Overview of 5G Field Trials toward Social Implementation, and Experimental Trials of 5G in the Entertainment Area

Yukihiko Okumura, Satoshi Suyama, and Jun Mashino

Abstract

The Ministry of Internal Affairs and Communications of Japan began field trials of fifth-generation mobile communications systems (5G) in fiscal year 2017. This effort is aimed at developing a new market through social implementation of 5G. These Feature Articles explain the results of experimental trials conducted by NTT DOCOMO and NTT Communications. In this article, a brief overview of the project is outlined, and some experimental examples concerning applications of 5G in the entertainment area are introduced.

Keywords: 5G, experimental trials, entertainment

1. Introduction

Fifth-generation mobile communications systems (5G) provide not only large capacity and ultrahigh throughput but also new capabilities and features such as massive connectivity, low latency, and high reliability. Early realization of 5G is desired as an information and communication technology (ICT) infrastructure in the Internet of Things (IoT) era, which is essential for economic growth.

To ensure that Japan leads the world in social implementation of 5G while strengthening collaboration with the United States, Europe, and other Asian countries, the Ministry of Internal Affairs and Communications (MIC) of Japan initiated a research and development (R&D) project in fiscal year 2015 to achieve a 5G system, and NTT DOCOMO and NTT have been entrusted with two projects related to that R&D. Additionally, in October 2016, MIC took steps to study the technical requirements of 5G by consulting with the Information and Communications Council and by conducting studies on securing radio frequencies for 5G. MIC began comprehensive demonstration testing of 5G (5G Field Trials [1]) in fiscal year 2017.

These Feature Articles introduce the experimental trials conducted by NTT DOCOMO and NTT Communications and explain their results [2, 3]. In this article, we describe the trial conducted by NTT DOCOMO under a project commissioned by MIC to examine the technical specifications for 5G that can achieve a data communication speed exceeding 10 Gbit/s in densely populated areas (study group GI) as part of the 5G Field Trials, and introduce examples of experimental trials carried out in the entertainment area.

2. Overview of 5G Field Trials

The 5G Field Trials are led by Japan's MIC and are being carried out in various application areas. The trial project involves six study groups, as listed in **Table 1**. The trials have started in Tokyo and other metropolitan areas as well as in rural areas. We aim to lead the world in social implementation of 5G in Japan by establishing an open environment in which

Table 1. Study groups conducting the 5G Field Trials initiated by MIC.

Study group	GI	GII	GIII	GIV	GV	GVI
Outline of trials	• Ultrahigh-resolution video streaming • Advanced city security • Remote medical services	• Entertainment for high mobility transportation	Remote operation for construction machinery	• Entertainment in stadiums • Ultrahigh-resolution video streaming	Platooning vehicles and remote operation for trucks	• Logistics • Smart office
Technological target	eMBB (enhanced mobile broadband) • 5 Gbit/s/UE; over 10 Gbit/s/BS	eMBB • 2 Gbit/s in high mobility environments	URLLC (ultra reliable and low latency communication) • Low latency communication within 1 ms (radio frame)	eMBB • 5 Gbit/s/UE; over 10 Gbit/s/BS	URLLC • Low latency communication within 1 ms (radio frame)	mMTC (massive machine type communication) • 1 million UE/km^2
Mobile velocity	Up to 30 km/h	More than 90 km/h	Up to 60 km/h		Up to 90 km/h	
Experimental environment	Densely populated urban environment	Urban or rural environment	Urban or rural environment	Indoor/closed-space environment	Urban or rural environment	Indoor/closed-space environment
Radio frequency	• 3.7-GHz band etc. • 28-GHz band	• 28-GHz band	• 3.7-GHz band etc. • 28-GHz band	• 28-GHz band	• 3.7-GHz band etc. • 28-GHz band	• 3.7-GHz band, etc., 28-GHz band, less than 1-GHz band, and unlicensed band (920-MHz and 2.4-GHz bands, etc.)

BS: base station
UE: user equipment

companies and universities around the world can participate and by contributing to international standardization activities.

NTT DOCOMO is undertaking the implementation of study group GI as part of the 5G Field Trials. We are carrying out 5G performance evaluations in densely populated urban environments with user equipment (UE) that moves at speeds up to 30 km/h to elucidate radiowave propagation characteristics in the frequency bands of 3.6–4.2 GHz and 4.4–4.9 GHz (3.7-GHz band etc.), and 27.5–29.5 GHz (28-GHz band) in Japan, and evaluating ultrahigh-speed communication using these frequency bands with the aim of introducing 5G in these bands.

Specifically, while utilizing various 5G wireless platforms, which is the result of the R&D project to realize the 5G system, we efficiently prepared an environment for the field trials that combine services and applications for the 5G era. By providing such opportunities for vertical players from the viewpoint of telecommunications carriers, we are facilitating the creation of new industries based on 5G and strengthening the competitiveness of Japanese companies, as well as encouraging collaboration between service providers, wireless platform vendors, and carriers.

Study group GI is conducting various investigations and analyses. Technical aspects such as evaluation of radiowave propagation characteristics and simulation-based evaluations on radio transmission characteristics are being evaluated by the study group, while the feasibility of services and applications using 5G (**Table 2**) are being evaluated in cooperation with various partner companies in three application areas (namely, entertainment, smart city/smart area, and medical).

3. Examples of experimental trials in the entertainment area

We conducted various experimental trials related to the entertainment area by using high-presence, high-resolution video transmission using the features of 5G ultrahigh-speed and large-capacity communication (**Fig. 1**).

Table 2. Companies participating in GI and their roles.

Companies participating in GI	Role
NTT DOCOMO	• Overall implementation and supervision of the field trials • Provision of test environment (5G Trial Site)
Fujitsu	• Experimental trial of high-resolution video transmission in densely populated indoor environments such as shopping malls • Provision of 5G wireless devices (in the entertainment area)
Huawei	• Experimental trial of communication system that projects MR images through a holographic lens • Provision of 5G wireless devices (in the entertainment area)
Ericsson	• Experimental trial of 5G transmission in densely populated environments • Provision of 5G wireless devices
Nokia	• Experimental trial of 5G transmission in populated environments and sports stadiums • Provision of 5G wireless devices (in the entertainment area)
Tobu Railway, Tobu Tower Skytree	• Promotion of experimental trial in the entertainment area • Preparation and installation of experimental environment at 5G Trial Site at Tokyo Skytree Town®
Panasonic	• Experimental trial of VR entertainment with 4K 360° live camera • Provision of wide-viewing-angle (220°) head-mounted display (in the entertainment area) and 4K close-up camera (in the medical area)
Sharp	• Experimental trial of 8K multichannel MMT transmission • Provision of 8K decoder supporting forward error correction in the application layer
Japan Display	• Experimental trial of outdoor digital signage with low-power-consumption display • Provision of 4K reflective display
NTT	• Experimental trial of high-resolution relay-camera video transmission at sports events • Provision of cooperative wireless LAN system
INFOCITY	• Experimental trial of high-resolution live-viewing service at sports events • Provision of high-resolution camera, 4K live encoder, and image switcher

LAN: local area network
MMT: MPEG (Moving Picture Experts Group) Media Transport
MR: mixed reality
VR: virtual reality

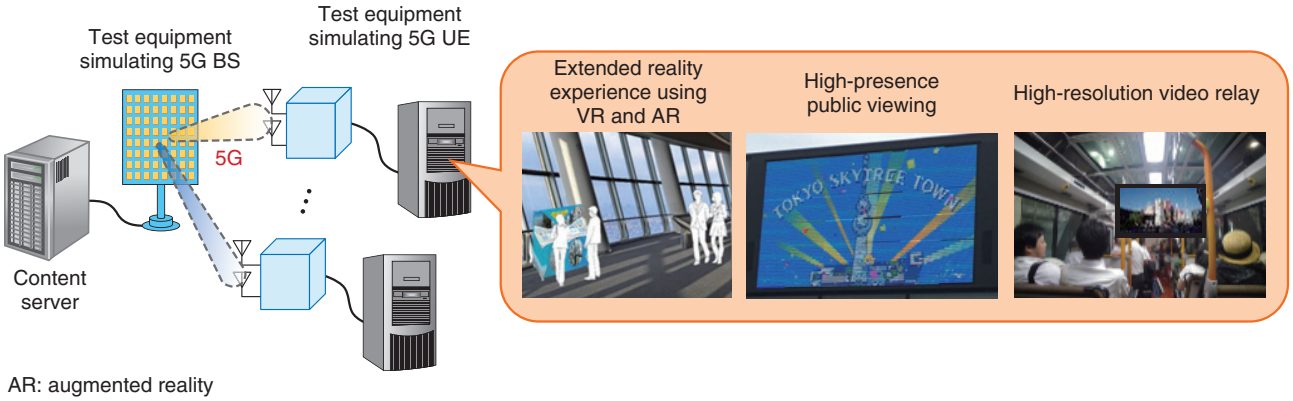

Fig. 1. Overview of experimental trial in the entertainment field.

3.1 Virtual reality (VR) entertainment system

In cooperation with Tobu Railway Co., Ltd., Tobu Tower Skytree Co., Ltd., and Panasonic Corporation, we conducted an experimental trial of a VR entertainment system (**Fig. 2**) that transmitted 5G video images at Tokyo Skytree Town® Space 634 from December 8 to 10, 2017. The 5G VR images were taken with a 4K high-resolution 360-degree live camera for viewing on a wide-viewing-angle (220°) head-mounted display. A maximum transmission bandwidth

Fig. 2. VR entertainment system.

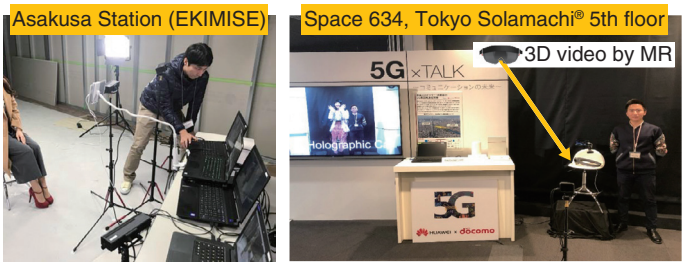

Fig. 3. New communication system utilizing MR.

of about 70 Mbit/s is required for transmission of live concert video with high presence; even so, it was possible to deliver images to multiple users in real time via 5G wireless transmission. In addition, the image transmission was kept stable by compressing the video according to the ever-changing wireless transmission condition of each user by means of a variable-rate video encoder.

It is assumed that this system will be used as a new form of entertainment by which viewers can experience the realistic feeling of being in a sports stadium or at a concert venue. About 70% of the general public who experienced the system evaluated it favorably and commented that they would like to experience live concerts remotely via the system.

3.2 New communication system utilizing mixed reality (MR)

During the same period as the demonstration described in the preceding section, in cooperation with Tobu Railway, Tobu Tower Skytree, and Huawei Technologies Japan K.K., we connected the indoor observation deck (Tembo Deck; 340 m above) of Tokyo Skytree® to the rooftop of EKIMISE of Asakusa Station via 5G, and we experimentally demonstrated a new communication style, namely, reproducing the image of a person in an area further away in three-dimensional (3D) images on a head-mounted display by using MR technology (**Fig. 3**). Although the wireless transmission conditions were challenging, (such as a long transmission distance of 1.2 km and insertion loss due to the glass covering of the Tembo Deck), a maximum transmission rate of 4.5 Gbit/s was achieved, and a 3D image of the person was successfully reproduced on the holographic display at a remote location. Real-time conversations with realistic sensations via this system are expected to be utilized for services such as bidirectional 3D

Experimental trial of 8K video multichannel MMT transmission

Experimental trial of digital signage with 4K reflective display

Construction of 5G communication environment at Sky Arena on 4th floor of Tokyo Skytree Town

Experimental trial of high-resolution video transmission using ultrahigh-density distributed antennas

Fig. 4. Experimental trials at Tokyo Skytree Town.

video transmission in anticipation of relaying sports events in the future.

3.3 Experimental trials at Tokyo Skytree Town

From March 5 to 8, 2018, we constructed experimental environments indoors and outdoors at Tokyo Skytree Town and used them to verify the feasibility of services using 5G in densely populated commercial facilities (**Fig. 4**).

In cooperation with Sharp Corporation, we conducted an experimental trial of multichannel MMT (MPEG Media Transport) transmission of 8K video via 5G, and we confirmed that stable video quality can be obtained by forward-error-correction processing in both the wireless (physical) layer and the video (application) layer. In the preliminary indoor experiments, we successfully transmitted 8K video, which requires an average transmission rate of 80 Mbit/s, on 12 channels via 5G by H.265/HEVC (High Efficiency Video Coding). This technology is expected to be applied, for example, to temporary public viewing at various events.

In cooperation with Japan Display Inc., we installed a low power consumption reflective display outdoors and used it to experimentally demonstrate digital signage in a commercial area. In this test, 4K resolution was achieved by tiling four displays, and high-resolution video content—assumed to consist of advertisements—was transmitted from the base station (BS) and sequentially displayed. Consequently, we confirmed that it was possible to display sufficient contrast and color reproducibility without degrading image quality under outdoor light. Through a questionnaire targeting general tourists, we obtained positive feedback on the natural appearance peculiar to a reflective display. In the future, it is expected that combining such a device with 5G UE will enable flexible installation of digital signage without the need for cables (i.e., an AC (alternating current) power supply).

In cooperation with Fujitsu Limited, we deployed 5G ultrahigh-density antennas in an indoor model of a commercial facility, and we conducted a test to transmit 4K high-resolution video to UE assumed to be displaying product information at shopping malls. We experimentally demonstrated simultaneous high-resolution video transmission to multiple UE devices in motion (i.e., devices held by numerous pedestrians

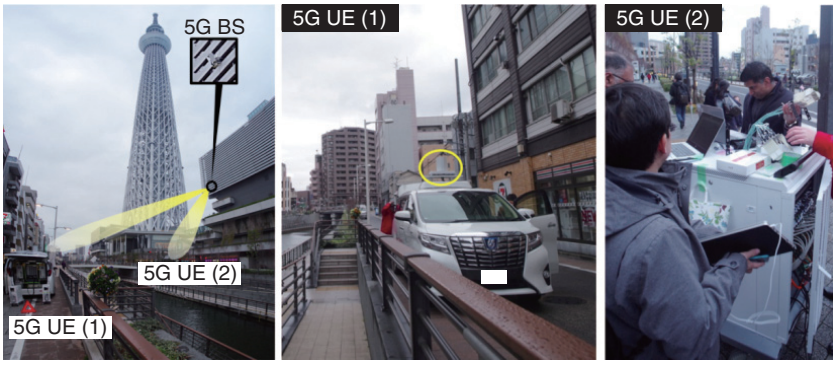

Fig. 5. Radio transmission test at 5G Trial Site.

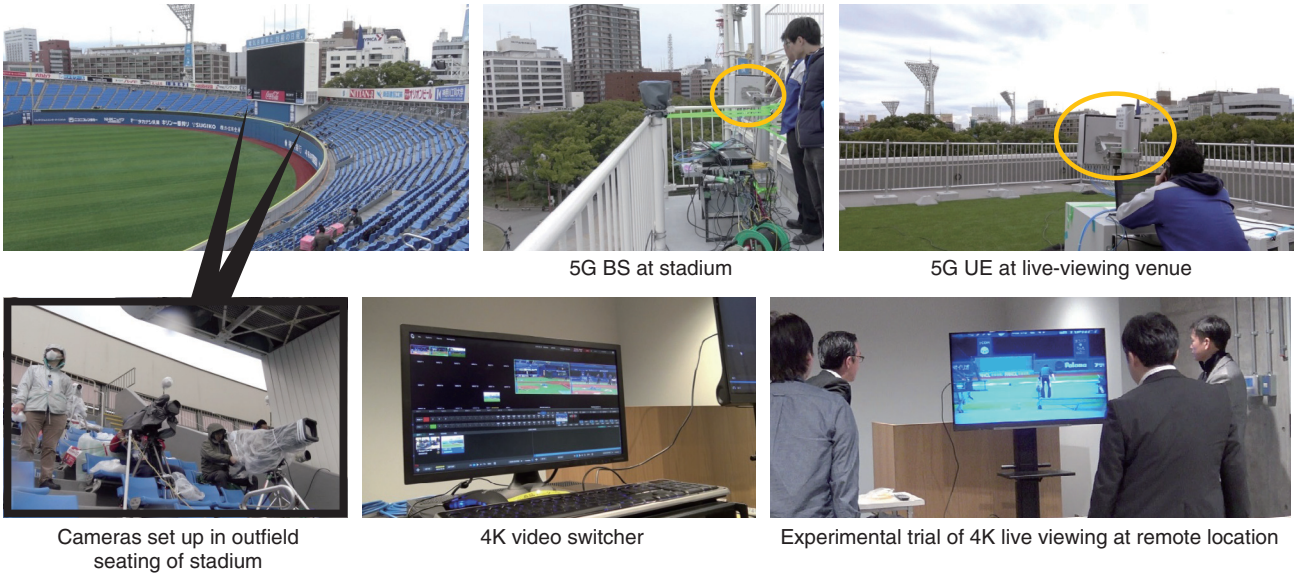

Fig. 6. Experimental trial of live viewing of sports events.

walking around), and we confirmed that it was possible to stably transmit video by employing dynamic virtual cell technology using cooperative control of the distributed antennas even in complex structures with uneven shapes.

3.4 Wireless transmission test at 5G Trial Site

From March 19 to 20, 2018, a 5G wireless transmission test was conducted at a 5G Trial Site constructed at Tokyo Skytree Town by NTT DOCOMO (**Fig. 5**). The major specifications of the radio devices were as follows: the center frequency was 27.9 GHz, the bandwidth was 730.5 MHz, and there were two units of 128 antenna elements for BSs and 8 antenna elements for UE.

We measured a maximum throughput of 10.2 Gbit/s when two users in outdoor environments were simultaneously connected, and we confirmed that ultrahigh-speed and large-capacity communication was possible in the actual field.

3.5 Experimental trial of live viewing of sports events

On March 19, 2018, we conducted an experimental trial of a 4K high-resolution live-viewing service of a sports event at a stadium (**Fig. 6**).

In this trial, large data of high-resolution videos captured by cameras installed in the stadium were

transmitted to a remote area in real time with low latency using 5G, and we demonstrated the prospect of providing entertainment services that enable viewers to experience watching events with a feeling of being there at the same time not only within the stadium facilities but also in the space outside them.

More specifically, images captured by three 4K high-resolution relay cameras installed in the outfield seats of the stadium were transmitted to a 5G BS installed near the stadium's centerfield screen via a cooperative wireless LAN (local area network) system and passive optical network provided by NTT Access Network Service Systems Laboratories and then retransmitted from there to the facilities outside the stadium via 5G.

Moreover, in cooperation with INFOCITY, INC., we constructed a 4K live-viewing system by which the multiple high-resolution videos transmitted by 5G were converted by a 4K video switcher for viewing on a large monitor at the live-viewing site. We confirmed that even outside the facility in places located far from the stadium, viewers were able to experience watching an event in real time just as it was being experienced in the stadium itself, and that it was possible to greatly reduce the time needed for setting up the service by using wireless transmission, as compared to that needed by a conventional system.

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Trademark notes

Yukihiko Okumura
Senior Manager, 5G Laboratories, NTT DOCOMO, INC.

He received a B.S. and M.S. in electrical engineering from Tokyo University of Science in 1989 and 1991, and a Ph.D. in engineering from Tohoku University, Miyagi, in 2006. In 1991, he joined NTT Radio Communication Systems Laboratories. Since 1992, he has been engaged in the research, standardization, and development of wideband/broadband mobile radio communication technologies, terminals, and systems at NTT Mobile Communications Network, Inc. (now NTT DOCOMO, INC.). He is currently involved in researching 5G system technologies. He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE).

Satoshi Suyama
Manager, 5G Laboratories, NTT DOCOMO, INC.

He received a B.S. in electrical and electronic engineering, an M.S. in information processing, and a Dr. Eng. in communications and integrated systems, all from Tokyo Institute of Technology, in 1999, 2001, and 2010. From 2001 to 2013, he was an Assistant Professor in the Department of Communications and Integrated Systems at Tokyo Institute of Technology. He has been engaged in research on OFDM (orthogonal frequency division multiplexing) mobile communications systems and applications of adaptive signal processing, including turbo equalization, interference cancellation, and channel estimation. In April 2013, he joined NTT DOCOMO and has been involved in research and development of 5G systems. He received the Young Researchers' Award from the Institute of Electronics, Information and Communication Engineers (IEICE) in 2005, the Best Paper Prize from the European Wireless Technology Conference (EuWiT) in 2009, the Paper Award from IEICE in 2012, and the Best Paper Award from International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC) in 2016. Dr. Suyama is a member of IEEE and IEICE.

Jun Mashino
Manager, 5G Laboratories, NTT DOCOMO, INC.

He received a B.E. in electrical and electronic engineering and an M.E. in communications and computer engineering from Kyoto University in 2003 and 2005. He joined NTT Access Network Service Systems Laboratories in 2005. He has been engaged in the research and development of intelligent interference compensation technologies and signal processing for future wireless communications systems. Since 2016, he has been working as a research engineer at NTT DOCOMO 5G Laboratories. His current interests include wireless transmission technologies for 5G systems. He received the IEICE Young Researchers' Award in 2009 and the APMC 2014 Prize at the Asia-Pacific Microwave Conference in 2014. He is a member of IEEE and IEICE.