Field Trial for LTE Mobile Network System

● Hiroyuki Kiyanagi ● Morihiko Minowa

The Long Term Evolution (LTE) mobile network system is slated to become the wireless broadband infrastructure for constructing the smart ubiquitous society. Fujitsu has conducted a field trial toward the early implementation of an LTE system as a field-proven platform for the cloud era. An end-to-end LTE system targeting the global market was set up using a 5-MHz bandwidth in the 1.7-GHz band, and measurements were taken to assess system performance and the applicability of LTE system operations for the coming cloud era. The achievement of a maximum throughput of 34.6 Mb/s for the downlink and 9.5 Mb/s for the uplink shows that the LTE system has sufficient performance for use in the field. Testing of applications traditionally used in a fixed Internet protocol network showed that they could also run well on an LTE system. This article presents and discusses the results of this field trial.

1. Introduction

The Long Term Evolution (LTE) mobile network system (referred to below as "LTE system") is expected to become the wireless broadband infrastructure for the smart ubiquitous society. In Japan, NTT DOCOMO has been providing an LTE-based service called "Xi" (Crossy)[note)] since December 2010, and Fujitsu has conducted an LTE field trial to move quickly on constructing an LTE system as a field-proven platform for the cloud era.

This article describes the configuration, execution, and results of this field trial.

2. Construction of field trial environment

Using a 5-MHz bandwidth in the 1.7-GHz band, Fujitsu carried out the field trial in an urban/residential area with a radius of about 1.2 km in the neighborhood of Fujitsu Kawasaki Research & Manufacturing Facilities in Nakahara ward of Kawasaki City, Japan. The experimental parameters are listed in **Table 1**. The LTE system uses orthogonal frequency division multiple access (OFDMA) in the downlink and single-carrier (SC) FDMA in the

note) "Xi" (Crossy) and its logo are trademarks or registered trademarks of NTT DOCOMO.

Table 1
Experimental parameters.

	Description
Field environment	Urban/residential area
Station/cell configuration	3 stations, 7 cells
Carrier frequency (DL/UL)	1862.4 MHz / 1767.4 MHz
System bandwidth	5 MHz
Base-station transmit power (max.)	43 dBm
Antenna configuration (Tx/Rx)	2/2
DL radio access system	OFDMA
UL radio access system	SC-FDMA
Transmission mode	4
MIMO transmission method	Closed-loop with rank adaptation

DL: downlink; UL: uplink; Tx: transmit; Rx: receive uplink as radio access systems. Both are robust to multipath interference, and throughput in these systems is improved by performing scheduling in the time and frequency domains. In downlink circuits, the LTE system uses a multi-antenna technology called multiple-input multiple-output (MIMO) that significantly improves throughput for users near the cell center, where propagation quality is good compared with that at the cell edge. In this field trial, we used a closed-loop, precoding MIMO system consisting of a 2 × 2 antenna configuration (two antennas for both the transmitter and receiver) in the downlink. For a bandwidth of 5 MHz, with overhead taken into account, this configuration achieves a theoretical maximum throughput of 35 Mb/s for the downlink and 9.5 Mb/s for the uplink.

The LTE system constructed for this field trial consisted of LTE base-station equipment (eNodeB) developed for the global market, Evolved Packet Core (EPC) as the core network, and a terminal end-to-end system in a three-base-station, seven-cell configuration. A number of evaluation devices and simulators were used as LTE terminals, i.e., user equipment (UE). The backhaul connecting the EPC network and base stations was achieved through an in-house intranet. The structure of this experimental LTE system is shown in **Figure 1**.

One of the seven cells was implemented indoors to create an environment for testing indoor propagation. The base stations were designed to use natural energy generated by a hybrid wind and solar power generator and provided to the remote radio head (RRH) equipment making up each base station.

3. Execution and results of field trial

This section describes how the field trial was executed and presents the results obtained.

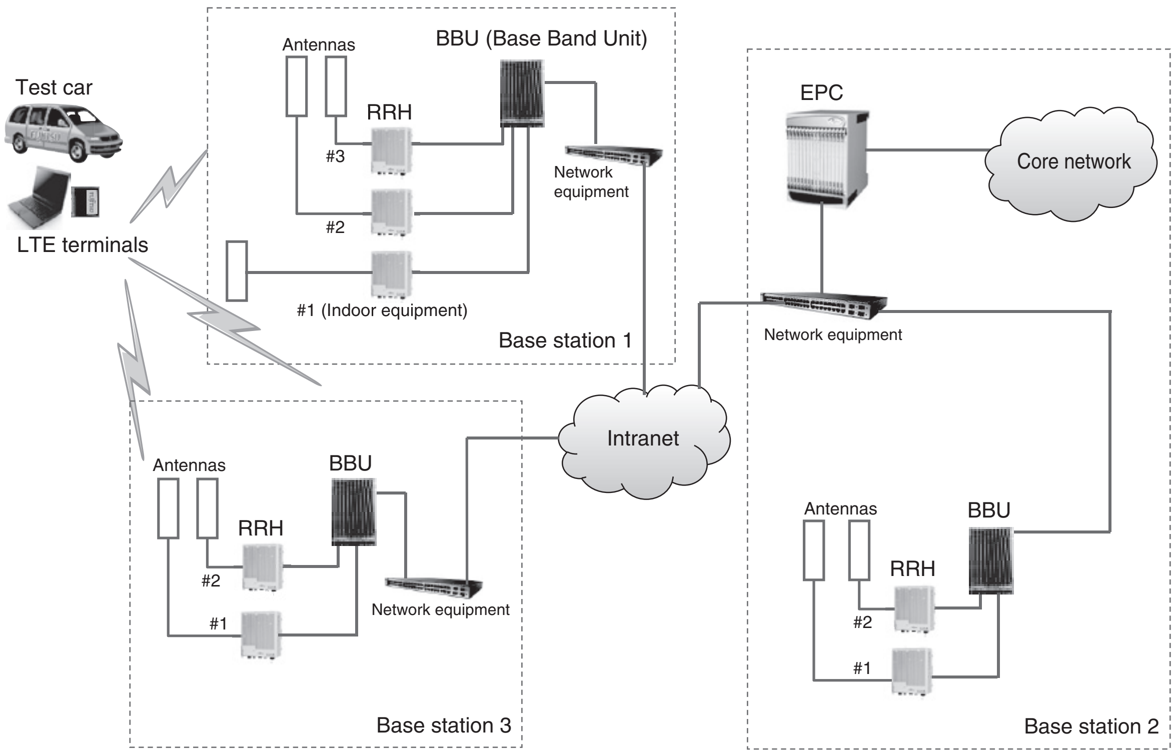


Figure 1
LTE system structure.

(a) Base station (b) Test car

Figure 2
Base station and test car.

3.1 Throughput performance

Each base station was equipped with two sector-directional antennas having vertical (V) and horizontal (H) polarizations. These antennas were installed at a height of about 30 m on the roof of a building, as shown in **Figure 2(a)**. A test car [**Figure 2(b)**] carrying LTE terminals was driven along roads in the field trial area, and throughput was measured. The maximum throughput values obtained are listed in **Table 2**. The measured throughput was about the same as the theoretical throughput for both the uplink and downlink.

Table 2
Maximum throughput.

	Measured	Compared with Theoretical
Downlink	34.6 Mb/s	98.8%
Uplink	9.5 Mb/s	100.0%

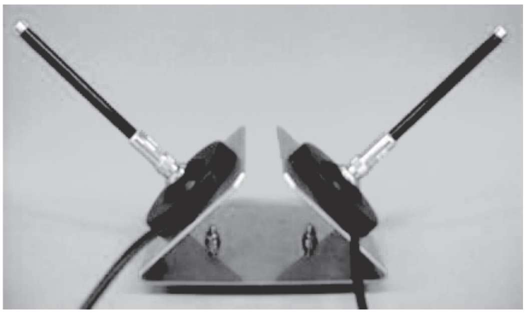
(Throughput is average of measurements over 1 s.)

Additionally, although a MIMO configuration improves throughput performance, the effect of the polarization characteristics of the UE antennas (in addition to the GPS antenna for measurement) on throughput was measured for the downlink.[1] This was done by installing two V-polarized omnidirectional UE dipole antennas on the roof of the test car so that their tips were about 2 m from ground level and by preparing two antenna patterns: one in which the two antennas are arranged vertically side by side at an interval of 1.5 λ (VV pattern), as shown in **Figure 3(a)**, and the other in which each antenna is tilted outwards at an angle of 45° (±45° pattern), as shown in **Figure 3(b)**.

The location of base station 1, shown in Figure 1, and the route taken by the test car are shown in **Figure 4**. Most of the route is in a non-line-of-sight zone with respect to the base station due to the presence of buildings while the route between points F and G is in a line-of-sight zone. The measured downlink throughputs are shown in **Figure 5**. While the antenna pattern had little effect on throughput in the non-line-of-sight zone (from points S to E), it had a substantial effect in the line-of-sight zone (between points F and G): a throughput nearly equal to the maximum theoretical one of 35 Mb/s was stably obtained with the ±45° antenna pattern while a throughput of only about 25 Mb/s was obtained with the VV pattern despite the line-of-sight conditions.

Table 3 summarizes the radio characteristics for each antenna pattern. There was little difference in average throughput between them for the non-line-of-sight zone. For the line-of-sight zone, however, average throughput for the VV pattern was about 20% lower. This was because the signal-to-noise interference ratio (SINR) obtained with the VV pattern was smaller than that with the ±45° pattern for both V and H polarizations and also because the correlation between the receive antennas was larger with the VV pattern.

(a) VV pattern



(b) ±45° pattern

Figure 3
UE antenna pattern.

Figure 4
Route of test car.

Table 3
Radio characteristics by antenna pattern.

Pattern		VV	±45°
Non-line-of-sight average throughput		20.7 Mb/s	21.7 Mb/s
Line-of-sight	Average throughput	27.2 Mb/s	34.1 Mb/s
	SINR (base-station V polarization)	31.8 dB	37.7 dB
	SINR (base-station H polarization)	29.8 dB	36.8 dB
	Receive-antenna correlation	0.64	0.18

(Throughput is for downlink.)

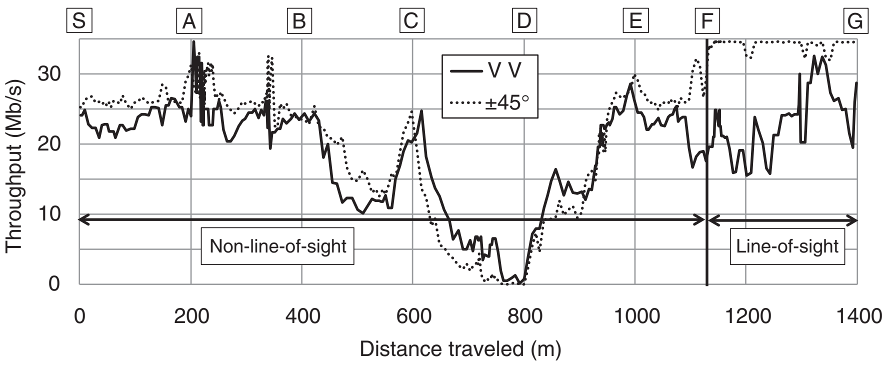


Figure 5
Downlink throughput (outdoor environment).

3.2 Area coverage and handover evaluation

The area-coverage rate was evaluated by making repeated calls at random while the test car was being driven through the field trial area and using the call-connection success rate as the metric. Similarly, the handover success rate was measured by forcing the system to repeatedly switch between base stations. The call-connection success rate within the service area was better than 95%. The main reason calls could not be made at certain locations is that the quality of the received signal dropped due to inter-cell interference and/or building shadows. These coverage holes must be eliminated by implementing appropriate measures, such as installing additional low-power base stations. The handover success rate within the service area was also better than 95%, as shown in **Table 4**. The locations where handovers are likely to occur and the occurrence rate of handover are calculated in advance by using a model simulator with the receive power and other characteristics calculated during the design stage. To increase the handover success rate, handover operations were optimized by making throughputs before and after handover the same so that the user does not sense that a handover has taken place and by optimizing the parameters so that handovers occur less frequently and system resources are used more efficiently.

3.3 Indoor performance

An LTE system can be separately introduced into a building or underground complex where radio signals cannot normally reach by installing a base station and antenna indoors. In this field trial, we performed a basic test of indoor radio-propagation characteristics for a base station and antenna indoors using the indoor equipment configuration (#1 for Station 1) in Figure 1. The throughput obtained on the downlink in this test is shown in **Figure 6**. A throughput in excess of 20 Mb/s was obtained at nearly all points in the target area, thereby demonstrating that the MIMO effect—a particular feature of LTE—is also effective in achieving high throughput in an indoor environment.

Table 4
Call-connection and handover success rates.

	Rate
Call connection	Better than 95%
Handover	Better than 95%

3.4 Energy saving

Energy saving (ES) is a main use case of a self-organizing network (SON) and a solution to reducing operational expenses. The idea behind ES is to reduce the amount of power consumed by the network by optimizing the number of base stations operating to match traffic conditions. This can be done, for example, by shutting down a base station under certain traffic conditions and having neighboring base stations cover its service area.

In the field trial, we assumed a situation in which user traffic drops—such as in a residential area during the day—and measured characteristics such as power consumption, area-coverage rate, and throughput for a service area

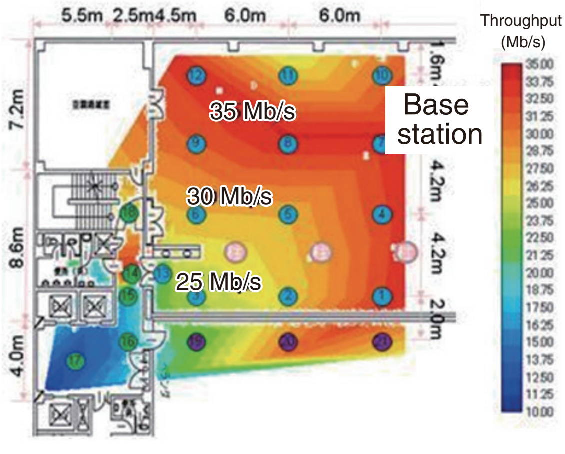


Figure 6
Downlink throughput (indoor environment).

operating three cells (normal mode) and for the same service area operating only one cell (ES mode).[2] In ES mode, settings such as antenna tilt and transmit power are adjusted so as to cover nearly the same area covered in normal mode. Although the measured reference signal received power (RSRP) dropped near base station that had been shut down, the area-coverage rate did not drop significantly, as shown in **Table 5**. Moreover, power consumption in ES mode was about 44% that in normal mode. In other words, a power-consumption reduction effect of over 50% was obtained by decreasing the number of working cells without the area-coverage rate dropping below 95%.

3.5 Use of natural energy

The base-station equipment was partially powered using natural energy to reduce the load on the environment. To give some background, the amount of power generated by a conventional wind or solar power generator is sensitive to weather while a hybrid wind and solar power generator can provide power in a relatively stable manner as natural energy (**Figure 7**). In the field trial, some of the power needs of the base-station equipment were met by supplying it with natural energy, and basic data on supplying power to LTE equipment was obtained.

4. Testing of application operations environment

The LTE system is expected to become the infrastructure for the ubiquitous society. With this in mind, we tested the application operation environment on the LTE system by running various types of applications such as videoconferencing, video delivery using high-definition television (HDTV) video encoder/decoder equipment (Fujitsu IP-9500), and online games that have been used on a fixed Internet protocol (IP) network. We found that applications traditionally used on a fixed network could indeed run on an LTE system thanks to the high-speed, large-capacity, and low-latency features of the LTE standard. These videoconferencing and HDTV video delivery applications on LTE were exhibited at Fujitsu Forum 2010 and Wireless Japan 2010 (**Figure 8**) in the form of real-time demonstrations. Specifically, a test car equipped with a videoconferencing system and HDTV video encoder/decoder equipment was driven inside the field trial area in Kawasaki city, and video from cameras on the moving car were delivered live to the exhibition hall by establishing a connection through an experimental LTE network. Trial personnel in the test car were also able to converse with exhibition visitors by videoconferencing in an exhibit that enabled participants to experience first-hand the high

Table 5
Comparison between normal and ES modes.

	Mode		Notes
	Normal	ES	
System power consumption	1.00	0.44	Calculated with normal mode taken to be 1
Area-coverage rate (%)	99.5	97.8	Defined as points with RSRP of –120 dBm or greater

Figure 7
Hybrid power generator.

Figure 8
Wireless Japan 2010 exhibition.

responsiveness of the LTE system.

5. Conclusion

The field trial described in this article evaluated an end-to-end LTE system covering an urban/residential area in Kawasaki City, Japan. The findings were used to assess system performance, from basic characteristics such as area coverage and throughput to energy saving and power supply from natural energy sources. Results showed that the system has sufficiently high performance even in the field. Also tested in the field trial was the applicability of LTE system operations for the coming cloud era. The findings showed that applications traditionally used on a fixed IP network could also operate on an LTE system.

The type of base station used in the field trial had a relatively large cell radius, covering a broad area (macro base station). In future trials, Fujitsu will test systems designed for various types of areas such as coverage holes and indoor dead zones and will test solutions to problems faced by telecommunications operators.

References

1) T. Oyama et al.: Downlink MIMO Throughput Study in the LTE Field Trial. (in Japanese). IEICE Society Conference 2010, B-5-43.
2) H. Yokoyama et al.: A Evaluation to reduce Cell Sites in the Field Trial on the LTE Network. (in Japanese). IEICE Society Conference 2010, B-5-44.

Hiroyuki Kiyanagi
Fujitsu Ltd.
Mr. Kiyanagi is engaged in the design of mobile communications systems.

Morihiko Minowa
Fujitsu Ltd.
Mr. Minowa is engaged in the design of mobile communications systems and formulation of product strategy.