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NTT docomo

Toward the 5G Era

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The first research theme given to me on entering NTT DOCOMO was “4G.” At that time, there was no 3G system much less i-mode—in fact, we were at the stage in which digital cell phones with maximum data transmission speeds of 9,600 bps were just starting to appear. While we knew that 4G would be coming something in the near future, we had no idea what it would entail, what its aim was, and what problems could arise, so we were essentially groping about in the dark. However, since 100BASE-T Ethernet was already the norm in fixed-line communications at that time, we thought that 4G despite being a wireless system would surely have transmission speeds of around 100 Mbps as well. So with this in mind but still unsure as to what problems could arise with what kind of wireless transmission system, I began research with my superior while searching for some direction. Looking back at that period, I was not as pressed for time as I am now, so I was able to do my research while taking a variety of detours. This was a good experience, and I learned the value of an approach that considers things from various angles.

At the time of 3G commercialization, the 4G study team took on more members and the breadth of research extended not only to the physical layer but to upper layers as well. Furthermore, to bring 4G to the world, it was not simply a matter of increasing speed and expanding capacity, the universal problems in communications. We also had to explain the concept of 4G, that is, we had to answer the question “What exactly is 4G?” Then, when replying “It’s QoS!” hinting at the next big trend, we would be asked “What do you mean by QoS?” or “Please explain in concrete terms.” but we would be stuck for an answer. From then on, we included QoS in our research and began to study what form it would take in 4G, but at that time, voice was still positioned at the core of mobile communications. On the other hand, data communications using TCP/IP in fixed-line communications was becoming mainstream, so the expectation was that data communications would someday also become important in mobile communications. In voice communications, controlling quality requires the shortening of latency when establishing a connection and while a call is in progress, and in data communications, it requires the shortening of end-to-end latency assuming TCP. With this in mind, we simplified QoS in 4G as a matter of “controlling latency” and proposed at standardization meetings that latency be significantly reduced. Though not necessarily precise, I believe that addressing the problem first in conceptual terms in this way was how we were later able to reduce it to more concrete, physical indicators.

We are now at the dawn of the 5G era. Achieving higher speeds and greater capacities will always be an important item as long as traffic volumes continue to increase, so we can expect it to be a core issue in 5G. As for latency, the plan for 4G was to reduce it from several hundred milliseconds to several tens of milliseconds taking into account the applications that people would be using, so given the requirements of future devices in fields such as machine type communication, we can expect that a further reduction to several milliseconds will be needed. In short, reducing latency even further will be another core issue of 5G. It is also thought that many and varied terminal connections (massive connectivity) targeting IoT devices that first attracted attention in 4G will likewise be a core issue in 5G.

The 4G era enabled users to take full advantage of all the features that smartphones had to offer thanks to significant improvements in transmission speeds, picture quality, and latency that were insufficient for smartphone use in 3G. Now, in 5G, we can foresee the need for features that will enable users to navigate the world in a more intuitive, reflexive, or even unconscious manner much like human reaction via the spinal cord. In addition, we can expect the connection of all sorts of devices to the network to contribute to the creation of new industries through inter-industry collaboration and to the formulation of solutions to pressing social problems such as regional revitalization and labor shortages. At NTT DOCOMO, we have had experience with people-to-people connections since the 1G era, so the problems associated with such connections are relatively easy to understand, but we have yet to have sufficient experience with connecting things via mobile communications. I would therefore like to enter this new stage in communications by observing phenomena closely and identifying problems as quickly as possible.

Moreover, to swiftly and flexibly deal with a variety of new use cases, it is important that we construct an environment (ecosystem) in which equipment can be freely selected according to the rollout scenario. Starting with 4G, NTT DOCOMO has been providing interoperability between different vendors by standardizing the interface to radio access network equipment, and with 5G, we expect even more vendors to be adopting a common interface as a means of dealing with new use cases. NTT DOCOMO is a founding member of the O-RAN Alliance and a leader in interoperability initiatives that aim to facilitate cooperation with other operators and achieve open and interoperable interfaces on a global scale.

Going forward, I see NTT DOCOMO R&D as a pioneer opening up the 5G era by identifying new problems and taking the initiative to find their solutions.

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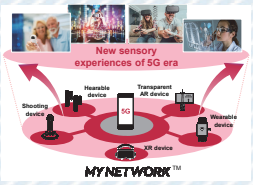

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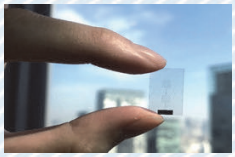

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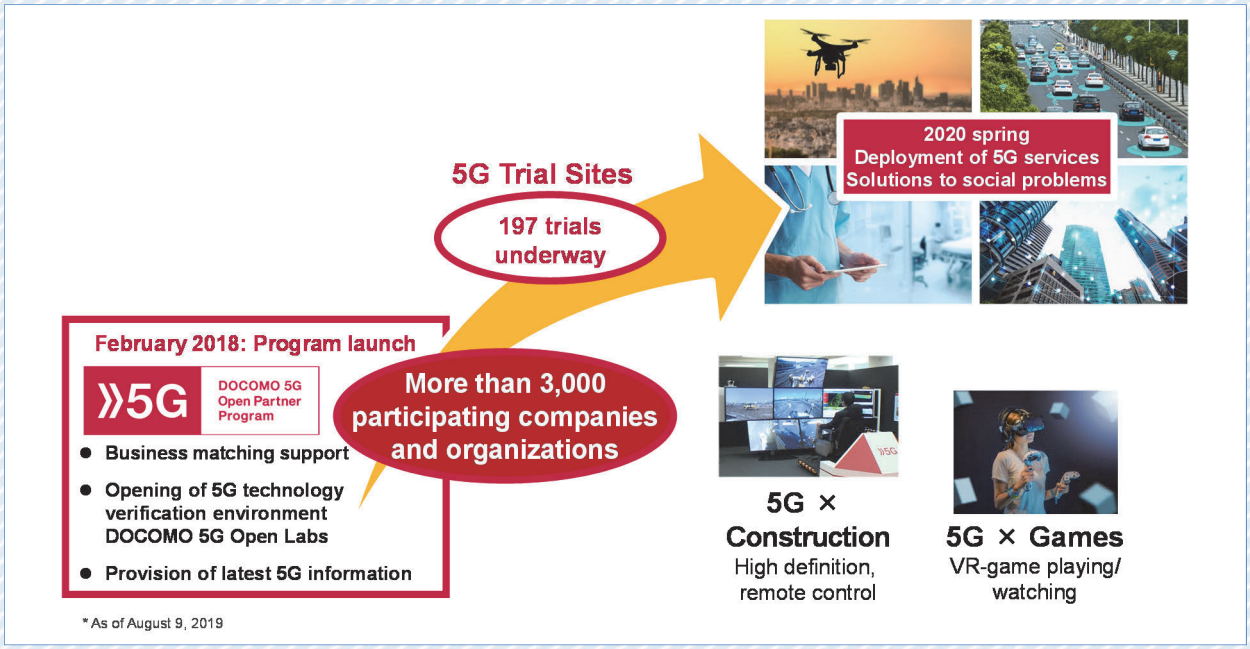

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Special Articles on 5G Pre-commercial Service

Overview of 5G Pre-commercial Service

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NTT DOCOMO launched its 5G pre-commercial service in September 2019 following the allocation of 5G frequency bands in Japan in April 2019. This launch was preceded by the creation of a wide variety of solutions through many field trials carried out with co-creation partners. The key features of 5G are high speed and large capacity, low latency, and massive connectivity. With these exceptional communications specifications, the industrial world has high expectations of 5G as a means of solving social problems and creating new industries. This article describes 5G technical features, presents a system overview, and introduces featured services and terminals in the 5G pre-commercial service.

1. Introduction

NTT DOCOMO has been constantly upgrading its network in step with increasing volumes of data traffic as reflected by its transitions from 3G to 4G, and within 4G, from LTE to LTE-Advanced. Today, data traffic continues to increase, and since we can expect the large-capacity plans and rich content like video services to become increasingly dominant in the future, there is no reason to doubt that this trend toward higher volumes of traffic will continue.

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In addition, mobile communications will generate higher expectations and become all the more important from the viewpoint of solving social problems and creating new industries through the expansion of the Internet of Things (IoT)*1 and the emergence of AI. With this in mind, NTT DOCOMO has been aggressively conducting experimental deployments at 5G trial sites*2 and creating new services that make the most of 5G features (**Figure 1**).

NTT DOCOMO launched its 5G pre-commercial service in September 2019. The purpose of this pre-commercial service is to create new solutions in collaboration with co-creation partners and to provide 5G-unique services to consumers. Additionally, as the millimeter waves*3 in the frequency bands allocated for 5G deployment in April 2019 feature extremely high directional propagation, another objective of the pre-commercial service is to acquire new technologies and knowledge in addition to radio technologies that we have so far developed.

In this article, we describe 5G technical features, present a system overview, and introduce featured services and terminals in the 5G pre-commercial service.

We ask the reader to refer to other articles in this issue for details on services that exploit 5G features, on MY NETWORK*4 that broadens the user's world through "smartphone" × "peripheral devices," and on solutions achieved through the DOCOMO 5G Open Partner Program.

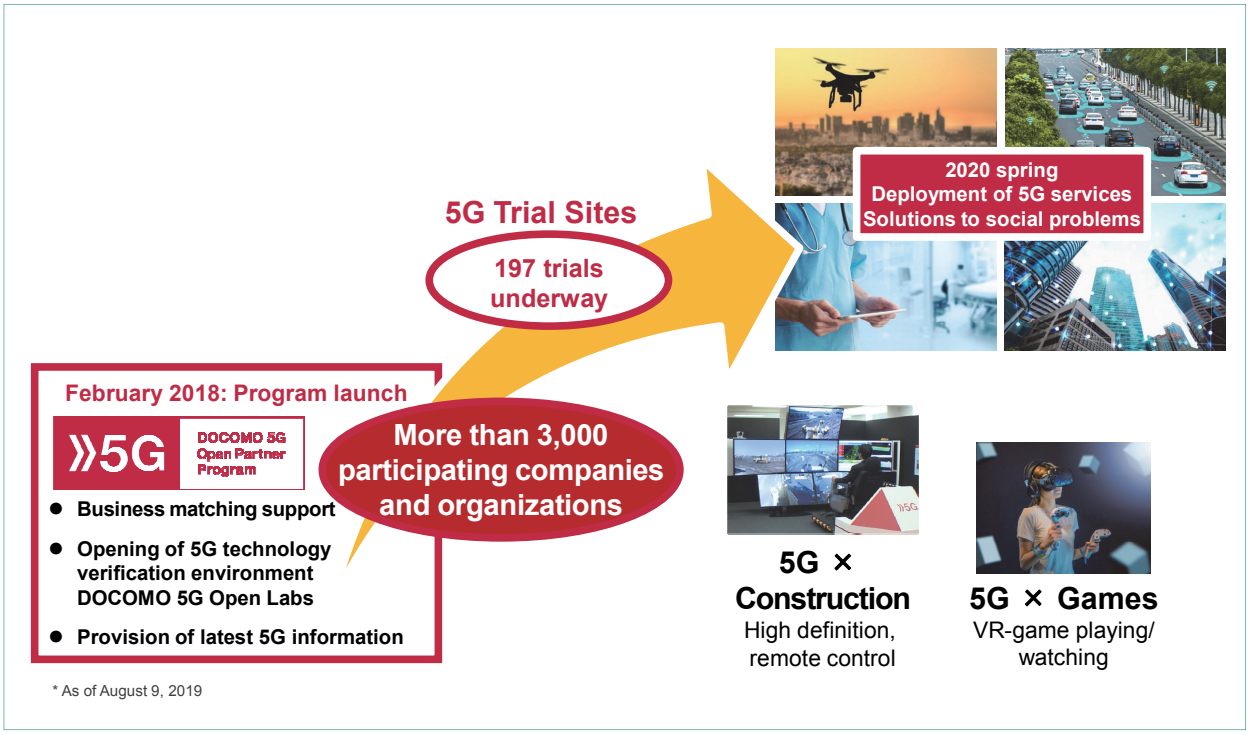

Figure 1 NTT DOCOMO initiatives toward early deployment of 5G services

*1 IoT: General term for the format of connecting all sorts of "things" to the Internet and cloud for control and information communications.

*2 5G trial sites: An environment using the NTT DOCOMO 5G network.

*3 Millimeter waves: Radio signals in the frequency band from 30 GHz to 300 GHz as well as the 28 GHz band targeted by 5G that are customarily called "millimeter waves."

*4 MY NETWORK: A trademark or registered trademark of NTT DOCOMO.

2. 5G Technical Overview

2.1 Three Technical Features

Featuring high speed and large capacity, low latency, and massive connectivity, 5G will provide compelling services in a wide range of use cases.

1) High Speed and Large Capacity

The 5G system will enable data transfers at speeds and capacities much higher than existing systems. This feature will make it possible to deliver high-definition video including Virtual Reality (VR)*5 and Augmented Reality (AR)*6 so that many people will be able to access and enjoy high-presence video and services.

2) Low Latency

This 5G feature will enable control with high real-time characteristics by making delay times even shorter. It will make even greater contributions to automation, for example, by enabling the grasping, controlling, and operating of plant and machine conditions in real time.

3) Massive Connectivity

In 5G, simultaneous connection of not just smartphones but also of all sorts of things such as sensors and electronic devices will become possible thereby furthering the penetration of IoT and enhancing the use of information helpful to life (such as vending-machine and meter information).

2.2 Major 5G Radio Technologies

1) Technologies for Achieving High-speed and Large-capacity Transmission

These technologies include high-frequency/ultra-broadband transmission and antenna techniques typified by Massive Multiple Input Multiple Output (MIMO)*7.

While LTE has been using frequency bands up to 6 GHz, 5G is expected to supplement those frequency bands with high frequency bands up to 100 GHz to achieve ultra-broadband capabilities. In particular, the 25 – 40 GHz band, which includes the 28 GHz band used by NTT DOCOMO's 5G pre-commercial service, features signal propagation characteristics different than those of existing frequency bands, so new specifications appropriate for using high frequency bands have been specified and a basic bandwidth of 400 MHz has been set.

Massive MIMO is a technology that uses many antenna elements to control the shape of the transmit/receive beam (beam forming) and configure an optimal area according to the environment. It can be used to expand an area by combining individual antenna elements and concentrating energy in one direction and to achieve a high-capacity system by simultaneously generating multiple beams and increasing the number of simultaneously connected users.

2) Technologies for Achieving Low Latency

New Radio (NR), a newly introduced radio access technology, achieves even shorter delays in the radio interval by shortening the smallest unit of radio transmission. While the transmission unit in conventional LTE was 1 ms, NR will transmit data in units of 0.25 ms at the time of 5G deployment. Furthermore, to achieve low latency in services, it will be necessary to shorten delays on an end-to-end basis, so combining low latency in the radio interval with low latency on the fixed-line interval will be critical. Specifically, end-to-end low latency can be achieved by combining NR with

*5 VR: Technology for producing "virtual reality" using a computer.

*6 AR: Technology for superposing digital information on real-world video in such a way that it appears to the user to be an actual part of that scene.

*7 Massive MIMO: A generic term for MIMO transmission technologies using very large numbers of antennas. MIMO is a signal technology that improves communications quality and spectral efficiency by using multiple transmitter and receiver antennas to transmit signals at the same time and same frequency.

Multi-access Edge Computing (MEC) that deploys computing resources at locations even closer to terminals. To test the effectiveness of these low-latency measures, the 5G pre-commercial service will provide services and solutions in combination with the docomo Open Innovation Cloud*8 that NTT DOCOMO provides as one form of MEC.

3) Technologies for Achieving Massive Connectivity

These technologies include IoT technology as part of the continuous evolution of LTE/LTE-Advanced (enhanced LTE (eLTE)*9) and other technologies such as LTE-M*10 and NarrowBand (NB)-IoT*11 introduced for the purpose of simplifying signal processing. They make it possible to install many IoT terminals (environmental sensors, meters, etc.) that transmit small amounts of data with low frequency within a certain area and to achieve massive connectivity [1].

3. System Overview

3.1 Concept of 5G Deployment

NTT DOCOMO plans to deploy 5G by combining NR and eLTE, where the former achieves dramatic jumps in transmission-speed and capacity performance using a wide range of frequency bands and the latter enables the provision of a basic coverage area*12 and services such as broadcast.

3.2 5G System Configuration

NTT DOCOMO has achieved a 5G pre-commercial service through a non-standalone*13 format in which terminals connect to the mobile network through both the NR and eLTE radio access systems. Specifically, it leverages the know-how obtained in deploying an Advanced Centralized Radio Access Network (C-RAN)*14 in LTE to provide high-speed communications through Dual Connectivity (DC)*15 using two radio access systems in an area in which both NR and eLTE can be used. A system configuration diagram of the 5G pre-commercial service is shown in **Figure 2**.

4. Overview of 5G Pre-commercial Services/Solutions and Terminals

In the 5G pre-commercial service, NTT DOCOMO will roll out a variety of services and solutions that exploit the 5G features of high-speed/large-capacity transmission starting with spectator support services such as multi-angle (multipoint) viewing and high-presence public viewing. The plan is to provide even more new 5G services and solutions for the Tokyo 2020 Olympic and Paralympic Games to be held in the summer of that year.

For the 5G pre-commercial service, 5G-compatible terminals will perform NR communications using a 100 MHz bandwidth in the "sub-6" 3.7 GHz and 4.5 GHz frequency bands and a 400 MHz bandwidth in the "millimeter-wave" 28 GHz frequency band. Using wide frequency bandwidths not available in past systems makes it possible to achieve the 5G feature of high-speed/large-capacity transmission. On the other hand, in addition to wide frequency bandwidths, millimeter waves correspond to frequencies having extremely high directional propagation, so there will be a need for advanced radio technologies enabling high-frequency and ultra-broadband transmission not provided in past systems.

*8 Docomo Open Innovation Cloud: A trademark or registered trademark of NTT DOCOMO.
*9 eLTE: An LTE communication specification conforming to 3GPP Rel. 15 or later.
*10 LTE-M: An LTE communication specification for terminals that communicate at low speed using narrow bandwidth, for IoT devices (sensors, etc.).
*11 NB-IoT: An LTE communication specification for terminals that communicate at even lower speed and narrow bandwidth than LTE-M, for IoT devices (sensors, etc.).
*12 Coverage area: The area over which a single base station can communicate with UE (cell diameter). As coverage is increased, the number of base stations required decreases.
*13 Non-standalone: An operation format that provides services through a combination of NR and an LTE area—in this format, a service area cannot be provided by NR alone.

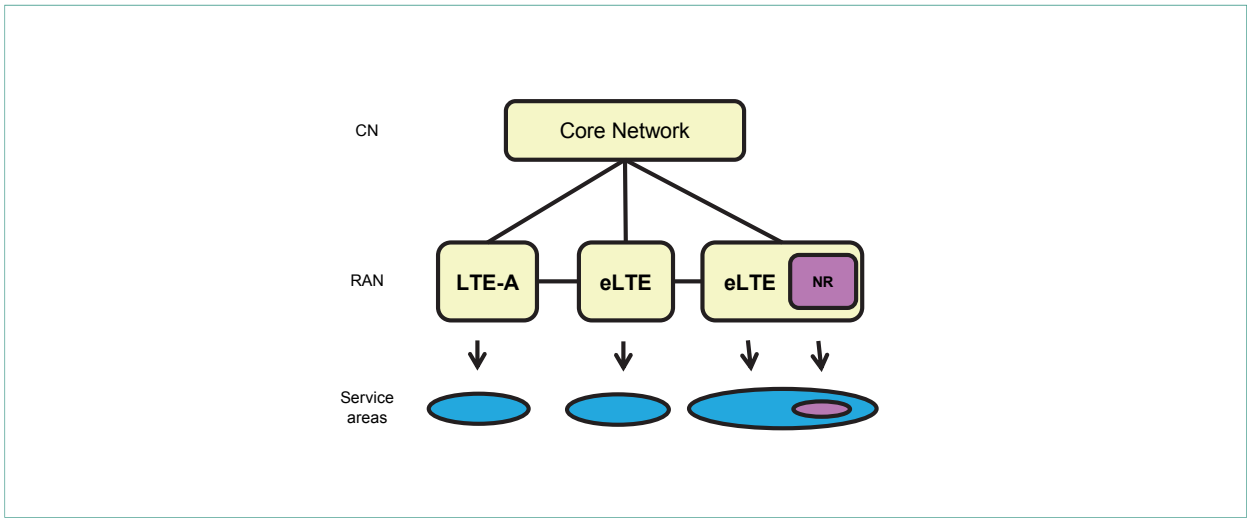

Figure 2 System configuration diagram

5. Service Areas

NTT DOCOMO plans to construct and roll out a variety of service areas in sequence for the 5G pre-commercial service such as major train stations/airports and stadiums in urban and regional areas as well as diverse facilities in collaboration with co-creation partners.

6. Conclusion

This article provided an overview of NTT DOCOMO's 5G pre-commercial service.

At NTT DOCOMO, we began 5G-related studies in 2010, and our efforts in accelerating the drafting of standard specifications in collaboration with major mobile operators throughout the world led to the completion of these specifications in December 2017. Then, after moving forward with more 5G-related R&D, we received our frequency allocation for deploying 5G in April 2019 and launched the 5G pre-commercial service in September 2019.

The full rollout of 5G commercial services is scheduled for spring 2020. NTT DOCOMO will be providing a variety of 5G services at the Tokyo 2020 Olympic and Paralympic Games to be held in the summer of that year. In this way, 2020 looks to be a memorial year in the history of 5G, and looking to the future, NTT DOCOMO is intent on making positive contributions to the worldwide dissemination of advanced and forward-looking technologies through 5G services.

REFERENCE

[1] S. Abeta, et al.: "Radio Access Network in 5G Era," NTT DOCOMO Technical Journal, 25th Anniversary, pp.16–24, Dec. 2018.

*14 Advanced C-RAN: A new centralized radio access network (C-RAN) architecture proposed by NTT DOCOMO. Being controlled by the same base station, a radio access network makes a linkage between a macro cell (which covers a wide area) and a small cell (which covers a local area) by applying carrier aggregation.

*15 DC: A technology that connects multiple base stations and performs transmission and reception using multiple component carriers supported by those base stations.

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Special Articles on 5G Pre-commercial Service

5G Pre-commercial Services Making Full Use of 5G Features

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NTT DOCOMO launched a 5G pre-commercial service in September 2019 ahead of its 5G commercial service scheduled for spring 2020. Coinciding with the holding of "Rugby World Cup 2019™*1 in Japan," the 5G pre-commercial service is rolling out spectator support services such as 5G high-presence public viewing and multi-angle viewing. It is also providing the "Shintaikan Live" service featuring live streaming and multi-angle viewing as a new form of entertainment for the 5G era. This article introduces key 5G pre-commercial services deployed by NTT DOCOMO, a driving force of the 5G era, and describes NTT DOCOMO's 5G event held at Tokyo Game Show 2019®*2 prior to the launch of the 5G pre-commercial service.

1. Introduction

NTT DOCOMO's 5G pre-commercial service got under way on September 20, 2019 providing a variety of new user experiences reflecting the 5G era. These include spectator support services for the Rugby World Cup, the first to be held in Asia, and the Shintaikan Live service that enables users to view live performances by artists through live streaming and multi-angle viewing. NTT DOCOMO also held an event envisioning a new era in gaming through 5G at Tokyo Game Show 2019 held

*1 Rugby World Cup 2019™: Rugby World Cup and its logo are trademarks or registered trademarks of Rugby World Cup Limited.

*2 Tokyo Game Show: A registered trademark of Computer Entertainment Supplier's Association (CESA).

from September 12 to 15, 2019 just prior to the launch of the 5G pre-commercial service. This article describes a variety of 5G pre-commercial services deployed by NTT DOCOMO, a major force behind the 5G era.

2. Initiatives toward Rugby World Cup 2019 in Japan

NTT DOCOMO's 5G pre-commercial service was launched alongside "Rugby World Cup 2019 in Japan." This is because the Rugby World Cup, which drew a total attendance of 2,470,000 fans last time [1], is an international sporting event on par with the FIFA World Cup®*3 and Olympics®*4 making it a perfect opportunity for large-scale promotion of 5G both inside and outside Japan. This time, moreover, it was the first Rugby World Cup to be held in Asia, so it was thought that it would attract considerable attention not only from diehard rugby fans but also from the general public in Japan thereby enabling even more users to recognize the merits of NTT DOCOMO 5G services. NTT DOCOMO was also a cosponsor of this event in its role as a Tournament Supplier, so as part of its 5G pre-commercial service, it provided the following 5G spectator support services during the tournament at various stadiums and at a public viewing site (**Figure 1**).

2.1 5G High-presence Public Viewing

NTT DOCOMO held "Rugby World Cup 2019 5G Public Viewing" events inviting a total of 600 general users to participate. At these events, match video from either Tokyo Stadium®*5 or International Stadium Yokohama®*6 was transmitted to a public viewing site (Bellesalle®*7 Shiodome) sponsored by NTT DOCOMO over a 5G network and projected

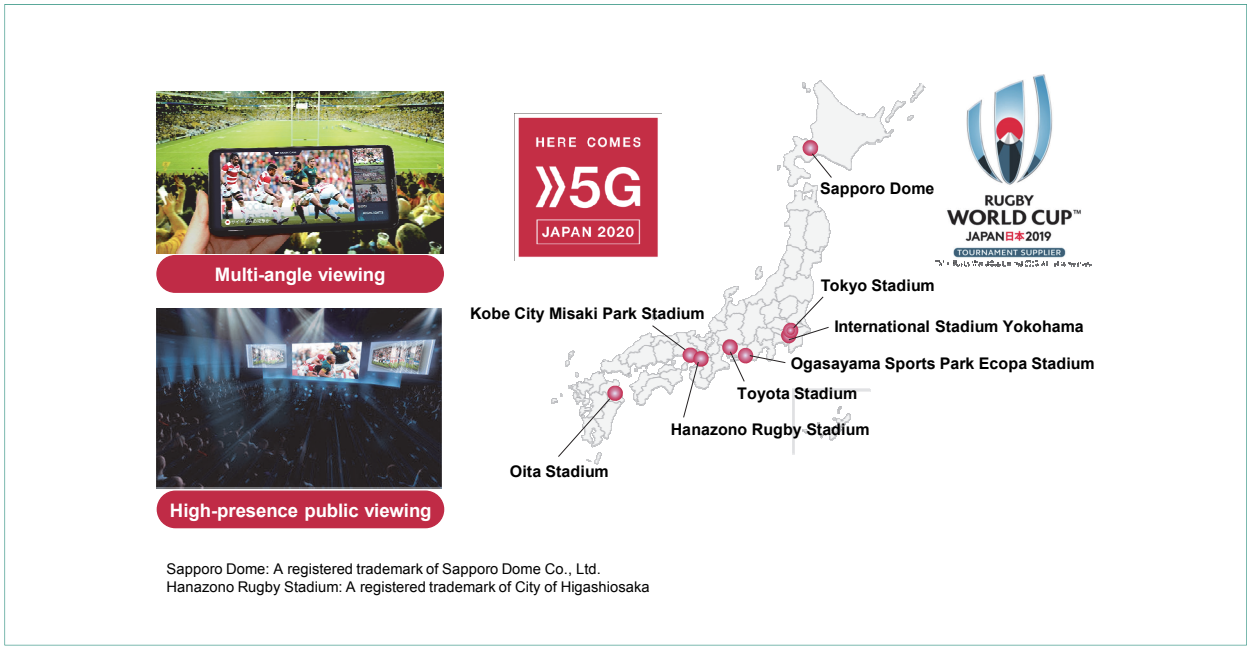


Figure 1 Spectator support services at Rugby World Cup 2019

*3 FIFA World Cup®: A registered trademark of Fédération Internationale de Football Association.
*4 Olympics®: A registered trademark of the International Olympic Committee.
*5 Tokyo Stadium®: A registered trademark of Tokyo Stadium Co., Ltd.
*6 International Stadium Yokohama®: A registered trademark of Yokohama Sports Association.
*7 Bellesalle®: A registered trademark of Sumitomo Realty & Development Co., Ltd.

onto large screens for viewing. Making full use of the high-speed, large-capacity, and low-latency features of 5G, this service can transmit large amounts of information such as video and audio at multiple angles from a match venue with low latency. It enabled an exciting public viewing experience at locations away from the stadium (**Figure 2**).

2.2 Multi-angle Viewing

This service delivered multi-viewpoint video of matches played at eight venues around Japan along with additional information such as commentaries, player data, and replay video via a 5G network to 5G terminals provided by NTT DOCOMO within a stadium or public viewing site (for two matches). With this service, users could check out video from various angles, player data, etc. at their fingertips while watching a match at a stadium or public viewing site, all of which made the watching of those sporting events even more enjoyable (**Figure 3**).

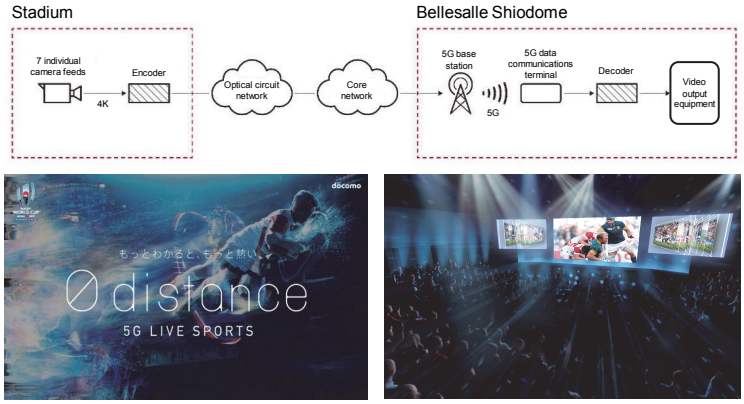
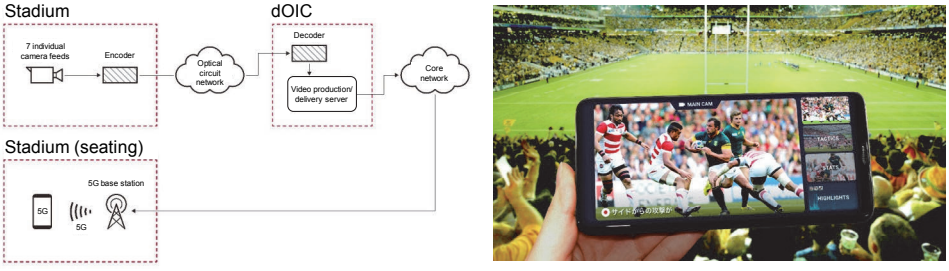


Figure 2 High-presence public viewing service



dOIC: Docomo Open Innovation Cloud™. Featuring Multi-access Edge Computing (MEC) that reduces network transmission delay and achieves a secure cloud environment, dOIC connects a cloud infrastructure to the NTT DOCOMO network. Docomo Open Innovation Cloud is a trademark of NTT DOCOMO.

Figure 3 Multi-angle viewing service

3. Entertainment for the 5G Era

In addition to services for Rugby World Cup 2019 in Japan, NTT DOCOMO is providing consumer-oriented services applying the 5G features of high speed and large capacity, low latency, and massive connectivity.

3.1 Shintaikan Live

Shintaikan Live is a service that uses cutting-edge 5G video technologies to enable users to experience and enjoy a new style of watching live video anywhere. This service features "Multi-Angle Live" and "AR Figurines," each of which includes interactive communication functions.

Multi-Angle Live means the viewing of live video of concerts, stage performances, sporting events, etc. from various camera angles. The user can select and view video shot from among multiple angles and delivered in real time from the venue. For example, while Multi-Angle Live can, of course, deliver video showing all members of a band, it can also deliver individual fixed-camera video of a guitar, drum, bass, etc. enabling the user to specify preferred angles. In short, the user has the option of displaying and zooming in on the video from cameras fixed on favorite band members all on one screen. Furthermore, since live streaming video can also be viewed later as a missed program (deferred delivery), users can enjoy an artist's live performance without time or geographical constraints on a smartphone, tablet, or personal computer if viewing in real time is impractical. An interactive function is also provided so that users can post comments in real time during live streaming.

With AR Figurines, a computer-generated (CG) figurine of an artist appears on the user's screen when reading with a specialized app an AR marker[*8] printed on merchandise or other items related to that artist. At this time, the user can view a performance by the artist from any angle throughout a 360-degree range. The video in this case is not simply an illustration of the artist but rather digital data obtained by shooting the artist while wearing a motion capture suit. This approach can faithfully reproduce the artist's singing style, mannerisms while performing, etc.

The Shintaikan Live service has also introduced TIG®[*9] technology in promotional content for Multi-Angle Live and AR Figurines. This is interactive video technology provided by Paronym Inc. that enables a user to access desired information simply by touching an object of interest in video. Going forward, the plan is to introduce TIG technology in real-time video as well under a joint-development project between NTT DOCOMO and Paronym. In this way, NTT DOCOMO is promoting new video viewing experiences in which information navigation can be performed through simple operations from the video itself.

Following the launch of 5G services, NTT DOCOMO will continue to take advantage of the 5G features of high speed, large capacity, and low latency to study Multi-Angle Live with even higher levels of picture quality and more viewpoints as well as enhanced high-presence viewing styles that incorporate Virtual Reality (VR)[*10] technology (**Figure 4**).

3.2 Tokyo Game Show

The 5G era will not simply "enable" online gaming entertainment—it will also change the style

*8 AR marker: Technology that uses image recognition via a device such as a smartphone or tablet equipped with a specialized app to display previously prepared 3D CG video on the smartphone/tablet screen in such a way that the CG appears to be real.

*9 TIG®: A registered trademark of Paronym Inc.

*10 VR: Technology that gives the user the illusion of being in a virtual world.

of such entertainment by enabling commentary, watching, and communication during a competition. NTT DOCOMO introduced the creation of new value in this evolving gaming industry at TOKYO GAME SHOW 2019 held at Makuhari Messe®*11 in September 2019.

In particular, NTT DOCOMO held a trial of simultaneous competition among many players using smartphones making full use of the 5G features of high speed, large capacity, and low latency while live streaming the event. Additionally, as optical circuits were no longer essential to online gaming thanks to 5G, NTT DOCOMO proposed the concept of a "LAN Party" in which participants compete with each other anywhere using all sorts of equipment such as personal computers and gaming devices and also proposed a new game watching style using AR in esports (**Figure 5**).

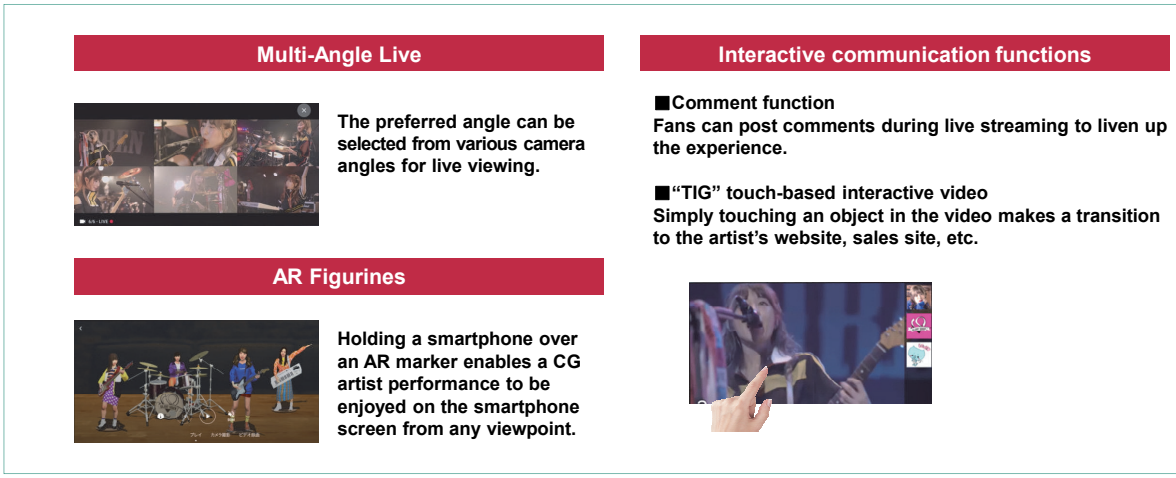


Figure 4 Shintaikan Live service

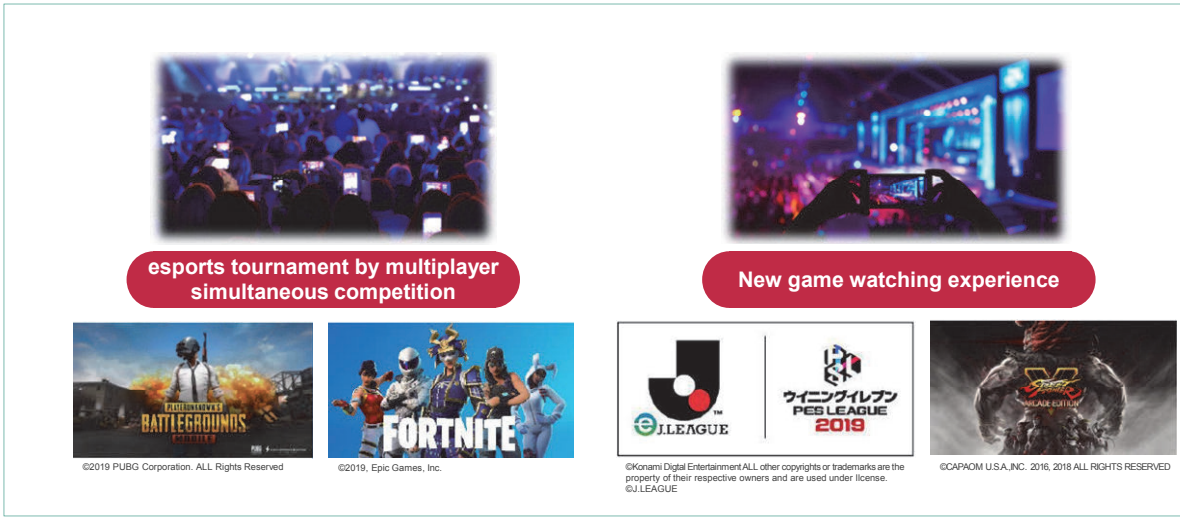


Figure 5 TOKYO GAME SHOW 2019

*11 Makuhari Messe®: A registered trademark of Makuhari Messe, Inc.

4. Conclusion

Through collaboration with many partners, NTT DOCOMO's 5G pre-commercial service has been supporting business development through sports-viewing solutions, management solutions, and tourism solutions including inbound traveling to Japan and consumer-oriented service development such as Shintaikan Live and esports. At present, the 5G pre-commercial service is also taking up solutions and services that make extensive use of 5G features in the fields of medicine and industry.

At NTT DOCOMO, we seek to co-create "new value" for 2020 and beyond along with partners in diverse fields through innovative initiatives that make maximum use of 5G features. We wish to contribute to society by providing amazing and moving experiences exceeding everyone's expectations while aiming for a super prosperous future made possible by the wonders of 5G.

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[1] Ministry of Internal Affairs and Communications, Regional Power Creation Group, Regional Development Office: "Survey and Research Report on Regional Revitalization through Rugby World Cup 2019," p.1, Mar. 2018 (in Japanese).

Technology Reports MY NETWORK 5G Era Creation of Services & Solutions

Special Articles on 5G Pre-commercial Service

MY NETWORK Initiative

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From 2020 on, we can expect the 5G features of high speed and large capacity, low latency, and massive connectivity to bring added convenience and new sensory experiences to many aspects of people's lives. We can also expect smartphones and other advanced devices to give users an even greater sense of real-time, immersive operation. Nevertheless, achieving such sensory experiences that only 5G can offer within the screens and formats of current smartphones is difficult, so the need arises for cutting-edge devices such as head-mounted displays, wearable devices, and hearable devices that can support VR, AR, MR and other XR applications. Against the above background, NTT DOCOMO is promoting the MY NETWORK™*1 concept as a way of coordinating a variety of peripheral devices using a 5G smartphone as hub. The aim here is to develop and deploy advanced services and solutions together with business partners via the DOCOMO 5G Open Partner Program.

1. Introduction

Thanks to the spread of smartphones and tablets in modern society, accessing the Internet or viewing video outside the home is now an extremely common occurrence. In fact, the posting of high-quality photos on a professional level or real-time video on Social Networking Services (SNSs) by ordinary users is no longer out of the ordinary. In addition, the soon-to-be-deployed 5G features of high speed and large capacity, low latency, and massive connectivity will enable services and solutions that have so far been difficult to achieve while bringing added convenience and new sensory experiences

*1 MY NETWORK™: A trademark of NTT DOCOMO.

to people's lives.

Furthermore, as smartphones and other devices become 5G compliant, they should become more real-time and immersive in nature. On the other hand, new sensory experiences that leverage 5G strengths are difficult to achieve within the screens and formats of current smartphones, so to enable users to sufficiently experience Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), etc., the need has arrived for cutting-edge devices such as head-mounted displays, wearable devices, and hearable devices that can support XR*2.

In response to this need, NTT DOCOMO proposes "MY NETWORK" as a way of coordinating a variety of peripheral devices with a 5G smartphone as hub with the aim of rolling out advanced services and solutions in collaboration with business partners.

NTT DOCOMO aims to apply the specialized technologies of its partners and to link devices in diverse ways to provide users with a variety of new 5G-unique sensory experiences that could not be achieved in the past with smartphones alone.

In this article, we provide an overview of MY NETWORK and related services.

2. MY NETWORK

2.1 Overview

The idea behind MY NETWORK is to coordinate not just a single smartphone but also a diverse array of peripheral devices such as XR devices with services and solutions of the 5G era while making full use of the 5G features of high speed and large capacity, low latency, and massive connectivity. The goal here is to configure an advanced network for each and every user and provide new sensory experiences.

NTT DOCOMO aims to link peripheral devices and services/solutions to a smartphone as hub in collaboration with device vendors and service/application vendors through the DOCOMO 5G Open Partner Program. A conceptual diagram of MY NETWORK is shown in **Figure 1**.

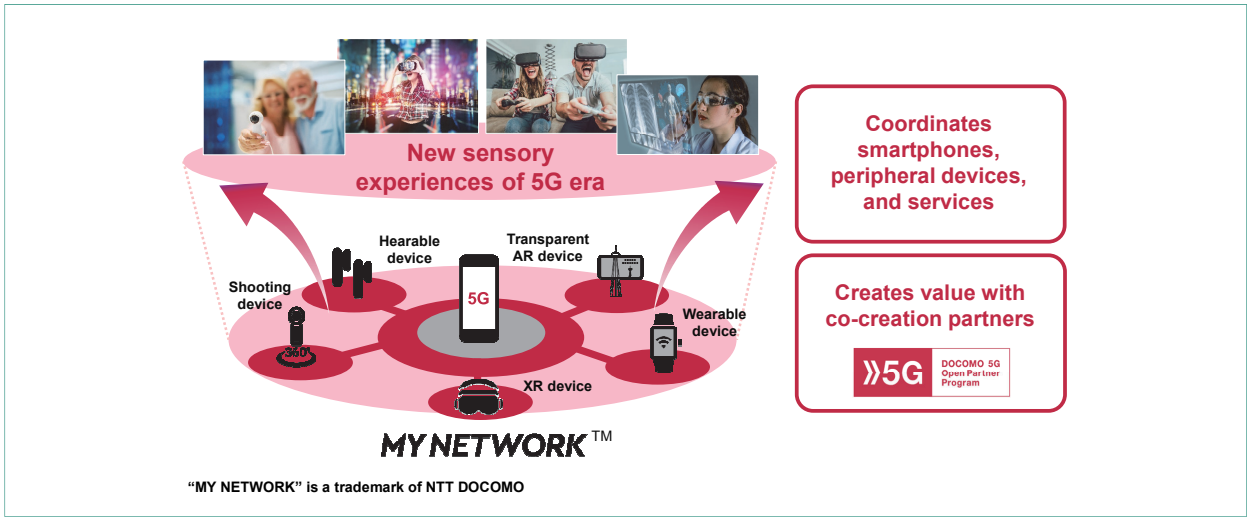

Figure 1 MY NETWORK vision

*2 XR: A generic term for AR, VR, MR, etc.

2.2 MY NETWORK Development Activity

As a specific example of MY NETWORK development activity, NTT DOCOMO entered into a partnership agreement with Magic Leap, Inc. for funding and business collaboration in April 2019 with the aim of strengthening its efforts in the area of MR using spatial computing*3.

MR is a technology that can provide new added value heretofore nonexistent such as highly immersive digital sensory experiences and interactive services that merge the real and digital worlds. It is an area that is expected to grow significantly in the years to come. By collaborating with Magic Leap having advanced spatial computing technology, NTT DOCOMO plans to link MR technology with the 5G features of high speed, large capacity, and low latency, and NTT DOCOMO assets such as d ACCOUNT with the aim of creating MR services using spatial computing and expanding its market within Japan [1] (**Figures 2** and **3**).

3. Conclusion

This article provided an overview and specific application examples of MY NETWORK, NTT DOCOMO's new initiative in the burgeoning 5G market. NTT DOCOMO has already been conducting 5G trials through its 5G pre-commercial service launched in September 2019, but it will accelerate the creation of new services and solutions for the 5G era toward the launch of 5G commercial services in spring 2020 using MY NETWORK as a part of this effort.

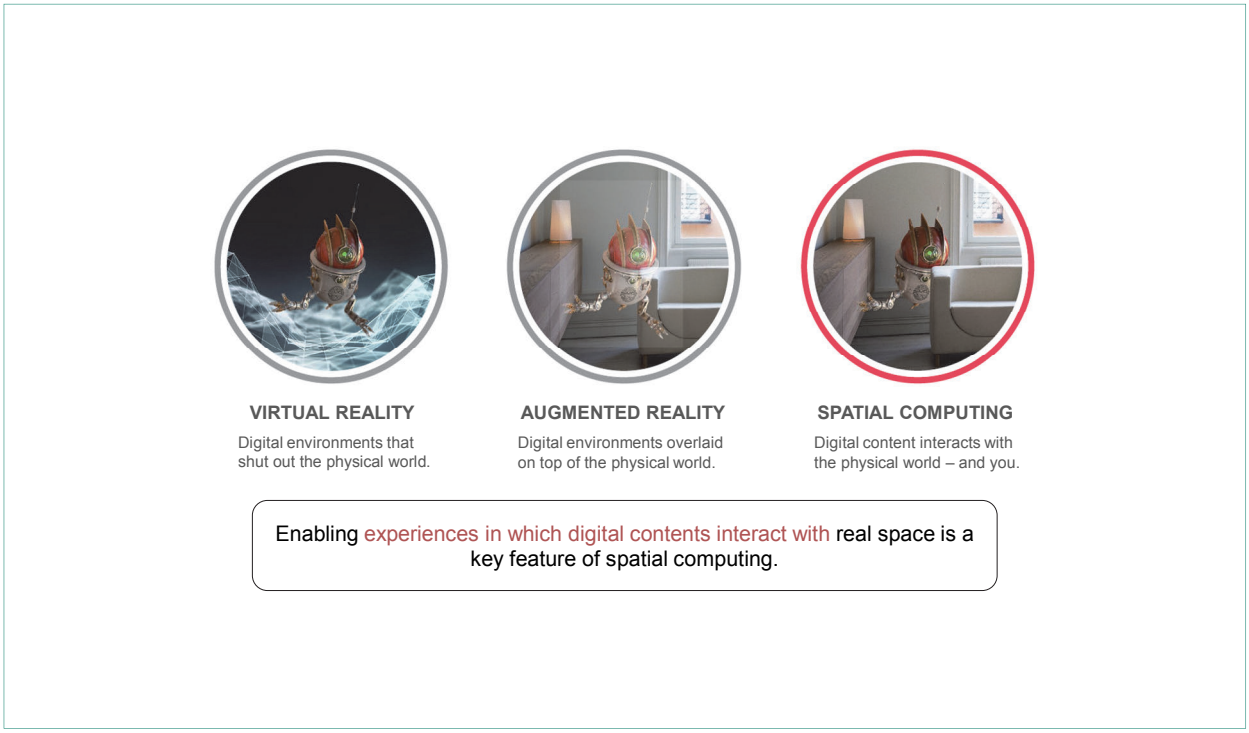

Figure 2 Feature comparison between MR and VR/AR

*3 MR using spatial computing: A world that seamlessly integrates the real world and digital world beyond the constraints of a two-dimensional world and that enables us to interact with the digital world in the same way as the real world.

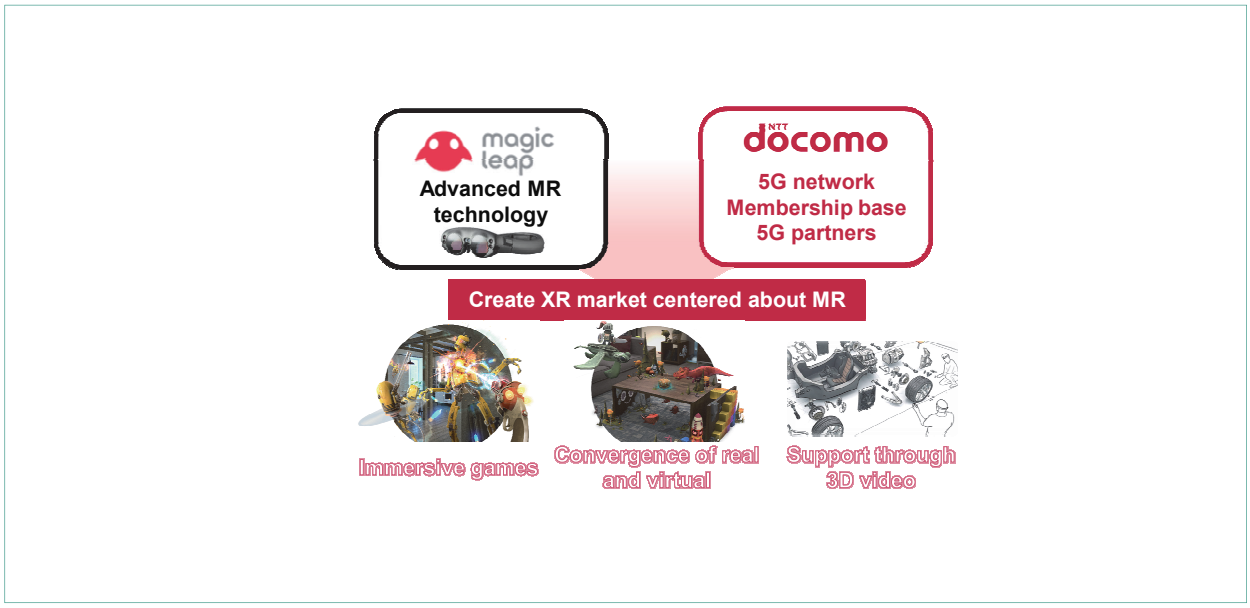

Figure 3 Funding and business collaboration with Magic Leap

REFERENCE

[1] NTT DOCOMO Press Release: "NTT DOCOMO Enters a Partnership Agreement with Magic Leap, Inc. for Funding and Business Collaboration," Apr. 2019 (In Japanese).

Technology Reports | 5G | DOCOMO 5G Open Partner Program | Solution Co-creation

Special Articles on 5G Pre-commercial Service

NTT DOCOMO Activities toward the 5G Era —Solution Co-creation with Partners—

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NTT DOCOMO is promoting solution co-creation with a variety of business partners toward the 5G era and providing the DOCOMO 5G Open Partner Program to drive this effort forward. Expectations toward 5G are increasing day by day for a wide range of scenarios and it is anticipated that 5G will bring great changes to people's lifestyles. NTT DOCOMO seeks to contribute to the creation of new value and the solution of social problems by simultaneously providing services and solutions for the 5G era.

1. Introduction

NTT DOCOMO has been active in the "co-creation" of new added value and promotion of business growth through collaboration with a wide range of companies and organizations. In 5G, as well, it has been providing the DOCOMO 5G Open Partner Program since February 2018 to promote co-creation. Starting out with about 500 participating companies and organizations, this program continues to grow expanding to more than 3000 participating partners as of September 2019. Far from being limited to large urban areas, these participants come from all over Japan and overseas too while representing a wide range of fields including construction, transport, manufacturing, media, retail sales, finance, and local government administration.

In this article, we describe NTT DOCOMO's activities in co-creation with business partners toward the 5G era.

2. Three Values Provided by DOCOMO 5G Open Partner Program

NTT DOCOMO provides the companies and organizations participating in the DOCOMO 5G Open Partner Program with three key values, namely, "information sharing," "communication," and "5G experience," at no charge (**Figure 1**).

2.1 Information Sharing

Information sharing means the releasing of 5G-related information on a website targeting participants in the DOCOMO 5G Open Partner Program. This includes information related to 5G technologies and specifications, videos related to events held by NTT DOCOMO, and 5G trial reports. Partners can browse this information freely as a source of ideas for creating new solutions and solving problems (**Figure 2**).

2.2 Communication

NTT DOCOMO has been holding workshops and other events with the aim of creating new services and solutions using 5G by promoting communication among the participating partners of the DOCOMO 5G Open Partner Program. Many partners have been participating in these events.

The last four workshops featured talks by NTT DOCOMO and its partners as well as exhibits and demonstrations of partner products. In addition, NTT DOCOMO promoted communication among participants in several ways, such as by holding mini-workshops after those talks to give speakers and fellow partners a chance to casually interact and by enabling participants to post ideas freely on an idea board (**Figure 3**).

NTT DOCOMO also held a 5G Business Camp at six locations around the country with the purpose of accelerating the creation of specific services and solutions in its 5G pre-commercial service. At

Figure 1 DOCOMO 5G Open Partner Program

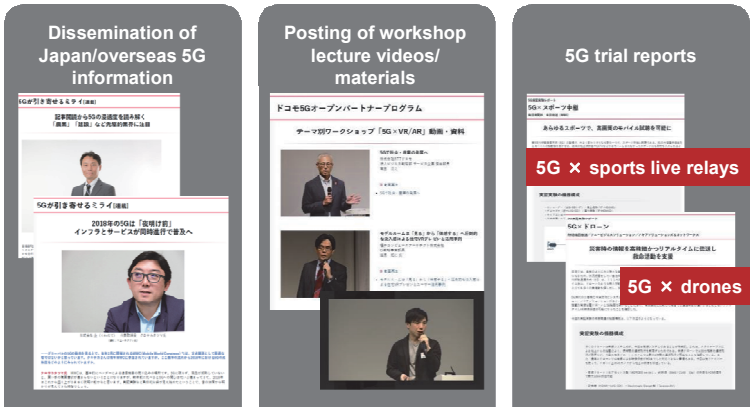

Figure 2 Provision of 5G information

Figure 3 Information exchange with partners centered about 5G

this event, NTT DOCOMO gave talks on its approach to pre-commercial services and introduced many products via an "idea creation zone" that introduces ideas for solutions, a "service creation environment zone" that introduces peripheral devices, and a "solution exhibition zone" that displays solutions for the 5G era. About 1,000 partner companies and 2,500 individuals attended this event at

all six venues with more than 100 companies expressing a desire to use some of the solutions being provided in the 5G pre-commercial service. NTT DOCOMO's corporate sales members are active in making this a reality (Table 1).

NTT DOCOMO includes corporate sales members in all of Japan's prefectures as well as 2,300 docomo Shops throughout the country. It also provides Business Plus®*1 as a scheme for introducing partner products to other enterprises by NTT DOCOMO corporate sales. For NTT DOCOMO, providing this sales power on behalf of its partners is an important key to rolling out created solutions as a business.

2.3 5G Experience

With the aim of expanding activities toward the creation of new 5G usage scenarios together with a wide array of partners, NTT DOCOMO has opened up permanent 5G technology verification environments under the name of "DOCOMO 5G Open Lab" so that partner companies and organizations participating in the DOCOMO 5G Open Partner Program can experience for themselves 5G experimental base stations and other 5G-related equipment at no charge.

A DOCOMO 5G Open Lab is equipped with 5G experimental equipment (base stations, mobile stations, etc.) for conducting 5G connection tests, 5G demonstration environments, and a variety of devices that connect to 5G experimental equipment. Partners may also bring their own devices for connecting to this equipment. The aim here is to

Table 1 Workshop results

	Date(s)	Venue	No. of participants
5G Partner Workshop	February 21, 2018	Bellesalle Shiodome	389 companies (731 attendees)
Workshop "5G × VR/AR"	May 24, 2018	Tokyo Fashion Town (TFT) Building	152 companies (229 attendees)
Workshop "5G × Industry Reform/Creation"	September 6, 2018	Herbis Hall Osaka	161 companies (276 attendees)
5G Idea Co-creation Workshop (Held during DOCOMO OPEN HOUSE 2018)	December 6–7, 2018	Tokyo Big Sight	482 companies (4,061 attendees)
5G Business Camp in Tokyo	March 8, 2019	Bellesalle Shiodome	314 companies (676 attendees)
5G Business Camp in Osaka	March 20, 2019	MyDome Osaka	138 companies (261 attendees)
5G Business Camp in Nagoya	April 19, 2019	Nagoya Convention Hall	113 companies (371 attendees)
5G Business Camp in Sendai	May 10, 2019	Sendai Kokusai Hotel	134 companies (342 attendees)
ICT Seminar in Okinawa 2019	May 22, 2019	Okinawa Kariyushi Urban Resort Naha	179 companies (437 attendees)
5G Business Camp in Fukuoka	Jun 3, 2019	Hotel New Otani Hakata	144 companies (382 attendees)

*1 Business Plus®: A registered trademark of NTT DOCOMO. Business Plus is a cloud-based service that can be used for a fixed monthly fee to improve business efficiency using corporate smartphones and other devices.

create diverse services and solutions while expanding usage needs by enabling partners to quickly conduct all sorts of tests and trials. A DOCOMO 5G Open Lab was opened in Tokyo in April 2018, Osaka in September 2018, Okinawa in January 2019, and Guam in March 2019. More than 400 partner companies and 2000 individuals have so far visited and used a DOCOMO 5G Open Lab (Table 2).

An overview of DOCOMO 5G Open Lab is shown in Figure 4 and examples of trials conducted at DOCOMO 5G Open Labs are shown in Figures 5 and 6.

3. 5G Benefits Observed from Trials

In Japan, laboratory tests and regional trials of 5G technologies can help bring the goal of "conquering time and distance"—the essence of communications—even closer to reality. For example, a common scenario at present is to have a skilled person travel to a site with a problem to perform maintenance work or instruct others in a very time-consuming process. However, the 5G features of high speed and large capacity make it possible to observe the conditions at a problem site via high-definition video from a separate location thereby

Table 2 DOCOMO 5G Open Lab locations and opening dates

Name	Opening date
DOCOMO 5G Open Lab Yotsuya	April 2018
DOCOMO 5G Open Lab OSAKA	September 2018
DOCOMO 5G Open Lab OKINAWA	January 2019
DOCOMO 5G Open Lab Guam	March 2019

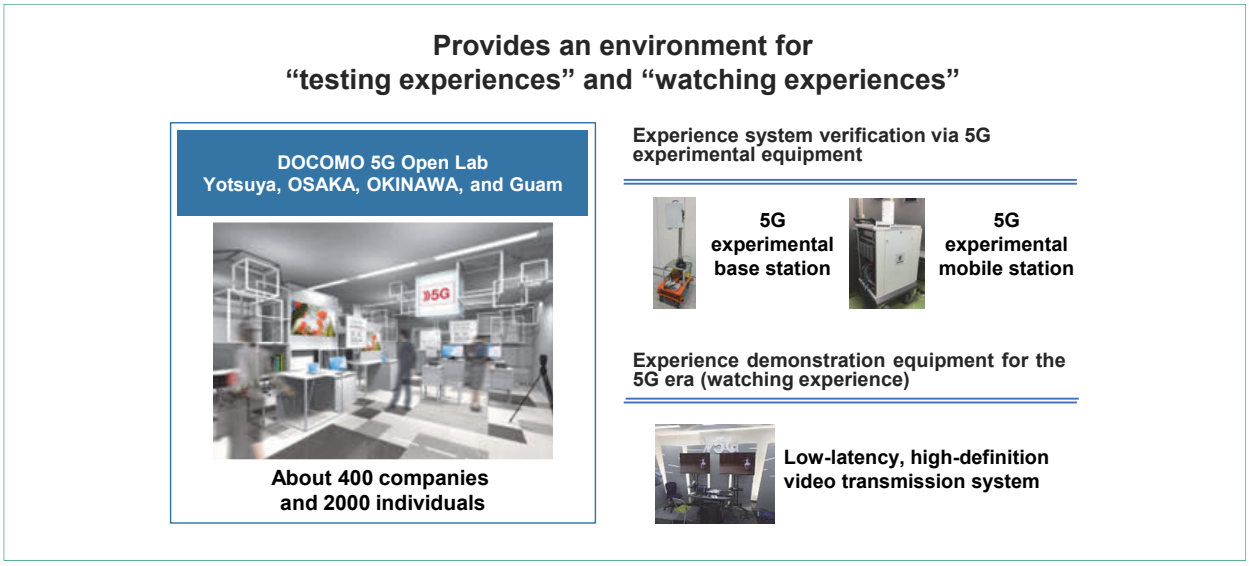

Figure 4 Overview of DOCOMO 5G Open Lab

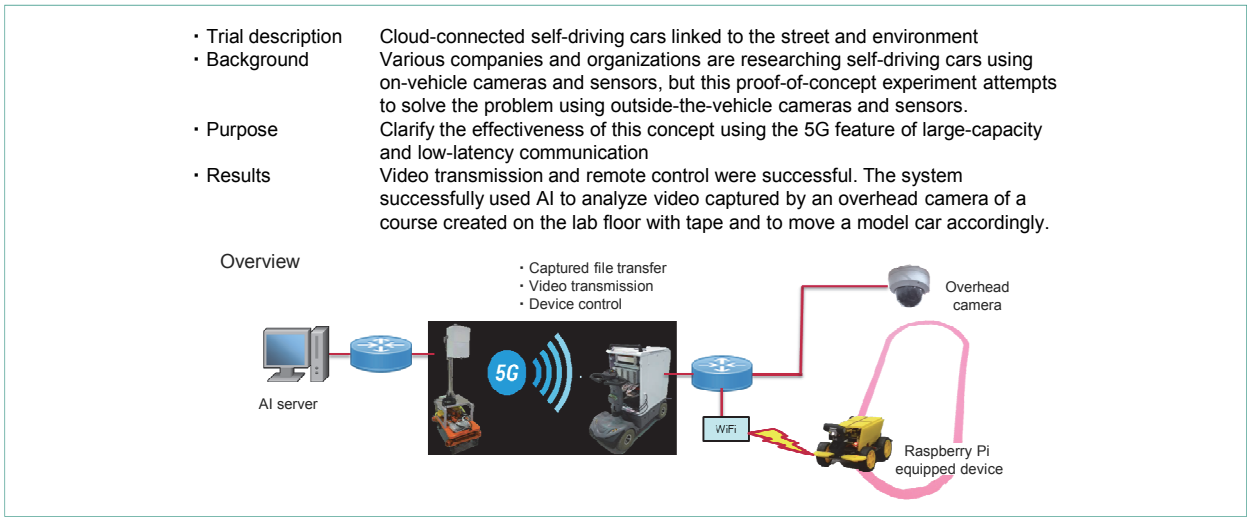

Figure 5 DOCOMO 5G Open Lab trial example (1)

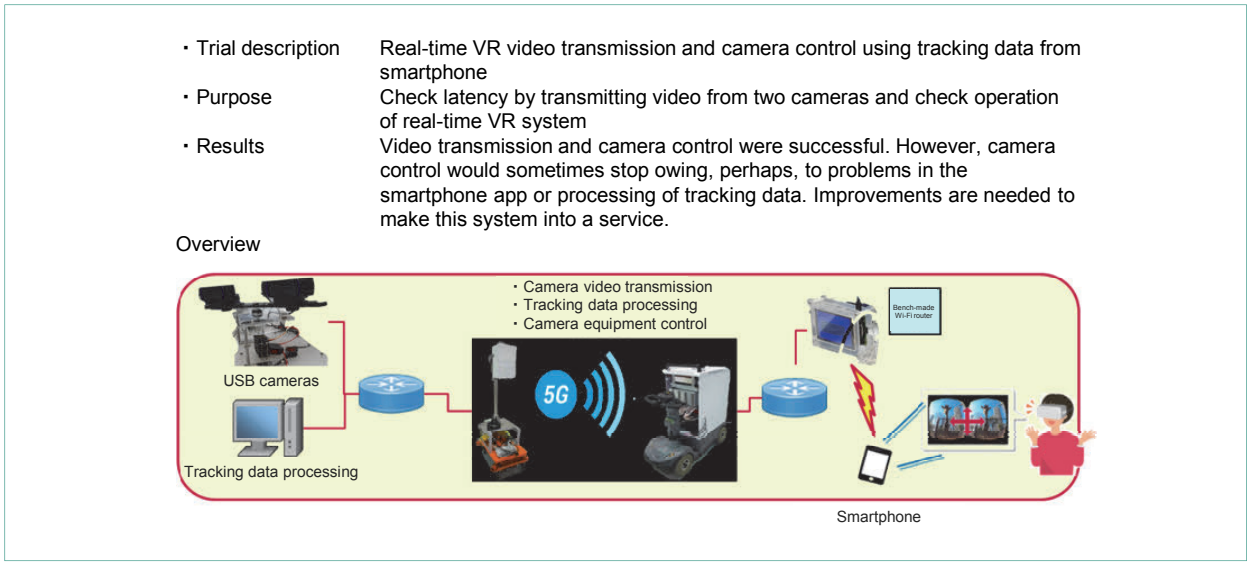

Figure 6 DOCOMO 5G Open Lab trial example (2)

enabling remote support without having to travel.

3.1 Examples of Trials

The following introduces some of the trials that NTT DOCOMO has so far performed.

1) Disaster Prevention and Disaster Mitigation

NTT DOCOMO considers that combining 5G, high-definition street cameras, and Artificial Intelligence (AI) will enable the automatic detection of disasters or accidents in real time with high accuracy and thereby contribute to disaster prevention and disaster mitigation.

Focusing on disaster response, fire fighting, etc. in the city of Aso, Kumamoto Prefecture, Japan,

this experiment used 5G equipment and a wire-powered (tethered) drone equipped with a 4K[*2] camera to perform real-time 4K video transmission (**Figure 7**, **Table 3**). Shooting aerial 4K video in this manner enabled those concerned to assess conditions over a wide range and check on places difficult for people to enter via high-definition video. In the future, we expect that combining this system with AI and image analysis technology should enable its application to the inspection of high-rise buildings including the automatic detection of cracks, fires, etc.

2) Education

The 5G feature of ultra-high-speed communications can be used to receive classes from experts in real time regardless of location. In addition, the enriching of educational content can deepen a student's involvement in the learning process.

With this in mind, NTT DOCOMO conducted a trial on the 5G-based delivery of Virtual Reality (VR)[*3] and Augmented Reality (AR)[*4] content for history education at Nakijin Castle in Okinawa Prefecture in collaboration with Okinawa Convention & Visitors Bureau and Toppan Printing Co., Ltd. (**Table 4**, **Figure 8**).

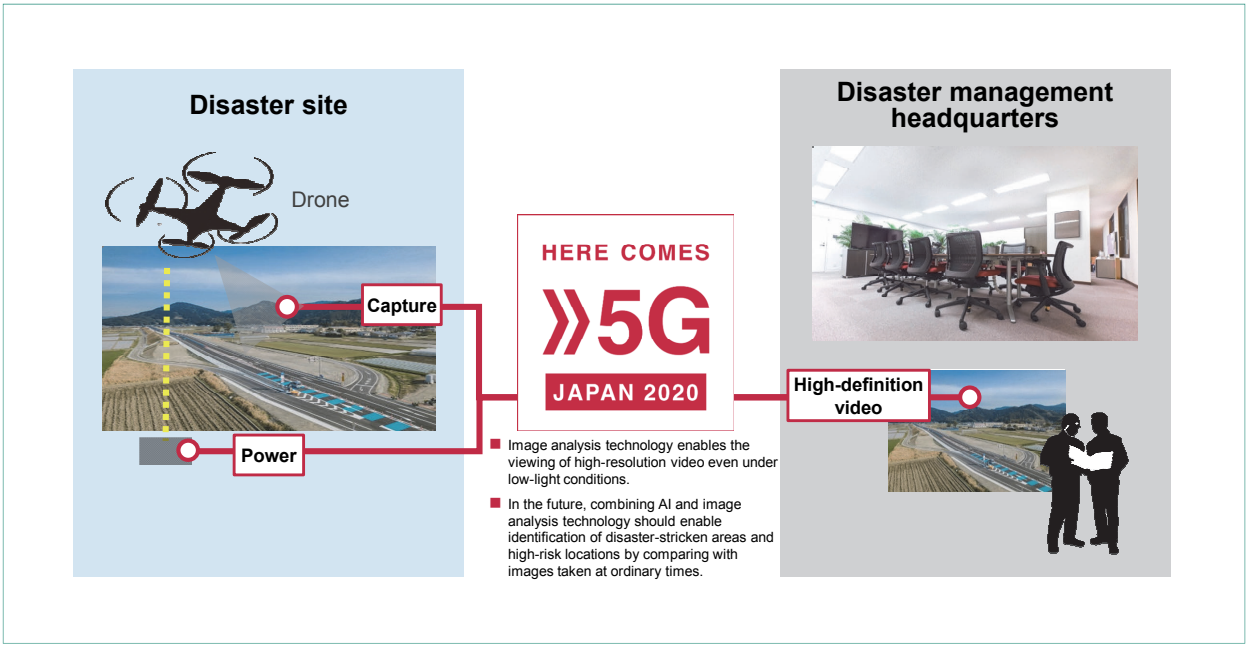

Figure 7 Trial (disaster prevention/mitigation)

Table 3 Overview of solution package in the disaster prevention/mitigation field

Industrial fields	Disaster prevention, security
Service targets	Public offices, local governments, security businesses
Service description	Urban monitoring for disaster prevention/mitigation
Main functions used	High speed and large capacity

*2 4K: Picture format having a display resolution of 3,840×2,160 pix or 4,096×2,340 pix.

*3 VR: Technology that gives the user the illusion of being in a virtual world.

*4 AR: Technology for superposing digital information on real-world video in such a way that it appears to the user to be an actual part of that scene.

Table 4 Overview of solution package in the education field

Industrial fields	Education field
Service targets	Students, etc.
Service description	Intuitive learning experience through VR/AR content using 5G
Main functions used	High speed and large capacity

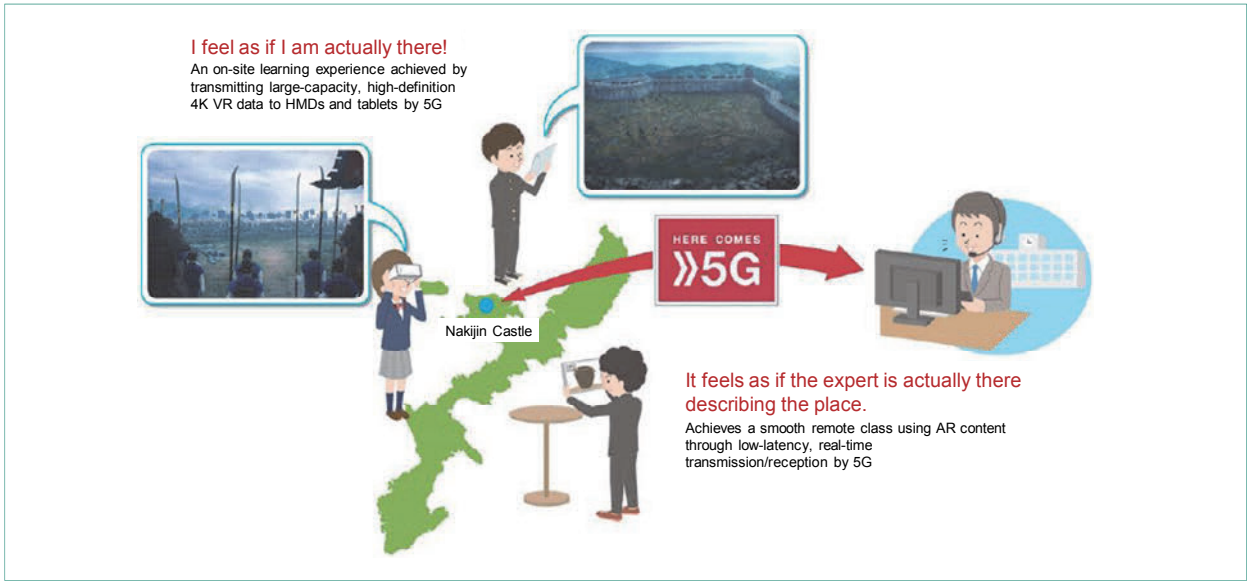

Figure 8 Trial experiment (education)

Under the supervision of Takashi Uezato, researcher at Hosei University Institute for Okinawan Studies, this experiment reproduced with a high sense of immersion the situation of Nakijin Castle in the Sanzan period focusing on castle structure and the king and his soldiers. This was accomplished by delivering high-definition 4K VR content to devices such as Head-Mounted Displays (HMDs)*5 and tablets using 5G with the aim of providing middle-school and high-school students visiting Nakijin Castle on school excursions an intuitive learning experience on the history of that castle. In addition, NTT DOCOMO used 5G to deliver a remote lecture by Mr. Uezato on historic sites and archeological artifacts using AR content in real time to tablets.

This trial made it possible to study material that has traditionally been presented by text and simple illustrations as an experience much closer to reality. Students who participated in this experiment made comments like "It was as if the teacher was explaining everything by my side!" and "It felt as if I had traveled back in time to that period!"

3.2 Creation of 5G Use Cases Based on Activities to Date

Based on a variety of activities as described above, NTT DOCOMO has been creating use

*5 HMD: Display equipment which is worn on the head, in the form of goggles or a helmet, with small display screens positioned directly in front of the eyes. There are monocular types, which display an image for only one eye, and binocular types, which display images for both eyes.

cases in collaboration with business partners. Typical examples of these creative efforts are listed in Table 5.

3.3 Activities with Local Governments

NTT DOCOMO has also been building up its collaborative relationships with local governments. About 100 local governments are participating in the DOCOMO 5G Open Partner Program. NTT DOCOMO has concluded 5G-related collaboration agreements with the local governments listed in Table 6.

Table 5 Typical examples of creating 5G use cases

	Example	Partner
1	Remote medical examination by high-definition diagnostic images	Wakayama Prefecture / Wakayama Medical University
2	Future construction site	Komatsu Ltd.
3	12-channel MPEG Media Transport (MMT) transmission of 8K video	Sharp Corporation
4	5G FACTORY III	NS Solutions Corporation
5	Security area by face-authentication gate	Sohgo Security Services Co., Ltd. / NEC Corporation
6	Urban space security	Sohgo Security Services Co., Ltd. / NEC Corporation
7	New Concept Cart	Sony Corporation
8	5G transmission of 4K sports live relays	The Mainichi Newspapers Co., Ltd
9	Diorama Studio	Fuji Television Network, Inc.
10	360-degree 8K VR live streaming/viewing system	Niigata City
11	4K video transmission using wire-powered (tethered) drone	Aso City, Kumamoto Prefecture
12	Connected cars trials	Toyota Motor Corporation / Ericsson Japan / Intel Corporation
13	Trials on use of traffic data	Sumitomo Electric Industries, Ltd.
14	Remote monitoring system by self-driving vehicles	DeNA Co., Ltd.
15	360-degree virtual exhibition tour	Panasonic Corporation
16	Street museum 5G	Toppan Printing CO., LTD.
17	IoA Virtual Teleportation	Toppan Printing CO., LTD.
18	Free View Point Live II	Crescent, Inc.
19	Music jamming experience over 5G network	Yamaha Corporation
20	VR space generation by 3D CAD model × 5G transmission	DVERSE Inc.

Table 6 Collaboration agreements concluded with local governments

Date concluded	Name of agreement	Local government
May 10, 2018	Collaboration agreement on promotion of urban development using ICT	Maebashi City
May 23, 2018	Agreement on collaboration between Osaka Prefecture and NTT DOCOMO	Osaka Prefecture
Jun 5, 2018	Agreement on promotion of open innovation using 5G	Hiroshima Prefecture
July 10, 2018	Collaboration among NTT DOCOMO, Okinawa Prefecture, IT Innovation and Strategy Center Okinawa (ISCO), and Okinawa Open Laboratory toward industry promotion and social problem solving in Okinawa Prefecture by 5G	Okinawa Prefecture
September 28, 2018	Collaboration agreement between Matsuyama City and NTT DOCOMO on regional revitalization by 5G/IoT/AI	Matsuyama City
Nobember 5, 2018	Collaboration agreement on promoting the use of 5G/ICT in Sustainable Development Goals (SDGs) (Hakusan City, Kanazawa Institute of Technology)	Hakusan City
January 24, 2019	Collaboration agreement on urban development using Smart Mobility, etc. (Yokosuka City, Keikyu Corporation)	Yokosuka City

4. 5G Pre-commercial Service

NTT DOCOMO launched a 5G pre-commercial service on September 20, 2019 to provide sites for experiencing 5G in actual 5G coverage areas using 5G terminals.

The benefits provided by this service to partners participating in the DOCOMO 5G Open Partner Program can be broadly divided into (1) areas, (2) devices, (3) docomo Open Innovation Cloud™*6, and (4) solution packages as described below.

4.1 Areas

DOCOMO 5G Open Labs at NTT DOCOMO branches in Japan have been made into pre-commercial service 5G areas with the aim of providing sites where services can be tested with a variety of partners. Opportunities for experiencing 5G were also provided at Rugby World Cup venues reflecting the expansion of 5G testing to diverse fields.

4.2 Devices

NTT DOCOMO considers that expanding the range of user experiences such as “watching,” “listening,” and “shooting” by linking a 5G terminal with various types of devices can lead to new and innovative solutions for the 5G era.

For example, the use of VR/AR devices in the trial conducted in Okinawa described above has expanded the act of “watching” and enabled an immersive experience at Nakijin Castle.

4.3 docomo Open Innovation Cloud

A cloud environment*7 for use by business partners as a 5G co-creation platform was launched in September 2019 as “docomo Open Innovation Cloud” (hereinafter referred to as “dOIC”). This is a cloud environment featuring secure transmission with low latency by virtue of being connected to

*6 docomo Open Innovation Cloud™: A trademark of NTT DOCOMO.

*7 Cloud environment: A virtual computing environment created on a network for use at the required time and in the required amount.

the NTT DOCOMO network (**Figure 9**). The 5G feature of low latency is 1 ms as a target value, but this applies only to the wireless interval, so from the viewpoint of the user experience, end-to-end latency that includes the wired interval must be considered. NTT DOCOMO considers that dOIC can reduce latency on the wired interval by directly connecting the cloud to the NTT DOCOMO network.

In addition, loading not just NTT DOCOMO applications but also partner applications on dOIC means that partner matching can be performed between solution providers and solution users thereby promoting solution co-creation for the 5G era. The loading of multiple solutions on dOIC has already begun and partners are being recruited to make use of them simultaneously.

The dOIC, moreover, has been developed to enable connection from LTE in addition to 5G pre-commercial service areas. The aim here is to secure a fixed level of quality even on the LTE network and thereby accelerate the rollout of business solutions.

4.4 Solution Packages

NTT DOCOMO is moving forward on the packaging of devices, terminals, cloud computing, and applications to provide solutions that can be applied to the solving of diverse problems.

Solutions can be used or applied in various ways depending on the target industry or problem. With this in mind, NTT DOCOMO seeks to connect solutions to problem solving by listening to partners describe their problems and having them try out solutions via the 5G pre-commercial service.

NTT DOCOMO also wants to actively market those packages that can use these solutions via LTE and to connect them to solving social problems by refining the solutions using 5G (**Figure 10**).

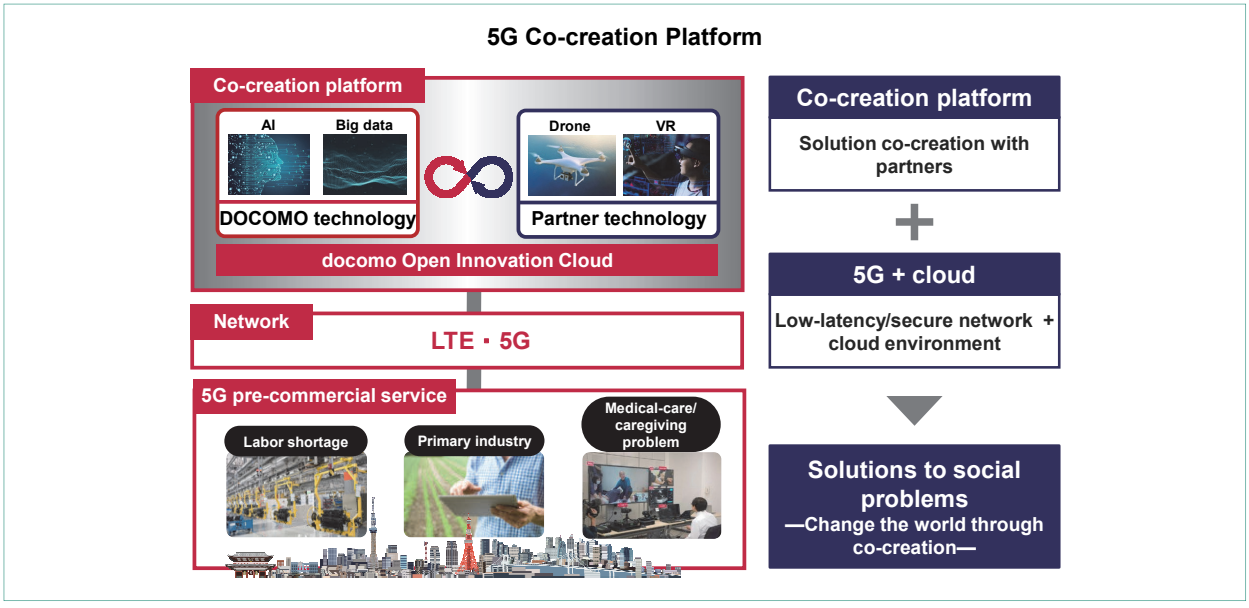

Figure 9 Concept of docomo Open Innovation Cloud

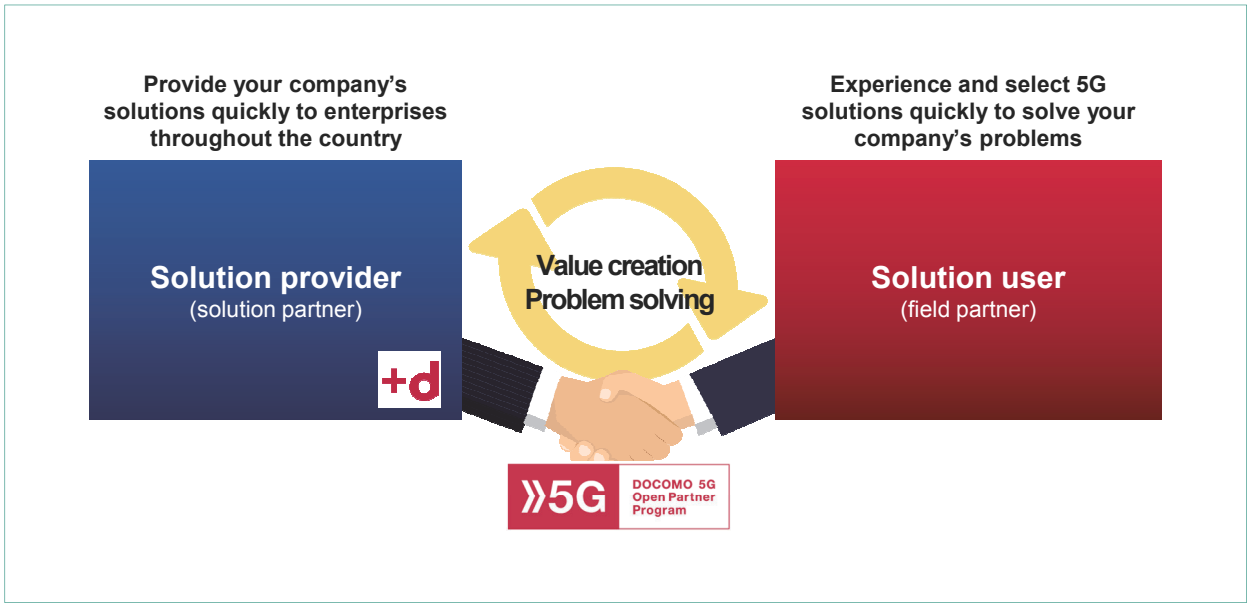

Figure 10 Matching of solution partners and field partners

5. Conclusion

Focusing on solution co-creation with business partners, this article provided an overview of the DOCOMO 5G Open Partner Program, introduced examples of solutions undertaken through this program, and described solution packages provided to business partners in NTT DOCOMO's 5G pre-commercial service.

Japan is a developed country facing a number of unprecedented problems such as a labor shortage. How Japan intends to solve these problems is attracting worldwide attention. If solutions arising out of the DOCOMO 5G Open Partner Program can be used to help solve these problems, we can expect them to find application throughout the world.

Co-creating solutions through the wonders of 5G can invigorate Japan and change the world. NTT DOCOMO seeks to achieve this in collaboration with many partners.

Technology Reports

AI Multilingual Inbound

Interactive and Multilingual AI-based “Oshaberi Annaiban”

Solution Service Department Shin Oguri

Communication Device Development Department Naofumi Hara Anna Shima

Japan’s labor force is decreasing year by year and recruiting qualified personnel is becoming difficult in a variety of industries. As a result, foreign workers are being increasingly accepted to fill this void, but providing support for them as well as for foreign visitors to Japan whose numbers are expected to grow is now a major issue facing Japan.

To help mitigate this labor shortage and provide smooth support for foreign visitors, “Oshaberi Annaiban” (Multilingual Information Board with Touch and Voice) has been developed using NTT DOCOMO AI technology. This service consists of an AI information board supporting touch operations and voice functions. It features an interactive multilingual format and customization capabilities and the ability to be used as a source of marketing data. Given that the number of foreigners coming to Japan—including workers and immigrants in addition to inbound travelers—is expected to increase from here on, there are great expectations that this service will be a tool not only for providing sightseeing information but also for other purposes such as displaying disaster information and providing evacuation instructions.

1. Introduction

The number of foreign visitors to Japan is increasing steadily with expectations that it will reach 60 million people by 2030 [1]. Furthermore, due to a revised Immigration Law that took effect in April 2019, the acceptance of foreign workers will be expanded over the next five years [2] pointing

to an increase in the number of foreigners living in Japan [2] (**Figures 1** and **2**). However, while environments that will help foreigners adapt to life in Japan are now being set up in large metropolitan areas, there are still many local governments and companies in regional areas that are not sufficiently prepared [3]. This is turning out to be a major problem especially at times of an emergency such as a natural disaster since measures should be established for providing information and evacuation instructions to people living in an evacuation zone [4] [5]. On the other hand, Japan's working population is on a downward trend, which means that there is a limit as to how much support can be provided by

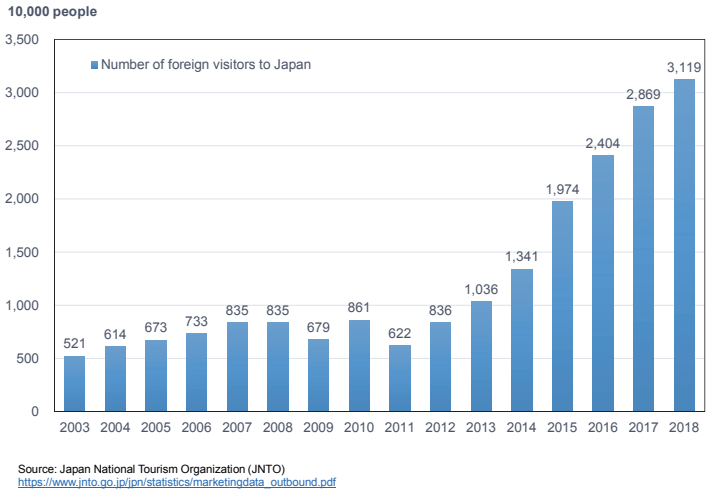

Figure 1 Number of foreign visitors to Japan

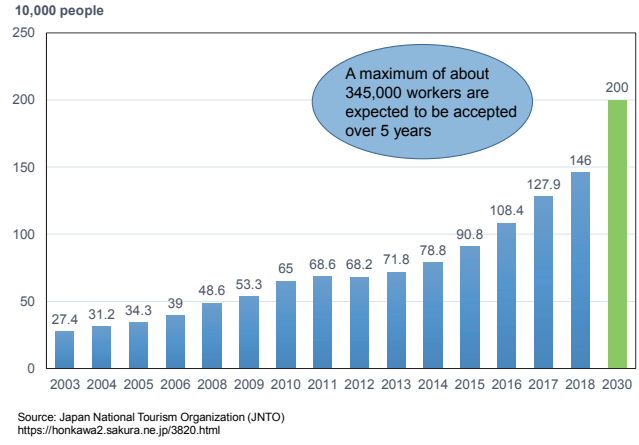

Figure 2 Change in number of foreign workers

people to foreigners who are increasing in number.

Against the above background, NTT DOCOMO has developed "Oshaberi Annaiban" that is cheaper to operate and easier to customize than communication robots using NTT DOCOMO's own AI technology. This is a multilingual information board that can be tailored to the location targeted for installation. As a service, it can provide disaster-related information as described above as well as helpful sightseeing information, event updates, etc. particular to that region. In short, it can provide real-time information that is needed "here and now."

This article describes NTT DOCOMO's "Oshaberi Annaiban" developed with the aim of achieving multilingual guidance using AI.

2. Overview of Oshaberi Annaiban

In contrast to conventional information boards or electronic message boards, Oshaberi Annaiban is an interactive, multilingual AI-based information board that supports touch operations and voice by adopting a touch-panel display and voice-input function. It can customize characters and backgrounds to match the purpose of use and installation location and therefore provide a spatial presentation at that site. It can also perform intention interpretation[*1] against utterances made by a user during conversation with a character appearing on the screen so as to provide the information needed in response to each utterance. It also provides an interface that induces the user to think "I would like to try talking to this board." or "I would like to ask something else."

2.1 Interactive Guidance Supporting Voice and Touch Operations

Oshaberi Annaiban features voice input and touch operations and provides multilingual support including Japanese, English, Chinese, and Korean. It can provide guidance to foreign visitors in place of staff at facilities having no interpreters or bilingual staff (**Figure 3**).

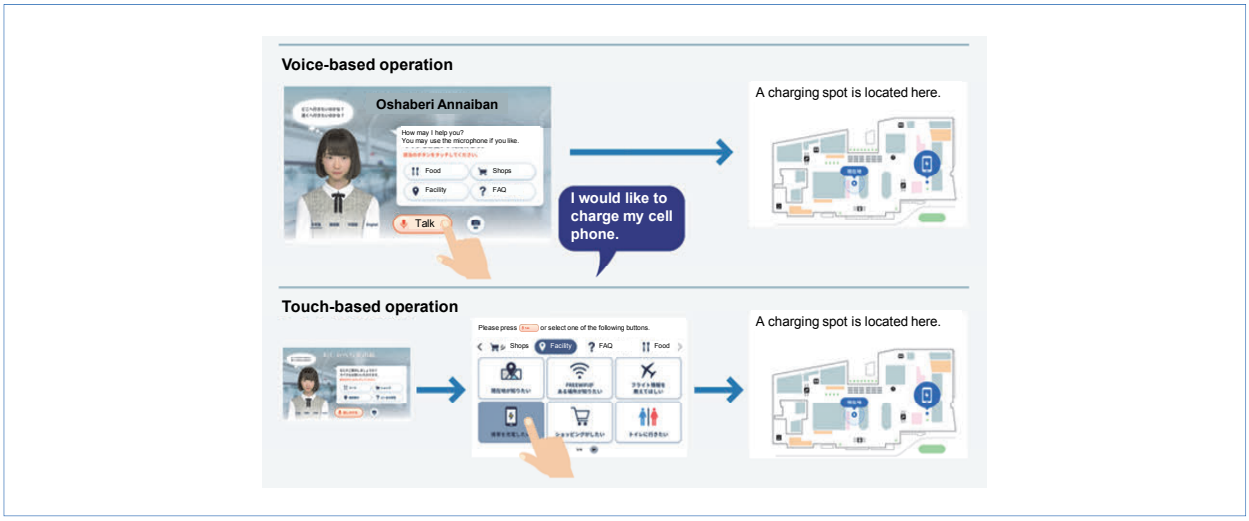

Figure 3 Communication by voice and touch operations

*1 Intention interpretation: Technology that uses machine learning and so forth to determine the user's intention from the user's utterances (natural language). User intentions are called "tasks." For example, all the utterances "What's tomorrow's weather?," "I wonder if tomorrow will be fine?," and "Is it going to rain tomorrow?" are judged as weather tasks.

2.2 Friendly Communication

In conjunction with providing voice-based communication, Oshaberi Annaiban was designed to have an interface that would make it easy for the user to converse. This was accomplished through the following three features.

- To achieve a friendly tone, the content of the conversation is linked with the facial expressions of a three-Dimensional Computer-Generated (3DCG) character through intention interpretation using AI technology (**Figure 4**).
- To provide the user with optimal information, the conversation and guidance is made to match the attributes of the user during the conversation between the user and character.
- "Trigger" for expanding the conversation is created by displaying the character's "inner thoughts" in a speech balloon (**Figure 5**).

Even with a design geared to responding efficiently and correctly to a user's inquiry, the interface also incorporates measures for alleviating hesitancy in a user who might be thinking "I really don't know what to say …" by becoming familiar with that person's current situation and providing a warm communication experience.

Oshaberi Annaiban also features architecture that enables the character, tone of voice, etc. to be changed as desired, which means a format that can be customized according to the purpose of use and installation location. For example, collaboration between Oshaberi Annaiban and 3DCG character Saya[*2], who was born with the role of connecting people to people or people to place, enables the character's facial expressions to be matched to the user's utterances to create a friendly atmosphere. This function enables the provision of added value by combining Oshaberi Annaiban with any existing assets possessed by the board implementer such as a local mascot or corporate spokesmodel and enabling a person visiting the board to meet that character and receive local information.

2.3 Survey Function during Conversation

Up to now, most digital signage[*3] or information boards have simply provided the information that the implementer wants to convey in a one-way

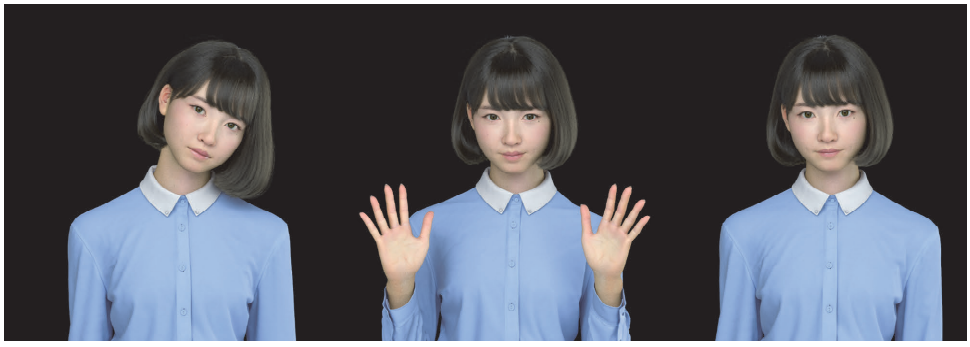

Figure 4 Communication linked with facial expressions of 3DCG character Saya [6]

*2 Saya: An original virtual human created by a husband and wife duo known professionally as TELYUKA. Using advanced computer graphics as an expressive medium, Saya was announced in 2015 becoming a worldwide sensation practically overnight. Born as a handmaid, Saya is an ongoing project showing evolution and growth as she searches out a new role (guide) with a unique organic existence different from humans.

*3 Digital signage: Advertising media using digital technology. Using displays or projectors to change advertising content in response to time or location, this technology is gaining attention as an alternative to conventional advertising media such as posters etc.

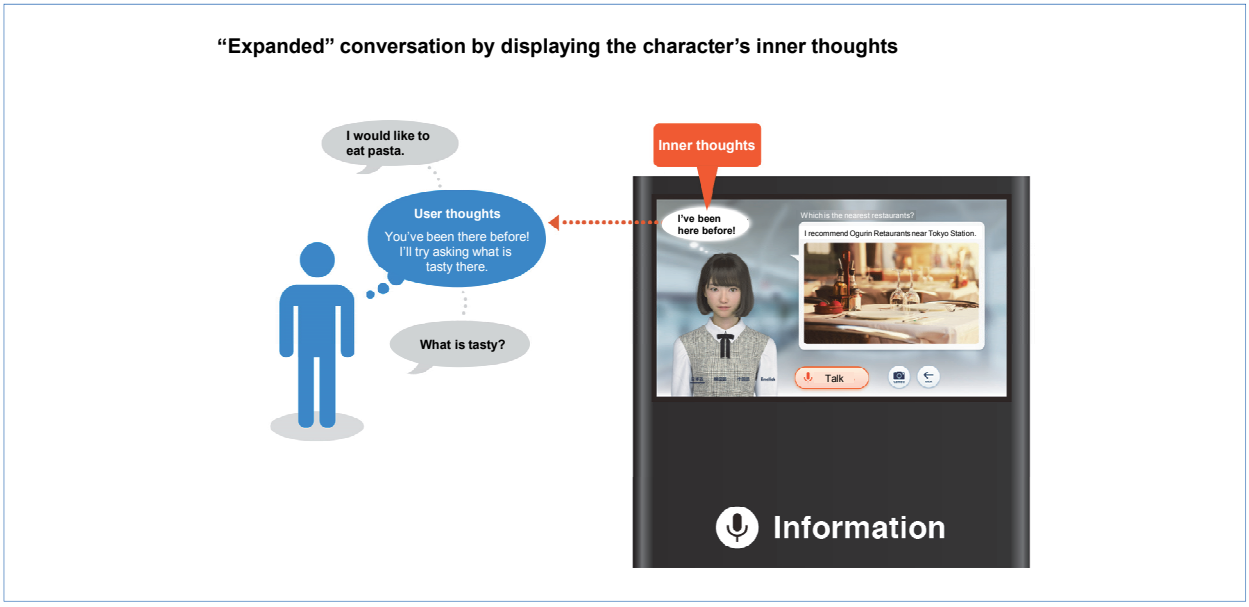

Figure 5 "Trigger" for expanding the conversation by presenting the character's inner thoughts

manner to the user. For Oshaberi Annaiban, we have developed a survey function for asking the user questions from the character side during the course of a conversation. With this function, responses from users can be fed back to the installation company and used as marketing data for a variety of purposes such as measuring the impact of events, refining facility planning, and improving user satisfaction. By having the character ask questions in this way during a voice-based conversation, the user is able to complete the survey in a comfortable manner while enjoying the conversation (**Figure 6**).

In certain previous trials, the collection rate of paper-based surveys was a problem, and it was said that even a rate of 30% was good. In contrast, the survey collection rate by Oshaberi Annaiban was high at about 60%. There is also the capability of outputting tabulation results in the form of a log making it unnecessary to manually collect survey forms. This service improves the survey collection rate through conversation and simplifies the tabulations of results, so its use in marketing tasks is anticipated.

2.4 Display of Disaster Information

In addition to the display of information at normal times, we also developed a function for receiving and displaying disaster information*4 at times of emergency. This information can be obtained from a local public agency corresponding to the terminal's installation location, from the Japan Meteorological Agency, etc.

3. System Architecture

Oshaberi Annaiban is centered about Android™*5 applications that store content such as images and video separately and that link up with a variety of Application Programming Interfaces (APIs)*6

*4 Disaster information: Refers to earthquake bulletins, evacuation recommendations/instructions, civil protection information, evacuation-center opening information, weather alerts, tsunami alerts, etc. Disaster information is displayed using an information delivery platform provided by NTT Resonant Inc.

*5 Android™: A software platform for smartphones and tablets consisting of an operating system, middleware and major applications. A trademark or registered trademark of Google Inc., in the United States.

*6 API: An interface that enables software functions to be used by another program.

(Figure 7). These constituent elements make for easy and flexible customization.

3.1 Free Dialogue through Natural Language Processing

DOCOMO “AI Agent API”*7 is a service that can embed a dialogue engine in a variety of devices to provide information matching the user’s needs during free conversation using AI technology. It allows the API user to create an original agent*8, which is a distinctive feature that makes for a high degree of freedom in customizing speech

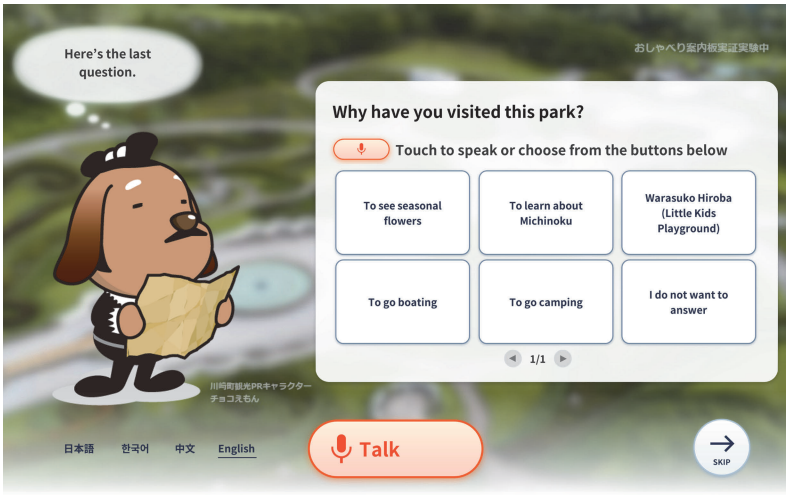

Figure 6 Survey function at Michinoku Park [7]

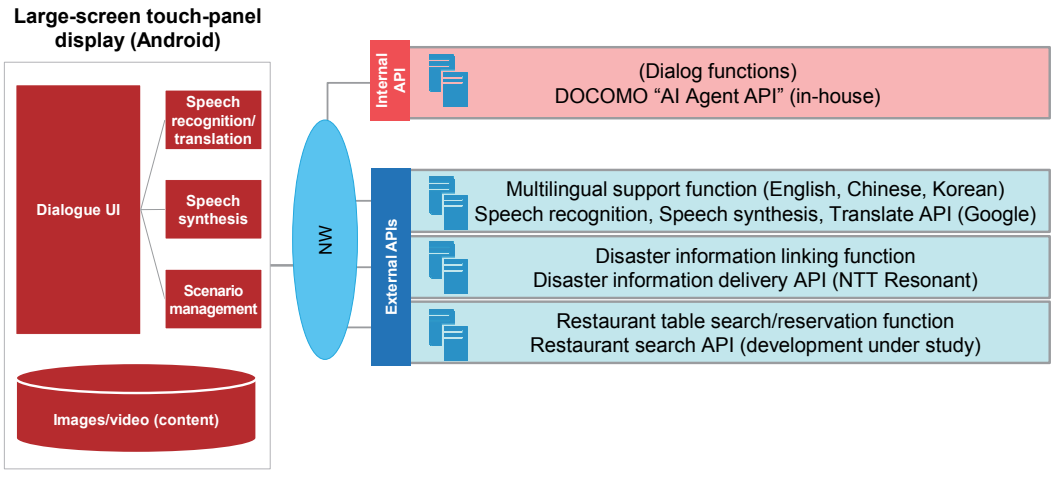

Figure 7 System configuration diagram

*7 DOCOMO “AI Agent API”: As part of NTT Group’s AI technologies under the “corevo®” brand name, this is an interactive AI-based Application Service Provider (ASP) service that packages a voice-based user interface. It can be used to achieve complex interactive scenarios by creating simple dialogue on a GUI and using Artificial Intelligence Markup Language (AIML). It can also be used to respond to common inquiries as a chatbot for FAQ use that automatically generates interactive scenarios from question Q&A lists. “corevo” is a registered trademark of Nippon Telegraph and Telephone Corporation. DOCOMO “AI Agent API” is a registered trademark of NTT DOCOMO.

synthesis and using external content tailored to the environment where the API is being used, to user objectives and needs, etc.

Thanks to natural language processing in DOCOMO "AI Agent API", Oshaberi Annaiban can now search for and provide information in a format that advances conversation with a 3D character, an actual image of a person, etc. displayed on the screen of a tablet or digital signage.

In addition, Oshaberi Annaiban links with Translate API* from Google to achieve a multilingual support function. This feature enables development of flexible multilingual support in a relatively short period of time.

3.2 Customizable Character Settings

Oshaberi Annaiban enables the information-providing character or screen background to be customized. It treats characters and tones of voice as content that can be replaced so that an implementer can easily customize the target installation by deciding on the character to be used and setting tone of voice. In addition, the system is configured so that the selected character can operate in conjunction with DOCOMO "AI Agent API" or other third-party APIs from Google and other companies. This configuration makes it possible to display different types of interfaces for a variety of characters. It also enables flexible spatial presentation by tailoring the background image to the atmosphere of the installation location (**Figure 8**).

4. Trial Report

Since launching the project in August 2018, NTT DOCOMO has been conducting trials in cooperation with corporate-sales managers at NTT DOCOMO branch offices and stores to assess the usefulness of Oshaberi Annaiban for inbound travelers and to test the business model in terms of sales system, price setting, etc. Functional improvements have been made as a result of analyzing the needs of

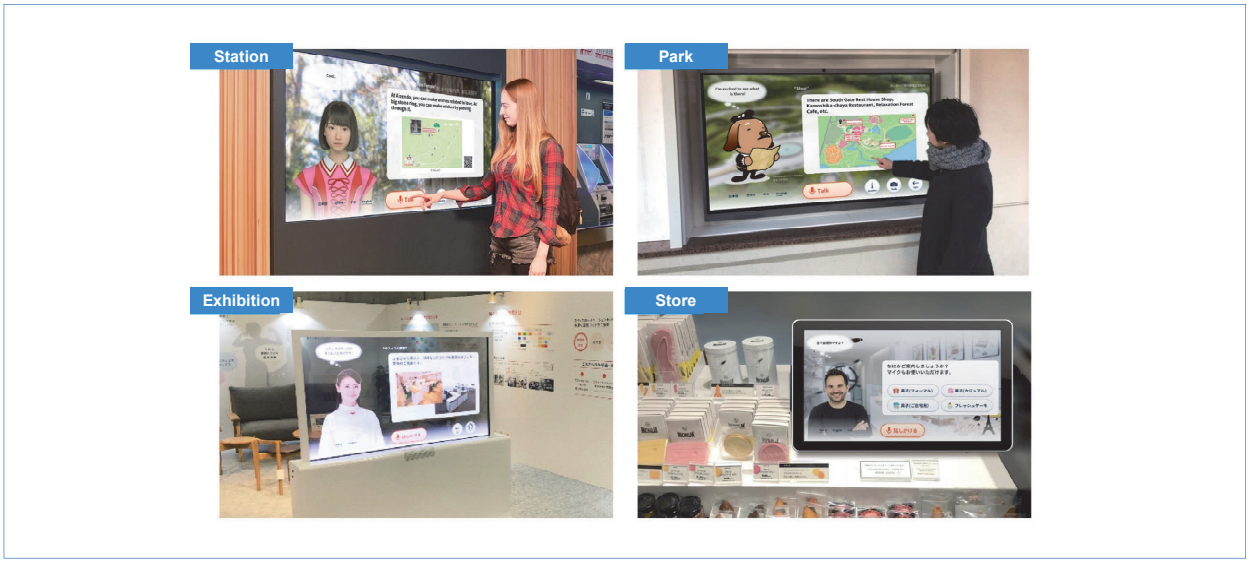

Figure 8 Character customization

*8 Agent: Software that acts as a representative of a user or other system, that functions as an intermediary among multiple elements. DOCOMO "AI Agent API" creates agents using a FAQ bot function.

* links with Translate API: At present, disaster information is displayed only in Japanese—it is not a target of multilingual translation.

implementers and of analyzing logs recording user interaction when customizing Oshaberi Annaiban. The following describes in particular a trial that NTT DOCOMO performed in Okinawa at Naha Bus Terminal.

4.1 Trial Description

Naha Bus Terminal is a transportation hub for traveling to tourist attractions within the city of Naha and throughout Okinawa Prefecture. As part of a remodeling initiative completed in October 2018, a “concierge counter” was set up to provide guidance on bus routes. However, at times of congestion, it could be seen that the counter would fill up with customers and that foreign travelers who do not speak Japanese would hesitate to talk to counter staff.

Naha Bus Terminal also welcomes many tourists from the Asia region, but the difficulty of recruiting personnel that can provide multilingual guidance in Chinese, Korean, and other Asian languages has presented a problem. In response to the above issues, we conducted a trial to see if the installation of Oshaberi Annaiban could be effective in helping inbound travelers and reducing the workload of the concierge staff.

Oshaberi Annaiban used in this trial provided route information for four bus companies that depart from Naha Bus Terminal. The user could receive bus route information by speaking to the board and indicating what tourist site or attraction he/she would like to go to. We developed this bus-route searching function so that it could provide bus-route information by linking Oshaberi Annaiban to the Naha bus navigation site via an API (**Figure 9**).

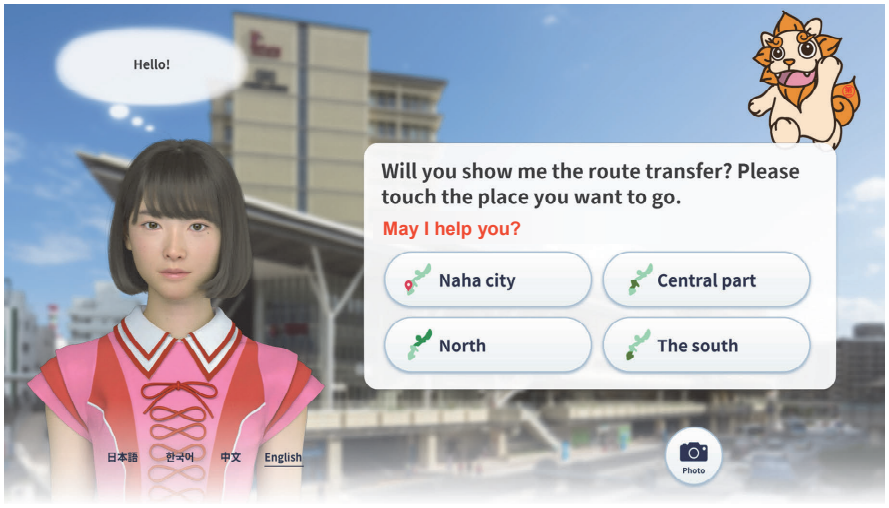

Figure 9 Application example at Naha Bus Terminal

4.2 Trial Results

The trial revealed that Oshaberi Annaiban was used when the concierge counter was crowded and that foreign visitors would ask counter staff questions to obtain more detailed information after first conducting a search on the board with its multilingual support. It was found through interviews that this coordination between Oshaberi Annaiban and counter staff helped to raise customer satisfaction. Management of Naha Bus Terminal gave this trial and Oshaberi Annaiban high praise, saying "The appropriate dissemination of information is essential to getting foreign visitors to Japan, whose numbers are increasing sharply every year, and local residents as well to use the bus more often. This trial revealed that Oshaberi Annaiban is highly effective in holding down labor expenses and making business operations more efficient."

This trial involved the development of a new function for API-based linking with other companies' sites, and though the scale of software development was large, the trial showed that the function could be customized for each implementer.

It was also found that achieving API-based linking with other companies' sites in Oshaberi Annaiban could lead to the provision of information of even greater value to users through system linking with assets possessed by NTT DOCOMO business partners. In other words, the trail showed that API-based linking opens up new possibilities in customization.

On analyzing the effectiveness of support for inbound travelers using actual data obtained from this trial, we found that Oshaberi Annaiban was used in Japanese about 65% of the time and in a foreign language (English, Chinese, or Korean) about 35% of the time. As for use in a foreign language, this was a high result compared with the usage rate of around 10% obtained in trials of the same service in other regions (**Table 1**). These results showed that Oshaberi Annaiban was effective to a certain degree in providing support when guidance from the concierge counter was not available and in providing multilingual support for inbound travelers.

Next, on analyzing the change in the number of times Oshaberi Annaiban was used in one day during the trial period, it was found that a certain amount of usage could be obtained. Nevertheless, we will continue to conduct tests and make improvements to ensure that Oshaberi Annaiban comes to be used on an ongoing basis (**Figure 10**). In particular, we plan to work on increasing usage by encouraging users by some means to search out Oshaberi Annaiban at various types of locations and to use it by speaking to it and touching it.

5. Conclusion

This article provided an overview of NTT DOCOMO's interactive and multilingual AI-based "Oshaberi Annaiban," explained its system architecture, and

Table 1 Usage and language breakdown of Oshaberi Annaiban at Naha Bus Terminal

Language	No. of Times (Percentage)
Japanese	1,870 times (64.75%)
English	377 times (13.05%)
Korean	460 times (15.93%)
Chinese (simplified)	181 times (6.27%)
Total	2,888 times

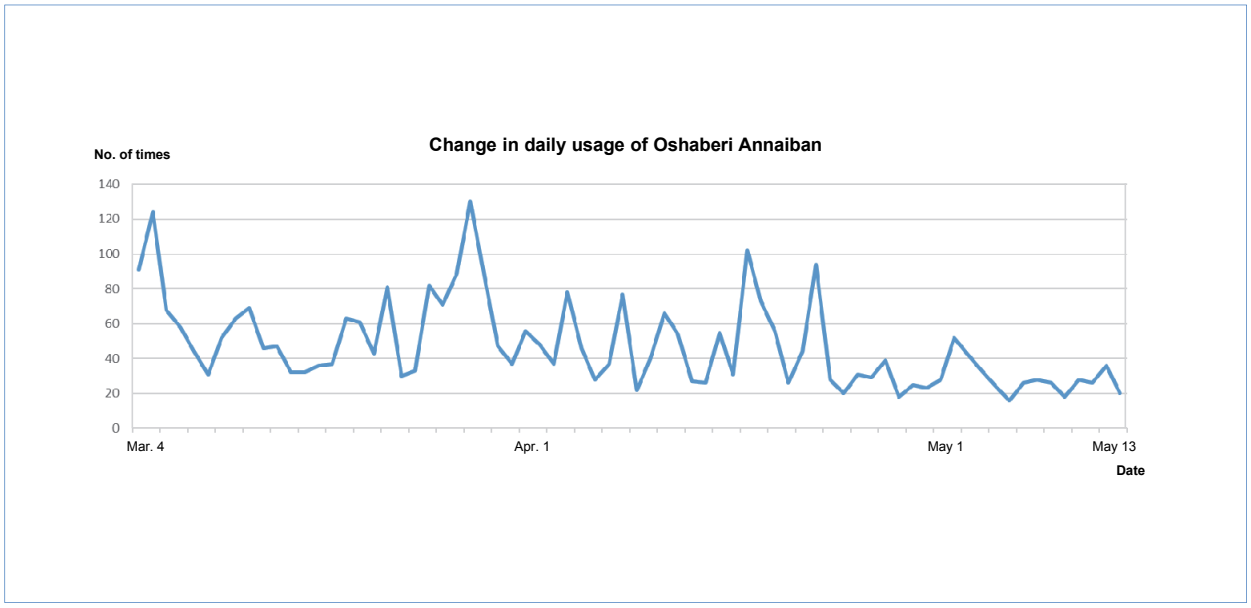

Figure 10 Daily usage of Oshaberi Annaiban at Naha Bus Terminal

described a trial held to assess its effectiveness.

The above trial was followed by the launch of Oshaberi Annaiban as a commercial service on July 8, 2019. Going forward, we plan to work together with corporate-sales managers at NTT DOCOMO branch offices and stores in proposing that Oshaberi Annaiban be applied to diverse usage scenarios such as stations, halls, and other public facilities throughout Japan, tourist attractions like hotels and leisure facilities, and commercial facilities and offices. We are committed to obtaining feedback from implementers and users to enhance the interactive and customization capabilities of this service. Finally, with the aim of providing users with highly convenient information, we will concentrate on information with high real-time properties reflecting the "here and now" at that location and will study the development of functions that can provide information on the availability of cooperating facilities, traffic congestion, etc.

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https://www.nttdocomo.co.jp/info/notice/tohoku/page/2019/190123_01.html

Technology Reports CSR Speech Recognition Telephone Speech-voice to Text Conversion

Development and Testing of the “Mieru Denwa” Service Supporting Users with Hearing Impairment

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Service Design Department Junsuke Morita

In an effort to provide products and services that are accessible to everyone from a CSR perspective, NTT DOCOMO has proposed a service that is able to convert the speech-voice of a telephone call to text in real time, and display it on a smartphone screen for users that have hearing disabilities or are hard of hearing. We consulted many users with hearing impairments in development of this system and application, and conducted repeated hypothesis testing on the usability of the application and to tune the speech recognition engine based on a simple prototype.

1. Introduction

The Act for Eliminating Discrimination against Persons with Disabilities (enacted April 1, 2016) requires that in Japan, services in society function with reasonable consideration for people with disabilities, and there are over seven million persons in Japan, including the aged, that have difficulty hearing speech during telephone calls.

We have become an Internet-based society and Web services are common, but there are still many scenarios that can only be handled on the telephone, such as making inquiries or applying for services. This presents obstacles in the lives of those with hearing disabilities. In an actual survey of people with hearing disabilities, the most common response regarding difficulties due to hearing disability was “Situations that require using the telephone” (58.1%).

† Curently Solution Service Division

Particularly in emergencies, when having troubles with life-line services such as loss of a credit card, or plumbing problems, there are issues that cannot be resolved without speech-voice on the telephone, and this can be extremely troubling.

There are existing services for communication through an operator, but they are only available at limited times and they are costly, so they are not well used.

On the other hand, with the maturation of speech recognition technology, it has become possible to convert speech-voice to text in real time, so NTT DOCOMO has begun studying a service for users with hearing disabilities called “Mieru Denwa,” which converts speech-voice to text and displays it in real time. In studying this service, we encountered the issue that the accuracy of speech recognition decreased because the people were not aware that speech recognition was being used. As such, we needed to check that the speech recognition was accurate enough to provide as a service that enables telephone communication for people with hearing disabilities. We conducted tests using a prototype Android™*1 application for users with hearing disabilities to verify the service concept, to conduct a user evaluation of the current state of recognition accuracy, and to select the minimum required functionality.

The results indicated that many users would be eager to use such a service if the recognition accuracy was improved. In fact, it was clear that they would use it more in scenarios speaking with someone they did not know, such as making an inquiry to a company, than with friends, family and other people they know.

Taking this into account, we attempted to expand functionality considering such scenarios, and to improve the recognition accuracy. We provided the resulting system as a trial service a second time and it was evaluated highly in terms of quality and performance as a service, attaining a level suitable for a commercial service.

This article describes the speech-voice to text conversion implementation used in the Mieru Denwa trial service, details of measures taken to improve the accuracy of speech recognition, and the system and application developed for providing it as a commercial service.

2. Trial Service

2.1 Overview

To measure the demand for and user satisfaction with speech-voice to text conversion, and to improve the accuracy of speech recognition, we began providing a Mieru Denwa trial service in October 2016.

An overview of the Mieru Denwa trial service is shown in **Figure 1**. The trial service design defined the following functional requirements [1].

(1) Real-time performance requirements

During a call, the system must recognize the speech-voice from the other party and display it as text on the screen of the service-user’s smartphone in real time. The call status must also be displayed on the smartphone screen, showing the user when they can start speaking.

*1 Android™: A software platform for smartphones and tablets consisting of an operating system, middleware and major applications. A trademark or registered trademark of Google LLC., in the United States.

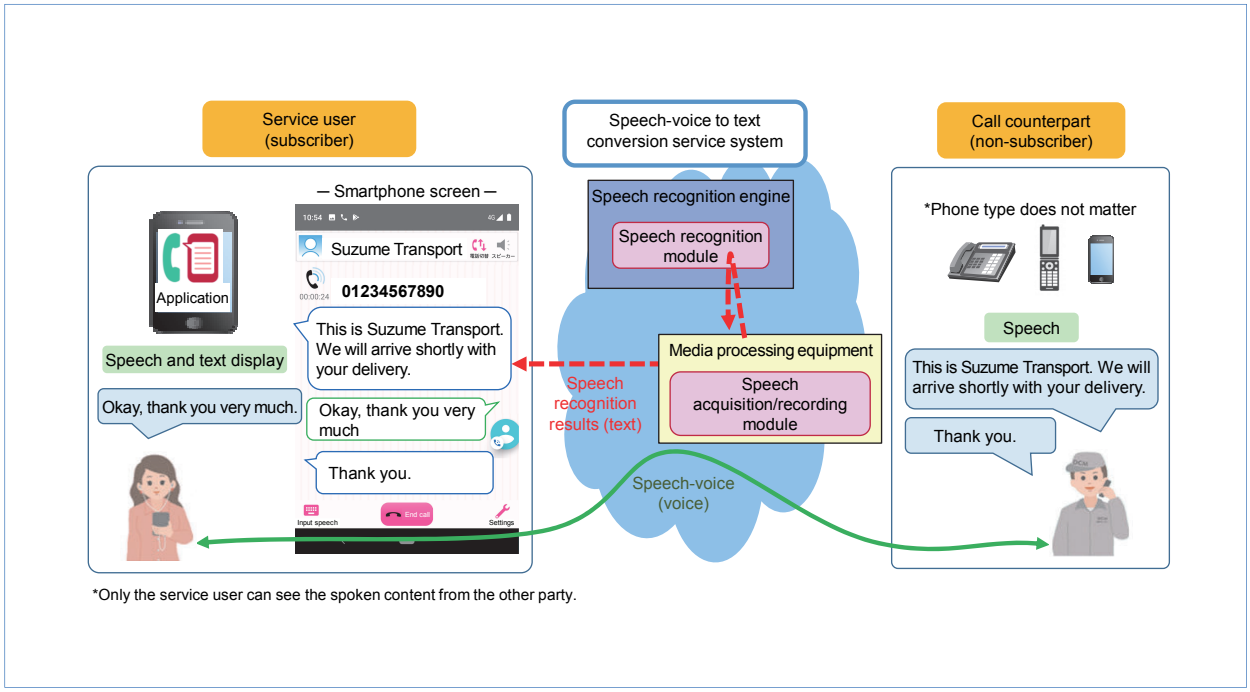

Figure 1 Overview of “Mieru Denwa” trial service

(2) Requirement for terminal independence

The service must be usable on a wide range of smartphone devices, regardless of OS. The other party must be able to use any device, as long as it is capable of speech-voice communication and must not require use of an application or have other requirements.

(3) Requirements for legal considerations

The service must have a mechanism to explain to the service user that speech-voice will be recorded and converted to text and that the recordings could be used to improve service performance, and must obtain agreement from the user. The other parties in calls must also be notified, giving consideration for privacy.

2.2 Implementation of the Speech-voice to Text Conversion Service

We adopted implementation as a network service to satisfy the requirements described above. The network service consists of media processing equipment able to record the speech-voice on the call path, transfer the recorded speech-voice to the speech recognition engine*2, and obtain the resulting text from the speech recognition engine. The trial system architecture is shown in **Figure 2**.

(1) Ensuring real-time performance

The media processing equipment was designed to detect silences in the speech, and at that point, perform speech recognition on the recorded speech-voice and display the result in real time.

*2 Speech recognition engine: Equipment that takes voice data as input, and converts it to text representing what was spoken.

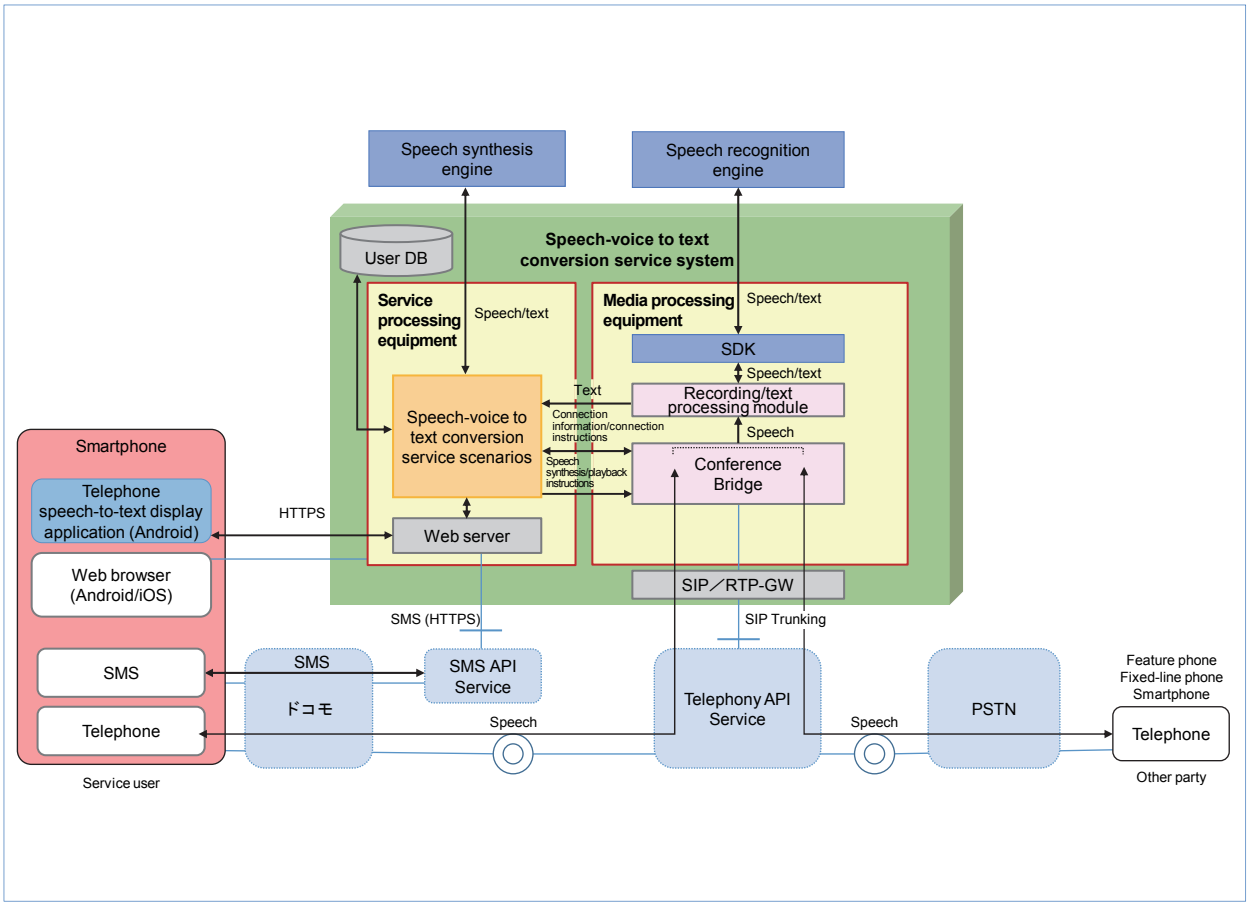

Figure 2 Trial system architecture

Note that the state of call is displayed on the smartphone screen so that the service user knows when playback of guidance has finished and speech can proceed.

(2) Ensuring independence from terminal type

With this architecture, call speech-voice is recorded on the call path, so there is no need for either terminal to have a speech-voice recording function, and terminals need only to support voice calls and the ability to display simple text. Specifically, we used the native telephone application on the terminal and developed a dedicated Android application to display the text of speech-voice.

For devices with a different OS, we built a Web application in the service processing equipment that enables the service function to be used on a standard browser screen and regardless of OS, without using a dedicated application.

This implementation enables the service to be used on any smartphone, regardless

of device type or OS.

Note that by using an architecture able to record speech-voice on the call path, the other party in the call can use any device capable of voice calls, without other requirements such as using an application.

(3) Implementing legal considerations

To obtain consent regarding the confidentiality of communication, the fact that call content will be converted to text is displayed on the service user’s application (or Web application) screen, and they must click an “Agree” button explicitly, each time the service is used.

To consider privacy for the other party, the media processor provides speech guidance indicating that the call will be recorded and converted to text when they accept the call, or when the service user initiates it manually.

2.3 Improving the Accuracy of Speech Recognition

1) Tuning Guidance to Improve the Accuracy of Speech Recognition

The usefulness of Mieru Denwa will vary greatly depending on the correctness of the text, in other words, the accuracy of speech recognition. It is technically difficult to achieve perfect recognition for all types of conversation, so we are currently working to increase the accuracy of speech recognition, defining improvement objectives within a practical scope according to usage scenarios. In particular, since our objective is to support those with hearing disabilities in situations where they have had difficulty, we are aiming for a level of performance that will enable the reader to decide what to do next, based on the results of speech recognition. We are working on two approaches to improve the accuracy of speech recognition. The first is to increase the probability that the speech will be easy to recognize by using guidance and usage scenarios, and the second is to tune the speech recognition engine using actual speech data.

Most of the scenarios in which Mieru Denwa will be used are when the telephone is needed to make inquiries to public institutions, retail businesses or companies. In such situations, speech recognition tends to be accurate because users make clear statements that are easy to recognize. The system also plays a message at the beginning of the call, requesting users to speak clearly because speech recognition is being used, to raise awareness of speaking clearly.

To tune the speech recognition engine, we periodically used the speech logs to improve speech recognition accuracy while we were offering the trial service. Speech collected with permission of users was analyzed, and frequently occurring words such as store names and words associated with the scenarios being used were registered in the dictionary of the speech recognition engine.

By training the speech recognition engine with uttered phrases, we optimized for usage scenarios, and as a result, we saw an improvement of almost 10% in the accuracy of recognized texts, compared with results at the beginning of the trial service. We expect that with the start of a commercial

service, the number of users will increase, allowing us to collect more speech samples, and take measures to improve the accuracy more effectively.

2) Improving the Continuous Recognition Method

Speech-voice requires continuous, real-time speech recognition. Initially, the equipment automatically started recording and speech recognition when the voice call started and then stopped when a silence in speech was detected. It then resumed after the detected silence [2]. In this case, there was a gap of unrecorded sound between detection of the silence and start of the next recording, but it was assumed that this missing section would only be a few tens of milliseconds and fall within the silence in speech-voice. However, when building and testing a real system, the gaps in recorded speech-voice lasted hundreds of milliseconds, causing the beginning of sentences to be clipped (not having been recorded), and resulting in poor speech recognition (speech was not recognized due to the clipping). To resolve this issue, we switched to a continuous process that does not silence recording and speech recognition after the call starts. However, it still detects and uses pauses to finalize conversion of the recorded and recognized speech to text. This approach avoided clipping of the beginning of sentences and improved speech recognition accuracy.

2.4 User Responses and Comments

1) Functional Improvements

During the service trial period, we conducted surveys of the users being monitored and continuously worked to improve the functionality, to develop a service and application suitable for use by people with hearing disabilities. Here we describe the input utterance function that we developed based on comments from many people with hearing or speaking difficulties.

(a) Input utterance function for words to be conveyed as speech

We implemented a text-to-speech function that starts a smartphone application (or Web application) to get text input of what the user wants to say during a telephone call and sends the text to system, which uses a speech synthesis engine to generate and play back the speech to the other party [3]. The synthesized speech is mixed with the spoken voice and sent to both parties, so that it can be transmitted even if the two audio streams overlap. To help conversation flow smoothly, we also incorporated some predefined phrases in the smartphone and Web applications so the service user can say the phrases with a simple tap of a button.

(b) User friendly interface, including for users with difficulty hearing or speech

To facilitate conversation, text from both sources are displayed together on the service user’s smartphone screen, which clarifies the sequence of statements from the other party and entered by the service user using the input utterance function. The applications also show the user exactly when playback of synthesized speech begins and ends, so that they can understand the timing of responses from the other party, and

so they can respond using input utterance at the right time.

In our implementation, we used a WebSocket*3 for communication between the user's smartphone and the service processing equipment, and we added a mechanism to send signals from the service processing equipment to the smartphone when playback of synthesized speech starts and finishes. The input text is displayed on the screen when the signal indicating that playback of the synthesized speech has started is received, and the color of the bubble displaying the text changes when the signal indicating that playback has completed is received.

2) User Evaluation Survey

The objective of the trial service was to determine receptivity to the service concept and the level of user satisfaction with current speech recognition accuracy, so we conducted a user survey to check these aspects. Although there were still speech-recognition errors, the Mieru Denwa service enabled users to use voice call, which they previously could not or had given up on. Most users encouraged us to continue providing the service, so we decided to proceed with the commercial service.

3. Commercial Development

3.1 Overview

The trial service required use of a dedicated telephone number and had restrictions on services such as emergency and Free-dial®*4 calling. With the commercial service, ordinary 090/080/070 numbers can be used, and emergency bulletins and other voice call services are supported (work to support emergency bulletins is still in progress). Also for the trial, the application was launched with an SMS*5 notification, but this was changed to a push notification.

3.2 Service Implementation

1) System Development

The system architecture for the commercial Mieru Denwa service is shown in **Figure 3**. Voice call processing is implemented using a Service Enabler Network (SEN)*6, which is a platform for executing service scenarios composed, in part, of a virtual Service Composition Node (vSCN)*7 and a virtual Media Processing Node (vMPN)*8 [4]. The speech recognition and speech synthesis*9 engines are within the platform for a speech translation service, and share interfaces with the existing Hanashite Hon'yaku service.

(a) Call processing

When a service user initiates or receives a call, the Mieru Denwa service initiates a voice call connection with the other party through the SEN platform. Ordinarily, the IP Multimedia Subsystem (IMS)*10 platform makes the voice call connection through U-Plane transport equipment (VGN, SIN) within the IMS platform, but for Mieru Denwa, speech communication must be routed into the vMPN to perform speech recognition. Specifically, when the user enables the Mieru Denwa service on the application, connection

*3 WebSocket: A protocol that realizes real-time full-duplex communication between Web server and a client.
*4 Free-dial®: A registered trademark of NTT Communications Corp.
*5 SMS: A service for sending and receiving short text-based messages. SMS is also used for sending and receiving mobile terminal control signals.
*6 SEN: A platform able to provide added value by combining multiple enablers (See *17). Provides functions such as telecom, Web access, and media control.
*7 vSCN: Equipment that combines enablers (See *17) to provide a service based on a service scenario.
*8 vMPN: Media processing equipment. Provides various audio media services such as Voice Answering, and Melody Call services.
*9 Speech synthesis: Technology for artificially creating speech data from text and verbally reading out text.

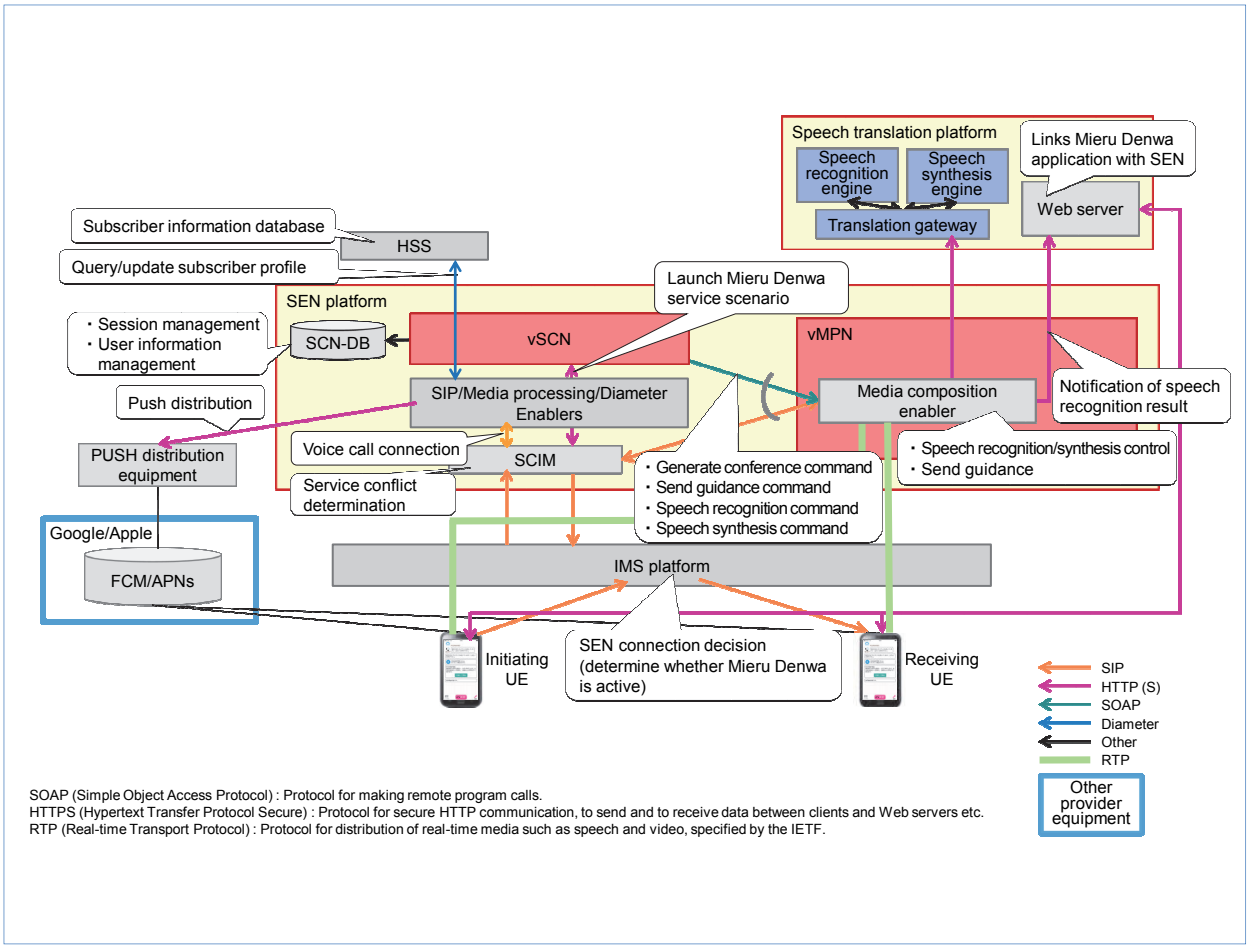

Figure 3 Mieru Denwa system architecture

information for the Service Capability Interaction Manager (SCIM)*11 is registered in the Shared initial Filter Criteria (SiFC)*12 of the IMS platform Service Call Session Control Function (S-CSCF)*13. Then, upon initiation or reception of a call, this causes the Session Initiation Protocol (SIP)*14 INVITE*15 (SIP-INVITE), which requests the voice call connection, to be sent to the SCIM, which is the SIP receiver module in the SEN platform.

In the SCIM, the subscriber’s Mieru Denwa contract status and conflict with various other services is determined based on the subscriber profile*16 data, and a Mieru Denwa scenario is launched the vSCN. Based on the SIP-INVITE from the SCIM and with enablers*17 for SIP, media process and Diameter*18 and the service scenario, a conference room is generated in the vMPN, a conference service with the call initiator and

*10 IMS: Standardized by the 3GPP. A call control procedure that realizes multimedia communications by consolidating communication services offered over fixed and mobile networks using SIP (see *14), a protocol used on the Internet and in Internet phones.
*11 SCIM: Function that selects service scenarios according to user requests and controls service conflicts.
*12 SiFC: Criteria for determining which Application Server (AS) to send a request signal to, or the function for doing so.
*13 S-CSCF: A SIP server that performs UE session control and user authentication. A session refers to a continuous period of communication between a client and a server, or between two servers.
*14 SIP: A call control protocol defined by the Internet Engineering Task Force (IETF) and used for IP telephony with VoIP, etc.
*15 INVITE: A SIP signal that requests a connection.
*16 Subscriber profile: Information required for controlling services, including contract, user configuration, and location information.

receiver as participants is launched, and speech-voice is routed to the vMPN.

(b) Guidance control/speech-voice-to-text conversion

At the starting of a voice call, the Mieru Denwa service scenario first instructs the vMPN to playback voice guidance that introduces the service and then to perform continuous speech recognition. The vMPN plays speech guidance according to the service scenario instructions, and begins speech recognition. The speech recognition engine converts input voice data to text representing what was spoken and sends them to the user's smartphone through a Web server, which displays the received text in the smartphone application.

To display text of the voice call continuously in the application, the vMPN sends voice data to the speech recognition engine continuously during the call so it can continue, while performing speech recognition when it detects silent segments[*19] in the voice call. A WebSocket connection is also used between the Web server and the application so that text of the speech-voice can be displayed continuously, in real time in the application.

(c) Input utterance function

The vSCN instructs the vMPN to synthesize and play back text input by the user on the application, based on a speech synthesis requests sent by the Web server. On instructions from the vSCN, the vMPN sends the text to the speech synthesis engine, retrieves the synthesized speech, and starts playback of the speech. The synthesized speech is mixed with the spoken voice and transmitted so that it can be heard by the user and the other party.

(d) Application launch function using standard Android and iOS[*20] push notifications

Application launching using standard OS push notifications was adopted so that the Mieru Denwa application can be displayed in the foreground[*21] during a call. The Mieru Denwa application is launched by a push notification, either Firebase Cloud Messaging (FCM)[*22] or Apple Push Notification service (APNs)[*23]. Device information is stored in the SEN platform beforehand to identify where the notification from FCM or APNs is to be sent. When a call is started, a push notification send containing device information is sent to the PUSH distribution equipment[*24], which is a gateway[*25] within NTT DOCOMO. By launching the application using push notifications, it can be launched without the messaging application having to receive successive SMS messages. Note that on iPhones[*26], the notification must be tapped to launch the application.

2) Application Development

For the trial service, an application was only provided for Android devices, but for the commercial Mieru Denwa service, applications for both Android and iOS were developed. The Mieru Denwa application displays the text of speech from the other party on the screen during a call. Users of

*17 Enabler: A componentized function that can be used by multiple services.

*18 Diameter: An extended protocol based on the Remote Authentication Dial-In User Service (RADIUS), and used for authentication, authorization, and accounting in IMS.

*19 Silent segment: A segment of audio determined to be absent of speech on a telephone connection.

*20 iOS: A trademark or registered trademark of Cisco in the United States and other countries and is used under license.

*21 Foreground: Display of an application in front of other items on a smartphone screen so that the user can operate it immediately, even if other applications are shown on the home screen.

*22 FCM: A PUSH notification service that enables data to be sent from a server to a client, which is an application on an Android device.

*23 APNs: A service that uses PUSH technology to send notifications to an application on an iPhone device from a server through an always-open IP connection.

the service have hearing disabilities, so they converse with the other party by reading the displayed text to understand what was spoken, and then responding. Calls using Mieru Denwa involve the additional effort of converting to text and reading the text, so they proceed at a slower pace than otherwise. To enable calls with Mieru Denwa to proceed at a pace similar to regular voice calls, we also made some adjustments to how text conversion results are displayed and to the UI[*27]. Rather than waiting for full sentences to be completely converted before displaying them, intermediate results are displayed in real time in units of words (**Figure 4**). Then, when the utterance has completed, revised text for the whole sentence is displayed (**Figure 5**). Recognition results are displayed by words as the other party speaks, so conversation can proceed with as few obstacles as possible. A flashing icon appears on the screen showing clearly that the other party is speaking from the moment they begin. A glance shows whether the other party is speaking or silent, so users can easily know how to time their responses.

4. Conclusion

This article has described details of initiatives to commercialize the Mieru Denwa service and how it has been implemented. The service plays an important role supporting the lives of people with hearing disabilities, but it could potentially also be useful for people without such disabilities in some scenarios, such as environments with noise that makes it difficult to hear what the other

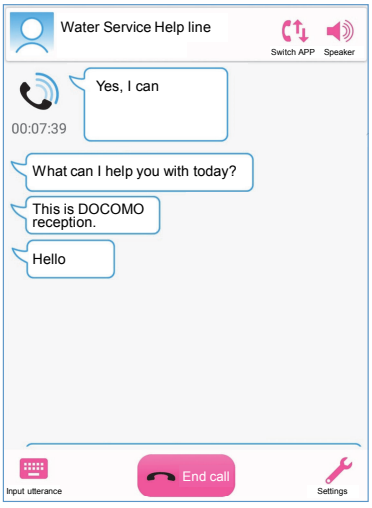

Figure 4 Screen shot with partial results during a call

*24 PUSH distribution equipment: Equipment that sends, receives and responds to SMS from a push client.
*25 Gateway: Equipment having functions such as protocol conversion and data transforming.
*26 iPhone: A registered trademark of Apple, Inc. United States, used within Japan under a license from Aiphone Co., Ltd.
*27 UI: Operation screen and operation method for exchanging information between the user and computer.

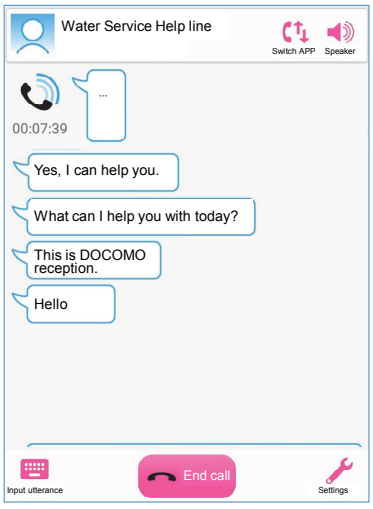

Figure 5 Screen shot with finalized result during a call

person in a phone call is saying. We will continue to improve the accuracy of speech recognition to further enhance the service in the future.

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5G | Connected Car | Cellular V2X

Collaboration Projects

Vehicle Antenna Technology for Stable 5G Communications without Compromising Vehicle Design —5G Vehicle Glass Antennas—

5G Laboratories Minoru Inomata Tetsuro Imai

To achieve the 5G enabled connected cars of the future, NTT DOCOMO has developed 5G vehicle glass antennas that enable moving vehicles to receive the appropriate base station radio waves. These antennas are 28 GHz-band devices that can be mounted on the windows of automobiles to enable 5G communications without compromising the vehicle design. Installing these antennas in various positions on vehicle windows enables stable transmission and reception of 5G radio waves, and achieves stable high-speed communications. This research was conducted jointly with AGC Inc.

1. Introduction

Currently, the introduction of 5th-generation (5G) mobile communication systems - the communications networks characterized by high-speed, high-capacity, low-latency and multi-device connection set to become commonplace from 2020 onwards - is being studied energetically, because use of the 28 GHz frequency band with 5G will enable ultrawide bandwidth*1 and hence is expected to achieve these high-speed and high-capacity communications [1] [2]. Cellular V2X (Vehicle to everything)*2 to connect cars to various other things has also been discussed in 3GPP, etc., and major groups and corporations in various countries are forging ahead with demonstration experiments [3] [4].

The 28 GHz-band has stronger directionality, due to its wavelengths, which are shorter than those of the frequencies used with the older 4th-generation mobile communications systems (4G). This can cause unstable communications because the radio waves tend to be weakened by the vehicle body when communicating from inside a vehicle. To address this issue, NTT DOCOMO and AGC Inc. (hereinafter referred to as "AGC") have developed the world's first 5G vehicle glass antennas to enable radiowave transmission and reception in

*1 Ultrawide bandwidth: Bandwidth of 100 MHz or greater. In Japan, 400 MHz of bandwidth has been assigned in the 28 GHz band for 5G radio communications.

*2 V2X: V2X is a generic name for radio communications systems for communications between vehicles and other vehicles (V2V: Vehicle to Vehicle), vehicles and infrastructure such as traffic signals and road signs (V2I: Vehicle to Infrastructure) and between vehicles and pedestrians carrying smartphones (V2P: Vehicle to Pedestrian).

the 28 GHz-band and achieve stable 5G high-speed communications with automobiles [5] - [9].

NTT DOCOMO's development partner, AGC, has 40 years experience in design, development and manufacture of vehicle antennas, and possesses technologies to incorporate antennas for AM, FM and TV broadcast and LTE communications, etc. into the glass of vehicle windows. Combining these technologies with the high-frequency (28 GHz-band) 5G technology that NTT DOCOMO has built up through research with major vendors all around the world has enabled the development of these 5G vehicle glass antennas. Using these antenna elements installed on vehicle window glass for transmission and reception of 28 GHz-band radio waves before the radio waves are weakened by the vehicle body enables stable high-speed 5G communications. Also, installing these antennas on the glass surfaces of vehicle windows does not impair vision, and does not compromise vehicle design.

This article describes the 28 GHz-band 5G vehicle glass antennas and related experiments.

This research was conducted jointly with the Automotive Company and Materials Integration Laboratories of AGC.

2. Requirements and Technical Issues of the 5G Vehicle Antenna

Because the 28 GHz-band used with 5G has stronger directionality than the frequency bands used with LTE, etc., it's easier for radio waves to be cut off by the vehicle body and greater propagation loss[*3] to occur with communications from the vehicle cabin. To address this issue, methods to compensate for 28 GHz-band propagation loss by the application of beamforming[*4] technology using Massive Multiple Input Multiple Output (MIMO)[*5] antennas in base stations and achieve high antenna gain[*6] are being studied. However, the more the antenna gain is improved, the beam width becomes narrower. During driving, it is desirable to have high gain and omni-directional (non-antenna directivity[*7]) antennas to enable reception of high-power, multipath waves from structures in the vicinity of the vehicle so that the base station beam can be properly selected. Also, MIMO[*8] transmission technology is used with 5G because it improves communication speeds by simultaneously transmitting different data from multiple antennas with horizontally and vertically polarized antennas. For this reason, 5G vehicle antennas must be able to properly receive multiple beams with both polarizations.

Conventional vehicle antennas included antennas for AM, FM and TV broadcast, etc. (**Photo 1**), and antennas for LTE communications printed on vehicle windows surfaces, and designed not to hinder the vision of the driver or compromise vehicle design.

Thus, with requirements including unhindered driver vision and uncompromised vehicle design, NTT DOCOMO began studying development of 5G vehicle glass antennas to support the 28 GHz-band and enable high-speed, high-capacity communications.

3. The 5G Vehicle Glass Antenna Development

3.1 Concept

Structures that use omni-directional antennas

*3 Propagation loss: The amount of power of radio wave decay from their emission from a transmitter to their arrival at a receiver.

*4 Beamforming: A technique for increasing or decreasing the gain of multiple antennas in a specific direction by controlling the phase of the antennas to form a directional pattern of the antennas.

*5 Massive MIMO: MIMO transmission formats use multi-element antennas at both the transmitter and receiver to spatially multiplex the radio signal. Massive MIMO is a technique that enables narrow radio wave beam forming to compensate for carrier losses when using high frequency bands or to transmit more streams at the same time, by utilizing super multi-element antennas with more antenna elements than MIMO. Massive MIMO achieves high speed data communications while securing the desired service area.

have lower antenna gain. Thus, to form omni-directional radiation patterns, achieve high antenna gain and support MIMO transmission without using omni-directional antennas, a distributed array of multiple directional antennas can be used to form beams in all directions around a vehicle. There are vehicle windows facing in every direction of the vehicle that are positioned at intervals longer than the wavelength, and are desirable as antenna mounting positions to lower signal correlation*9 and improve MIMO transmission efficiency.

The mounting positions are shown in **Figure 1**. As shown by the stars in Fig. 1, directional antennas are installed on four windows - the windshield, the rear quarter windows on both sides, and the rear window - to achieve near omni-directionality on the horizontal plane. In the 28 GHz-band, multipath radio waves from structures around the vehicle exist in urban areas, therefore, with this installation method, it's possible to select a directional antenna in the direction of the strongest radio waves among the radio waves arriving from all around, transmit and receive data, and achieve stable high-speed communications in urban areas where radio waves may be easily interrupted.

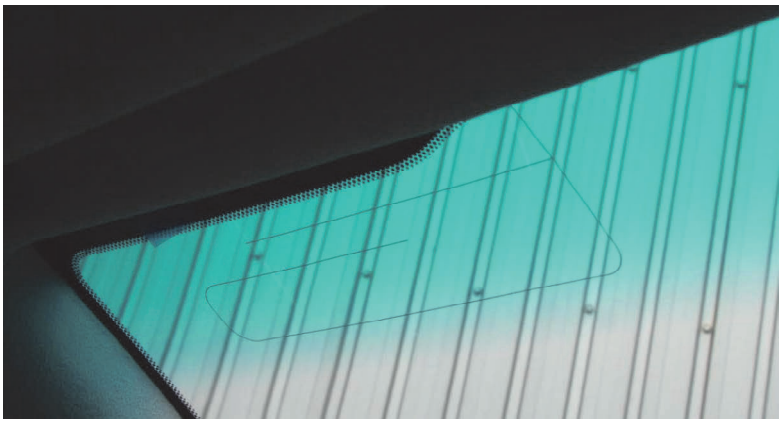


Photo 1 A conventional TV broadcast glass antenna

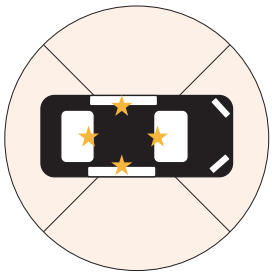


Figure 1 Antenna mounting positions and antenna patterns

*6 Antenna gain: The power radiated in the direction of maximum radiation, usually expressed as the ratio of radiated power to that of an isotropic antenna.

*7 Antenna directivity: The directional characteristics of the strength of radio emission or sensitivity to radio reception of the antenna.

*8 MIMO: A radio communication format in which transmitted data is divided into multiple signals (streams) and then transmitted and received on the same frequency band using multiple antennas at both the transmitter and the receiver.

*9 Correlation: An index expressing similarity between different signals. Expressed as a complex number, its absolute value range from 0 to 1. Similarity increases as the value approaches 1, which makes signal separation at the receiver difficult, and results in degraded throughput in MIMO communications.

3.2 Achieving the Concept through Joint Research with AGC

NTT DOCOMO began joint research to achieve this concept with AGC in June 2018. **Photo 2** shows the 5G vehicle glass antennas we developed.

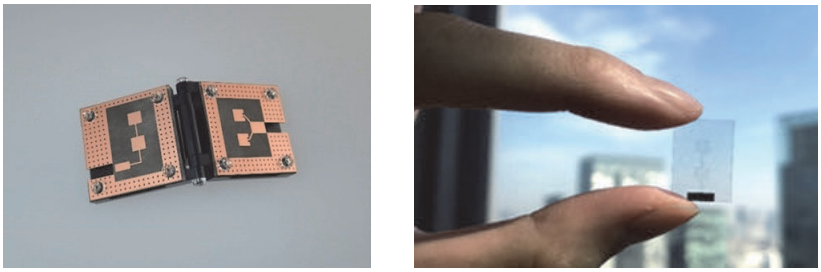
1) On-glass Antenna

Photo 2 (a) shows the glass-mounted antenna (hereinafter referred to as "on-glass antenna") we developed in June 2018. The on-glass antenna is a compact radio unit*10 combining antennas for both horizontally and vertically polarized waves to support MIMO transmission. Two antenna elements are used respectively to perform electrically tilting*11 of the vertically oriented beam so that it comes horizontal. To improve radio emission efficiency in the 28 GHz-band, we designed the on-glass antenna using fluoropolymer resin because of its low dielectric constant*12 and low dielectric loss tangent*13. Also, the antenna has a three-dimensional structure which makes it easy to orient to optimize antenna directionality. Although this antenna can only be mounted on the places where it will not interfere with the driver's field of vision, it is easy to orient for directionality to enable efficient radio wave reception and high communication speeds.

2) Glass-integrated 5G Antenna

Photo 2 (b) shows the glass-integrated 5G antenna we developed in May 2019. This antenna is a compact, thin and clear glass antenna, and similar to the on-glass antenna, it has two antenna elements for horizontal and vertical polarization to perform electrically tilting of the vertically oriented beam so it becomes horizontal. This antenna has been designed with a synthetic fused silica glass substrate that has low dielectric constant and dielectric loss tangent properties similar to the on-glass antenna. This antenna is integrated with glass and less visible than the on-glass antenna, and will not hinder vision when multiple antenna elements are installed on vehicle windows. However, the flat structure of this antenna limits the directionality of the antenna pattern, which causes inferior communications speeds compared to the on-glass antenna.

Photo 3 shows examples of on-glass antenna installation. Installing four on-glass antennas on the car windows in the four places - the windshield, the right and left rear quarter windows, and the rear window - enables omni-directionality for data transmission and reception. We also installed glass-



(a) On-glass antenna (b) Glass-integrated 5G antenna

Photo 2 The 5G vehicle glass antenna we developed

*10 Radio unit: Part of the equipment comprising a base station, which performs transmission and reception by converting digital signals to a radio signals, amplifying them and sending or receiving them to or from the antenna elements. It also performs the processing required to generate beam forming for Massive MIMO.

*11 Tilting: Inclination of an antenna's main beam direction in the vertical plane. There are mechanical tilt systems that physically tilt the antenna and electrical tilt systems that control the amplitude and phase of antenna array elements to tilt the main beam.

*12 Dielectric constant: A material-specific quantity related to the distribution of an electric field when a current is passed through a circuit. While it's possible to make antennas small if their dielectric constant is high, their operational frequency bandwidth tends to become narrow.

integrated 5G antennas in four places in the same way as the on-glass antennas.

4. Demonstration Experiment

4.1 Overview of Experiment

We performed the experiments in urban small cell*14 environments around Sumida Ward in Tokyo. **Photo 4** shows our experimentation vehicle with on-glass and glass-integrated 5G antennas installed on the windows, which were connected to 5G equipment installed inside the vehicle. 5G base station radio equipment was installed on the roof of another experimentation vehicle, and throughput*15 was obtained while driving in the urban area at a speed around 30 km/h while using the 28 GHz-band between the 5G base station and the 5G equipment connected to the 5G vehicle glass antennas. For bandwidth, the maximum transmission bandwidths for the experimental equipment of 800 MHz and 400 MHz were used.

Table 1 shows the main specifications of the 28 GHz-band 5G base station and terminal equipment used in this experiment. The 5G base station uses a 128-element horizontally and vertically polarized antenna panel for beamforming, transmits a maximum of four streams, and has beam tracking functions for following the movement of the experimentation

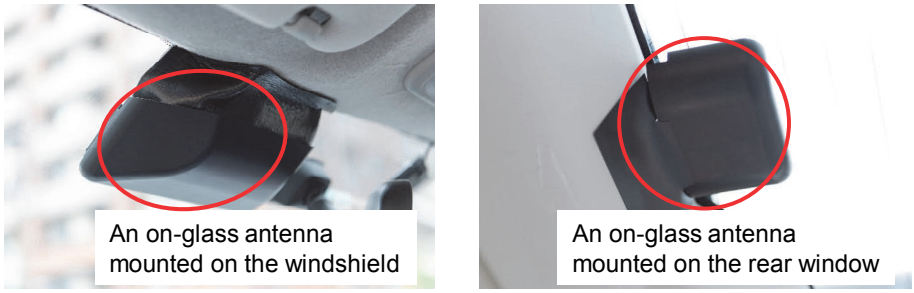


Photo 3 Example on-glass antenna installations

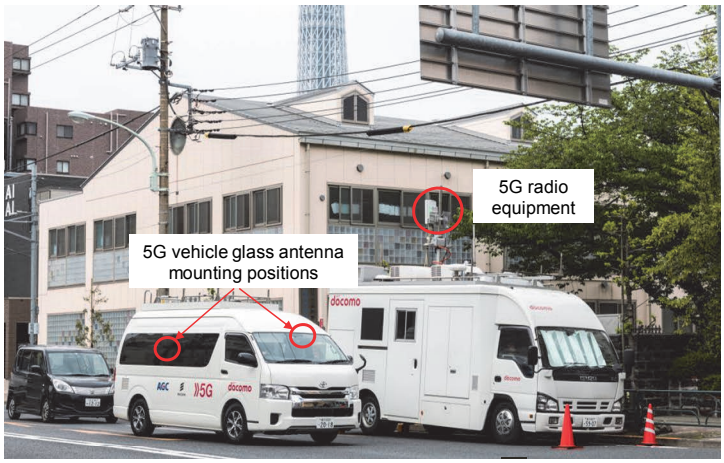


Photo 4 A scene during demonstration testing

*13 Dielectric loss tangent: A material-specific value used as an indicator of the amount of leakage that does not reach the antenna when a current flows through a circuit. If the value is high, less of electric energy intended for communications is transmitted to the antenna, which deteriorates its radiation efficiency.

*14 Small cell: A cell smaller than a macro cell, and covering a relatively small area. Also called a microcell.

*15 Throughput: The amount of data transferred through a system without error per unit time.

vehicle. The 5G terminal equipment was installed in the backseat of the experimentation vehicle and connected to the on-glass and glass-integrated 5G antennas. With the experimental equipment, because the 5G base station must precisely and quickly select the optimal antenna beam to perform beam tracking, a suitable base station antenna beam was selected in response to the driving position of the experimentation vehicle using a mobility reference signal (MRS) to reference the reception power of each beam. The terminal feeds back several candidates with favorable reception power from among the base station antenna beams, and then based on this feedback, the base station determines which base station antenna beam to use for transmission. This enables beam tracking by optimal selection of base station antenna beams for the driving position of the experimentation vehicle.

4.2 Experimental results

Table 2 shows the throughput obtained for the on-glass and glass-integrated 5G antennas in the urban area.

800 MHz of bandwidth was used for the on-glass antenna experiment. When using the on-glass antennas, the throughput was a maximum of 7.9 Gbps

Table 1 Main specifications

5G base station equipment	Frequency	27.9 GHz
	System bandwidths	732 MHz, 366 MHz
	Duplex method	TDD (UL:DL = 2:48)
	Radio access method	OFDMA
	Antenna structure	Vertical and horizontal polarization, 2 per polarization x 128 elements
	Max. no. of MIMO streams	4
	Modulation method	QPSK, 16QAM, 64QAM
5G terminal equipment	Antenna structure	Vertical and horizontal polarization, 8 elements per polarization x 2 elements in a sub array

OFDMA: Orthogonal Frequency Division Multiple Access
QAM: Quadrature Amplitude Modulation
QPSK: Quadrature Phase Shift Keying
TDD: Time Division Duplex

Table 2 Experimental results

Antenna type	Bandwidth	Throughput obtained from experimental equipment
On-glass antenna	800 MHz	Max 7.9 Gbps Average* 3.0 Gbps
Glass-integrated 5G antenna	800 MHz	Max 7.5 Gbps Average* 2.5 Gbps
	400 MHz	Max 3.8 Gbps Average* 1.3 Gbps

*Calculated with an area 100 m in radius from the base station

downlink, with an average of 3 Gbps within a 100 m radius of the base station, and a maximum communications distance of 232 m.

For the glass-integrated 5G antenna experiment, both the 400 MHz and 800 MHz bandwidths were used. With the 400 MHz bandwidth the maximum downlink was 3.8 Gbps, with an average of 1.3 Gbps within a 100 m radius of the base station. With the 800 MHz bandwidth, the maximum downlink was 7.5 Gbps, with an average of 2.5 Gbps within a 100 m radius of the base station, and the maximum communications distance was 178 m.

These experimental results showed that the use of the 5G vehicle glass antennas enabled stable, high-speed 5G communications. Also, on comparison of the antennas, the on-glass antenna enabled higher throughput and longer distance communications. The 3-D structure of the on-glass antenna enables easy optimization of antenna patterns and hence improvements in communication performance, whereas the flat structure of the glass-integrated 5G antenna makes optimizing antenna patterns more difficult with the same number of antenna elements, which accounts for the differences in throughput.

5. Conclusion

This article described 5G vehicle glass antennas and related experiments. NTT DOCOMO and AGC will continue these studies to further improve communication speeds with Massive MIMO with these antennas. We also plan to advance initiatives to enlarge 5G areas and expand applications using these antennas in environments where base station installation is problematic or 5G demand is temporary.

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NTT DOCOMO Awarded World First Place in the "KDD Cup 2019" - the World's Leading Data Analysis Competition

On August 4, 2019, Keiichi Ochiai of Research Laboratories, and Akihiro Kawana, Tsukasa Demizu, Shin Ishiguro of the Service Innovation Department, and Shohei Maruyama of the Radio Access Network Development Department of NTT DOCOMO were awarded first place in the world in the KDD CUP 2019 data analysis competition.

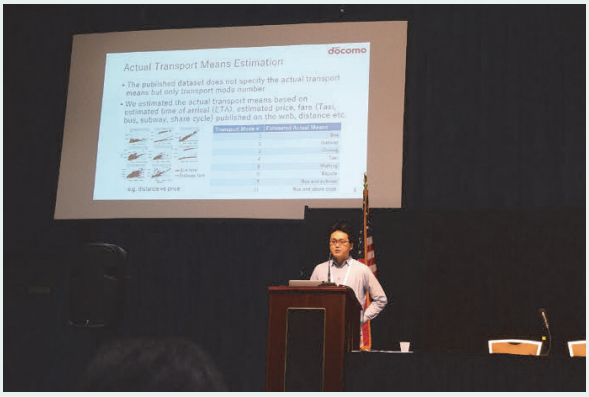
The KDD CUP is a data analysis competition hosted by the Association for Computing Machinery (ACM) Special Interest Group on Knowledge Discovery and Data Mining (SIGKDD), and is held at the International Conference on Knowledge Discovery and Data Mining (KDD). It is the world's oldest and leading data analysis competition, having a history stretching back to 1997, a time when the words "big data" and "data scientist" didn't exist.

This year's competition was divided into four categories. The category in which we won the first place entailed setting a research question and divising its solution using big data containing search routes of transit guidance functions for domestic transport systems in China, and the results of user selections. Differing from the norm, participants set the problem themselves, and were questioned about its significance and the validity of its solutions.

Focusing on the air pollution problem in China, the characteristics of the transportation systems of the data provided, and the expansion of the bike share market, we devised a method to select environmentally friendly transportation means, for example bicycles, while minimizing increases in travel time, which led to our winning the first place.

On a daily basis, NTT DOCOMO has been working on setting and solving business issues making effective use of big data in collaboration with its partner companies. We believe this led to the result. Going forward, we will continue to advance initiatives to expand business using big data and solve social issues.

(From left) Ochiai, Demizu



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