Evolution of the 3G Cellular Phone System

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Abstract

The cellular phone system is migrating from 2G to 3G, and from the perspective of the long-term evolution of the 3G system the study of the 3G RAN Long Term Evolution (LTE) is proceeding with the aim of realizing high speed multimedia services at 30 to 100Mbps. This paper introduces the LTE element technologies of the communications methods and network architecture and the associated efforts being made by NEC.

Keywords

LTE, OFDMA, SC-FDMA, evolved UTRAN

1. Introduction

The 3G cellular phone service “W-CDMA” was started in October 2001 in Japan, and it is currently provided by more than a hundred cellular phone carriers in 42 countries in Europe, North America and Asia. At the 3GPP, which is the standardization organization of W-CDMA, the HSDPA (High Speed Downlink Packet Access) and HSUPA (High Speed Uplink Packet Access) are under study as short to mid-term evolution of 3G. As a study of the prospects for the long-term evolution has become necessary, a workshop called the 3G RAN LTE was held in November 2004 in Toronto, Canada, and an agreement was made to complete the basic study by June 2006 and the standard specifications by June 2007. After the requirements (see **Table 1**) were agreed in June 2005, studies of the specific technologies are being advanced by various study groups.

2. Communications Methods

2.1 Multi-Access Methods

The study into the multi-access method of LTE was made by comparing the following four methods.

① DS (Direct Spread)-CDMA (WCDMA) with broadened bandwidth
② MC (Multi Carrier)-CDMA
③ OFDMA
④ SC (Single Carrier)-FDMA

Table 1 Requirements.

Peak data rate	Downlink: 100M bits/sec. Uplink: 50M bits/sec.
C-plane latency	Less than 100msec.
U-plane latency	Less than 5msec
Spectrum efficiency	Downlink: 3 to 4 times R6 HSDPA Uplink: 2 to 3 times R6 HSUPA
Spectrum flexibility	1.25MHz, 2.5MHz, 5MHz, 10MHz, 15MHz, 20MHz

For the downlink access in which a reduction of the receiver circuit in terminals is necessary, the OFDMA (Orthogonal Frequency Division Multiple Access) was selected because it can make the circuit simple for the MIMO reception, which enables broadband signal reception in multi-path fading environments with favorable performance. Moreover, the DS-CDMA cannot offer favorable reception performance via RAKE combining for a broadband signal. MC-CDMA requires multiple RAKE combiners, as the SC-FDMA requires an equalizer and both of these systems would increase the circuit scale.

For the uplink access, the OFDMA is problematic because the high PAPR (Peak to Average Power Ratio) of its modulation wave degrades the efficiency of the transmission amplifier and decreases the maximum transmission power (= reduces the cell radius) or increases the power consumption. Consequently, the SC-FDMA was selected because it can reduce the PAPR though the circuit scale of the base stations should be increased slightly. The use of the SC-FDMA is also advantageous in that it makes all the users in the cell orthogonal for uplink access. With regard to the circuit scale, various methods are under study in anticipation that it can be reduced by applying equalization in the frequency domain.

Both the OFDMA and SC-FDMA permit scheduling of the frequency and time axes and thereby improve the frequency utilization efficiency.

2.2 Frame Configuration Parameters

Although different multi-access methods are used for uplink and downlink access, the parameters for the frame configuration are designed to be as compatible as possible, as shown in **Table 2**.

In order to reduce the transmission delay and increase the throughput, a value of 0.5msec was selected for the sub-frame length, which is 1/4 that of the HSDPA/HSUPA (2msec. TTI).

For the CP length that corresponds to the guard interval and corresponds to a delay spread of 1 to 1.5km, a value of 4 to 5usec is selected. In addition, for the downlink, a value of 16.7usec that corresponds to a propagation delay of 5km is also defined so that terminals can receive the broadcast signals like MBMSs (Multimedia Broadcast and Multicast Services) from multiple cells simultaneously with spatial diversity. In this case, the frame configuration changes to one with a different number of symbols per sub-frame.

The symbol length is the reciprocal of the OFDMA (Orthogonal Frequency Division Multiple Access) sub-carrier interval. There is a tradeoff for the symbol length. A larger symbol length can reduce the overheads due to the CP, but it increases the number of FFTs and the degradation due to frequency errors that tends to occur when the sub-carrier interval is small. Therefore, we selected a value of 66.7usec (15kHz sub-carrier interval), with which the overhead is about 7.5%. In addition, for the uplink access, the pilot signals should be inserted per user. We decided to insert short blocks in two positions per sub-frame so that they can be used as the pilot signals (see **Fig. 1**).

Table 2 Parameters.

Item	Downlink	Uplink
Access method	OFDMA	SC-FDMA
Sub-frame length	0.5msec	
CP (Cyclic Prefix) length	4-5usec. (Short CP) 16.7usec.(Long CP)	4-5usec.
Symbol length /block length <Sub-carrier interval>	66.7usec. <15kHz>	66.7usec. (Long) 33.3usec. (Short)
Symbols (per sub-frame)	7 (Short CP) 6 (Long CP)	6 x Long Block +2 x Short Block

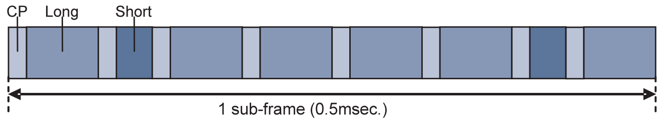

Fig. 1 Configuration of the uplink sub-frame.

3. Network Architecture

The LTE network architecture has been actively discussed at 3GPP meetings as the evolved UTRAN architecture.

The 3GPP discussions were convened in order to specify an architecture that could meet the requirements shown in Table 1 and has the function layout as shown in **Fig. 2**. In this figure, the relationships between the functions required for the LTE and the nodes that may be realized are shown using arrows.

Although opinions were divided whether some functions are to be implemented on the evolved Node B (eNodeB) that are the radio base stations or on the access gateway (aGW), which is one node of a core network (CN), most of the standardization members converged on the following two options.

[Option 1]

- aGW: Connection Mobility Control, RRC "Upper Part", ARQ.
- eNodeB: Functions other than above.

[Option 2]

- aGW: Connection Mobility Control.
- eNodeB: All of the functions that are not yet defined are to be realized here.

Table 3 shows the comparison of configuration plans 1 and 2.

At NEC, we considered that configuration option 2 is capable of making the end user experience high transmission speeds and short connection delays and made some contributions to 3GPP meetings. After various discussions, the option 2 was eventually agreed as the network architecture for the LTE.

Aiming at improving option 2 further, we are conducting R&D into the Multi-cell RRM server (MR server) by assuming an evolved UTRAN architecture as shown in **Fig. 3**.

The MR server is used to reduce interference between radio channels used by different radio base stations and increase the

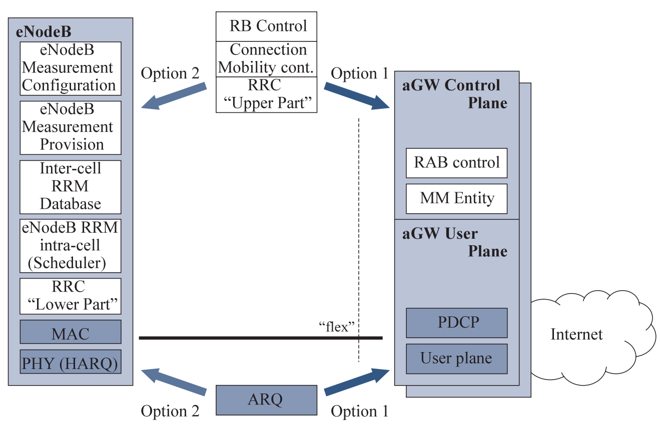

Fig. 2 evolved UTRAN architecture.

Table 3 Comparison of option 1 and 2.

Item	Option 1	Option 2
Transmission delay	Large transmission delay due to location of the retransmission control function in aGW.	Small transmission delay due to location of the retransmission control function in eNodeB.
Call establishment time	Large call establishment time due to exchange of many control signals between nodes.	Small call establishment time due to exchange of less control signals between nodes.
Radio resource management	Efficient radio resource use is possible thanks to ease of control across radio base stations.	Coordination between radio base stations is difficult due to lack of control across them.

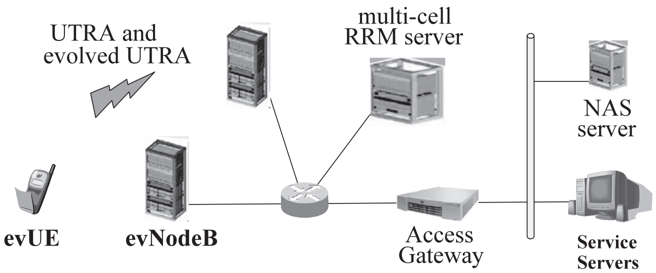

Fig. 3 evolved UTRAN architecture including MR server.

subscriber capacity by collecting information on multiple radio base stations and radio channels, perform efficient handovers across radio base stations.

We are at present studying various methods for implementing the MR server function so that we can contribute to 3GPP with the results of the study.

4. Conclusion

In the above, we reviewed the requirements for the LTE and described the element technologies for its communications method and network architecture as well as outlining the efforts being made by NEC.

We will continue to make proposals for standardizations based on the mobile communications and network technologies that we have cultivated up to the present time and also provide our customers with systems that will enable flexibility in migration from the 3G to the next generation.

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