Activities and Contributions for Completion of the 3GPP LTE/SAE Standard Specifications

The 3GPP Release 8 standard specifications completed in March 2009 are a major advance beyond the previous specifications. Since 2004, there has been progress in the key standardization sets in both the radio access specifications and the core network specifications, under the respective working item names of LTE and SAE. NTT DOCOMO has been active in the technical proposals and providing input to the standard process from the beginning. We have contributed greatly through serving as important positions and other ways in both the plenary meetings and the WG meetings for finalizing specification sets. Eventually, the set of standard specifications required for LTE/SAE development were completed.

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1. Introduction

At the 3GPP Technical Specification Group (TSG) #43 plenary meeting[*1] of March 2009, the System Architecture Evolution (SAE) specifications were declared frozen, and the main items of the 3GPP Release 8 specifications, which represent the Long Term Evolution (LTE) and SAE specifications, were completed. This LTE and SAE are greatly advanced relative to the previous specification set. Specifically, the radio access specifications, LTE, adopt the new Orthogonal Frequency Division Multiple Access (OFDMA) for the access scheme, which improves spectrum efficiency by a factor of three to four compared to the Rel. 6 High Speed Packet Access (HSPA) transmission technique. The SAE core network specifications adopt a network architecture that is optimum for IP packet transmission, making it a network platform that can accommodate various types of access, including LTE.

3GPP standardization of LTE and SAE is the result of standardization activities that extended over a five-year period, from the beginning of stage 1 of Rel. 7 to the completion of stage 3 of Rel. 8. The LTE and SAE standardization milestones are shown in **Figure 1**. 3GPP standardization has three stages. Stage 1 deals with the requirements; stage 2 specifies related architectures based on the requirements; and stage 3 specifies the protocols based on the architecture.

NTT DOCOMO was active in concept proposals and technical proposals in the progressing of the LTE and SAE specifications, making active contributions in leading roles as rapporteur[*2] and editor in working group (WG) meetings and plenary meetings. As a result, the related standard specifica-

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*1 **Plenary meeting**: The highest level of the 3GPP TSG meetings. Currently, there have been four plenary meetings, TSG SA, TSG RAN, TSG CT, and TSG GERAN.

*2 **Rapporteur**: The role of editing specifications, managing work progress and reporting at WG meetings on individual WI and specifications.

tions were completed in March 2009, allowing operators to initiate timely development for their commercial services.

In this article, we explain mainly NTT DOCOMO activities and contributions in the both areas of radio access and core network technology that relates LTE and SAE standardization, as well as the future network as proposed by NTT DOCOMO, with how the requirements have been reflected in the 3GPP technical specifications, and what kinds of technical proposals NTT DOCOMO has made to 3GPP.

2. Approach to Network Migration toward LTE and SAE in NTT DOCOMO

The maximum data transmission rate of the FOMA high-speed service NTT DOCOMO currently provides is 7.2 Mbit/s, but the technical specifications allow for 14.4 Mbit/s on the downlink using High Speed Downlink Packet Access (HSDPA) and 5.7 Mbit/s on the uplink using High Speed Uplink Packet Access (HSUPA). Nevertheless, increasing data traffic demand and the rapid expansion in the data volume of content have clearly expedited the inadequacy of transmission speed and capacity, and lowering bit cost has become a serious problem. Reduction of connection delay and

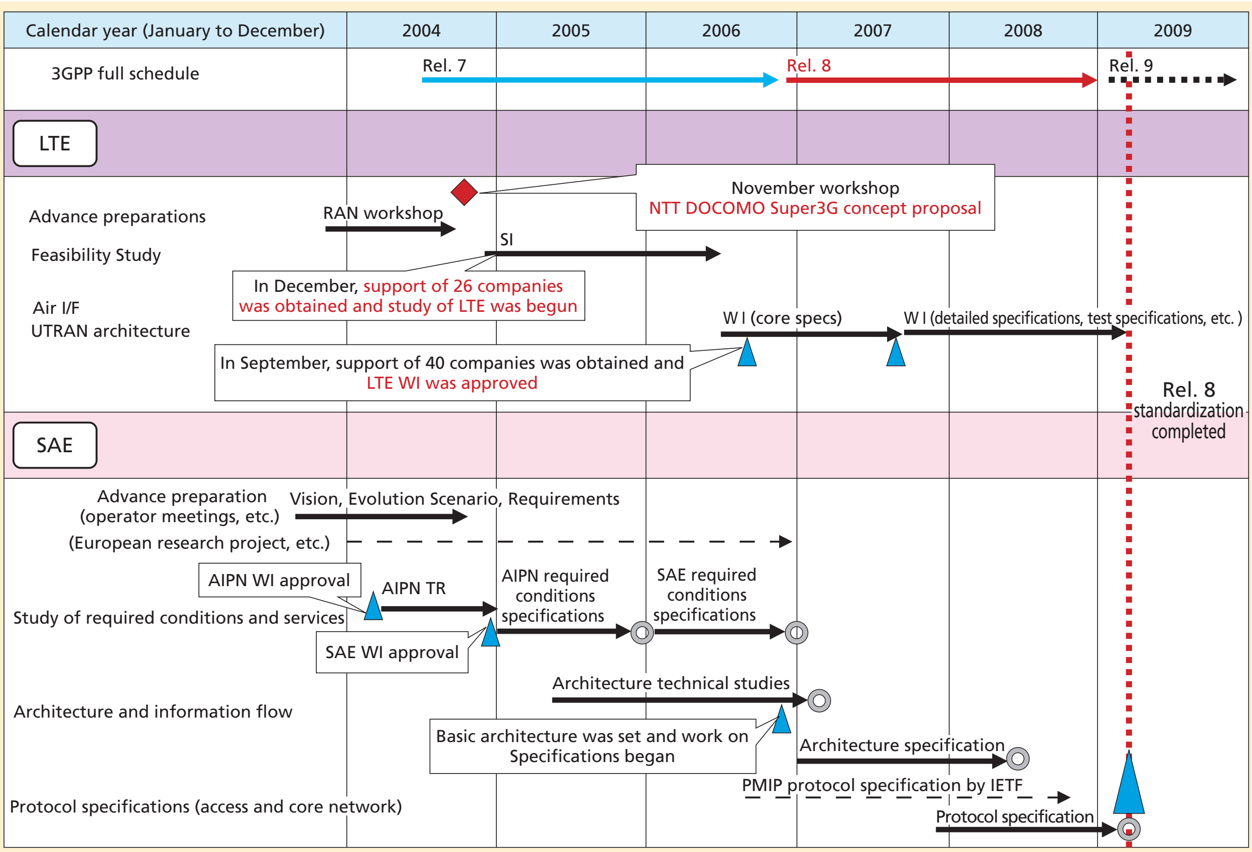

Figure 1 Standardization schedule

transmission delay are also important issues for high-speed data transmission by Transmission Control Protocol /Internet Protocol (TCP/IP), etc. and for stress-free communication by users. Also, to reduce facilities investment and operating cost to a reasonable level for system introduction, there has been a need for simplification of architectures related to the wireless network and mobile terminals.

Regarding to the core network, we have to consider two aspects. Firstly future service trend shifts from volume-based tariffs to fixed-rate tariffs, and secondly the requirement for networks has a flexible mechanism for facilitating advanced services and adding value for future service development when introducing new wireless systems such as LTE. To satisfy both of those requirements, NTT DOCOMO has advocated transition of the core network to IP, which is to say the All-IP Network (AIPN) [1], and has proceeded with its step-wise development. That proposal begins with introduction of IP to the network (Phase 1), followed by transition of the FOMA voice network to IP by applying core function of IMS (IP Multimedia Subsystem) (Phase 2) [2]. The next phase is SAE, which enhances the network with the main objectives for accommodation of LTE with other additional access networks in all IP based network, i.e, AIPN Phase 3.

3. Activities and Contributions to 3GPP TSG SA/CT

3.1 Study of Required Conditions

In the March 2004 TSG Service & System Aspect (SA)-WG1, the Work Item (WI) of the AIPN requirement was approved and the study begun in 3GPP. Activities in 3GPP begin with this WI proposal. In the initial stage of the study, a Technical Report (TR) is formed to verify the feasibility of the work [3] . To finalize this documents, NTT DOCOMO actively made proposals for the basic objectives, necessity, and vision of AIPN [4]. As a result, the AIPN Technical Specifications (TSs) [5] were finalized and they were approved as Rel. 7 specification in December 2005. Then, SAE requirement TSs were set with a scope narrowed to accommodate LTE under the umbrella[*3] of AIPN. The TSs were approved in Rel. 8 specifications as SAER (TS22. 278) in December 2006. These service specifications have served as the basis for discussion on the SAE architecture specifications in SA-WG2 since April 2005.

3.2 SAE Architecture

1) Standardization History and NTT DOCOMO's Contributions

Concerning the common functions that are independent of radio access, such as mobility control and QoS control, NTT DOCOMO has actively advocated an AIPN architecture based on the previously mentioned service TSs that aims for commonality with 3GPP2[*4], Next Generation Network (NGN)[*5] etc., as well as 3GPP. This network control is a fundamental technology implemented with generic IP-based technology that is widely used by diverse mobile and fixed system operators, and not just by 3GPP operators, thus improving roaming and interconnectivity and reducing system cost.

SA-WG2 has been engaged in long study and discussion of two approaches, NTT DOCOMO's proposed AIPN architecture that achieves highly generality through introduction of IP-based protocols, and General Packet Radio Service (GPRS) network extended architecture, which emphasizes migration from existing protocols. NTT DOCOMO advocated the idea that both architectures aim for an IP-based core network that will accommodate a diversity of future access systems. That concept has broad acceptance by 3GPP members who support either architecture. At the December

*3 **Umbrella**: A higher-level WI that encompasses multiple WI.

*4 **3GPP2**: A Third-Generation Mobile Communication System (3G) standardization project that is standardizing the cdma2000 technical specifications, which are part of the IMT-2000 specifications.

*5 **NGN**: The next-generation AIPN; under study by ITU-T, etc.

2006 TSG SA#34 plenary meeting, agreement on an "SAE architecture" that encompasses both the AIPN architecture and the GPRS network extended architecture was reached[6]. The SAE architecture adopts the IP-based mobility control that NTT DOCOMO advocated as part of the AIPN architecture.

Because no IP-based mobility control technology satisfied the operator requirements at the time the AIPN architecture was proposed, NTT DOCOMO was active in international standardization of the technology. Regarding standardization activities, we have input the mobility methods that are being studied in the IP-based IMT network Platform (IP^2) research and verification experiments [1] to the Internet technology standardization organization Internet Engineering Task Force (IETF), and have taken a leading role from the start of the January 2006 WG to the August 2008 completion of the Proxy Mobile IPv6 (PMIPv6) [7] standard specifications, aiming for introduction of 3GPP as a part of those activities.

2) SAE IP-based Network Architecture

An SAE architecture that applies IP-based mobility control technology is shown in **Figure 2**. In addition to the functional entities specified by GPRS[8], SAE comprises Mobility Management Entity (MME), Serving-Gateway (S-GW), Packet Data Network-Gateway (P-GW) and Policy and Charging Rules Function (PCRF). The MME and S-GW accommodate the LTE eNodeB (eNB) access system base stations. P-GW is the connection point for packet data networks that are outside the core network, such as the i-mode and IMS, and accommodates 3GPP access and non-3GPP radio access. PCRF controls QoS and charges, etc.

MME accommodates eNB through the S1-MME interface and executes terminal mobility management, authentication (security control) and user data transmission path setup. The terminal mobility management and authentication processing is done in cooperation with the Home Subscriber Server (HSS) via the S6a interface. For more efficient location registration processing in mobility management for terminal movement between LTE and 3G wireless areas, the MME can cooperate with the Serving GPRS Support Node (SGSN), which is a 3G core network logical node, via the S3 interface to execute location registration control. MME also exchanges control signals with the eNB and S-GW through the S1-MME and S11 interface to establish and release user data transmission paths between the S-GW and the eNB

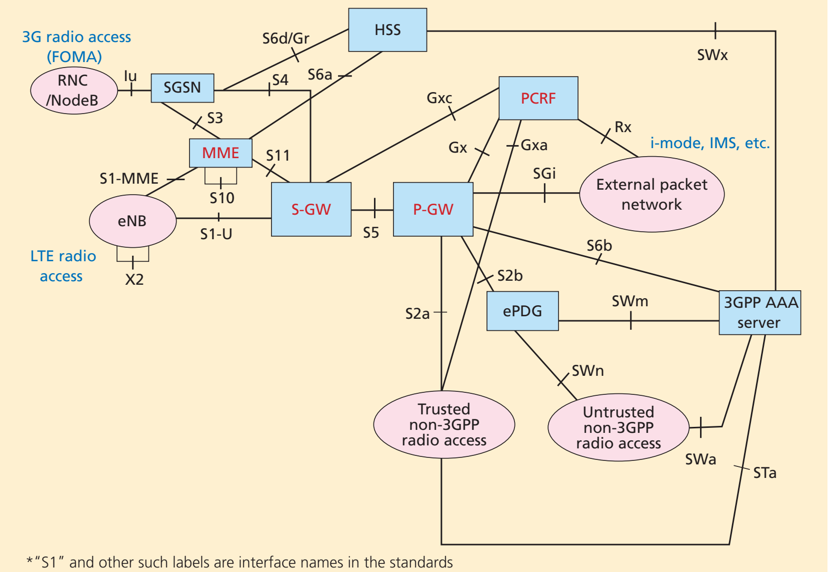

Figure 2 SAE architecture

over the S1-U interface.

The S-GW is a packet gateway that sends and receives user data between S-GW and eNB and also establishes and releases transmission paths between the S-GW and P-GW via the S5 interface in units of connected outside packet network (PDN). It also sends and receives control signals between SGSN connected by the S4 interface when a mobile terminal is in a 3G area to establish a user data transmission path between the S-GW and the SGSN. That is to say, the S-GW is a path switching point for transmission of user data towards LTE and 3G wireless. In data transmission, the S-GW performs IP packet transmission quality control, etc. according to policy control information received from the PCRF via the Gxc interface.

The P-GW connects to the PDN via the SGi interface to assign IP addresses, etc. The P-GW also serves as a user data transmission switching point when a mobile terminal moves between areas of radio access specified by 3GPP (LTE or 3G) and areas of non-3GPP radio access. The P-GW also executes IP packet transmission quality control, etc. on the basis of policy control information received from the PCRF via the Gx interface.

The PCRF sets IP packet forwarding policies such as QoS and charging method for executing call quality control and distributes the policy control information via the Gx, Gxc, and Gxa interfaces to P-GW, S-GW and trusted non-3GPP IP access where received policies are enforced.

The enhanced Packet Data Gateway (ePDG) is the gateway to which mobile terminals connect for untrusted non-3GPP IP access with respect to security, such as a public wireless LAN. The ePDG connects to the P-GW via the S2b interface.

In addition to the above, the HSS, 3GPP AAA server, and SGSN continue to provide the respective functions of maintaining subscriber profile, authentication of users connecting from non-3GPP radio access, and accommodation of 3G radio access in the same way as they have in 3G.

3) Features of the SAE Architecture

SAE architecture embodies the AIPN required conditions and has the following features regarding function and service provision.

- Support for terminal movement between different types of access systems

  The P-GW provides a mobility control anchor function*6 that allows a mobile terminal to continue a communication with the same IP address, even when the terminal moves between areas of other access systems during the call.

- Specialization on packet switching

  SAE specifies only packet switching to simplify the network and make it more efficient; the same services provided by circuit switching are provided by the IMS over the packet switching network instead of the circuit switching method specified by the 3G network. Also, assuming network migration, a method for voice call continuity between IMS and a circuit switching network is specified [9].

- Network control premised on the always-on concept

  In SAE, connection setup delay related to packet transmission is minimized by connecting a mobile terminal to a preset PDN at the same time it is registered to the network (attach*7). The core network always has an established communication path with the PDN, so when a mobile terminal actually initiates a call, only the wireless connection need be set up, which may reduce connection setup delay.

- Support of simultaneous connection to multiple PDN

SAE allows multiple simultaneous PDN connection so the user can connect to the IMS and enjoy an i-mode

*6 **Anchor function**: Switches communication paths to match the area in which a mobile terminal is dwelling and transmits the packets for that mobile terminal to that area.

*7 **Attach**: The process of registering a mobile terminal to a network when the terminal's power is turned on, etc.

service and voice service at the same time. Thus, in addition to allowing provision of services similar to the simultaneous use of circuit switching and packet switching as can be realized in the 3G network, it is possible to change the PDN according to the type of packet service.

- Control for cooperation with 3G circuit switching services

A mechanism is provided to allow a terminal to make and receive 3G circuit switching services such as voice calls when camping on an LTE wireless area. Thus, existing 3G circuit switching services can be provided even while the network is migrating to the SAE.

3.3 Standardization of CS Fallback

Even in the situation where IMS voice services are not provided over LTE, a mechanism for switching a mobile terminal from LTE radio access to the overlapping 3G radio access's circuit switched domain when a voice call is made or received was devised. This mechanism is called CS fallback and allows provision of voice services to handset type mobile terminal users. NTT DOCOMO played a central role from the proposal of that function to the completion of standardization. Since June 2007, NTT DOCOMO has raised the issue of the necessity of CS fallback for mobile terminals equipped for both SAE and 3G at the SA-WG2 meeting, and the CS fallback specifications [10] were completed in Rel. 8.

The basic concept of CS fallback is shown in **Figure 3**. Even dual terminals that have the functions of both LTE and 3G radio accesses cannot use LTE and 3G radios at the same time. To notify a mobile terminal camping on LTE of an incoming voice call, the overlapping 3G location area has to be identified from the location of the LTE location registration area, and mobility management is executed for the circuit switch that accommodates that 3G location area. That function notifies a mobile terminal camping on LTE of incoming call request from the circuit switched domain switch (MSC) via MME. The mobile terminal that receives the notification then switches from LTE access to 3G access to receive the voice service.

3.4 Standardization of Emergency Information Broadcast Platform in LTE

Aiming at an even faster and more advanced 3G "Area Mail Service" [11] emergency information broadcast platform, NTT DOCOMO proposed in 3GPP a system called Earthquake and Tsunami Warning System (ETWS) [12][13], which fulfills the special requirements of Japan. NTT DOCOMO actively led the standardization, working as a rapporteur. ETWS was originally only specified for 3G, however, a mechanism for faster and more efficient broadcast of information about earthquakes and other emergencies to more users and a platform for it are required. Agreement was reached on the NTT DOCOMO ETWS proposal to extend the work for LTE, which shares a common emergency broadcast

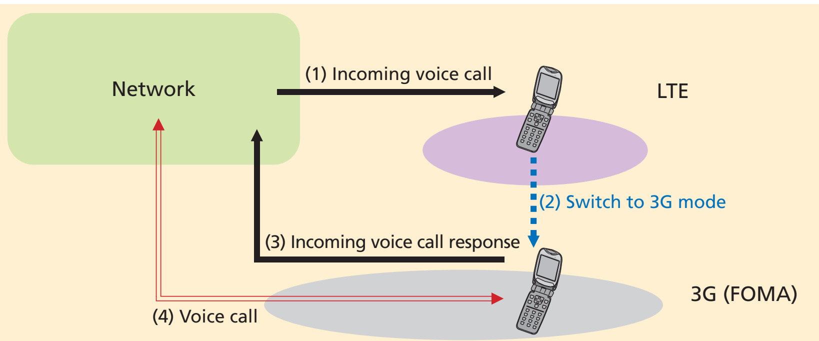

Figure 3 CS fallback

server with 3G and satisfies the same requirements as 3G. 3G adopts an architecture in which information is transmitted from the emergency broadcast server directly to the RNC (Radio Network Controller). LTE, on the other hand, adopts a hierarchical architecture in which the emergency broadcast server sends emergency information messages in units of MME that accommodate eNB, and the MME then broadcasts the messages to the eNB within the specified area (**Figure 4**). That architecture reduces the load on the emergency broadcast server at the time of information broadcast and prevents the accompanying delay.

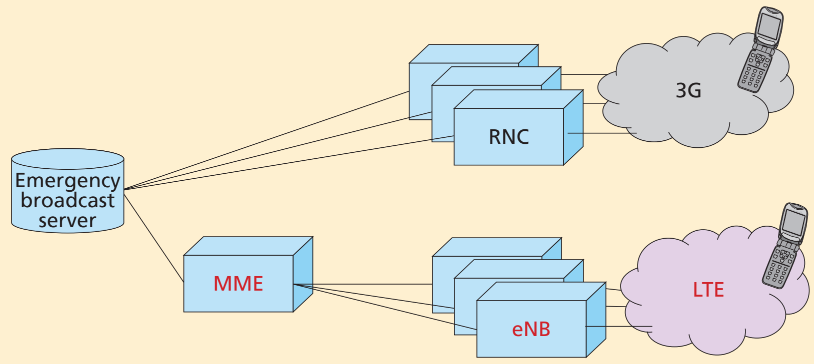

Figure 4 ETWS architecture

3.5 Contribution on the SAE Protocol Specifications

The SAE architecture framework was agreed on in December 2006, and then the work phase of protocol specifications began in the TSG Core Network and Terminals (CT) WG. In the various SAE interfaces, CT-WG1 is dealing with the specifications for the Non-Access Stratum (NAS) protocol between the mobile terminal and MME, CT-WG3 is dealing with the Diameter protocol for QoS and authentication, and CT-WG4 is dealing with the PMIP and GPRS Tunneling Protocol (GTP) for mobility control within the network as SAE topics. NTT DOCOMO has made major contributions to the relevant protocol specifications by working as rapporteur, specifically in the study on LTE access restriction methods in CT-WG1 and so on. Eventually, these NAS protocol standard specifications essential for development of LTE terminals, TS24.301 [14], TS24.302 [15], TS29.118 [16], etc., were completed. In the CT-WG4 meetings, NTT DOCOMO served as rapporteur of the standard specifications for PMIP and the LTE emergency information broadcast protocol SBc Application Part (SBc-AP), contributing greatly to the PMIP [17] and Diameter protocol [18] mentioned above. Through these activities, the set of SAE protocol specifications was completed on schedule in March 2009.

4. 3GPP TSG RAN Activities and Contributions

In 3GPP, with the high demand for long-term development of the 3G system, the "3G RAN LTE" workshop was held in November 2004. NTT DOCOMO proposed the Super3G concept at that workshop. A proposal to begin LTE study in 3GPP was approved with the support of 26 companies at the end of 2004.

4.1 LTE Required Conditions

Discussion on the requirements of LTE began with the March 2005 Radio Access Network (RAN) meeting. As the LTE rapporteur company, NTT DOCOMO led the discussion by putting the discussion items into concrete form and compiling the opinions of the various companies, etc. As a result, TR25.913 [19], which concerns requirements, was approved in June 2005. The main LTE requirements are listed below.

1) Support for variable bandwidth from 1.4 to 20 MHz
2) Specialized for the packet switched domain (with supports of VoIP)
3) Low delay
   - From idle to active mode: 100 ms or less
   - From dormant to active mode: 50 ms or less
   - One-way delay for data transfer within the RAN: 5 ms or less
4) Peak data rate
   - Downlink: 100 Mbit/s
   - Uplink: 50 Mbit/s
5) Spectrum efficiency (value relative to Rel. 6 HSDPA, HSUPA)
   - Downlink: a factor of 3 to 4; uplink: a factor of 2 to 3
6) Coexistence with 3GPP Radio Access Technology (RAT)
7) Minimization of complexity

4.2 LTE Features and WG Activities

Together with the LTE required conditions, Study Items (SI) were discussed until June 2006. Technical specification group RAN comprises five WGs. For the SI, the study of systems that meets the agreed requirements was discussed vigorously into the late night by each WG. The agreed items of the study results and performance evaluation results were summarized in TR25.912. NTT DOCOMO has also been contributing as an editor of those TRs. After completion of the SI, they moved to the WI phase, which sets the detailed specifications. In March 2009, the specifications including the detail coding called ASN.1 were frozen.

Below, the various WG activities and NTT DOCOMO activities are described briefly.

1) RAN-WG1

In RAN-WG1, which specifies the physical layer, multiple radio access methods have been proposed and discussed. Considering the strong requirement for the commonality of Frequency Division Duplex (FDD)/ Time Division Duplex (TDD), the downlink OFDMA and uplink Single Carrier - Frequency Division Multiple Access (SC-FDMA) that was supported by many companies, including NTT DOCOMO, was finally adopted. OFDM is highly robust against the multipath interference that greatly affects broadband transmission, and it can flexibly handle a wide range of frequency bandwidths by changing the number of subcarriers. On the other hand, reduction of power consumption by reducing the mobile terminal (UE: User Equipment) Peak-to-average Power Ratio (PAPR) is an important element for the uplink. SC-FDMA reduces the PAPR because it uses a single carrier, and can also reduce interference between users within a cell through frequency orthogonality between users. To realize an even greater improvement in maximum throughput and spectrum efficiency, a large improvement in spectrum efficiency has been achieved by incorporating various types of technology such as Multiple Input Multiple Output (MIMO) and frequency domain scheduling in addition to existing technology such as adaptive modulation and Hybrid Automatic Repeat and reQuest (ARQ) [20][21]. NTT DOCOMO has input many technical contributions in many fields, including these techniques. As well as contributing to improvement of LTE performance, as vice chairman and rapporteur, we produced a list of issues to promote discussion and summarized the RAN-WG1 technical study results as the editor of TR25.814 [22], thus contributing to the promotion of LTE.

2) RAN-WG2

RAN-WG2, which specifies radio protocols, realized a radio protocol that is simple and efficient to configure by focusing on the packet switched domain while supporting VoIP and greatly reducing the number of mobile terminal states, compared to the 3G system, to only two, Radio Resource Control (RRC) connected mode and RRC idle, and reducing the number of transport channels[*8] as well. As a result, reduction of testing cost was achieved by reducing the number of test patterns as well as reduction of delay [21]. NTT DOCOMO contributed to the completion of the specifications by promoting discussions as many moderators[*9] and standard specification editors in addition to inputting many technical contributions.

3) RAN-WG3

RAN-WG3, which specifies RAN architecture, has achieved a reduction in the number of interfaces by configuring a flat architecture that has no radio network control node and has realized simple and seamless handover (**Figure 5**). NTT DOCOMO contributed as standard specifications editor in addition to inputting many technical contributions.

4) RAN-WG4

RAN-WG4 specifies radio performance specifications for mobile terminals and base station equipment, and base station test specifications. This WG studies interference within systems and between systems, and specifies spurious signal relating to undesired radiation, etc., RF performance requirements such as reception sensitivity, baseband reception performance and mobility performance. NTT DOCOMO input a great number of contributions regarding simulation results and other such technical studies in addition to requirements from the operator's point of view, thus promoting the improvement of LTE reliability, stability, and performance.

5) RAN-WG5

In RAN-WG5, which specifies mobile terminal conformance test[*10] specifications, performance concerning the mobile terminal transmitting and receiving and specifications for LTE/SAE communication protocol testing. NTT DOCOMO input a great number of technical contributions, promoted discussion on specification of test parameters and testing procedures assuming actual operation, etc., improving LTE/SAE system interoperability. NTT DOCOMO also contributed greatly to completion of the specifications by serving as the RAN-WG5 Chairman and specifications editor.

In RAN-WG1 to 5, NTT DOCOMO, in addition to inputting SI and WI technical contributions (more than 3,000 in total) and promoting improvement of LTE performance, reliability and stability etc., promoted LTE standardization in volunteer

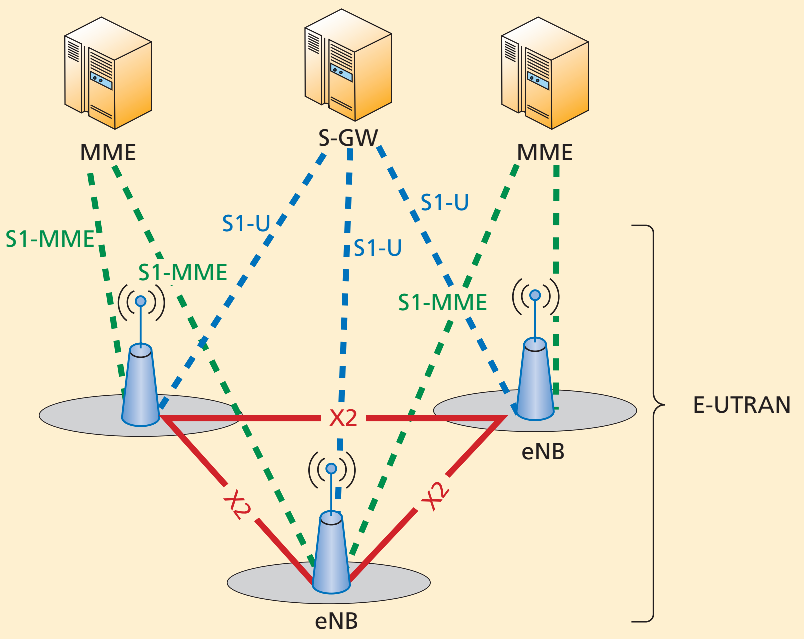

Figure 5 RAN architecture

*8 **Transport channel**: A channel defined in an intermediate layer for efficient physical channel mapping by bundling multiple logical channels.

*9 **Moderator**: Compiles e-mail discussions and reports them to the WG.

*10 **Conformance test**: A test to verify correct operation of functions.

positions such as serving as editors of specifications relating to LTE, and, as an LTE rapporteur company, guided the direction of discussion, and coordinated multiple groups within 3GPP and adjusted and managed the LTE schedule. Finally, we list the 3GPP positions NTT DOCOMO held during the standardization of LTE and SAE in **Table 1**.

5. Conclusion

We have explained the NTT DOCOMO contributions concerning the LTE/SAE specifications, which are the 3GPP Rel. 8 core technical specifications, including the necessity of LTE, contributions to standardization activities, and the main technical proposals. Currently, 3GPP is beginning work on the Rel. 9 specifications and the study that precedes that. NTT DOCOMO has launched development based on the Rel. 8 specifications, aiming for beginning of LTE service in 2010, but at the same time we continue to watch future network evolution and engage in standardization activities. ITU-R has already begun standardization of IMT-Advanced and 3GPP has begun study of an extended LTE referred to as LTE-Advanced. NTT DOCOMO continues to contribute, including coordination with ITU-R as a continuing rapporteur from LTE. In June 2009, Takehiro Nakamura of the NTT DOCOMO Radio Access Network Development Department was elected Chairman of TSG RAN, and our leading contribution to standardization activities in 3GPP will continue.

Table 1 Positions held in 3GPP TSG RAN

Chairman/Vice chairman	TSG RAN Vice chairman TSG RAN-WG5 chairman TSG RAN-WG1 Vice chairman
LTE rapporteur	TSG RAN TSG RAN-WG1
Specifications editor	TR 25.912 TR 25.913 TS 36.211 (co-editor) TS 36.322 TS 36.412/422 TS 36.508 TS 36.523-1 (co-editor)

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Access Network (E-UTRAN) access."
[14] 3GPP TS 24.301: "Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3."
[15] 3GPP TS 24.302: "Access to the 3GPP Evolved Packet Core (EPC) via non-3GPP access networks; Stage 3."
[16] 3GPP TS 29.118: "Mobility Management Entity (MME) - Visitor Location Register (VLR) SGs interface specification."
[17] 3GPP TS 29.275: "Proxy Mobile IPv6 (PMIPv6) based Mobility and Tunneling protocols; Stage 3."
[18] 3GPP TS 29.272: "Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol."
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