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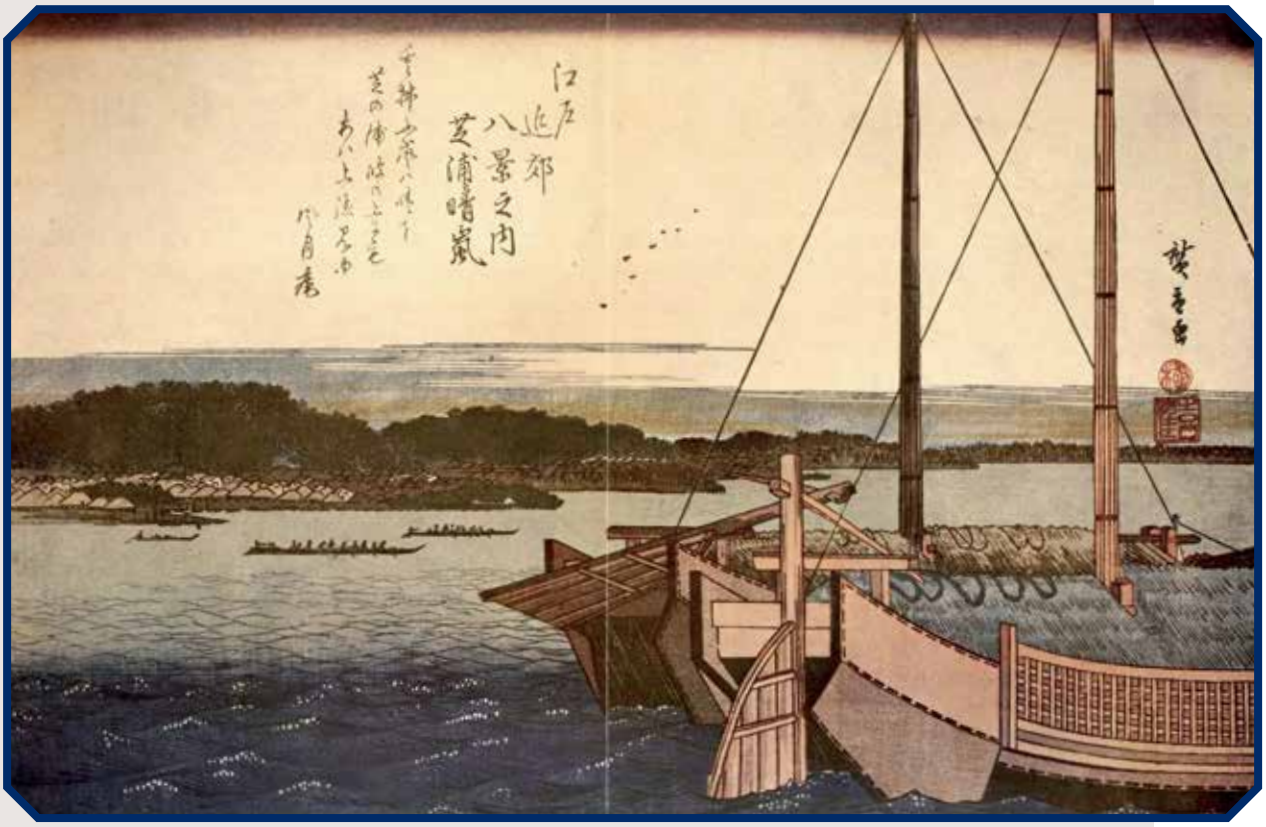

New Year Messages

From the Minister for Internal Affairs and Communications, Secretary-General of ITU, President of ITU-AJ

Special Feature

Field Trials of Fifth Generation Mobile Communications System (5G)

General Outline of 5G Field Trials
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Promotion of 5G Field Trials and Reflections

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About ITU-AJ

The ITU Association of Japan (ITU-AJ) was founded on September 1, 1971, to coordinate Japanese activities in the telecommunication and broadcasting sectors with international activities. Today, the principle activities of the ITU-AJ are to cooperate in various activities of international organizations such as the ITU and to disseminate information about them. The Association also aims to help developing countries by supporting technical assistance, as well as by taking part in general international cooperation, mainly through the Asia-Pacific Telecommunity (APT), so as to contribute to the advance of the telecommunications and broadcasting throughout the world.

2021 New Year Remarks from Minister Takeda

TAKEDA Ryota
Minister for Internal Affairs and Communications

Happy New Year to all!

I was appointed Minister for Internal Affairs and Communications in September of last year, and as such, take responsibility for various issues in the fields within its jurisdiction.

This includes many fields closely related to citizens' daily lives, and many policies underlying our new vision for society and social structures. We are working to produce results with solutions to issues, looking calmly and thoroughly at whether policies are appropriate for daily life from the perspective of citizens, with plans both to handle the COVID-19 pandemic and to revitalize regional economies, building a high-quality economy and society suitable for the post COVID-19 era.

For the "new normal," building information and communications infrastructure to support teleworking, remote learning, and telemedicine will be essential. We are working to consolidate national 5G and optical fiber networks quickly, and to promote the development and spread of Local 5G, which will contribute to solving regional issues.

Regarding fees for mobile phones, which are a life necessity for citizens, operators are announcing new, low-cost plans and the range of choices is expanding, but we continue to push hard so that citizens have a real sense that they are benefiting from lower prices, by promoting a fair competitive environment based on the Action Plan announced last year.

As all of society undergoes the current digital reformation, we must also ensure that everyone is able to benefit from it. We are providing comprehensive support to build an environment in which all citizens can handle digital devices to obtain and use the information they need.

To assure that citizens can use digital technology, it is extremely important to ensure safety, security and reliability in cyberspace. To do so, we are building an environment for integrated analysis of cybersecurity information and training for related personnel. We have a strategy to develop advanced technologies intensively, such as quantum encrypted communication.

How each and every citizen uses digital technology is also important. In particular, defamation of people on the Internet must not be allowed. We are taking comprehensive measures, including educational activities to improve information ethics and ICT literacy and developing policies to prevent online defamation.

At the same time, we are gathering the knowledge and intelligence of government and the private sector, establishing R&D infrastructure for 5G and "Beyond 5G" technologies, and strengthening the base for research and development on advanced technologies such as quantum encrypted communication and AI simultaneous translation, to improve industrial competitiveness in the post-COVID-19 world. To also encourage Japanese companies to run business in the global market, we will promote the acquisition of intellectual property and the international standardization of R&D results.

To contribute to the global digital revolution, we are also planning to bridge digital divides with 5G and submarine optical cables, and fostering international shared understandings regarding the use of AI, the free flow of data, and other issues.

We are also supporting circulation of broadcast content overseas, bringing the fascination of rural areas to the world. In fields broadly related to citizens' daily lives, such as postal service, fire prevention, government offices and statistics, the Ministry of Internal Affairs and Communications is also mobilizing policy resources to promote international development.

The Ministry of Internal Affairs and Communications is actively working to enable all of society through ICT, to realize the services that our citizens have come to expect, and to create a society in which the benefits of digitalization can truly be felt. Based on basic policies decided at the end of last year, we will continue collaboration to establish a digital agency as planned for this year, and to promote cooperation regarding digital-related policies with all related ministers.

I would like to extend New Year's greetings to all and wish everyone good health and happiness through the coming year!

New Year's Day, 2021

New Year's message from ITU Secretary-General "The path towards a safer, more sustainable, and better-connected digital future for all"

Houlin Zhao
Secretary-General
International Telecommunication Union

Dear Friends of ITU in Japan,

The year behind us was particularly challenging due to the COVID-19 pandemic, which has cost countless lives and placed enormous strain on socio-economic conditions worldwide.

2020 was also a year where information and communication technologies (ICTs) took centre stage. I have seen first-hand how central ICTs were to the important discussions that have taken place in the last several months, be it at the 75th session of the United Nations General Assembly, at the G20 meetings of ICT, finance and health ministers or at the Ministerial Council Meeting of the Organization for Economic Cooperation and Development (OECD).

The new circumstances brought about by COVID-19 have dramatically illustrated the vital importance of ICTs and broadband connectivity for societies and economies everywhere.

But the pandemic has also revealed stark inequalities in access to ICTs, reminding us of the digital divide that still prevents 3.6 billion people around the world from benefiting from the digital technologies and services that have proved so essential during the pandemic.

Now more than ever, ICTs are key to achieving the UN Sustainable Development Goals (SDGs) and tackling the world's most pressing challenges, including COVID-19. And Japan has a prominent role to play in this effort.

I commend the Ministry of Internal Affairs and Communications of Japan for its support of ITU's Connect2Recover initiative, which helps countries recover from COVID-19 by expanding access to affordable and reliable connectivity, with an initial focus on hard-hit and least well-connected African countries.

Japan has been a member of ITU for more than 140 years and has been elected to the ITU Council on every occasion since 1959. We at ITU are grateful for Japan's active participation in our activities, from harmonizing the use of the radio-frequency spectrum and satellite orbits to developing international standards enabling next-generation technologies to assisting developing countries with infrastructure and policy development.

As we look to the year ahead of us, not only do we need to connect the unconnected, but we also need to upgrade our services with new technologies such as 5G, cloud computing, AI, and many more.

Japan has long been a global source of ICT innovation and a leader in important and emerging areas of ITU's work, from space to AI to 5G. I was pleased to see several operators launch 5G services in Japan in 2020.

5G services will see the advent of new applications in areas as diverse and promising as automated vehicles, telemedicine, smart cities, and collaborative robotics, to name a few. Already during COVID-19, we have seen innovative applications of 5G in fields such as health, education, finance, and transportation.

In these critical and challenging times, Japan serves as an example for other countries to follow.

I would like to thank the government of Japan for its role in the development of ICTs and its significant financial support to ITU. My thanks also go to the many Japanese companies that are Sector Members of ITU, and to our Japanese Academia Members. Both provide ITU with valuable technical expertise. And thank you to the ITU Association of Japan for its continued support to our organization.

In 2021, Japan will host the Summer Olympic Games in Tokyo. I am confident that these Games will showcase Japan's ICT innovation capabilities and will offer the world great hope for the future.

In 2021, ITU will also convene its World Telecommunication Development Conference for the first time on the African continent in Addis Ababa in Ethiopia. It will be the opportunity to mobilize the global community around digital transformation in support of the SDGs.

With only 10 years left to achieve these goals and amidst an unprecedented crisis, leveraging ICTs for inclusive development is more important than ever before.

I call on all our Japanese Members and friends of ITU in Japan to rise to the challenge and help us use this moment to build a safer, more sustainable, and better-connected digital future for all.

I wish you all a healthy, peaceful, and happy 2021!

Welcoming a New Year

Tetsuo Yamakawa
President
The ITU Association of Japan

Sincere wishes for a Happy New Year!

I assumed the position of President in December of last year, and I hope you will all continue to support me as you did the previous President, Toshiyuki Minami.

In 2020, the global spread of the new coronavirus pandemic had a great effect on social and economic activity, and it is still not subsiding around the world. The contagion has also spread in Japan, through urban and rural areas alike, and although measures to prevent the spread continue, businesses have had to adjust to the corona era, with remote work, staggered work hours and online meetings in wide use. We hope that the New Year will be a good one, full of vitality.

Reflecting back on the year, meetings and events with the ITU and APT that we were involved in last year were also affected. The ITU-T SG9 assembly (Japan) planned for April was suspended, ITU Telecom World (Vietnam) in September and WTSA (India) in November were postponed, and the APT General Assembly/Management Committee (Japan) in December were held virtually. Under these circumstances, Katsunori Kondo was elected the secretary general of APT at the General Assembly in December. May I offer my congratulations, and best wishes for these activities in the future.

On October 6, we held the "Celebration of World Telecommunication and Information Day." This is normally held in May each year, but was postponed to October and scaled down due to the pandemic. In the ceremony, Yushi Naito, who has been involved in international standardization activities with ITU-T for many years, received the MIC Minister's Award, and Kazuko Ito, who has contributed to building an inclusive society through para-sports using ICT technology, received a Special Achievement Award. Accomplishment Awards were also given to 18 other people and two organizations, and Encouragement Awards were given to 18 people and one organization. Congratulations to all who received awards. In November and December, the first online APT training course was also held.

This year, we are anticipating expansion of the next-generation 5G commercial services, which were launched last year in Japan. With the corona plague, we have strong hopes that we will solve societal issues and leap toward Society 5.0, through 5G and other ICT technologies. There are also plans to hold the Olympics and Paralympics this summer, postponed from last year. We hope that, with enough preparation, this event anticipated the world over, will be held, putting the spotlight on all of Japan.

In ITU events, the postponed World Telecom (Vietnam) is scheduled for October, and WTDC (Ethiopia) is scheduled for November. It is expected that real events will be difficult, but based on previous experience, we are being flexible with preparations and cooperating with everyone involved in ITU and APT meetings and events.

This year, we will reach 50 years since our association was founded. I would like to thank all of you for your support, and for the future, it is my desire to work even harder, to mediate among all of our members, the Japanese Government, and the ITU.

I wish you all a Happy New Year, and for your health and vitality for the coming year.

Celebration of World Telecommunication and Information Day (October 6, 2020)

General Outline of 5G Field Trials

Marubashi Hirohito
Assistant Director
New-Generation Mobile Communications Office
Land Mobile Division, Radio Department
Telecommunications Bureau
Ministry of Internal Affairs and Communications

1. The start of commercial 5G services

In March 2020, mobile phone carriers began offering commercial 5G (5th generation mobile communication system) services. The three main benefits of 5G are that it enables ultra-high speed communication, has ultra-low latency, and supports multiple simultaneous connections. It is expected that these benefits will enable the development of completely new services, such as allowing people to view realistic live images of remote locations like tourist spots and sports stadiums from various different angles.

In particular, 5G is the only technology that supports ultra-low latency and multiple simultaneous connections. The former allows real-time communication to be implemented with low delays, while the latter makes it possible to connect multiple IoT devices at the same time (Figure 1). Applications that take advantage of these features are being considered for use in various industrial fields, such as automatic farm management in agriculture, smart factory applications in the manufacturing industry, and the remote control of construction machinery in the construction industry.

2. 5G Field Trials

The Ministry of Internal Affairs and Communications (MIC) has promoted efforts aimed at the realization of 5G, including research and development, international cooperation and standardization, allocation of frequencies to 5G, and the formulation of technical standards. As a part of this, with the aim of creating new markets through the realization of 5G, a three-year program of 5G Comprehensive Demonstration Tests (hereinafter referred to as "5G Field Trials") was performed from FY2017 through FY2019 with the participation of stakeholders from various fields related to the use of 5G technology (Figure 2). In this article, we look back on the achievements of this program.

In the first year (FY2017), mobile phone operators proactively selected multiple themes and locations in which 5G is envisaged to be used in practice, and performed technical studies relating to the benefits of 5G with regard to speed, latency and connectivity.

In FY2018, 5G technical verification and performance evaluation tests were conducted for various use cases based on eight issues identified by the ICT Infrastructure Regional Development Strategy Study Group of the Ministry of Internal

Figure 1: What is the 5th generation mobile communication system (5G)?

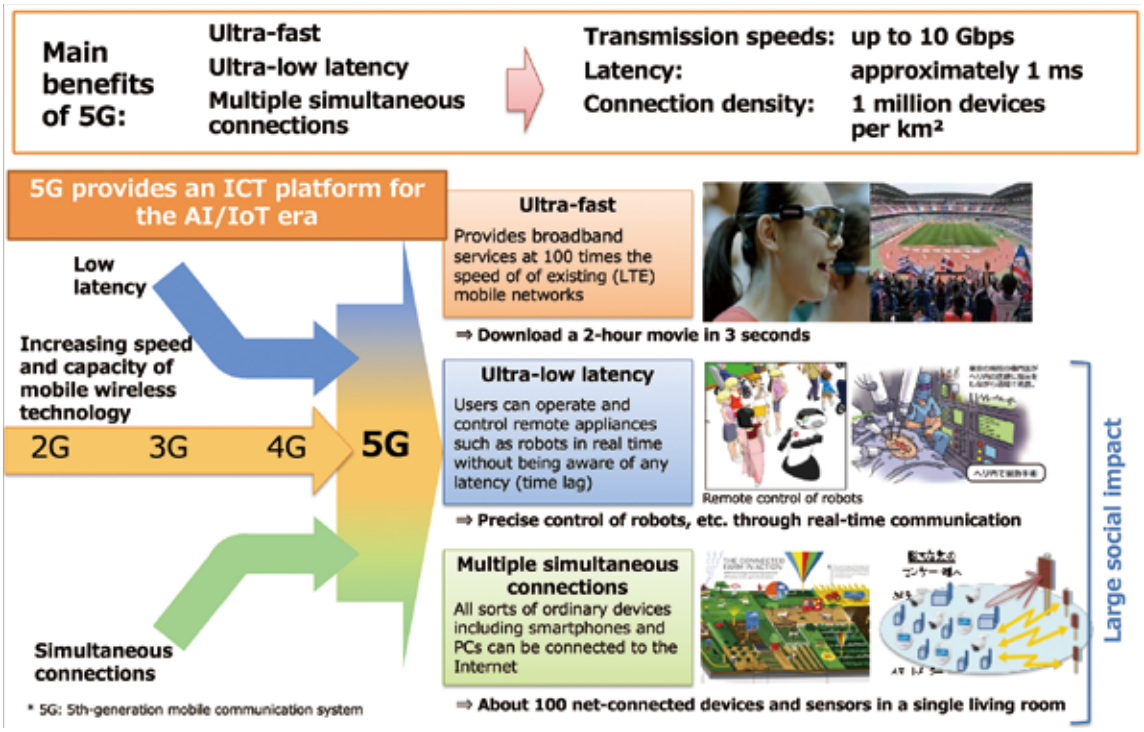


Figure 2: Implementation status of 5G Field Trials

- In the first year (FY2017), technical verification of the fields in which the use of 5G was envisaged were investigated based on themes that business operators wanted to implement.
- In the second year (FY2018), technical verification and performance evaluation tests were conducted for various use cases based on eight issues identified by the ICT Infrastructure Regional Development Strategy Study Group. In addition, a 5G Utilization Idea Contest was held to attract proposals for verification tests based on regional ideas.
- The third year (FY2019), which is the third year of this project, based on the results of previous technical verifications and the Idea Contest, we are working with regional business partners to implement comprehensive verification focused on utilization models that use 5G to address regional issues.

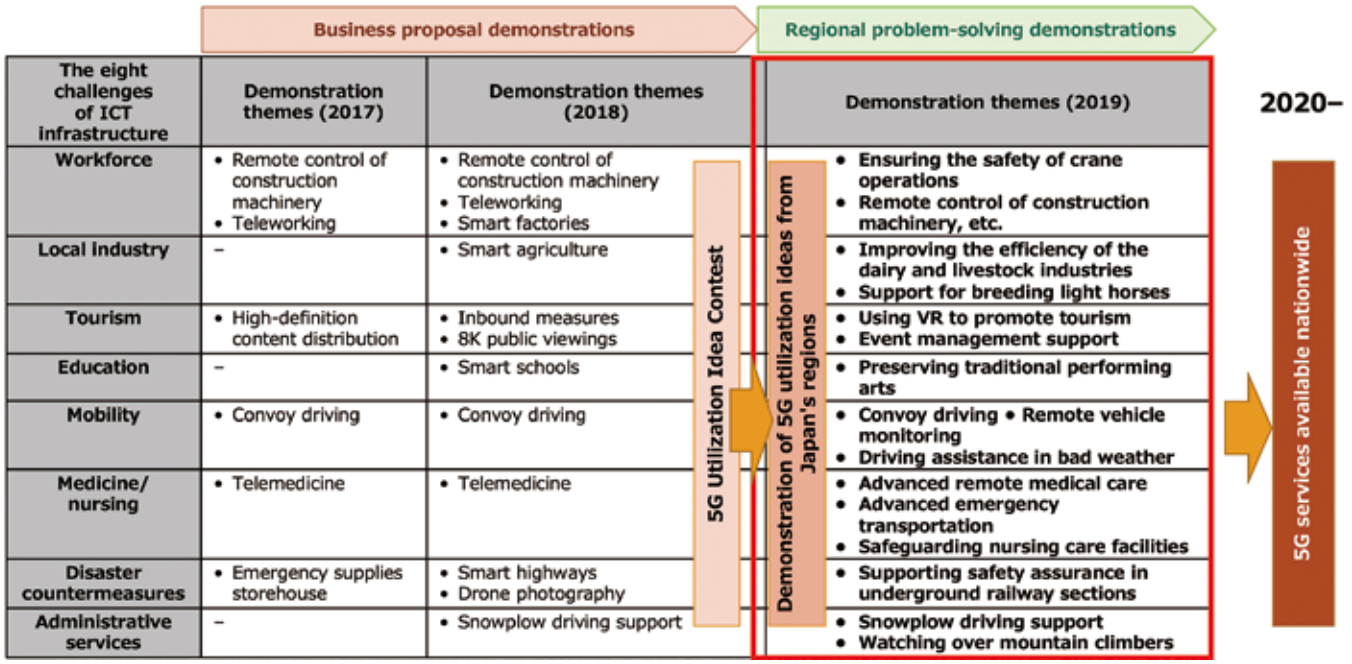
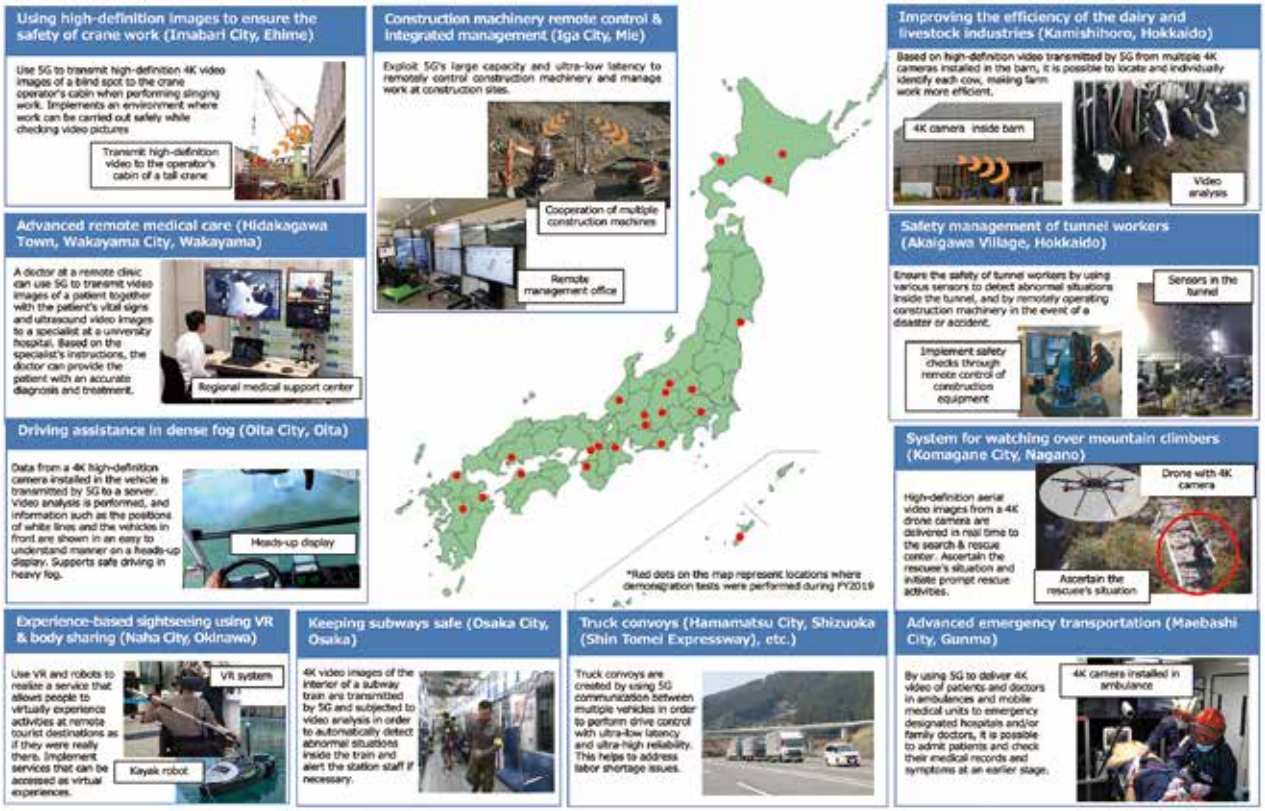


Figure 3: Outline of 5G Field Trials (FY2019)

Technology classification	Technical goals	Main tasks	Main venues	Main implementers
Ultra-fast, large capacity	Implement ultra-fast communication (average 4–8 Gbps per base station) in an environment with multiple base stations and terminals	(1) Using high-definition images to ensure the safety of crane work (2) Watching over and monitoring the behavior of care home residents (3) Editing and relaying video on the cloud in real time (4) Preserving traditional performing arts (through remote education) (5) Supporting hearing-impaired people by visualizing sounds (6) Using VR and Body Sharing technology for experience-based sightseeing (7) Advanced remote medical care (8) Advanced emergency transportation	(1) Ehime prefecture (2) Hiroshima City (3) Sendai City (4) Tono district, Gifu (4) Tono district, Gifu (6) Naha City, Okinawa (7) Wakayama City, Wakayama etc. (8) Maebashi City, Gunma	NTT DOCOMO (1) Ehime University (2) SOMPO Holdings (3) Sendai Television (4) CBC Creation (5) Sun (6) H2L (7) Wakayama Prefecture (8) Maebashi City
	Implement ultra-fast mobile communications at average speeds of over 1 Gbps per base station in an environment with multiple base stations and terminals	(1) Dealing with snow damage (more efficient snow removal) (2) Driving assistance in dense fog (3) Providing assistance for golfers (4) Supporting safety assurance in underground railway sections	(1) Eiheiji Town, Fukui (2) Oita prefecture (3) Nagano City (4) Osaka City, etc.	NTT Communications (1) Eiheiji Town (2) Oita prefecture (3) MIRAIT (4) ITOCHU Techno-Solutions
	Implement ultra-fast communication indoors with an average terminal uplink speed of over 300 Mbps	(1) Creating a sense of unity between sports players and spectators (2) Improving the efficiency of the dairy and livestock industries (3) Support for breeding light horses	(1) Higashi Osaka City, Osaka (2) Kamishihoro, Hokkaido (3) Niikappu, Hokkaido	Advanced Telecommunications Research Institute International (1) Jupiter Telecommunications (2) Tokachi Murakami Ranch (3) Hidaka Keishuba Kyoudou Ikusei Kousha
Ultra-low latency	Implement highly reliable low-latency communication with transmission times of 10 ms end-to-end and 1 ms between wireless cells when moving at high speed	(1) Evacuation guidance and traffic control in the event of a disaster (2) Remote monitoring and remote control of truck convoys	(1) Kitakyushu City, Fukuoka (2) Hamamatsu City, Shizuoka etc.	Wireless City Planning (1) Nippon Signal (2) Advanced Mobility
	Support the needs of users while providing ultra-fast low-latency communication (average uplink speed 300 Mbps) in an environment with multiple base stations and terminals	(1) Watching over mountain climbers (2) Sports (slacklining) event management support (3) Using VR to promote tourism (4) Remote control and integrated construction management system for construction machinery	(1) Komagane City, Nagano (2) Obuse Town, Nagano (3) Minamiaso Village, Kumamoto (4) Iga City, Mie	KDDI Corporation (1) Shinshu University (2) Goolight (3) Tokai University (4) Obayashi Corporation
Many Simultaneous connections	Implement communication with support for simultaneous connection requests from a large number of terminals	(1) Safety management of tunnel workers (2) Using visualization to improve the efficiency of logistics	(1) Hokkaido (2) Nerima-ku, Tokyo	Wireless City Planning (1) Taisei Corporation (2) Nippon Express Co., Ltd.

Projects shown in blue are based on the 5G Utilization Idea Contest

Figure 4: 5G Field Trials around Japan (FY2019)



Affairs and Communications. The ministry also organized a 5G Utilization Idea Contest with the aim of soliciting unique ideas from around Japan that provide solutions to various local problems. A total of 785 entries were received during October and November 2018. In December of the same year, primary screening was performed by the ministry's Regional Bureaus of Telecommunications and Offices of Telecommunications (11 locations nationwide), and in January 2019, the leading proposals selected in primary screening were entered into a contest (secondary screening) held at the Ministry of Internal Affairs and Communications. In the secondary screening, presentations were made by each proposer, and as a result of examination by a panel of judges, the overall grand prize was awarded to an entry from Shikoku, which proposed exploiting the characteristics of 5G to provide a better working environment, safer working conditions, and the transfer of skills from highly skilled workers (proposer: Distributed Processing Systems Laboratory, Ehime University Graduate School of Science and Engineering). Other proposals also received awards, including the 5G Characteristic Utilization Award and the Regional Problem-Solving Award.

In FY2019, based on the results of previous technical verification and the results of the 5G Utilization Idea Contest, we conducted demonstrations at 23 locations nationwide with an emphasis on models that use 5G to help solve local issues (Figures 3, 4).

The implementation status of the 5G Field Trials in FY2019 is introduced below.

For example, based on Ehime University's prize-winning idea mentioned above, NTT DOCOMO entered into a joint verification trial aimed at ensuring the safety of crane operations through the use of high-definition images at a shipyard in Imabari City, Ehime Prefecture. To operate a shipyard crane more safely, ultra-fast high-capacity 5G communication was used to transmit high-definition video images of a crane's blind spot to the crane operator's cabin, thereby eliminating the blind spot and providing a safe work environment where the crane can be operated safely while checking this video.

KDDI Corporation and others demonstrated a remote control and integrated construction management system for construction machinery in Iga City, Mie Prefecture. This uses 5G's ultra-low latency communication to resolve worker shortages and observe working conditions in real time by using remote control of construction machinery and management of construction work at a site where roadbuilding at a dam construction site was being simulated.

Also, a group including a company called Wireless City Planning demonstrated the provision of safety management for tunnel workers in Akaigawa Village, Hokkaido. Using 5G's support for multiple simultaneous connections, they made it possible to detect anomalies inside the tunnel with environment sensors during tunnel engineering works, and by performing remote operation of construction machinery in the event of a disaster or accident, they were able to ensure the safety of workers.

The Ministry of Internal Affairs and Communications has also been working on publicity and advertising related to 5G, including holding the 5G International Symposium 2020 in February 2020 in order to publicize the results of the 5G Field Trials in 2019 in Japan and around the world.

3. The deployment and evolution of 5G

To make 5G available throughout Japan, it will be necessary to set up as many 5G base stations as possible. Here, we introduce the frequency allocations for 5G.

On April 10, 2019, the Ministry of Internal Affairs and Communications allocated frequencies for 5G to four mobile phone carriers (planning and accreditation of specific base stations). In the 3.7 and 4.5 GHz bands, NTT DOCOMO was allocated 200 MHz of bandwidth (3600–3700 MHz and 4500–4600 MHz), KDDI Corporation and Okinawa Cellular Telephone Co., Ltd. were allocated 200 MHz (3700–3800 MHz and 4000–4100 MHz), 100 MHz (3900–4000 MHz) was allocated to SoftBank Corp., and 100 MHz (3800–3900 MHz) was allocated to Rakuten Mobile Inc. In the 28 GHz band, NTT DOCOMO was allocated 400 MHz of bandwidth (27.4–27.8 GHz), KDDI Corporation and Okinawa Cellular Telephone Co., Ltd. were allocated 400 MHz (27.8–28.2 GHz), SoftBank Corp. was allocated 400 MHz (29.1–29.5 GHz), and Rakuten Mobile Inc. was allocated 400 MHz (27.0–27.4 GHz).

To promote early deployment, the Ministry of Internal Affairs and Communications obliged each mobile phone operator to begin offering 5G services in all prefectures within two years when allocating frequencies for 5G in April 2019. To promote the broad expansion of 5G services across the entire country, these deployment guidelines divided the whole of Japan into a grid of 10 km squares, and evaluated the performance of 5G providers in terms of the number of squares in which they had deployed 5G base stations with advanced characteristics. According to the preparation plans of each mobile phone operator, 5G will have been deployed across 98% of the country by the end of FY2023, by which time 5G networks are expected to be deployed throughout the whole of Japan, including rural areas. 5G is expected to be rapidly deployed nationwide as a core infrastructure for the 21st century, which is indispensable for regional development.

4. Local 5G

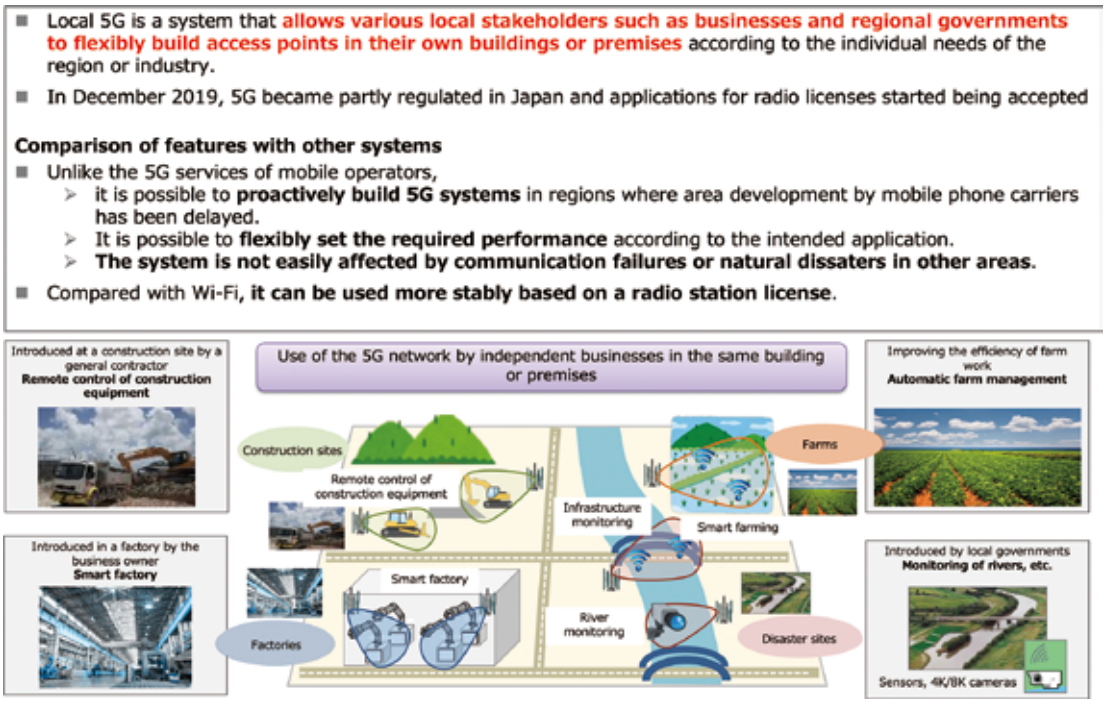
Ministry of Internal Affairs and Communications is promoting an initiative called Local 5G, whereby organizations such as local companies and local governments can flexibly deploy and use 5G hotspots in their respective buildings and premises according to the individual needs of the region and industry (Figure 5).

In FY2020, to enable local businesses and other organizations to solve regional issues through the use of Local 5G, Local 5G technical verification tests were performed in use cases assuming a diverse variety of Local 5G base station installation locations and usage environments, and through these verification tests, development demonstrations are being performed in which Local 5G is used to construct regional problem-solving models. In FY2020, demonstrations are being performed to address issues in the fields of primary industries (agriculture, fisheries), factories, infrastructure/mobility, tourism/culture/sports, disaster prevention/crime prevention, work style reform, and medicine/healthcare.

Through these efforts, the Ministry of Internal Affairs and Communications will continue to make a concerted effort to promote the development of 5G infrastructure and the promotion of 5G applications including Local 5G.

Finally, in order to solve regional issues with 5G, in addition to the knowledge of telecommunications carriers and equipment vendors, it is also essential to consider the viewpoints and ideas of 5G end-users. It is hoped that knowledge gained from the 5G Field Trials will be put to good use and that 5G will become more widespread and popular through the cooperation of various stakeholders including telecommunications carriers, equipment vendors, and end-users.

Figure 5: Overview of Local 5G



Field Trial Group 1 Field trials of Use Cases Employing 5G Ultra-fast Communication in Outdoor Environments

Field Trial Group 2 Field trials of Use Cases Employing 5G Ultra-fast Communication in Mobile Environments

Takashi OKADA
Senior Manager
6G Laboratories
NTT DOCOMO, INC.

Masanori Ichinose
Senior Manager
Solution Services Division
NTT Communications Corporation

1. Introduction

As part of the FY2019 5G Comprehensive Demonstration Tests (hereinafter referred to as "5G Field Trials") initiative of the Ministry of Internal Affairs and Communications[1], NTT DOCOMO and NTT Communications have joined forces to perform field trials of use cases exploiting the benefits of 5G communications[2]. Specifically, we performed an investigation of technical criteria relating to 5G mobile communication systems that facilitate ultra-fast communication at an average of 4–8 Gbps in outdoor environments populated by many base stations and terminals (referred to as use cases involving ultra-fast 5G communication in outdoor environments), and an investigation of the technical criteria relating to 5G mobile communication systems that facilitate high-speed mobile communication at average speeds of over 1 Gbps in mobile communication involving many base stations and terminals (referred to as use cases involving ultra-fast 5G communication in mobile environments). This article introduces the main field trial results.

2. Field trials of use cases exploiting ultra-fast 5G communication in outdoor environments

Field Trial Group 1 NTT DOCOMO, Inc.:
Takashi Okada, Kentaro Fujii, Tomoaki Minamida, Shunsuke Nakamura, Yoshifumi Morihiro, Kensuke Takahashi, Satoshi Suyama, Yukihiko Okumura

Of the field trials conducted in FY2019, we discuss here the field trials conducted with partners regarding use cases where 5G ultra-fast communication is applied to the five fields shown in Table 1. The technical goal of these field trials was to achieve ultra-fast communication at average speeds of 4–8 Gbps in outdoor environments with multiple base stations and multiple terminals.

2.1 Field trials of a real-time cloud editing/relay solution using 5G

In December 2019, we conducted a verification trial in Sendai City, Miyagi Prefecture using the 4.5 GHz band in DOCOMO's 5G pre-service area with a view to implementing a service that facilitates video transmission and video editing over a 5G network during a live event broadcast. In this field trial, 5G was used to seamlessly deliver live video (about 24 Mbps) from four cameras at a remote outdoor

Table 1: List of field trials

Utilization field	Use case	Frequency band	Implementers/partners
Entertainment	Real-time cloud editing/relay solutions*	4.5 GHz	NTT DOCOMO, Inc., Sendai Television, Sony Business Solutions
Offices/workplaces	Ensuring the occupational safety of highly skilled workers*	28 GHz	NTT DOCOMO, Ehime University, Asakawa Shipbuilding, Sumitomo Heavy Industries Transport Systems, Ehime Prefecture
Medicine	Advanced mobile telemedicine	4.5 GHz	NTT DOCOMO, Wakayama Prefecture, Wakayama Medical University, Tokyo Women's Medical University
Smart House/Life	Traditional performing arts instruction (distance learning)*	28 GHz	NTT DOCOMO, CBC Creation, Chubu Nippon Broadcasting, CBC Television
Traffic	Supporting people with hearing impairments by visualizing sounds*	28 GHz	NTT DOCOMO, Sun Electronics

* Projects that won the top prize in the 5G Utilization Idea Contest held by the Ministry of Internal Affairs and Communications in 2018[3]

Figure 1: Field trials of a real-time cloud editing/relay solution using 5G

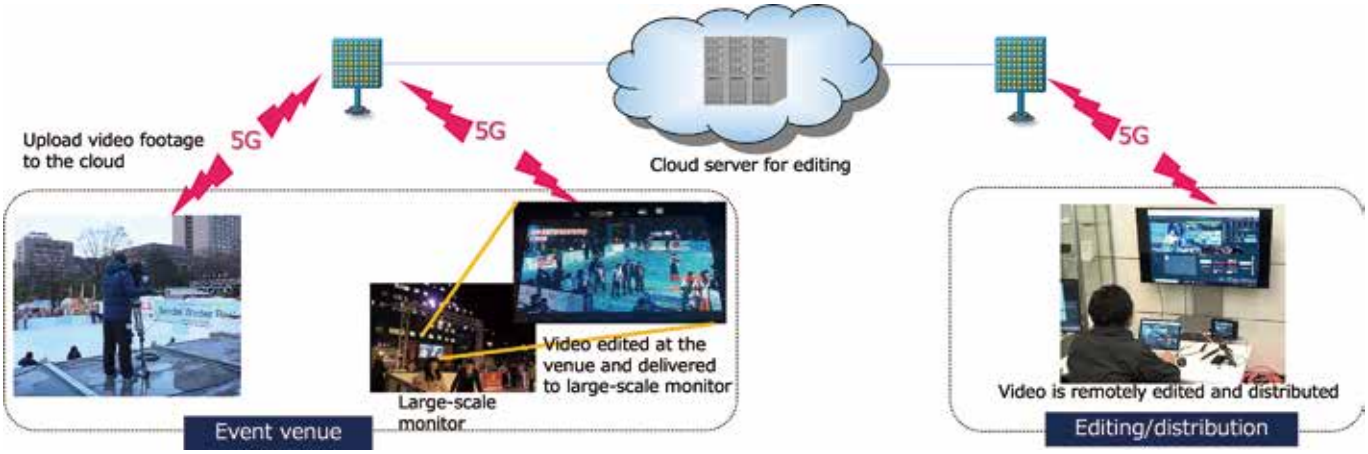


Figure 2: Editing and switching at locations away

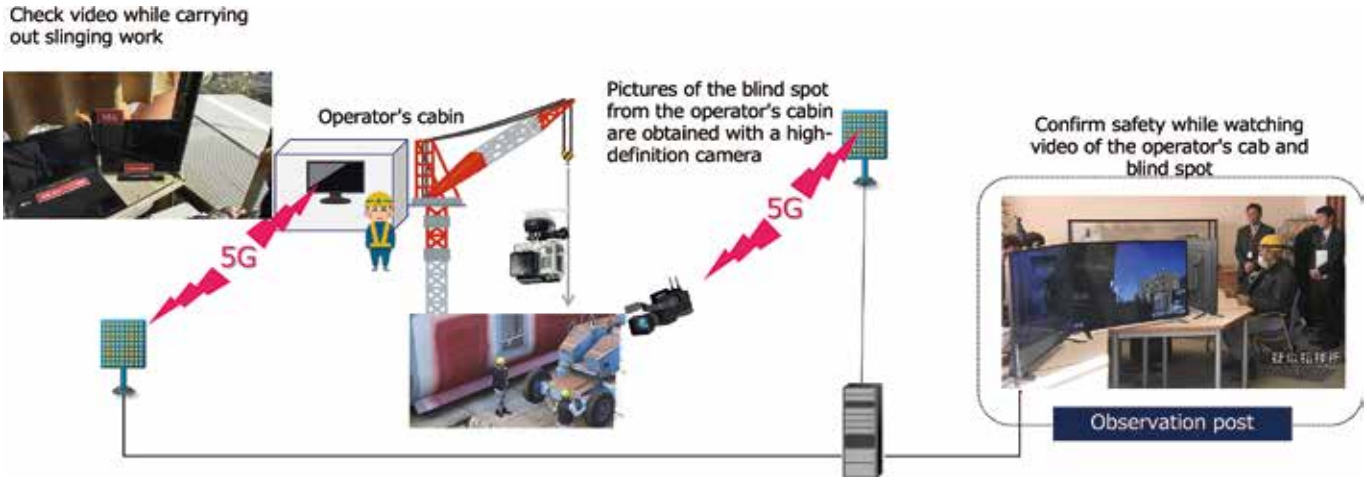
event location, to transmit video for distribution without using large-scale relay equipment, and to perform editing and distribution of full-scale video content even at locations away from the broadcasting station that has specialist equipment and software.

2.2 Using 5G to ensure the occupational safety of skilled workers

In December 2019, we performed a field trials during slinging work by a crane situated in Asakawa Shipbuilding in Imabari City, Ehime Prefecture, to examine the possibility of using 5G equipment operating in the 28 GHz band to relay high-definition

Figure 4: Field trials to ensure the occupational safety

Figure 3: Field trials to ensure the occupational safety using 5G

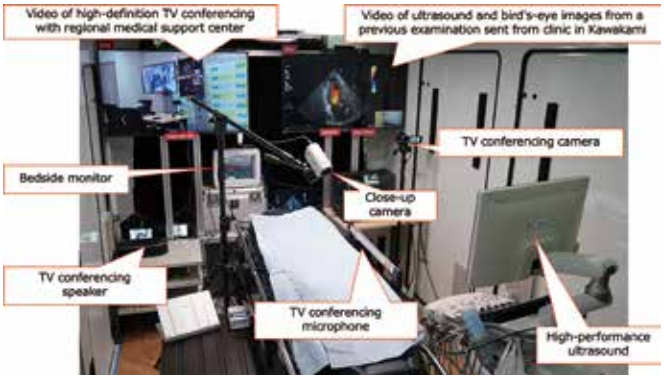


video images of a blind spot to the crane operator's seat in order to create a safer working environment. In this field trial, 5G was used to stably transmit 2K low-latency video images of the blind spot (50–60 Mbps) to a display installed in the operator's cabin to provide the operator with high-definition video images to ensure that slinging work and crane operations could be performed more safely. It is expected that this approach could be used to improve the safety of crane operations in the shipbuilding industry by transmitting video images of places that cannot be seen by the operator, not only for viewing blind spots, but also for purposes such as confirming the center of mass of loads carried by the crane.

2.3 Using 5G to deliver advanced remote mobile medical care

In January 2020, we continued with a field trial in Hidakagawa Town, Wakayama Prefecture that had been started in FY2018 to examine the potential for improving the quality of remote diagnosis as a means of addressing the disparity between urban and rural healthcare provision. In FY2019, in addition to the verification trials conducted up to FY2018, we also used 5G wireless equipment operating in the 4.5 GHz band to transmit video images from high-definition cameras and medical equipment in a mobile medical unit ("Hyper Doctor Car") capable of supporting high-quality diagnosis and treatment. We confirmed that the ability of 5G to deliver high-definition video images made it possible to perform medical examinations together with specialists in remote clinics and even in other mobile medical units. Doctors at university hospitals were able to observe patients via 5G video just as clearly as if they were right in front of them, and reported that this new technology constituted a major step forward from conventional systems. In this demonstration, we confirmed that mobile medical units can be used to perform more advanced forms of diagnosis, and we expect that they will be able to improve the level of medical care available in mountainous areas.

Figure 6: Medical equipment and a bed in a mobile medical unit ("Hyper Doctor Car")



2.4 Using 5G to support traditional performing arts (through remote education)

In October 2019, a field trial was conducted in Nakatsugawa City, Gifu Prefecture to connect a Kabuki master with multiple Kabuki classrooms via 28 GHz band 5G wireless devices to

Figure 5: Field trials to deliver advanced remote mobile medical care using 5G

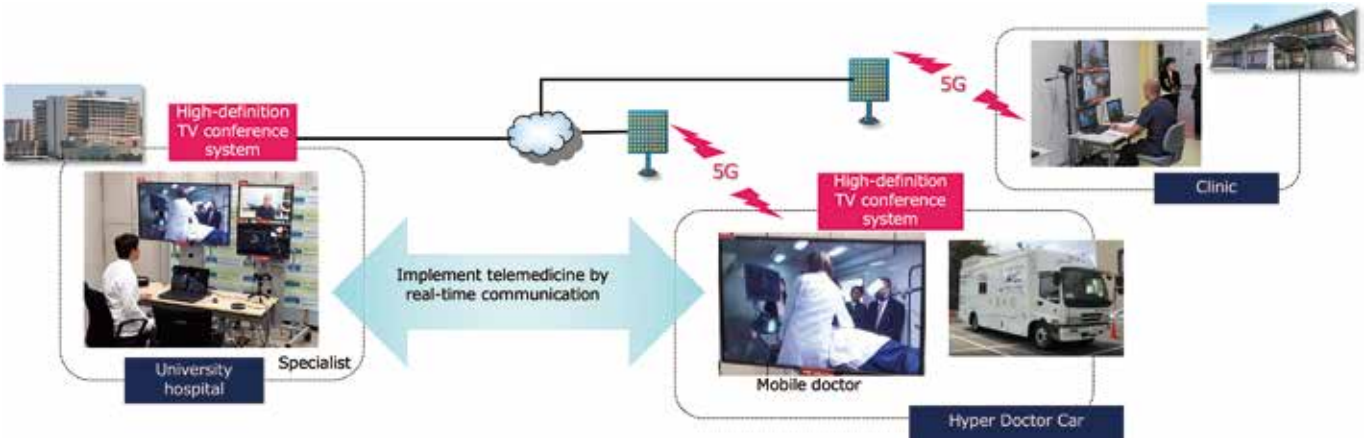


Figure 7: Field trials to deliver remote education using 5G

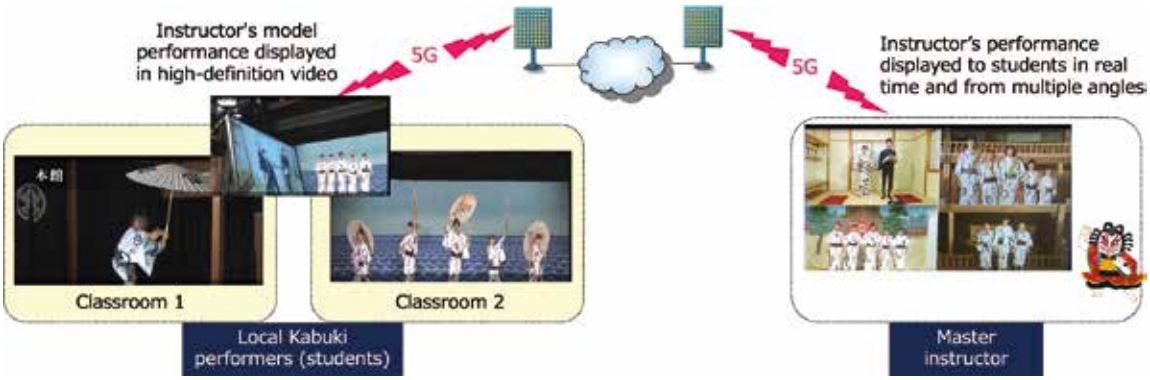


Figure 8: Providing guidance on performances while over a 4K two-way video link

provide guidance on performances while over a 4K two-way video link. We confirmed that four streams of live 4K video can be transmitted simultaneously, and that it is possible to provide remote instruction with such a level of reality that even small details such as eye movements can be conveyed between teachers and students in Kabuki classes. Multi-point remote lessons are expected to support efficient tuition regardless of location, making them a suitable way of handing down traditional performing arts skills that are in danger of being lost due to Japan's dwindling and aging population. By providing greater numbers of people with the opportunity to experience Kabuki through television broadcasting and the like, it is hoped that there will be a resurgence of interest in the art, thereby contributing to the revitalization of Japan's tourism industry.

2.5 Supporting everyday life by using 5G to visualize sounds

In October 2019, with the aim of providing hearing-impaired people in Nakatsugawa City, Gifu Prefecture with new lifestyle support services based on 5G wireless devices operating in the 28 GHz band, we conducted verifications trials of a service that detects dangerous sounds in the vicinity and conveys them as visual information. This information is analyzed and presented to the user via smart glasses. We were able to confirm that this system was able to provide users with warnings and other content, including playing back videos and 3D model data describing the danger, within one second of detecting a dangerous noise. In addition to supporting people with auditory impairments, we expect that this technology could also be used in various other fields including entertainment as a means of displaying content in response to sounds.

Figure 9: Field trials to support everyday life by using 5G to visualize sounds

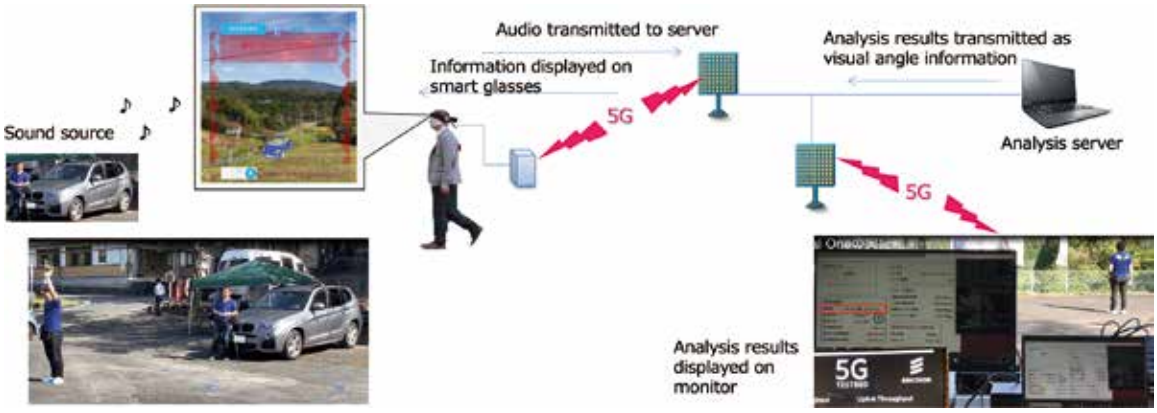


Figure 10: Analyzing sounds in the vicinity and provide users with warnings

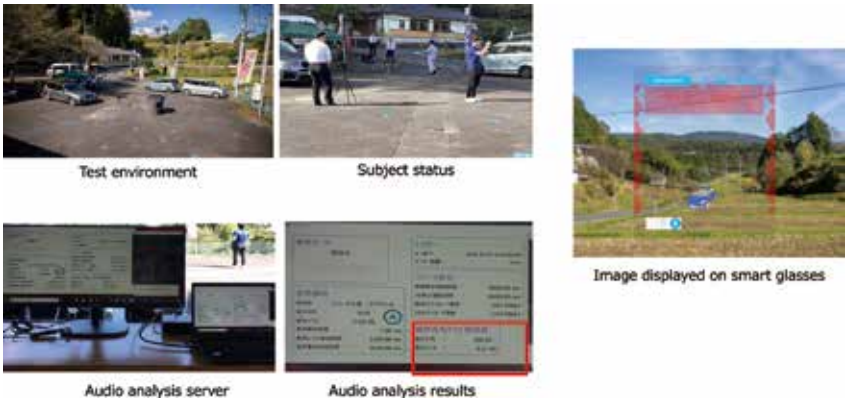


Table 2: List of field trials

Utilization field	Use case	Frequency band	Implementers/partners
Sport	Providing on-course support for golfers*	28 GHz	NTT Communications, MIRAIT, Nagano Keikyu Country Club, Fujitsu, NTT DOCOMO
Smart cities/areas	Subway safety assurance support*	28 GHz	NTT Communications, Hanshin Electric Railway, ITOCHU Techno Solutions, Fujitsu BSC, NTT DOCOMO
Traffic	Providing driving assistance in dense fog*	4.5 GHz	NTT Communications, Oita Prefecture, Autobacs Seven, Oita Prefecture Fog Countermeasures Council, T Plan, NTT DOCOMO

* Projects that won the top prize in the 5G Utilization Idea Contest held by the Ministry of Internal Affairs and Communications in 2018[3]

3. Field trials of 5G ultra-high-speed communication in mobile environments

Field Trial Group 2 NTT Communications Corporation:
Masanori Ichinose, Ichiro Nakagawa

Of the field trials conducted in FY2019, we discuss here the field trials conducted with partners regarding use cases where 5G ultra-fast communication is applied to the three fields shown in Table 2. The technical goal of these field trials was to achieve high-speed communication at average speeds of over 1 Gbps in mobile environments with multiple base stations and multiple terminals.

3.1 Using 5G to provide support on a golf course

In November 2019, we constructed a 28 GHz band 5G communication area at the first hole of the Nagano Keikyu Country Club in Nagano City, Nagano Prefecture, and we performed a field trial in which AI was used to analyze video captured by a 4K 360° camera in order to estimate the landing spots where balls came to rest, and to show the state of play as live video on a next-generation display cart. With this system, we were able to achieve stable transmission of live 4K video in an environment with many connected base stations and terminals, even when the

Figure 11: Field trials to provide support on a golf course using 5G

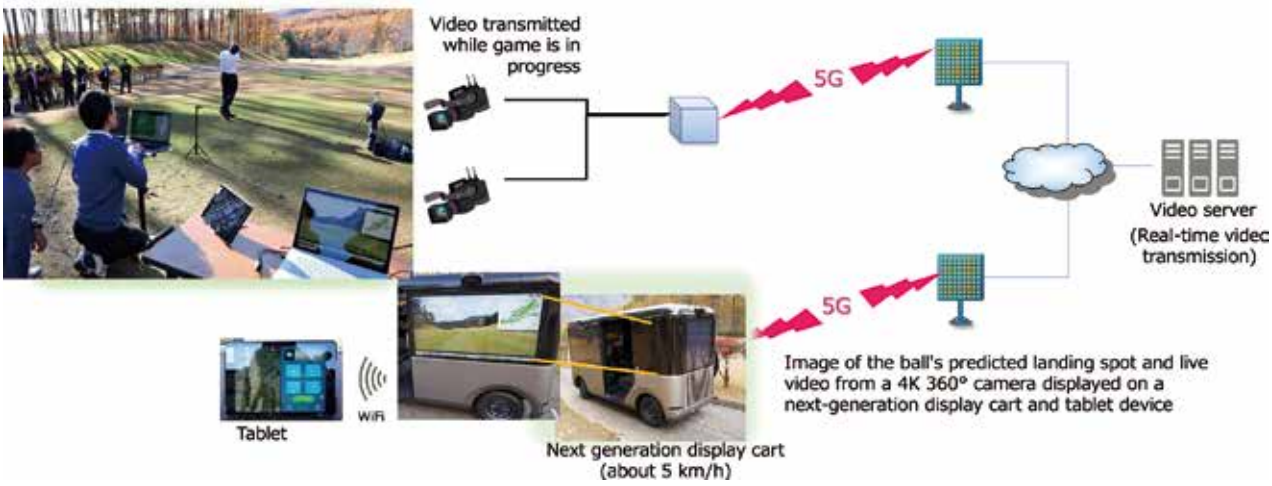
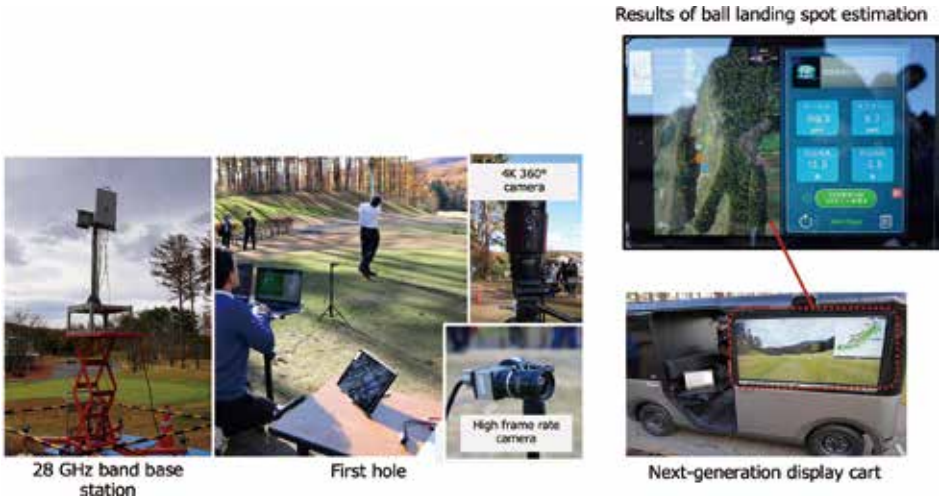


Figure 12: Field trials to provide support on a golf course



next-generation display cart was moving. This system is expected to have several benefits, including an improved play turnover rate due to the ball landing spot estimation service, the ability to implement alternative services where a caddy is not required, and the ability to provide a service that attracts golfers from further afield.

3.2 Using 5G to provide subway safety assurance support

In January 2020, at Fukushima Station on the Hanshin Electric Railway in Osaka, images from inside trains and from station platforms were transmitted via 5G to an AI analysis server that automatically looked for people behaving abnormally or entering restricted areas, and alerted station staff by sending messages to their smart phones. We confirmed that this system was capable of providing stable safety assurance support. In this field trial, train-mounted mobile stations were able to use the 28 GHz band to connect to the base station from a distance of about 300 m outside the line of sight, allowing video to be transmitted before the train reached the platform. We confirmed that this made it possible for station staff to deal with abnormal situations. We also confirmed that abnormalities could be detected correctly and reported to station staff without human intervention. It is expected that this could be used as a safety assurance support service to avoid dangerous behavior such as rushing towards an arriving train.

Figure 13: Field trials to provide subway safety assurance support using 5G

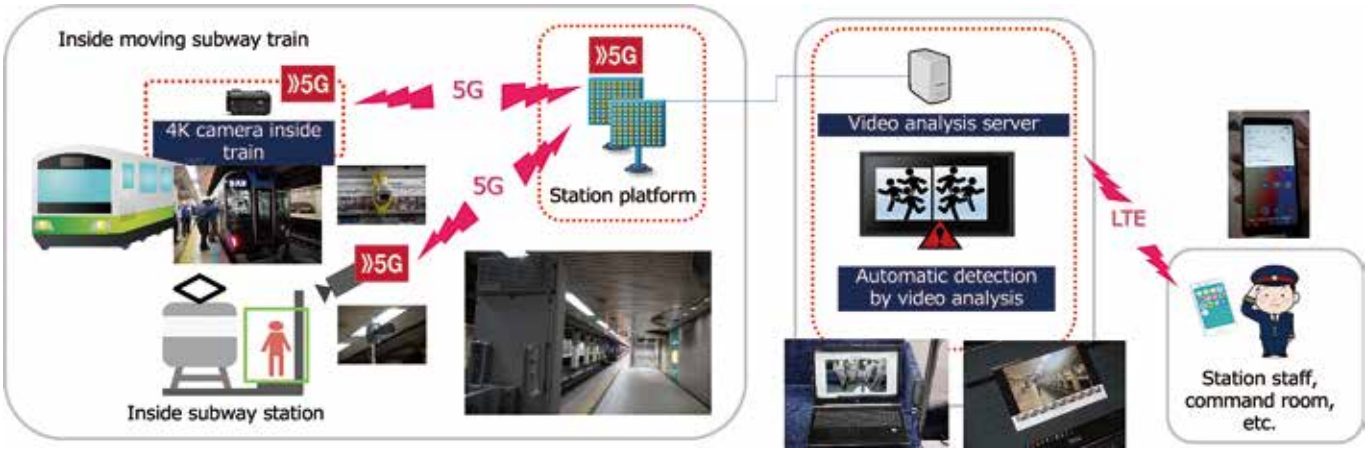
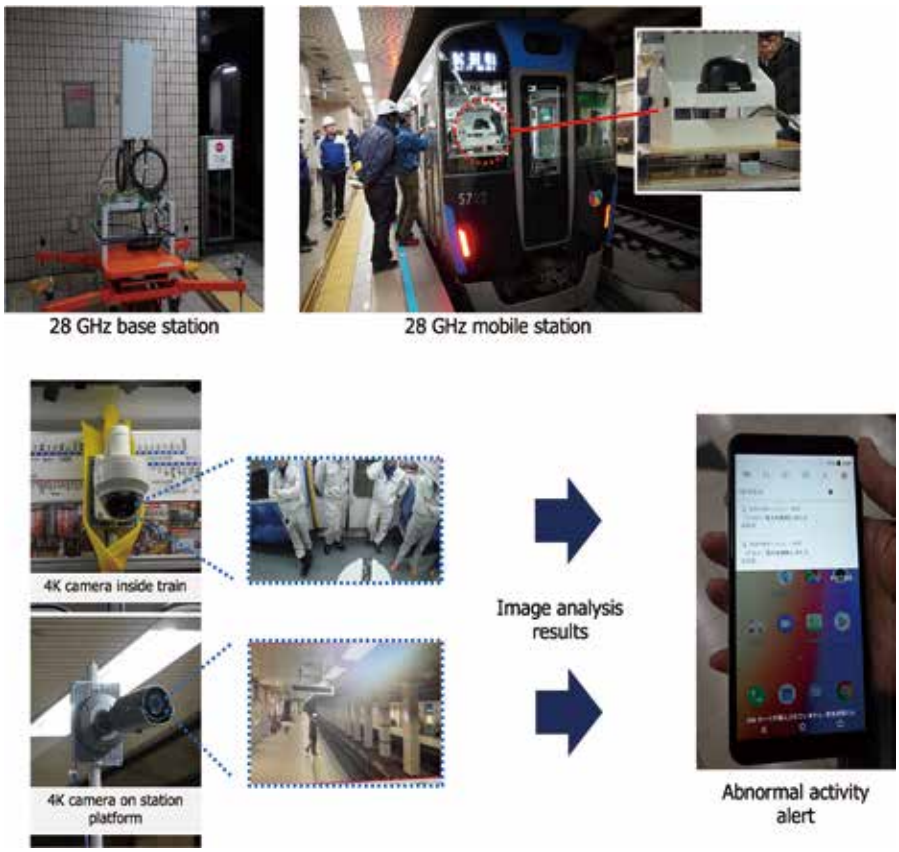


Figure 14: Field trials to provide subway safety assurance support



3.3 Using 5G to provide driving assistance in dense fog

In February 2020, on the expressway in Oita Prefecture and at the Oita Dome stadium, we performed Japan's first verification trials of a driving support system that uses thermal cameras and 4K cameras together with 5G transmission to allow the driver to check in front of and behind the vehicle even in fog with poor visibility. For this field trial the fog was generated artificially, and the video pictures from the vehicle-mounted thermal cameras and 4K cameras were transmitted to a cloud-based image analysis AI system, taking advantage of 5G's high-speed, high-capacity and low-latency characteristics to provide a head-up display of obstacles to the front and rear of the vehicle. Based on the AI analysis detection results, we confirmed that vehicles can be driven safely by providing the driver with auxiliary information about obstacles and the like that are difficult to visually confirm.

Figure 15: Field trials to provide driving assistance in dense fog using 5G

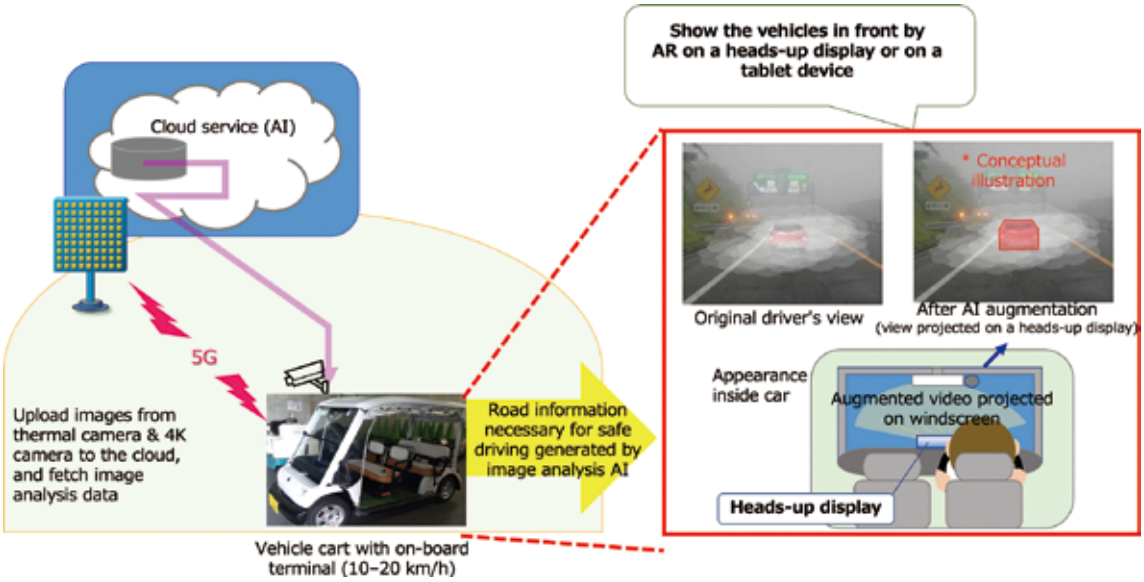


Figure 16: Field trials to provide driving assistance in dense fog

4. Conclusion

We have introduced the field trials performed in FY2019 as part of the 5G Field Trials initiative of the Ministry of Internal Affairs and Communications ("field trials of use cases employing 5G ultra-fast communication in outdoor environments" and "field trials of use cases employing 5G ultra-fast communication in mobile environments"). In the future, we plan to build on the experience of these field trials to continue working towards the realization of diverse 5G applications.

Acknowledgments

We would like to express our deep gratitude to the Ministry of Internal Affairs and Communications, our field trial implementation partners, and other related parties for the opportunity to conduct these field trials.

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2019 Field Trial Results: Part 2

Field Trial Group 3

Field Trials of Use Cases Exploiting 5G Ultra-high-speed Communications in Urban and Suburban Settings

Field Trial Group 4

Field Trials of Use Cases Exploiting 5G Ultra-high-speed Communications in Indoor Environments

Akira Matsunaga
Mobile Network Technical Development Division
KDDI

Hiroyuki Yokoyama
Advanced Telecommunications
Research Institute International

1. Introduction

The FY2019 5G Comprehensive Demonstration Tests[1] (hereinafter referred to as "5G Field Trials") initiated by the Ministry of Internal Affairs and Communications (MIC) included field trials of use cases leveraging the features of the 5th generation mobile communications system (hereinafter referred to as "5G"). These field trials were part of a "contract for investigating technical criteria of a 5th generation mobile communications system capable of ultra-high-speed communications exceeding a bit rate of 300 Mbps on average in the uplink from a terminal in an urban or suburban environment consisting of multiple base stations and multiple terminals" (hereinafter referred to as "field trials of use cases exploiting 5G ultra-high-speed communications in urban and suburban settings") and of "achieving ultra-high-speed communications exceeding a bit rate of 300 Mbps on average in the uplink from a terminal in indoor environments" (hereinafter referred to as "field trials of use cases exploiting 5G ultra-high-speed communications in indoor environments"). This article provides an overview of these field trials. Videos of these field trials have been placed on the Web.[2]

2. Field Trials of Use Cases Exploiting 5G Ultra-high-speed Communications in Urban and Suburban Settings

Field Trial Group 3 KDDI:
Akira Matsunaga, Satoshi Nakano,
Masahiko Nakao, Yuki Shida,
Seiichiro Sakai

Envisioning four use cases exploiting 5G, we conducted field trials in collaboration with partners (Table 1). The technical objective of these field trials was to achieve ultra-high-speed communications in uplink communications from user terminals in an environment consisting of multiple base stations and multiple terminals.

2.1 Invigorating the new sporting event of "slacklining"

The promotion of new sporting events suffers from a number of problems due, for example, to the inability of spectators to understand the rules of the game or the difficulty of the skills required. As a result, the appeal of new sports has not been adequately conveyed and a sense of unity has not been created among spectators as well as between spectators and athletes. The purpose of this field trial was to revitalize regional communities by giving a boost to sporting events rooted in regional areas. Specifically, we conducted a field trial of a new viewing experience for the new sporting event of "slacklining" exploiting the ultra-high-speed and low-latency features of 5G at the 2019 Slackline

Table 1: List of use cases

Use case	Frequency band	Implementers/partners
Invigorating the new sporting event of "slacklining" *	28 GHz	KDDI, Goolight, Asobism, Japan Slackline Promotion Organization, Obuse Town
Discovering potential distress and sharing information in a mountain climber observation system *	28 GHz	KDDI, Shinshu University, Chuo Alps Kanko Co., Ltd., Komagane City
Promotion of tourism using high-definition omnidirectional VR video *	28 GHz	KDDI, Tokai University, Air Camera, Agrid, Minamiaso Village
Integrated management system of construction work	28 GHz 3.7 GHz	KDDI, Obayashi Corporation, NEC Corporation

Note: Use cases marked with an asterisk (*) were top winners in the 5G Utilization Idea Contest held by the Ministry of Internal Affairs and Communications in FY2018[3].

Figure 1: Slacklining competition

Figure 2: Configuration of field trial for promotion of slacklining

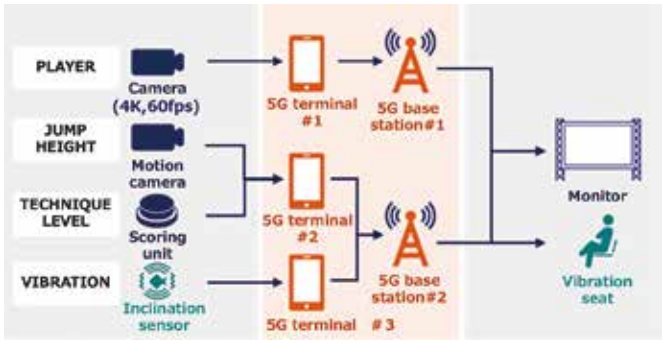


Figure 3: Monitor video and vibration seat at venue

World Cup Japan FULL COMBO held at Obuse Park in Nagano prefecture in September 2019.

Slacklining is a sport that lets players compete in acrobatic skills while jumping on a 5 cm wide line and that involves competition in terms of trick difficulty, proficiency of movements, etc. (Figure 1).

In this field trial, we installed two 5G base stations at a height of 5 m above the ground and set up three 5G terminals to conduct two separate field trials as use cases (Figure 2).

In the first field trial, we transmitted 4K high-definition video of the competition by 5G together with information such as the height of a jump automatically determined from the video of a motion camera and trick level, number of consecutive jumps, etc. determined by a judge. We then combined all of this information in the video and relayed it in real time to a large monitor at the venue so that spectators could better understand trick level and other aspects of the sport. Next, in the second field trial, we used inclination sensors installed on the slackline to detect the instantaneous vibration that occurs when a player makes contact with the slackline and transmitted that sense of vibration to vibration seats installed in the spectator seating area via 5G. We were able to transmit this vibration information with a delay of 41 – 50 ms by exploiting the low-latency characteristics of 5G. This enabled spectators to feel the impact of a jump synchronized with what they were seeing with their own eyes and to feel a sense of unity with the player. Spectators that experienced this sensation offered comments such as "I felt as if I was jumping in the air! I'd like to try slacklining" (Figure 3).

This field trial demonstrated that a transmission system leveraging the ultra-high-speed and low-latency features of 5G could promote understanding of important game rules and the challenge of certain skills while contributing to new and exciting experiences for spectators.

2.2 Discovering potential distress and sharing information in a mountain climber observation system

In recent years, the number of disasters and accidents involving mountain climbers has been on an upward trend thereby increasing the workload of rescue operations. To solve this problem, we have developed a mountain climber observation system that can detect the location of a mountain climber by having mountain climbers carry a Low Power Wide Area (LPWA) terminal with a built-in GPS function and transmitting that GPS location information to alpine rescue headquarters by LPWA at the time of an accident.

The purpose of this field trial was to help improve rescue operations by first obtaining accurate information on the location of the victim through the mountain climber observation system and to then transmit high-definition video of the accident scene from a drone having a compact airframe and excellent mobility using the 5G feature of ultra-high-speed communications in the uplink. The first step in this trial was to capture the reaction of the victim when hailed from the drone equipped with a 4K camera, loudspeaker, and 5G terminal. The next step was to relay that 4K high-definition video to a monitor at the alpine rescue headquarters and a tablet-type 5G terminal held by the rescue team (Figure 4). To test the feasibility of these operations, we conducted this field trial in the vicinity of Hotel Senjojiki at Mt. Komagatake in Nagano prefecture in October 2019.

Prior to testing this use case, we evaluated the 5G radio performance by equipping the drone with a 5G terminal and measuring uplink throughput at 15 points (Figures 5 and 6). Based

Figure 4: Configuration of field trial of mountain climber observation system

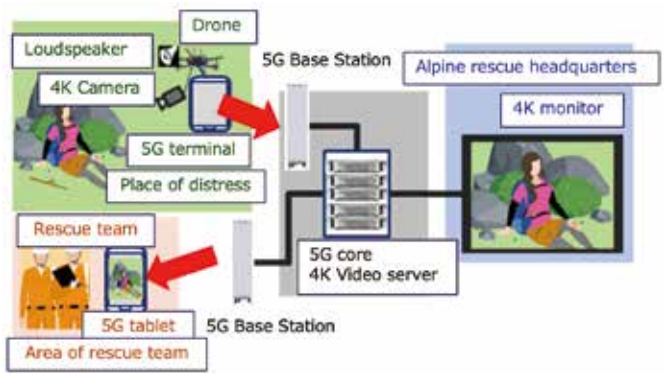


Figure 5: External view of drone

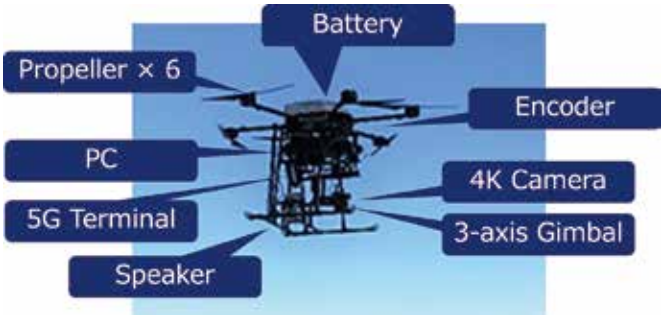


Figure 6: Measurement points

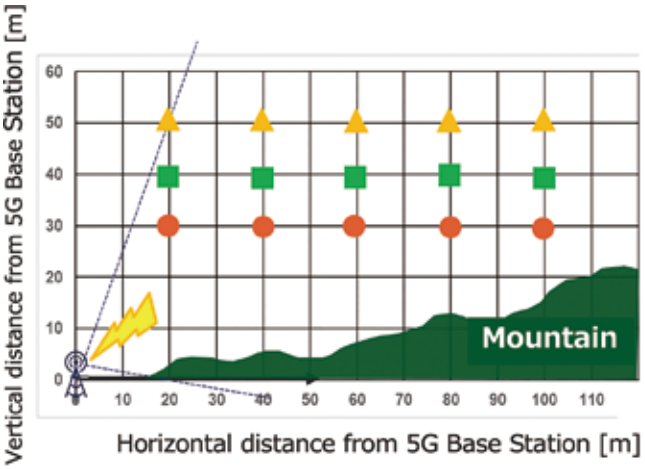


Figure 7: Measurement results

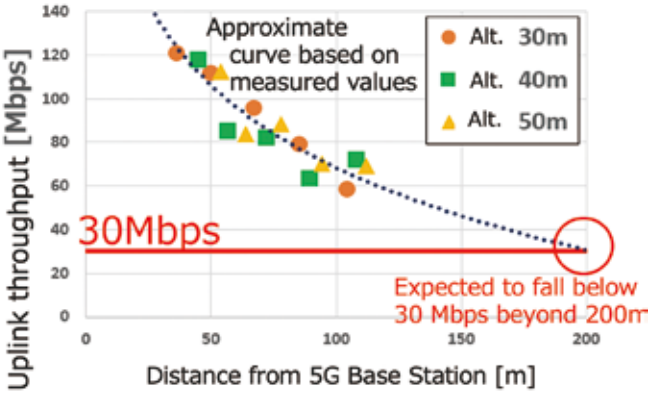


Figure 8: Scene of field trial of mountain climber observation system

on the results of these measurements, we inferred, for this field trial configuration, that the maximum range for achieving 30 Mbps in the uplink as required for this use case involving 4K video transmission was approximately 200 m from the 5G base station (Figure 7).

Next, we successfully transmitted 4K high-definition video from the drone to both the alpine rescue headquarters and rescue team by 5G and showed that the accident scene could be grasped in greater detail in this way (Figure 8). The rescue team that participated in this demonstration commented that they looked forward to actual implementation of the system because, in their words, "We could obtain a better understanding of the victim's situation."

2.3 Promotion of tourism using high-definition omnidirectional VR video

Since the Kumamoto earthquake in 2016, the revitalization of tourism to ignite a recovery in tourist numbers has been a major issue for Minamiaso village. However, many tourist sites in the Minamiaso area such as the Mt. Aso crater and colonies of rare plants have become off limits or severely limited from the viewpoints of safety or environmental protection. As a result, traditional approaches to tourism have not been sufficiently conveying the charm of this region. In this field trial, we flew two drones each equipped with a high-definition omnidirectional virtual reality (VR) camera over such tourist sites and presented the video to individual tourists visiting the area in real time through a head-mounted display (HMD). In this way, we envisioned a use case that could provide a means of tourism that was safe and not environmentally destructive and that could convey the beauty and charm of the Minamiaso area (Figure 9).

In this field trial, we installed two 5G base stations at roadside station "Asobou no Sato Kugino" in Minamiaso village and conducted the field trial in December 2019 (Figure 10).

We flew the two drones each equipped with a 5G terminal over two overlapping areas each covered by one of the base stations in an airspace ranging as far as 67 m from the base station. We captured high-definition omnidirectional VR video on the two drones and transmitted the video in real time to two HMDs, respectively (Figure 11). We also supplemented this live video transmitted from the drones with prerecorded video of structural remains from the earthquake that are now off limits as well as regional images and seasonal images and enabled tourists to switch between the video and images via a HMD as desired.

Figure 9: Overview of field trial for promoting tourism using VR video

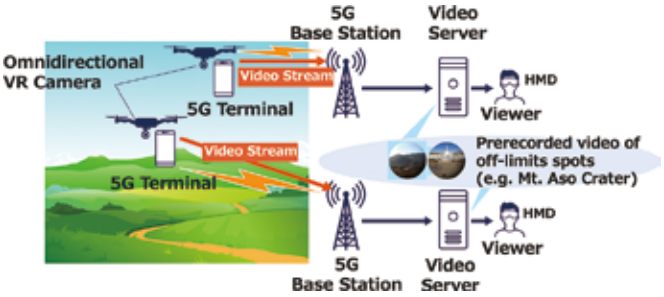


Figure 10: 5G evaluation environment

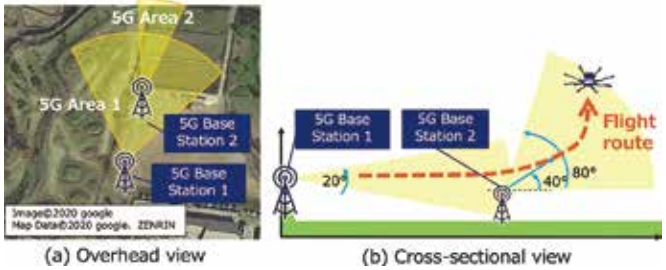


Figure 11: Scenes of field trial

The president of "Asobou no Sato Minami-Aso," a company involved in local tourism and a collaborator in this field trial, said "Aerial sightseeing by helicopter, which was popular in the past, is now on hold due to noise issues associated with flights, but I feel that this demonstration that included scenes from below and behind may even be better. Image quality is good and I expect further improvements to be made." This comment underscores the possibility of creating attractive sightseeing services using 5G.

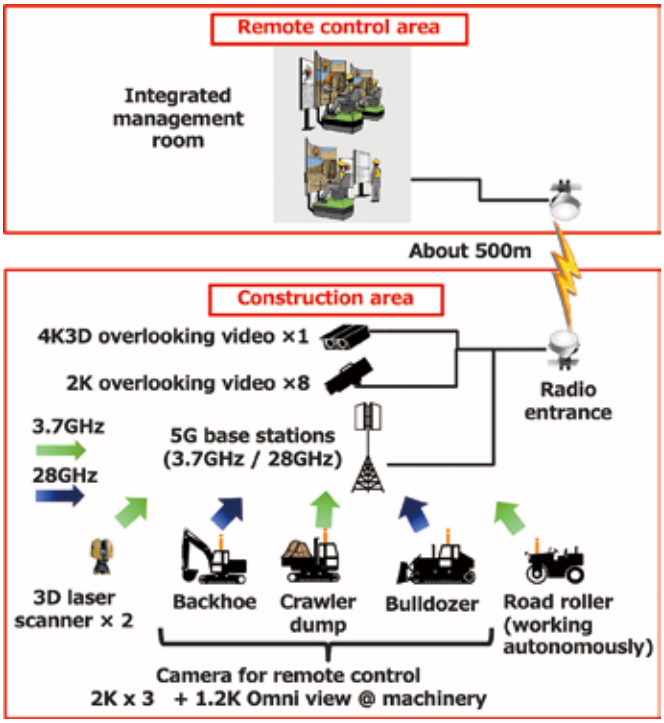
2.4 Integrated management system of construction work

The purpose of this field trial was to deal with the shortage of on-site workers in construction work and to achieve real-time management of massive amounts of on-site work data to make the entire process more efficient. We conducted this field trial simulating road construction at a dam construction site exploiting the 5G features of ultra-high-speed and low-latency communications.

As part of the 5G Field Trials, trials examining the remote control of construction machinery using 5G began in FY2017 and the successful remote control of a single machine was demonstrated in the same year. Then, in FY2018, a field trial envisioning the work of recovering from a landslide disaster was conducted. This trial involved the rapid deployment of a 5G network in the disaster-hit area, the remote control of two machines that work together, and the removal of landslide debris.

Next, in FY2019, with an eye to applying remote control to general construction work based on construction drawings, an "integrated construction management system" was created that combined the remote control system with a machine guidance system for determining machine working status and 3D laser scanners for measuring work results. Using this system, a field trial simulating road construction was conducted at Kawakami Dam in Mie prefecture in February 2020. In the trial, road construction was performed by three pieces of machinery (backhoe, crawler dump, and bulldozer) remotely controlled via 5G and by an

Figure 12: Configuration of field trial of integrated management system of construction work

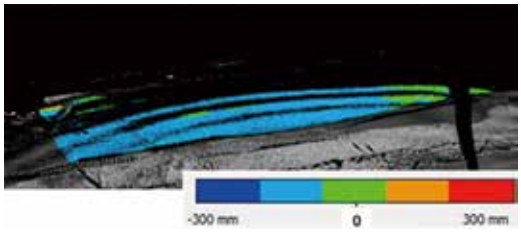


autonomously operated machine (road roller). This was combined with high-precision management of completed work important in general construction work and with real-time remote quality management of compactness, which is the most important factor in road construction (Figure 12). The results of this field trial revealed video transmission latency of 140 ms – 220 ms. The standard target for transmission latency for achieving remote operation without discomfort or confusion is no more than 200 ms, so from an operator's viewpoint, these results showed that work could be sufficiently performed.

This field trial also showed that the state of earth leveling by the bulldozer, the number of surface compaction runs by the road roller, etc. could be displayed on machine guidance system screens in color-coded schemes and that the results of measuring unevenness of the constructed road by the 3D laser scanners could also be displayed. In short, it was possible to present the state of construction work to construction supervisors in real time (Figure 13).

In this field trial of road construction, we measured work time in relation to transport and construction and compared measured values with labor productivity standards of the Ministry of Land,

Figure 13: Deviation from targeted height after road construction



Infrastructure, Transport and Tourism (MLIT). Construction work by remote control is generally considered to require 1.5 – 2.0 times the corresponding labor productivity standards, but in this field trial, we obtained work times of approximately 1.4 times those standard values, which was a favorable outcome. The reasons for this were (1) the transmission of high-definition video could be integrated with supplementary information such as that from 3D laser scanners and (2) operators working together could control their machines sitting side-by-side in the management room within the remote control area and could therefore communicate smoothly with each other, which would not normally be possible at a noisy construction site. Operators involved in this remote operation were impressed with "a sense of operation without any discomfort or confusion" and evaluated the trial positively with comments like "I could perform construction in a comfortable environment through remote operations."

At this construction site, the work surface was prone to unevenness due to the cohesive and soft soil of the foundation, and we found that leveling the soil by bulldozer via video-assisted remote control was quite difficult since this type of work requires sensitive operations. We therefore determined that there was room for system improvements with respect to work that requires a finished form. In the machine guidance system used in this trial, the operator controlled the bulldozer's blade for soil leveling and the direction taken by the bulldozer. However, if a recently automated system were to be introduced, the operator could concentrate on only bulldozer direction and entrust this automated system with blade operations that are highly difficult in remote manual control. In this way, we can expect the required level of precision to be achieved even in remote operations.

This field trial demonstrated the feasibility of road construction by remove control of construction machinery using 5G and the possibility of applying 5G to general construction work. At present, the construction industry assumes that all construction work must be carried out on-site since it is not possible to concentrate operations in the manner of a manufacturing hub in the manufacturing industry. However, remote control as demonstrated by this field trial opens up the possibility of consolidating at least part of the construction process in a permanent hub and revolutionizing construction work including worker roles and production management.

3. Field Trials of Use Cases Exploiting 5G Ultra-high-speed Communications in Indoor Environments

Field Trial Group 4 Advanced Telecommunications Research Institute International:
Hiroyuki Yokoyama

Envisioning four use cases exploiting 5G, we conducted field trials in collaboration with partners (Table 2). The technical objective of these field trials was to achieve ultra-high-speed communications in uplink communications from a user terminal in indoor environments.

3.1 Sports viewing to enhance sense of unity between players and spectators

With the aim of revitalizing regional sports stadiums, we conducted a field trial of a new sports-viewing system at the Hanazono Rugby Stadium in Higashiosaka, Osaka in October 2019. This system exploits the 5G feature of ultra-high-speed communications to share players' vital data and the level of spectator cheering and bring about a sense of unity between the players and spectators. It enables degree of player fatigue, level of cheering, etc. obtained from sensor data to be visualized and delivered to 5G terminals and the main stadium screen after being synthesized with the live video (Figures 14 and 15). In the trial, spectators were encouraged to cheer on the players when they got tired, and at halftime, the spectators themselves participated in a cheering competition that included game-like elements.

These new sports viewing technologies powered by 5G can enhance the sense of unity between players and spectators, and increase the number of people attending regional stadiums.

Figure 14: Concept of sports-viewing field trial

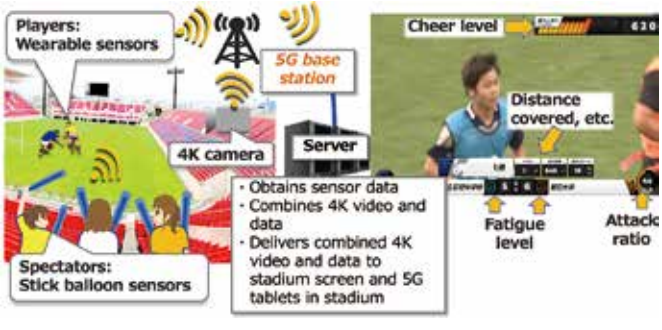


Table 2: List of use cases

Use case	Frequency band	Implementers/partners
Sports viewing to enhance sense of unity between players and spectators *	28 GHz	ATR, KDDI, Jupiter Telecommunications, Data Stadium, Knows, TECHTUITE
Streamlining of diary/livestock industry *	28 GHz	ATR, KDDI, Waseda University, University of Miyazaki, Kamishihoro Town, Tokachi Murakami Farm
Support of racehorse breeding *	28 GHz	ATR, KDDI, The University of Tokyo, Sharp Corporation, Niikappu Town, Hidaka Racehorse Cooperative Upbringing Center

Note: Use cases marked with an asterisk (*) were top winners in the 5G Utilization Idea Contest held by the Ministry of Internal Affairs and Communications in FY2018[3].

Figure 15: Video delivered in sports-viewing field trial

(a) Video delivered to a 5G terminal

(b) Video delivered to stadium screen

3.2 Streamlining of diary/livestock industry

With the purpose of raising the efficiency of the dairy/livestock industry, we conducted a field trials for two use cases in November 2019 at Tokachi Murakami Farm in Kamishihoro town, Hokkaido (Figure 16). The first trial aimed to detect the location of cows within a cowshed from 4K video transmitted by 5G such as when a veterinarian wants to check for signs of a breeding period or diagnose the health of a cow. In this trial, we installed multiple 4K cameras within the cowshed, shot the cows while fixed to a stanchion during feeding, and transmitted the video to servers by 5G. The ID numbers on the ear tags of the cows were identified using a video analysis program running on these servers and were then used to display the positions of these cows on a tablet (Figure 17 (a)).

The second field trial aimed to remotely monitor cows from an office via 4K video to observe, for example, cows with low milk production. We confirmed that real-time or stored 4K video of the cows specified by ID numbers could be shown on the screen in the office (Figure 17 (b)).

These results showed that the time required to search for a cow's location, which takes more than 15 minutes per head by visual means, could be greatly reduced and that a specific cow could be remotely monitored, all of which should increase work efficiency in this industry.

3.3 Support of racehorse breeding

To support the racehorse breeding industry, we envisioned the use of 5G to enable horse owners and production ranch owners to observe the raising of entrusted horses from afar. To judge the

Figure 16: Overview of field trials for dairy/livestock industry

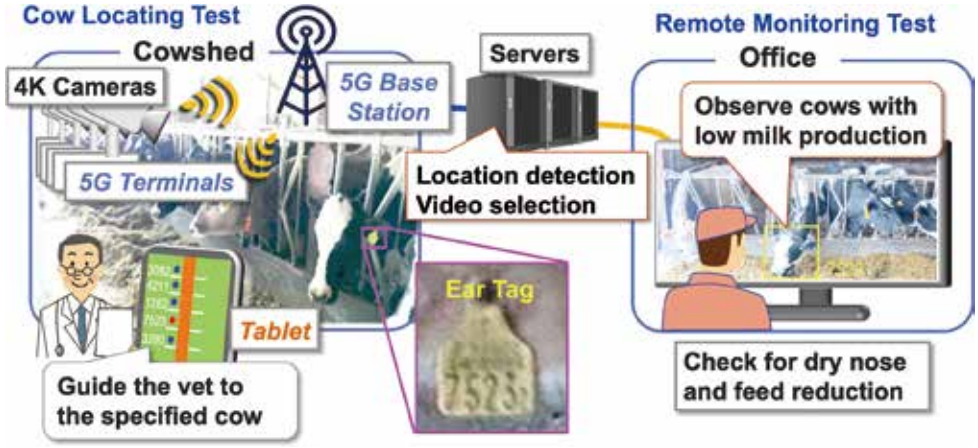
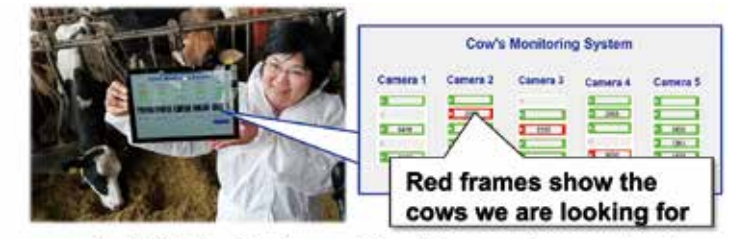


Figure 17: Field trials for dairy/livestock industry



(a) Field trial of searching for cows in cowshed

(b) Field trial of monitoring cows from an office

Figure 18: Overview of field trials in support of racehorse breeding industry

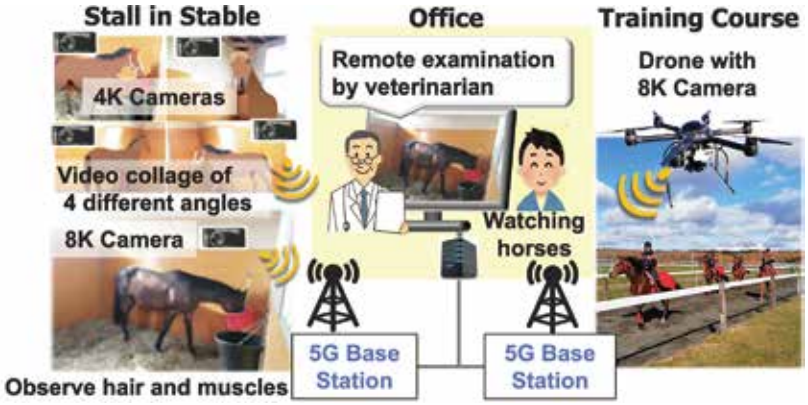


Figure 19: Field trials in support of racehorse

merits of this premise, we conducted a field trial of using 5G ultra-high-speed communications to transmit 8K video of racehorses at the Hidaka Racehorse Cooperative Upbringing Center in Niikappu town, Hokkaido in November 2019 (Figure 18). In this trial, we installed 5G base stations at two locations inside a stable and beside the training course. We also installed four 4K cameras within a stall in the stable for monitoring by staff and remote diagnostics by veterinarians. These four 4K video streams were combined into one 8K video stream and transmitted by 5G to an office. In addition to the above, we installed an 8K camera in the stable passageway to capture a horse's gait and transmitted this video by 5G to the office in the same way. At the training course, we captured the running of horses by a drone equipped with an 8K camera and succeeded in transmitting 8K video streams with uplink throughput over 120 Mbps (Figure 19). In this way, the condition of a horse's muscles built up through training, its hair gloss, and other characteristics could be checked through remote monitoring, which shows that 5G and 8K video can be useful tools in racehorse breeding.

These technologies will improve service and access for horse owners and increase ranch-related tourism through video distribution.

4. Conclusion

This article introduced the results of conducting "field trials of use cases exploiting 5G ultra-high-speed communications in urban and suburban settings" and "field trials of use cases exploiting 5G ultra-high-speed communications in indoor environments."

Acknowledgments

We would like to express our deep gratitude to the Ministry of Internal Affairs and Communications and related institutions for their cooperation in holding these field trials.

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https://www.soumu.go.jp/menu_news/s-news/01kiban14_02000390.html, Aug. 2019.
https://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/pressrelease/2019/8/16_1.html (in English)
[2] URLs to reference videos on KDDI's official YouTube channel for each section of this article:
Section 2.1: https://youtu.be/S_mOloyQk6s
Section 2.2: https://youtu.be/Zr3u0xCFBuE
Section 2.3: https://youtu.be/JcrIzK7nLac
Section 2.4: https://youtu.be/fZ_vm5U8LTI
Section 3.1: https://youtu.be/clhCCTTi-7U
Section 3.2: https://youtu.be/DyQqvYx0mhY
Section 3.3: https://youtu.be/WtvhSTebvLw
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2019 Field Trial Results: Part 3

Field Trial Group 5

Use Case Field Trial of 5G Low Latency Reliable Communication in a High-speed Mobile Environment

Field Trial Group 6

Use Case Field Trial of 5G Massive Machine-type Communication in Indoor and Rural Outdoor Environments

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Part I: Field Trial to Realize Connected and Automated Vehicles using 5G Ultra Reliable and Low-latency Communication

Field Trial Group 5 SoftBank Corporation:
Hitoshi Yoshino, Manabu Mikami

1. Introduction

5th Generation Mobile Communication Systems (5G) encompasses not only enhanced Mobile Broadband (eMBB), which is a further enhancement of conventional Mobile Broadband capabilities, but also the new features of Ultra Reliable and Low Latency Communication (URLLC) and massive Machine Type Communication (m-MTC). These new features are anticipated as infrastructure for our advanced information society. Commercial deployment of eMBB has already begun. The new 5G features, URLLC and m-MTC, have potential to open up new markets in industrial applications. It is important to establish concrete 5G use cases in these new areas as early as possible.

From FY2017 to FY2019, the Ministry of Internal Affairs and Communications (MIC) of Japan conducted 5G Comprehensive Demonstration Tests[1] (hereinafter referred to as "5G Field Trials"). These field trials needed not only to assess technical aspects of 5G radio systems for commercial deployment, but also to conduct the 5G field trials in cooperation with potential industrial 5G users (Vertical sectors).

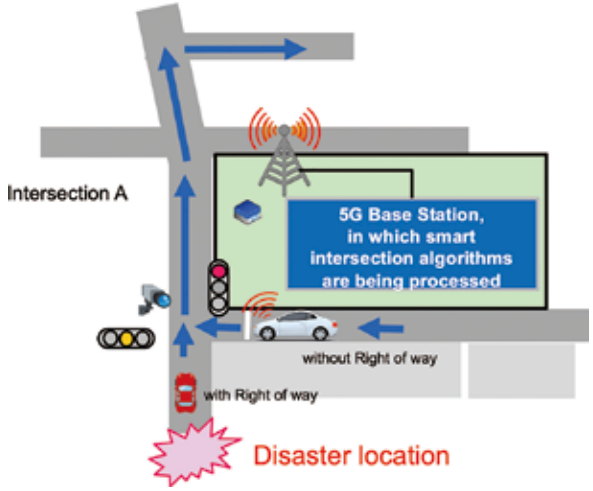
For this field trial, SoftBank Co. Ltd. and Wireless City Planning Co. Ltd. were members of Field Trial Group V (GV), which handles the 5G URLLC domain. The 5G URLLC field trials handled mission-critical use cases, studying applications of 5G to remote operation of passenger vehicles and truck platooning. This article reports on the activities of GV.

2. Evacuation Guidance during Disaster (Smart intersections)

In the use case category of connected vehicles, a field trial was conducted using the low-latency feature of 5G to provide guidance for safe and rapid evacuation during a disaster. The trial was carried out in March 2020, in collaboration with the City of Kitakyushu and the Kitakyushu Foundation for the Advancement of Industry, Science and Technology (FAIS) and in partnership with Nippon Signal Co. Ltd., at the Kitakyushu Science and Research Park (KSRP) in Kitakyushu City, Fukuoka Prefecture. Car collisions and traffic congestion are issues during evacuation when disaster occurs. The trial verified that smart intersections utilizing 5G can help avoid collisions and ensure that evacuations proceed smoothly. The demo scenario examined (i) controlling traffic to merge smoothly at intersections during an evacuation, and (ii) how to avoid collisions between vehicles and protect pedestrians at intersections during evacuation. For use of 5G to provide evacuation guidance during a disaster, the trial focused on three issues: (i) when implementing smart intersections, whether it is possible to significantly reduce the cost at an intersection by utilizing the high capacity and low-latency communication of 5G, (ii) whether advanced intersection control such as collision prevention can be done for vehicles entering an intersection using 5G low-latency, and (iii) whether a low-cost smart intersection with advanced functionality can be built without installing special equipment for traffic control on the roadside, using the high capacity and low latency of the wide-area 5G network.

The evacuation guidance field trial scenario using 5G is shown in Figure 1. In the figure, a 4K surveillance camera is installed at intersection A, and the video from the camera is sent to a Mobile Edge Computing (MEC) server at the 5G base station by a 5G user terminal device installed on the traffic-light pole. The MEC server uses AI image processing to detect the positions of vehicles entering the intersection (in the figure, the red car with the right-of-way, and the white car without right-of-way), and if they get close within a predetermined zone, it sends warnings that they are getting too close, to terminals in the cars via 5G. If they get too close, it also sends a stop command through the 5G connection to the vehicle entering the intersection that does not have right-of-way (the white vehicle in the figure), forcing it to stop and

Figure 1: Field trial scenario for evacuation guidance PoC



preventing a collision. If a pedestrian crosses the intersection, they are also detected in the surveillance camera video using AI image processing, and if the pedestrian and a vehicle get close within a prescribed area, The MEC server at the base station sends a stop command to the 5G terminal in the vehicle, giving it a warning, and even forcing it to stop.

The course used for the field trial at KSRP is shown in Figure 2.

Photographs of the traffic signal, surveillance camera, and 5G terminals installed for the field trial are shown in Figure 3, the 5G base station used is in Figure 4, and the remote-controllable vehicle with 5G terminal installed is in Figure 5.

Figure 2: PoC field trial course

Kitakyushu Science and Research Park

Figure 3: Smart intersection

Figure 4: Experimental 5G base station

Figure 5: Remote-controlled car with onboard 5G user terminal

The results of the field trial showed that a low-cost smart intersection able to protect pedestrians and prevent vehicle collisions can be implemented, without installing expensive sensors at intersections, using just a 5G terminal and a surveillance camera (with 4K resolution) at the smart intersection. The cost of the smart intersection system at each intersection for installation and maintenance can be reduced significantly, because AI and other advanced image analysis of video from the intersection can be performed centrally by a MEC server at the 5G base station.

3. 5G Application to remote operation of abandoned vehicle

In the use case category of connected vehicles, a field trial of remote vehicle operation using the low-latency feature of 5G was conducted. The trial was demonstrated in March 2020, in collaboration with the City of Kitakyushu and the Kitakyushu Foundation for the Advancement of Industry, Science and Technology (FAIS) and in partnership with FEV Japan, Co. Inc., which develops remote control vehicles, at the Kitakyushu Science and Research Park (KSRP) in Kitakyushu City, Fukuoka Prefecture. The scenario for this field trial was the removal of abandoned vehicles by remote operation, to open up roadways for disaster relief, to help with rapid rescue and recovery during disaster. For disaster rescue, any obstacles on roadways must be removed quickly, so that rescue vehicles can get through. In contrast with wireless control systems using dedicated frequency bands, or local remote control using wireless LAN, using a 5G wide-area cellular communications network for remote operation enables abandoned vehicles to be moved to a vacant area from

Figure 6: Field trial scenario for remote operation of abandoned car

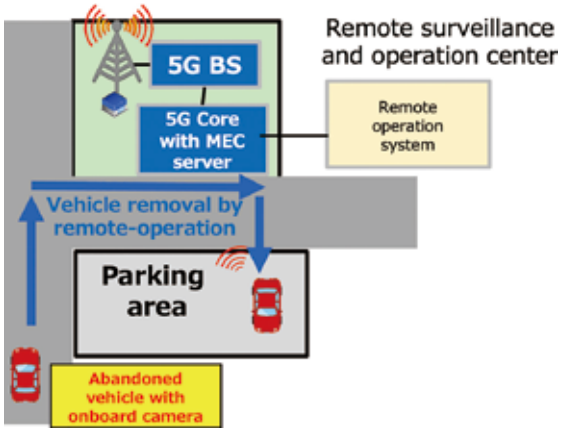


Figure 7: Remote operation of abandoned car from a remote surveillance and operation center

distances of hundreds of km or more away. In other words, using 5G enables disaster rescue and recovery activities to be done in real time from outside of the disaster area.

In the field trial, vehicles were controlled remotely from the remote-vehicle control center through 5G, while looking through a forward-facing onboard camera in the vehicle, and abandoned vehicles were moved from the roadway to a vacant area (Figure 6). In fact, to get a feel for 5G radio control in the trial, the remote vehicle control center was set up under the 5G base station used for the trial and not at a distant location, for demonstration purposes. Figure 7 shows a photograph of performing remote vehicle operation at the remote vehicle operation center.

Conventionally, remote operation has been done with systems using dedicated frequency bands or wireless LAN systems, within the operator's field of view and the radio signal range (tens to hundreds of m). The trial showed that, using the high capacity and low-latency of 5G communication, an operator can operate a vehicle by looking through a high-resolution onboard camera with low-latency communication rather than having the vehicle in their field of view. 5G networks have low latency in the tens of milliseconds, even including network delay, so remote operation will be possible even from locations hundreds of kilometers away in the future. This field trial showed that when a disaster occurs, damage recovery with remote operation from outside the disaster area will be possible using the low latency and high-capacity of wide-area 5G networks.

4. 5G Application to truck platooning

In the use case category of automated vehicles, a field trial of truck platooning (self-driving following vehicles) using the high reliability and low latency of 5G was conducted. With truck platooning, several trucks form a platoon and drive together. Communication between trucks is used to control the platoon as one unit.

Truck platooning can be used to solve various societal issues. The distance between trucks can be reduced through platooning, reducing air resistance, and improving fuel economy. It has been shown that a three truck platoon travelling at 80 km/h with 4 m between trucks would reduce fuel consumption by 15%[2]. By further reducing the separation to 2 m, fuel consumption would be reduced by 25%. Reducing the distance between vehicles also increases capacity of the roadway, mitigating congestion. This can also reduce CO2 emissions. There are also other societal issues in Japan, such as an aging driver population and driver overwork. Platoon driving can be expected to reduce driver workload and improve safety.

Use of 5G for communication between vehicles can improve stability and reduce a phenomenon called hunting (fluctuation of distances between vehicles), which is caused by delay in the control process. To further reduce fuel consumption and increase capacity of roadways, the distance between vehicles must be reduced still more, and the number of vehicles in a platoon increased, while still maintaining safety, so application of 5G URLLC, with its low latency and high reliability, is anticipated for application in this field.

In FY2019 (Feb. 2020), a field trial was conducted on the Shin-Tomei expressway using 5G URLLC for platooning, with an inter-vehicle distance of 10 m (trials in FY2018 used 35 m), and with later trucks following the lead truck (steering control). The trial was done in partnership with Advanced Smart Mobility Co. Ltd. (ASM) and received technical and operational support from the Platooning Project of the Ministry of Economy, Trade and Industry (METI) and the Ministry of Land, Infrastructure and Transport (MLIT). Several 5G bases stations were also installed along the Shin-Tomei Expressway and trials were conducted on dynamic switching with two modes of radio resource management: (1) base station control mode and (2) autonomous

Figure 8: Field trial of 5G Truck platooning on Shin-Tomei expressway —CACC—

Figure 9: Field trial of automated following of a leading vehicle using 5G —automated steering—

control mode; for 5G New Radio (NR) Sidelink (vehicle-to-vehicle direct communication).

Trial conditions on the Shin-Tomei Expressway are shown in Figure 8 and Figure 9.

5. Conclusion

Field trials of 5G ultra-reliable low latency communication (URLLC) in the use case category of connected cars and automated vehicles were conducted. For connected vehicles, field trials of smart intersections and vehicle remote control were done in the city of Kitakyushu. The actual use cases for the trials were of giving fast and safe evacuation guidance and of clearing roadways during a disaster. Results showed that smart intersections can be created at low cost per intersection using 5G, and that vehicles can be cleared from roadways using remote control from outside of the disaster area, even hundreds of kilometers distant.

In the field of automated vehicles, 5G was applied to truck platooning (automatic driving of following trucks), and driving trials were conducted on the Shin-Tomei Expressway. Results verified that 5G was effective in two cases: for low-volume, low-latency communication needed for truck platooning (for vehicle control), and for high-volume, low-latency communication (for monitoring the following trucks).

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Part II: Field Trial for Early Introduction of 5G Massive Machine-type Connectivity

Field Trial Group 6 Wireless City Planning Inc.:
Hideto Funayoshi, Yusuke Tajima

1. Introduction

Products are currently being developed and implemented for commercialization of 5th Generation Mobile Communication systems (5G) in 2020. 5G is anticipated as next generation social infrastructure featuring ultra-high-speed communication, but it also features ultra-reliable low-latency communication (URLLC) and massive Machine-Type Communication (mMTC). Establishing concrete uses cases for these features is an urgent matter.

This article introduces field trials of two such use cases, conducted as 5G commercial services were starting in 2020. The first was i-Construction, which was proposed at a 5G utilization ideas contest for solutions to regional issues, with the theme, "Safe, secure, labor-saving, and usable anywhere." The second use case was smart logistics, to deal with a serious labor shortage in the logistics industry.

2. 5G for i-Construction

Because the population of working-aged people in Japan is decreasing, various industries need to increase labor productivity by upgrading information and communications (ICT) and other equipment, reducing travel and labor by utilizing data, and other measures. Japan is also very mountainous, with many tunnels as part of the social infrastructure. Serious accidents can occur on tunnel construction work sites, such as cave-ins, landslides, suffocation, and fires, so safe and secure work environments must be implemented.

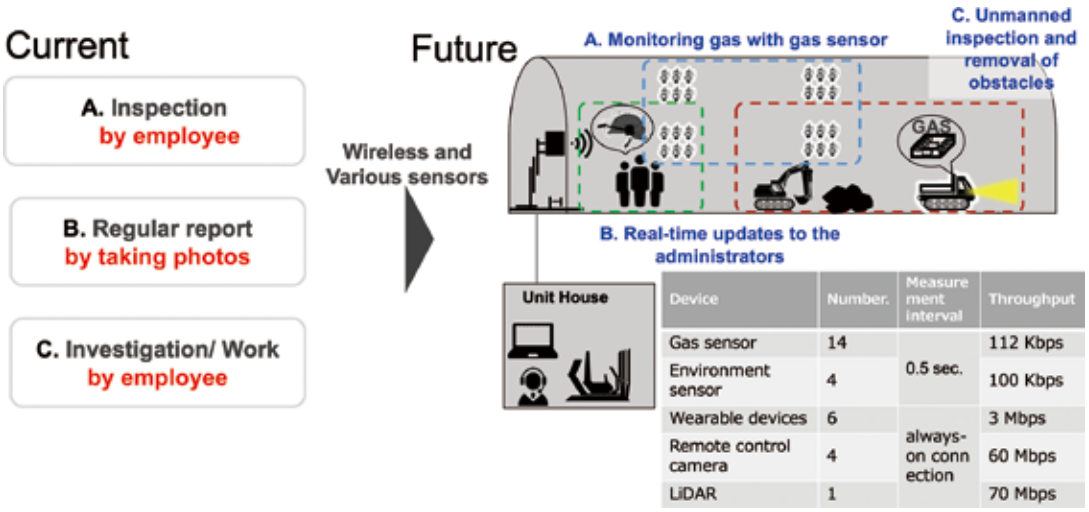
In this field trial, sensors for dangerous toxic or flammable gases, and other indexes of work environment conditions such as temperature and carbon dioxide were installed to detect hazards within a tunnel, and data was collected through 5G, making it easier to detect these dangers. If an accident occurred, unmanned construction equipment was also remotely operated to perform an initial safety check inside the tunnel.

2.1 Tunnel construction site safety monitoring with gas sensors, environment sensors and wearable sensors, and remote operation of construction machinery for initial safety confirmation during disaster

This trial involved a system to monitor safety in tunnel worksites, using gas and other environmental sensors and wearable sensors to gather data on poisonous or flammable dangerous gases that can occur in tunnel worksites, to monitor work environment indices such as temperature and carbon dioxide levels in real time, and to send alerts to workers if dangerous levels were detected.

Then, 5G terminals were installed with remote control equipment on a hydraulic shovel and crawler carrier at the tunnel work site, to build an environment remotely operating construction equipment from an operator room outside of the tunnel. By using 5G high capacity communication and a MEC server, the trial verified that construction equipment could be operated remotely from the operating room, approximately 1,400

Figure 1: Issues with tunnel work and trial details



Device	Number.	Measurement interval	Throughput
Gas sensor	14	0.5 sec.	112 Kbps
Environment sensor	4		100 Kbps
Wearable devices	6	always-on connection	3 Mbps
Remote control camera	4		60 Mbps
LiDAR	1		70 Mbps

Figure 2: System architecture

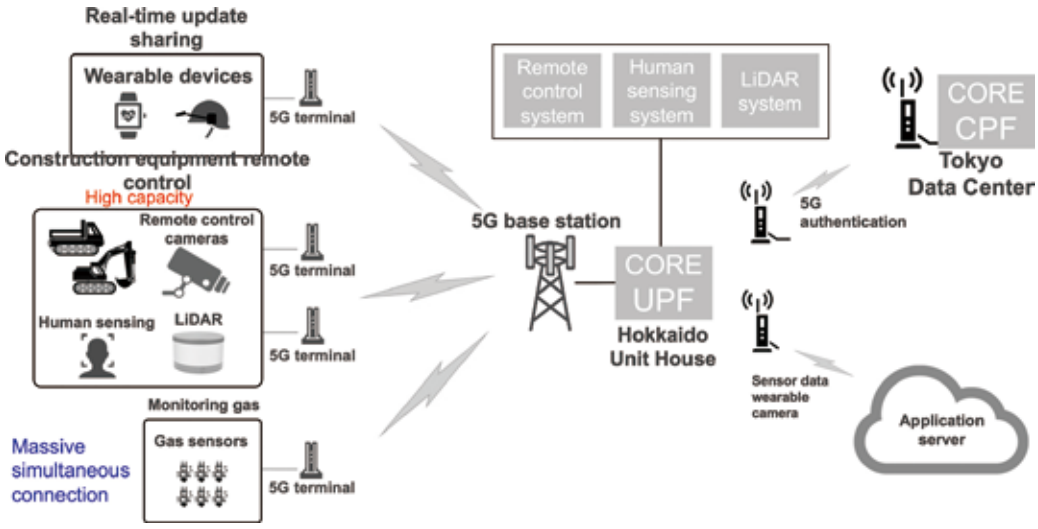
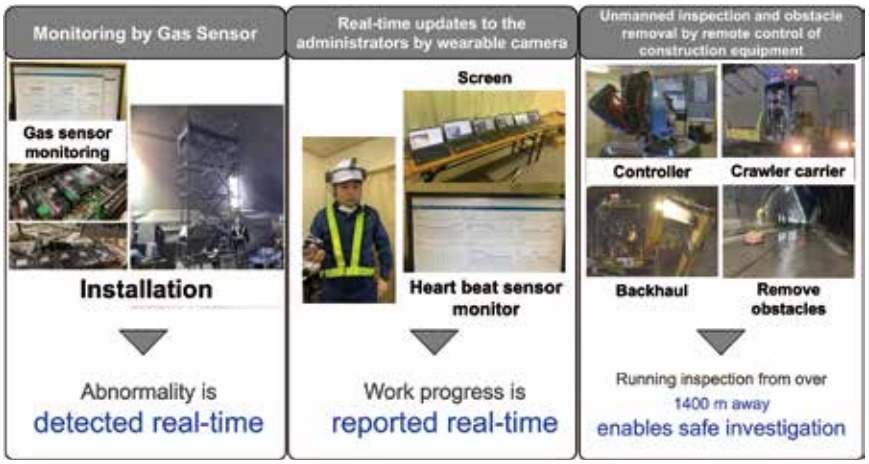


Figure 3: Trial results



m from the 5G equipment, and that video from four, full-HD cameras mounted on the equipment could be transmitted to the control room, with no problems due to data loss or delay. Gas sensors were also installed on the construction equipment, and the trial verified the ability to check the environment in the tunnel.

2.2 Verifying slicing functions integrating various communication requirements

It was anticipated that wireless communication capacity could be strained when remotely controlling construction equipment to check site safety when a disaster has occurred. This would

require high-capacity communication in a tunnel construction site with many IoT devices such as gas and other environmental sensors. Accordingly, the trial also verified the performance of per-application priority control using the network slicing function. The slicing function allows the required bandwidth to be guaranteed for the priority application, according to a pre-determined priority profile, even if the capacity is strained. In this trial, gas sensor data, which is life-critical, was given the highest priority and communication for remote operation of equipment was given the next highest priority. In this way, the ability to transmit gas sensor data without loss, and to transmit the video data required to control equipment remotely, with acceptable delay, was verified.

3. Smart logistics

A promising way to address significant issues in the logistics industry, such as the shortage of truck drivers and reforming work practices, would be to build an efficient cargo loading system. As Mobility as a Service (MaaS) has developed, various measures have also been proposed, such as mixing loads of passengers and goods or sharing transport, and there is increasing need to visualize load data in order to implement such measures.

To deal with such needs and issues, Wireless City Planning and Nippon Express are conducting a field trial using 5G networks with LiDAR (laser scanners) to visualize the state of the load on a truck, and acceleration and other sensors to make decisions about loading the storage compartment. A field trial

Figure 4: Use of network slicing

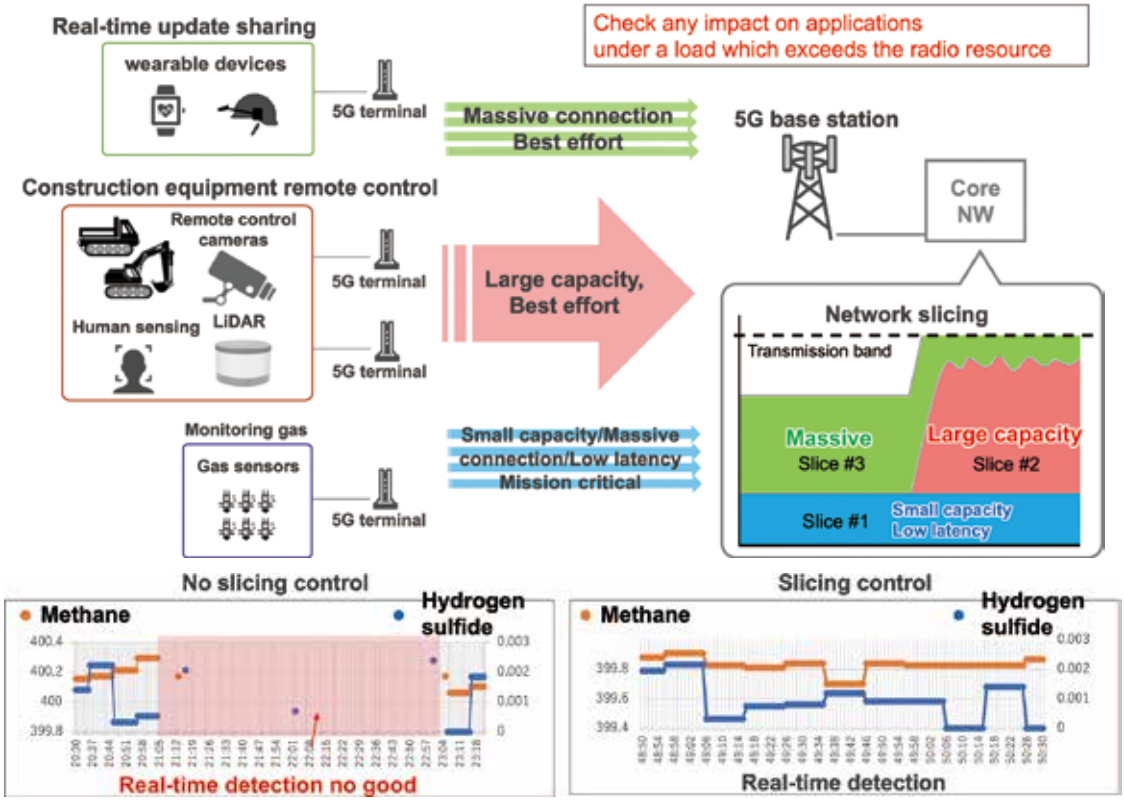
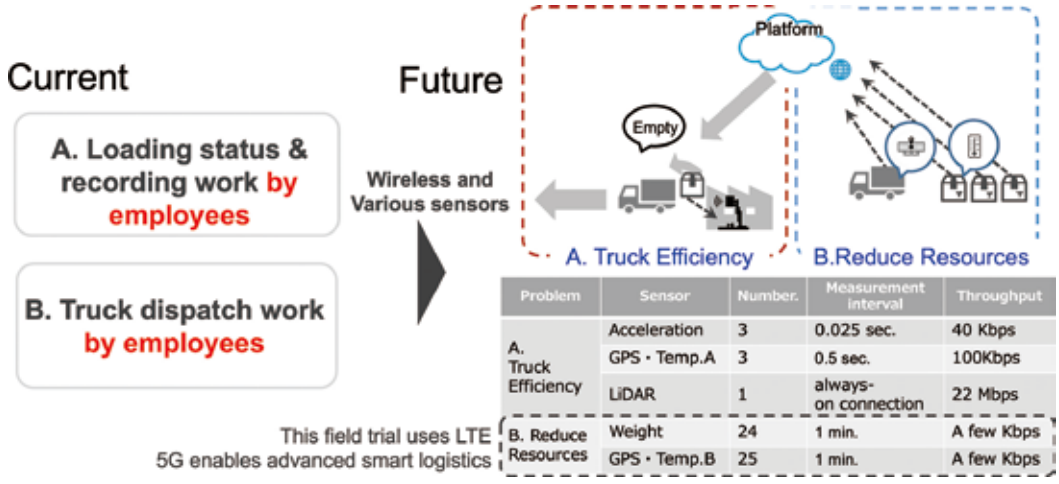
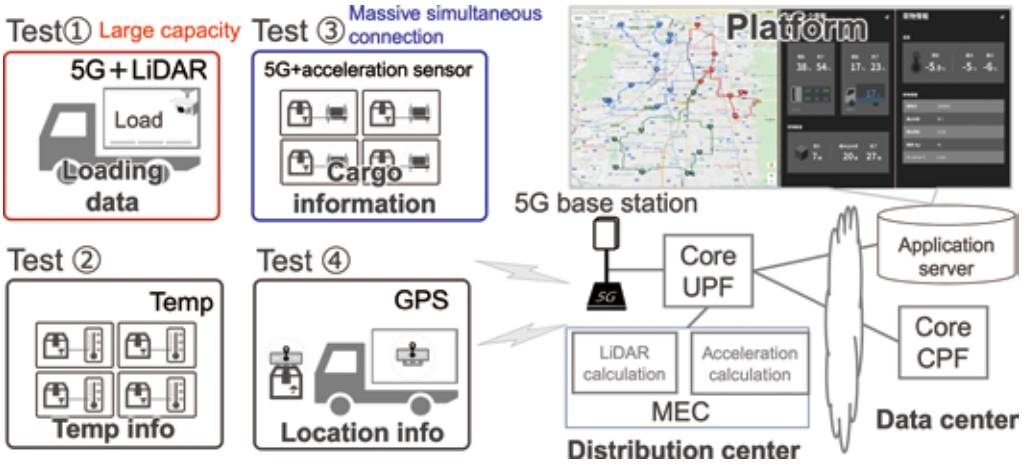


Figure 5: Issues with cargo loading work and trial details

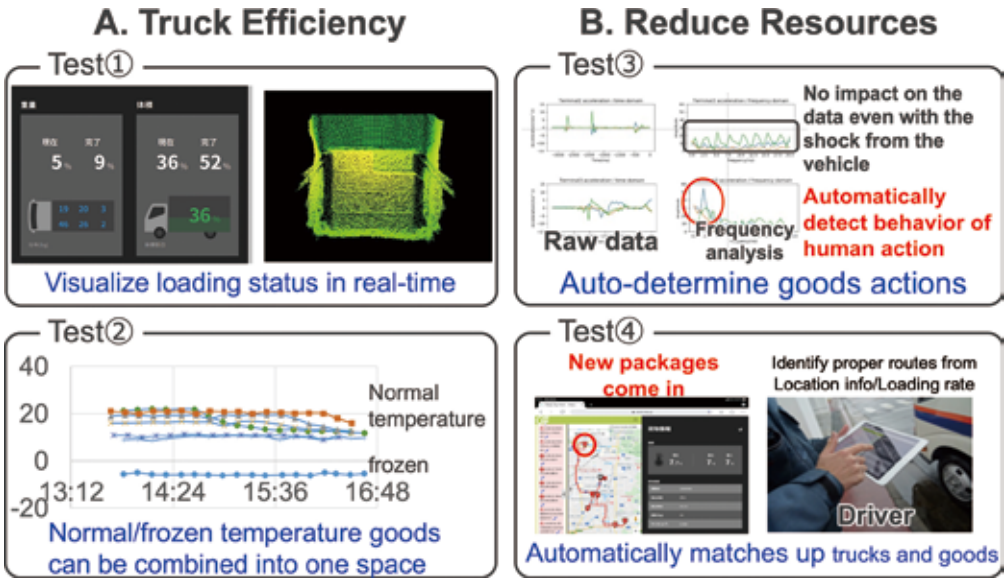


Problem	Sensor	Number.	Measurement interval	Throughput
A. Truck Efficiency	Acceleration	3	0.025 sec.	40 Kbps
	GPS・Temp.A	3	0.5 sec.	100Kbps
	LiDAR	1	always-on connection	22 Mbps
B. Reduce Resources	Weight	24	1 min.	A few Kbps
	GPS・Temp.B	25	1 min.	A few Kbps

■ **Figure 6: System architecture**



■ **Figure 7: Trial results**



was also conducted using Cat. M1 to check load temperature and weight.

3.1 Truck load state visualization and loading decisions using 5G and a MEC server

To visualize the space available in the cargo area of a truck, a 5G terminal was used to send a point set of the space, obtained using LiDAR, to a manager in a location distant from the truck. Using high-capacity 5G communication and a MEC server, the point set data from the cargo area can be transmitted and analysed in real time, and the load state can be visualized on the manager's screen. By attaching sensors to the freight that send data frequently, the trial verified that whether the freight has been packed in the cargo area can be detected based on the acceleration and location data from the sensors.

4. Conclusion

This article has described two usage scenarios envisioned for 5G mass connectivity, working toward implementations of 5G in society that provide solutions to regional issues.

In tunnel recovery work after a disaster as envisioned for i-Construction, workers would conventionally have to check the environment with absolutely no idea what the conditions were. However, by using remote operation of equipment and gas sensors to get information, it was demonstrated that a higher level of safety can be expected. With smart logistics, it was shown that the system could be used to save labor by reducing the amount of work in loading cargo, and also by increasing loading efficiency. Both of these use cases required an amount of traffic exceeding that specified by ITU-R, but the implementation operated without difficulty using 5G. The two use cases also required the 5G network to satisfy both ultra-fast communication and massive connectivity requirements at the same time, and this was shown to be possible with a single base station.

These trials also revealed further issues with implementation of 5G in society, including packaging, reducing the size, power consumption and price of 5G terminals, and selecting sensor devices with consideration of measurement accuracy. Further study of these issues will need to continue in the future.

Promotion of 5G Field Trials and Reflections

— Path of 5GMF/5G Trial Promotion Group Activities—

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1. Introduction

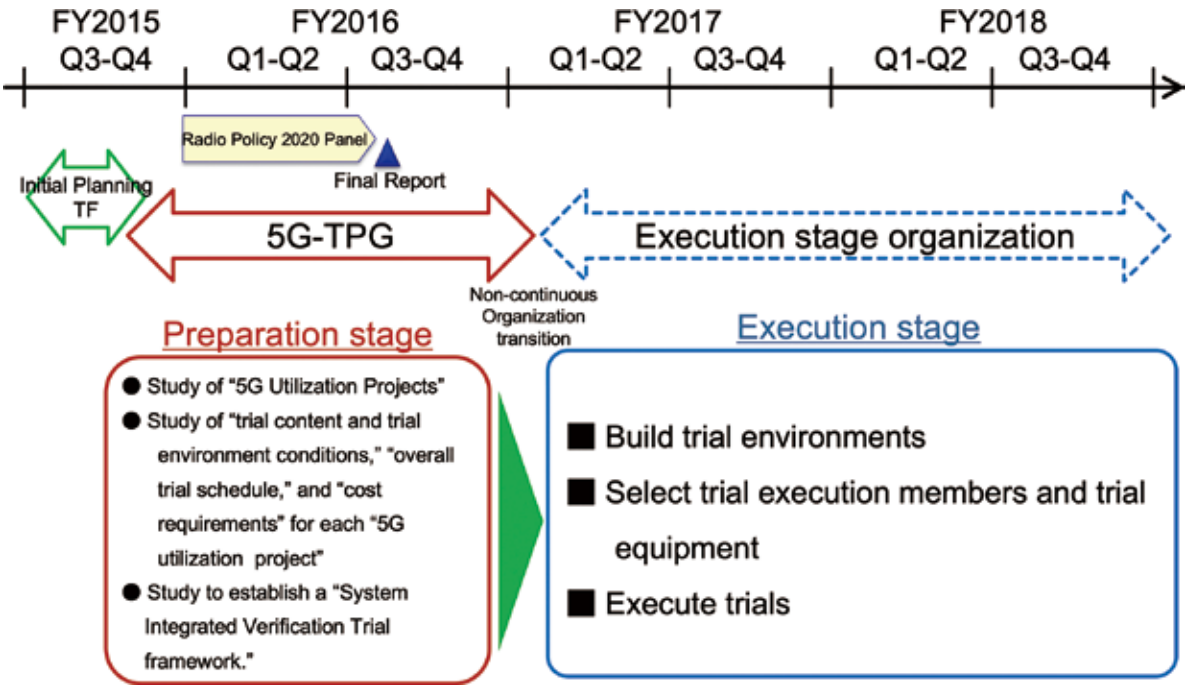
The Fifth Generation Mobile Communications Promotion Forum (5GMF) was established in September, 2014, to promote implementation of 5th Generation mobile communications systems (5G). It proposed that system integrated verification trials of 5G linking wireless communication, network applications and user devices (UE), be conducted starting in FY2017, and established a task force and then a 5G trial promotion group to study specific content of such trials. This article discusses the path taken by the promotion group in its activities, and reflects on promotion of system trials on 5G.

2. Preparation for System Trials on 5G

In September, 2015, the 5GMF planning committee established the System Integrated VerificationTrial Initial Planning Task Force (called the "Initial Planning TF") as a subcommittee, to draft a plan for conducting system integrated verification trials of 5G. Based on the results of hearings with 5GMF members, the Initial Planning TF created a draft plan enumerating trial items, details, equipment, and examples of applications and services that could be tested, for three categories of radio communication trials. These included a trial of high speed and capacity of the low-SHF band (below 6 GHz) communication, of high-speed and ultra-high-speed (ultra-low-latency) high-SHF band (over 6 GHz) communication, and of device-to-device communication with different types of wireless systems. Later, in January 2016, the 5G Trial Promotion Group (5G-TPG) was established within the 5GMF, to study a concrete plan and framework for conducting system trials across the various 5GMF committees, for technology, networks and applications. The 5G-TPG was composed of members elected from each committee (from 28 5GMF ordinary members as of June 2016). In the FY2016 preparation stage of the 5G-TPG activities schedule at the time (Figure 1), the group promoted advance preparation and planning for conducting system integrated verification trials based on results from the Initial Planning TF, and in the FY2017 and later execution stage, the reorganized group promoted building the actual trial environments, selecting trial execution members and trial equipment, and executing the trials.

In the actual preparation stage, the 5G-TPG solicited proposals for concrete 5G utilization projects (suitable as trial themes) from the constituent members. After organizing the

Figure 1: 5G-TPG activity schedule



proposed projects in terms of trial content, trial environments, trial time-frames, related organizations and other factors, the results were published in a report (5G Utilization Project Plan – English Edition)[1] in September, 2017. The report mentions a wide range of use cases in a total of 35 5G utilization projects, which are categorized into six fields such as Entertainment, Automobile-related, Crime prevention, and Disaster prevention. It lists trial environments associated with each use case, such as stadiums, shopping malls, theme parks, train stations, and airports; and gives specific locations with consideration for regional balance, and a desire to build trial environments in all regions, and not just the Tokyo area.

3. Execution stage for 5G Field Trials

The 5G-TPG later identified several projects desirable to execute as the system integrated verification trials of 5G at the beginning of FY2017, and began study with the goal of creating concrete execution plans and frameworks for each of the projects by the end of 2016.

On the other hand, the Ministry of Internal Affairs and Communications (MIC) had been promoting research and development on 5G radio communication technologies to realize ultra-high speed, high capacity, low latency and massive connectivity since FY2015. The basic framework for conducting the 5G Field Trials also incorporated this 5G research and development, and so called, "Technical Examination Service" work by the MIC, on systems that combined new applications and services envisioned for 5G, to identify any issues in implementing 5G systems and to perform studies necessary for creating the technical standards.

The trial items and content of these 5G Field Trials by the MIC also referred to the 5G-TPG report (5G Utilization Project Plan) mentioned earlier and conducted trials anticipating 5G utilization in various fields, while including study of the radio propagation characteristics of the new frequency bands for 5G and evaluation of system performance. After the MIC established the new trial framework, the 5G-TPG has continued its activities since FY2017, actively supporting implementation of the 5G Field Trials.

Table: Domestic and international presentations and exhibits

Date	Title	Sponsor	Type	Format
Oct. 2016	5th Generation Mobile Communication Systems (5G) Workshop 2016 @ CEATEC2016 "5G System Trials for Realizing 5G Systems"	MIC, 5GMF	Domestic event	Presentation (5G-TPG Sub-leader)
Oct. 2016	5G Technology Workshop "5G Key Concept and System Trial in Japan"	TAICS	International event	Presentation (5G-TPG Sub-leader)
May 2017	The 3rd Global 5G Event in Tokyo, Japan Session 3: "Overview of 5G System Trial Concept & Plan in Japan"	5GMF	International event	Presentation (5G-TPG Leader)
Oct. 2017	5th Generation Mobile Communication Systems(5G) Workshop 2017 @ CEATEC2017 "Activity Status of 5G Trial Promotion Group in 5GMF"/"Overview of 5G System Trials Project Execution"	MIC, 5GMF	Domestic event	Presentation (5G-TPG Leader/ Test Groups)
Nov. 2017	The 4th Global 5G Event in Seoul, Korea "Recent Activities on 5G System Trials in 5GMF"	5G Forum	International event	Presentation (5G-TPG Leader)
Nov. 2017	MWE2017 Microwave Workshop/Microwave Exhibition "5th Generation Mobile Communication Systems System Trials for Realizing 5G"	IEICE APMC Japan Committee	Domestic conference	Presentation/Exhibit (Test groups)
Mar. 2018	5G International Symposium 2018 Part 1: What can we do with 5G? — Results from the 5G System Trials —	MIC, 5GMF, ARIB	Domestic event	Presentation/Exhibit (Test Groups)
Mar. 2018	2018 General Conference BP-1 "System Trials for Realizing 5G and Future Expectations"	IEICE	Domestic conference	Presentation (Test Groups)
May 2018	The 5th Global 5G Event in Austin, USA "5G System Trials in Japan -Activities of 5G Trial Promotion Group (5G-TPG) in 5GMF-"	5G Americas	International event	Presentation (5G-TPG Leader)
Nov. 2018	APMC2018 Workshop "5G System Trials in Japan"	IEICE	International meeting	Presentation (5G-TPG Leader)
Nov. 2018	The 6th Global 5G Event in Rio de Janeiro, Brazil Panel 7: "5G System Trials in Japan"	5G Brazil	International event	Presentation (5G-TPG Leader)
Nov. 2018	MWE2018 Microwave Workshop/Microwave Exhibition "5th Generation Mobile Communication Systems System Trials for Realizing 5G II"	IEICE APMC Japan Committee	Domestic conference	Presentation/Exhibit (Test Groups)
Jan. 2019	5G International Symposium 2019 Part 2: 5G System Trial Results Presentation	MIC, 5GMF, ARIB	Domestic event	Presentation/Exhibit (Test Groups)

Date	Title	Sponsor	Type	Format
Mar. 2019	2019 General Conference BI-4 "[5G Day] Part II, 5G System Trial Results and Development for the Future"	IEICE	Domestic conference	Presentation (Test Groups)
June 2019	The 7th Global 5G Event in Valencia, Spain Session 2: "5G System Trials in Japan"	5G-IA	International event	Presentation (5G-TPG Leader)
Aug. 2019	2019 Next-Generation Mobile Communication Technology and Application Workshop "R&D Activities and Field Trials toward 5G Actualization in Japan"	FuTURE Forum	International meeting	Presentation (5G-TPG Leader)
Sept. 2019	IEEE VTC2019-Fall WS-TPoC5GE2019 "Outcomes of Korea - Japan Joint 5G Collaboration -5G Field Trials in Japan-"	IEEE VTS	International meeting	Presentation (5G-TPG Leader)
Oct. 2019	5G International Seminar 2019 @CEATEC2019 "5G System Trials in Japan"	MIC, 5GMF, ARIB	Domestic event	Presentation (5G-TPG Leader)
Nov. 2019	MWE2019 Microwave Workshop/Microwave Exhibition "5th Generation Mobile Communication Systems System Trials for Realizing 5G III"	IEICE APMC Japan Committee	Domestic conference	Presentation/Exhibit (Test Groups)
Dec. 2019	Shimane Prefecture 5G Utilization Workshop "5G Overview and Use Cases – Overview of 5G System Trials–"	Shimane Prefecture	Domestic event	Presentation (5GMF Office)
Jan.-Feb. 2020	IoT/ICT Implementation Seminar	MIC Bureau of Telecommunications at 11 locations throughout Japan	Domestic event	Presentation (5GMF Office)
Feb. 2020	5G International Symposium 2020 Part 1: 5G System Trial Results	MIC, 5GMF, ARIB	Domestic event	Presentation/Exhibit (Test Groups)
Mar. 2020	2020 General Conference TK-5 "5G System Trial Results and Future Expectations"	IEICE	Domestic conference	Presentation (Test Groups)
Jun. 2020	CSA Japan Summit 2020 "Trends in Testing New 5G Services in Japan —MIC 5G System Trial Results for Starting 5G Commercial Services—"	CSA Japan	Domestic event	Presentation (5G-TPG Leader)
July 2020	Yamaguchi Prefecture 5G Research Conference and Lectures "5G/Local 5G Utilization— 5G System Trial Results (3 years) —"	Yamaguchi Prefecture	Domestic event	Lecture (5GMF Office)
Oct. 2020	CEATEC 2020 ONLINE "5G Special Day II/ 5G Workshop" Session 1 "5G System Trials Review"	ARIB, 5GMF, CIAJ	Domestic event	Presentation (5G-TPG Leader)

Figure 2: Global 5G Event

The 5G Field Trials begun in FY2017 are introduced in the MIC articles in this Special Feature, and were conducted for three years until FY2019, with participation from people in various utilization fields, to help create new markets through implementation of 5G. Each year, six trial groups conducted trials throughout Japan specializing on their respective themes. Technical objectives for ultra-high speed, high-capacity, low latency and massive connectivity were set for different areas; whether urban or rural, indoor or outdoor; and testing was done using the new frequency bands introduced for 5G (3.7/4.5/28 GHz), through collaboration among partners from a wide range of industries, application fields and participants involved in the mobile communications industry. Articles from each of the trial groups are included in this special feature, introducing specific themes tested in FY2019 and results from those trials.

4. Support for performing 5G Field Trials

The latest trial conditions being implemented by each trial group (trial plans, results) are being reported quickly at domestic and international conferences and other events as shown in the Table. The 5G-TPG has been supporting each trial group with their presentations and exhibits as well as coordinating and summarizing each group's results. The goal of these activities is to inform people from a wide range of industries and businesses, not limited to telecommunications, of the details of the trials and to provide an opportunity to feedback their comments and opinions to the trial members, so this appeal is also being spread with articles in academic journals[2]. At the Global 5G Events (Figure 2), held twice yearly by 5G promotion organizations in various countries and regions, the 5G-TPG introduces the latest

Figure 3: 5G-TPG reports (booklets)

trial results from each trial group, spreading the development and testing of 5G use cases in Japan across various regions, and promoting the use of 5G to find solutions to various societal issues faced, not only by Japan, but by countries around the world.

The 5G-TPG also creates the 5G-TPG Report (Figure 3), which can be considered its annual report, and distributes it as a booklet at the Global 5G Event. The first and second editions of this report are also published on the 5GMF web site[3]. The "General Report on 5G System Trials in Japan from 2017 to 2020," can be considered the third edition and is currently in progress. It includes results from trials conducted in FY2017 and FY2018 as well as the FY2019 Trials introduced in this special feature, and will be published on the 5GMF web site before the end of 2020, after the booklet is completed and arrangements are made.

5. Conclusion

Commercial 5G services were started by operators in Japan towards the end of March, 2020, but several operators outside of Japan announced that they had started the world's first commercial 5G services about one year earlier. This has led to suggestions that Japan is lagging the rest of the world in 5G, but a new generation of mobile communication system has evolved about every decade in the past. We expect that 5G will also spread and use of services will continue to expand in the next decade, and we are confident that the system integrated verification trials of 5G, discussed and implemented by the 5GMF and 5G-TPG over the five years from 2015 until commercial services began, will be a driving force behind this expansion.

Acknowledgements

We would like to take this opportunity to express deep gratitude to those at MIC, the 5GMF general meeting and advisory council and other committees for their guidance in 5G-TPG activities, and to everyone at 5G-TPG, the 5G Field Trial groups and the 5GMF office for their collaboration in these efforts.

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[1] 5GMF, "5G System Integrated Verification Trial Report—5G Utilization Project Plan—Ver. 1.0 English Edition," https://5gmf.jp/whitepaper/5g-tpg-report-1-0/, Sept. 2017.

[2] Y. Okumura, M. Minowa, S. Suyama, "5G System Trials by All Japan," IEICE Journal, Vol. 101, No. 11, pp.1058-1065, Nov. 2018.

[3] 5GMF, "The First Report on 5G System Trials in Japan 2018 Rev.1," "The Second Report on 5G System Trials in Japan 2019," https://5gmf.jp/whitepaper/, Apr. 2018/June 2019.

Cover Art

Eight Views in the Environs of Edo
Clearing Weather at Shibaura

Utagawa Hiroshige (1797~1858)

Collection of the Art Research Center (ARC)
Ritsumeikan University
Object number: BN03828992-1-04

Overview of the 2020 Information and Communications White Paper

Economic Research Office, ICT Strategy Policy Division,
Information and Communications Bureau,
Ministry of Internal Affairs and Communications

1. Introduction

The first part of the 2020 Information and Communications White Paper has adopted the special theme, "Digital Transformation and New Lifestyles Promoted by 5G," looking at two issues: 5th generation mobile communication systems (5G), which began commercial services in Japan in 2020, and the global spread of the new coronavirus disease (COVID-19). It summarizes current conditions, how they have affected society, the economy, and the digital revolution in Japan, and the outlook for Japanese society into the 2030s. The second part of the white paper provides the latest data indicating the state of information and communications in Japan and discusses policy trends, mainly related to initiatives of the Ministry of Internal Affairs and Communications (MIC). This article gives an overview of the First part of the white paper.

2. 5G: Infrastructure for the New Era (Reiwa Era)

(1) Evolution of mobile communication systems

Since the 1st Generation mobile communication system (1G) was introduced in Japan in 1979, performance improved with each successive generation approximately every ten years, and it has now grown to be essential infrastructure for everyday life and for corporate economic activity. Now, commercial 5G services began in Japan in 2020, and it is expected to have even more impact on society than before, being implemented as infrastructure for the IoT era in various fields and industries. This is because, in addition to enhanced Mobile Broadband (eMBB), which increases the speed and capacity of earlier mobile communication systems, it can also fulfill requirements for Ultra-Reliable Low Latency Communications (URLLC) and massive Machine Type Communication (mMTC). These are expected to be used as infrastructure, creating new value by improving efficiency and convenience in industry and society.

With the appearance of 5G, mobile communications systems are evolving further, from lifestyle infrastructure to industrial and societal infrastructure, and we expect it to contribute to economic growth and finding solutions to societal issues in Japan.

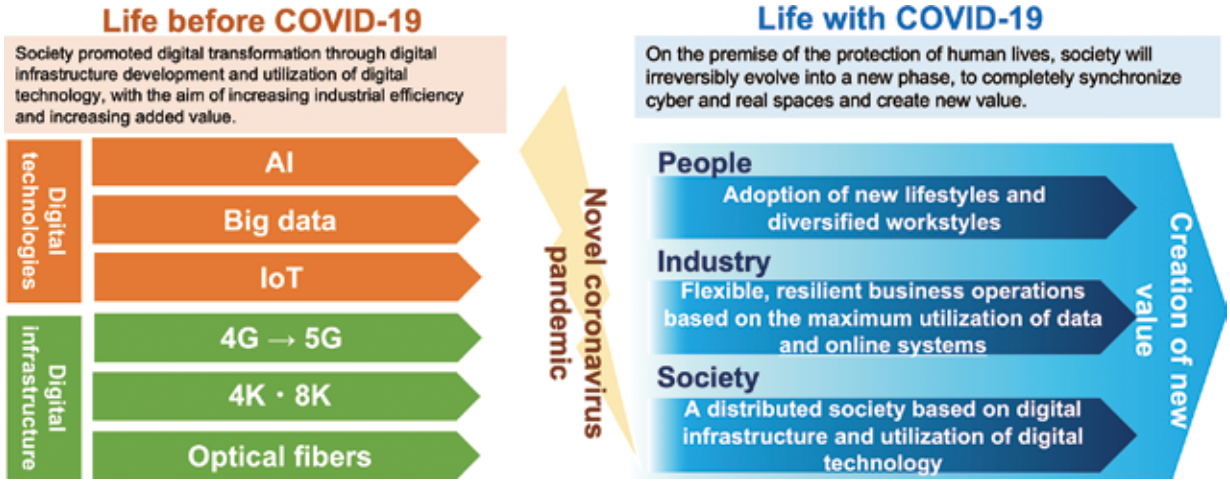
(2) 5G Trends in various countries

5G commercial services were started earlier in the USA, Europe, China, and South Korea than in Japan. After three carriers in South Korea simultaneously initiated mobile 5G services for smartphones on April 3, 2019, Verizon started a mobile 5G service in the USA. China started their service in November, 2019, approximately one year earlier than originally planned, and 11 countries in Europe had started commercial 5G services as of March, 2020.

On April 10, 2019 in Japan, the MIC approved plans by NTT DOCOMO, KDDI/Okinawa Cellular, SoftBank, and Rakuten Mobile, to deploy specified base stations, and commercial services started in March, 2020.

As described in detail in Section 4 of Chapter 2 of the white paper, Japan has created a "Local 5G" system, separate from the nation-wide services provided by mobile phone operators. The system provides flexibility for various entities to build mobile

Figure 1: Life before COVID-19 and with COVID-19



communication systems that can be used to meet the needs of individual regions or industries, and currently various development demonstration tests are in progress. Similar systems are also being implemented in Germany and the UK.

(3) Structural changes in the telecommunications market

As commercial 5G services have started and with the spread of IoT and AI technologies, the number of IoT devices in the world is expected to increase dramatically, particularly in industrial applications and consumer information appliances. On the other hand, according to the GSM Association (GSMA), an industry association of mobile phone operators from various countries, 5G lines will make up only 20% of all mobile lines by the year 2025. Although the ratio will exceed 30%, particularly in North America, Greater China, and Europe, it is expected to remain in the single digits or teens in other regions. This is because the higher frequency bands used by 5G require more base stations than 4G, to cover an equivalent area. Although the telecommunications operators in Japan share their networks, it will take time to expand the 5G area, so building up the market is expected to proceed at a relatively leisurely pace.

In the past ten years, companies in South Korea and China have greatly expanded their shares of the global mobile phone devices market, and there have been great changes in the structure of the ICT industry ecosystem in Japan, as the GAFA companies and other platform providers have joined the conventional telecommunications operators. These changes in the structure of ICT industries may continue in the future, with the implementation of 5G in various industries and fields.

3. Digitalization of all of society prompted by 5G

(1) ICT as a means to solve issues and initiatives anticipating the 2020s

Japan is known as one of the leading nations on issues, and also leads in population decrease and aging, so for some time, there has been a need to actively introduce and use ICT to improve quality of life and employment, and to increase work productivity. Regional governments have had various initiatives using ICT to find solutions to societal issues, and the white paper introduces several cases including a "workation" initiative in Nagano Prefecture, an e-sports initiative in Arima Onsen, and an initiative to introduce a residents' collaboration application in Chiba City.

Among digitalization initiatives being conducted with an eye to completion in 2020, new technologies are being introduced such as cashless transactions, multilingual translation, and facial recognition, and there are measures to reform work styles with telework, and to reduce and prevent disaster.

As for cashless transactions, Japan has not made progress because of the convenience and reliability of cash, but prompted by cashless point-return programs and measures against COVID-19, settlement using QR codes or barcodes has become more common, particularly on smartphones. With this development, JPQR, which is a standard integrating both QR codes and barcodes, is also being introduced. High quality translation is also becoming possible with improvements in AI deep-learning technology, so multilingual translation is also becoming practical.

Figure 2: Ecosystem transitions in Japan's mobile industry

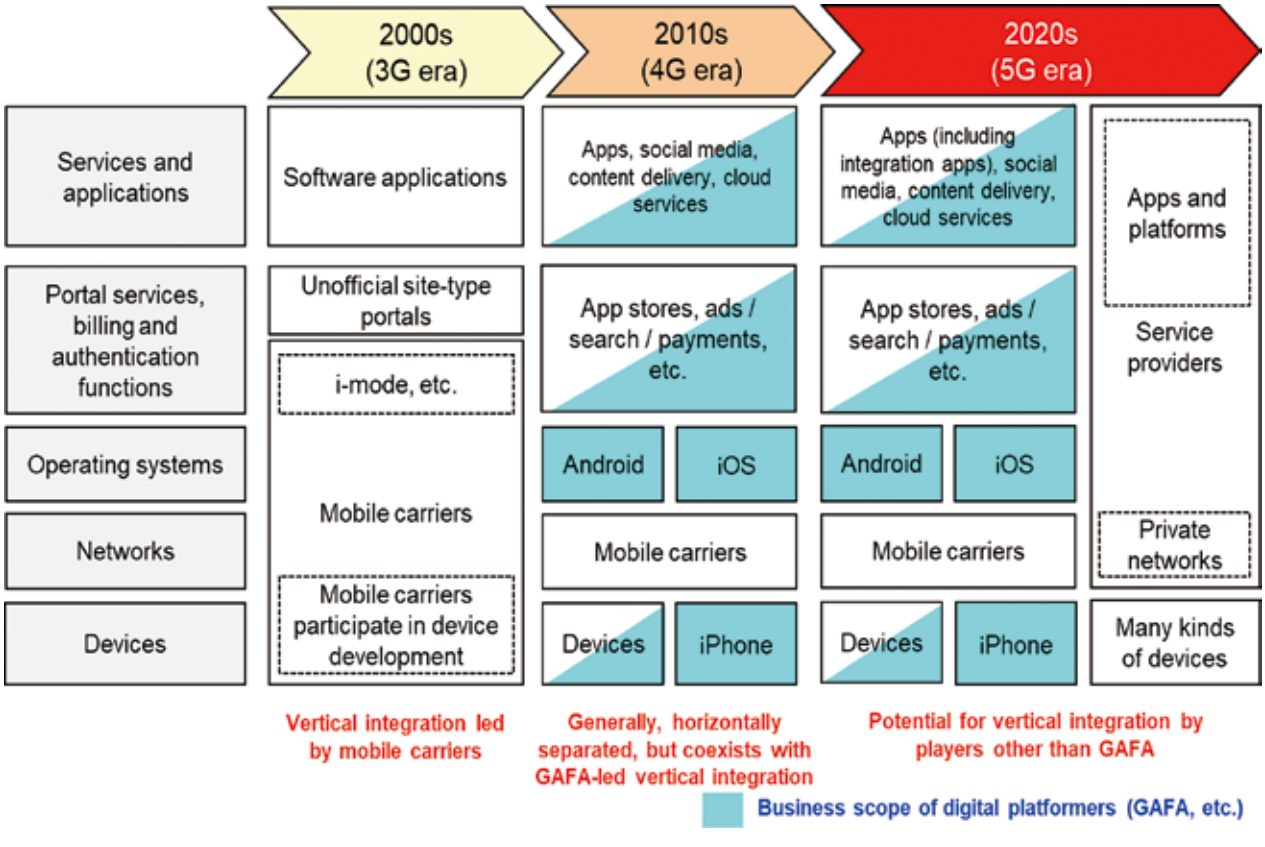
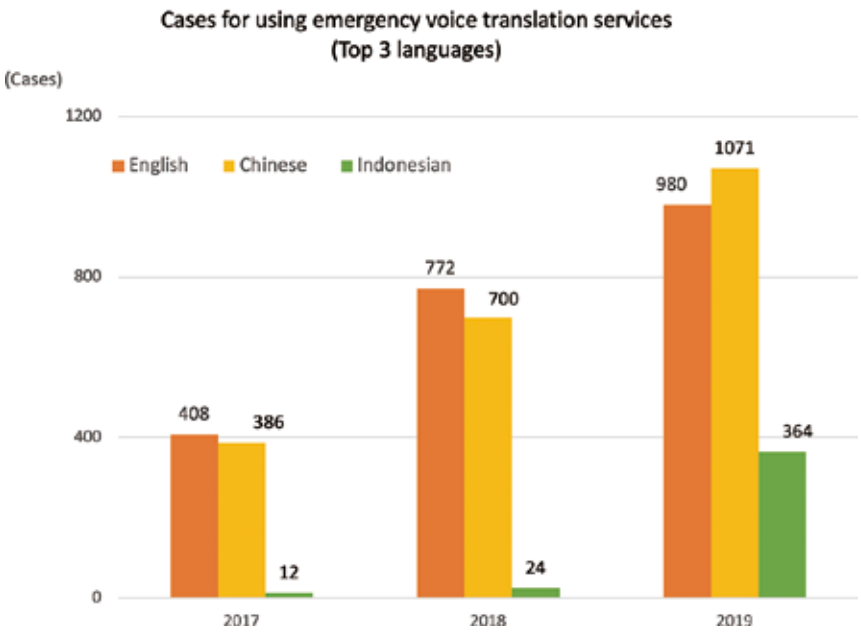


Figure 3: Multilingual translation used by local fire department



(2) Migration of industry to wireless, driven by 5G

In the future, 5G will be implemented as infrastructure for industry and society in Japan in various industries and fields. It is expected to improve business efficiency and creating new added value by contributing to solving issues in these industries and fields.

According to a survey conducted by the MIC in 2020, before commercial 5G services commenced, corporate interest in 5G is high in all fields, particularly in manufacturing, and large enterprises have more interest than medium and small enterprise.

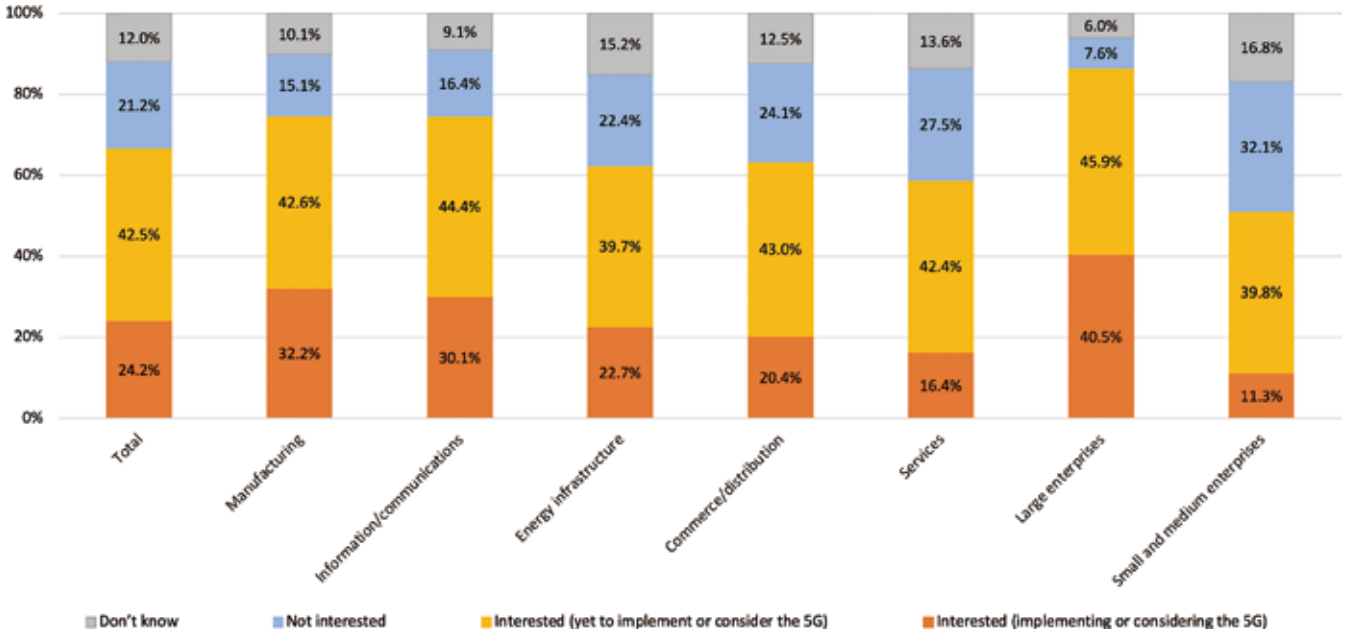
Individual users are looking forward to higher communication speeds, but there is concern that fees will increase, so it will be important to eliminate these concerns and to provide enticing services and applications, in order to spread 5G to ordinary users in the future.

(3) Effects on society of the spread of COVID-19

The global spread of COVID-19 has had huge effects on the flow of information and the digital economy in Japan, and is requiring transition to new ways of life in all kinds of scenarios. In such conditions, initiatives such as actively distributing accurate information to prevent the spread of infection, and introducing ICT to ensure social distancing, including data analysis and utilization, are increasingly important.

In the short term, various initiatives are expanding, such as visualization of human-contact risk through collaboration among administration, civic tech and private enterprise; telework in enterprise; introduction of remote lectures in schools; and relaxation of requirements on remote medicine for special cases and limited times. However, various other issues are also materializing due to the sudden increase in ICT use. Many issues are not new, such as increasing traffic, insufficient measures against security risk, the need to review business details such as moving to paperless workflows and digital contracts; and finding balance between public health and utilization of personal data, but this "COVID-19 Era" requires introduction of irreversible new ways of life at all levels: personal, industrial, and societal; and these issues must absolutely be dealt with.

Figure 4: Enterprise interest in 5G



4. Data flow in the 5G era and security

(1) Current state and issues with utilization of digital data

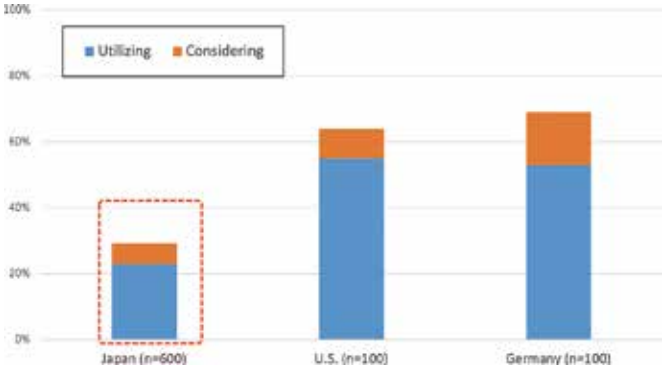
The spread of IoT devices and the increase in the amount of video and other content, mainly because of the proliferation of smartphones has increased the flow of data in recent years, and this is expected to accelerate and become more important as 5G spreads, particularly with applications in industry.

Currently in Japan, the proportion of all data used by enterprise for analysis that is obtained from IoT devices is growing quickly, at four to seven times that of 2015 levels, but this is still low compared with use of digital data by enterprises in the USA and Germany.

The amount of data crossing national borders is also increasing because it is becoming normal for enterprises to act globally, and to provide services in other countries through the Internet. According to the Japan External Trade Organization (JETRO), a total of 1,608 Gigabits crossed the Japanese border every second in 2001, and this had increased by 165 times, to 265,000 Gigabits in 2016.

With this increase in cross-border data, the flow of personal data has also increased, and according to a survey conducted by the MIC in 2020, approximately 20% of enterprises in Japan transfer personal data across borders. This figure is approximately 40% in the USA, and up to 50% in Germany. The white paper introduces several concrete examples of how data is being utilized by enterprises in Japan.

Figure 5: Enterprise utilization of digital data

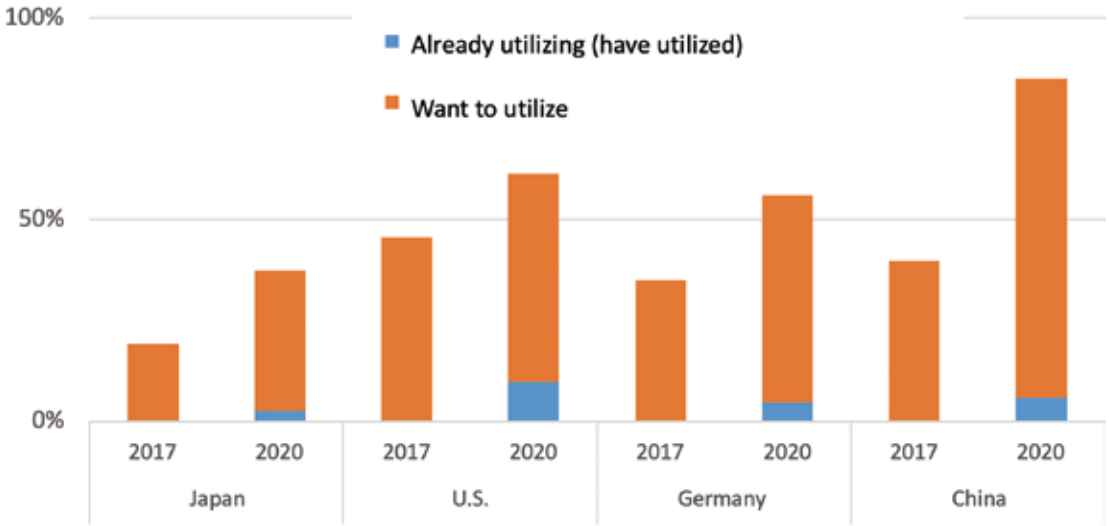


(2) Use of personal data in the future

As is shown by the growth of digital platform providers, this growth in digital data is a promising new source of value. However, concern among consumers in Japan regarding use of personal data has increased, and enterprises have not exploited it to the extent they have in some other countries. More recently, compared with the results of a survey conducted in 2017, this trend has decreased slightly, possibly due to authorization of so-called personal data trust banks and the appearance of Personal Data Store (PDS) services. For example, regarding their intension to use services such as a personal data trust bank, the proportion of consumers responding that they would like to use one has increased compared to 2017, and this is similar to other countries.

However, concern regarding information leaks remains high relative to other countries, and the use of anonymized

Figure 6: Consumer intention to utilize personal data trust banks or personal data stores



2017: n=1030, 2020: n=1000

data is expected to expand utilization of personal data in Japan. Anonymized data is data that has been processed so that specific individuals cannot be identified and the original data cannot be recovered, providing a safe and secure way to use personal data.

(3) Cyber security in the 5G era

With increasing activity utilizing data, society as a whole is becoming much more digitized, and it is becoming more important to deal with cyber-security risk. "Ten Information Security Threats in 2020," from the Information-Technology Promotion Agency (IPA) stated that the number-one threat to individuals is smartphone settlement fraud, suggesting that cyber attacks on smartphones are also increasing.

With the introduction of 5G services, installation and operation of IoT devices for industrial applications will also increase, and the potential for industrial equipment and infrastructure that was previously isolated from the Internet to be connected will increase. It has been pointed out that security measures for these sorts of cases will be much more important in the future. Security risks related to use of IoT devices have often been overlooked, but it will be even more important to foster awareness of security issues with IoT users in the future.

5. Beyond 5G

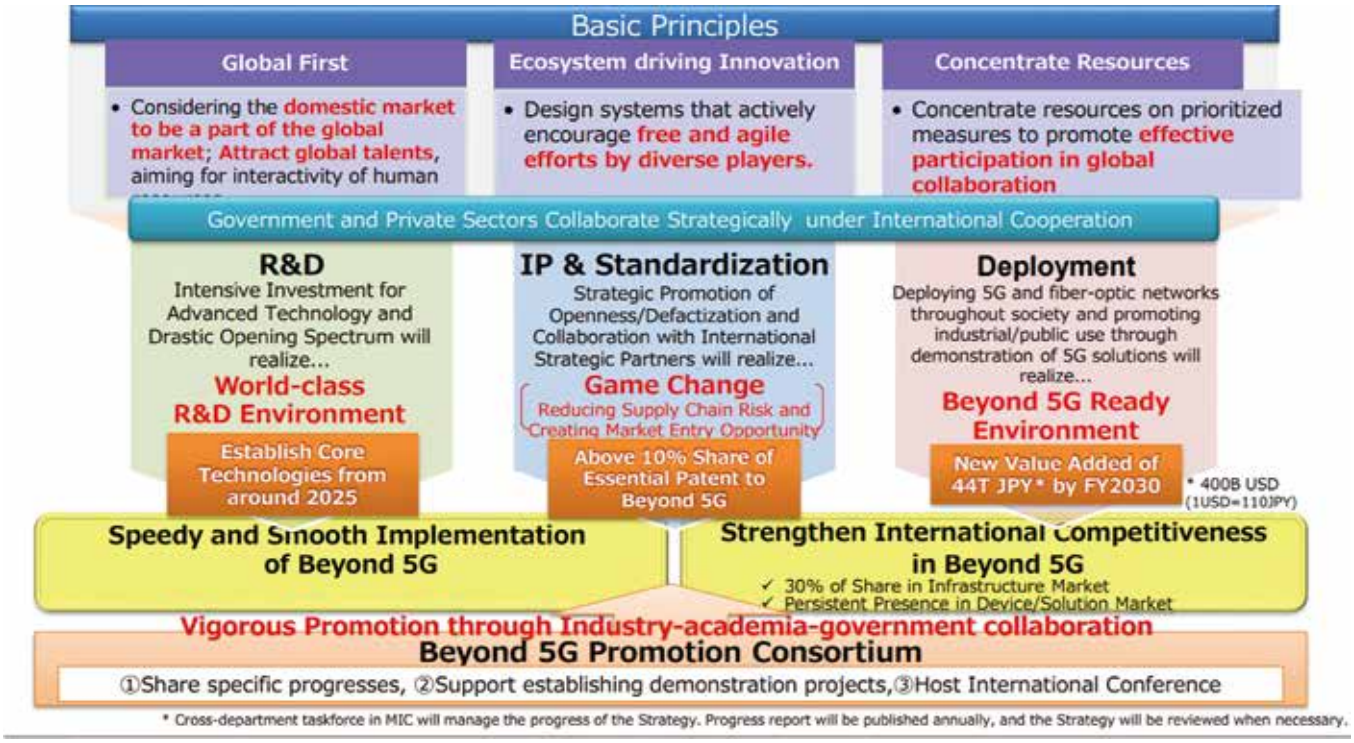
The fourth chapter discusses the prospects for society in Japan in the 2030s, in light of innovations such as 5G, IoT and AI, and introduces domestic and international trends surrounding "Beyond 5G," which will be needed to realize such a society.

With the implementation of 5G in society, exchange of data between physical space and cyber space will take place faster, at higher-volume, and with less delay. This will lead to realization of cyber-physical systems (CPS) that further integrate these two spaces in the 2030s, and will help realize a vigorous and resilient society where cyber space can enable economic activity and the lives of citizens to continue smoothly, even when new contagions or disasters occur in physical space.

To realize the extremely high level of synchronization required for such CPSs in the 2030s, communications infrastructure that is faster than 5G and able to deliver large amounts of data, safely, reliably and without delay to anywhere, will be needed.

Initiatives for the successor of 5G, or "Beyond 5G," are already in progress in advanced countries. Japan also created a "Beyond 5G Promotion Strategy" in June, 2020, as a strategic initiative to bring people and government together based on international collaboration. To ensure Japan's competitiveness in the future, we will take our strengths and focus on reinforcing our R&D capabilities on technologies with which we are already actively engaged, such as tera-hertz waves, all-photonic networks, quantum cryptography, sensing, and low-power consumption semiconductors.

Figure 7: Beyond 5G Promotion Strategy — Basic Principles —



52nd Celebration of World Telecommunication and Information Society Day

6 October 2020 at KEIO PLAZA HOTEL

The ITU Association of Japan

Ceremony at Keio Plaza Hotel, Tokyo

Award Winner and Honorable Guests

MIC Minister's Award Winner Mr. NAITO

ITU-AJ Special Achievement Award Winner Ms. ITO

Honorable Guest : Mr. SHINTANI State Minister, MIC

Honorable Guest : Mr. ONO Director-General for Global Issues, MOFA

Anniversary Keynote Presentation: Mr. TANIWAKI Vice-Minister for Policy Coordination, MIC

The List of the Award Winners on 6 October 2020

MIC Minister's Award

Mr. Yushi NAITO (Mitsubishi Electric (Retired))

ITU-AJ Award
ITU-AJ Special Achievement Award

Ms. Kazuko ITO (STAND)

ITU-AJ Accomplishment Awards

Dr. Shuichi AOKI (NHK)
Mr. Hiroshi AONO (NTT DOCOMO)
Dr. Masugi INOUE (NICT)
Mr. Hirosuke USUI (TBS)
Mr. Yuki UMEZAWA (KDDI Foundation)
Dr. Hiroyo OGAWA (NICT)
Dr. Toshiaki KURI (NICT)
Mr. Hiroshi KOMATSU (SoftBank)
Mr. Seiji SAKUMA (ARIB)
Mr. Norifumi TANAKA (TRANSEA)
Mr. Toshiyuki TAMURA (NEC)
Mr. Hideki TSUCHIDA (JTEC)
Mr. Kazuo NAKAMURA (KDDI/ARIB)
Mr. Mitsuo NOHARA (KDDI)
Mr. Hiroshi HAMANO (TTC)
Mr. Tatsumi MUNESATO (JTEC)
Ms. Keiko MORI (Washington CORE)
Mr. Junya YAMAGUCHI (JAPAN RECOM)
The Project for Expansion of Broadcasting Equipment of Myanma Radio and Television (NEC)
Wireless Access Systems Project, NTT Access Network Service Systems Laboratories (NTT)

ITU-AJ Encouragement Awards

Mr. Hiroshi ISHIKAWA (NTT DOCOMO)
Mr. Wataru ISHIDA (NTT EAST)
Mr. Noriyuki INOUE (KDDI)
Mr. Suguru OKUYAMA (NTT DOCOMO)
Dr. Hirokazu KAMODA (NHK)
Mr. Hiroyuki SAITO (OKI)
Mr. Morihiro SAKAKIBARA (KDDI Foundation)
Dr. Yicheng ZHOU (Fujitsu)
Mr. Takeshi SHIRAHASE (TV Asahi)
Mr. Kazuhisa TAKAYAMA (Fujitsu)
Mr. Hiroshi DEMPO (NEC)
Dr. Yoshiharu DOI (TOYOTA)
Mr. Teruaki TOEDA (NTT DOCOMO)
Dr. Yoshihide TONOMURA (NTT COMWARE)
Dr. Yoshihiro NAKAJIMA (NTT DOCOMO)
Dr. Yusei NISHIMOTO (NHK)
Mr. Kenichi YAMAMOTO (KDDI)
Dr. Rudi LUMANTO (ID-SIRTII/BSSN)
QKDN Standardization Team (NICT/NEC/Toshiba)

通巻百二十九号
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