LTE-Advanced IMT-Advanced Standardization

Technology Reports

Special Articles on LTE-Advanced Technology
—Ongoing Evolution of LTE toward IMT-Advanced—

Overview of LTE-Advanced and Standardization Trends

The standardization of LTE-Advanced, which is the development radio interface for LTE, is currently progressing at the 3GPP. LTE-Advanced maintains backward compatibility with LTE, while achieving higher system performance than LTE and satisfying the minimum requirements for IMT-Advanced, which is in the process of being standardized by the ITU-R. In order to achieve these goals, radio interface technologies such as support of wider transmission bandwidth, enhancement of MIMO technology used and relay, are being studied on a base of LTE technology.

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1. Introduction

Currently, NTT DOCOMO is developing a commercial mobile communications system to increase the data rate, sophistication and economy of our radio network, based on the LTE*1 Release 8 (hereinafter referred to as "LTE Rel. 8") specifications [1][2] which completed standardization by the 3GPP in the spring of 2009. LTE Rel. 8 adopts various high-level radio interface technologies such as orthogonal multi-access, frequency-domain scheduling and Multiple Input Multiple Output (MIMO)*2, and provides even higher system capacity and cell edge user throughput than High Speed Packet Access (HSPA)*3. It also significantly reduces transmission and connection set up delays, making major improvements on system performance[3]. NTT DOCOMO is playing a central role in advancing the standardization of LTE in the 3GPP, from proposing the basic concepts to completing the specifications. NTT DOCOMO is also supporting the standardization of LTE Rel. 9, which will further increase the sophistication of LTE, enabling the economical introduction of many different services, and meeting the demands of LTE users in the future. LTE Rel. 9, which was completed in spring, 2010, provides various new functions including Closed Subscriber Group (CSG) functions, extensions to network self-optimization, location information services and Multimedia Broadcast and Multicast Services (MBMS) [4].

NTT DOCOMO is also promoting the standardization of LTE-Advanced (LTE Rel. 10 and beyond), which will further increase the system performance of radio access networks. This is in consideration of the need to respond quickly to the demands of traffic which is expected to increase dramatically as

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*1 **LTE**: Extended standard for the 3G mobile communication system studied by 3GPP. Achieves faster speeds and lower delay than HSPA (see *3).

*2 **MIMO**: Wireless communications technology for expanding transmission capacity by using multiple transmit/receive antennas.

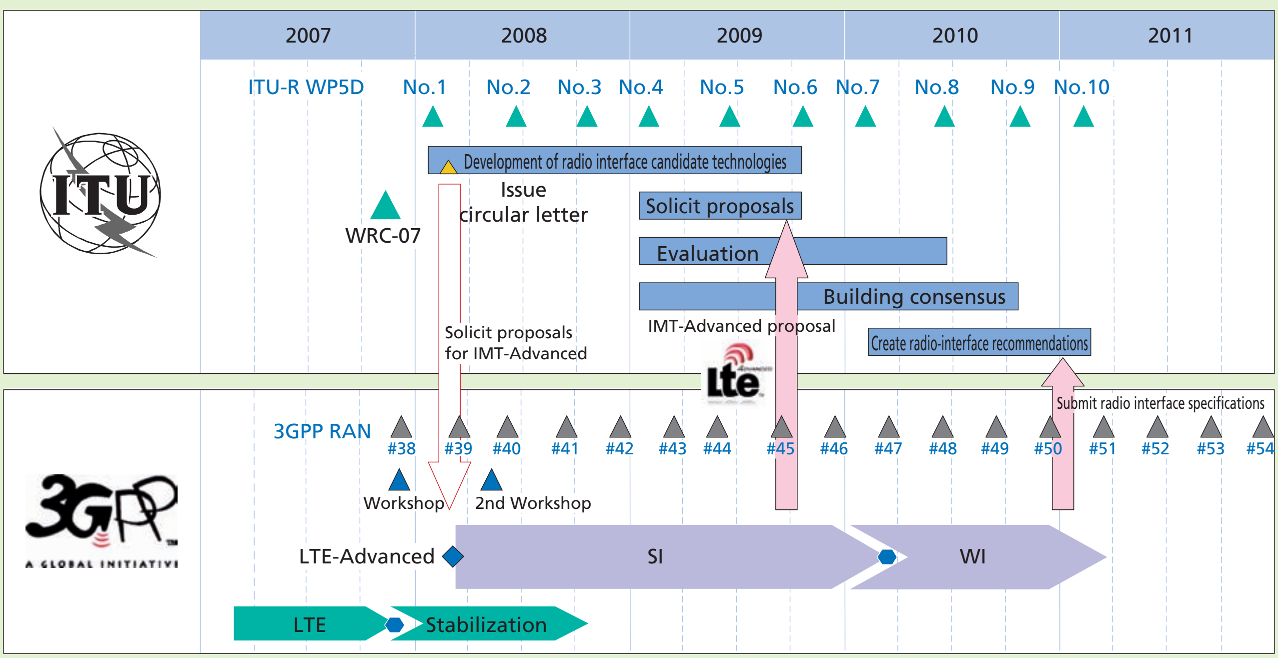
high-volume content services such as video continue to spread [5]. NTT DOCOMO acted as rapporteur for the LTE-Advanced Study Item (SI)[6], which was approved at the 3GPP in March, 2008, and study is now advancing on the detailed specifications for LTE Rel. 10.

In addition to realizing major system performance increases over LTE Rel. 8, maintaining backward compatibility with LTE Rel. 8 is an important requirement of LTE-Advanced, to enable smooth development of the system [7]. On the other hand, standardization of IMT-Advanced is progressing at the International Telecommunications Union-Radio communications sector (ITU-R), as the successor to the International Mobile Telecommunications 2000 (IMT-2000)[*4] system, and LTE-Advanced is also a radio interface candidate for this new system. Because of this, it is very important for LTE-Advanced, that the minimum requirements for IMT-Advanced are realized within the IMT-Advanced standardization schedule [7].

In this article, we provide an overview of standardization trends with LTE-Advanced, the main radio interface technologies involved, and the results of 3GPP system performance evaluation. Please refer to other articles for details on the radio interface technologies [8]-[10].

2. Standardization Schedule

The schedules for standardization of IMT-Advanced with the ITU-R and LTE-Advanced with the 3GPP are shown in **Figure 1**. At the ITU-R, new frequency bands for IMT were identified at the World Radiocommunication Conference 2007 (WRC-07)[*5] held in November 2007, and a circular letter[*6] soliciting radio interface proposals for IMT-Advanced was issued in March 2008 [11][12]. In the same year, the requirements and evaluation conditions for IMT-Advanced were specified [13][14], and by the end of the proposal submission period in October 2009, two proposals, based on LTE-Advanced and



*3GPP logo : European Telecommunications Standards Institute (ETSI) trademark.
*LTE logo : ETSI trademark.

Figure 1 Standardization schedules for IMT-Advanced (ITU) and LTE-Advanced (3GPP)

*3 **HSPA**: A specification for increasing packet-data rates in W-CDMA, and a general term encompassing High Speed Downlink Packet Access (HSDPA), which increases the speed from the base station to the mobile terminal, and High Speed Uplink Packet Access (HSUPA), which increases speed from the terminal to the base station.

*4 **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.

IEEE 802.16m[*7] respectively, were received. After that, external evaluations by evaluation groups registered with the ITU-R began, and completion of recommendations for the radio interface specifications is expected at the beginning of 2011, after final agreement on IMT-Advanced has been reached.

At the 3GPP, an SI for the LTE-Advanced radio interface was started in March 2008[6], prompted by issue of the circular letter by the ITU-R, and the requirements and evaluation conditions for LTE-Advanced were specified [7][15]. Then, technical study of the LTE-Advanced radio interface proceeded, and a proposal for LTE-Advanced was submitted to the ITU-R in October 2009 [16]. Doing so showed that all of the requirements for IMT-Advanced were satisfied through the 3GPP's self-evaluation results, as described below. A Work Item (WI) to study the detailed specifications for the LTE-Advanced radio interface was started in December 2009, and approval of this specification is planned for December 2010, to match the IMT-Advanced standardization schedule.

3. Major Radio Interface Technologies for LTE-Advanced

To satisfy the requirements for LTE-Advanced, improvements to the radio interface technologies were studied, with LTE Rel. 8 as the base, as described below.

LTE Rel. 8 supports bandwidths to a maximum of 20 MHz, but support for peak data rates of up to 1 Gbit/s on the downlink and 500 Mbit/s on the uplink is a goal of LTE-Advanced, so wider bandwidths are needed. On the other hand, LTE-Advanced must also maintain backward compatibility with LTE Rel. 8. Accordingly, wider bandwidths are supported by combining multiple frequency blocks of bandwidth supported by LTE Rel. 8, called Component Carrier (CC). This technique is called Carrier Aggregation (CA) [8].

With LTE Rel. 8, MIMO multiplexing up to 4 layers is supported on the downlink, but MIMO multiplexing is not supported on the uplink. Conversely, LTE-Advanced supports single-user MIMO[*8] multiplexing with up to 8 layers on the downlink and 4 layers on the uplink in order to satisfy the peak spectral efficiency[*9] requirements of 30 bit/s/Hz on the downlink and 15 bit/s/Hz on the uplink. Multi-user MIMO[*10] has also been improved in order to increase system capacity. We are also studying the introduction of Coordinated Multi-point transmission/reception (CoMP), which coordinates communication among multiple cells, in order to improve throughput for cell edge users in particular [9].

Another important requirement for LTE-Advanced is to reduce the cost of the radio access network, so use of radio relay transmission for the backhaul is being introduced as a low-cost means to expand coverage in environments where wired transmission is particularly expensive [10].

4. System Performance Evaluation Results Relative to ITU-R Requirements

ITU-R has specified eight items as the minimum requirements for IMT-Advanced.

- Peak spectral efficiency
- Cell spectral efficiency
- Cell edge user spectral efficiency
- Bandwidth
- Latency
- Mobility
- Handover interruption time
- VoIP capacity

Next, we will describe some of the results of the self-evaluation done at the 3GPP.

The peak spectral efficiency results for the uplink and downlink are shown in **Table 1**. For details on overhead and other assumptions, refer to [17]. The table shows that ITU-R requirements can be satisfied by using 4-layer MIMO multiplexing, which can implement LTE Rel. 8 single-user MIMO, for the downlink and 2-layer MIMO multiplexing, which is able to implement LTE-Advanced single-user MIMO, for the uplink. As well, the requirements for LTE-Advanced specified by 3GPP

*5 **WRC-07**: A global wireless communications conference held in 2007. This conference is held every three to four years in order to revise international Radio Regulations (RR) for use of radio waves, including use of various frequency bands, operation of radio base stations, technical standards, and use of satellite orbits, to ensure efficient use of radio frequencies.

*6 **Circular letter**: An official document used to communicate among participating national regulatory agencies, companies and organization members.

*7 **IEEE 802.16m**: The IEEE candidate radio interface for IMT-Advanced.

*8 **Single-user MIMO**: Technology which uses MIMO transmission over the same time and frequency for a single user.

(30 bit/s/Hz downlink, 15 bit/s/Hz uplink) can also be satisfied using the up-to-8-layer multiplexing on the downlink and up-to-4-layer multiplexing on the uplink. This can be achieved with LTE-Advanced single-user MIMO.

The cell spectral efficiency and cell edge-user spectral efficiency requirements [13] of the test environment specified by the ITU-R [14] are shown in **Table 2**. For IMT-Advanced, four test environments are specified, called the indoor, microcellular (microcell)[*11], base coverage urban (macrocell)[*12] and high speed environments, respectively. For the three environments besides indoor, a wrap-around[*13] multi-cell structure with 19 sites (3 cells/site) is used, with cell size, mobility speed and channel models differing according to environment. Refer to [17] for details on other characteristics and evaluation conditions.

The cell spectral efficiencies and cell edge user spectral efficiencies for the uplink and downlink in the ITU test environments are shown in **Figures 2** and **3**. The characteristics of the downlink were evaluated with four transmit and two receive antennas (4×2) for LTE Rel. 8 single-user MIMO, and with four transmit and two receive antennas (4×2) for LTE-Advanced multi-user MIMO. On the uplink, the characteristics were evaluated with one transmit and four receive antennas (1×4) for LTE Rel.8 single-antenna transmission, and with two transmit and four receive antennas (2×4) for LTE-Advanced single-user MIMO.

Fig. 2 shows that on the downlink, the requirements are satisfied by LTE Rel. 8 single-user MIMO, in the indoor and high speed environments, but not in the microcellular and base coverage urban environments, and that these requirements can be satisfied by using LTE-Advanced multi-user MIMO. It also shows that LTE-Advanced multi-user MIMO provides a significant improvement over LTE Rel. 8 single-user MIMO. Accordingly, in addition to single-user MIMO, which increases the peak rate by increasing the per-user multiplexing factor, specifications are also being created at the 3GPP for multi-user MIMO as one of the core technologies of LTE-Advanced, increasing network capacity by increasing the number of users able to connect simultaneously.

Figure 3 shows that on the uplink, LTE Rel. 8 single-antenna transmission

Table 1 Peak spectral efficiencies

	Downlink		Uplink	
ITU-R requirement (bit/s/Hz)	15		6.75	
MIMO multiplexing	4-Layer	8-Layer	2-Layer	4-Layer
Peak spectral efficiency (bit/s/Hz)	16.3	30.6	8.4	16.8

Table 2 ITU test environment and requirements

(a) ITU test environment

Test environment	Indoor	Microcellular	Base coverage urban	High speed
Carrier frequency (GHz)	3.4	2.5	2.0	0.8
Cell layout	Rectangular (2-cell model)	Hexagonal, 19-cell site, 3 cells/site		
Inter-site distance (m)	60	200	500	1,732
Mobility speed (km/h)	3	3	30	120
Traffic model	Full-buffer model	Full-buffer model	Full-buffer model	Full-buffer model
System bandwidth (MHz)	20	10	10	10
Number of users (per cell)	10	10	10	10

(b) ITU requirements

Cell spectral efficiency (bit/s/Hz/cell)	Downlink	3.0	2.6	2.2	1.1
	Uplink	2.25	1.8	1.4	0.7
Cell edge user spectral efficiency (bit/s/Hz/cell/user)	Downlink	0.1	0.075	0.06	0.04
	Uplink	0.07	0.05	0.03	0.015

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

*10 **Multi-user MIMO**: Technology which uses MIMO transmission over the same time and frequency for a multiple users.

*11 **Microcell**: A communications area of radius from several tens to several hundreds of meters, covered by a single base station.

*12 **Macrocell**: A communications area of radius from several hundreds to several tens of kilometers, covered by a single base station.

*13 **Wrap-around**: In a system-level simulation using a limited number of cells, an arrangement in which cells are placed surrounding a central cell in order to simulate any interference a cell receives from outside of the cell.

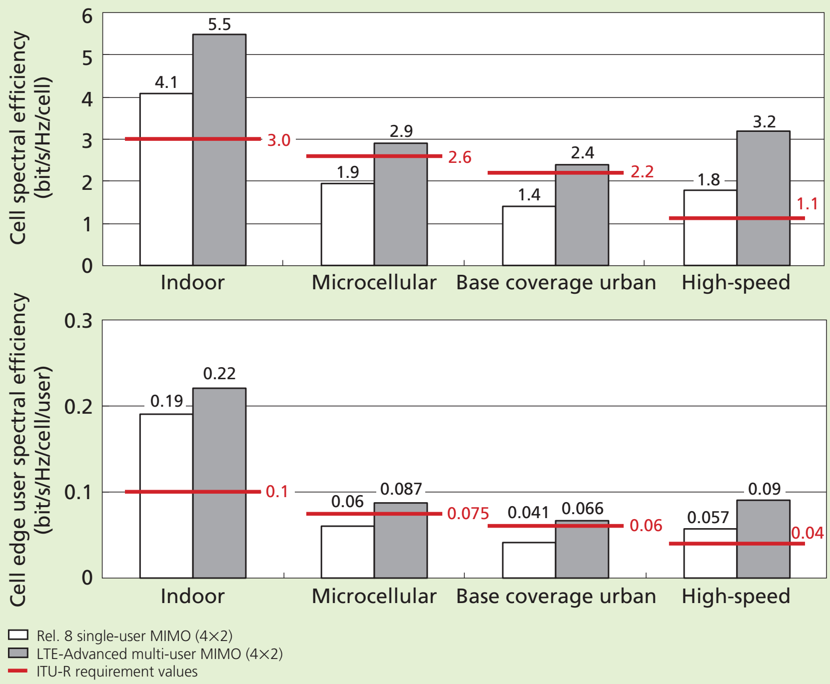


Figure 2 Spectral efficiency in the ITU test environment (downlink)

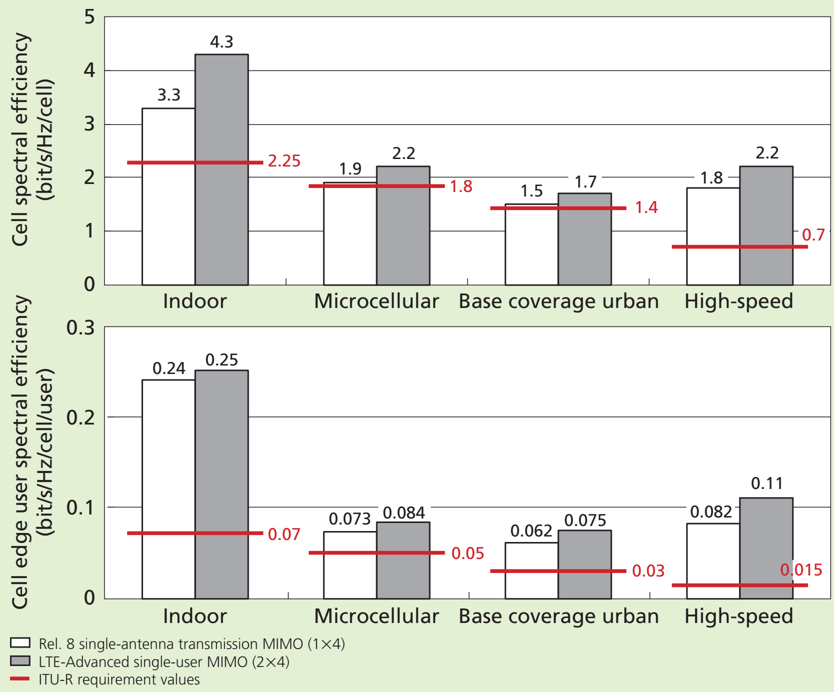


Figure 3 Spectral efficiency in the ITU test environment (uplink)

satisfies the requirements in all of the environments. Additionally, LTE-Advanced single-user MIMO provides even further improvements to the characteristics.

In addition to these results, the 3GPP is evaluating CoMP technology as part of the evaluation of ITU-R requirements, and application of CoMP has provided still further improvements to characteristics [17].

In addition to spectral efficiency evaluations, the 3GPP evaluations show that the IMT-Advanced requirements are satisfied by LTE Rel. 8 and LTE-Advanced in areas of bandwidth, latency, mobility, handover-interruption time and in the number of VoIP users accommodated [17].

5. Conclusion

In this article we have given an overview of standardization trends proceeding at the 3GPP for LTE-Advanced, of the main radio interface technologies and of system performance evaluation results. Standardization work for LTE-Advanced will continue, and approval of the standard specifications for the LTE Rel. 10 radio interface is planned for the end of 2010.

References

[1] 3GPP TS36.300 V8.11.0: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2," 2009.

[2] T. Nakamura et. al: "Activities and Contri-

butions for Completion of the 3GPP LTE/SAE Standard Specifications," NTT DOCOMO Technical Journal, Vol. 11, No. 2, pp. 39-49, Sep. 2009.

[3] 3GPP TS25.912 V8.0.0: "Feasibility study for evolved Universal Terrestrial Radio Access (UTRA) and Universal Terrestrial Radio Access Network (UTRAN)," 2008.

[4] M. Iwamura et. al: "Further Enhancements of LTE—LTE Release 9—," NTT DOCOMO Technical Journal, Vol. 12, No. 1, pp. 45-53, Jun. 2010.

[5] S. Abeta et. al: "Standardization Trends in LTE Enhancement," NTT DOCOMO Technical Journal, Vol. 12, No. 1, pp. 42-44, Jun. 2010.

[6] 3GPP TD RP-080137: "Proposed SID on LTE-Advanced," 2008.

[7] 3GPP TR36.913 V8.0.1: "Requirements for further advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) (LTE-Advanced)," 2009.

[8] N. Miki et. al: "CA for Bandwidth Extension in LTE-Advanced," NTT DOCOMO Technical Journal, Vol. 12, No. 2, pp. 10-19, Sep. 2010.

[9] H. Taoka et. al: "MIMO and CoMP in LTE-Advanced," NTT DOCOMO Technical Journal, Vol. 12, No. 2, pp. 20-28, Sep. 2010.

[10] M. Iwamura et. al: "Relay Technology in LTE-Advanced," NTT DOCOMO Technical Journal, Vol. 12, No. 2, pp. 29-36, Sep. 2010.

[11] ITU-R Conference Publications: "Final Acts WRC-07, Geneva," 2007.

[12] ITU-R Document IMT-ADV/1: "Background on IMT-Advanced," 2008.

[13] ITU-R Report M.2134: "Requirements related to technical performance for IMT-Advanced radio interface(s)," 2008.

[14] ITU-R Report M.2135: "Guidelines for evaluation of radio interface technologies for IMT-Advanced," 2008.

[15] 3GPP TR36.814 V1.0.0: "Further Advancements for E-UTRA Physical Layer Aspects," 2009.

[16] ITU-R Document 5D/564: "Complete submission of 3GPP LTE Release 10 and beyond (LTE-Advanced) under Step 3 of the IMT-Advanced process," 2009.

[17] 3GPP TR36.912 V.9.0.0: "Feasibility study for Further Advancements for E-UTRA (LTE-Advanced)," 2009.