3GPP Release 11 LTE/LTE-Advanced IMT-Advanced

Technology Reports

Further Development of LTE/LTE-Advanced – LTE Release 10/11 Standardization Trends –

Advanced Technologies in LTE/LTE-Advanced

LTE was standardized at 3GPP, an international standards organization, as 3GPP Release 8 in 2008 with an eye to achieving dramatic improvements over the third-generation mobile communications system. This was followed by the standardization of LTE-Advanced as Release 10 to achieve even higher speeds and capacities in mobile communications. At present, 3GPP is in the process of completing Release 11 specifications and beginning the formulation of Release 12. This article describes an overview on the progression of LTE and LTE-Advanced standardization and summarizes the main function extensions in the above releases.

Radio Access Network Development Department

Takehiro Nakamura
Sadayuki Abeta
Hideaki Takahashi
Satoshi Nagata

1. Introduction

The 3rd Generation Partnership Project (3GPP), which had previously formulated the specifications for WCDMA and High-Speed Packet Access (HSPA)[*1] as a third-generation mobile communications system, formulated a radio system called Long Term Evolution (LTE) in 2008 as 3GPP Release 8 specifications (hereinafter referred to as "Rel. 8") in response to growing market demands. It then went on to formulate LTE-Advanced[*2] as 3GPP Release 10 specifications (hereinafter referred to as "Rel. 10") making further enhancements to LTE. Nevertheless, market demands for enhanced performance continued to grow and diversify, and in 2012, 3GPP formulated Release 11 specifications (hereinafter referred to as "Rel. 11") with the aim of extending the functions and raising the performance of LTE-Advanced. In this article, we describe an overview on how LTE specifications have progressed over the years and summarize the main function extensions in the releases up to LTE Rel. 11.

2. Progression of 3GPP Specifications

Since the formulation of W-CDMA specifications as Release 99[*3], many functions have been added at 3GPP in the form of new release specifications in response to growing demands from the market. The progression of these specifications is shown in **Figure 1**. High-Speed Downlink Packet Access (HSDPA)[*4] and High-Speed Uplink Packet Access (HSUPA)[*5], which are

*1 **HSPA**: A specification for increasing packet-data rates in W-CDMA and a general term encompassing HSDPA (see *4), which increases the speed from the base station to the mobile terminal, and HSUPA (see *5), which increases the speed from the terminal to the base station.

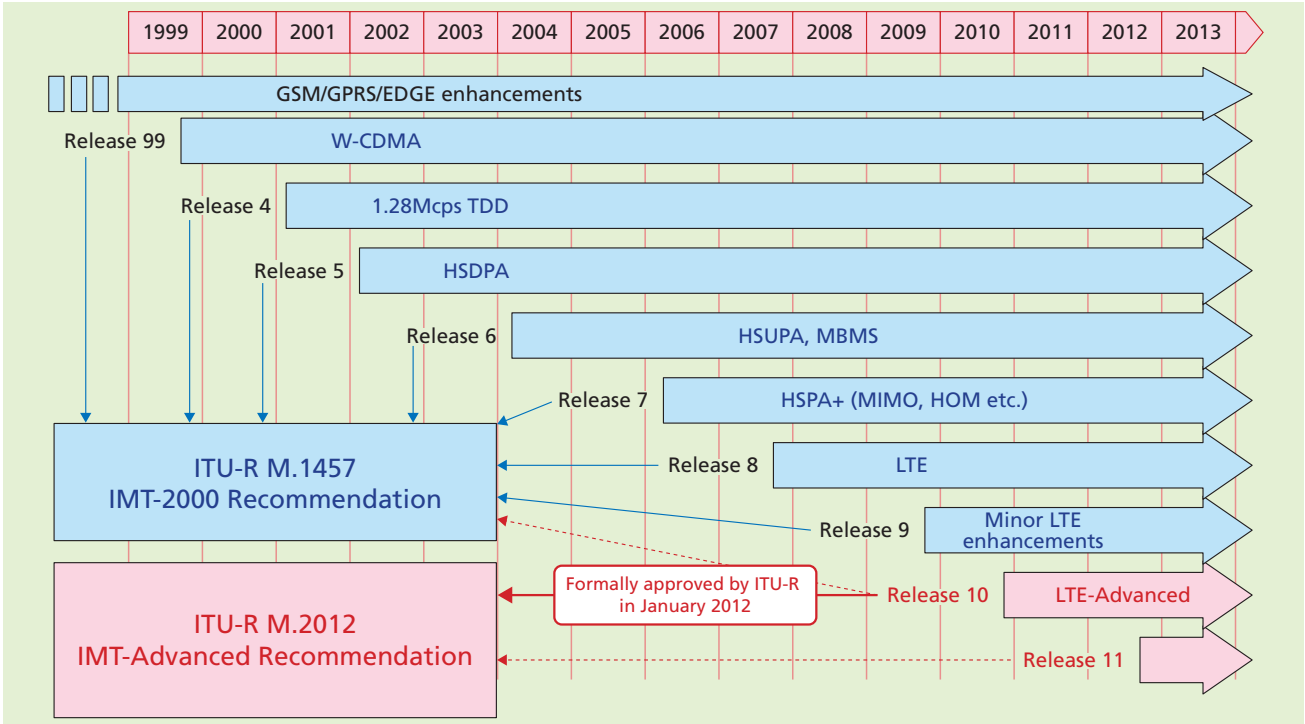

Figure 1 Progression of 3GPP specifications

already in widespread use around the world, are included in Release 5 and Release 6, respectively. These 3GPP specifications related to W-CDMA and HSDPA/HSUPA are contained in the International Mobile Telecommunications-2000 (IMT-2000)[*6] Recommendation of the International Telecommunication Union-Radiocommunication sector (ITU-R)[*7].

The LTE system was formulated at 3GPP at the end of 2007 as Rel. 8 specifications to provide a mobile communications system that could perform at a dramatically higher level than HSDPA/HSUPA. The motivation behind this development was to satisfy growing demands from the market for enhanced specifications as well as to achieve a competitive mobile communications system. At present, the commercial deployment of LTE is progressing well in Japan and elsewhere throughout the world and its high level of performance is being recognized. Following Rel. 8, technologies for achieving a number of function extensions mainly in LTE upper layers were developed and incorporated in Release 9 specifications in 2009.

Next, as market demands continued to intensify and as the need arose to satisfy the requirements of IMT-Advanced[*8], which is a true fourth-generation mobile communications system then being standardized at ITU-R, 3GPP set out in 2008 to formulate specifications for LTE-Advanced with the aim of making further performance improvements and function extensions to LTE. Those specifications were standardized as Rel. 10 in 2011. LTE-Advanced was proposed as a candidate technology for ITU-R IMT-Advanced, and deliberations at ITU-R concluded that LTE-Advanced did indeed satisfy the requirements of IMT-Advanced. In January 2012, LTE-Advanced was formally approved as one radio interface of the IMT-Advanced system.

The formulation of Rel. 11 specifi-

*2 **LTE-Advanced**: Name of IMT-Advanced in 3GPP. IMT-Advanced is the successor to the IMT-2000 third-generation mobile communications system.

*3 **Release 99**: Indicates a version of 3GPP specifications. Release 99 was formulated as the initial 3GPP specification in 1999. The HSDPA (see *4) function was added in 2005 as Release 5.

*4 **HSDPA**: A high-speed downlink packet transmission technology based on W-CDMA and standardized by 3GPP. It optimizes the modulation method and coding rate according to reception conditions at the mobile terminal.

*5 **HSUPA**: A high-speed uplink packet transmission technology based on W-CDMA and standardized by 3GPP. It optimizes the coding rate, spread factor, and transmission power according to reception conditions at the base station.

*6 **IMT-2000**: The 3G mobile communications systems for increasing the speed of communication. These are summarized in ITU-R recommendations, and there are currently six variations, including W-CDMA.

cations as function extensions of LTE-Advanced was energetically pursued at 3GPP in 2012. Most of the specifications were completed in 2012 and the freezing of those specifications was announced in March 2013.

3. LTE Function Extensions in Various Releases

At 3GPP, new functions have been added in various releases and extensions have been added to existing functions by applying enhanced technologies. The correspondence between main function extensions and recent releases is shown in **Figure 2**. The following describes the progression of extensions made for key LTE functions.

3.1 Bandwidth Widening Technology

Widening the frequency bandwidth is an effective means of improving user throughput. The bandwidth under W-CDMA/HSDPA/HSUPA was 5 MHz, but LTE supported a maximum bandwidth of 20 MHz beginning with its initial specifications in Rel. 8. Then, in LTE Rel. 10, carrier aggregation was adopted with the aim of maintaining backward compatibility while widening bandwidth even further. This technique makes it possible to bundle multiple frequency carriers of LTE Rel. 8 and to support a maximum bandwidth of 100 MHz.

3.2 Multi-antenna Technology

In its initial Rel. 8 specifications, LTE adopted Multiple Input Multiple Output (MIMO)[*9] multi-antenna technology in the downlink to increase transmission speed and capacity. In Rel. 8, the maximum number of layers (number of spatially multiplexed transmission signals) was four, but in Rel. 10, the maximum number of layers in the downlink was extended to eight and support was initiated for a maximum of four MIMO layers in the uplink.

3.3 Inter-cell Coordination Technology

As an effective measure for improving cell-edge performance, inter-cell coordination technology has been actively studied for every release. First, in Rel. 8, Inter-Cell Interference Coordination (ICIC) technology was adopted as an inter-base-station interface on top of Fractional Frequency Reuse (FFR)[*10], which applies frequency reuse between cells only at the cell edge. Then, in Rel. 10, a Heterogeneous Network (HetNet) was adopted as a configuration that could efficiently improve system capacity by overlaying large cells (macrocell[*11]) and small cells (picocell[*12]/femtocell[*13]) having different transmission power levels. This release also initiated support of Transmission Power Control (TPC)[*14] for large cells

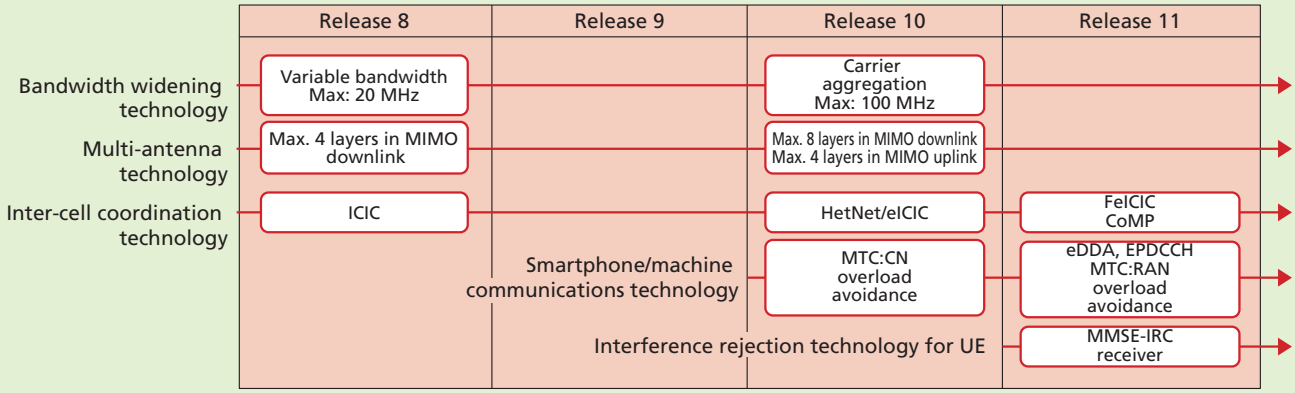

Figure 2 Correspondence between main function extensions and releases

*7 **ITU-R**: A department of ITU, an organization that specializes in the field of telecommunications. It manages and coordinates international matters related to radio communication, such as radio regulations and spectrum use in various countries.

*8 **IMT-Advanced**: A standard positioned as the successor to IMT-2000 at ITU-R. It calls for data rates of about 100 Mbit/s for high mobility and 1 Gbit/s for low mobility.

*9 **MIMO**: A signal transmission technology that improves communications quality and spectral efficiency by using multiple transmitter and receiver antennas for transmitting signals at the same time and same frequency.

*10 **FFR**: A control method that allocates a different frequency band to cell-edge UE.

*11 **Macrocell**: Cellular communication area with a radius of several hundred meters to several tens of kilometers mainly covering outdoors. Usually, antennas are put up on towers or on roofs of buildings.

and enhanced ICIC (eICIC) for small cells adopting current-cell identification technology, both with the aim of increasing capacity and improving cell-edge performance in a HetNet configuration. Next, in Rel. 11, Further enhanced ICIC (FeICIC) was specified as a means of reducing interference power by canceling the reference signal emitted from a high transmission power cell at User Equipment (UE) connected to a small cell.

In addition to the above, Coordinated Multi-Point transmission/reception (CoMP) was specified for the first time in Rel. 11 to coordinate transmission and reception signals among multiple base stations. This technology adopts, for example, an intra-eNode B coordination technique that enables UE to select an optimal base station at high speed and a technique that reduces interference by halting transmission from an adjacent base station when transmitting to cell-edge UE.

3.4 Smartphone/Machine Communications Technology

The demand for communication services between equipment without human intervention is growing, and such services have become a topic of study at 3GPP under the name of Machine Type Communication (MTC). Support has been given, in particular, to a function called Core Network/Radio Access Network (CN/RAN) overload avoidance to prevent system congestion[*15] when many devices such as water-level sensors along rivers generate transmissions in unison. In addition, transmissions from an extremely large number of terminals can be envisioned due to the spread of MTC and smartphone communications, and there are concerns that the capacity of the Physical Downlink Control CHannel (PDCCH)[*16] will eventually fall short. A new downlink control channel called Enhanced PDCCH (EPDCCH) was therefore specified in Rel. 11 to increase control channel capacity in the downlink.

The ongoing expansion of smartphone use is also creating a need for handling various types of data traffic. Studies are therefore proceeding at 3GPP on ways for the network to deal with such traffic under the name of Diverse Data Applications (DDA)[*17]. In particular, to optimize power consumption at UE, a function named enhanced DDA (eDDA) has been added in Rel. 11 to enable UE to notify the network that it needs to reduce power consumption.

3.5 Interference Rejection Technology for UE

To improve reception characteristics on the mobile-device side, reception performance requirements have been specified in Rel. 11 under the name of Minimum Mean Squared Error[*18] - Interference Rejection Combining[*19] (MMSE-IRC). A receiver equipped with MMSE-IRC generates a reception weight[*20] taking into account an interference signal arriving from another cell thereby enabling that interference to be effectively suppressed in accordance with the receiver's spatial degrees of freedom[*21].

3.6 Other Major Functions

Although details have been omitted in this article, extensions have also been made to the following functions in various LTE releases.

(1) Home eNode B (HeNB): A low-power LTE base station called a femtocell in the market. First specified in Rel. 8, it is expected to be introduced worldwide.

(2) Self-Organizing Network (SON): A function for automatically configuring or optimizing a system with the aim of reducing a telecommunication carrier's CAPital EXpenditure (CAPEX)[*22] and OPerating EXpense (OPEX)[*23]. First specified in Rel. 8.

(3) Minimization of Drive Tests (MDT): A feature that aims to reduce an operator's quality management costs by equipping UE with functions for measuring and recording quality and notifying the network of measurement results as traditionally done through drive tests conducted mainly by operators to manage service area quality. First

*12 **Picocell**: A cell having a radius up to several tens of meters configured mainly for indoor use.
*13 **Femtocell**: A very small area with a radius of several tens of meters covering homes and/or small shops.
*14 **TPC**: Function for controlling transmission power to maintain constant signal quality by using the TPC information bit to inform the transmitter of channel quality, packet error rate, etc. as measured at the receiver.
*15 **Congestion**: A state where communication requests are concentrated inside a short time period and exceed the processing capabilities of the network, thereby obstructing communications.
*16 **PDCCH**: Control channel for the physical layer in the downlink.
*17 **DDA**: A control method for dealing with various types of data traffic on the network.
*18 **MMSE**: A method for suppressing interference from other signals by multiplying the received signal with calculated weights.

specified in Rel. 10.

(4) enhanced Multimedia Broadcast Multicast Service (eMBMS): A function for orienting MBMS specified for 3G systems to LTE. First specified in Release 9.

(5) Relay Node: A node that aims to effectively extend coverage. In contrast to existing repeater[*24] equipment, this is a regenerative relay node that terminates not only in the physical layer but in upper layers too. First specified in Rel. 10.

4. Conclusion

This article provided an overview on the progression of LTE/LTE-Advanced standardization at 3GPP and on main function extensions in various LTE releases. Main features in Rel. 11, the latest set of 3GPP specifications, include HetNet-related technology, smartphone/machine-related technology, mobile-device interference-rejection technology, M2M congestion countermeasure technology, and VoLTE roaming technology. The reader is asked to see other articles in this issue for more details on these features [1]-[5].

References

[1] Y. Kishiyama et al.: "Heterogeneous Network Capacity Expansion Technology for Higher Speeds in LTE/LTE-Advanced," NTT DOCOMO Technical Journal, Vol. 15, No. 2, pp. 9-17, Oct. 2013.

[2] Wuri A. Hapsari et al.: "Radio System Optimization toward Smartphone/machine Communications for Higher Speeds in LTE/LTE-Advanced," NTT DOCOMO Technical Journal, Vol. 15, No. 2, pp. 18-26, Oct. 2013.

[3] Sagae et al.: "Improved Interference Cancelling and Suppression Technology in LTE Release 11 Specifications," NTT DOCOMO Technical Journal, Vol. 15, No. 2, pp. 27-30, Oct. 2013.

[4] Sasada et al.: "Core Network Infrastructure and Congestion Control Technology for M2M Communications," NTT DOCOMO Technical Journal, Vol. 15, No. 2, pp. 31-36, Oct. 2013.

[5] Tanaka et al.: "VoLTE Roaming and Interconnection Standard Technology," NTT DOCOMO Technical Journal, Vol. 15, No. 2, pp. 37-41, Oct. 2013.

*19 **IRC**: A method for rejecting an interference signal by creating an antenna-gain drop point with respect to the arrival direction of that signal.

*20 **Reception weight**: Amount of fluctuation in amplitude and phase needed to synthesize and separate signals received at multiple receive antennas.

*21 **Spatial degrees of freedom**: Signal processing/separation performance obtained by increasing the number of antennas.

*22 **CAPEX**: Amount of money expended for investing in facilities.

*23 **OPEX**: Amount of money expended for managing operations.

*24 **Repeater**: Relay equipment on the physical layer to amplify a downlink receive signal from a base station and transmit it to a mobile station.