Next-Generation Mobile Network

● Tsuguo Kato

The number of people using mobile phones in the world has exceeded 4.5 billion and this figure is continuing to grow. For the past several years, mobile data traffic such as Internet access, the downloading of music, and video communication has been nearly tripling every year. With the popularity of smartphones, mobile data traffic will increase 200 times in the 10 years up to 2020. There are high expectations that Long Term Evolution (LTE), which is known as a 3.9G wireless system, will be a new service platform that can support such a huge amount of mobile data traffic. This paper describes the features, technologies and network architecture of LTE, which started commercial service in December 2010 in Japan, realizing high-speed wireless access.

1. Introduction

The number of mobile phone users in the world has exceeded 4.5 billion and looks to grow further. Above all, mobile data traffic such as Internet access and video communication has been nearly tripling every year for the past several years. With cloud computing, smartphones and sensors all expected to be widespread in the future, mobile data traffic will likely show explosive growth, and this has further raised expectations for high-speed wireless access. Mobile data traffic is estimated to increase 200 times in the 10 years up to 2020[1] and Long Term Evolution (LTE), which is known as a 3.9G wireless system, is attracting attention as a new service platform that can support such a huge amount of mobile data traffic.

This paper describes the features, technologies and network architecture of LTE, which started commercial service in December 2010 in Japan, realizing high-speed wireless access. It also outlines the future trends toward a further speed increase.

2. About LTE

Figure 1 shows trends of wireless access systems. High-speed wireless access systems that accommodate mobile data communications traffic can be roughly classified into two trends: mobile phone-based and wireless LAN-based. LTE is an enhanced standard of High Speed Packet Access (HSPA), which is a high-speed data communications standard for Wideband Code Division Multiple Access (W-CDMA), a 3rd generation mobile telecommunications (3G) system. To realize high-speed communications with a downlink of at least 100 Mb/s and uplink of at least 50 Mb/s, LTE was specified as Release 8 in March 2009 by the 3rd Generation Partnership Project (3GPP), the W-CDMA standardization organization. Smooth transition to the 4th generation (4G) is intended by providing services using the technologies developed for 4G and the same frequency bands as for 3G. While HSPA is called the 3.5th generation (3.5G), LTE is referred to as the 3.9th generation (3.9G) in the sense that the system is extremely close to 4G.

The requirements for LTE have been

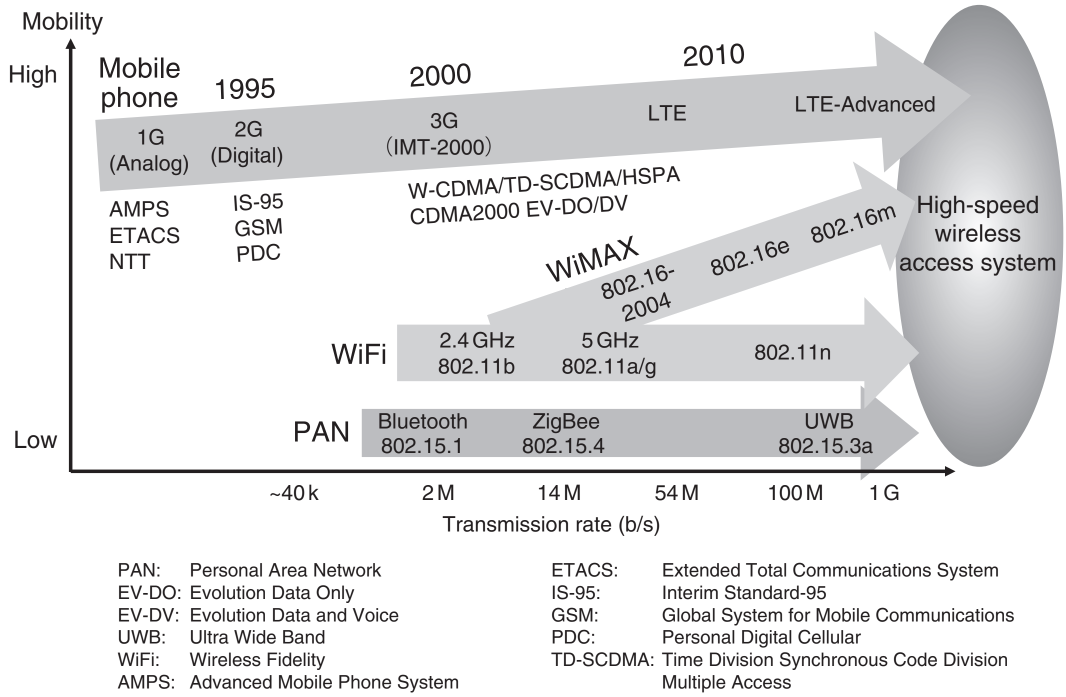

Figure 1
Trends of high-speed wireless access mobile communication systems.

discussed by the 3GPP starting in March 2005. Up to 3G, both the Circuit Switched (CS) domain for voice communications and Packet Switched (PS) domain for data communications were supported. With LTE, however, in order to reduce costs by simplifying the system, focus is placed on data communications, which is expected to be the mainstream of traffic in the future, to support the PS domain only. Voice services are assumed to use voice over IP (VoIP) for provision in the PS domain as data communications. Another aim is to significantly improve delay time, which has been an issue with 3G.

The requirements of LTE finally approved by the 3GPP as TR25.913[2] can be summarized as follows:

1) Specialization in data communications (packet switching)
2) Support for a variable bandwidth (1.4 to 20 MHz)
3) Realization of low latency
- Connection delay: up to 100 ms
- Transfer delay: up to 5 ms (wireless sections)
4) Realization of high speed
- Downlink: at least 100 Mb/s
- Uplink: at least 50 Mb/s
5) Improvement of frequency utilization efficiency (with reference to 3.5G)
- Downlink: at least triple
- Uplink: at least double
6) Coexistence with the existing systems (3G and 3.5G)

The following sections outline the key technologies and network architecture adopted for LTE to satisfy the requirements listed above.

3. Key technologies

The biggest purpose of LTE is the realization of high-speed wireless access. For higher speed, it is necessary to improve utilization efficiency of the available frequency bandwidth and expand the bandwidth. For that reason, LTE uses the following technologies.[3)–5)]

1) Wireless access system

The downlink uses orthogonal frequency division multiple access (OFDMA), which is also applied to wireless LAN and other systems. OFDMA assigns channels (subcarriers) to users along the frequency and time axes. The frequency utilization efficiency can be improved by assigning channels with higher transmission efficiency according to the wireless access environment of the user. It also features high resistance to multi-path interference. As compared with the code division multiple access (CDMA) system used for 3G and 3.5G, the same frequency width can accommodate three to four times as much data. On the other hand, the uplink uses single-carrier (SC) FDMA, which has a small peak-to-average power ratio of transmission signals and allows easy high output transmission.

2) Application of multi-antenna technology

Support for transmitting and receiving technology that uses multiple antennas both at the base station and terminal has allowed an improvement in the frequency utilization efficiency and expansion of coverage. The most suitable technique can be selected according to factors including the propagation environment out of options such as multiple input multiple output (MIMO), transmit diversity and beam forming. MIMO is a technology to transmit and receive different data on the same frequency by using multiple antennas. The frequency utilization efficiency can be improved according to the number of antennas. LTE supports up to four-stream MIMO access for downlink in terms of the specifications.

3) Expansion of bandwidth

While 3.5G HSPA uses a frequency band with a width of 5 MHz, LTE supports up to 20 MHz bandwidth. Bandwidth and transmission rate are nearly proportional to each other and a quadrupled bandwidth allows a speed increase of four times. In addition, LTE supports 1.4, 3, 5, 10, 15 and 20 MHz bandwidths to provide applicability to frequencies of different bandwidths.

4) Reduction of transmission delay

To support VoIP and allow comfortable use of real-time applications such as online games, the transmission delay must be minimized. LTE has achieved this by adopting a wireless channel structure exclusively for short wireless frame lengths and packet transmission. Regarding the wireless network architecture, the two-layer structure with wireless base stations and a wireless control station, which was used for generations up to 3.5G, has been revised to provide a flat structure without the wireless control station, as shown in **Figure 2**. In this way, one-way transmission delay of 5 ms maximum in the optimum condition without congestion has been realized.

Table 1 shows a comparison of the specifications and performance of LTE and 3G and 3.5G wireless systems.

4. Network architecture

The discussion on the core network for accommodating LTE started under the name of

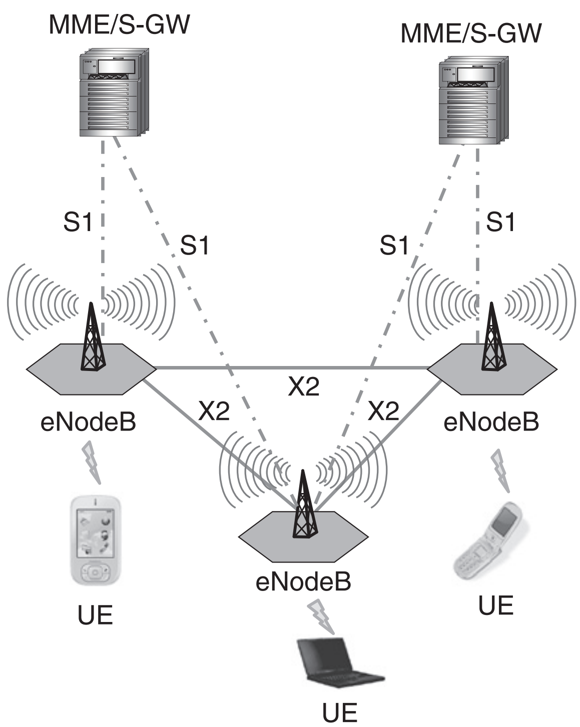

Figure 2
LTE wireless network architecture.

Table 1
Comparison of high-speed wireless access systems.

	W-CDMA (3G)	HSDPA/EUL (3.5G)	CDMA2000 1xEV-DO		LTE
			Rev.0	Rev.A	
Multiplexing scheme	DL: CDMA UL: CDMA	DL: CDMA UL: CDMA	DL: CDMA UL: CDMA	DL: CDMA UL: CDMA	DL: OFDMA UL: SC-FDMA
Frequency band	5 MHz	5 MHz	1.25 MHz	1.25 MHz	20 MHz
Modulation scheme	HPSK, QPSK	HPSK, QPSK 16QAM	BPSK, QPSK 8PSK, 16QAM	BPSK, QPSK 8PSK, 16QAM	QPSK, 16QAM 64QAM, etc.
Data rate (Maximum)	DL: 384 kb/s UL: 64 kb/s	DL: 14.4 Mb/s UL: 5.7 Mb/s	DL: 2.4 Mb/s UL: 154 kb/s	DL: 3.1 Mb/s UL: 1.8 Mb/s	DL: 325 Mb/s UL: 86 Mb/s
Start of commercial service	2000	HSDPA: 2006 EUL: 2008	2003	2006	2009

system architecture evolution (SAE) by 3GPP. As a result, Evolved Packet Core (EPC) as a next-generation IP-based core network was established as the standard specification of 3GPP Release 8 as with LTE. EPC is an architecture exclusively for data communications and has the following characteristics.[6), 7)]

1) Packet-based architecture

Data communications including Internet access is expected to be the mainstream of traffic in the future and only packet switching is specified to achieve more simplified and efficient networks. For circuit switching services provided in 3G systems, capabilities of IP multimedia subsystem (IMS) are used for offering equivalent services.

2) Always-on connection

To reduce connection delay, EPC establishes a logical transmission path when the terminal is turned on and registered with the network. On a core network, the established status of the transmission path is always maintained, and only wireless connection settings between the mobile terminal and base station need to be configured for actual communications. In this way, the connection delay can be significantly reduced. This, together with the simplification of protocols in the wireless sections and the flattening of the wireless network architecture mentioned above, has achieved a connection delay time of 100 ms maximum.

3) Accommodation of different wireless systems

EPC has been specified with the focus on accommodating LTE. However, it is established as a common core network capable of not only accommodating various wireless access systems such as CDMA2000, WiMAX and WiFi in addition to 3GPP-compliant wireless systems including 3G W-CDMA and 3.5G HSPA but also handover between these different wireless access systems. A network architecture independent of the wireless access systems has been constructed by widely incorporating general-purpose IPs.

An overview of the EPC network architecture is shown in **Figure 3**. A Mobility Management Entity (MME) manages the authentication and movement of terminals. It also handles interworking with the existing W-CDMA and HSPA and configures user data transfer paths in the EPC. A Serving Gateway (S-GW) accommodates enhanced Node Bs (eNodeBs), which are LTE wireless base stations, and transfers user data. It is also provided with a function of an anchor point that switches user data between LTE and the existing W-CDMA/HSPA. A Packet data network Gateway (P-GW) has a function to connect with IP service systems operated by operators themselves such as IMS and IP service providers other than operators and assigns IP addresses to mobile terminals. It also accommodates non-3GPP wireless access systems such as WiMAX and WiFi. Policy and Charging Rules Function (PCRF) establishes

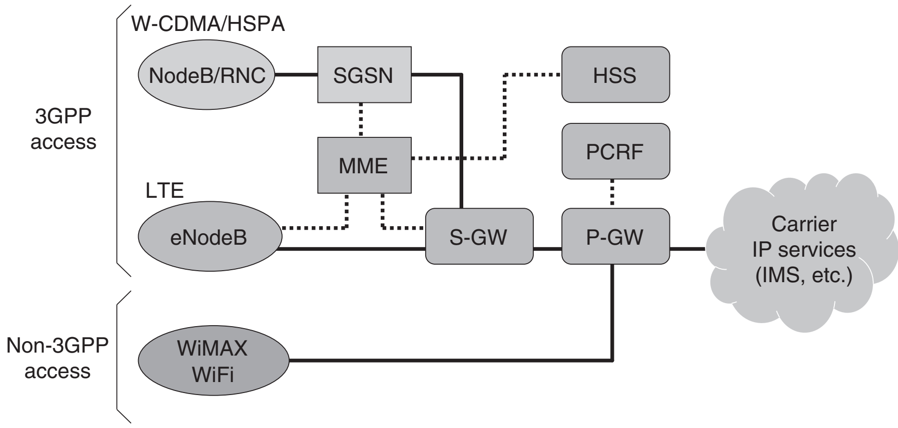

Figure 3
EPC network architecture.

policies including QoS and charging rules in the EPC. In the P-GW and S-GW, policy control and charging control take place according to the instructions from PCRF. A home subscriber server (HSS) stores user profiles such as various identifiers for identifying users and information about services to which users subscribe. When a user accesses the network via an eNodeB or NodeB, MME references the profile stored in the HSS for user authentication and service authentication. A serving GPRS support node (SGSN) handles the authentication and location management of terminals connected to W-CDMA and HSPA. General-purpose IPs are used to connect between these nodes, which has enabled EPC to realize efficient transfer of high-speed data communications independent of the wireless access systems.

5. Conclusion

This paper has described LTE, which realizes high-speed wireless access services, by outlining its characteristics, key technologies and network architecture. For even higher-speed wireless access, 3GPP is already working on the standardization of LTE-Advanced. LTE-Advanced is a wireless access system positioned as 4G and based on the LTE technology, as its name indicates. It is targeted to realize high-speed transmission of 1 Gb/s. This can be achieved by using carrier aggregation technology, which aggregates multiple wireless bands of 20 MHz in LTE for a high bandwidth of up to 100 MHz, and enhancing MIMO to support up to eight streams. Fujitsu has already been developing LTE terminals, base stations and core network devices and various elemental technologies for realizing these devices. Fujitsu is also working on the development of management and engineering technologies required for efficiently building and operating LTE and EPC and has been contributing to the start of commercial LTE services. Fujitsu intends to continue to work on development for the full-scale diffusion of LTE. In addition, for the realization of LTE-Advanced, Fujitsu will move ahead with unceasing research and development from the standardization activities to commercialization.

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