirements for Phase 2 in December 2005, to submit framework proposals before March 2006, to close Phase 2 in October 2006, to Close Phase 3 in December 2006, and to release the standards in April 2007. Moreover, many companies have submitted numerous documents about simulation methodology for Phase 2.

3 Promotion of 3G Evolution Technology Standardization

The 3GPP and 3GPP2 have been actively promoting the standardization of LTE and AIE technologies, but the overall progress somehow falls behind the original schedules. The intense debate between 3GPP all-IP network architecture and existing conventional architecture adds up to the uncertainty of function split between the RAN and core network. All in all, the 3GPP and 3GPP2, thanks to their years of experience in standardization, are expected to effectively promote eventual selection of key technologies.

As for the technology adopted for air interfaces, both LTE and AIE pick OFDM as the mainstream solution. If compared with the IEEE 802.16 standardization process, LTE and AIE put more emphasis on such performance indexes as terminal's Peak-to-Average Ratio (PAR), as well as on network frequency configuration and interference cancellation approaches. This helps ensure the operability of mobile terminals and the effective organization of cellular networks. Moreover, this may make the maximum use of current networks.

China has made certain achievements in LTE and AIE programs. Of its 190 documents submitted to 3GPP LTE in December 2005, 28 were accepted, and of the 20 documents for 3GPP2 AIE, 10 were accepted.

The selection process of multiple access solutions for the LTE program took the TDD-specific characteristics (such as TD-SCDMA frame structure) proposed by China into account. In addition, LTE accepted the documents on TDD frequency bandwidth and parameter design submitted by China. Other documents submitted by China and accepted were primarily concerned with the inter-cell interference cancellation, pilot frequency design, and PAR reduction.

Most Chinese documents for the AIE program were targeted at service requirements and high-layer protocols of the radio interface.

The 3GPP and the 3GPP2 are currently at halfway of their standardization work. Technical contents of the standards are getting detailed. By June 2006, 3GPP LTE will fulfill key technological items. March 2006 was the deadline for 3GPP2 to decide the technical candidate solutions. With the help of its broadband wireless mobile expert group, China will continue to make its own efforts, including technological innovations and revisions, to help 3G evolution technology standardization to move forward.

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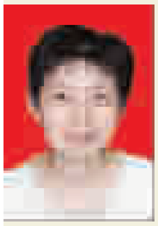
Biographies



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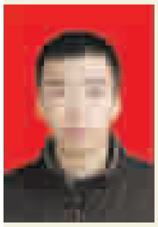

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