Further Development of LTE-Advanced—Release12 Standardization Trends—

LTE-Advanced Release 12 Standardization Technology Overview

The international standards organization, 3GPP, specified the Release 10 specification for the LTE-Advanced standard, which introduces advanced technologies of LTE. 3GPP has continued to study technologies to further advance the functionality of LTE/LTE-Advanced, and has recently completed the Release 12 specification. In this article, we describe the main functionalities decided in Release 12.

5G Laboratory *Satoshi Nagata*
Kazuaki Takeda
Radio Access Network Development Department *Hideaki Takahashi*

1. Introduction

The 3rd Generation Partnership Project (3GPP), which developed the specifications for W-CDMA*1 and HSPA*2, published the Release 8 specification for the LTE standard in 2008, to introduce a more competitive mobile communications system able to meet the expanding needs of smartphone users. Then, 3GPP expanded and extended LTE to meet the market need for higher performance and service diversification, publishing the Release 10 specification for LTE-Advanced*3 in 2011. Later, to further extend functionality and increase performance of LTE-Advanced, 3GPP published the Release 11 specification in 2012, and Release 12 in March 2015. In this article, we describe background considerations and the main new functionalities introduced in Release 12, the latest specification for the LTE-Advanced standard.

2. Release 12 Specification Background Consideration

Release 10, the first release of the LTE-Advanced standard, introduced technologies to deal with increasing mobile traffic while maintaining backward compatibility with LTE, including Carrier Aggregation (CA)*4, which enables extending transmission and reception bandwidth up to 100 MHz, and advanced multi-antenna technologies, supporting up to eight transmissions on the downlink and four transmissions on the uplink [1]. Also, for Heterogeneous Networks (HetNet)*5, which deploy smaller cells in urban and other areas with more traffic, a technology called Inter-Cell Interference Coordination (ICIC)*6 was introduced. Release 11 also introduced a technology called Coordinated Multi-Point (CoMP)*7 transmission and reception

*1 **W-CDMA:** Wideband Code Division Multiple Access.

*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).

between cells on HetNet. Solutions for Machine-to-Machine (M2M) services such as smart meters (electricity and gas meters) incorporating LTE communications modules were also supported in Release 11 [2].

3GPP has been fulfilling the market demands in these ways, based on recent diversifying trends and requirements in the mobile communications market. The main functionalities in the recent Release 12 specification can be classified into three main categories, which are: (1) New technologies increasing user throughput[*8] and capacity, (2) New technologies for expanding service areas, and (3) Enhanced functionality based on network operations experience.

3. New Functionality in Release 12

The standard technologies mentioned above were actively discussed with great interest by the various companies participating in the 3GPP, and an overview of the functionalities included in Release 12 of the standard is shown in **Figure 1**. Functions in each of the categories are described in more detail below.

3.1 New Technologies for Increasing User Throughput and Capacity

This study area focused on HetNet scenarios based on CA, deploying a large number of small cells using different frequencies than the existing macro cells[*9] in high-traffic areas. One reason for this is that with many operators using LTE with multiple frequencies, it is a way to use high frequencies (e.g., the 3.5 GHz band) efficiently, by using CA to establish communication with macro cells and small cells simultaneously. The following six technologies for HetNet scenarios using different frequencies

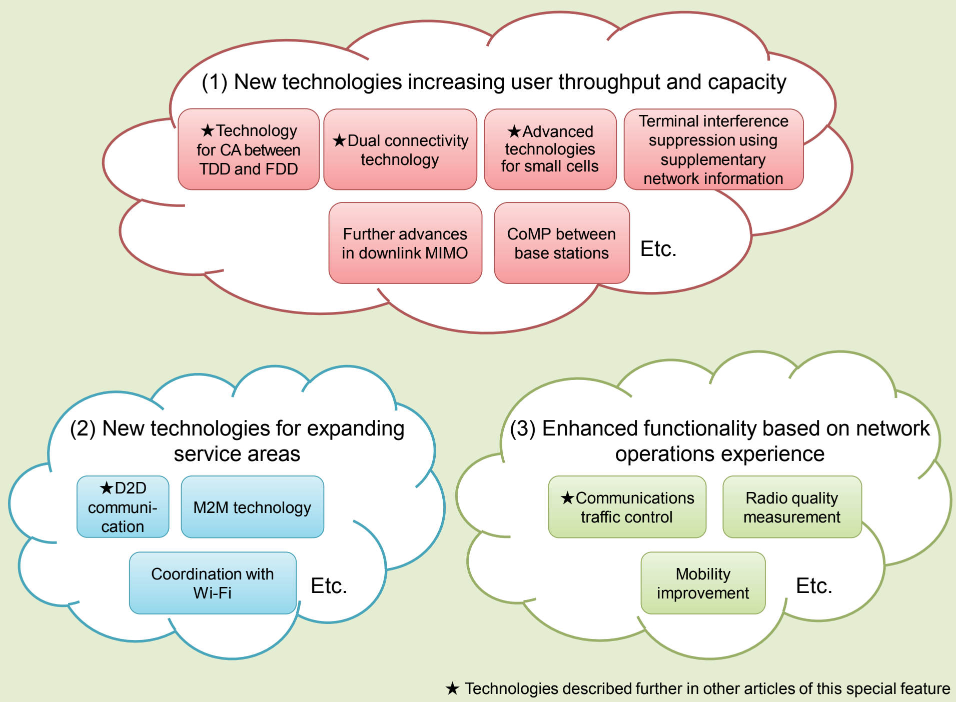

Figure 1　Main functionality decided in Release 12 specifications

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

*4 **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.

*5 **HetNet:** A network configuration that overlays nodes of different power. It typically includes picocell, femtocell, Wi-Fi and other base stations of lower power than conventional base stations, mixing, linking and integrating multiple technologies.

*6 **ICIC:** A technology that reduces the effects of inter-cell interference by semi-statically allocating different time/frequency radio resources between cells.

*7 **CoMP:** Technology which sends and receives signals from multiple sectors or cells to a given UE. By coordinating transmission among multiple cells, interference from other cells can be reduced and the power of the desired signal can be increased.

*8 **User throughput:** The amount of data that one user can transmit without error per unit time.

attracted much interest at the 3GPP, and specifications were decided for them.

1) CA between TDD and FDD

CA was introduced from Release 10, for increasing user throughput, but was limited to LTE carriers that use the same duplex scheme, either Frequency Division Duplex (FDD)*10 or Time Division Duplex (TDD)*11. Considering that frequency bands that can be used with the LTE TDD scheme are increasing and there was demand from operators in Japan, the United States, and Europe that have already adopted the LTE FDD scheme, CA between FDD and TDD frequencies was introduced in Release 12. This will enable user throughput to be increased further by making it possible for operators to cooperate across different duplex schemes in various frequency bands through CA.

2) Dual Connectivity

In the operation of CA, backhaul*12 delay was assumed to be negligible when transmitting multiple LTE carriers simultaneously, such as when transmitting them from the same base station, or if transmitted from different base stations (e.g., a macro base station and Remote Radio Equipment (RRE)*13), that they are connected by optical fiber. However, in many countries and regions, base stations are usually connected by a backhaul that permits delay, because the equipment is relatively less expensive. Thus, due to strong demand from operators in various countries, a new technology called Dual Connectivity was specified, which enables user throughput to be increased using the multiple LTE carriers provided by different base stations. Dual Connectivity enables simultaneous communication on LTE carriers between any two base stations that are connected by an X2*14 interface. This will enable operators to implement improved user throughput in a variety of base station deployment scenarios.

3) Advanced Technologies for Small Cells

In studying small cell deployment scenarios, various technologies were adopted for densely arranged small-cell environments, under the name, Small Cell Enhancements (SCE). Advanced technologies for small cells include (1) higher order modulation using 256QAM on the downlink, and (2) technologies for small cell on/off switching and small cell discovery during CA, to reduce interference between densely deployed small cells when they are configured as Secondary Cells (SCells). Using these technologies in small cell environments is expected to increase user throughput and capacity.

4) Terminal Interference Suppression Using Supplementary Network Information

Release 11 specified interference suppression that only uses information obtainable on the terminal. With Release 12, user throughput and capacity can be further increased using neighboring cell and other supplementary information provided by the base station.

5) Further Advances in Downlink MIMO

Downlink Multiple Input Multiple Output (MIMO)*15 technology, which increases user throughput and capacity, has been further advanced. Release 12 assumes multi-user MIMO*16 transmission using four orthogonal polarized antennas on the base station transmission, and specifies a codebook*17 able to realize higher resolutions than Release 8. It also specifies new feedback modes, providing feedback information such as Channel Quality Indicators (CQI)*18 from terminals to the base station in sub-band units that partition the system bandwidth.

6) CoMP between Base Stations

CoMP in Release 11 assumed an active CoMP transmission and reception technology coordinating between macro base stations and RRE that are connected by a channel such as optical fiber, for which transmission delay can be ignored. In contrast, Release 12 assumed CoMP transmission and reception between base stations that are connected by a back haul that permits delay, and defines back haul signaling for its operation. This makes semi-static interference control for interference between cells possible, allowing increased throughput, for users at the cell edge in particular.

---

*9 **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.

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

*11 **TDD:** A bidirectional transmit/receive system. It achieves bidirectional communication by allocating different time slots to uplink and downlink transmissions that use the same frequency band.

*12 **Backhaul:** Indicates the route connecting a wireless base station to the core network.

*13 **RRE:** eNB antenna equipment installed at some distance from an eNB using optical fiber or other means.

*14 **X2:** A reference point between eNodeB, defined by 3GPP.

*15 **MIMO:** A wireless communication technique that utilizes multiple paths between multiple antennas at the transmitting and receiving ends to exploit spatial propagation properties, causing the capacity of wireless links to increase in proportion with the number of antennas.

*16 **Multi-User MIMO:** A technology that improves spectral efficiency by applying MIMO multiplexed transmission to the signals for multiple users.

3.2 New Technologies for Expanding Service Areas

In addition to basic performance increases in the typical mobile telephone system as indicated in Section 3.1, interest in Device-to-Device (D2D) communication between terminals, M2M communication for terminals such as smart meters, and coordination with Wi-Fi®*19 communications is increasing rapidly.

1) D2D Communication

One application anticipated for D2D communication is for a public safety radio system. Direct communication between terminals co-existing with the LTE network was supported, so that a means of communication could be provided even if base stations were down due to large-scale disaster, or when in the mountains or other areas outside of base-station coverage. Another application of D2D is for commercial D2D proximity services, and a device-discovery technology was also introduced for receiving such services.

2) M2M Technology

Migration of smart meters and other services using W-CDMA/HSPA or GSM*20 M2M terminals to LTE is being widely considered. However, LTE modules for M2M terminals are currently expensive compared to W-CDMA/HSPA and GSM modules, so specifications for a low-cost module were desirable. As such, Release 12 supports a new category of terminal for M2M with features including (1) maximum data rates of 1 Mbps, (2) FDD half-duplex, and (3) reception with one antenna. New Power Saving Modes (PSM) for M2M terminals were also specified, along with functionality that considers communication traffic and frequency of handover*21 when setting the time for maintaining communication state.

3) Coordination with Wi-Fi

Wi-Fi is accommodated by Evolved Packet Core (EPC)*22, which are the core nodes of an LTE network, and technology to off-load some traffic to Wi-Fi has been included since Release 8. However, till now, traffic off-loading has been controlled using only information obtainable on the core network, such as traffic type and preconfigured priorities for LTE and Wi-Fi. Release 12 specifies a technology to control off-loading between LTE and Wi-Fi, taking radio quality for both LTE and Wi-Fi and the state of Wi-Fi congestion*23 into consideration.

3.3 Improved Functionality Based on Network Operations Experience

Functional improvements based on the experience of operators of LTE and LTE-Advanced networks were also introduced. Examples of these include a traffic control technology that considers Voice over LTE (VoLTE)*24, a radio quality measurement technology, and mobility improvement technologies.

1) Communications Traffic Control Technology

NTT DOCOMO began providing VoLTE services within Japan early, in June 2014, and operators outside of Japan are also introducing VoLTE commercially. With the spread of VoLTE, the ability to implement flexible access control*25 of data and voice traffic is becoming important for operation of LTE and LTE-Advanced networks.

Considering this, Release 12 specifies new technologies including (1) Smart Congestion Mitigation, which controls voice (VoLTE) and packet traffic independently, and (2) SSAC in connected, a control technology that can regulate voice (VoLTE) call initiation even when the user terminal is already communicating.

2) Radio Quality Measurement Technology

Mobile operators are operating more frequency bands for LTE in order to handle the increasing mobile traffic. Because of this, it is becoming increasingly important among operators for terminals to measure as many LTE frequencies as possible and control operation so that the best quality frequencies are always being used. As such, Release 12 includes specifications enabling terminals to measure more carrier frequencies at the same time.

It also includes specifications for a scheme to increase the accuracy of Ref-

---

*17 **Codebook:** A set of predetermined precoding-weight matrix candidates.

*18 **CQI:** An index of reception quality measured at the mobile station expressing propagation conditions on the downlink.

*19 **Wi-Fi®:** A registered trademark of the Wi-Fi Alliance.

*20 **GSM:** A Second-Generation mobile communication system used for digital mobile phones.

*21 **Handover:** The technique of switching from one base station to another without interrupting communication when a terminal moves between base stations.

*22 **EPC:** An IP-based core network standardized by 3GPP for LTE and other access technologies.

*23 **Congestion:** Impediments to communications services due to communications requests being concentrated in a short period of time and exceeding the processing capabilities of the service control server.

*24 **VoLTE:** A function to provide voice services over LTE using packet switching technologies.

*25 **Access control:** The restricting of location-registration and calling operations in mobile stations to effect an early recovery from a state of congestion caused by a processing anomaly or failure in Satellite-Base station Equipment (S-BE) owing to an accident, disaster, or popular event.

erence Signal Received Quality (RSRQ) measurements.

3) Mobility Improvement Technologies

To improve the success rates for handover in HetNet environments using the same frequency, functionality to adjust parameters related to handover for individual cells was specified. A mechanism was also specified for terminals in a standby state to notify base stations of their speed of motion (high/med/low) and a list of cells on which the UE has recently camped together with how long the UE was camped on the cells, for use in adjusting mobility-related parameters.

4. Conclusion

In this article, we have described background study and the main new functions introduced in Release 12 of LTE-Advanced. Of the main functions introduced here, "CA between TDD and FDD" in Section 3.1 1) [3], "Dual connectivity technology" in Section 3.1 2) [3], "Advanced technology for small cells" in Section 3.1 3) [4], "Terminal interference suppression using supplementary network information" in Section 3.1 4) [4], "D2D communication" in Section 3.2 1) [5], and "Communications traffic control technology" in Section 3.3 1) [6] are described in more detail in other articles in this special feature.

Initiatives to create Release 13 are also in progress, to further extend functionality of LTE-Advanced.

References

[1] T. Nakamura, et al.: "Overview of LTE-Advanced and Standardization Trends," NTT DOCOMO Technical Journal, Vol.12, No.2, pp.4-9, Sep. 2010.

[2] Wu. Hapsari, et al.: "Radio System Optimization toward Smartphone and Machine Communications for Further Development of LTE/LTE-Advanced," NTT DOCOMO Technical Journal, Vol.15, No.2, pp.18-26, Oct. 2013.

[3] T. Uchino, et al.: "Carrier Aggregation Enhancement and Dual Connectivity Promising Higher Throughput and Capacity," NTT DOCOMO Technical Journal, Vol.17, No.2, pp.36-46, Oct. 2015.

[4] K. Takeda, et al.: " Higher order Modulation, Small Cell Discovery and Interference Cancellation Technologies in LTE-Advanced Release 12," NTT DOCOMO Technical Journal, Vol.17, No.2, pp.47-55, Oct. 2015.

[5] S. Yasukawa, et al.: "D2D Communications in LTE-Advanced Release 12," NTT DOCOMO Technical Journal, Vol.17, No.2, pp.56-64, Oct. 2015.

[6] K. Aoyagi, et al.: "Access Class Control Technology in LTE/LTE-Advanced Systems," NTT DOCOMO Technical Journal, Vol.17, No.2, pp.65-76, Oct. 2015.