Technological Trends in Mobile Access Systems

● Hiroyuki Seki ● Morihiko Minowa

The amount of mobile data traffic is more than doubling each year because of the increase in mobile video traffic and spread of smartphones. Although a recent survey has predicted that the annual rate of increase in global mobile traffic will gradually slow in the future, we have to develop effective technologies to cope with this continuously growing amount of mobile data traffic. The Long Term Evolution (LTE) system, which offers higher speed and greater capacity than the 3G system, launched a commercial service in Japan and other countries to deal with the growing mobile data traffic. This paper describes the technological trends in the LTE mobile access system, and introduces an LTE macro base station (eNode B equipment) and LTE femto base station that are under development. It also describes the technological trends in an LTE-Advanced mobile access system which is an enhanced version of LTE and which is expected to be put to practical use in the near future after 2014.

1. Introduction

The amount of mobile data traffic is growing rapidly because of the increase in mobile video traffic and spread of smartphones. Recently, the traffic has reportedly been more than doubling each year.

This paper describes the state of the surging mobile traffic and the technologies said to be effective for accommodating it. Then, it gives an explanation, from the perspective of measures to deal with mobile traffic, about the technological trends in the Long Term Evolution (LTE) system, which offers higher speed and greater capacity than the existing 3G system and is now being introduced around the world. In addition, as technological trends in an LTE-Advanced system, which can provide even higher speed and greater capacity than LTE and is expected to be put to practical use in the future, major functions of LTE-Advanced will be described. This will be followed by a description of the technological challenges for Fujitsu to work on in the future so as to accommodate the ever-increasing mobile traffic.

2. State of and measures for mobile traffic

2.1 State of mobile traffic

The Information and Communications Council of the Ministry of Internal Affairs and Communications in Japan estimated in 2008[1] that the volume of mobile communications in 2007 would grow sixfold in 2012 and over two-hundred fold in 2017. This increase in 10 years corresponds to a 1.7-fold increase in the annual mean growth rate.

One recent investigation report[2] said that the annual growth rate of global mobile traffic has doubled for four consecutive years since 2008. As shown in **Table 1**, the annual growth rate is estimated to decrease gradually from now on. Still, with that taken into account, an increase of 18 times in five years from 2011 to 2016 (1.78 times in annual mean growth rate) is forecast.

2.2 Measures for mobile traffic

To deal with the surging mobile traffic, the following four methods are considered to be effective in order to increase the capacity of mobile communication systems.

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1) Improvement of frequency utilization efficiency

Frequency utilization efficiency is defined as the data transmission rate achievable with a unit frequency bandwidth and is realized by the evolution of wireless access systems such as orthogonal frequency division multiple access (OFDMA) and introduction of multi-antenna transmission technologies including multiple-input multiple-output (MIMO).

2) Frequency bandwidth expansion

Expanding frequency bandwidth means allocating new frequency resources to mobile communication to increase the frequency bandwidth available for mobile communication systems.

3) Cell size reduction

This is a technology for improving the throughput per user by increasing the number of base stations per unit area by such means as reducing the cell radius.

4) Traffic offload

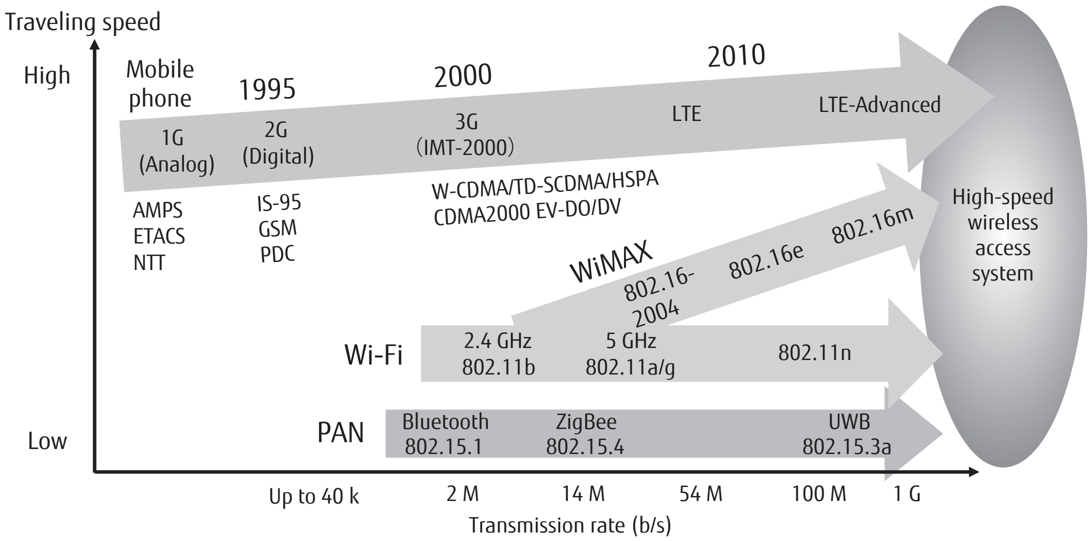
This technology is intended for accommodating the traffic of an indoor mobile device, which conventionally accessed an outdoor macro base station, using a Wi-Fi or femto base station installed indoors.

Figure 1 shows trends in high-speed wireless access systems. The mainstream wireless access system for mobile communication has been evolving from the third generation system (3G), called wideband-code division multiple access (W-CDMA), through the 3.5th generation system (3.5G), called high speed packet access (HSPA), and 3.9th generation system (3.9G) with LTE to a fourth generation system (4G) with LTE-Advanced. The rapidly increasing amount of mobile traffic is being dealt with by realizing the four measures for traffic mentioned above through this evolution. **Table 2** shows a comparison of 3G to 4G wireless access systems. The following sections describe the technological trends in LTE, which has already been in service,

Table 1
Annual growth rate of mobile traffic.

Annual growth rate of global mobile data traffic	
2009	140% (2.4-fold)
2010	159% (2.59-fold)
2011	133% (2.33-fold)
2012 (estimate)	110% (2.1-fold)
2013 (estimate)	90% (1.9-fold)
2014 (estimate)	78% (1.78-fold)

Source: Cisco VNI Mobile (2012)



AMPS: Advanced Mobile Phone System
ETACS: Extended Total Access Communications System
EV-DO: Evolution Data Only
EV-DV: Evolution Data and Voice
GSM: Global System for Mobile Communications
IS-95: Interim Standard-95 Multiple Access
PAN: Personal Area Network
PDC: Personal Digital Cellular
TD-SCDMA: Time Division Synchronous Code Division Multiple Access
UWB: Ultra Wide Band
Wi-Fi: Wireless Fidelity

Figure 1
Trends in high-speed wireless access systems.

and LTE-Advanced, the implementation of which is expected in 2014 or later.

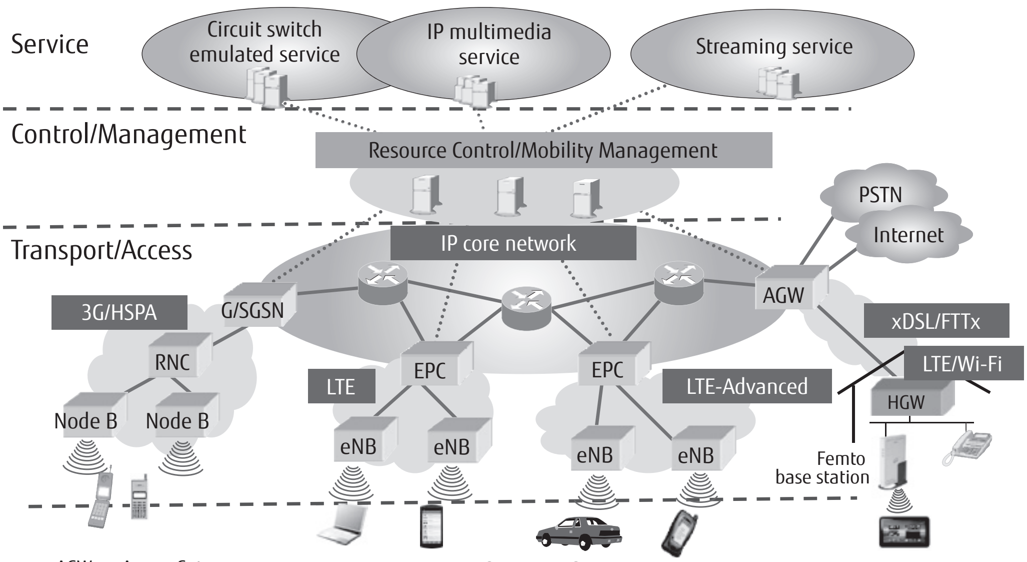
3. LTE technological trends

LTE is a standard for wireless communication specified as Release 8 by the 3rd Generation Partnership Project (3GPP), an organization for standardization.[3) As shown in Table 2, LTE adopts wireless communication systems that are effective in a multi-path environment: OFDMA for downlink (DL) and single-carrier frequency division multiple access (SC-FDMA) using cyclic prefix for uplink (UL). In addition, the data transmission rate has been significantly improved by combining multi-level modulation of up to 64 QAM with the MIMO multi-antenna technology. Furthermore, LTE uses a packet-based network architecture and LTE base station equipment is directly connected to a core network, which allows the connection delay to be significantly reduced by having a continuous device connection and simplifying protocol.[4) **Figure 2** shows an overall configuration of mobile network architecture including LTE.

Table 2
Comparison of specifications and performance of wireless systems.

	W-CDMA (3G)	HSPA (3.5G)	LTE (3.9G)	LTE-Advanced (4G)
Wireless system	DL: CDMA UL: CDMA	DL: CDMA UL: CDMA	DL: OFDMA UL: SC-FDMA	DL: OFDMA UL: SC-FDMA
Frequency bandwidth	5 MHz	5 MHz	20 MHz	100 MHz
Modulation scheme	HPSK, QPSK	HPSK, QPSK, 16QAM	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM
Maximum data rate	DL: 384 kb/s UL: 64 kb/s	DL: 14.4 Mb/s UL: 5.7 Mb/s	DL: 300 Mb/s UL: 75 Mb/s	DL: 3 Gb/s UL: 1.5 Gb/s
Feature	Applicability to circuit switching services	Improved packet data communication speed	Improved data rate and latency	Further improved data rate and mobility

DL: DownLink (from base station to mobile phone)
UL: UpLink (from mobile phone to base station)
CDMA: Code Division Multiple Access
HSPA: High Speed (Downlink/Uplink) Packet Access
OFDMA: Orthogonal Frequency Division Multiple Access
SC-FDMA: Single Carrier-Frequency Division Multiple Access



AGW: Access Gateway
eNB: Evolved Node B
EPC: Evolved Packet Core
G/SGSN: Gateway/Serving GPRS Support Node
HGW: Home Gateway
PSTN: Public Switched Telephone Networks
RNC: Radio Network Controller

Figure 2
Mobile network architecture.

3.1 LTE base station (eNode B)

LTE is characterized by its use of the same frequencies as 3G and, as shown in **Figure 3**, it makes it possible to smoothly migrate from 3G to LTE by gradually replacing some of the frequencies that mobile operators use for 3G services. For that reason, LTE base stations are installed along with the existing 3G base stations. To reduce the cell size, LTE base stations are installed in greater numbers (more densely) than 3G base stations.

Because of all these measures, LTE base stations need to have a significant reduction in the size, weight and power consumption compared with 3G base stations. The appearance of the eNode B equipment developed by Fujitsu is shown in **Figure 4** and its specifications in **Table 3**. An eNode B can be separated into a base band unit (BBU) and remote radio head(s) (RRH); one BBU and up to three RRHs are connected together by an interface compliant with standards such as the common public radio interface (CPRI). The features of Fujitsu's eNode B equipment are as described below.

1) Shared use of RRH between LTE and 3G

An RRH can be simultaneously connected to an LTE BBU and a 3G BBU via a CPRI sharing device, which allows LTE and 3G to be shared by using one RRH.

2) Outdoor installation of BBU

The size reduction of BBUs allows them to be installed outdoors as well as RRHs, and this eases the restrictions of installation location when adding new base stations, allowing for flexible installation.

3) Size and weight reduction of RRH

RRHs are installed near antennas such as on building roofs and steel towers. Fujitsu's RRH has reduced their size and weight by using plastic housing, which makes it easier to install additional RRHs that are needed in line with the additional installation of base stations.

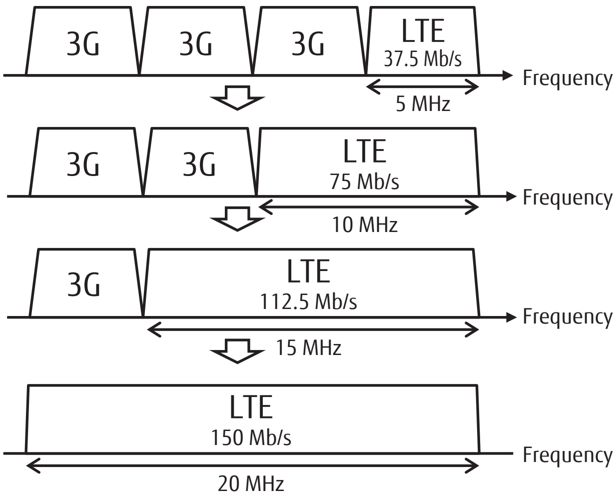


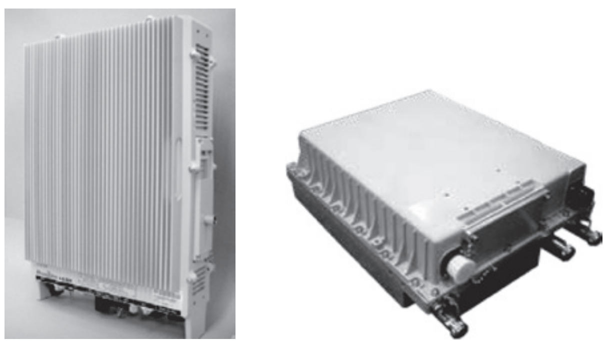
Figure 3
Migration scenario from 3G to LTE.

Table 3
Specifications of eNode B equipment.

Item	Specifications
Radio frequency band	700 MHz to 2.6 GHz
Bandwidth	5, 10, 15, 20 MHz
Access scheme	DL: OFDMA UL: SC-FDMA
Antenna technology	DL: 2 × 2 MIMO UL: 1 × 2 SIMO
No. of sectors	Up to 6 sectors
Maximum transmission power	40 W (20 W + 20 W)
Maximum transmission rate (per sector)	DL: 150 Mb/s UL: 50 Mb/s
BBU-RRH interface	ORI/CPRI/OBSAI
Equipment size/weight	BBU: 20 L max. RRH: 12 L (10 kg)

3.2 Femto base station

Femto base stations are raising expectations as a measure for "traffic offload" to address a traffic increase alongside the throughput increase of indoor devices. While 3G mainly offered voice services, data communication is the main service provided by LTE. For this reason, it is important to provide seamless outdoor to



(a) BBU (b) RRH

Figure 4
Appearance of eNode B equipment.

Figure 5
Appearance of femto base station equipment.

Table 4
Specifications of femto base station equipment.

Item		Specifications	
Equipment specifications		Size/weight	130 mm (W) × 25 mm (D) × 220 mm (H)/600 g
		Input power	100 to 240 VAC
		Power consumption	12 W
		Wired line	100Base-Tx/1000Base-T
Wireless access	LTE	Wireless frequency	3GPP bands supported
		Bandwidth	5 MHz, 10 MHz
		Antenna configuration	DL: 2 × 2 MIMO UL: 1 × 2 SIMO
		Maximum transmission power	10 mW × 2 (@10 MHz)
		3GPP specifications	Release 9
	Wi-Fi	Standard specifications	IEEE 802.11a/b/g/n

The specifications above are subject to change without notice.

indoor services while also achieving a high throughput in an indoor environment.

The appearance and specifications of the LTE femto base station equipment developed by Fujitsu are shown in **Figure 5** and **Table 4** respectively. The following describes the features of Fujitsu's femto base station.

1) Simple installation in any location

After power-up, femto base stations download the necessary parameters from the server and start their services (plug & play). Femto base stations are also equipped with original interference control functions that automatically avoid interference with the macro base station or neighboring femto base stations, thus making it easy to simply install them in any location.

2) LTE-Wi-Fi Interworking

Femto base stations are provided with functions for both LTE and Wi-Fi and devices can access the base station with either system. This feature is taken advantage of to conduct studies on switching control between LTE and Wi-Fi in view of interference and load balance and on link aggregation for high-speed data transmission by one device using LTE and Wi-Fi simultaneously.

3) Network service linkage

Femto base stations can be used to provide a gateway function that links ICT devices in homes and offices. In addition, provision of a new service with a service platform on a cloud platform that is linked with ICT devices through femto base stations is also being studied.

4. LTE-Advanced technological trends

In order to address the ever-increasing amount of mobile traffic, mobile communication systems need to continue to evolve. The 3GPP has advanced LTE specifications by adding new functions while covering the LTE functions and the specifications for Release 10 and later, which have made significant functional enhancement from Release 8, are specifically called LTE-Advanced.[5] The following describes the four major functions added with LTE-Advanced.

1) Carrier aggregation (CA)

To satisfy the minimum requirements for International Mobile Telecommunications (IMT)-Advanced specified by the International Telecommunication Union Radiocommunication Sector (ITU-R), LTE-Advanced targeted a maximum transmission rate of at least 1 Gb/s and frequency utilization efficiency of at least 15 b/s/Hz. CA, which was added with Release 10, is a function that gathers together up to five component carriers (bandwidths of up to 20 MHz of LTE) in order to support bandwidths of up to 100 MHz and ensure backward compatibility with LTE. With CA, frequency bands allocated to various frequency bands for mobile communication can be used to improve the transmission rate per device.

2) Multiple-antenna transmission (MIMO)

While LTE MIMO conventionally provided multiplexing of up to four layers for DL, it was extended to up to eight layers with Release 10. With a frequency band of 100 MHz, the maximum transmission rate is 3 Gb/s. Along with the greater number of layers multiplexed, the specifications of reference signals for channel estimation and propagation quality measurement have also been added. Specifications for multiplexing up to four layers have been added for UL as well, and codebook-based precoding has been applied as with DL.

3) Enhanced inter-cell interference coordination (eICIC)

For LTE-Advanced, a cell configuration called a heterogeneous network (HetNet) is under study, in which pico base stations, RRHs, femto base stations, and such like are provided in a macrocell to accommodate high-volume traffic in the cell. **Figure 6** shows a conceptual diagram of HetNet. eICIC is a technology that increases the cell capacity by reducing inter-cell interference between the macro base station and small cell base stations in the macrocell in a HetNet environment. Specifically, some of the subframes of a transmission frame of the macro base station are used as transmission stop intervals, during which small cell stations communicate with users in locations subject to large inter-cell interference, thereby mitigating the generation of inter-cell interference.

4) Coordinated multi-point transmission and reception (CoMP)

CoMP is a technology that improves the communication quality on cell boundaries by coordinating transmission and reception processing between different base stations and, is in the process of specification with Release 11. Coordination between base stations may be achieved by using a wired interface between independent eNode Bs or connecting multiple RRHs and a centralized eNode B with a high-speed interface such as CPRI. CoMP schemes include joint processing and coordinated scheduling/coordinated beamforming. Use of a high-speed interface with a low processing delay allows coordination of scheduling processing, which raises expectations for a greater effect.

5. Future issues

To deal with mobile traffic that will continue to increase in the future, reducing the cell size with HetNet is an important technology. In particular, use of a centralized BBU (C-BBU) with the baseband signal processing blocks centralized in one location for

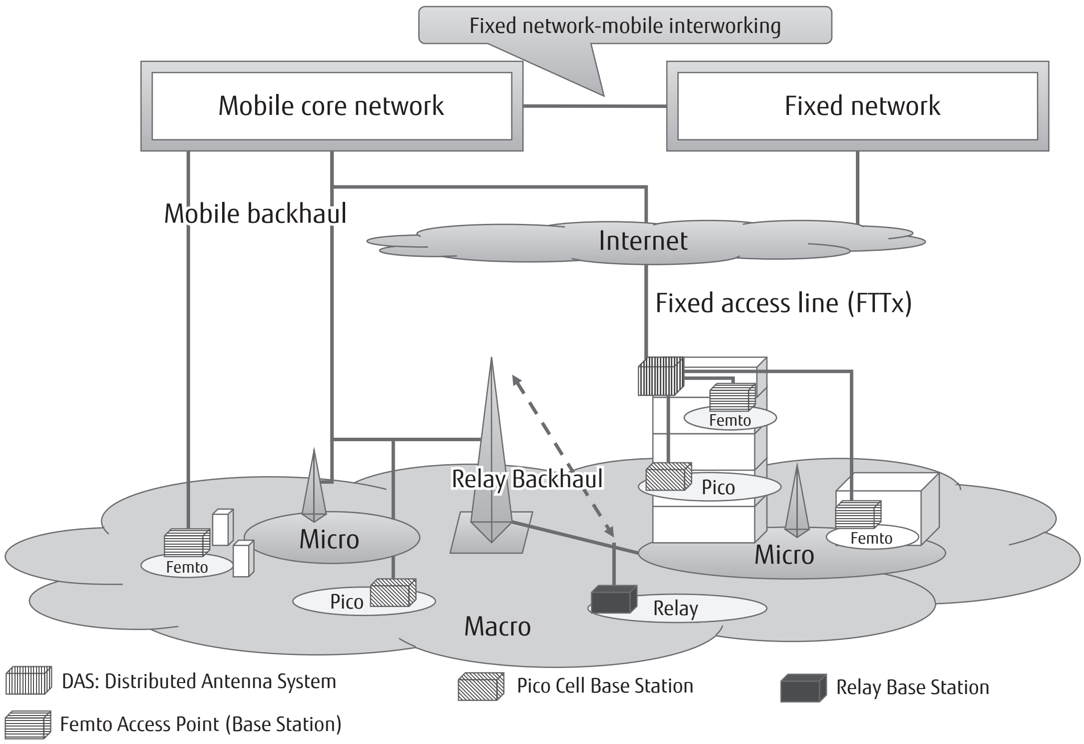


Figure 6
Concept of HetNet.

centralized control of multiple RRHs located remotely from the C-BBU allows high-speed coordination processing, such as scheduling, between macrocell and small cells. It realizes integration for optimization by combining various functions of LTE-Advanced including CA, MIMO and eICIC in addition to CoMP.[6)]

From now on, the development of technologies including:

1) Optimization algorithm through centralized control by C-BBU
2) Technology for implementation of large-scale signal processing of C-BBU
3) Optical and millimeter wave transmission technologies for realizing a high-speed interface between C-BBU and RRHs
4) RRH equipment capable of efficiently transmitting and receiving wide-band and multiple-band signals
5) Optimum interference management technology for an entire HetNet including femto base stations and relay stations

These technologies must be used to realize a HetNet that uses C-BBU and RRHs.

6. Conclusion

This paper has described four technologies considered to be effective as measures for accommodating the surging increase in mobile traffic: improvement of frequency utilization efficiency, frequency bandwidth expansion, cell size reduction, and traffic offload. It has also explained from the perspective of these measures for traffic the technological trends in mobile access systems, which are evolving from 3G to 4G. As technological trends in LTE (3.9G), a base station equipment configuration composed of a BBU and RRHs in view of smooth migration from 3G to LTE and femto base station equipment for providing an indoor measure for speed increase and traffic offload have been presented. In addition, as technological trends in LTE-Advanced (4G) expected to be put to practical use in the future, CA, MIMO, eICIC and CoMP, which are major functions of LTE-Advanced, have been described. As a future technology for accommodating the mobile traffic, which is expected to continue to grow, this paper has focused on HetNet and described a technology for having centralized control of multiple RRHs by using a C-BBU and an integration technology that uses a C-BBU to combine four functions of LTE-Advanced for optimization. Fujitsu intends to promote the development of future technologies for the practical implementation and commercialization of LTE-Advanced while moving ahead with technological development that targets the full-scale diffusion of LTE.

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Hiroyuki Seki
Fujitsu Laboratories Ltd.
Mr. Seki is currently engaged in research and development for next-generation cellular systems and wireless base station equipment.

Morihiko Minowa
Fujitsu Ltd.
Mr. Minowa is currently engaged in design for mobile communication systems and product strategy.