3GPP | Release 13 | LTE/LTE-Advanced

Technology Reports

Special Articles on LTE-Advanced Release 13 Standardization

LTE-Advanced Release 13 Standardization Technology Overview

The international standards organization, 3GPP, introduced the LTE-Advanced standard for extending and expanding LTE in their Release 10 specification. Since then, it has continued to specify extensions to the standard to further advance the elemental technologies of LTE/LTE-Advanced. In this article, we describe the main functions specified in Release 13 that was completed in March 2016.

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1. Introduction

The 3rd Generation Partnership Project (3GPP), which developed the specifications for Wideband Code Division Multiple Access (W-CDMA)*1, High-Speed Packet Access (HSPA)*2, and the LTE standard, established the Release 10 specification for LTE-Advanced to extend and expand LTE. This was done to meet the growing needs of smartphone users and support increasingly diversified services. NTT DOCOMO, for its part, launched its PREMIUM 4G service using LTE-Advanced technology in March 2015, and services using LTE-Advanced technology are now being rolled out in various countries around the world. Following the Release 10 specification, 3GPP continued to update specifications for extending the functionality and enhancing the performance of LTE/LTE-Advanced, and it completed its Release 13 specification in March 2016. In this article, we explain the background to the formulation of Release 13 and describe newly introduced functionality.

2. Background to Release 13 Studies

Release 10, the first specification for the LTE-Advanced standard, introduced technologies such as Carrier Aggregation (CA)*3, which increases bandwidth up to 100 MHz while maintaining backward compatibility with LTE, and advanced multi-antenna technology, which supports up to eight transmission layers on the downlink and four transmission layers on the uplink [1].

This was followed by Release 11

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*1 **W-CDMA:** A third-generation mobile communications system specified by 3GPP.

and Release 12 specifications to expand LTE-Advanced functionality. In addition to band-expansion and multi-antenna technologies for conventional mobile phones, these releases included extensive specifications for terminals equipped with communication modules such as smart meters (electricity and gas meters) [2] [3].

In a similar manner, studies for Release 13, which got under way in 2014, considered a wide range of market trends and needs beyond the domain of conventional mobile phones. As shown in **Figure 1**, the scope of study in Release 13 can be broadly divided into (1) new technologies for creating new services, (2) new technologies for increasing user throughput and capacity, and (3) improved functionality based on network operations experience.

3. New Functionality in Release 13

3.1 New Technologies for Creating New Services

Market expectations of the Internet of Things (IoT)*4 have been increasing, and to meet these expectations, 3GPP has developed specifications to provide IoT-oriented devices with communications capability. The Device-to-Device (D2D)*5 function specified in Release 12 has also been extended.

1) Machine Communication (Category M1 and NB-IoT)

A variety of organizations have been studying terminals oriented to machine communication for smart meters (electricity and gas meters) and other services. In Release 12, 3GPP specified low-price machine-communication terminals as LTE terminal Category 0. These terminals feature (1) a maximum data rate limited to 1 Mbps, (2) support for

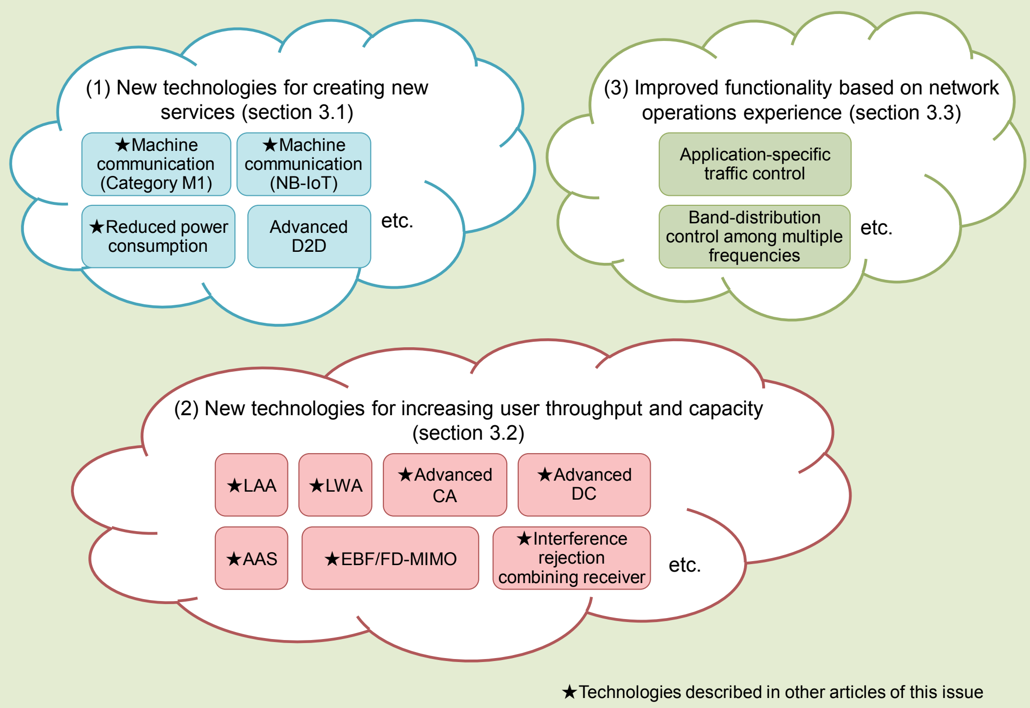

Figure 1 Main functionality in Release 13

*2 **HSPA:** Standard that enables the high speed packet data transmission in W-CDMA; collective term for High Speed Downlink Packet Access (HSDPA) that speeds up the downlink (from base station to mobile terminal) and High Speed Uplink Packet Access (HSUPA) that speeds up uplink (from mobile terminal to base station).

*3 **CA:** Technology to simultaneously transmit and receive signals from 1 user using multiple carrier waves to enable wider bandwidths while maintaining back compatibility with existing LTE, and achieve faster transmission speed.

*4 **IoT:** General term for a style of control and communication where various "things" are connected via the Internet or cloud services.

*5 **D2D:** A technology enabling direct communications between terminals. It supports both autonomous-type direct communications between terminals when outside of base station coverage and direct communications between terminals when inside of base station coverage based on control information from the base station.

Frequency Division Duplex (FDD)*6 and Half Duplex*7, and (3) support for single-antenna reception. Release 13, in turn, supports two new terminal categories to further lower terminal price and extend coverage, as described below.

(a) Category M1

In addition to the features provided by Category 0, Category M1 features (1) transceiver bandwidth limited to 1.08 MHz and (2) support for coverage extension of approximately 15 dB. This limitation of transceiver bandwidth is expected to have a significant cost-reduction effect and to reduce the price of the terminal chip by approximately 50% compared with Category 0.

(b) NB-IoT

Although specification studies for machine communication originally targeted the frequency bands of the Global System for Mobile communications (GSM)*8, NarrowBand (NB)-IoT has been common to studies aimed at enabling use of LTE frequency bands too. This NB-IoT category features (1) tranceiver bandwidth limited to 180 kHz and (2) support for coverage extension greater than 20 dB. Compared with Category M1, NB-IoT is inferior in data rate and spectrum efficiency*9, but the use of an even narrower band is expected to reduce the price of the terminal chip by approximately 25%.

2) Reduced Power Consumption

The Release 12 specification provided for Power Saving Mode (PSM), a technology for reducing power consumption in machine-communication terminals. This technology can greatly reduce power consumption by turning nearly all radio functions OFF without performing intermittent reception. On the other hand, an incoming call to such a terminal can only be received at the time of location registration, that is, during a tracking area update in LTE, which is performed periodically (normally every 54 min). To deal with this issue, Release 13 provides for extended Discontinuous Reception (DRX)*10 as a technology for shortening the call-receiving interval. This technology can greatly increase the intermittent reception period during standby from the existing maximum of 2.56 s to a maximum of 43 min.

3) Advanced D2D

Release 13 enhanced the D2D specifications established in Release 12 to expand the scope of D2D application to services. For example, in a public safety application to provide communications in times of an emergency, it specifies a User Equipment (UE)-to-network relay function that enables a UE within coverage to serve as a relay station to relay data of a UE outside of coverage to a base station. Providing network connectivity in this way by supplementing base-station coverage for public safety purposes can reduce investment costs. Also specified by Release 13 is D2D discovery*11 technology that can be applied, for example, to the discovery of such relay stations when a UE is outside of coverage.

Release 13 also specifies D2D discovery between carriers and between operators for commercial applications. It specifies, in particular, the use of resident cell*12 information to notify a UE of D2D settings for use with other carriers, and it specifies control procedures for switching transceiver functions in D2D discovery.

3.2 New Technologies for Increasing User Throughput and Capacity

New technologies for increasing user throughput and capacity are being established at 3GPP. A key feature of Release 13 is the specification of technologies for using LTE in unlicensed spectrum, as described below.

1) LAA

The explosive increase in data traffic in recent years is producing a serious shortage of available frequencies allocated for operator use (licensed spectrum). Under these conditions, some telecom operators are working to improve quality by using frequency bands not requiring a radio station license (unlicensed spectrum) to offload data in an area in which licensed spectrum is scarce. To meet the demand for improving capacity using unlicensed spectrum,

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*6 **FDD:** A method for transmitting signals using different carrier frequencies and bands in the uplink and downlink.

*7 **Half Duplex:** A communications method whereby signals can be transmitted in only one direction at a time; when transmission (reception) is being performed in one direction (by the base station, for example), reception (transmission) is being performed in the other direction (by the mobile terminal, for example).

*8 **GSM:** A second-generation mobile communications system used by digital mobile phones.

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

*10 **DRX:** Intermittent reception control used to reduce power consumption in UE.

*11 **D2D discovery:** Technology for discovering a nearby terminal.

*12 **Cell:** The smallest area unit for sending and receiving radio signals between a cellular mobile communication network and mobile terminals.

3GPP specified Licensed-Assisted Access (LAA) to promote a more effective use of unlicensed spectrum compared with the above offloading technology. This LAA technology enables aggregation of unlicensed spectrum in the 5-GHz band as a dedicated Secondary Cell (SCell)*13 with existing licensed spectrum as CA in the downlink, and performs simultaneous communications over both carriers. Additionally, as a result of studies on technologies for achieving a fair coexistence with other systems using the same frequencies, such as existing wireless LAN systems and LAA of other operators, Release 13 specifies channel access technology based on Listen-Before-Talk*14 while also establishing signal configurations for efficient transmission and reception of data on unlicensed spectrum. Moreover, for Release 14, studies are being performed on using unlicensed spectrum as a SCell in both the uplink and downlink of LTE CA.

2) LWA

Also specified in Release 13 is LTE-WLAN Aggregation (LWA) that bundles LTE and wireless LAN radio signals as a technology for increasing user throughput and capacity using unlicensed spectrum. In this regard, some telecom operators are working to enhance transmission speeds by providing Internet connections via wireless LAN using an existing wireless LAN access point*15. Here, the LTE base station and wireless LAN access point may be implemented in physically different equipment or in the same equipment, and the LWA function supports either scenario.

3) Advanced CA

(1) Extension of maximum number of LTE carriers

The CA function enables simultaneous communications over a maximum of five aggregated LTE carriers. It was originally specified in Release 10 and enhanced in various ways through Release 12, but the maximum number of carriers remained the same. However, the actual number of LTE carriers used in CA specified for various combinations of frequency bands has been approaching that upper limit. In addition, the LAA function described above is expected to use the 5-GHz unlicensed spectrum enabling the use of frequency bandwidths in excess of 100 MHz. The need was therefore felt for extending the number of LTE carriers that can be simultaneously used in CA so that even higher peak data rates could be achieved. In light of this need, Release 13 extended the maximum number of LTE carriers that can be simultaneously used to 32.

(2) New PUCCH format and functions

Conventional CA allowed uplink control signals to be transmitted to the base station from only the Primary Cell (PCell)*16. However, as the number of simultaneously usable LTE carriers increase, the number of uplink control signals that would have been handled by the PCell would likewise increase. To address this issue, Release 13 specifies a new Physical Uplink Control CHannel (PUCCH)*17 format that can accommodate large-capacity uplink control signals. Furthermore, considering that simply extending the PUCCH payload*18 will concentrate the load on the PCell, Release 13 also introduces a function that enables PUCCH to be transmitted from a SCell too as a solution based on load distribution. This is a general-purpose function that can be applied regardless of the number of LTE carriers that are being used at the time of CA. It is expected to help improve quality in CA not only when the number of LTE carriers increases beyond the present limit but also in a Heterogeneous Network (HetNet)*19 that overlays multiple instances of a small cell*20 on a macro cell*21 area.

4) Advanced DC

Dual Connectivity (DC), which enables data requiring the same Quality of Service (QoS) to be received from two different base stations, was originally specified in Release 12. That specification, however, supported simultaneous reception only on the downlink, so for Release 13, it was decided to support simultaneous transmission of data to two

*13 **SCell:** In CA, a cell that provides radio resources in addition to the PCell.

*14 **Listen-Before-Talk:** A mechanism that enables a terminal to check whether another terminal is transmitting data before transmitting data over the air.

*15 **Wireless LAN access point:** A connection control node for adding a WLAN terminal to a network. It serves as intermediary for terminal communication, corresponding to a cell phone base station.

*16 **PCell:** In CA, a cell that maintains connectivity between the UE and network.

*17 **PUCCH:** Physical channel used for sending and receiving control signals in the uplink.

*18 **Payload:** The part of the transmitted data that needs to be sent, excluding headers and other overhead.

*19 **HetNet:** A network configuration featuring an overlay of nodes having different power attributes; a network in which pico base stations, femto base stations and Wi-Fi hotspots having transmit-power levels smaller than conventional base stations coexist, interface and integrate.

different base stations on the uplink as well. Additionally, a mechanism has been achieved for asynchronous DC operation (that performs no time synchronization between the base stations) to enable the terminal to report the inter-base-station System Frame Number (SFN) and inter-base-station error, the latter in radio subframe*22 units. In Release 12, it was assumed that some sort of mechanism would be used on the network side to determine inter-base-station error. In contrast, introducing this new mechanism of UE-based reporting in Release 13 makes it possible to gauge inter-base-station error without having to perform measurements on the network side.

5) AAS

Specifications studies on an Active Antenna System (AAS) that integrates the transceiver and antenna at the base station have resulted in the completion of Radio Frequency (RF)*23 specifications in Release 13 following a feasibility study (Study Item: Release 11–12) and specifications study (Work Item: Release 12–13). In addition to downsizing equipment, AAS negates the need for a coaxial cable between the transceiver and antenna. This means reduced cable loss and more efficient use of power.

(a) Features from an operation viewpoint

In terms of operation, AAS enables the direction of the main beam to be varied in the horizontal and vertical directions by adjusting signal amplitude and phase between multiple antenna elements. This makes for more flexible area construction. In addition, formation of multiple beams in directions different from that of the main beam enables the creation of a multi-cell area with the same equipment.

(b) Features from a specifications viewpoint

In terms of specifications, RF specifications for conventional base stations and RF specifications for AAS differ greatly in the following two points.

(1) Specification point*24: In conventional specifications, there is only one specification point, namely, the connector that serves as the boundary between the transceiver and antenna. In AAS specifications, however, there are two specification points. The first is the antenna connector, which is called a Transceiver Array Boundary (TAB) Connector in AAS specifications, and the second is the space through which signals are radiated from the antenna. Application of the latter, however, is limited to only some characteristics. Additionally, in specifications using this specification point, provisions that include antenna radiation characteristics (hereinafter referred to as "Over The Air (OTA)*25 specifications") can be established enabling characteristics of the entire base station including the antenna to be evaluated.

(2) Specification unit in conducted specification (characteristics of input/output signals between the transceiver and antenna): In conventional specifications, radio characteristics are specified per connector. In AAS, they are specified per TAB connector or, in some cases, as a sum total of multiple TAB connectors.

Work Item discussions for stipulating all AAS RF specifications in terms of OTA have begun for Release 14. This should simplify testing and make it easier to guarantee total base station characteristics.

6) EBF/FD-MIMO

In conjunction with progress in AAS technology, the number of Multiple Input Multiple Output (MIMO)*26 antennas have been increasing and the accuracy of calibrating antennas and RF circuits has been improving. Envisioning that a maximum of 16 antennas will be arranged on a plane in the horizontal and vertical directions at a base station, Release 13 specifies Elevation Beam Forming/Full Dimension-MIMO (EBF/FD-MIMO) technology that achieves precoding control in the horizontal and vertical directions. This technology can

*20 **Small cell:** A general term for cells that transmit with power that is low compared to that of a macro cell transmitting at higher power.

*21 **Macro cell:** Cellular communication area with a cell radius of several hundred meters to several tens of kilometers mainly covering outdoors. Antennas are usually installed on towers or on roofs of buildings.

*22 **Subframe:** A unit of radio resources in the time domain consisting of multiple OFDM symbols (generally 14 OFDM symbols).

*23 **RF:** Frequency used in radio communications or the frequency used for the carrier wave of radio signals.

*24 **Specification point:** A point specified by base station RF specifications.

*25 **OTA:** Specifications and measurement method that establishes a specification point in signal radiation space from the antenna and in signal reception space to the antenna and that includes radiation characteristics from the antenna and reception characteristics to the antenna.

control the directivity*27 of a formed beam within a Cartesian coordinate system in three dimensions, which is why it is sometimes called three dimensional precoding. Additionally, envisioning an increase in the number of simultaneously multiplexed layers in Multi User (MU)-MIMO*28 transmission as well as system operation by Time Division Duplex (TDD)*29, Release 13 specifies technology for expanding the capacity of reference signals used for propagation-path assessment in the uplink.

7) Interference Rejection Combining Receiver on the Uplink

Release 13 specifies technology for suppressing interference and improving the quality of reception even on the uplink. This is achieved by using multiple receiving antennas mounted on the receiver to orient the antenna gain "drop points" in the direction of any interface signals arriving from adjacent cells.

3.3 Improved Functionality Based on Network Operations Experience

In the footsteps of previous releases, Release 13 continues to improve functionality based on network operations experience.

1) Application-specific Traffic Control

In traffic control technology up to Release 12, control was performed in units of specific packet services, such as voice calls, video calls, and emergency calls delivered by the IP Multimedia Subsystem (IMS)*30. Release 13 builds upon these specifications by establishing Application specific Congestion control for Data Communication (ACDC), a technology enabling application-specific traffic control. Compared with conventional technology that performed traffic control uniformly across a service requiring the same QoS, ACDC can perform different traffic control for different applications requiring the same QoS. For example, given a group of applications all of which perform packet communications, a telecom operator could give priority to those having a high degree of urgency, such as a disaster message board.

2) Band-distribution Control among Multiple Frequencies

(1) Inter-frequency cell reselection

As the migration from W-CDMA/HSPA to LTE continues in countries around the world, an increasing number of telecom operators are providing LTE over multiple frequency bands. However, when doing so, situations can occur in which traffic does not distribute uniformly among different frequency bands and instead comes to concentrate in a particular frequency band. To resolve this issue, Release 13 specifies technology for performing cell reselection between different frequency bands according to a probability value set in system information*31 while the UE is in idle mode. In this way, UEs can be idling under each of the target frequencies according to a probability value set by the telecom operator, which means that traffic at the time of actual communications should end up being distributed over those frequencies.

(2) RS-SINR

As a new index of signal quality to be measured by the UE, Release 13 specifies Reference Signal-Signal to Interference plus Noise power Ratio (RS-SINR) using cell-unique reference signals. It also specifies a mechanism for reporting this index from the UE. Given that terminal communications are distributed among different frequencies by handover*32 operations, RS-SINR is used as an index to predict the throughput that can be provided at a handover destination. Compared with the conventional Reference Signal Received Quality (RSRQ)*33 index, RS-SINR enables more accurate selection of a handover candidate cell that can achieve high throughput even in an area with relatively good signal quality.

4. Conclusion

In this article, we explained the background to Release 13 specification studies and described newly introduced functionality. Among the main Release 13 functions introduced in this article, category M1, NB-IoT, reduced power con-

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*26 **MIMO:** A signal transmission technology that uses multiple antennas for transmission and reception to improve communications quality and spectral efficiency.

*27 **Directivity:** An antenna radiation characteristic indicating the directional characteristics of radiation strength (or reception sensitivity) from the antenna.

*28 **MU-MIMO:** Technology that uses MIMO transmission over the same time and frequency for multiple users.

*29 **TDD:** A single transmission method that allocates different time slots on the uplink and downlink using the same carrier frequency and frequency band.

*30 **IMS:** A 3GPP standardized call control procedure that realizes multimedia communications by consolidating fixed and mobile network communication services with Session Initiation Protocol (SIP), which is a protocol used on the Internet and with Internet phones.

sumption, LAA, LWA, advanced CA/DC, AAS, EBF/FD-MIMO, and the interference rejection combining receiver are described in other articles of this issue [4]–[6]. Please refer to those articles for detailed descriptions of these functions. Formulation of the Release 14 specification has already begun at 3GPP. The plan going forward is to develop specifications for enhancing the functionality of IoT and unlicensed-spectrum technologies.

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*31 **System information:** Various types of information broadcast from each cell, such as the location registration area number required for judging the need for location registration in a mobile terminal, adjacent cell information and radio-signal quality for camping in that cell, and information for restricting and controlling outgoing transmissions.

*32 **Handover:** A technology for switching base stations without interrupting a call in progress when a terminal straddles two base stations while moving.

*33 **RSRQ:** Indicates the ratio of the power of the cell-unique reference signal to total power within the receive bandwidth.