Further Enhancements of LTE — LTE Release 9 —

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NTT DOCOMO is currently developing and testing a system conforming to the LTE Release 8 specification in an effort to commercialize the standard for next generation mobile communications systems created by 3GPP: LTE. Meanwhile, the 3GPP has been working on further enhancements of LTE toward Release 9, planned to be released in spring of 2010. LTE Release 9 enhances some of the features introduced in Release 8, including CSG control and SON functionality, and introduces additional features to support LCS and MBMS. In order to realize systems that support high data rates and a variety of services at low cost, NTT DOCOMO has contributed proactively in clarifying requirements and developing technical standards, and in participating as rapporteur and editor in creating specification documents.

1. Introduction

As a promising radio access technology for next generation mobile communication systems, LTE is being standardized by the 3GPP international standardization organization. With Release 8, the first specification version for LTE, being completed in March 2009 [1], the LTE standard is now being developed toward commercialization in various countries in the world. NTT DOCOMO has been contributing proactively to the standardization of LTE, since the basic concept proposal in 2004, in order to provide more efficient, more economical, and more sophisticated radio access networks to our valued customers. NTT DOCOMO personnel have promoted LTE standardization at 3GPP, acting as the rapporteur for LTE study items and working as editors for some of the core specification documents. Moreover, NTT DOCOMO has made large contributions in developing the requirements, proposing enabler technologies, and moderating discussions to create the technical specifications of LTE.

LTE Release 8 specifies fundamental features of LTE, including Orthogonal Frequency Division Multiple Access (OFDMA) based downlink access, Single Carrier FDMA (SC-FDMA) based uplink access, layer 2 control radio connection management, and handover control, achieving three to four times the spectral efficiency compared to conventional W-CDMA.

While development of LTE commercial systems is progressing in various countries around the world, the

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3GPP is already proceeding with enhancements, with Release 9 of the specification to be completed in spring of 2010. NTT DOCOMO is also contributing proactively to the standardization of Release 9, in order to provide various services more efficiently through LTE. The relationship between LTE Releases 8 and 9 is shown in **Figure 1**. In addition to extensions to various features provided in Release 8 such as Closed Subscriber Group (CSG) and Self Organizing Networks (SON)[*1] [2], LTE Release 9 also provides features to support new services, including Location Services (LCS) and Multimedia Broadcast Multicast Services (MBMS).

In this article, we describe the major functionality added in Release 9 of the LTE specification.

2. CSG Enhancements

2.1 Background

LTE Release 8 provides a function called CSG, a mechanism to limit cell access rights to only users belonging to the CSG. An example of a potential application is for a femtocell Base Transceiver Station (femto BTS)[*2] installed in a home (Home eNodeB (HeNB)), allowing access by family members only.

Through this function, the User Equipment (UE) stores a list of allowed CSG IDs, and accessibility is determined based on whether the CSG ID being broadcast in the cell is included in this list or not. Non-allowed CSG cells are not considered as cell selection candidates for camping by the UE in idle mode. In Release 8, such CSG-aware control was only possible when the UE is in idle mode (RRC_IDLE) [3].

Also, with Release 8, the UE performs autonomous search for CSG cells allowing camping in idle mode based on arbitrary "Fingerprint" information, which may include for example, the Physical Cell IDs (PCI)[*3] of surrounding visible cells or GPS data.

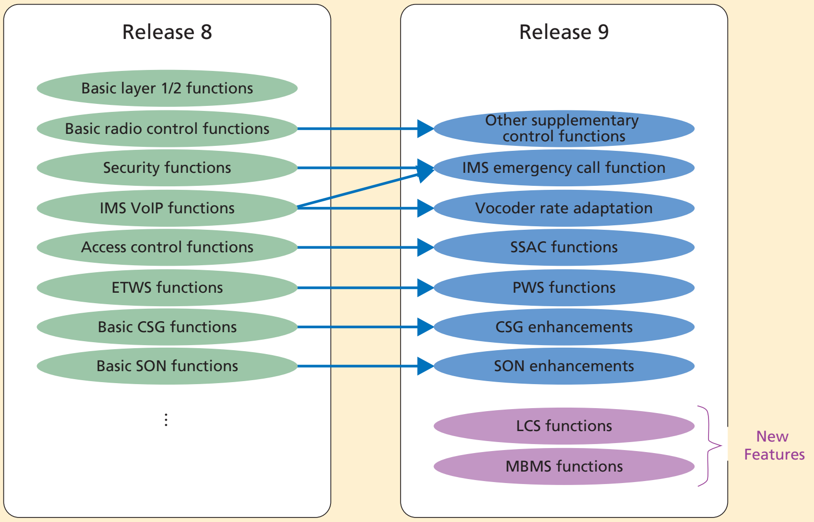

Figure 1 Relation between Release 8 and Release 9

2.2 Hybrid Access

With the CSG functionality in Release 8, only users specifically belonging to a CSG have access rights. However, these types of "Closed" cells can create interference problems on the operator's network, hence use was limited to places where the radio propagation is adequately isolated.

In contrast, Release 9 also allows cells to operate in a "Hybrid access" mode. In addition to its CSG ID, a cell in Hybrid-access mode broadcasts a "CSG Indicator," a single-bit flag indicating whether or not the cell is also opened to users not belonging to the CSG. Release 9 UEs belonging to the CSG cell will regard the cell as a CSG cell, while other Release 9 UEs will regard the cell as a regular macro cell. When the cell is seen as a CSG cell, the UE uses the autonomous search

*1 **SON:** A network installed with functions to self-configure and self-optimize its parameters.

*2 **Femto BTS**: Ultra-small cellular base station that covers a small area with a radius of several tens of meters, i.e., a femtocell.

*3 **PCI:** An identifier for a physical cell. In LTE 504 PCIs are available and reused.

function and prioritizes camping at CSG cells. Moreover, the UE is given premium services in terms of QoS and allocation/retention priority. In contrast, Release 8 UEs see all Hybrid-access cells as regular macro cells and cannot recognize them as CSG cells. Therefore, Release 8 UEs cannot exploit the benefits of CSG related control, although they can still access the cell as a regular macro cell.

This type of Hybrid-access cell is envisioned to be used in offices, schools or other public facilities in which employees or students belonging to the CSG would be provided with special services or QoS preference, and visitors or other non-members not belonging to the CSG would be provided with regular services in the normal way.

2.3 Handover in Connected Mode

As mentioned above, with Release 8, CSG related control is applied only in idle mode (RRC_IDLE). In other words, inbound handover towards CSG cells with access control is not supported in connected mode. However, this is possible with Release 9.

Also with Release 8, if there are multiple CSG cells using the same PCI in the vicinity of the current serving cell, the handover source base station (eNB) managing the serving cell cannot uniquely identify the handover target CSG cell based on the PCI of the CSG cell obtained from the UE in a measurement report. Such "PCI confusion" will become a prevalent issue in the future, when penetration of HeNBs increases (e.g., with use in homes). Functionality to resolve this issue is provided in Release 9.

The procedure implemented in Release 9 for handing over to a CSG cell in connected mode is shown in **Figure 2**. When a UE detects that it has entered the range of a potential handover candidate CSG cell to which it has access rights based on the Fingerprint data, it sends a Proximity Indication[*4] message (Fig. 2 (1)(2)) [4] to the eNB. In response, the handover source eNB configures the UE to perform relevant measurements of the CSG cell (Fig. 2 (3)). When certain radio conditions are met, the UE reports the PCI of the handover target candidate CSG cell in a measurement report message (Fig. 2 (4)). The source eNB then identifies whether the PCI is

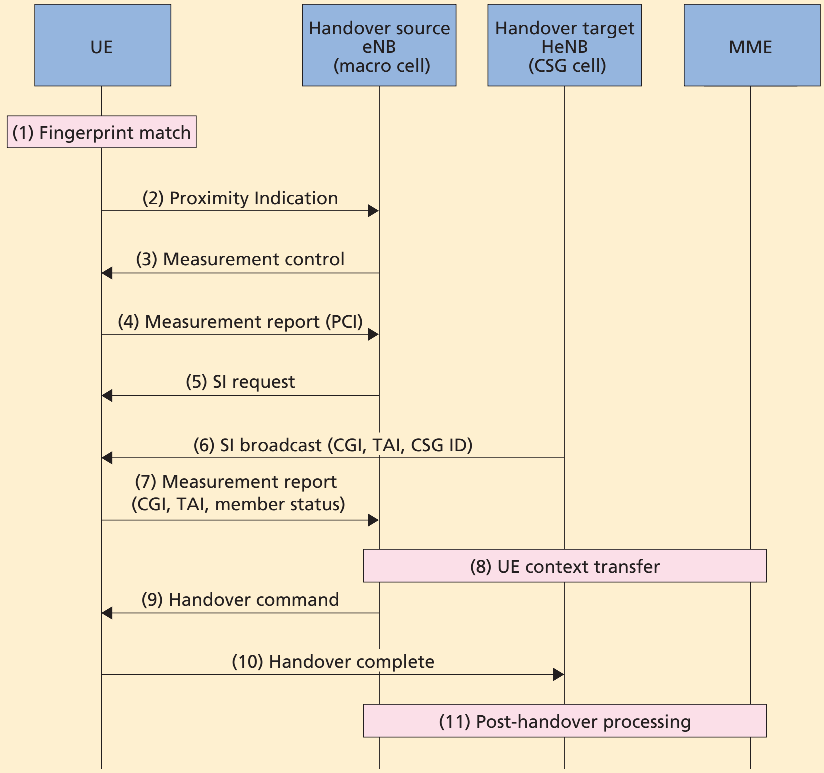

Figure 2 Inbound handover procedure to a CSG cell

*4 **Proximity Indication:** A message used to notify the eNB that a UE has entered the neighborhood of a CSG cell to which it has access rights.

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from an HeNB or not, and requests the UE to report the System Information (SI) of the particular cell (Fig. 2 (5)). The UE then reads the SI being broadcast from the target cell (Fig. 2 (6)) and reports information from the received SI back to the eNB, including the Cell Global Identity (CGI)[*5], Tracking Area Identity (TAI)[*6], and member status indicating whether it belongs to the CSG or not (Fig. 2 (7)). With the reported CGI and TAI from the UE, the source eNB is able to uniquely identify the target HeNB and transfer the UE context (Fig. 2 (8)). The eNB sends a handover command to the UE (Fig. 2 (9)) and post-handover processing is done upon receiving a completion message from the UE (Fig. 2 (10) (11)). Based on the member status indication from the UE, the source eNB can also decide whether to ask the core network to check validity of the UE's membership in the CSG.

3. SON Enhancements

NTT DOCOMO is constantly working on the design and optimization of radio parameters in order to improve the quality of its radio network. To operate the radio network efficiently in an optimized state, SON features would be beneficial. In Release 9, several SON functions, particularly focused on those that are useful when the network is first introduced, have been standardized.

3.1 Mobility Load Balancing

This function is aimed at distributing traffic load by optimizing the parameters for handover and cell reselection according to the load state among eNBs.

It standardizes the procedures for exchanging the load information needed for making adjustments between eNBs, as well as for exchanging parameters related to handover, although how the information is used to adjust parameters is left to eNB implementation. The following load information can be exchanged between eNBs.

- The number of Physical Resource Blocks (PRB), i.e., the unit of time-frequency resource allocation in LTE, in use.
- The load on the backhaul, which is the transmission link connecting an access network node to the core network.
- eNB hardware load
- The cell capacity class, which is an index indicating the relative capacities of the cells.

Note that in addition to load balancing between eNBs within LTE, balancing between systems using different 3GPP radio access technologies is also supported.

3.2 Mobility Robustness Optimization

This function has been standardized in order to adjust parameters when a handover failure is detected in the network, and to minimize the risk of loss of radio connection due to mobility.

With LTE, if the UE detects radio link failure or if a handover fails, it selects a suitable cell and attempts a connection re-establishment procedure with the selected cell. With this feature in Release 9, the eNB can request the UE to report the identity of the cell to which the UE was last connected when failure was detected. The radio measurements when failure was detected can also be reported. Based on this information, the target eNB and the source eNB exchange information regarding the failure event through the network interface[*7] so that threshold values and timer values for the handover can be adjusted.

For example, if the handover was executed too early, after handover failure the UE will likely re-establish connection to the source cell. On the other hand, if the handover was late, it will likely appear at the handover target cell through re-establishment. Alternatively, the UE could re-establish at a

*5 **CGI:** A unique identifier for all cells in the world which is broadcasted by each cell.

*6 **TAI:** The unit of area used to register locations in idle mode in LTE. It is composed of one or more cells, and each cell broadcasts which TAI it belongs to.

*7 **Network interface:** In LTE, X2 interfaces between two eNBs, and S1 interfaces between eNB and MME. Here, the interface between eNBs is referred to.

different cell, neither the source nor the target cell, after handover failure. These events can be distinguished by analyzing the UE report, and the handover parameters can be adjusted by exchanging information between eNBs.

3.3 Random Access Optimization

This function has been standardized in order to optimize the parameters of the Random Access Channel (RACH)[*8].

When the RACH is highly loaded, the collision probability on the RACH increases. This incurs more retransmissions before successful random access, and thus results in larger delay. On the other hand, since uplink radio resources must be reserved for RACH, configurations resulting in under-utilized RACH resources should be avoided. Hence, optimizing the amount of RACH resources based on the offered load is important.

To help optimize RACH configuration, Release 9 supports a procedure to report from the UE to the eNB, the number of RACH transmission attempts required for the most recent successful random access procedure and whether RACH collisions were detected.

4. LCS

LCS in Release 9 supports the following three positioning methods:

(1) Assisted-Global Navigation Satellite System (A-GNSS)

This positioning method utilizes GNSS (e.g., GPS satellite) information both received by the UE and obtained through the network to calculate final UE position. There are two ways to calculate the final positioning result; UE-assisted positioning, where the final result is computed by a server in the network, and UE-based positioning, where the final result is computed by the UE.

(2) Observed Time Difference of Arrival (OTDOA)

This positioning method utilizes the time differences in arrival times of a downlink positioning reference signal received from multiple eNBs. This information allows the computation of UE position by determining the intersection of several hyperbolas created from the time difference information.

(3) Enhanced-Cell ID (E-CID)

In this positioning method, information in addition to the serving eNB and the broadcast cell ID, such as propagation delay calculated from the difference in timing of signal transmission and reception and the Angle of Arrival (AoA), can be utilized to estimate the UE position.

Two control plane application protocols, namely LTE Positioning Protocol (LPP)[5] and LPP annex (LPPa)[6] are standardized to realize the LCS feature.

The LPP protocol is terminated between the UE and the positioning server (Enhanced Serving Mobile Location Centre (E-SMLC)), and hence, is transparent to the eNB and the Mobility Management Entity (MME) (**Figure 3**). On the other hand, the LPPa is terminated between the eNB and the E-SMLC, and hence, is transparent to the MME.

The LCS architecture in Release 9 locates the positioning server (E-SMLC) in the core network, instead of within the radio access network as done in earlier systems such as GSM EDGE Radio Access Network (GERAN)[*9] or Universal Mobile Telecommunications System Terrestrial Radio Access (UTRA)[*10]. One of the advantages of this architecture is that it allows implementation such that other non-3GPP standard positioning protocols (e.g., OMA Secure User Plane Location (SUPL)) can also be trans-

*8 **RACH:** A shared uplink channel used by UEs to access the cell. With LTE, only a 6-bit preamble is sent.

*9 **GERAN:** A radio access network based on GSM and EDGE 3GPP standards.

*10 **UTRA:** A 3GPP radio access technology standard based on W-CDMA. Used by NTT DOCOMO's FOMA service.

mitted over LPP.

5. MBMS

Another feature introduced with LTE Release 9 is the MBMS. MBMS is a bearer service for broadcast/multicast transmission of data, to transmit the same information to all interested UEs in an area over a common bearer. Note that MBMS has been supported in UTRA since Release 6.

LTE Release 9 supports basic MBMS functionality not requiring complex control. One of the main features is support for MBMS Single Frequency Network (MBSFN) transmission. With MBSFN transmission eNBs in the MBSFN area transmit the same signal simultaneously using the same time-frequency resource. The UE receives the combined signals as a single, strong signal, improving coverage and signal quality without much additional complexity in the UE. By applying MBSFN transmission, a 3GPP study concluded that to provide 95% coverage with a packet error rate of 1%, a spectral efficiency of 3 bit/s/Hz or greater can be achieved [7].

The logical architecture for MBMS in LTE is shown in **Figure 4**. The MBMS gateway (GW) distributes data received from the Broadcast Multicast Service Center (BMSC)[*11] to the relevant eNBs by IP multicast. The Multi-Cell Multicast Coordination Entity (MCE) specifies the radio resources to be used by eNBs comprising the MBSFN and ensures that the content is synchronized. To support MBMS, logical channels, namely Multicast Traffic

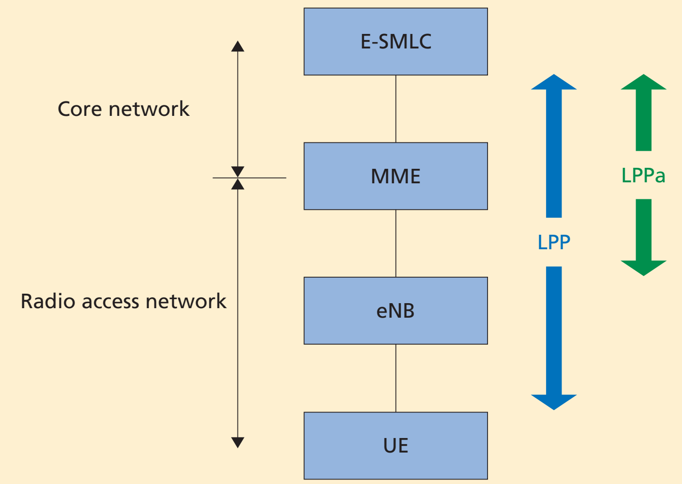
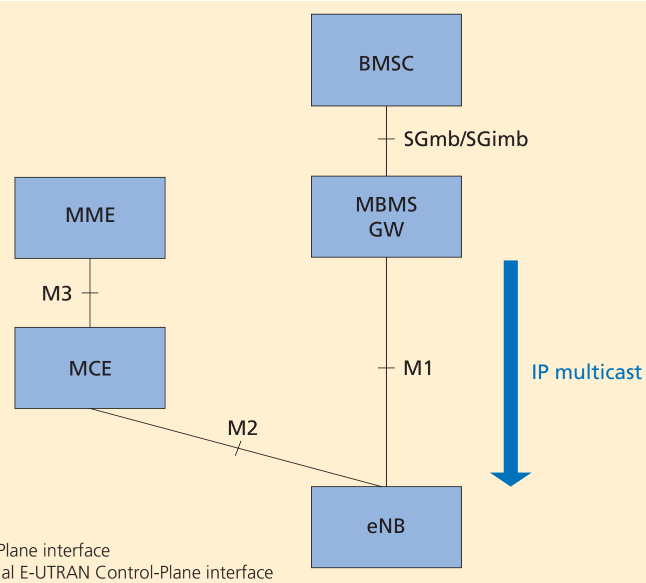


Figure 3 LCS Protocols in LTE



M1 : User-Plane interface
M2 : Internal E-UTRAN Control-Plane interface
M3 : Control-Plane interface between E-UTRAN and EPC
SGmb/SGimb : The Control-Plane/ User-Plane interfaces between BMSC and MBMS GW in the core network

Figure 4 Logical architecture of MBMS in LTE

*11 **BMSC:** A network node which stores content to be transmitted by MBMS and controls MBMS transmission.

Channel (MTCH) and Multicast Control Channel (MCCH), and a transport channel, namely Multicast Channel (MCH), are defined (**Figure 5**).

6. Other Enhancements

6.1 IMS Emergency Calls

With LTE Release 8, IP Multimedia Subsystem (IMS)[*12] emergency calls were not supported, and emergency calls had to be diverted to other radio access technologies supporting the Circuit Switched (CS) domain[*13], such as UTRA or GERAN by use of the CS fallback[*14] procedure [8][9].

LTE Release 9 introduces an emergency attach procedure[*15] and security enhancements[*16] (a NULL algorithm) in order to support IMS emergency calls by UEs without a valid Universal Subscriber Identity Module (USIM)[*17]. Priority control for IMS emergency calls is also supported.

6.2 SSAC

In UTRA, two network domains existed: a CS domain and a Packet Switched (PS) domain[*18]; and Domain Specific Access Control (DSAC) has been supported since Release 7. Through use of DSAC, independent access control is possible for voice calls on the CS domain, and data calls on the PS domain.

In cases of natural disaster, this mechanism can be used to suppress only voice calls, which occur in large numbers, so that means for getting in contact (e.g., through email and bulletin boards) can still be provided while ensuring connectivity for priority calls.

In contrast, since LTE only has a PS domain, DSAC is not applicable. Nevertheless, the same requirements for priority calls and means for providing contact in case of disaster still apply to LTE. Therefore, a means of access control depending on the service is required within the PS domain. For this reason, Release 9 introduces a function called Service Specific Access Control (SSAC), allowing IMS voice and video-phone calls to be con-

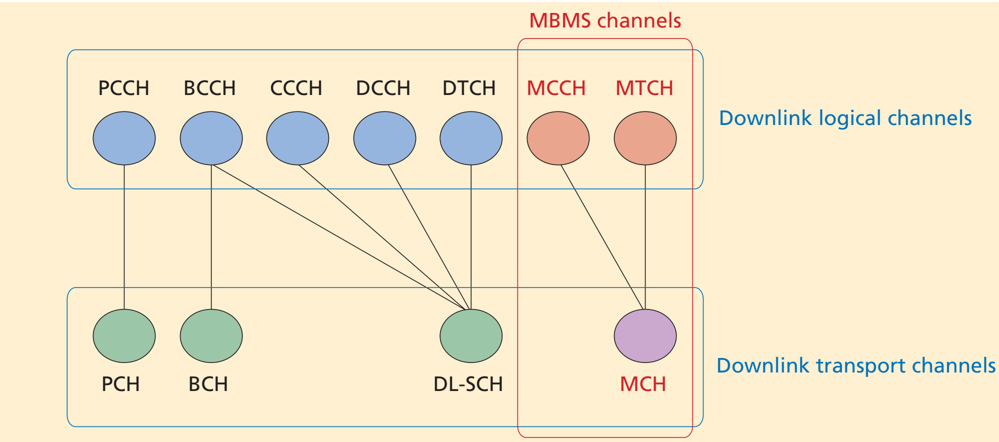


Figure 5 MBMS channel mapping in LTE

*12 **IMS:** A communication system standardized by 3GPP for implementing multimedia services. IMS uses IP and the SIP protocol used for Internet telephony to integrate the communication services of the fixed telephone and mobile communication networks.

*13 **CS domain:** A network domain that provides services based on circuit switching.

*14 **CS Fallback:** The procedure for switching to a radio access technology that supports CS domain when originating or receiving circuit-switched services such as voice calls while in LTE.

*15 **Emergency attach procedure:** A procedure in LTE for registering to a network in order to place an emergency call from a UE without a USIM (see *17).

trolled separately from other traffic.

6.3 PWS

The Public Warning System (PWS) is for transmitting emergency alerts in times of disaster. PWS includes the Earthquake and Tsunami Warning System (ETWS) and the Commercial Mobile Alert System (CMAS), and has been specified to conform to the requirements for emergency warnings on mobile phones in Japan and the USA. Note that ETWS has been supported since Release 8, and details can be found in reference [10].

Release 9 additionally supports CMAS, and its method of message transport is similar to that of ETWS. However, due to differences in requirements, CMAS and ETWS have some differences as follows.

- CMAS only has an equivalent to the Secondary Notification[*19] in ETWS, and there is no equivalent to the Primary Notification[*20]. This is because CMAS does not have a delay requirement as in ETWS.
- CMAS can provide up to 64 concurrent emergency warning messages. ETWS does not require provision of multiple concurrent emergency warnings, so it is only able to provide one emergency warning at a time in a given area.

Note that the number of CMAS messages that can be received by a UE supporting CMAS depends on the UE implementation.

6.4 Vocoder Rate Adaptation

With Release 9, voice coding rate control (Vocoder Rate Adaption) is supported.

Specifically, when the voice codec used by IMS VoIP supports multi-rate, this feature allows adaptive control of the voice coding rate as per the radio quality and/or state of congestion. This is done by overwriting the Explicit Congestion Notification (ECN) field [11] in the voice IP packets at the eNB.

When the radio link quality degrades or the capacity is strained, the eNB can cause the end-to-end voice coding rate to be reduced by rewriting the ECN field to a predefined value.

7. Conclusion

The major functions introduced in LTE Release 9 were described. LTE Release 8 provided a set of fundamental features to enable LTE networks to operate at high spectral efficiency and data rates. In Release 9, enhancements were made with regards to features such as CSG, SON, LCS and MBMS, thereby allowing a greater variety of services to be integrated, and adding value to LTE networks. At 3GPP, discussion regarding Release 10 has already begun, and various enhancements are being studied toward IMT-Advanced ITU-R recommendation. Examples of these include Carrier Aggregation, which allows multiple LTE carriers to be used in parallel, higher order MIMO transmission techniques, and relaying at the layer 3 level.

NTT DOCOMO will continue to promote standardization activities to further increase the performance and sophistication of LTE in the future.

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*16 **Security enhancement:** Ciphering and integrity protection of communication. Since normal security for ciphering and integrity protection cannot be performed by a UE without USIM (see *17), a NULL algorithm is provided.

*17 **USIM:** An application on a subscriber identification module that is inserted into a UMTS UE.

*18 **PS domain:** A network domain that provides services based on packet switching.

*19 **Secondary Notification:** A type of emergency bulletin used to announce secondary information such as evacuation information in times of disaster.

*20 **Primary Notification:** A type of emergency bulletin used to announce disasters such as earthquake or tsunami. Transmission within four seconds is a requirement.

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