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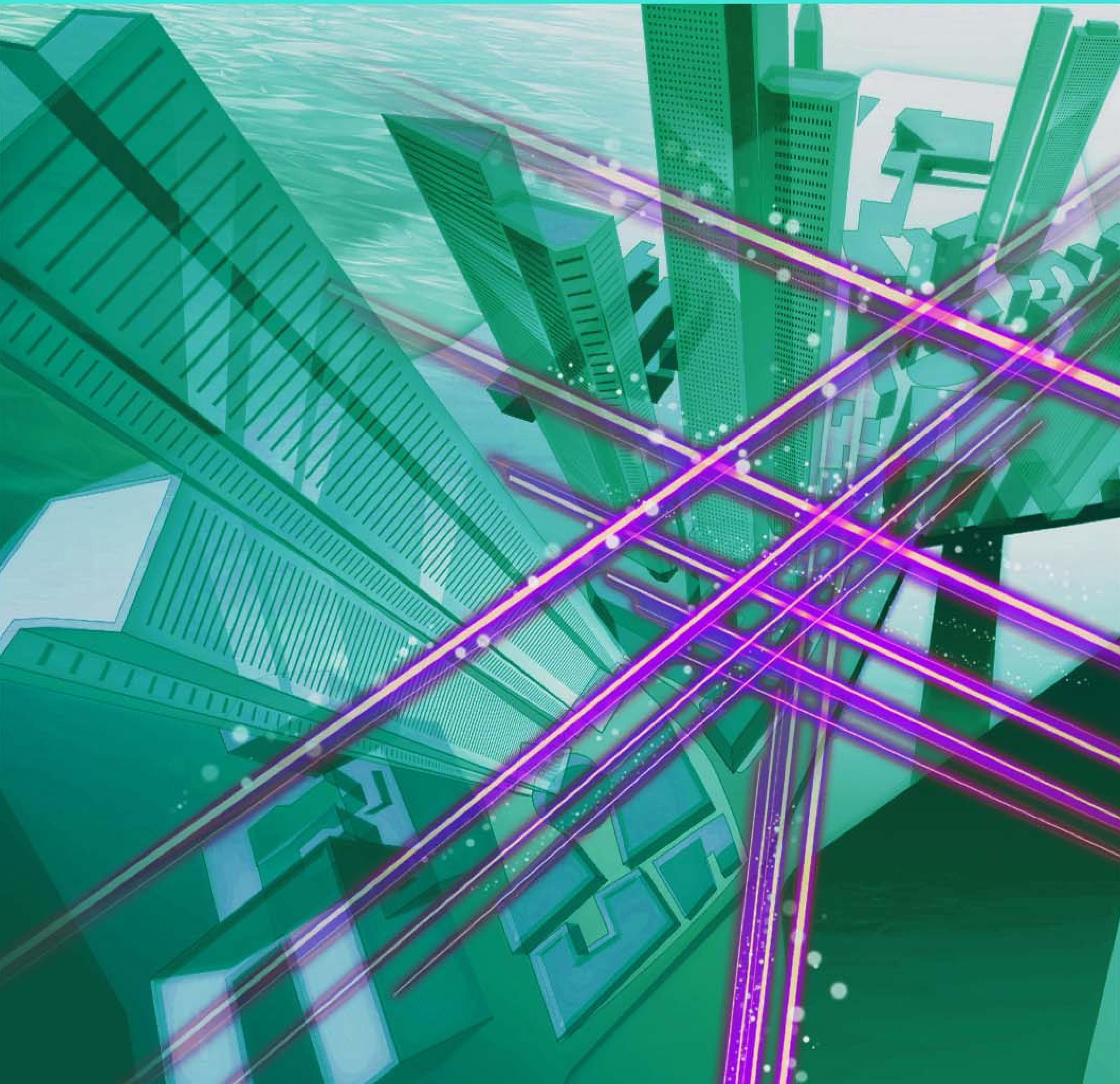

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Co-creating a Virtuous Cycle of New Value

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Overview

In this article, we introduce NTT Group's initiatives for B2B2X (business-to-business-to-X) models and acceleration of Society 5.0 through co-creation of new value. The contents of this article are based on a lecture given by Hiroo Unoura, NTT President and Chief Executive Officer, at NTT R&D Forum 2018 held in February 2018.

Keywords: B2B2X, Society 5.0, data integration and utilization

1. Social issues in Japan

Japan has long been said to be an *issue-facing developed country*, but unfortunately, it has yet to become an *issue-solving developed country*. These social issues include a falling population, super-aging society, deteriorating infrastructure, urban concentration, and environmental problems. The government report entitled *Growth Strategy 2017* issued by the Cabinet Office states that the key to overcoming these issues and achieving medium- and long-term growth is to introduce innovative technologies of the Fourth Industrial Revolution such as the Internet of Things (IoT), big data, and artificial intelligence (AI) into all sorts of industries and every corner of social life. In other words, the goal is to realize Society 5.0, which aims to solve diverse social challenges through the use of advanced technologies.

As information and communication technology (ICT) continues to progress together with accelerated use of networks and IoT, varieties of national strategies have been established throughout the world with the aim of maximizing the use of ICT in the field of manufacturing and bringing about change in the form of the Fourth Industrial Revolution. These include Industry 4.0 in Germany, the Advanced Manufacturing Partnership in the United States, and Made in China 2025 in China. Japan, meanwhile, is promoting a national strategy called Society 5.0 with the aim of digitizing not just manufacturing but also government, industry, and society through the development of innovative technologies and the use of diverse types of data [1].

Against this background, the Japan Business Federation (Keidanren) envisions a society having the following features as part of the Society 5.0 initiative:

(1) Smart society undaunted by population decreases
(2) Society in which individuals can actively participate, including the elderly and women
(3) Safe, secure society in both cyberspace and physical space
(4) Society where cities and regions are linked and it is possible to live comfortably anywhere
(5) Sustainable society that balances the economy and environment

In Society 5.0, solutions will be formulated to deal with social issues such as the falling population in the agricultural/farming industry and a decrease in industrial competitiveness. For example, sensors could be installed in fields to collect a wide variety of data (big data) on the growing environment of harvested crops,

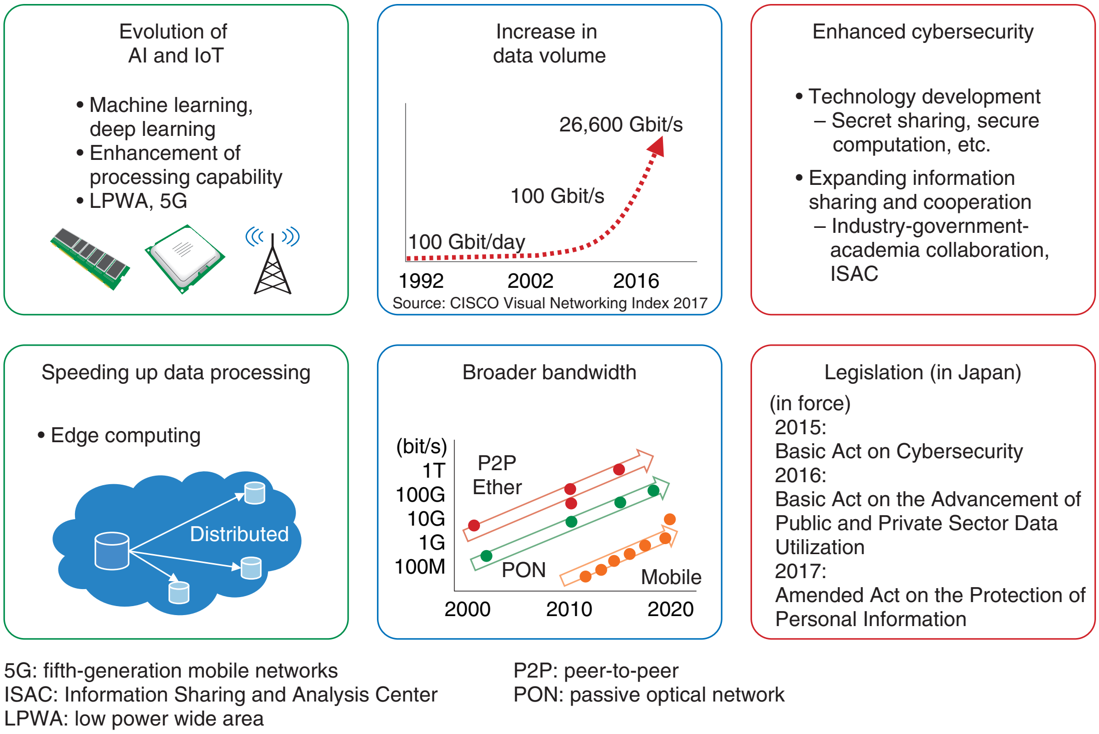

Fig. 1. Putting digital transformation into practice.

and such data combined with meteorological data could be analyzed using AI to improve productivity.

Society 5.0 is a world in which society on the whole is optimized through the use of data and the convergence of cyberspace and physical space. It will be achieved through the digital transformation of various sectors in society. *Digital transformation* means leveraging ICT tools to accumulate diverse data and using that data in management activities to create new business models and change existing business practices.

Digital transformation is a concept first proposed by Swedish professor Erik Stolterman in 2004. Since then, the ICT environment surrounding digital transformation and the systems used for handling data have changed considerably. Examples include the evolution of AI and IoT as ICT tools and the introduction of edge computing to achieve distributed and high-speed data processing. At the same time, the volume of traffic data has increased considerably, and network bandwidth supporting that data flow has expanded. Cybersecurity technologies and legislation in relation to the integration and utilization of data have also progressed. In the face of these environmental changes, digital transformation is moving from a conceptual stage to a practical stage (**Fig. 1**).

2. B2B2X (business-to-business-to-X) models

The world of Society 5.0 will be achieved through the digital transformation of various sectors in society. To this end, the NTT Group is committed to supporting digital transformation in companies and local governments with the aim of creating new value.

2.1 Direction of initiatives for B2B2X models

The NTT Group seeks to accelerate the creation of new value by promoting collaboration with diverse service providers. In our B2B2X models, we will support the digital transformation of a wide variety of service providers (the second ‘B’ in B2B2X) as a valuable supporting player with the aim of contributing to lifestyle changes and solving social issues.

We have numerous services and ICT tools that can support companies and local governments in their digital transformation. For example, in addition to our traditional strength in telecommunications infrastructures, we can provide main players (service providers) with services and ICT tools that make use of AI-related technologies such as those for speech/

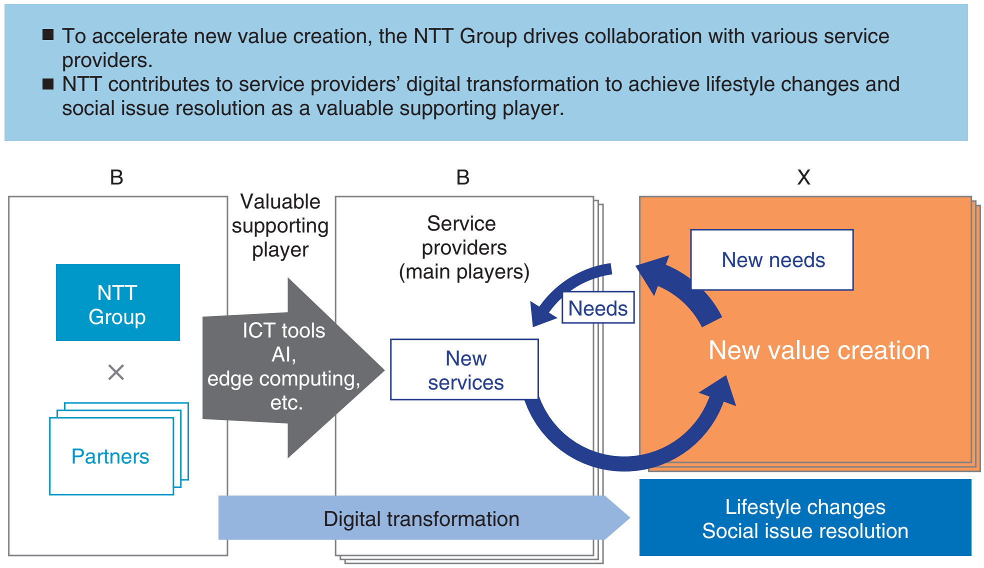

Fig. 2. Direction of initiatives for B2B2X models.

language processing and data analysis, as well as edge computing technologies, all cultivated through NTT research and development (R&D) efforts.

I believe that efforts such as these will generate new value for users (the 'X' in B2B2X) that can lead to lifestyle changes and solutions to social issues (**Fig. 2**). Just last year, we started new collaborative projects with a variety of service providers in diverse sectors from healthcare to automobiles, transport, manufacturing, agriculture, and tourism.

2.2 Kabuki that merges reality and virtuality

In the area of traditional performing arts, we are creating new value going beyond the boundaries of time and space through a collaborative effort between SHOCHIKU Co., Ltd. and NTT, using NTT's R&D technology.

At the Niconico Chokaigi festival hosted by Dwango Co., Ltd. held in April 2016 and April 2017, SHOCHIKU presented a public performance of "Cho-Kabuki" incorporating NTT's immersive telepresence technology called Kirari!. In this program, the kabuki actor Nakamura Shido II appeared on stage together with the vocaloid Hatsune Miku. By providing programs with such novel performances, SHOCHIKU has been able to attract the interest of young people and expand its kabuki fan base.

Then, in March 2017, NTT collaborated with the Kumamoto prefectural government in holding a Virtual Kabuki Theater as part of a prayer for recovery in the wake of the 2016 Kumamoto earthquakes. Through this effort, we were able to provide performances at a theater not specialized for kabuki and to expand theatergoing opportunities for the general public.

More recently in November 2017, NTT provided support for a presentation of "Miyako Musubi Yumeno Renjishi" by the kabuki actors Nakamura Shikan VIII, Nakamura Hashinosuke IV, Nakamura Fukunosuke III, and Nakamura Utanosuke IV as the first kabuki performance merging reality and virtuality. In this presentation, the three actors other than Nakamura Shikan performed their roles at the Miyakawacho Kaburenjo Theater in Kyoto, which was located about 1.5 km from the Pontocho Kaburenjo Theater where Nakamura Shikan was performing. We transmitted the video of those three actors in real time to the Pontocho Kaburenjo Theater to achieve a virtual co-performance of the Renjishi kabuki dance by Nakamura Shikan and his three fellow actors. Using NTT technology in this way made it possible for actors in different locations to perform as if they were all present in the same place (**Fig. 3**).

3. Initiatives toward the acceleration of Society 5.0

In this article, I have so far introduced NTT Group initiatives (B2B2X models) for achieving Society 5.0. From here on, I will introduce initiatives for

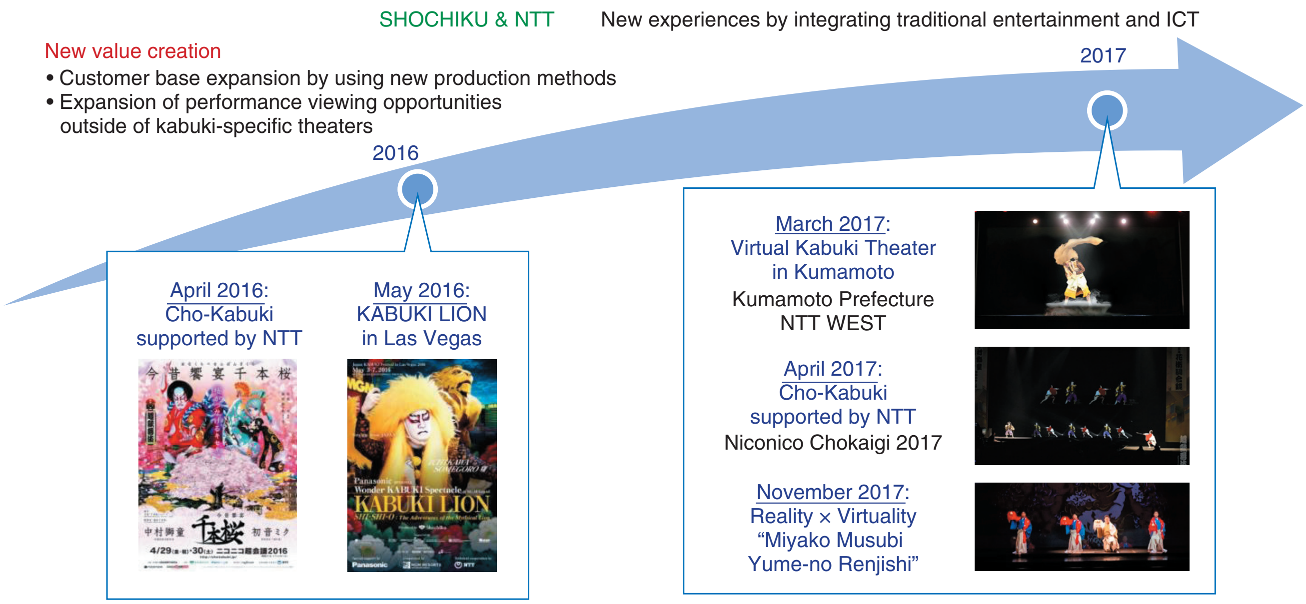

Fig. 3. Support for new value creation.

accelerating the realization of Society 5.0.

Digital transformation efforts are progressing at various companies and enterprises. These activities, however, are essentially independent of each other, with the result that most are not cross-sector efforts. I believe that we can accelerate the coming of Society 5.0 by promoting digital transformation across sectors instead of focusing only on individual fields or industries. In short, what is of importance here is to establish an environment for integrating and opening up data across sectors and for utilizing that data effectively.

3.1 Current status and direction of data integration and utilization

At present, the dominant trend in Japan is for companies and local governments to integrate data individually in a fragmented manner. The data that we possess, while being of very high quality, is perhaps small in volume compared with that of the global digital giants. However, if high quality data from several sources can be appropriately combined into mashups, it should be possible to speed up the digital transformation process (**Fig. 4**).

Let us consider reform of the agricultural sector as an example. First of all, simply applying a digital transformation to agricultural production is not sufficient in itself for improving agricultural output or food safety. A cross-sector approach that includes distribution of raw materials, food processing, distribution of processed foods, and other elements, is important. However, a mechanism for integrating and opening up essential data across various sectors in a digital transformation is unclear. This is a major issue in promoting Society 5.0 from here on.

In countries such as the United States and China, digital giants are advancing the integration and use of data. Unfortunately, in Japan, I believe this approach would be difficult to pursue. It is therefore important that we consider what other methodologies might be available and what direction solutions might take. Simply accumulating data is not the objective; the prime objective is to use the data properly. The issue of whom data belongs to is also being debated. Does it belong to the service provider that collected the data or to the individuals who created that data? It is my belief that data belongs to society, to the people making up a community. In other words, I consider that data should be used for promoting progress in regional communities.

3.2 New ecosystem

A new ecosystem is needed to accelerate Society 5.0 and promote the digitization of industry and society through the use of data. This ecosystem would not be on a municipal or even prefectural level; rather, it would be based on regional units each of a scale of several million people. In this ecosystem, data in each

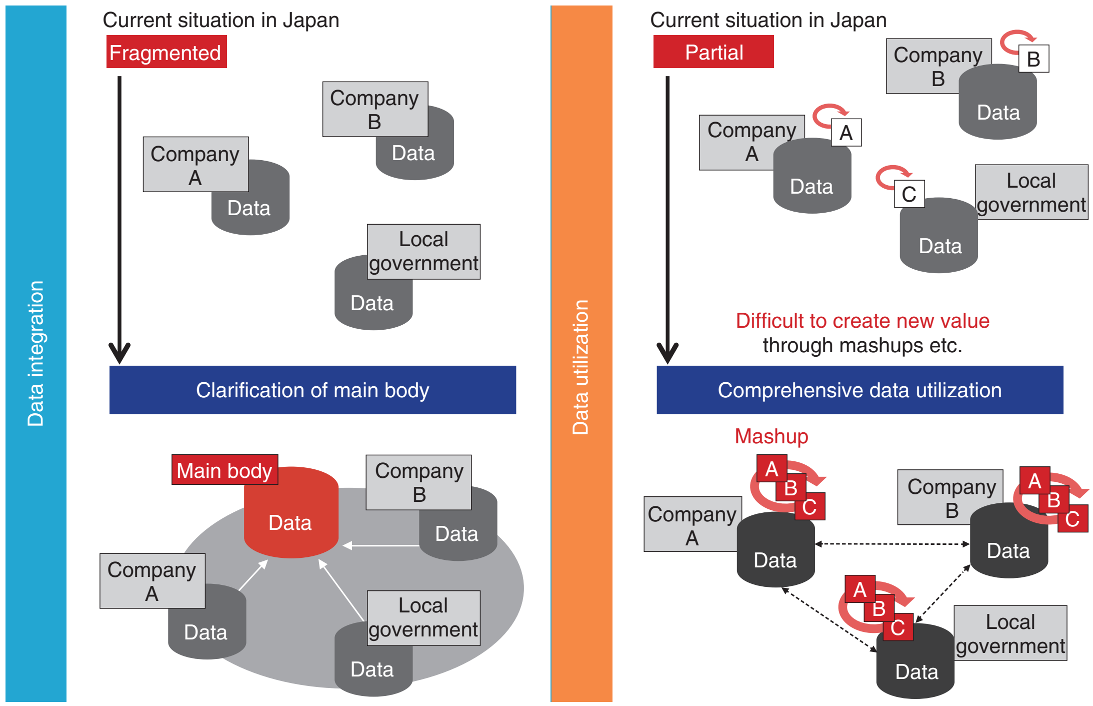

Fig. 4. Current situation and direction of data integration and data utilization.

regional unit would be managed by a quasi-public entity (e.g., an industry-government-academia consortium) that would promote the integration of data and the provision of open data.

The reason here for regional units is that social problems tend to be regional in nature, and the reason for having a quasi-public entity at the center of this ecosystem is that government needs to play a central role in finding solutions to social issues. The collection of data by the government for the purpose of solving social issues is a worthy endeavor. In addition, a public entity can be neutral with respect to corporate enterprises and can take on the responsibility of ensuring security.

I would like to create an ecosystem that converts correct and comprehensive data to open data, which can then be accessed and used by companies and venture-funded startups to create new value (**Fig. 5**).

I would also like to create a mechanism that would provide companies with an incentive to proactively provide data. In this mechanism, only companies that provide data to the quasi-public entity or that provide the results of using that data would be able to reference the big data held by the quasi-public entity. Creation of such an ecosystem with value enables even global digital giants to circulate the data they possess within that region in exchange for allowing them to reference the correct data. I believe that doing so would enable the creation of a self-reliant region and a society with a global presence.

3.3 Initiatives in Sapporo for value creation

We are supporting Sapporo City, Hokkaido, in its efforts to integrate and open up data as a first step toward achieving an ecosystem within a regional unit. Since concluding the Sapporo Town Planning Partner Agreement with Sapporo City in September 2015, we have been supporting Sapporo in its efforts to solve social issues in that region. In addition, the Sapporo City ICT Utilization Platform Study Panel was established in July 2016 with members coming from local companies, governments, and universities. This study panel was set up to study data integration and utilization guidelines, platform requirements, and an operational framework for the platform. The use of ICT in sports/tourism, traffic and snow-control measures, and health is being studied in separate subcommittees.

(1) Value creation by data integration and utilization

Here, I would like to introduce an example of data utilization by Sapporo City in the area of inbound

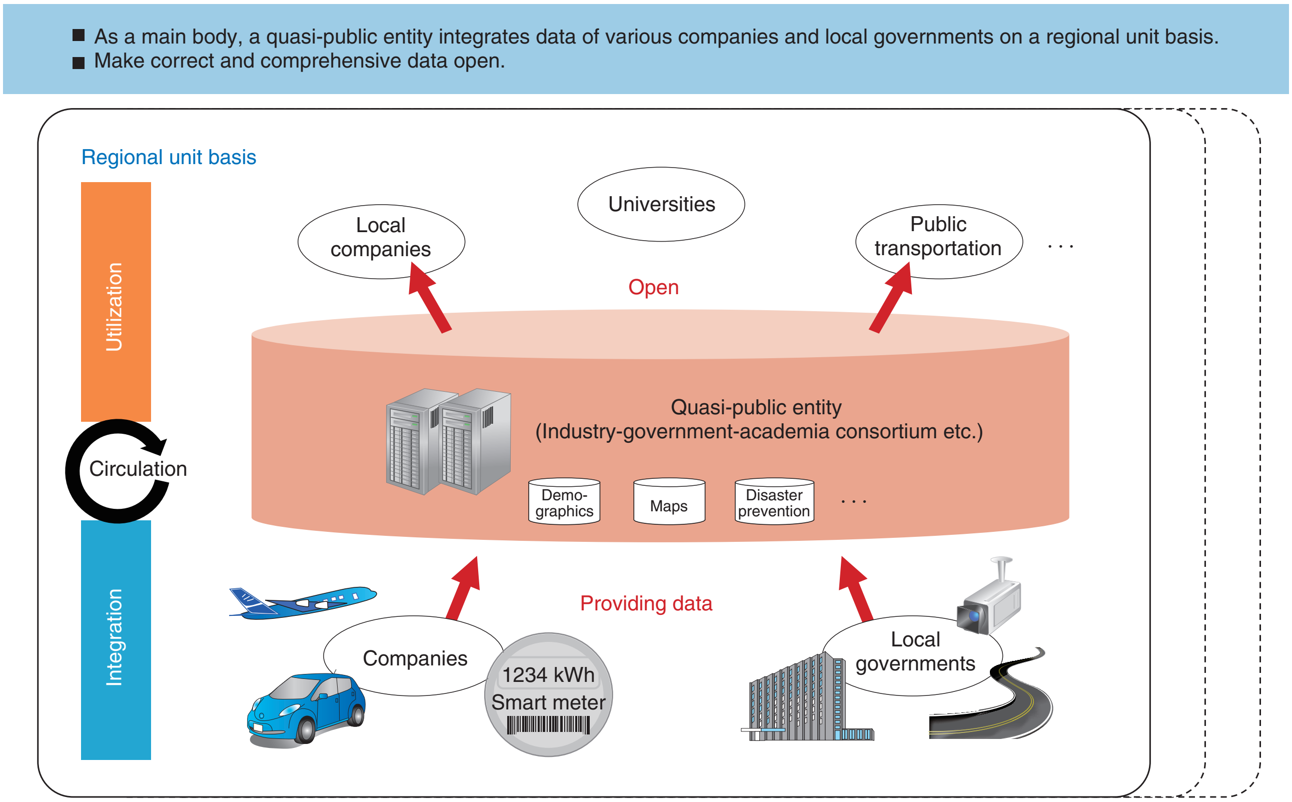

Fig. 5. Image of new ecosystem.

tourism. This initiative began with the integration and utilization of data from three companies, namely, a department store, supermarket, and drugstore. These companies provided data that they possessed on purchases made by tourists resulting in a database of purchase data for all of Sapporo. Each company could then compare its own purchase data with overall purchase data and thereby observe purchase trends that had gone unnoticed. In this way, each company could discover potential markets and increase sales by modifying its marketing strategy.

Since this initial effort, Sapporo has added other types of companies such as hotels, bringing the scale of participants to about 20 firms. From here on, the plan is to circulate the activities and results of each company back to Sapporo as data and to reconvert that information into open data that can be used to create new value.

Additionally, I believe that the introduction of e-money by local companies can respond to the need for diversified payment methods; that is, it can make shopping more convenient for tourists, thereby creating new value. In addition to reducing the cash handling costs of local companies, the digitization of payment methods can broaden the range of payment information that can be obtained as digital data, which should enable more effective sales promotions (**Fig. 6**).

In another initiative, we are formulating plans for collecting and analyzing data on road conditions during the snow season with the aim of operating snow plows more efficiently and providing Sapporo residents with snow-removal updates.

(2) ICT utilization platform

The results of these initiatives have been used to create the website "Sapporo City ICT Utilization Platform Data-Smart City Sapporo," which came online on January 31, 2018, under the management of the Sapporo Electronics and Industries Cultivation Foundation [2]. This website can be used by local companies and residents to access data from the public and private sectors integrated on the platform. It is helping to create an environment that provides users with content generated by the analysis of collected data and enables the sharing, comparison, and analysis of data among companies.

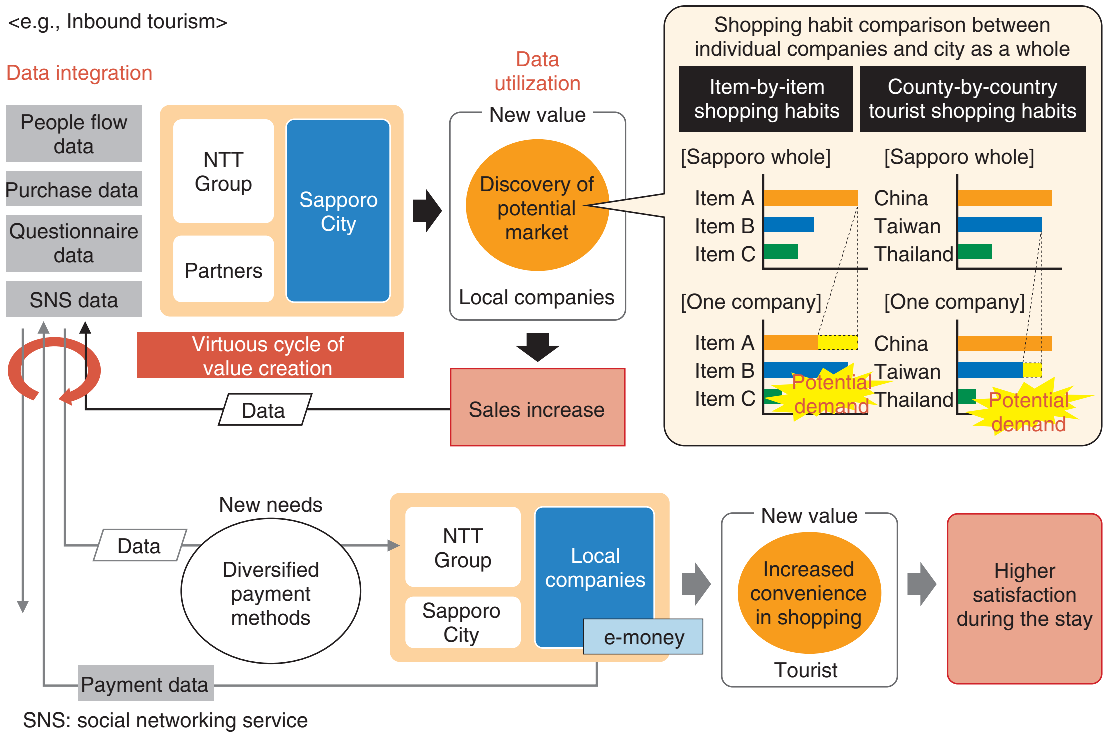

Fig. 6. Value creation through data integration and utilization.

The leadership demonstrated in this way by Sapporo City in promoting the integration and opening up of data is driving the use of data by local companies and the creation of new value for the region. Going forward, we expect the integration of cross-sector data, the broadening of data utilization, and the creation of new value to create a combined effect accelerating the solving of social issues.

I also envision the expansion of this Sapporo initiative to an even larger regional unit such as Hokkaido in total. This could result in even more effective integration and utilization of data. Moreover, I think that the results of competition among multiple regional units could be spread throughout Japan, thereby accelerating the drive toward Society 5.0.

(3) Secret sharing and secure computation

An example of security technologies supporting data integration and utilization is secret sharing technology and secure computation technology developed by the NTT laboratories. NTT secret sharing technology was adopted as the first international standard in this field by the International Organization for Standardization (ISO) in October 2017 [3].

NTT secure computation technology, meanwhile, provides robust security by dividing encrypted data among multiple servers in a distributed storage scheme. This technology also makes it possible to analyze and process that data directly in its distributed and encrypted form. Using these technologies to store information in distributed form among multiple datacenters prevents information leaks even if the data stored at one of those datacenters should be stolen. In fact, data can be restored even if the data at one of the datacenters are lost due to a natural disaster or other calamity. Stored data may be analyzed without having to restore the data to the original form (**Fig. 7**).

4. Toward the realization of Society 5.0

As we go forward, the NTT Group is committed to supporting digital transformation across diverse sectors as a value partner. We will promote the creation of an environment for integrating, opening up, and utilizing data across sectors based on a new ecosystem to accelerate the realization of Society 5.0.

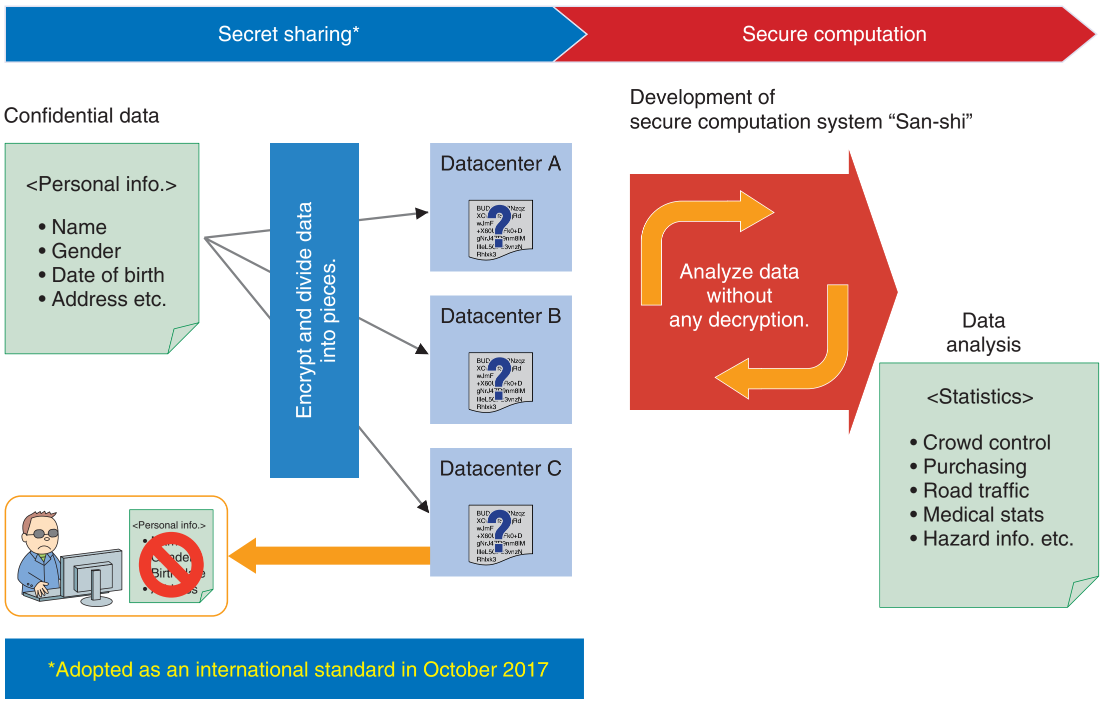

Fig. 7. Secret sharing and secure computation.

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Trademark notes

Creating a Prosperous Future through the Fruits of Research and Development

Hiromichi Shinohara
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Overview

This article introduces NTT's latest research and development activities based on a lecture presented by Hiromichi Shinohara, NTT Senior Executive Vice President and Head of the Research and Development Planning Department, at NTT R&D Forum 2018, which took place in February 2018.

Keywords: artificial intelligence, IoT, security

1. Introduction: roles of NTT research and development (R&D)

The roles of NTT R&D are to create new technologies and to work with NTT Group operating companies to address pressing issues such as the explosive growth in the traffic handled by telecommunications carriers and the increasing sophistication of cyberattacks. In addition, we aim to enhance productivity and address security and disaster prevention issues so that we can help strengthen industrial competitiveness and solve social issues. Because information and communication technology is employed across a wide range of fields, we are tackling these issues through collaboration with NTT Group companies and in partnership with different industries.

We believe that if our technologies are to be deployed in various fields, they should be made to feel as natural as possible to users (**Fig. 1**). To achieve this, it is necessary to take into account several perspectives: "enhance" to understand people's thoughts better and convey their intention correctly; "unconscious" to enable people to benefit from advanced technologies without making a conscious effort; and "barrier-free" to enable individuals to use technologies personally in ways that are adapted to their particular needs or preferences.

From a business standpoint, we believe that these technologies should evolve to enable enterprises to develop strong bonds with their customers. To achieve this, it is necessary to acknowledge other perspectives: "awareness" to rapidly understand changes in customer behavior or surrounding environments; "data-centric" to use various kinds of data processing to innovate business processes, create value, and support decision-making; and "servitization" to provide events (experiences) rather than things.

We believe that the key technologies to achieve these targets are artificial intelligence (AI), media, the Internet of Things (IoT), security, and the network. Our latest activities in these areas are introduced below.

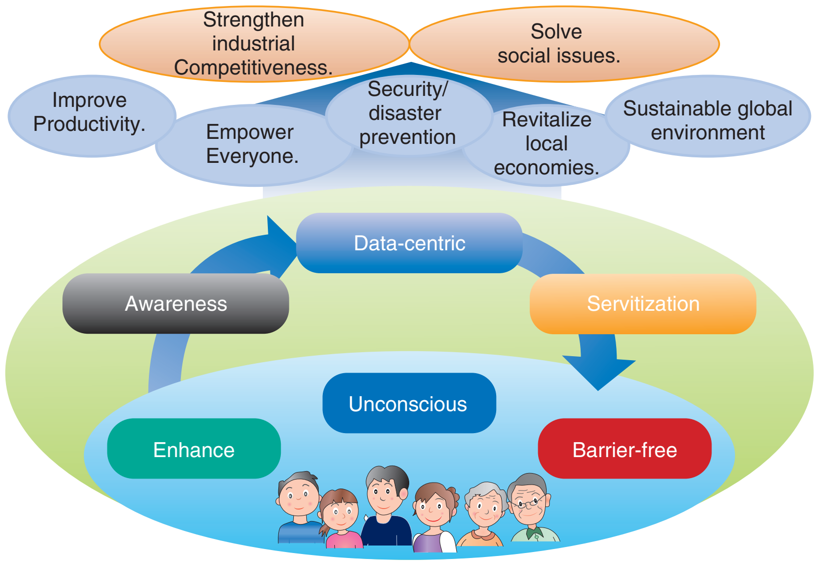


Fig. 1. Objectives of NTT R&D.

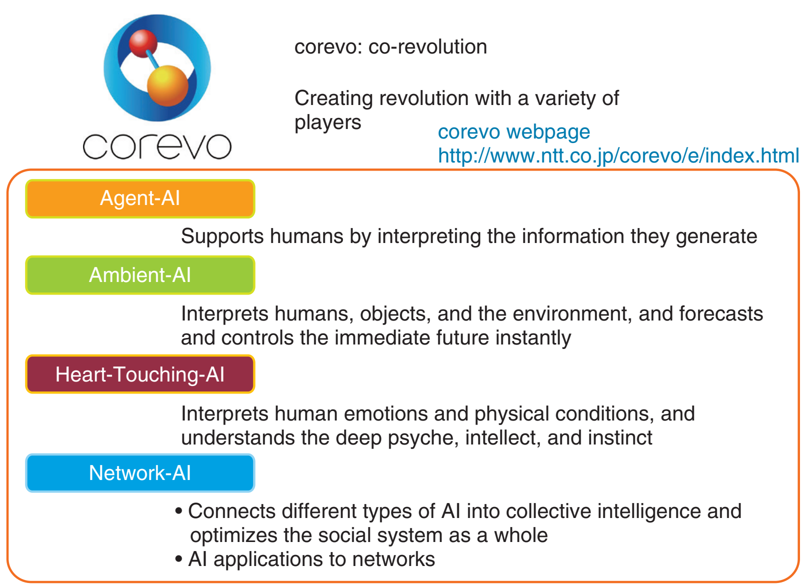


Fig. 2. NTT Group's AI technology: corevo®.

2. AI technologies: corevo®

The NTT Group's AI technologies are provided under the brand name "corevo," which expresses our wish to bring about new, revolutionary development in collaboration with a variety of players (*co-revolution*) by integrating different types of AI technology. We are focusing on four categories of AI (**Fig. 2**). The first is Agent-AI, which supports people. The second is Ambient-AI, which creates value from the things around us. The next is Heart-Touching-AI, which sees things from a human perspective by taking the subconscious or unconscious into consideration. The last is Network-AI, which embraces two concepts: connecting different types of AI in order to create new value and applying AI to networks in order to

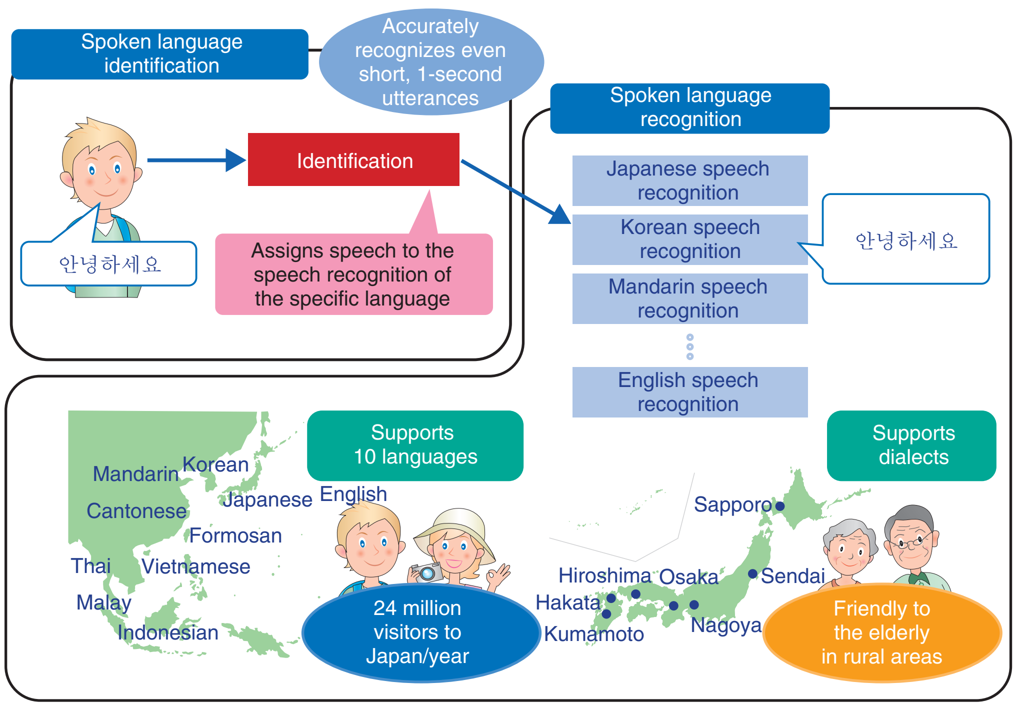


Fig. 3. Language comprehension.

enhance their operability [1].

2.1 Agent-AI

Auditory and dialog technologies employed in Agent-AI are presented here.

(1) Auditory technologies

To make it possible for a robot agent to correctly understand what a speaker says, we need noise suppression technology, as this enables the agent to hear a human voice clearly even in noisy environments. We have thus far finished developing a technology that makes it possible to hear a human voice even with background noise exceeding 100 dB. Speaker-separated voice pick-up technology enables the user to pick up the voice of a particular speaker from among many people speaking simultaneously. Currently, this technology can identify—using a single microphone—the voice of an individual person from among up to six people talking at the same time. We are also working on speaker tracking technology, which can pick up the voice of a moving speaker, and remote sound collection technology, which can pick up sound at a distance.

To understand speech that has been picked up as a spoken language, it is necessary to identify the language the person is speaking. We are developing spoken language identification technology, which can determine the spoken language with an accuracy rate of 90% just one second after vocalization was initiated and at a rate of 99% five seconds after the start of vocalization. After the language has been determined, the speech is recognized and the result is put into a database. NTT's spoken language recognition technology covers ten languages, including English and some Southeast Asian languages. In addition, we are improving the technology to support various Japanese dialects so that people can use this technology naturally (**Fig. 3**).

After a spoken language has been identified, it is necessary to understand what the speaker is saying. Two speech comprehension technologies are effective for this. First, people express the same thing in a variety of ways. We are developing speech intention comprehension technology that determines whether different expressions have the same meaning by evaluating speech data identified by spoken language recognition as high-level semantic vectors and calculating distances between these vectors. For example, "The golf ball does not fly very far" and "How can I extend the flying distance" are completely different character strings, but they essentially mean the same thing in the context of golf. This technology recognizes

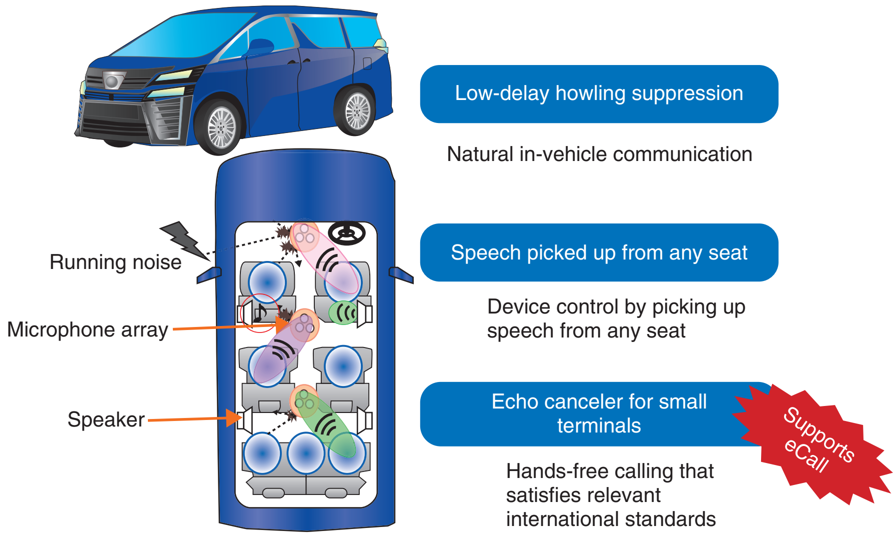


Fig. 4. Intelligent microphone for cars.

these phrases as having the same meaning.

The second speech comprehension technology is one that understands what emotion is being expressed. It recognizes whether the speaker is angry, happy, or satisfied. There are two types of anger: hot anger and cold anger. A person with hot anger shouts, whereas a person with cold anger is very calm and sarcastic. This technology can understand the emotions of hot anger, cold anger, satisfaction, joy, and sorrow.

(2) Dialog technology

When you talk with others, you will notice that some people are good at taking, or recognizing, speech cues and some are not. Most robot agents today cannot recognize such cues. When a person stops talking, the agent cannot control the timing of its speech unless it can determine whether the person has only paused, or if his/her speech has come to an end. Dialog control technology achieves natural dialog between a person and an agent by enabling the agent to do just this and also to detect that the person is interrupting the agent's speech so that the agent can respond appropriately.

Users may want the agent to speak by mimicking their own voices. Cross-lingual speech synthesis technology can synthesize any words with the user's voice quality from an approximately 30-minute-long recorded sample of his/her Japanese speech. Moreover, by incorporating the user's speech sample into other languages, this technology can synthesize speech in English or other languages so that it resembles the user's own voice.

Dialogs can be classified into two categories: task dialog intended to achieve a specific purpose, such as questions and answers, and desultory conversation, which tends to be random and spontaneous rather than focused on a specific topic. It is said that about 60% of daily exchanges are desultory. It is important that an agent is able to conduct both a task dialog and a desultory conversation. We are developing desultory conversation technology that enables an agent to continue chatting away by generating wide-ranging topics based on a large volume of text data and rules developed through research on desultory chats.

However, when an agent makes small talk with someone, the topic can drift in a direction the user is not happy with. To solve this problem, we are studying how to control the scope of topics. A way to regain a natural flow when a conversation goes astray is to have two agents speak with someone and have one of them put in a word to help out.

(3) Application example of Agent-AI

One application of auditory technologies is an intelligent microphone system for cars (**Fig. 4**). It enables natural conversations inside cars by combining intelligent microphone technology and low-delay howling suppression technology. In a small car, a person in the front seat can hear what a person in the back seat is saying. However, if there are three or four rows of seats as in a van, the driver cannot hear clearly when a person in the farthest seat speaks to him/her because of road noise, music, or other sounds. This technology enables people in any seat to

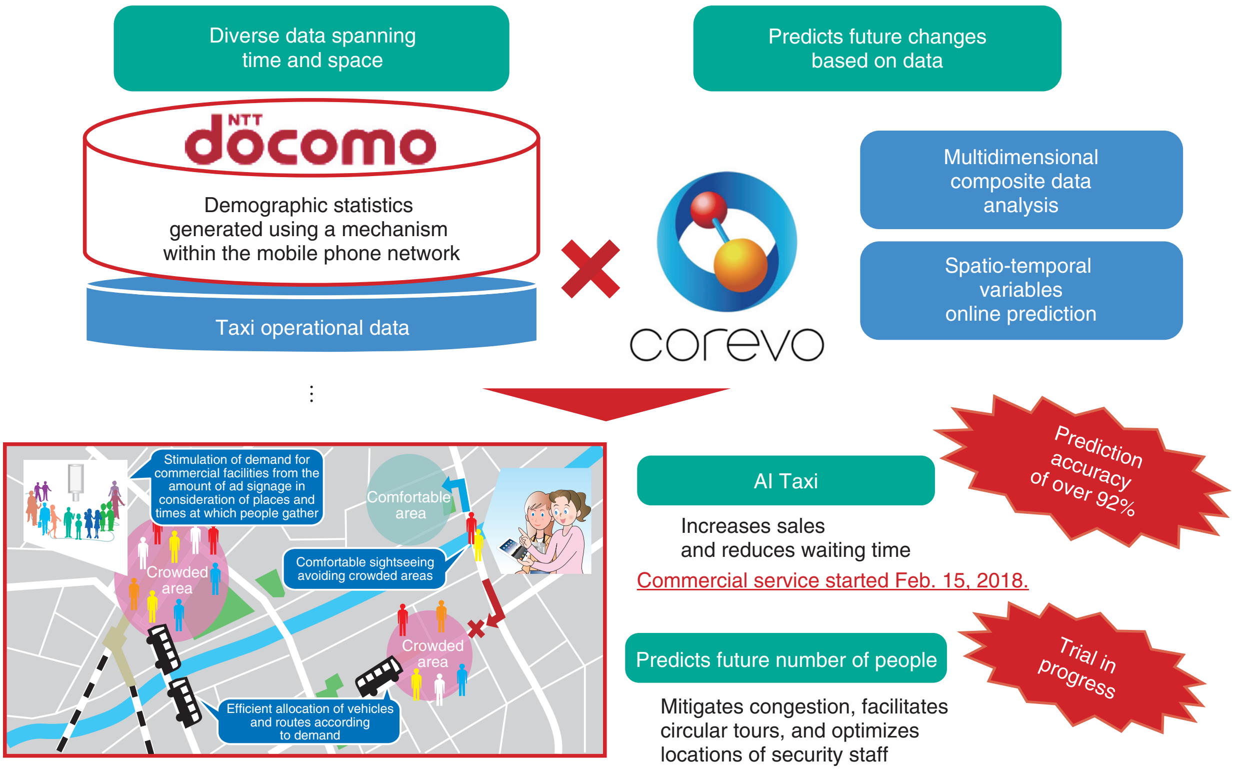


Fig. 5. Technology for predicting the near future.

conduct a smooth conversation. In addition, a person in any seat can use speech to control various in-vehicle devices such as the air conditioner and interior lights. When an echo canceler is incorporated, the driver can use a small microphone speaker to make a hands-free call that satisfies the audio quality standards for eCall (emergency call), which is a mandatory emergency reporting system in Europe.

2.2 Ambient-AI

One application of Ambient-AI is prediction of the flows and distribution of people. We are working on predicting the distribution of people 30 minutes, one hour, or two hours from the present time, for example, by combining demographic data derived from NTT DOCOMO's data on radio access acquired by smartphones and mobile phones with weather data and event data (**Fig. 5**). NTT DOCOMO has been using this technology in a service it offers called AI Taxi since February of 2018. This service is already in use by two taxi companies in Tokyo and Nagoya. In a field trial conducted in 2016 and 2017, it was confirmed that the service boosted drivers' income while at the same time reducing waiting times for taxi customers. This service predicts where people will be distributed 30 minutes from the present time. We are using spatio-temporal variables online-prediction technology to extend the prediction to one hour or two hours and conducting a field trial to predict the number of people in various areas in the near future.

In addition, we are also working on human flow guidance since it is important to reduce incidences of congestion and accidents by controlling the flow of people. For example, heavy congestion will occur if people head for a railway station en masse after the end of a sports event or concert. We are studying learning-based guidance technology that efficiently enables people to avoid congestion and select alternative routes [2].

A completely different type of Ambient-AI is pAUC (partial area under ROC [receiver operating characteristic] curve) maximization learning. With a high degree of accuracy, this technology learns only correct data from a group of data of which only an extremely minute fraction is correct. We are analyzing space photos in collaboration with the Japan Science and Technology Agency, the University of Tokyo, University of Tsukuba, and the Institute of

Statistical Mathematics. We have used this technology to achieve automatic detection of Ia-type supernovae from a multitude of space photos. Although only about one in 1000 novae in the learning data is a supernova, this technology has reduced the observation time required to zero in on supernovae to one several hundredth of that required where a conventional method is used.

2.3 Network-AI

Application of AI technology to networks makes it possible to analyze log data of network devices for prediction or early detection of latent faults or changes in demand and to control the devices to eliminate these problems or recover from them quickly. Network anomaly detection technology learns log data of network devices. However, very little learning of faults or anomalous states can be achieved because log data rarely contain data related to these problems. This technology uses deep learning to solve this problem. It learns normal states in log data and detects anomalies such as silent faults by identifying deviations from the normal states. This makes it possible to improve network operability.

The telecommunications infrastructure includes telephone poles and cables. We are developing 2D-3D (two dimension-to-three dimension) matching technology that uses a vehicle-mounted laser to automatically measure these types of infrastructure devices and then analyzes the measured data to detect tilting poles or hanging cables, thereby making it possible to downsize the maintenance workforce.

2.4 Heart-Touching-AI

We are carrying out a sports brain science project that is aimed at studying how the brains of top athletes function differently from those of amateurs [3]. It was found that top athletes excel at the unconscious or subconscious level rather than at the conscious level. We believe that further research into the role the unconscious or subconscious plays in human behavior will help develop AI that is agreeable to humans.

3. Highly realistic sensation technologies

We are taking three approaches to developing highly realistic sensation technologies. The first is to create and transmit a space, as represented by our immersive telepresence technology called “Kirari!”. The second is to *get into* a certain space. An example is enabling the user to experience a ball thrown by a professional baseball player from the perspective of a batter. The third is to create a space using an illusion. These technologies will provide a higher level of value and a new sense of excitement in sports and the performing arts, particularly stage performances. From a technical standpoint it is of course important to increase the number of pixels, but we believe that new possibilities will open up if we add a new element other than performance and precision.

3.1 Creating and transmitting a space

The immersive telepresence technology called “Kirari!” [4] has been exhibited at the NTT R&D Forum since 2015, when images of people were extracted from a recorded video and displayed in quasi-3D. In 2016, for the first time, images of people were extracted from a video in real time during my keynote address. In 2017, we extracted images of people from a wider area in a higher-definition video and explained that the future direction of Kirari! is to develop technology for projecting a 3D image in such a way that it can be viewed from an arena-shaped spectator area. In other words, the image will be viewed not just from one direction but from four different directions. In 2018, we implemented a real arena-type Kirari! system. We have thus developed technology that enables an image such as that of a karate contest or an ice skater to be viewed from four different directions (in a four-sided arena) (**Fig. 6**).

The advanced MMT (MPEG[*1] Media Transport) technology used in Kirari! can synchronize images sent from different sites. In autumn of 2017, we proved its feasibility by carrying out a live broadcast in which dance footage of the Japanese pop group called Perfume was shown. In that event, one group member was in Tokyo, one was in London, and one was in New York, and the three images of them were synchronized. The three cities are more than 10,000 km apart, so the image signals experienced delays and fluctuations. Although this would normally cause time misalignment among the images, this technology perfectly synchronized the broadcast images.

3.2 Creating illusory perceptions of space

We have technology capable of creating illusory perceptions of space [5]. Existing 3D movie images are blurred unless the viewer in a movie theater wears a dedicated pair of 3D glasses. Suppose two people want to go to a movie together. If one wants to see a film in 3D and the other in 2D, they have to go to different cinemas. Hidden Stereo is a technology that

*1 MPEG: Moving Picture Experts Group

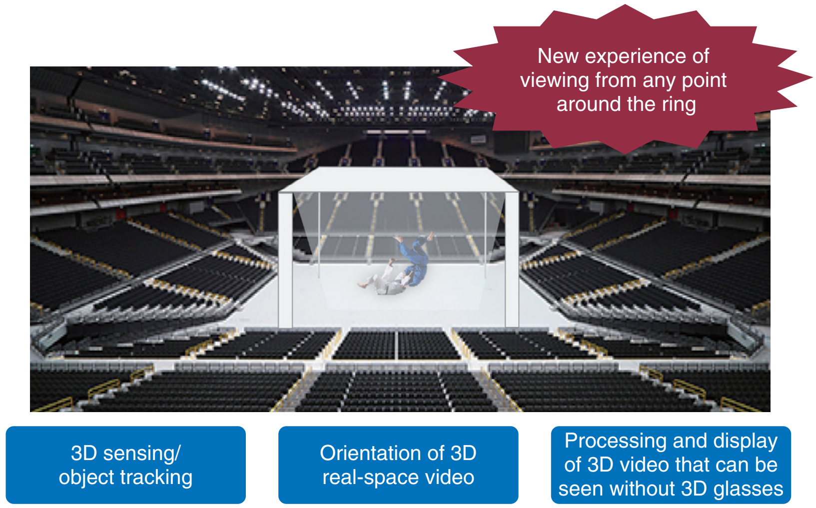


Fig. 6. “Kirari!” for an arena.

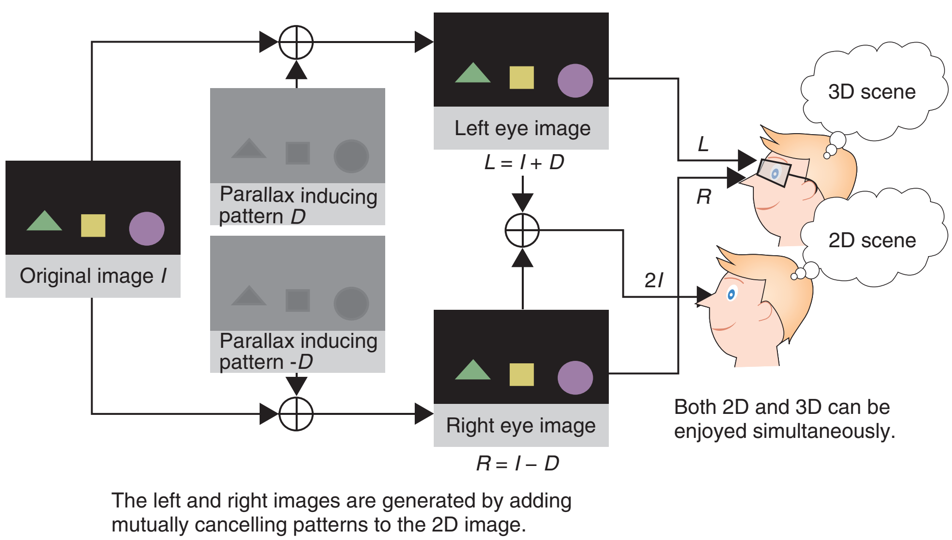


Fig. 7. Concept of Hidden Stereo.

uses illusion to solve this problem. It adds light patterns to a 2D image so that the 2D video can be viewed clearly without glasses, but a 3D video appears when the viewer wears 3D glasses (**Fig. 7**).

4. Activities involving IoT

The IoT is rapidly gaining momentum. Since IoT requirements vary depending on the application area, a single platform cannot support all types of IoT systems. In contrast, if IoT systems were to be developed individually without using a platform, it would be difficult to reuse technology. Therefore, we believe that a solution is to ensure that all IoT systems have a common architecture. NTT has defined a basic IoT architecture (**Fig. 8**) and is developing IoT systems that are built on this architecture and that will be used in several industries.

4.1 Optimization of manufacturing in factories

We intend to help factories continue to improve productivity by implementing advanced technology

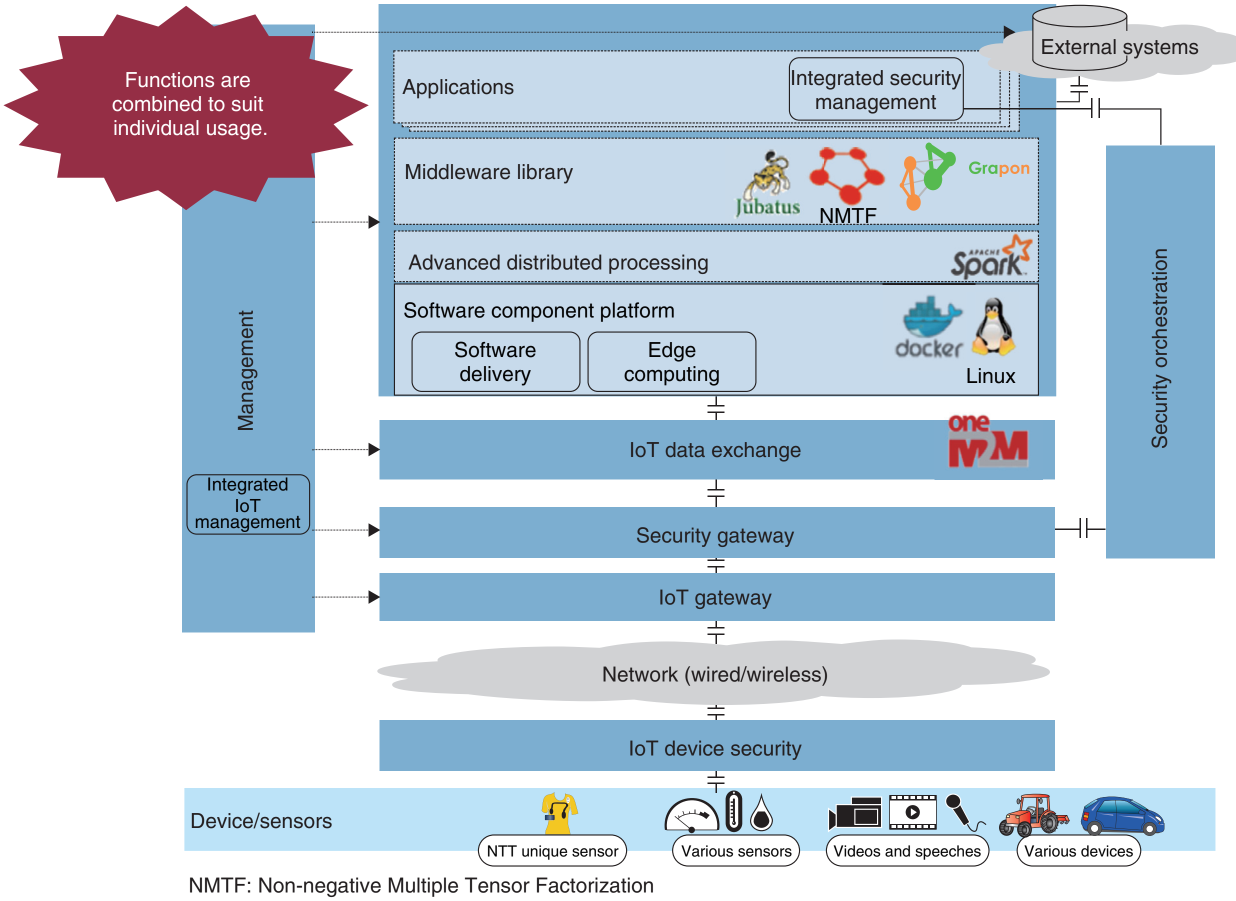


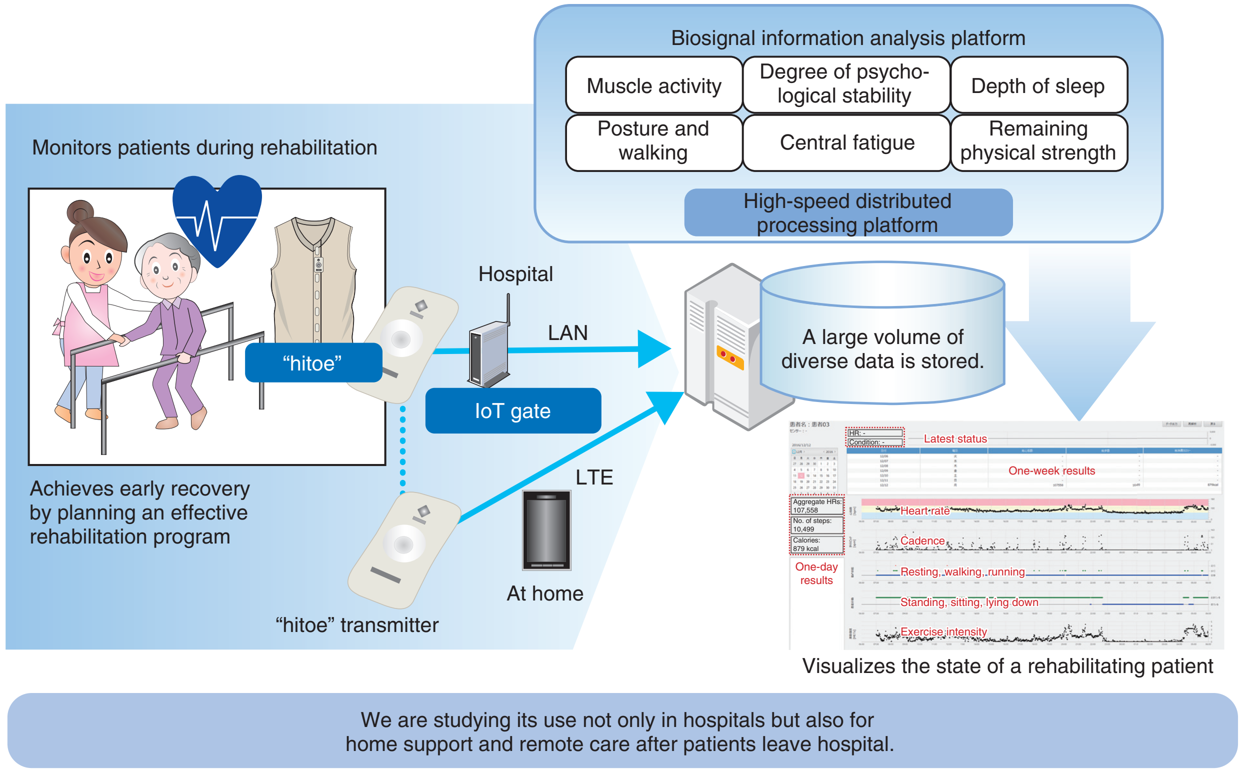
Fig. 8. IoT basic architecture.

and operations. A way to achieve this is to link operations of various machine tools in a factory in real time and to have the machine tools download and use the latest applications just as smartphones do. To ensure real-time operation, it is important to use edge computing, in which necessary functions are allocated to *edges* near machine tools rather than to a cloud. We have combined this edge computing technology with IoT data exchange technology, which enables information about different types of machine tools to be shared as common data, and software component delivery technology, which makes it possible to select applications that are appropriate depending on the particular purpose. We began providing a FIELD system*2 service in October 2017 in collaboration with FANUC CORPORATION.

4.2 Acceleration of development of next-generation IoT for ships

Ship IoT is designed to ensure the efficient and safe operation of ships by processing data collected by various sensors installed in a vessel. Ship IoT differs from general IoT in that, being at sea, vessels can use only a satellite link, which has a very low bit rate, to connect to an operation center on land. In collaboration with NYK Line and MTI Co., Ltd., we are conducting a field trial in which data from sensors in a vessel are pre-processed onboard, and the results are sent to an operation center on land. The center performs various operations for the vessel or delivers the latest software to the vessel. Since all sensors are concentrated onboard and only a satellite link is available, it is important to use processing technology that exploits both edge computing and the cloud in a hybrid configuration.

*2 FIELD (FANUC Intelligent Edge Link and Drive) system is an IoT system for manufacturers jointly developed by Cisco Systems, Rockwell Automation, Preferred Networks, and the NTT Group under a concept defined by FANUC.



LAN: local area network
LTE: Long Term Evolution

Fig. 9. Health management using "hitoe."

4.3 Health management with "hitoe"

We aim to help recovering patients select the rehabilitation activities best suited to them by providing upper body garments that incorporate "hitoe," a fabric that can collect biosignals from the body [6]. The ability to select the optimal rehabilitation activities will help to reduce the duration of hospitalization (**Fig. 9**). Currently, only heart rate information is available, but we are collaborating with Fujita Health University and Toray Industries, Inc. to measure myoelectric signals so that information about muscles can also be used to select the most appropriate rehabilitation activities. Technologies that are important for achieving this are a high-speed distributed processing platform for processing biological data that are constantly being generated in real time and IoT gate technology for collecting data from many people.

4.4 Activities involving connected cars

In the field of connected cars, we are working in conjunction with Toyota Motor Corporation to step up efforts to define the requirements for these cars. It is becoming apparent that this is a very difficult proposition partly because there are numerous cars on the road.

In addition to addressing the purely technical aspects, it is necessary to address issues related to standardization. For example, connected cars that satisfy the requirements defined by NTT and Toyota may work with cars from Toyota but may not work with cars from other automakers. Since it is paramount to avoid accidents, it is necessary for the requirements to be internationally standardized and adopted by all related industries. There are areas where all companies must cooperate and other areas where companies must compete with each other. Together with other partners, we have launched the Automotive Edge Computing Consortium to promote joint technical development in the cooperative area and press ahead with standardization. We are hoping that many companies worldwide will participate in this endeavor and contribute to the development of next-generation cars.

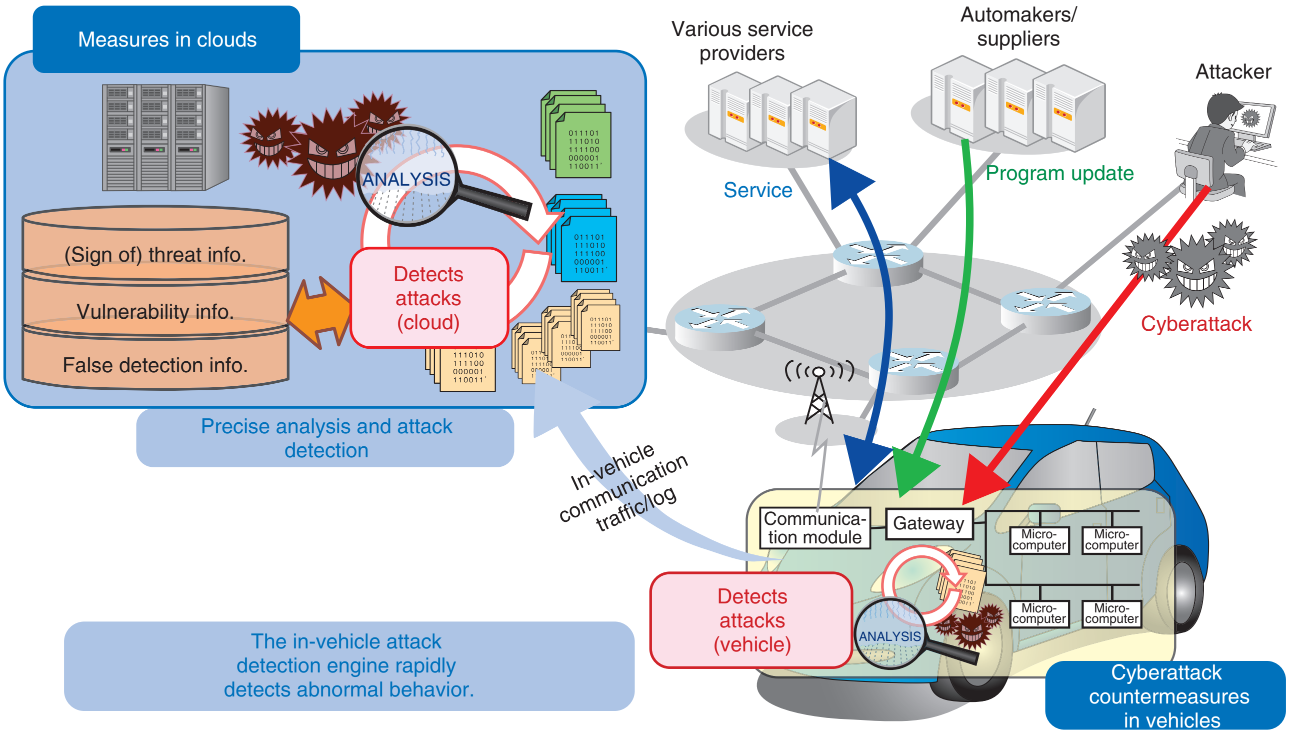


Fig. 10. Detection of cyberattacks on connected cars.

5. Activities involving security

While it is important for us to study cybersecurity and cryptographic theory to protect communication, it is also necessary to address the security of control systems in order to protect companies and institutions as well as society as a whole. NTT is working on IoT security and information technology (IT) security to make sure that information can be fully protected.

5.1 Control system security

Generally, it can be said that with information systems, priority is given to protecting confidentiality—that is, preventing information from being divulged. In contrast, with control systems, priority is given to maintaining availability and uninterrupted operation. NTT and Mitsubishi Heavy Industries, Ltd. have jointly developed "InteRSePT®*3," a security technology for automatically detecting cyberattacks on control systems and defending the systems against them. The beauty of this technology is that when it detects a cyberattack, it does not simply shut down communication, but rather, it selectively shuts down some parts but allows other parts to continue to operate in accordance with the specific conditions of the system so that the control system as a whole can continue to operate. It also supports protocols used by control systems. The message exchange frequencies and cycles of these protocols differ from those of ordinary communication.

We are also working on security technology for connected cars (**Fig. 10**). Since many cars are connected through a network, it is important to detect any cyberattack on a car and deal with it quickly. We have now reached a level at which an in-vehicle detection engine can detect anomalous behavior caused by an attack and shut down the control signal of the attacked car so that the car will not cause an accident. The next level we aim at is for the engine to achieve high-precision detection and response by working with clouds.

5.2 IoT security

We are working on FSU (Fujioka-Suzuki-Ustaoglu) protocol, a technology for achieving mutual authentication between a cloud and IoT devices using

*3 "InteRSePT" stands for "Integrated Resilient Security and Proactive Technology" and is a registered trademark of Mitsubishi Heavy Industries, Ltd. in Japan.

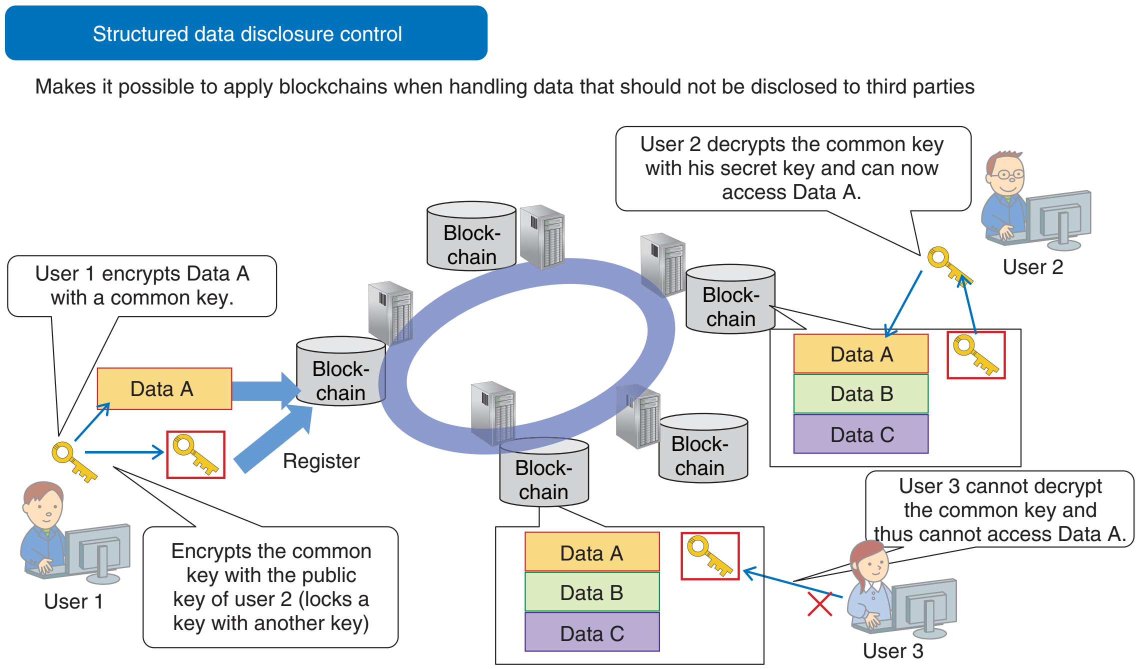


Fig. 11. Blockchains for managing secret data.

ID (identifier)-based encryption, which is a type of public key encryption. FSU has been adopted in an international standard (ISO/IEC*4 11770-3). Its main advantages are that there is no risk of authentication information being leaked because the server does not retain the authentication information of devices, and that authentication is extremely easy because devices do not have to have a password or certificate.

We are developing IoT device anomaly detection technology. It transfers device information and traffic data observed by the IoT gateway to the analysis server, which learns traffic data using machine learning and also monitors traffic. It can detect an anomaly with a high level of accuracy even when the anomaly was caused by an unknown attack.

5.3 IT security

Current methods of detecting malware to defend endpoints, which are typically personal computers, are mainly based on pattern matching of data in files. However, malware that cannot be detected by pattern matching is on the increase because many variations of malware are constantly being created. Taint analysis and symbolic execution can detect conventionally undetectable malware because they are able to find malware based on its behavioral characteristics.

We are studying blockchain technology that can be used for managing secret data (**Fig. 11**). Blockchains are beginning to be used in a variety of fields and are expected to be employed for business purposes. Some business activities involve handling data that should not be disclosed to third parties. Since the major feature of blockchains is that authority is distributed, our technology can control who is permitted to access data and who is not even when authority is distributed.

6. Activities involving networks

The environment surrounding networks has been changing dramatically. Both traffic and power consumption continue to rise. Needs are emerging to enable users to seamlessly access networks by selectively using various means of access, including not only fixed and mobile lines but also Wi-Fi and LoRa (long range). Telecommunications facilities are increasingly implemented using software-defined networking and network functions virtualization, and the amount being invested in facilities by OTT (over-the-top) operators such as Amazon, Google, and Facebook is exceeding the amount invested by telecommunications carriers in North America. In

*4 ISO/IEC: International Organization for Standardization and International Electrotechnical Commission

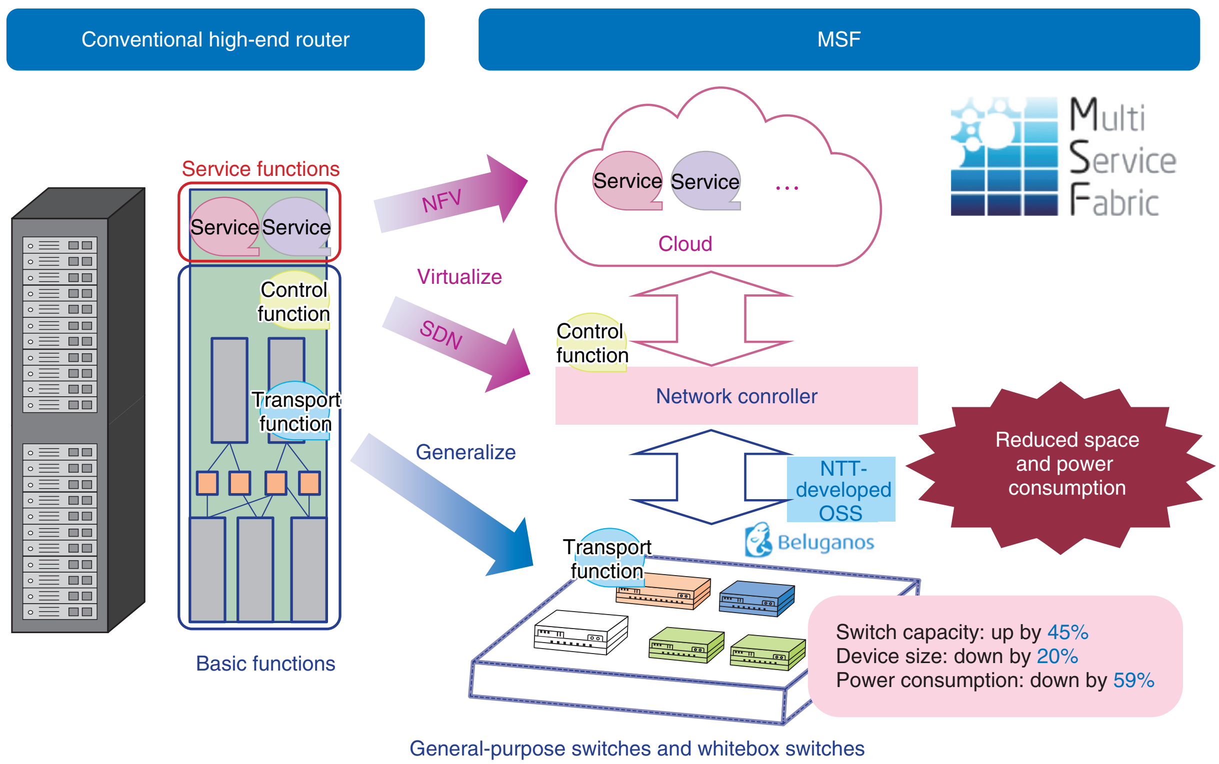


Fig. 12. Virtualization and generalization of high-end routers.

addition, implementation of telecommunications facilities in software has given rise to a trend to utilize open source software (OSS). As a telecommunications carrier, NTT is developing new networks by incorporating these trends. We would be left behind if we remained stuck following the conventional approach.

6.1 Virtualization and generalization of high-end routers

High-end routers have conventionally incorporated all the functions of transfer, control, and service. We are now working on MSF (multi-service fabric), which separates these functions and uses OSS. The transfer function will be implemented in a general-purpose switch or whitebox switch, the control function in a network controller, and the service function in a cloud. We have developed a prototype and confirmed that it is possible to increase switching capacity and reduce installation space and power consumption in comparison to conventional routers (**Fig. 12**). To carry out this type of activity globally, we are vigorously engaged in a variety of open source projects and open communities such as the Open Network Foundation and Telecom Infra Project.

7. Activities in basic research

The time it takes to transition from basic research to commercialization has been shrinking dramatically in recent years. For example, rapid progress in AI has already led to basic research in the acoustic, speech, and linguistic fields progressing to the development of commercial products. We believe that we must further strengthen our basic research in order to ensure sustained development of the NTT Group and NTT R&D.

7.1 LASOLV

A novel computer has recently emerged from our basic research. One of the combination optimization problems is the traveling salesman problem, which is a problem of minimizing the total travel cost when a salesman is required to visit each city once and return

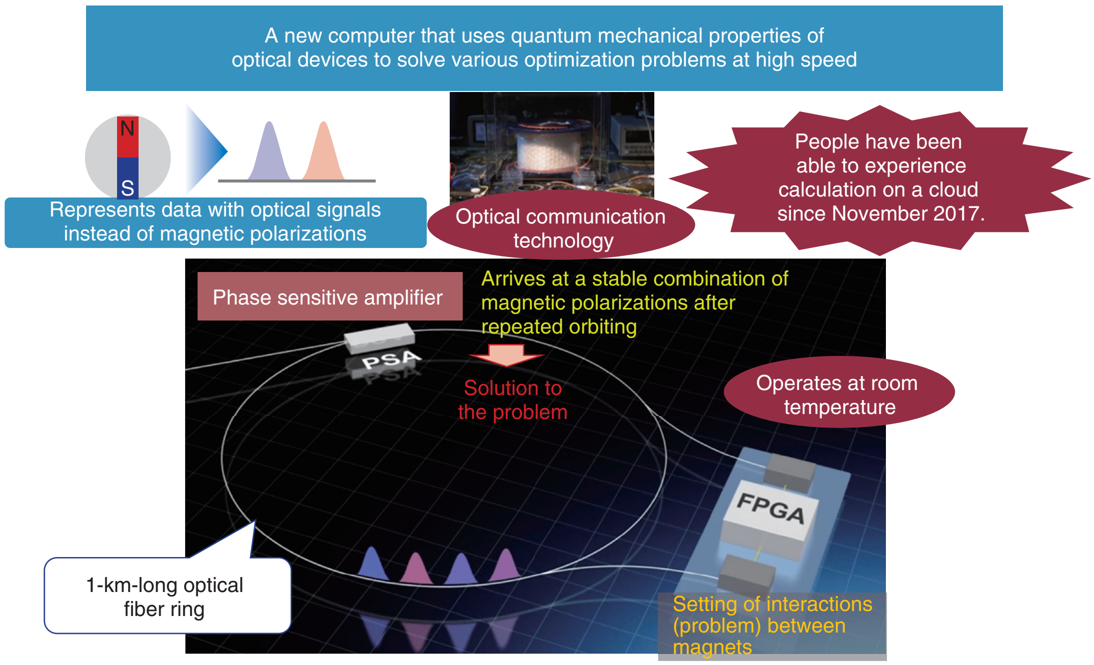


Fig. 13. New optical computer: LASOLV.

to the starting point. This problem can easily be solved if the number of city combinations is small. However, as the number of combinations increases, an enormous amount of computation is required. Conventional computers have not been able to solve this type of combination optimization problem.

We have developed a new computer called LASOLV based on the Ising model, which is a computer model that uses a physical phenomenon to solve this problem. The model represents this problem as positions of magnets and decides that the state in which the magnets are the most stable is the answer. LASOLV uses light pulses instead of magnets (**Fig. 13**). The name was coined by combining the words *laser* and *solve*. The key device is a phase sensitive amplifier, which the NTT laboratories have been studying for many years. Other computers based on the Ising model operate at an extremely low temperature of about –200°C and thus require large air conditioning facilities. In contrast, LASOLV can operate at room temperature. It has been made generally accessible as QNNcloud [7] since November 2017.

The current performance level of LASOLV is such that it can solve a problem of 2000 nodes with 2 million node connections. This is already unprecedented, but we are aiming to raise its performance further so that it can solve a problem of 100,000 nodes with 10 billion node connections by 2019 or 2020.

LASOLV can be useful, for example, for developing new drugs or solving traffic congestion problems. However, because users currently need to have special knowledge in mathematics and physics, it is not easy for drug developers to use LASOLV. Thus, we believe that it is important to build a computing environment in which LASOLV can be easily accessed by those without specialized programming knowledge.

7.2 Biodegradable battery

As IoT advances, we will be surrounded by various sensors. Each sensor contains a battery and a circuit. Ideally, all sensors should be recovered after use. However, some sensors may not be recovered. To prevent unrecovered sensors from having adverse impacts on the natural environment, we have developed a battery that decomposes into soil (**Fig. 14**). The battery is made only of fertilizer and biological materials. Currently, the battery can light up a lamp and operate a buzzer. However, the battery capacity is about one-tenth that of commercial batteries and thus can last for only a short time. Further technical development will be needed to extend battery life.

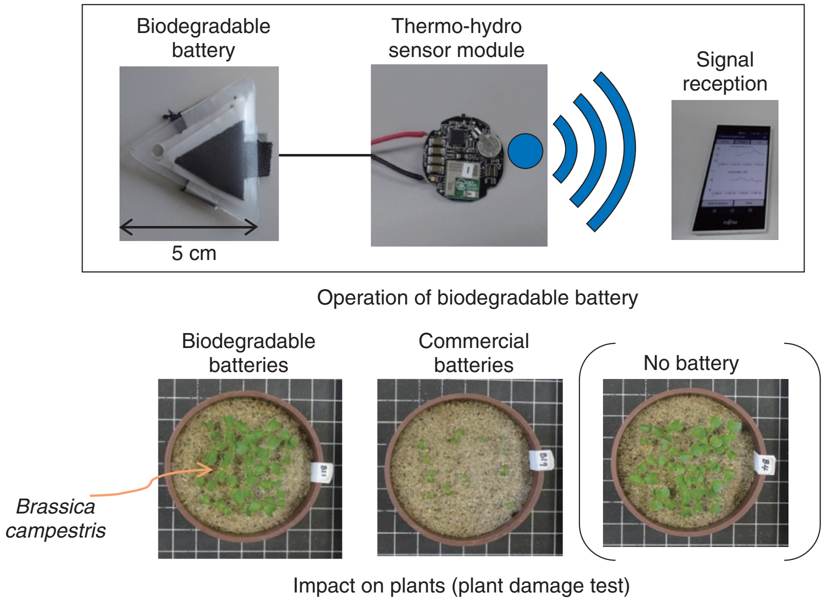


Fig. 14. Biodegradable battery.

8. Conclusion

I believe that we need to have two skills if we are to create new value in collaboration with partners in various fields. One is the ability to master forward-looking technologies. The other is the ability to combine the strengths of all collaborators. We will work to refine these two skills and endeavor to contribute to the development of society.

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Trademark notes

Internet of Things Approach for Creating Value in Various Fields

Shuichi Yoshino

Abstract

The Internet of Things (IoT) is expected to create high value services in various fields. We believe that the era in which IoT is fully utilized will have requirements different from those of the past for information and telecommunications networks. In this article, the influence of the new IoT era on networks and information processing is described, along with the resulting requirements. The NTT laboratories' efforts and assumed usage scenarios are also introduced. These Feature Articles are based on lectures given during workshops at the Tsukuba Forum 2017 held in October 2017.

Keywords: sensing, data exchange, prediction of social activities

1. Requirements for information communication and role of technology in the Internet of Things (IoT) era

In line with the increasing use of personal computers and the Internet and the adoption of mobile phones, information communication has become an essential function for social activities and daily life, and its value has rapidly increased and changed with society.

From the era in which simple connections were highly valued, as typified by telephones for the purpose of communication between people, access to the Internet in recent years has become valued for the acquisition of information and knowledge. The number of connections from devices, or *things*, to the network already exceeds the number of people connected using terminals, so the era of IoT has already begun, where communication between things and people, as well as between things and things is the main focus.

Currently, IoT, which integrates cyberspace and real-world society, is mainly utilized for linking things, gathering data, and visualizing social events and the movement of goods. In the future, it will also be used for utilizing the collected data. We believe that with progress, we will be able to predict what will happen at social events, and to control events to make social and industrial activities safer and more efficient. As this kind of utilization becomes more and more common, IoT technology will advance to the point where cyberspace will rapidly process and analyze the collected data, feed the results back to the real world, and/or control the real world. One ultimate goal of information communication is autonomous driving, which is expected to become a service highly valued in society.

Current IoT devices are vertically integrated, and few IoT devices are connected in certain fields, for example, agriculture and smart cities. However, work on horizontal linking is accelerating in the fields of manufacturing, automobiles, and transportation. This trend is expected to create new value services in a wide range of business fields. We believe that different requirements and much larger scale-out will be required to realize the high potential of IoT.

The requirements placed on information communication to fully achieve an IoT society are shown in **Fig. 1**, along with the amount of time and/or amount of data for each function.

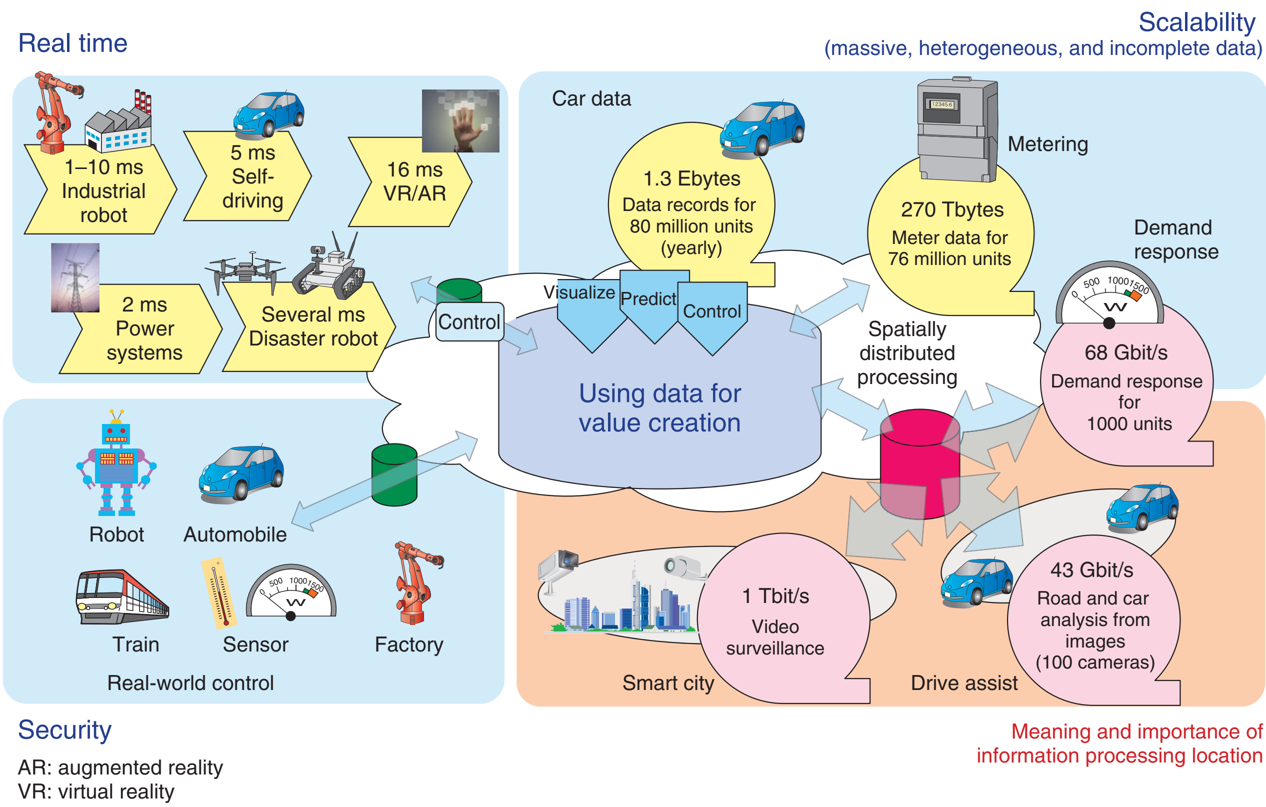

Fig. 1. Requirements for IoT society.

The first requirement is security. In becoming part of society, IoT can be expected to trigger greater damage from cyber-attacks than those triggered by communication between people, so stronger than ever security measures are needed. The second requirement is real-time response. In order to control a machine, information processing and communication must offer more real-time performance. For functions such as machine control in factories, safe driving assistance for automobiles, and the use of augmented reality and virtual reality, the response times of information communication and information processing must be on the order of milliseconds. The third requirement is scalability. For example, the total amount of probe data of cars, the images recorded by cars, and the data from smart meters will be on the order of petabytes. Moreover, the collected data are expected to be heterogeneous, as they will be generated by quite different objects. Accordingly, scalable information processing that can handle extremely large amounts of heterogeneous and incomplete data is required. The fourth requirement is value creation. We cannot realize sufficient value simply by gathering large sets of diverse data. To achieve efficiency in production and social activities, we must be able to utilize and analyze the collected data and create new value that can be used for forecasting and control.

In addition to these four requirements, it is necessary to meet specific IoT usage requirements. In many of the usage scenarios expected for IoT, the consumption of data and information will exhibit strong regionality. For example, data will be gathered at intersections for automatic driving support, while data will be gathered from devices such as meters and sensors for the purpose of energy conservation. In this way, the IoT will exhibit data locality; thus, an information communication and information processing architecture that can cope with this feature will be required.

In addition, certain IoT requirements cannot be solved by technology alone, for example, protection of rights to utilize the collected data safely and appropriately, and the necessity of forming a social agreement on the scope of use of such data. In response to these requirements, the NTT laboratories have formulated a basic functional architecture that can realize

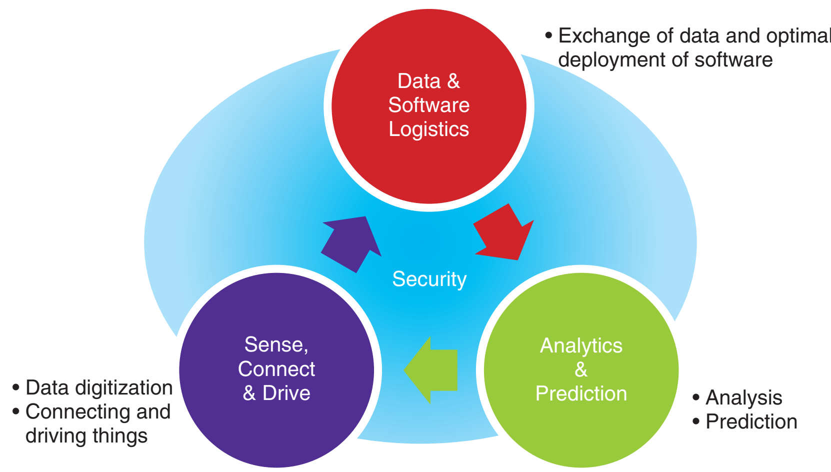

Fig. 2. IoT: four technology roles.

a complete IoT system. We are utilizing some of the current technologies available in the market, while also working on the research and development (R&D) of key technology groups [1].

These technology groups—classified into four roles—will realize the full-fledged IoT system. These roles are indicated in **Fig. 2**. The first role is Sense, Connect & Drive. This involves digitizing information on goods, responding to diversity, and securing storage capacity and the necessary user interfaces to exchange information with cyberspace via the network. The second role is Data & Software Logistics. This brings the collected data to the best location for use and/or processing and in doing so satisfies the real-time and information scalability requirements (Fig. 1), which are key IoT requirements. In addition, this includes the deployment of software/algorithms to use/process the data at the appropriate location. The third role is Analytics & Prediction, which combines big-data analysis technology such as the rapidly expanding machine learning and artificial intelligence (AI) technology, to provide new value services such as data analytics visualization and prediction. Security is the fourth role, and the functions necessary for each phase and process are used in conjunction with the other three roles. The IoT system will be achieved by integrating these four roles.

2. Technology group that realizes IoT and an application example

In this section, some of the main IoT services expected to be introduced in the future are described.

2.1 Biometric sensing

One expected IoT service involves the collection and processing of biological data as represented by healthcare. In collaboration with Toray Industries, Inc., the NTT Group has developed the functional material called "hitoe" that enables biometric sensing simply by having a user wear clothes made of the material. Work is underway on enhancing sensing performance and utilizing it in unprecedented environments and actions. For example, car drivers wearing "hitoe" shirts will have their biological data detected in real time, enabling early detection of driving problems such as driver fatigue. Moreover, by linking the shirt to a control system, we can contribute to the improvement of public safety as well as the improvements in company efficiency such as knowing when to change drivers of buses or other vehicles.

2.2 Wireless access

Various wireless access protocols currently exist for IoT, and it seems that changes in the existing methods and the development of new methods will continue into the future. A typical IoT radio access method is shown in **Fig. 3**, with the communication distance on the horizontal axis and the communication speed on the vertical axis.

With the growing social expectations for IoT, the wireless access technology called LPWA (low power wide area) is attracting attention since it offers wide area coverage and can be used for long periods due to its low power consumption; these benefits outweigh its low speeds. We note that in IoT, infrastructure monitoring, which requires long-term and wide-range

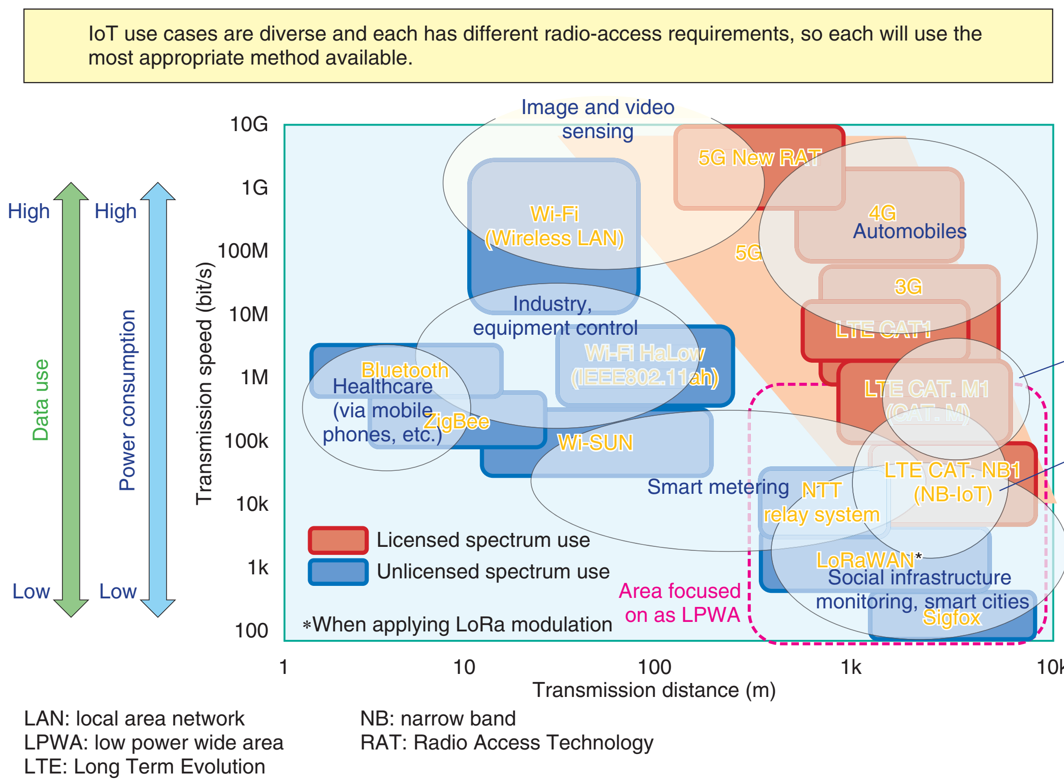

Fig. 3. Typical IoT radio access method.

data acquisition, is well supported by LPWA for smart cities. Another trend is the collection and processing of large amounts of video data. This demands high-capacity wireless access.

NTT laboratories' current efforts in using IoT to monitor the leakage from water supply pipes installed underground are shown in **Fig. 4**. Water leaks are currently found by conducting manual listening tests on site; this demands a high level of skill and the presence of an expert in the field. By collecting data in cyberspace on the sounds of water pipes, we believe that remote inspections will become possible using information technology such as machine learning. However, radio waves from devices attached to underground pipes will be strongly attenuated. Our solution is to acquire data reliably with a high level of power-saving by using radio relay systems on public utility poles. The high level of power efficiency achieved enables data collection for a long time after installing the sensor underground. With the cooperation of local governments, we are now proceeding with verification trials in the field for early social implementation.

2.3 Edge computing

It is important for IoT to perform information processing in the most suitable location, and the technology to achieve this is edge computing. This technology sets a processing site, called the edge, between the cloud and the terminal and thus offers various information processing benefits by utilizing the spatial dispersion characteristics not provided by the cloud. For example, we can achieve the benefits of proximity and high responsiveness. Moreover, spatial dispersion allows us to offload terminal functions to the network.

The NTT laboratories are also engaged in the R&D of this technology, not only in our own labs, but also with partners to realize attractive usage scenarios and projects [2]. An application example of this technology in automatic driving support is shown in **Fig. 5**. We believe edge computing will be used for horizontally distributed processing by providing information on the next intersection as well as vertically distributed processing for providing various pieces of map information. This will lead to the realization of automatic driving support; mass data will be gathered and recognized, and the circumstances that can be expected

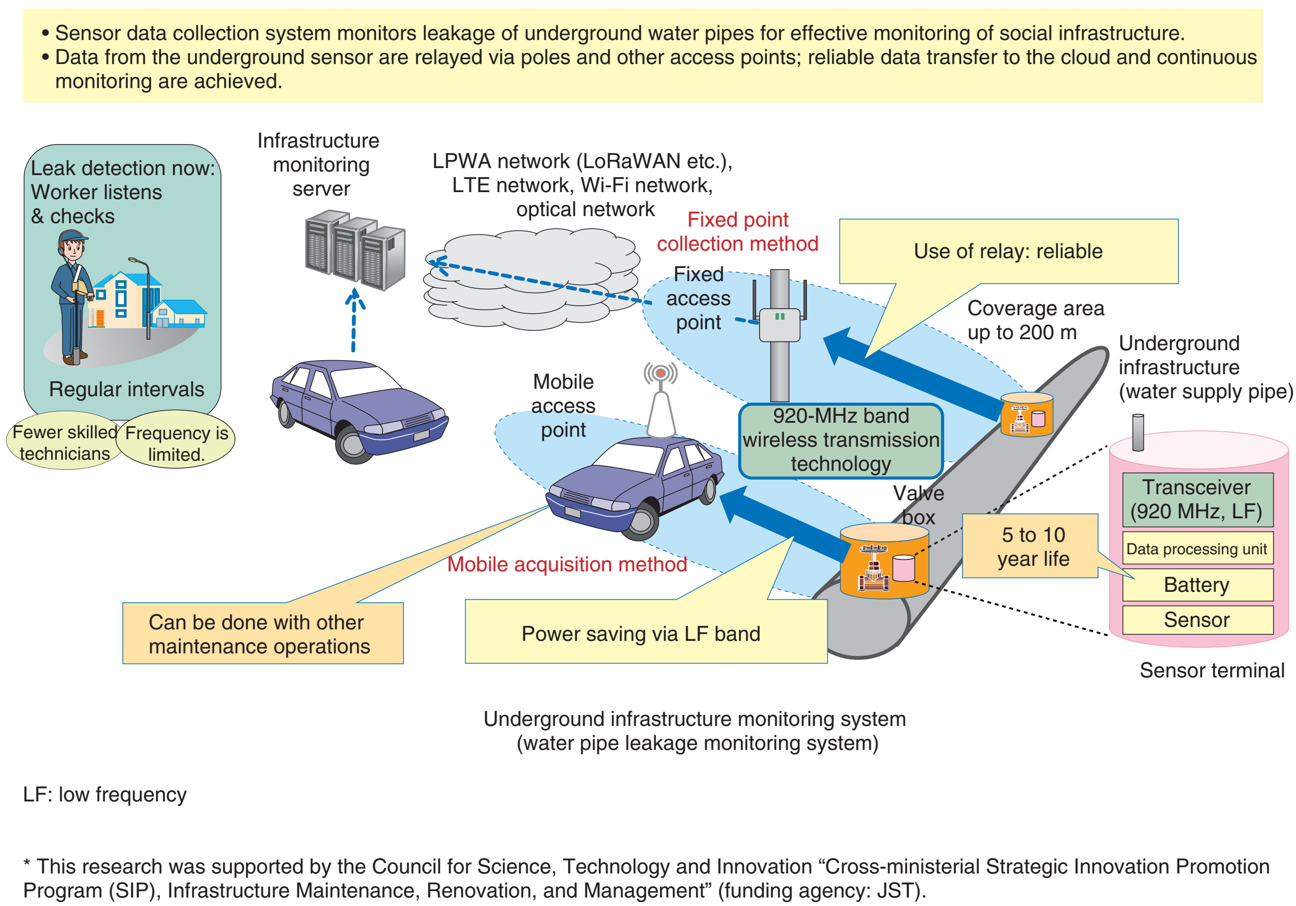

Fig. 4. Infrastructure monitoring (water pipe leak monitoring).

to change from moment to moment will be predicted and passed to the moving car.

2.4 Data utilization

The IoT is expected to utilize diverse heterogeneous data and create new value services. It is important to make good use of open data created by public agencies and local governments, especially for realizing smart cities. At the NTT laboratories, we are working with partners to improve the efficiency of urban management by combining open data with local data and by conducting modeling and data analysis utilizing AI technology [3]. From now on, we will pursue technical verification in real fields, while aiming to continue horizontal studies to solve the various problems hindering the realization of smart cities.

2.5 Security

The devices used in IoT are diverse, and since there are many devices that do not follow the Internet protocol, security must be provided using a different approach. The NTT laboratories are working on the R&D of anomaly detection technology. This can detect security risks from the behaviors of networks and devices. With this approach, security is assured by processing information observed from outside the device, so additions and changes to devices with limited processing capability and existing facilities are relatively easy. This is particularly important in factories where various protocols are used.

3. Conclusion

The NTT Group is using the B2B2X (business-to-business-to-X) model to solve social problems through collaboration with various partners in a wide range of fields. This approach will ensure the technical development of IoT. The aim is to create new business value by incorporating the knowledge and know-how from different industries.

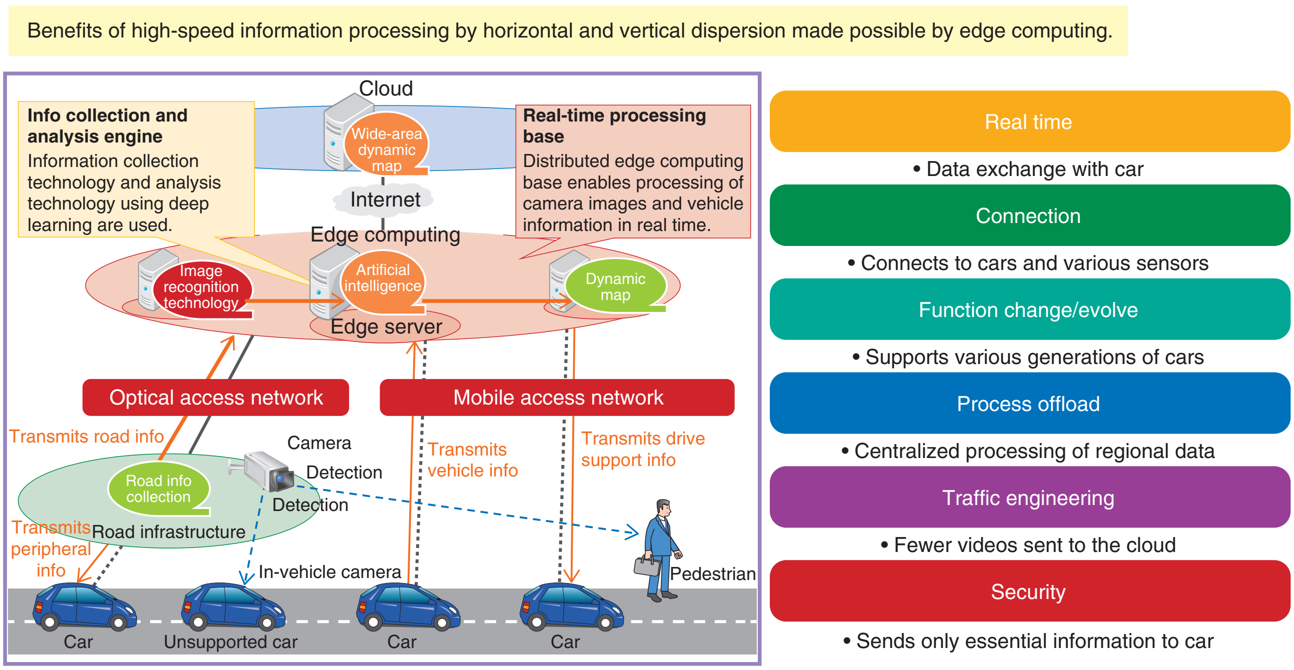

Fig. 5. Use case image: automatic driving support.

Acknowledgment

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Wireless Access Technologies to Provide Various Services in Future Networks

Hiroyuki Nakamura

Abstract

NTT Access Network Service Systems Laboratories is researching and developing wireless access technologies in two of its laboratory projects. This article introduces the wireless technologies being developed that will contribute to providing advanced mobile services of the 202X generation. These include future network services in the NTT Group as well as telephone services for extremely rural areas and essential services for disaster recovery.

Keywords: unlicensed band radio access, fifth-generation system, radio systems for telecommunications operators

1. Introduction

A wide variety of communication services can be enjoyed in a mobile environment. Furthermore, in the 2020s, it is expected that the existence of high-speed mobile communications will make it possible to offer numerous ICT (information and communication technology) services and that new value-added services will be achieved thanks to the Internet of Things (IoT). To make this a reality, there will be a need not only for higher speeds in the wireless system but also for optimal end-to-end quality and flexibility to achieve diversity. At the same time, providing telephone services in extremely rural areas and a means of communication to preserve essential services for disaster recovery is becoming increasingly important.

2. Wireless access technologies for 5G*/5G+ era

Mobile communications data traffic is increasing annually by approximately 1.4 times [1]. However, as content becomes further enriched and the use of the communications infrastructure becomes increasingly diversified, we can expect the total data traffic in wireless access to increase all the more in the 2020s. In wireless access at present, communication via mobile networks provided by carriers and communication via wireless local area network (LAN) are roughly equal in terms of traffic volume. In this regard, unlicensed radio bands such as wireless LAN have so far been individually controlled and utilized by users. However, the era is fast approaching in which wireless systems using unlicensed radio bands will take on a larger role in handling this ongoing increase in traffic (**Fig. 1**). In this era, technologies for overlapping and seamlessly controlling mobile networks and unlicensed radio bands and for enabling the expansion of base stations and access points (APs) in massive quantities will be important for achieving an environment in which users can enjoy high-quality services. In particular, we believe that some means of controlling unlicensed radio bands and APs used and installed by users themselves is key to achieving such an environment, and we are therefore developing the specific technologies described below.

* 5G: fifth generation

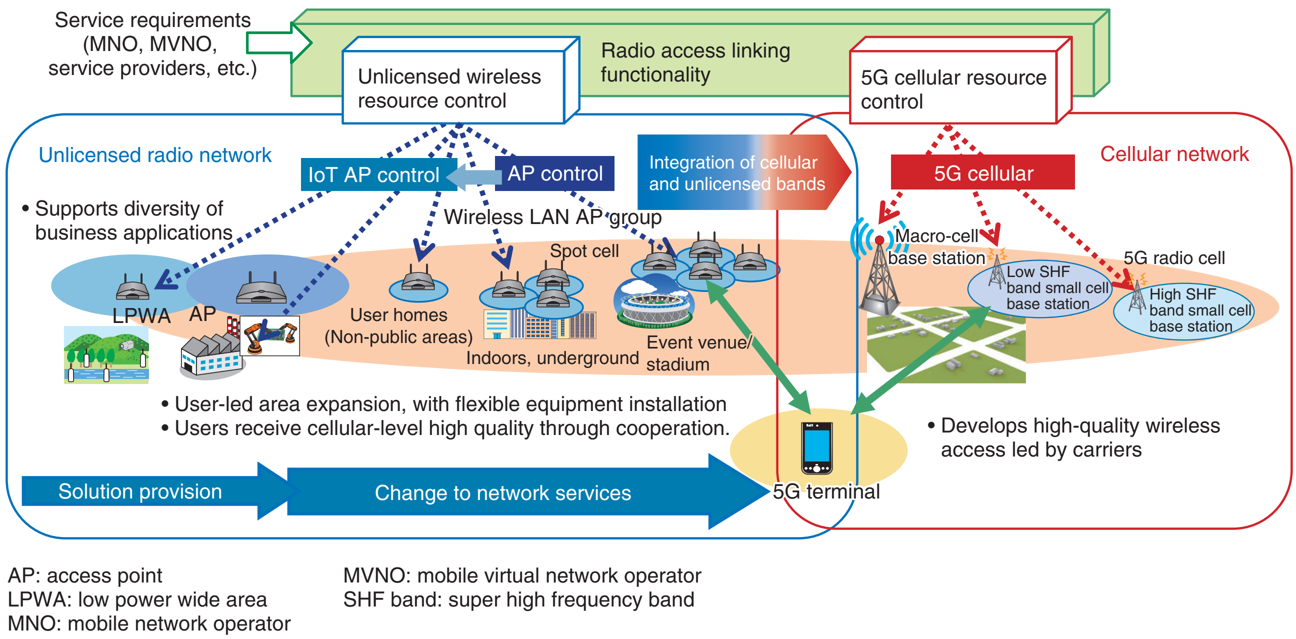

Fig. 1. Integration of cellular/unlicensed bands.

2.1 Technologies for linking unlicensed radio band systems

Various wireless standards for radio access in unlicensed radio bands have been developed for different uses, so it is envisioned that users will install APs as they see fit according to their target applications. To manage these APs across the network in an optimal manner, our aim is to achieve radio resource management through an unlicensed-band platform and software-based white-box radio base stations. Additionally, as part of the 5G comprehensive demonstration test launched in 2017 by the Ministry of Internal Affairs and Communications of Japan, some of these technologies will be used in the deployment of high-density wireless LAN and in control tests of wireless LAN linked to 5G cellular [2].

2.2 High-capacity wireless relay technology

We aim to promote the deployment of small-cell base stations and APs in massive quantities and are therefore studying high-capacity wireless relay technology in order to replace some relay lines with wireless networks in locations where the laying of optical fiber is difficult (**Fig. 2**). For this technology, we are assessing the use of high-frequency bands such as the millimeter-wave band capable of comparatively high-capacity transmission, but there is also a need for technology that can simplify installation requirements and achieve high efficiency. To solve these issues, the NTT laboratories are developing spatial multiplexing technology in the millimeter-wave band capable of high-capacity communications, antenna high-gain technology based on large-scale arrays to compensate for propagation loss, and point-to-multipoint technology for simultaneously accommodating multiple stations.

2.3 Next-generation advanced wireless LAN technology

We are developing next-generation wireless LAN technology to provide unlicensed-band radio with sophisticated functions. Up to now, wireless LAN standards have been progressing as part of efforts to increase throughput in one-to-one communication and improve the area coverage rate. Recently, however, throughput degradation in dense environments, for example, congested train stations, has brought to light the problem of how to improve communication quality in such environments. To solve this problem, the NTT laboratories have developed distributed smart antenna technology that performs high-speed switching among multiple antennas in units of packets at a wireless LAN AP and an algorithm for performing optimal control of the radio resources (frequency channel, transmission output, etc.) (**Fig. 3**). We tested this technology in an actual stadium and

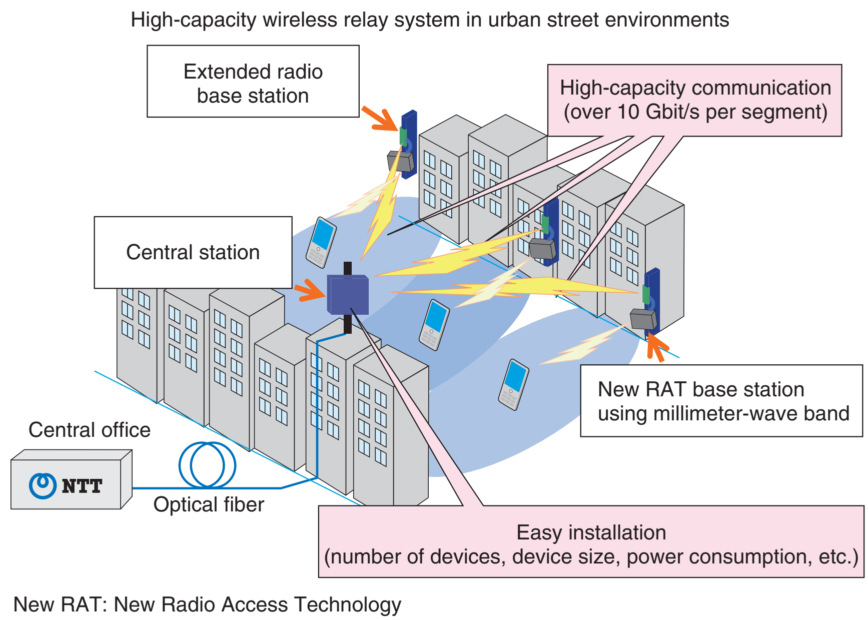

Fig. 2. High-capacity wireless relay technology.

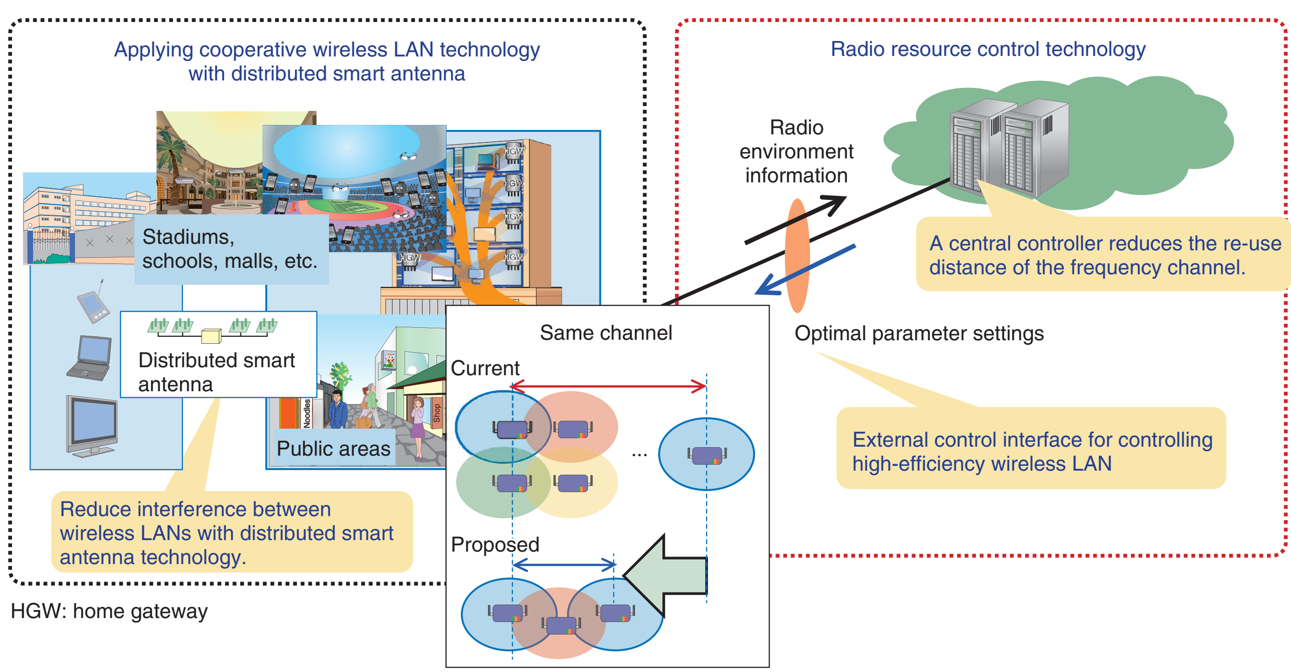

Fig. 3. Cooperative wireless LAN technology with distributed smart antenna system.

found it to be effective in reducing signal interference between APs and in improving transmission speeds even for densely installed APs [3].

At the same time, we have been promoting the drafting of related standards and have participated in formulating the IEEE (Institute of Electrical and Electronics Engineers) 802.11ax standard for achieving high transmission efficiency in dense environments

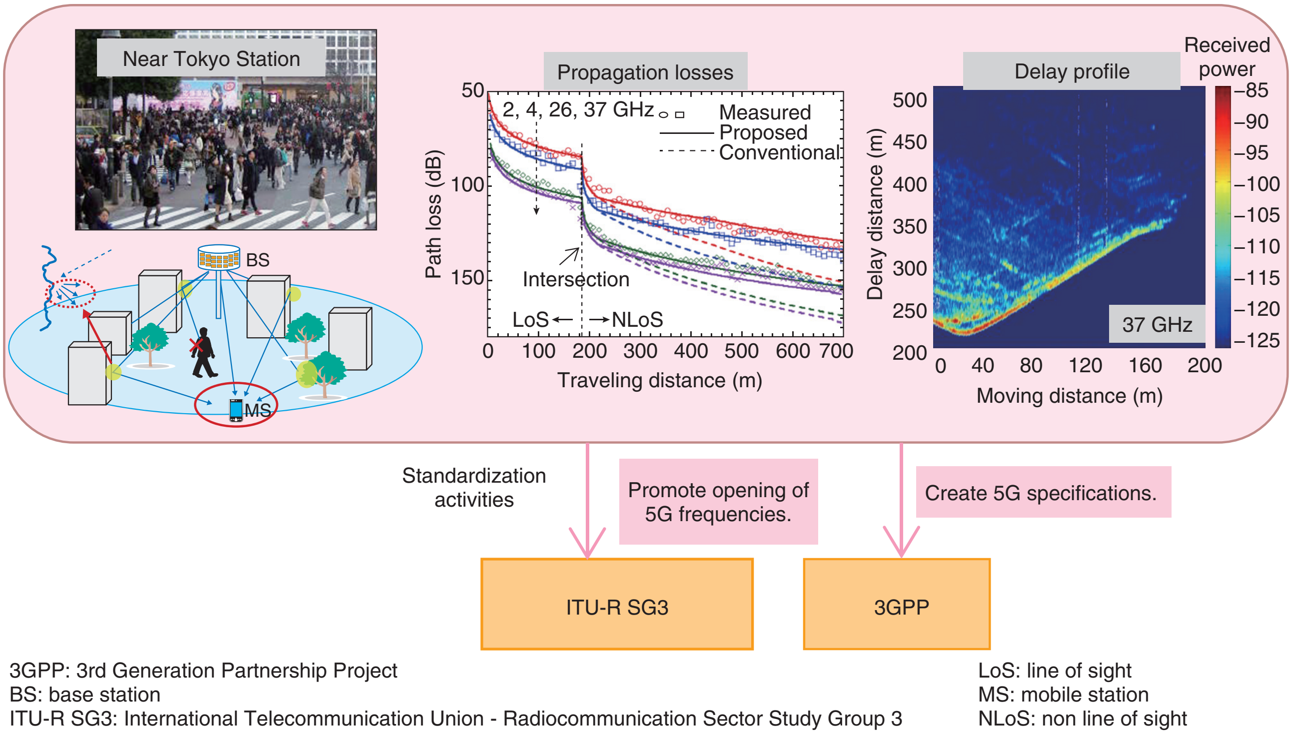

Fig. 4. Investigation of radio propagation models for 5G+.

since the task group was established for this purpose in May 2014 [4].

2.4 Multi-frequency signal propagation modeling technology

Technology for modeling the characteristics of wireless signal propagation is essential to all wireless communication systems, including 5G/5G+. The NTT laboratories have established a new method of frequency allocation through a study on ongoing coexistence with current wireless systems plus a new system design and communication method through an evaluation of propagation characteristics. We have been reflecting these new methods in cell design and area design according to the propagation conditions of individual locations.

More recently, we have been conducting propagation measurements and modeling using multiple frequency bands in the 800 MHz–66 GHz range in diverse environments, including urban and congested environments that are expected to become key targets of 5G/5G+ (**Fig. 4**). We are working to standardize these results as part of standardization efforts at ITU-R (International Telecommunication Union - Radiocommunication Sector) and 3GPP (3rd Generation Partnership Project) with the aim of promulgating new methods and specifications for frequency allocation.

3. Use of wireless systems to provide essential services, and related activities

The NTT laboratories are researching and developing wireless systems for telecommunications operators. These mainly consist of wireless systems to provide communication services to extremely rural areas not conducive to the laying of optical cable, for example, mountainous areas and isolated islands, and wireless systems to provide customers with a means of communication at the time of a disaster. Each of these types of systems, in turn, features terrestrial wireless systems and satellite communications systems. These wireless systems for telecommunications operators are expected to play an important role in securing a safe and secure communications infrastructure in the future. For this reason, the cost of these systems must be further reduced, and in addition, their maintainability and operability must be improved taking into consideration the ongoing decrease in the number of radio engineers and

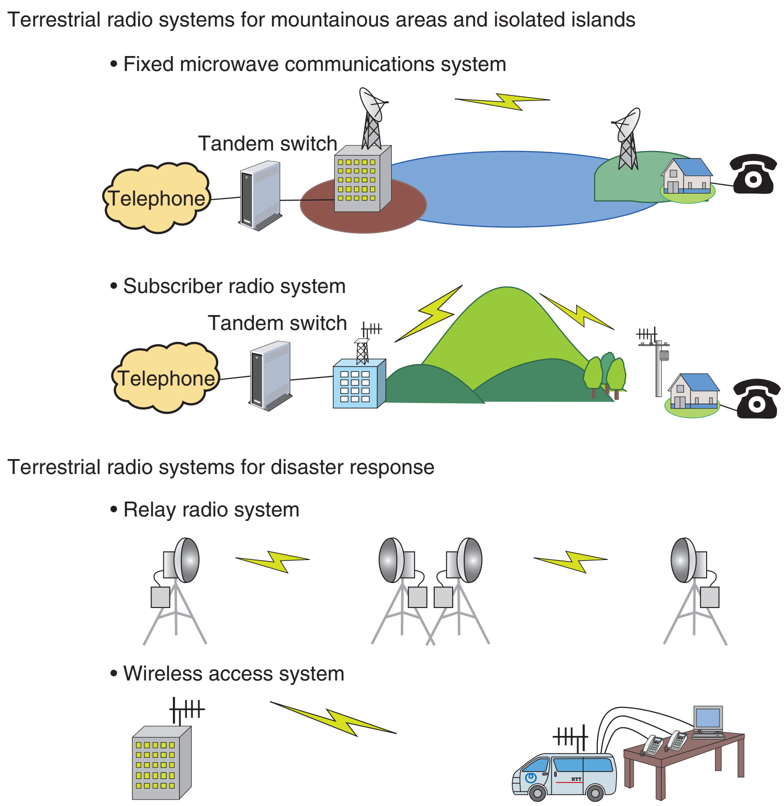

Fig. 5. Terrestrial radio systems.

technicians with advanced skills. The NTT laboratories are working to improve maintainability and operability and to reduce equipment costs using NTT technologies. The following describes current activities surrounding these systems.

3.1 Terrestrial wireless systems for mountainous areas and isolated islands

The terrestrial wireless systems for mountainous areas and isolated islands consist of a fixed microwave communications system and a subscriber radio system (**Fig. 5**). The fixed microwave communications system [5] is a wireless system that provides transmission links to areas where optical transmission paths are difficult to construct for topographical and/or economic reasons. The subscriber radio system, meanwhile, is a wireless system that provides telephone lines, for example, to extremely rural areas, mountain huts, or other remote facilities where the laying of metal or optical cables is difficult.

The NTT laboratories are expanding the applicable areas for such wireless systems through technology that achieves long-distance and high-quality transmission while increasing transmission capacity. The goal here is to bring uniformity and standardization to multiple terrestrial wireless systems and to reduce equipment costs.

3.2 Terrestrial wireless systems for disaster recovery

There are four NTT laboratories products that make up these terrestrial wireless systems for disaster recovery: a business radio system, a relay radio system, a wireless access system, and a cell and radio frequency planning tool. The business radio system [6] is a wireless system for establishing communications within a company to disseminate current disaster conditions, instructions on recovery tasks, or other necessary information to personnel in the field. The relay radio system [7] is a portable wireless system capable of high-capacity wireless communications for quickly restoring services when relay transmission paths are disrupted during a disaster. The wireless access system [8] provides special public telephone and Internet services to customers at evacuation centers and other locations at the time of a

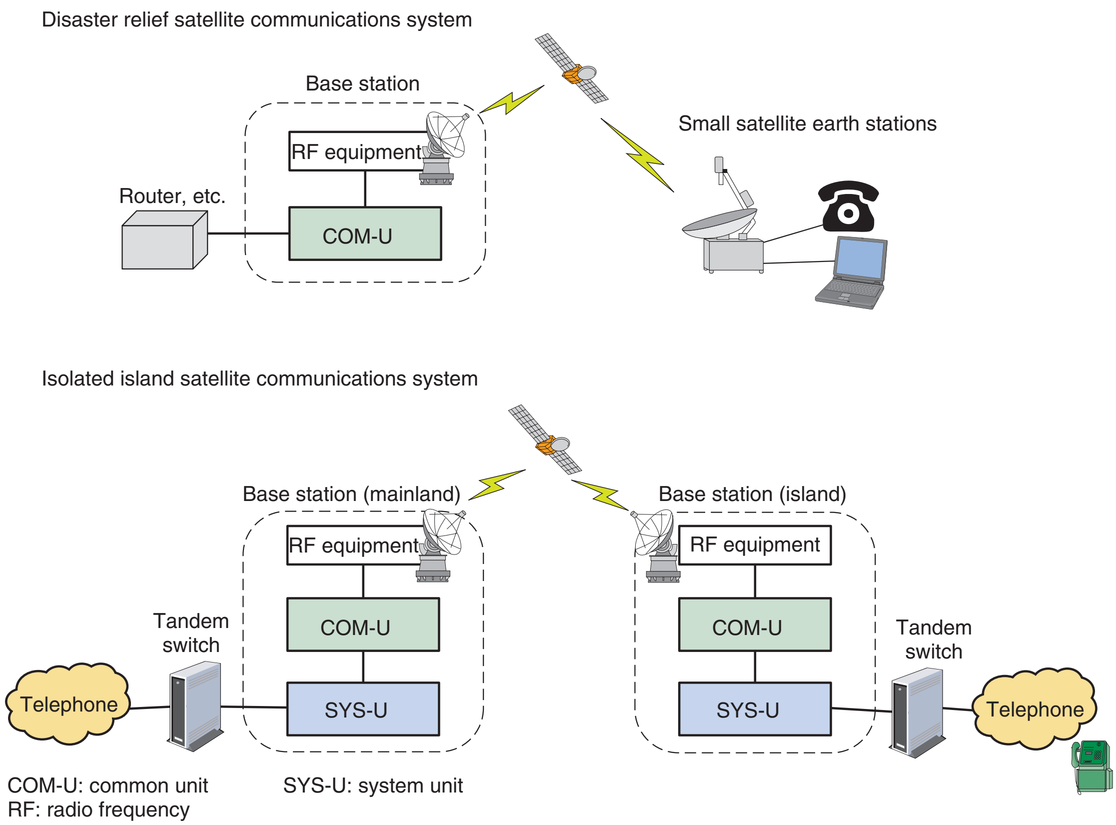

Fig. 6. Satellite communications systems.

disaster. Finally, the cell and radio frequency planning tool [9] is used to select optimal buildings for installing base stations in terrestrial wireless systems for disaster recovery.

These four products have smaller and lighter configurations and more advanced functions than past systems. The objective is to downsize the antennas in the business radio system and wireless access system to contribute to even greater portability.

3.3 Satellite communications systems

The satellite communications systems being researched and developed at the NTT laboratories mainly consist of a satellite communications system for disaster recovery and a satellite communications system for isolated islands (**Fig. 6**). The system for disaster recovery provides special public telephone and Internet services to customers at evacuation centers in the event of a disaster. The system for isolated islands provides a communications infrastructure for areas where it is difficult to lay submarine optical cable.

We have developed a satellite communications modem unit, or common unit (COM-U) [10] that can be applied to base stations in both types of satellite communications systems. COM-U enables frequency placement to be set as desired and therefore improves spectrum utilization efficiency compared with existing satellite communications modem units. Furthermore, although current satellite communications systems combine multiple pieces of equipment, the equipment is consolidated and mounted on a single rack, thereby eliminating the need for wiring and improving maintainability and operability.

4. Future outlook

At NTT Access Network Service Systems Laboratories, we are contributing to the rollout of diverse mobile services using wireless LAN to deal with the accelerated increase in traffic that can be expected with the coming of a full-scale 5G era.

Additionally, considering that the number of radio engineers and technicians is expected to drop in the years to come, we are working to improve operability in radio systems used by telecommunications operators. At the same time, we are helping to further reduce the burden placed on operators caused by the migration of multiple radio systems and contributing to the development of low-cost radio equipment.

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Research and Development of Optical Fiber and Cable Technology

Atsushi Nobiki

Abstract

NTT Access Network Service Systems Laboratories has initiated the Access Media Project to further the research and development (R&D) of optical fiber and cable technologies for broadband network services. This article introduces the latest R&D in operations, administration, and management technologies that will be used to make the operation of a massive number of optical facilities more efficient. It also reviews next-generation optical fiber technologies to handle the explosive future growth of data traffic.

Keywords: optical fiber and cable, operations, administration, and management, next-generation optical fiber

1. Introduction

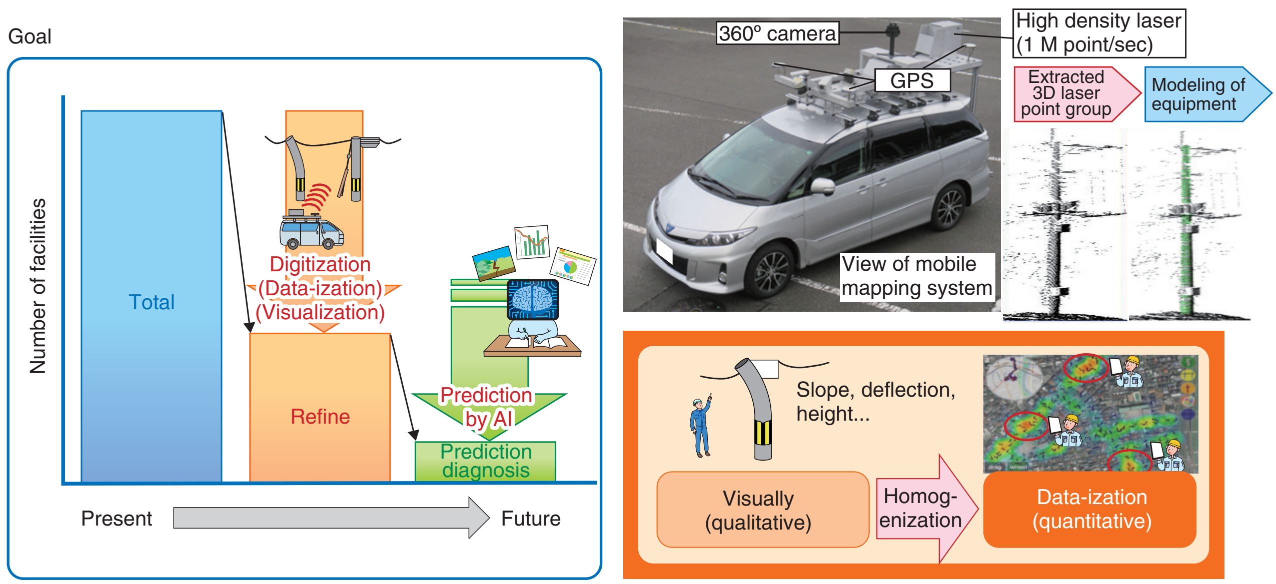
NTT has been involved in the development of optical fiber technology for over 40 years. This technology includes fiber manufacturing methods such as VAD (vapor-phase axial deposition), cabling and connection technology for use as communication equipment, and testing technology for network management. A commercial optical fiber network service was started in Japan in a trunk-line network in 1982, and the Japan longitudinal optical fiber network was completed in 1985. In access networks, the full-scale fiber-to-the-home (FTTH) service called B FLET'S began in 2001.

Optical fiber for trunk lines requires large capacity transmission and high reliability. Furthermore, economic efficiency and operability are very important for application to access networks.

NTT Access Network Service Systems Laboratories (AS Labs) has developed various optical components and systems to implement these commercial optical fiber services. In the recent decade, we have focused in particular on improving fiber and cable technologies for use in optical access networks to facilitate the deployment of the FTTH service. HAF (hole-assisted fiber) has holes around an optical fiber core and provides easy in-house DIY (do it yourself) capabilities based on ultralow bending loss characteristics due to the confinement effect of optical power distribution in the optical fiber core [1]. Ultrahigh-count and high-density optical fiber cable with a rollable ribbon structure achieves twice the density of conventional cable and improves accommodation in pipes because of its thinness [2]. In this article, we introduce the latest research and development (R&D) on optical fiber technology for access networks and for next-generation optical fiber networks.

2. Future direction of R&D of optical fiber and cable technology

Internet traffic is continuing to increase dramatically. The net increase in the number of FLET'S service users has stabilized in the last several years, although we are still managing a huge number of facilities for the optical fiber network. Also, due to the declining birth rate and aging population, the number of people available to work on the operation and maintenance of these facilities will certainly decrease. Thus, in the future, it will be essential to



AI: artificial intelligence
3D: three-dimensional
GPS: global positioning system

Fig. 1. Inspection technique for outdoor facilities.

deploy optical communication facilities that are more functional and efficient.

AS Labs is striving to achieve operational innovation and facility renovation, which respectively mean simple operation for managing the huge number of facilities and redeployment of network functions in the future. For operational innovation, we are working on improving the operations process so that it will require significantly less manpower by innovatively automating and improving the work flow for existing facilities. Namely, we are using (1) automation technology for equipment inspection work and (2) advanced sensing technology. We aim to implement planned maintenance work before spontaneous breakdowns occur.

In addition to the renovation of facilities, we plan to improve the efficiency of operations work and the fluidization of facility maintenance personnel by achieving greater efficiency of on-site work through (3) one-stop maintenance and (4) simple tasks, when constructing and renewing facilities. Furthermore, in order to support network traffic that continues to expand in the future, we are pursuing R&D aiming to realize (5) an innovative next-generation network represented by multi-core fiber/multi-mode fiber as an ultralarge capacity optical transmission technology.

3. Recent R&D topics

A lot of research is underway to find ways of improving facilities and their operation. The research being done on the five areas mentioned in section 2 is described here.

3.1 Inspection technique for outdoor facilities

I introduce here our inspection technique for outdoor facilities that enables efficient management of the huge number of these facilities. As shown in **Fig. 1**, this technique involves the use of technology that can automatically quantify the state of equipment during inspections and degradation diagnostic work currently underway at all outdoor facilities. In the future, less time and effort will be needed for facility maintenance because automatic diagnosis of damage and prediction of deterioration by artificial intelligence (AI) will reduce the number of unforeseen problems and free maintenance personnel from having to carry out unplanned work.

We will utilize as a feature of the technology a system called three-dimensional mobile mapping system (3D MMS), which carries out space measurement in 3D. This system operates with a GPS (global positioning system) antenna, 3D laser scanner, and a camera mounted on a car. The MMS collects 3D point cloud data, which will be stored in a facility

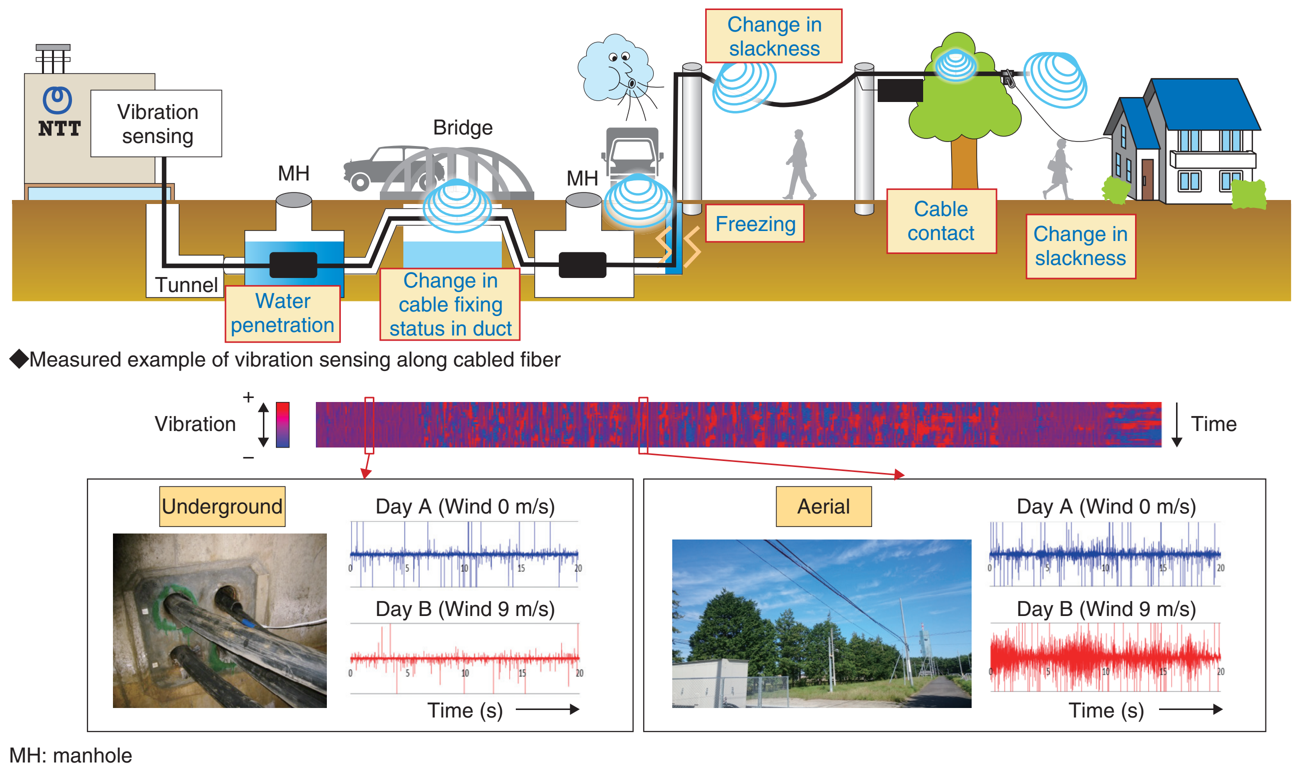


Fig. 2. Optical fiber cable sensing technology for visualizing outdoor equipment.

database. We will first collect point cloud data on equipment such as utility poles, cables, and branch lines. The system will then automatically analyze information such as the tilt and deflection of poles or the height of cables and then extract the facilities that need preferential inspection. The inspection targets will therefore be narrowed down, which will reduce the amount of work time needed for facility management. In the future, we will employ AI diagnosis using information on aging changes or environmental data around facilities to prevent facility faults before they occur. This will improve the reliability of the network and greatly contribute to streamlining facility maintenance operations.

3.2 Optical fiber cable sensing technology

We are also investigating optical fiber cable sensing technology for managing outside facilities by measuring an optical fiber installed as a sensor. In this work, the goal is to achieve the ability to remotely detect equipment abnormalities using acoustic/vibration remote sensing technology (**Fig. 2**). If this technology can be achieved, it will be possible to identify the location of faults or abnormal events such as water penetration into an optical closure, freezing, sagging, or points where cables have come into contact with objects (for example, trees), and we will be able to deal efficiently with the issue and prevent a communication breakdown before it occurs. Predicting failures and implementing plans to replace degenerate facilities will make it possible to minimize the impact on services and to streamline maintenance operations.

To realize facility state estimation, it is necessary to clarify the correlation between the state of deterioration of the facility and the measured result using a vibration or acoustic sensing technique. We will therefore try to elucidate the deterioration mechanism of network facilities in the future. However, since optical fiber is contained within a cable, and the cable has a secure coating, it is not easy to examine the external state of the optical fiber through such a structure. We plan to investigate various estimation techniques to find one that is accurate while also considering a combined approach with other measurement methods.

We are also working on ways to measure the deterioration of the optical fiber itself. In optical fibers

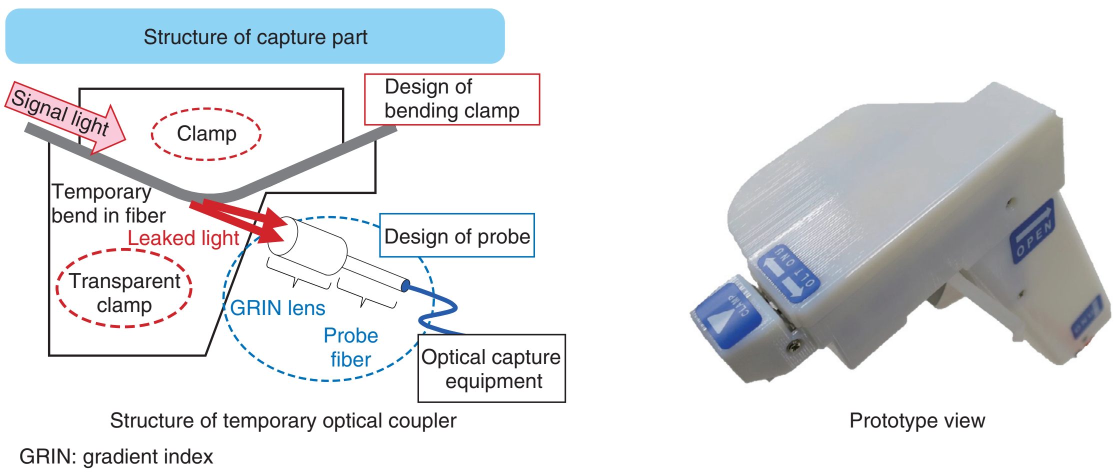


Fig. 3. Capturing MAC address of ONU signal using non-destructive fiber bending technique.

installed in the field, the loss characteristics may gradually increase due to freezing, side pressure, or other factors. The huge quantity of optical fiber already installed for FTTH services is expected to be used for a long time in the future. To efficiently maintain and operate the optical fiber network, it is necessary to be able to accurately measure the deterioration status of every optical fiber and to replace them as necessary.

At AS Labs, we are collaborating with NTT Communications to develop high-sensitivity technology to measure loss in the optical fiber network. The point of this technology is not to use optical pulses in the usual single-mode region wavelength (1260 nm~) but to use optical pulses in the multi-mode region wavelength (near 1050 nm) to measure loss in single-mode optical fiber. This generates back scattering light of a higher-order mode that is sensitive to loss and enables high-sensitivity loss measurement. Although it is now possible to measure loss with high sensitivity, we will continue to develop this technology in the future to predict the life expectancy of optical fiber and to predict deterioration of equipment.

3.3 MAC address capture technology

We are developing media access control (MAC) address capture technology that will achieve greater efficiency of service orders and maintenance operations. When information discrepancies occur between the facility database and the actual facility during service order and maintenance work, many adjustment operations have to be done at the construction site to check the usage status of the optical fiber line. It is possible to maintain an accurate facility database by checking the unique identification address (MAC address) that includes a signal from the optical network unit (ONU). Until now, if we had wanted to monitor the MAC address of an ONU, we would have had to install a monitoring point such as an optical coupler in the optical fiber network.

We are studying a temporary optical coupler that will make it possible to temporarily bend the optical fiber without cutting it, and to leak and input the optical communication signal (**Fig. 3**). This will enable us to capture a transmission signal from the ONU without interrupting services. By reflecting accurate information from such live optical fiber lines to the facility database, we will be able to carry out reliable construction work.

3.4 Fail-safe single-fiber cleaving technique

Here, I introduce a fail-safe single optical fiber cutter that enables connection work to be done on optical fibers without requiring special skills of the maintenance workers (**Fig. 4**). For optical fiber connection, it is necessary to vertically cut the end face of the optical fiber in order to precisely match the optical fiber cores that have a diameter of only about 10 µm. With conventional optical fiber cutters, skilled workers had to periodically carry out maintenance of cutters in order to maintain the optimum cutting conditions. With the fail-safe single-fiber optical fiber cutter, the blade structure has been changed from a metal blade to a plastic one with diamond abrasive grains, and we have also adopted a method that does not apply stress to the optical fiber at the time of cutting.

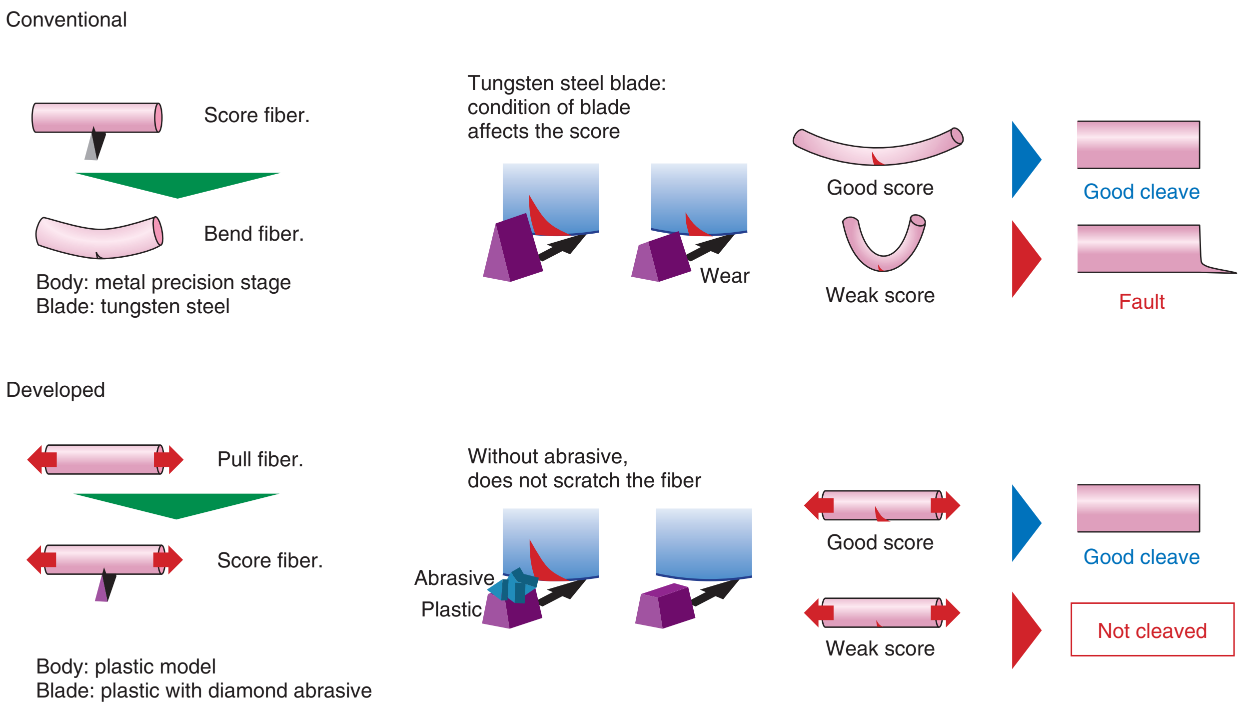


Fig. 4. Fail-safe single-fiber cleaving technique.

This means that if the cutter's condition has deteriorated and cutting cannot be performed normally, the cutter will not break the optical fiber. This prevents the occurrence of cutting failures due to insufficient maintenance of the cutter and improves the reliability of construction.

3.5 Next-generation ultrahigh speed and capacity fiber technology

Finally, I introduce ultralarge capacity fiber technology, which is a mid- and long-term effort to prepare for the explosive growth of future traffic. Until now, the transmission capacity per optical fiber has been dramatically increased by multiplicity and high signal density, for example, by applying TDM (time division multiplexing), WDM (wavelength division multiplexing), and digital coherent technology. However, as the number of multiplexed wavelengths increases, the signal power density per unit area of the optical fiber also inevitably increases, and as the power density of light increases, the occurrence of optical nonlinear effects in the optical fiber—thermal destruction phenomena (fiber fusing)—happens. Therefore, there is a limit to the optical power that can be input to optical fiber. In addition, due to the nonlinear effect, there is a trade-off relationship between the multi-valued level of the signal and the transmission distance, and it is subject to the transmission distance limitation. Therefore, the capacity limit is thought to be up to 100 Tbit/s per optical fiber line in the conventional technology.

Recently, space division multiplexing (SDM) has been attracting interest as a new method to overcome this capacity limit and deal with the future explosive increase in traffic. Various kinds of space multiplexing have been proposed, including multi-core fiber, in which there are multiple cores in a fiber, and multimode fiber, in which multiple modes are propagated in a core. In our project, we succeeded in conducting world-first mode-multiplexed transmission experiments and achieved the largest ever number of 114 channels through transmission of 19 cores × 6 modes with a multi-core structure optical fiber. With SDM technology, we will continuously challenge the utmost limits of transmission capacity of optical fiber with the outer diameter of 250-μm multi-core and muti-mode fiber, aiming to achieve ultrahigh density transmission. We will also work to make progress on the practical applications utilizing multi-core fiber with a standard clad outer diameter of 125 μm that is compatible with conventional manufacturing or peripheral (connection and cable) technology

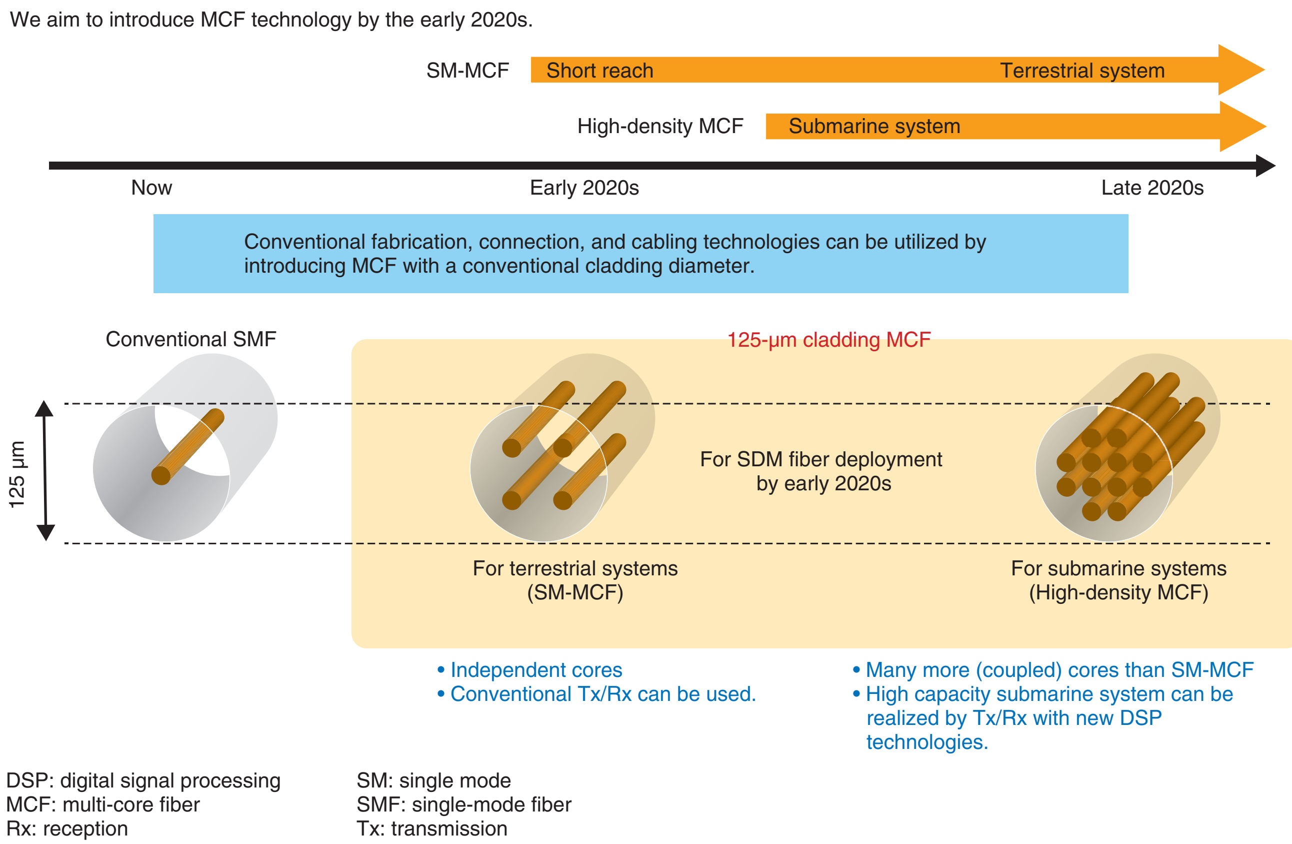


Fig. 5. SDM technology (multi-core and few-mode fibers).

(**Fig. 5**).

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Demonstration of Single-mode Multicore Fiber Transport Network with Crosstalk-aware Optical Path Configuration

Takafumi Tanaka, Takayuki Mizuno, Akira Isoda, Kohki Shibahara, Tetsuro Inui, and Yutaka Miyamoto

Abstract

Space-division multiplexing using multicore fiber (MCF) is considered to be one of the most promising technologies for breaking the capacity limit of traditional single-mode fibers and advancing fiber optic communication systems. For transport networks to utilize the capacity of MCF efficiently, it is essential to consider inter-core crosstalk (XT) in provisioning optical paths. We developed an MCF transport network testbed and used it to demonstrate our optical path configuration scheme, in which a software-defined networking controller configures programmable transponders that include a beyond-100G digital signal processor that factors in XT.

Keywords: space-division multiplexing, inter-core crosstalk, software-defined networking

1. Introduction

The maximum capacity of practical single-mode fiber (SMF)-based transmission systems is thought to be around 100 Tbit/s per fiber due to the fiber fuse phenomenon [1]. Efforts are underway to break the capacity limit of SMF, and space-division multiplexing (SDM) is one of the most active areas of research intended to achieve this [1, 2]. The European Union (EU)-Japan coordinated research and development (R&D) project named Scalable And Flexible optical Architecture for Reconfigurable Infrastructure (SAFARI) was launched in 2014 and has achieved many of the world's most significant advances in realizing Pbit/s/fiber-class and over 1000-km-distance programmable optical networks. For example, high-core-count single-mode multicore fiber (MCF) with spatial multiplicity of over 30 was demonstrated in the project [3], and it was used to achieve dense-SDM (DSDM) transmission with Pbit/s/fiber-class capacity [4].

If MCF-based transmission is to become feasible for wide-area transport networks, the effect of inter-core crosstalk (XT) must be considered. It is an important factor that occurs only in MCF and that limits the transmission distance and the modulation formats that can be used. A core in an MCF is affected by the XT generated in its adjacent cores, and the XT impairment accumulates as the transmission distance increases. In addition, the XT in a core will change over time in response to changes in optical path assignments to its adjacent cores. Therefore, careful consideration of XT is essential, especially for long-distance and dynamic MCF transport networks.

In this article, we report the recent achievement of the SAFARI project, a single-mode MCF transport network that offers XT-aware and programmable optical paths with XT monitoring [5]. We used the testbed to demonstrate an XT-aware traffic engineering

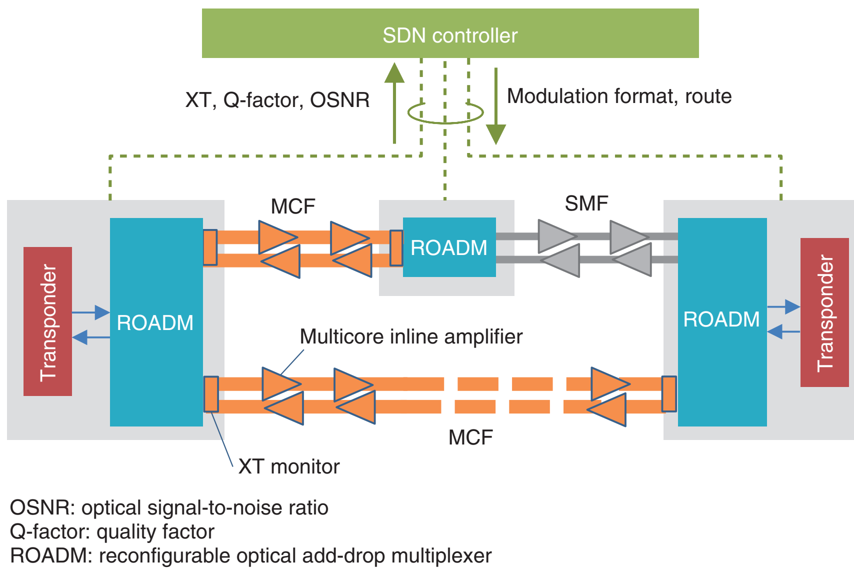


Fig. 1. XT-aware MCF transport network architecture with SDN controller.

use case, in which optical paths were adaptively (re)configured subject to consideration of inter-core XT with the help of a software-defined networking (SDN) controller.

2. MCF transport network architecture

The proposed XT-aware MCF transport network architecture is shown in **Fig. 1**. This network contains a mixture of MCFs and SMFs, as the former will incrementally replace the latter. The network connects three reconfigurable optical add-drop multiplexers (ROADMs) using three SMF/MCF links that include inline amplifiers. Of particular note is the fact that the MCF links contain FI/FO (fan-in/fan-out) devices and XT monitors to estimate the inter-core XT values of each link. The transponders have the ability to adaptively select the modulation formats from among quadrature phase-shift keying (QPSK), 8 quadrature amplitude modulation (8QAM), and 16QAM.

The SDN controller collects transmission performance data such as inter-core XT, Q-factor (quality factor), and optical signal-to-noise ratio (OSNR) values at regular intervals from each node. The SDN controller uses the monitored values to set the transponders to an appropriate modulation format and/or configure the ROADMs to change optical path routes.

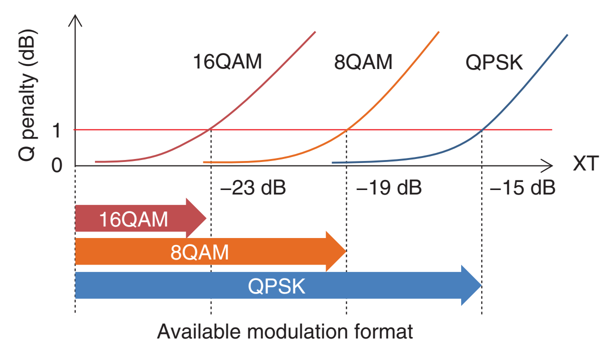


Fig. 2. Available modulation formats with respect to XT.

3. XT-aware optical path configuration scheme

This section describes how XT is taken into consideration in optical path configuration. The initial step prior to optical path configuration is to associate XT values with suitable modulation formats, as shown in **Fig. 2**. In long-distance MCF transmission, transmission quality (e.g., Q penalty) mainly depends on the XT induced in the MCF link. If a certain level of allowable Q penalty due to XT is set (typically < 1 dB as shown in Fig. 2), the XT threshold for each modulation format is automatically determined.

In the second step, the XT values are monitored continuously or periodically during operation of the transport network because it will change dynamically

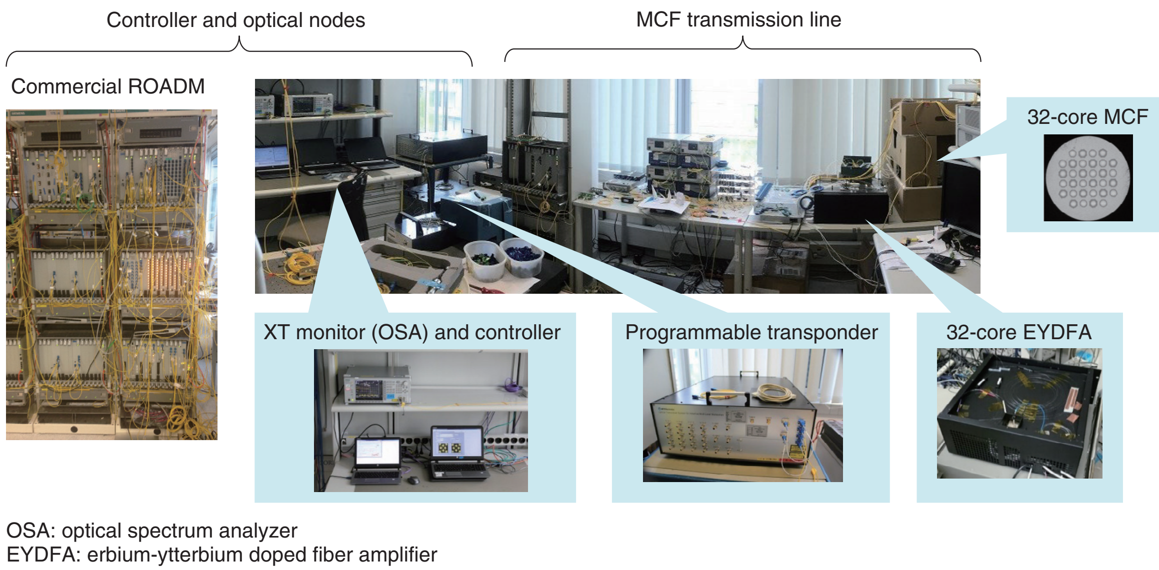


Fig. 3. Constructed testbed.

over time as optical path assignment conditions in adjacent cores change. In addition, to ensure high-quality network services, in-service XT measurement is necessary, which means that the XT monitoring method should not affect or interrupt the wavelength-division multiplexing (WDM) signals. Our in-service XT measurement scheme has been adopted in the network [6].

In the final step, the SDN controller commands the transponders and ROADMs to (re)configure the modulation format and the optical path route. The modulation format is determined by plotting the measured XT value, as in Fig. 2, and selecting the format with the highest modulation level.

4. Testbed setup and evaluation results

We constructed a testbed in order to evaluate the system. The testbed setup and the results of our experiments are described in this section.

4.1 Use case

The constructed testbed is shown in **Fig. 3**. The testbed is designed to demonstrate XT-aware traffic engineering, shown in **Fig. 4(a)**, as a representative use case where XT-awareness is a key attribute. First, for this use case, we assume a low priority optical path established on a low-XT MCF span (Link A in Fig. 4(a)). Since the XT is low, the span supports 16QAM. Next, we assume that a request for a high priority optical path arrives that needs to be served using Link A. This forces the route of the low priority path to be changed to a less favorable route (Link B-C) to make room for the newly arrived high priority path. Since the XT level of the new route (Link B-C) is higher than that acceptable for 16QAM, a lower-order modulation format is selected, that is, QPSK or 8QAM.

4.2 Testbed setup - transmission line

The right side of **Fig. 4(c)** represents the DSDM transmission line. It consists of a 51.4-km 32-core single-mode MCF [3], a 32-core erbium-ytterbium doped fiber amplifier (EYDFA) [7], and in-service inter-core XT monitors [6].

To model different levels of XT and their effects on an MCF network, sets of cores were connected in series in various combinations. As shown in **Fig. 4(b)** and Fig. 4(c), a set of eight concatenated cores (blue-colored cores in Fig. 4(b)) surrounding several high input power cores was used to represent a 411.2-km high-XT line. Another set of eight concatenated cores around the outer perimeter of the fiber (orange-colored cores in Fig. 4(b)) yielded a 411.2-km low-XT line. Further, a set of two cores (red-colored cores in Fig. 4(b)) represented a 102.8-km line with minimum XT. This arrangement shows how different deployment and operation scenarios can be tested.

For XT monitoring, two pilot tones are combined with the input WDM signal by a 2 x 2 coupler for

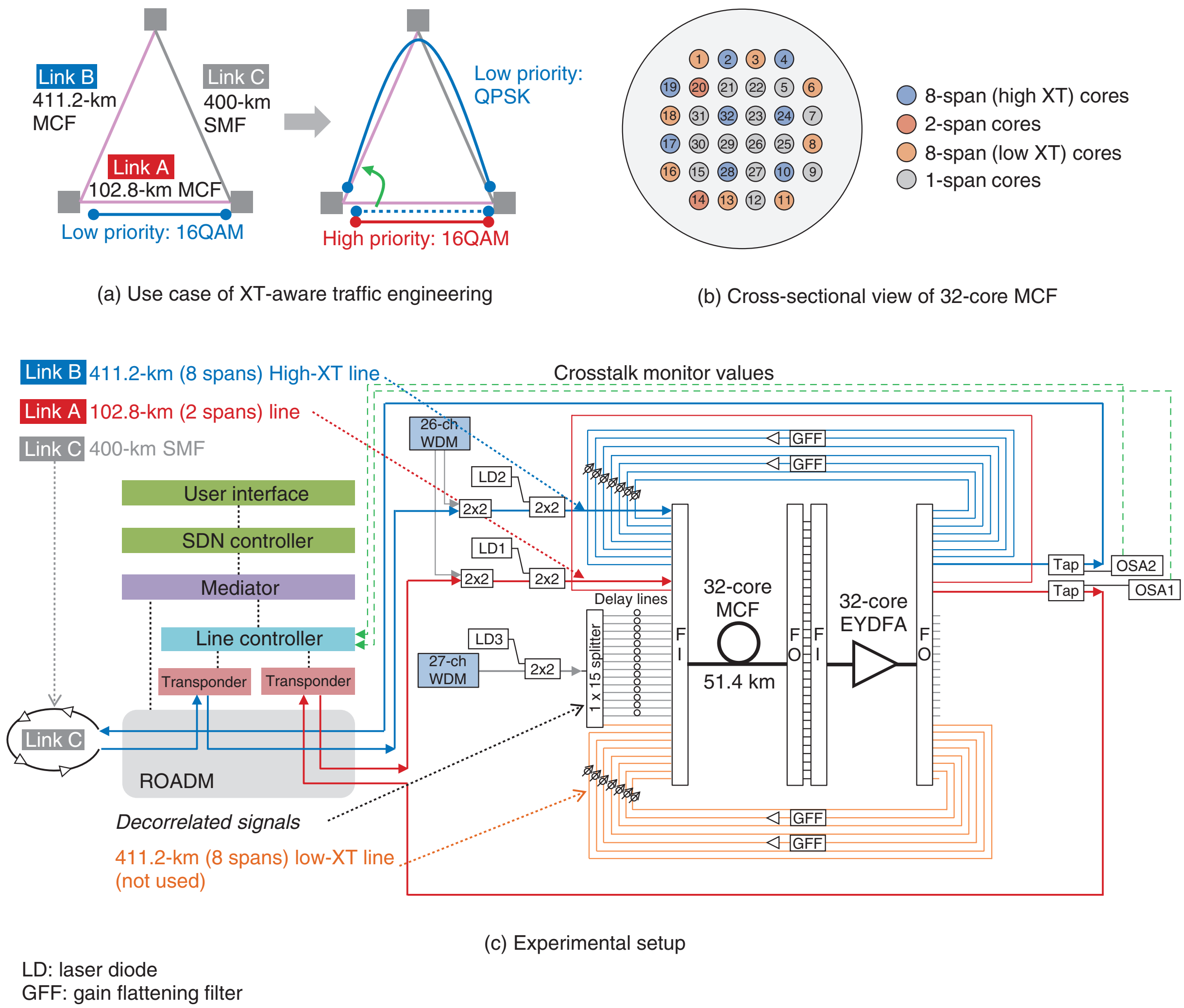


Fig. 4. Use case and experimental setup.

each transmission line, and the output signal is tapped and its spectrum is measured using an optical spectrum analyzer (OSA).

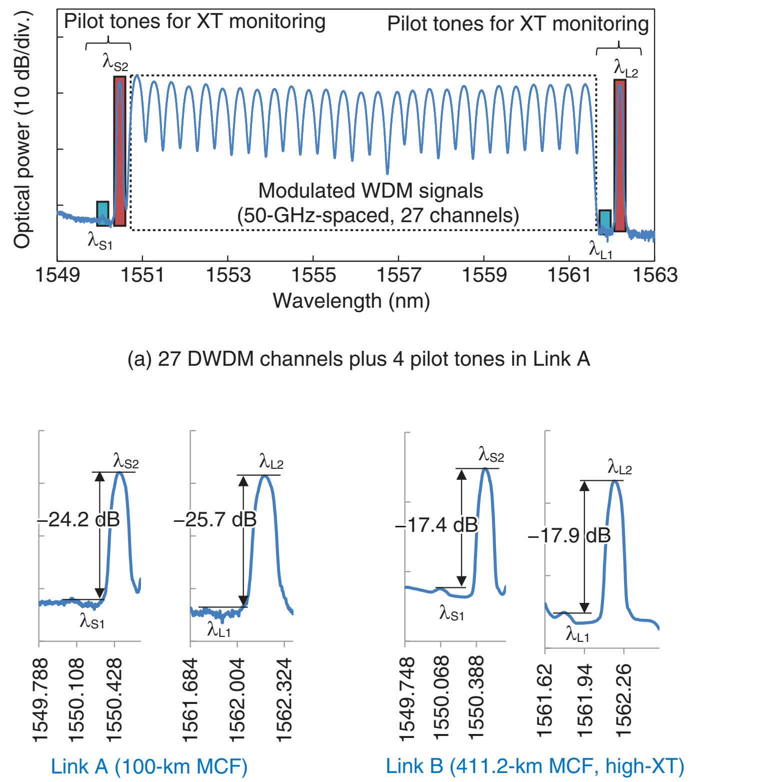
4.3 Testbed setup - SDN controller

The SDN controller in the testbed adopts the hierarchical layer model as shown on the left side of Fig. 4(c). The MCF transmission line is controlled using the SDN controller via its user interface. We assume the adoption of OpenDaylight [8], a widely used open-source SDN controller. However, it lacks several specific functions required for the use case, for example, identifying the MCF core number, collecting XT values, and setting the modulation format, so we added an intermediate function named Mediator that can issue commands to implement these functions to the ROADM and transponders.

The line controller controls and manages the programmable transponders and the MCF transmission line. This implementation enables (re)configuration of the modulation format, wavelength, laser on/off, and performance monitoring. The controller also collects the monitored XT values from the OSAs and forwards them to the SDN controller to determine the modulation format.

4.4 Results

The DWDM (dense-WDM) spectrum in Link A measured using the OSA after transmission is shown in **Fig. 5(a)**. The inter-core XT outside both ends of the WDM signal bandwidth were estimated by comparing the optical power differences between the



(a) 27 DWDM channels plus 4 pilot tones in Link A

(b) Excerpt of pilot tone channels in Link A (c) Excerpt of pilot tone channels in Link B

Fig. 5. Measured XT monitoring performance in the testbed.

corresponding reference and XT pilot tones. The XT at the signal wavelength was estimated by linear interpolation of the estimated XT values at the WDM spectral edges. For example, we can see that the XT range of Link A is estimated to be between –25.7 dB and –24.2 dB by taking the differences between reference and XT pilot tones at the respective WDM spectral edges (the difference between λ_{S2} and λ_{S1} at a short wavelength, and the difference between λ_{L2} and λ_{L1} at a long wavelength) (**Fig. 5(b)**). By linearly interpolating these values, we can estimate that the XT at the wavelength used by the test signal in Link A is about –24.9 dB. Similarly, XT at the same wavelength in Link B is estimated to be about –17.7 dB (**Fig. 5(c)**). By comparing these estimated XT values with those in Fig. 2, which represent the relationship between Q penalty and XT, we can see that QPSK, 8QAM, and 16QAM formats are available for Link A, while QPSK is the only available modulation format for Link B.

The real-time measurement data for a low priority, 16QAM path initially routed across the two-core 102.8-km MCF link (Link A) having low XT is shown in **Fig. 6**. Since the SDN controller continuously collects inter-core XT of the low priority path from the OSA, we can see that the inter-core XT of the low priority path is initially kept low. When the request for a high priority 16QAM path arrives, the low priority path is pre-empted by the high priority path and rerouted to the eight-core high-XT MCF link and 400-km SMF (Link B-C). Accordingly, the modulation format of the low priority path was changed to QPSK. After waiting a few minutes for the change in modulation format to be completed, the low priority channel was successfully switched to the new route, and all established paths showed stable error-free operation after forward error correction (FEC) decoding.

5. Conclusion

We presented the concept of the single-mode MCF transport network orchestrated by an SDN controller. To suppress the effect of inter-core XT impairment,

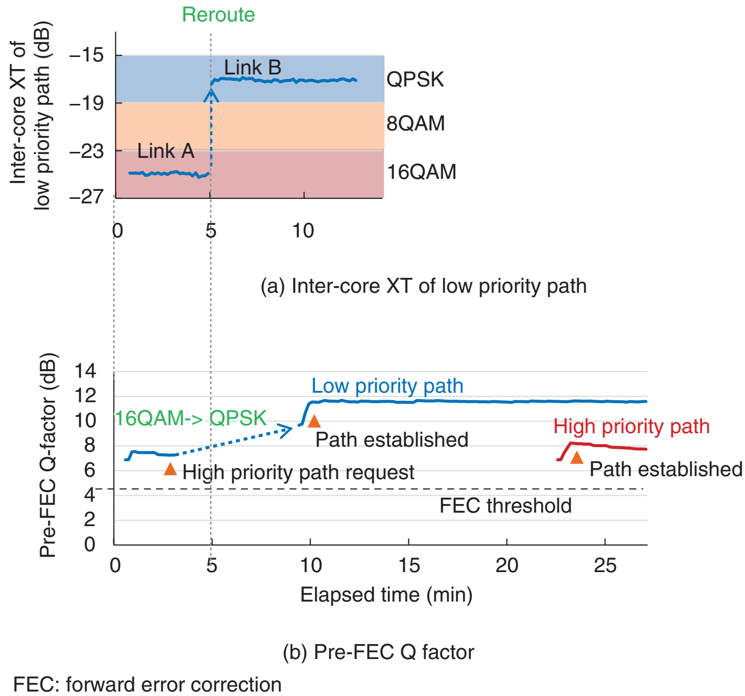


Fig. 6. Transition of inter-core XT and pre-FEC Q factor.

which is the main factor limiting the transmission distance and which modulation formats can be used, we applied our SDN-supported XT-aware optical path control scheme with in-service XT monitoring. We constructed an MCF transport network testbed around a 32-core MCF and EYDFA, programmable transponders, 3-degree ROADM, and an SDN controller. An XT-aware traffic engineering scenario was examined as a use case, and the results confirmed that the SDN controller was able to dynamically change both the modulation format and the optical path route.

Some technological advances are required in order to further improve the feasibility of the MCF transport network. These include an MCF-compatible optical node that can connect to multiple MCFs and switch optical paths at multi-granular levels (e.g., fiber, core, wavelength), and an efficient optical path assignment algorithm that calculates optimal parameters such as route, core, wavelength, and modulation format.

Acknowledgments

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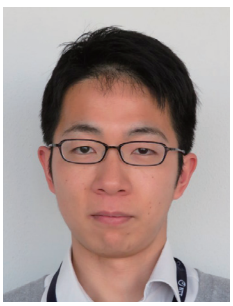

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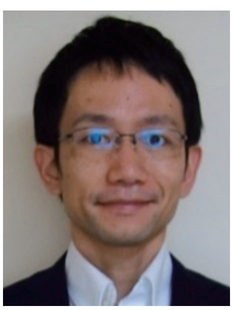

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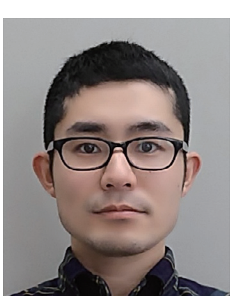

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High-speed Modulator for Next-generation Large-capacity Coherent Optical Networks

Josuke Ozaki, Yoshihiro Ogiso, and Shinsuke Nakano

Abstract

Modulators with very high speeds are necessary to achieve the next-generation of 1-T/λ coherent optical networks. In this article, we describe our recently developed InP (indium phosphide)-based in-phase and quadrature (IQ) modulators with ultrahigh bandwidth and low half-wavelength voltage (V_π). We utilize a structure with extremely low electrical loss and obtain a 3-dB electro-optic bandwidth of over 67 GHz without degrading other characteristics such as driving voltage and optical loss. The IQ modulator performs IQ modulation at up to 120 Gbaud without optical and electrical pre-equalization. Furthermore, we developed an ultralow power modulator driver employing 65-nm CMOS (complementary metal-oxide semiconductor) technology and fabricated an IQ modulator co-assembled with this driver IC (integrated circuit), and successfully demonstrated 64-Gbaud/16QAM (quadrature amplitude modulation) operation.

Keywords: InP-based modulator, digital coherent technology, high-speed modulation

1. Introduction

Optical transport networks require more channel capacity and greater flexibility in the modulation format in order to cope with the ever-growing global IP (Internet protocol) traffic [1, 2]. Digital coherent optical transmission technology is a key for increasing the capacity of optical networks. The Optical Internetworking Forum (OIF) is discussing a polarization-division multiplexing in-phase and quadrature (IQ) modulator with high bandwidth and flexible modulations for 400 and 600 G/λ, such as 64 Gbaud/16 quadrature amplitude modulation (16QAM) and 64 Gbaud/64QAM. Moreover, much higher baud-rate modulation targeting 1-T/λ, for example, 100 Gbaud/32QAM and 100 Gbaud/64QAM, has been demonstrated in the research phase [3, 4].

To achieve the high-speed, high-order modulation format and low power consumption, it is necessary to improve modulator performance with regards to the electro-optic (EO) bandwidth, half-wavelength voltage (V_π), and the optical insertion loss of the modulators. To extend the transmission distance, a higher baud rate is preferred over higher-level modulation [5]. For example, the transmission distance of a 128-Gbaud/quadrature phase-shift keying (QPSK) signal is theoretically more than twice that of a 64-Gbaud/16QAM signal. Thus, a higher bandwidth modulator is a key component for the next-generation of metro-regional area and long-haul transmission networks. Moreover, optical transceivers tend to have low power consumption and small footprints. Therefore, it is very important to achieve a high bandwidth modulator with a low V_π.

Lithium niobate ($LiNbO_3$: LN)-based modulators have been used in digital coherent systems, and they now support baud rates of up to 64 Gbaud (3-dB bandwidth: ~35 GHz, V_π: ~3.5 V). However, further extending the bandwidth and reducing the V_π of LN modulators is challenging due to the material properties. In contrast, indium phosphide (InP)-based Mach-Zehnder modulators (MZMs) and IQ modulators have several excellent features for achieving high speed and low V_π (3-dB bandwidth: ~40 GHz,

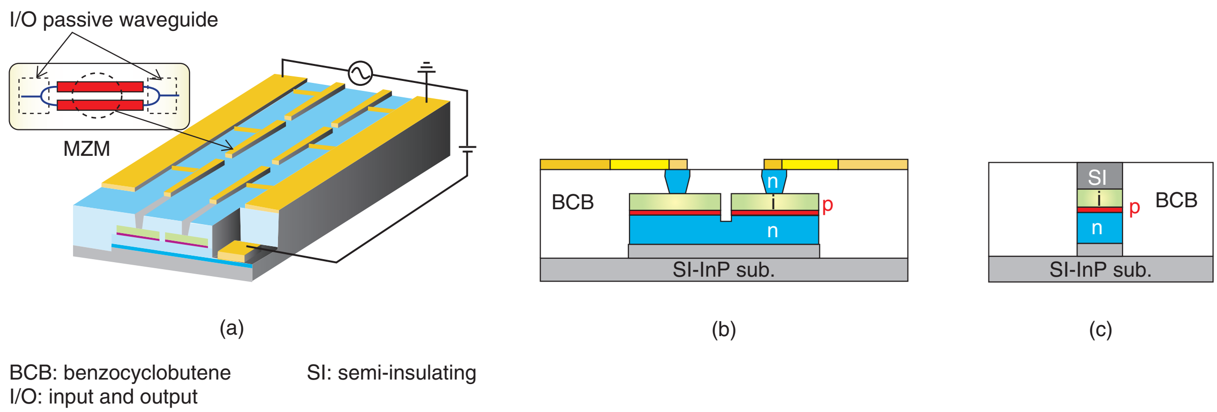


Fig. 1. Schematic illustration of (a) MZM, and cross-section diagrams of (b) its modulation region and (c) its I/O passive waveguide region.

V_π: < 2.0 V). For example, InP-based MZMs exploit the quantum-confined Stark effect and use waveguides with strong optical confinement, which are beneficial for reducing the driving voltage with a short interaction length.

Several high-speed InP IQ modulators with a capacitive-loaded traveling-wave electrode (CL-TWE) design have been reported [6–10]. The CL-TWE allows the optimization of the EO frequency response for high baud-rate applications because its design flexibility enables us to achieve low radio frequency (RF) loss, impedance matching, and velocity matching between RF and optical signals. InP IQ modulators can perform modulations at up to 100 Gbaud [4]; however, the rate of 100 Gbaud has not been exceeded yet. A bandwidth of over 60 GHz is ideally needed for operations at rates beyond 100 Gbaud.

Reducing the EO interaction length is one way to extend the EO bandwidth; however, V_π is increased [9, 10]. An effective way to overcome this trade-off and to achieve both higher speed and lower V_π in InP-based modulators is to reduce the series resistance of the semiconductors. Namely, since a p-doped InP layer has about one order of magnitude higher bulk and contact resistivity than those of an n-doped InP layer, reducing the resistance of the p-doped cladding layer is a promising way to extend the EO bandwidth without increasing the V_π and the optical propagation loss.

In this article, we introduce our recent work on ultrahigh-bandwidth InP IQ modulators with a low V_π and low optical loss. By employing a new n-i-p-n heterostructure—where a thick p-doped cladding layer replaces a thick n-doped layer and a thin p-doped layer—and a conventional CL-TWE, we have developed a modulator with an extremely low electrical loss. The device exhibits a 3-dB EO bandwidth of over 67 GHz and a V_π of less than 1.5 V. We demonstrated 120-Gbaud QPSK modulation toward achieving ultrahigh-speed operation [11]. Furthermore, we developed the most power-efficient MZM driver using complementary metal-oxide semiconductor (CMOS) technology and demonstrated 64-Gbaud/16QAM operation with ultralow power dissipation by co-assembling the driver integrated circuit (IC) with our IQ modulator [12].

2. Modulator design

In this section, we describe our modulator design for achieving a much higher EO bandwidth. Schematic illustrations and cross-sectional diagrams of the fabricated MZM are shown in **Fig. 1**. We found that we could improve the bandwidth further by replacing the thick p-doped (conventional) overcladding layer with an n-doped layer. For that reason, we employ an n-i-p-n heterostructure; namely, an n-doped InP lower cladding layer, a thin p-doped layer, an undoped core layer (InGaAlAs/InAlAs (indium gallium aluminium arsenide and indium aluminium arsenide) multi-quantum well), and an n-doped InP upper cladding layer are grown on an InP (100) semi-insulating (SI) substrate. The thin p-doped layer acts as an electron carrier blocker, which enables us to apply voltage efficiently across the undoped core layer. The modulator has an inverted trapezoidal ridge waveguide in the modulation

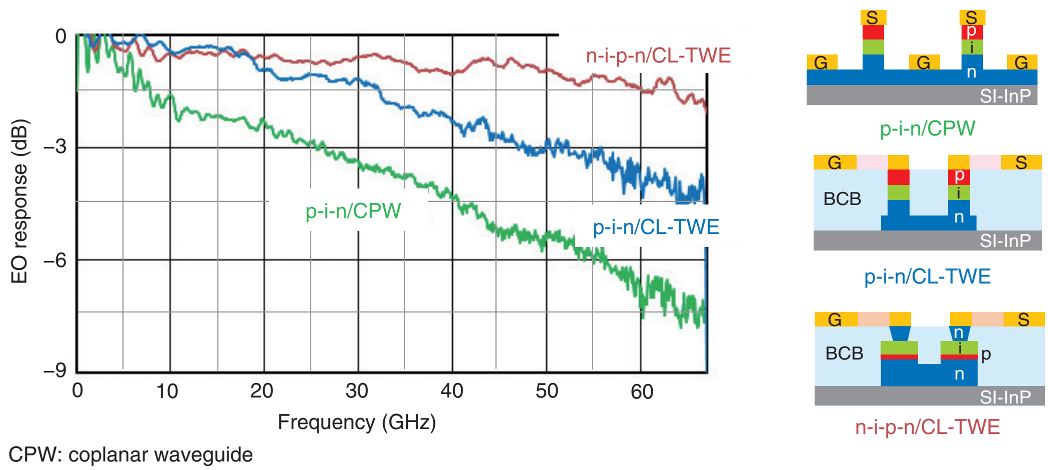


Fig. 2. EO-response comparison of a conventional p-i-n/CPW, p-i-n/CL-TWE, and this work (n-i-p-n/CL-TWE).

region and a deep-ridge waveguide in the I/O (input and output) passive waveguide region, as shown in Fig. 1(b) and (c), respectively. The inverted trapezoidal ridge shape has the potential to achieve lower contact resistivity and parasitic capacitance, which provides more bandwidth improvement than a trapezoidal ridge shape. The n-doped upper cladding layer in the non-modulation region is replaced with an SI cladding layer to achieve electrical isolation and a lower optical propagation loss. These waveguides are formed along the [011] stripe direction to obtain a synergistic EO effect [13]. The [011] direction waveguide also enables us to fabricate an inverted trapezoidal ridge shape by chemical wet etching.

The EO response of our newly developed n-i-p-n structure MZM with CL-TWE is shown in **Fig. 2**. The EO responses for conventional p-i-n structure MZMs are also given for comparison. Utilizing the n-i-p-n structure makes it possible to greatly reduce the series resistance of the MZM. In addition, the CL-TWE potentially has a low electrical loss and offers flexibility in terms of optimizing the impedance and microwave velocity. As a result, we can extend the EO bandwidth further; in fact, we achieved an EO bandwidth of over 67 GHz (1.5-GHz reference).

3. Basic IQ modulator characteristics

In this section, we describe the characteristics of the IQ modulator.

3.1 Static characteristics

The DC (direct current) extinction characteristics at wavelengths between 1530 and 1560 nm are shown in **Fig. 3**. The V_π is less than 1.5 V, and the static extinction ratio (ER) exceeds 24 dB for all the sub-MZMs and the entire C-band, as shown in the figure. We confirmed that the ER characteristics had good uniformity. The fiber-to-fiber optical insertion loss at peak transmission was less than 9 dB, which includes the coupling loss of lensed fibers (~3.5 dB/facet). The on-chip loss was estimated to be approximately 2 dB, which is equivalent to that of an InP MZM formed with a passive waveguide. This indicates that the absorption loss of the thin p-cladding layer is negligibly low, and the optical loss of our waveguide is lower than that of a conventional p-i-n waveguide.

3.2 High-frequency responses

We measured the small-signal high-frequency characteristics. In this experiment, the 50-Ω termination chip resistors were flip-chip bonded on a die, which has the advantage of eliminating the parasitic inductance caused by gold (Au) wire bonding and improving the impedance matching [14]. This configuration contributes to improving the EO bandwidth and reducing the electrical reflections (S11).

The measured EO responses and S11 are shown in **Fig. 4**. The measured 3-dB EO bandwidth for all channels exceeded 67 GHz, which was the limit of the measuring instrument. The electrical reflection was less than –10 dB, which is small enough for practical use. These results indicate that our IQ modulator meets the requirements for both a high-speed response and low-drive voltage by the use of a low-loss waveguide configuration and an optimized

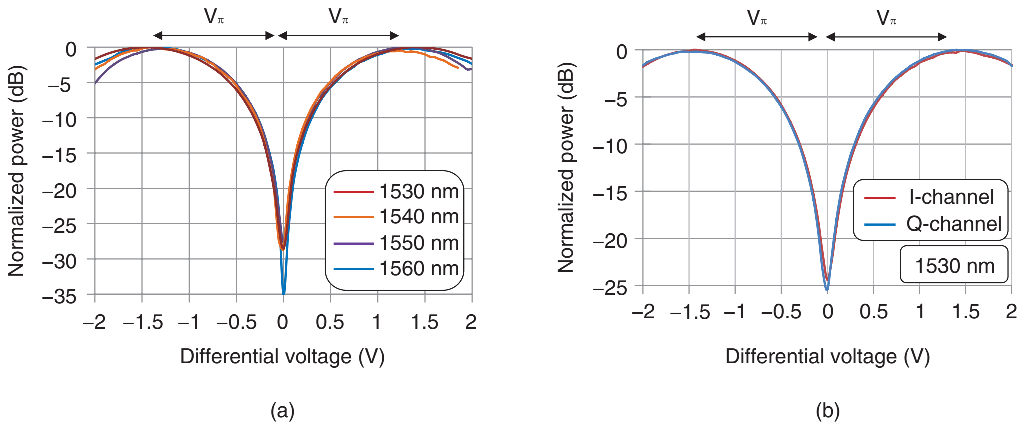


Fig. 3. Extinction ratio (ER) characteristics: (a) wavelength and (b) I-Q channel dependence.

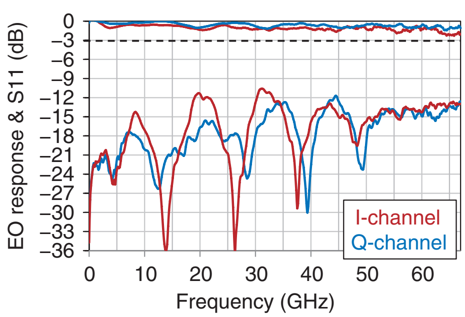


Fig. 4. Small-signal EO responses (1.5-GHz reference) and electrical reflections (S11) of the IQ modulator.

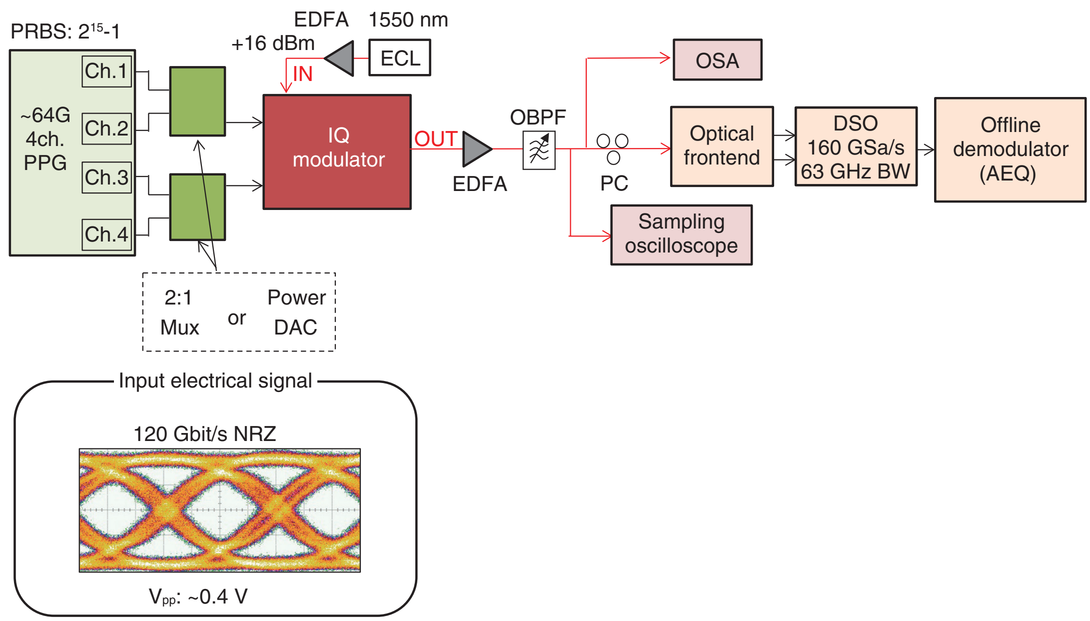
electrode design. Furthermore, we believe that the flip-chip configuration is a promising approach for high baud-rate operation compared with conventional RF-terminating connection techniques such as Au-wire bonding.

4. Single-IQ modulator characteristics

We also investigated the dynamic characteristics of our IQ modulator. The modulator was driven as a single-ended drive for 80- and 120-Gbaud QPSK modulations. The experimental setup for IQ modulations is shown in **Fig. 5**. We used an external cavity laser (ECL) with a < 30-kHz linewidth as the signal light source. The wavelength and power of the optical input were 1550 nm and +16 dBm, respectively. An up to 64-Gbit/s quad-channel pulse-pattern generator (PPG) was used as an electrical signal source. For 80- and 120-Gbaud QPSK signals, we used high-speed 2:1 multiplexers with an output voltage of ~0.4 V_{pp}, and multiplexed the electrical signals from the PPG into 80-Gbit/s and 120-Gbit/s signals.

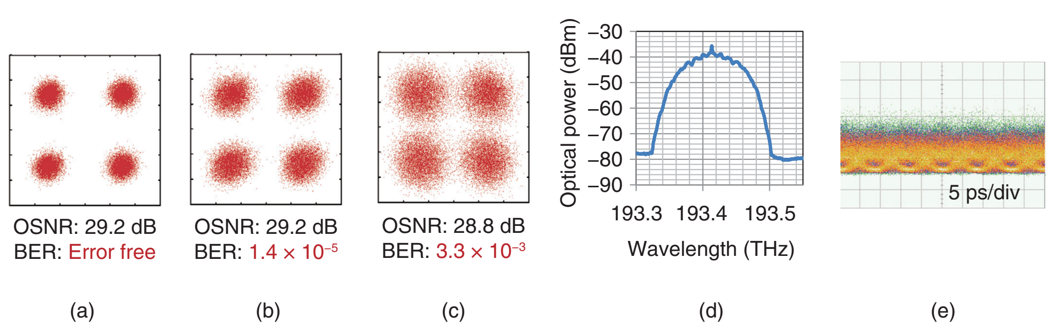
The generated electrical signals are shown in Fig. 5. These signals with a PRBS (pseudo random bit sequence) of 2^{15}-1 were then fed into the modulator via a multiport RF probe. The modulated optical signals were amplified by an EDFA (erbium-doped fiber amplifier) and passed through a 100-GHz optical filter. On the receiver side, we used a single-polarization offline coherent receiver consisting of an optical frontend, a DSO (digital storage oscilloscope) with a sampling rate of 160 GSa/s and an analog bandwidth of 63 GHz, and an offline demodulator, where we used an AEQ (adaptive equalizer). We also observed the modulated signals using an OSA (optical spectrum analyzer) and a sampling oscilloscope with an unfiltered optical bandwidth of 65 GHz.

The back-to-back constellation diagrams for 80-Gbaud QPSK and 120-Gbaud QPSK signals are shown in **Fig. 6(a)**, **(b)**, and **(c)**. Clear constellations were obtained for all modulations. We estimated the bit error rate (BER) for up to 120-Gbaud QPSK modulations, with the modulator driven directly by the multiplexer signals (without RF amplifiers), because no amplifier supporting a 120-Gbaud rate was available. We achieved error-free 80-Gbaud QPSK generation at the optical signal-to-noise ratio (OSNR) of 29.2 dB as shown in Fig. 6(a). We also evaluated the modulation without equalization and obtained a BER of 1.4×10^{-5} as shown in Fig. 6(b), when the length of the finite impulse response filter was set at 1. In the 120-Gbaud QPSK modulation, the BER at an OSNR of 28.8 dB was 3.3×10^{-3}, which is



AEQ: adaptive equalizer
BW: bandwidth
DAC: digital-to-analog converter
DSO: digital storage oscilloscope
ECL: external cavity laser
EDFA: erbium-doped fiber amplifier
Mux: multiplexers
NRZ: non return to zero
OBPF: optical bandpass filter
OSA: optical spectrum analyzer
PC: polarization controller
PPG: pulse-pattern generator
PRBS: pseudo random bit sequence

Fig. 5. Experimental setup for IQ modulations and generated electrical signals.



BER: bit error rate
OSNR: optical signal-to-noise ratio

Fig. 6. Constellation diagrams of (a) 80-Gbaud QPSK, (b) 80-Gbaud QPSK without equalization, and (c) 120-Gbaud QPSK signals. (d) and (e) are the optical spectrum and waveform of a generated 120-Gbaud QPSK signal.

still below the limit of the soft-decision 20%-overhead forward error correction in 400G systems.

The optical waveform and spectrum of the generated 120-Gbaud QPSK signal are respectively shown in **Fig. 6(d)** and **(e)**. Although the driving voltage was insufficient for a full swing condition (2 V_{π}), a clear 120-Gbaud rate modulation was confirmed. These results indicate that our modulator has an ultrahigh bandwidth characteristic. We can improve the BER characteristics by using an ultra-broadband amplifier and obtaining an adequate modulation depth.

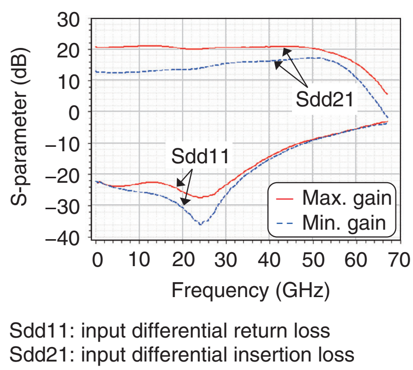


Fig. 7. Measured differential S-parameters.

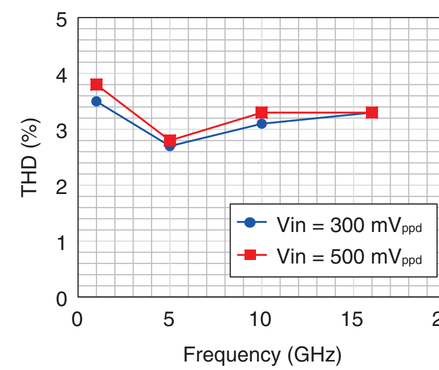


Fig. 8. Measured THD versus frequency.

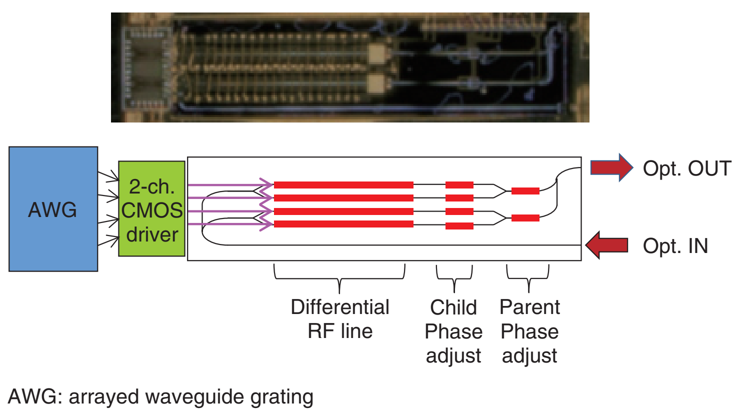


Fig. 9. Microscope image and schematic diagram of fabricated IQ modulator.

5. Driver IC co-assembled IQ modulator characteristics

For short reach applications such as metro-regional areas and transmission links between datacenters, small pluggable digital coherent transceivers with lower power consumption are needed. To meet this demand, we have developed modulator drivers with ultralow power dissipation, because a large portion of power for transceivers is consumed by driver ICs. We utilize a stacked current mode architecture and an open-drain structure to achieve the lower power consumption [15]. To obtain a wide bandwidth, three-dimensional inductors were used for the inductor peaking techniques [16]. Our modulator driver was fabricated using 65-nm CMOS technology. When the driver drives a 50-Ω impedance load, the consumed power is only 180 mW. The measured differential S-parameters (scattering parameters) at the maximum and minimum gain settings are shown in **Fig. 7**. At the maximum gain setting, the 3-dB bandwidth and the differential gain are 56.2 GHz and 20.8 dB, respectively. At the minimum gain setting, they are 60.6 GHz and 12.9 dB, respectively.

Single-tone sine wave responses were measured to evaluate the linearity of the driver. The measured total harmonic distortion (THD) versus frequency at an output swing of 2 V_{ppd} is plotted in **Fig. 8**. From a 300- to 500-mV_{ppd} input swing and in a 1- to 16-GHz frequency range, the THD remains less than 4%.

A microscopic image and a schematic diagram of the fabricated IQ modulator co-assembled with the dual-channel CMOS differential driver IC we developed are shown in **Fig. 9**. The differential drive scheme provides the IQ modulator with both lower power operation and broadband pure push-pull (zero chirp) drive [17]. In the experimental setup, we used an arbitrary waveform generator with a sampling rate

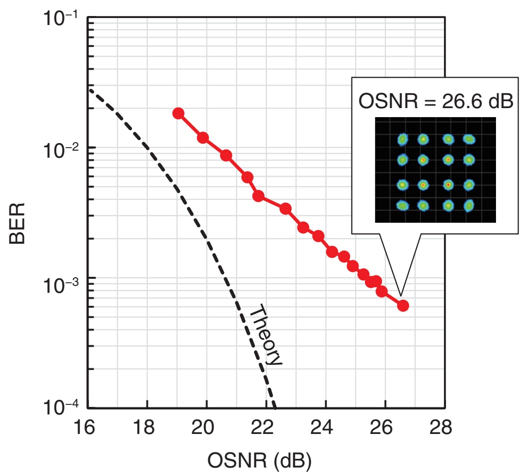


Fig. 10. Constellation diagram and BER characteristics of 64-Gbaud/16QAM.

of up to 92 GSa/s (Keysight M8196A) as a signal source, and an optical modulation analyzer (OMA) (Keysight N4391A OMA) on the receiver side. In addition to the OMA, we used an offline demodulator for BER measurements as well as for the single-IQ modulator evaluation. Similarly, other instruments in our setup such as the ECL and the optical filter were also the same as those for the previous experiment.

The measured single-polarization 64-Gbaud/16QAM constellation diagram and the back-to-back BER as a function of the OSNR are shown in **Fig. 10**. We obtained a clear constellation and a BER of less than 10^{-2} for an OSNR of more than 20.3 dB. The OSNR penalty from the theoretical limit at a BER of 10^{-2} was approximately 2.3 dB. The difference is mainly due to the performance limitations of the experimental instruments and imperfect adjustment of the IQ modulator driving condition. The consumed power of the two channels of the driver IC was only 495 mW. These results indicate that we have attained a driver IC power dissipation of less than 1 W for dual-polarization IQ modulation in 400-G/λ systems.

6. Conclusion

We described an ultrahigh bandwidth and low-V_π InP IQ modulator with an n-i-p-n heterostructure. The device exhibited a 3-dB EO bandwidth of over 67 GHz, a V_π of less than 1.5 V, and low optical loss operation. We obtained clear IQ modulation signals at a rate of up to 120 Gbaud without optical pre-equalization. Furthermore, we developed the most power-efficient modulator driver—a 56-GHz-bandwidth 2.0-V_{ppd} linear modulator driver employing 65-nm CMOS technology—and succeeded in demonstrating 64-Gbaud/16QAM operation by co-assembling the driver IC with an IQ modulator chip on a carrier. We believe our low electrical and optical loss modulator is suitable for both ultrahigh speed and ultralow power modulation for use in next-generation coherent transmitters.

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Standardization Trends of oneM2M for Horizontal Internet of Things Platform

Kei Harada, Hiroyuki Maeomichi, and Ikuo Yamasaki

Abstract

The oneM2M partnership project was founded to promote the standardization of a horizontal Internet of Things (IoT) platform. The aim is to establish specifications for a functional group that can be used in common by many IoT systems as a platform, while also formulating specifications for interworking with other existing standards. This article introduces the overall organization and specifications of oneM2M and reports some recent trends.

Keywords: IoT, horizontal IoT platform, oneM2M

1. Overview of oneM2M organization

The oneM2M organization was founded in 2012 in order to avoid having an overabundance of standards for Internet of Things (IoT) platforms and to promote the drafting of specifications for a horizontal IoT platform. It was formed as a partnership project by seven standards development organizations (SDOs) in Europe, the United States, Japan, China, and Korea, including the European Telecommunications Standards Institute (ETSI), the Association of Radio Industries and Businesses (ARIB), and the Telecommunication Technology Committee (TTC). Now, with the addition of Telecom Standards Development Society, India (TSDSI) in 2015, oneM2M is managed by eight regional SDOs as Partner Type 1 organizations. In addition, members selected by Partner Type 1 organizations form a Steering Committee that oversees a Technical Plenary followed by six Working Groups (**Fig. 1**). Technical discussions related to oneM2M specifications are held at six face-to-face meetings every year and in conference calls conducted between those meetings.

Release 1 and Release 2 of oneM2M specifications were released in May 2015 and August 2016, respectively. As of this writing, Release 3 is scheduled for March 2018.

2. Basis specifications in Release 1

The oneM2M specifications are divided into two levels: high-level architecture independent of communication methods and specific lower-level communication methods [1, 2].

An overview of this architecture is shown in **Fig. 2**. Here, entities related to communications include an Application Entity (AE), which represents an application, and a Common Services Entity (CSE), which is a collection of common functions in the IoT system. Also specified are reference points between these entities such as Mca (between CSE and AE) and Mcc (between CSE and CSE). In this architecture, CSEs are deployed at the cloud, edge, gateways and other areas and are interconnected in a tree structure. An AE operates in conjunction with one of these CSEs. It can also exchange messages with a CSE to which it is not directly connected by routing via other CSEs.

A CSE is a collection of common functions required by many IoT systems. There are 12 types of functions in all, including those for data management, device management, and security (**Fig. 3**). These functions are expressed as resources to enable external use through resource operations performed via an external AE or CSE. Resource operations have

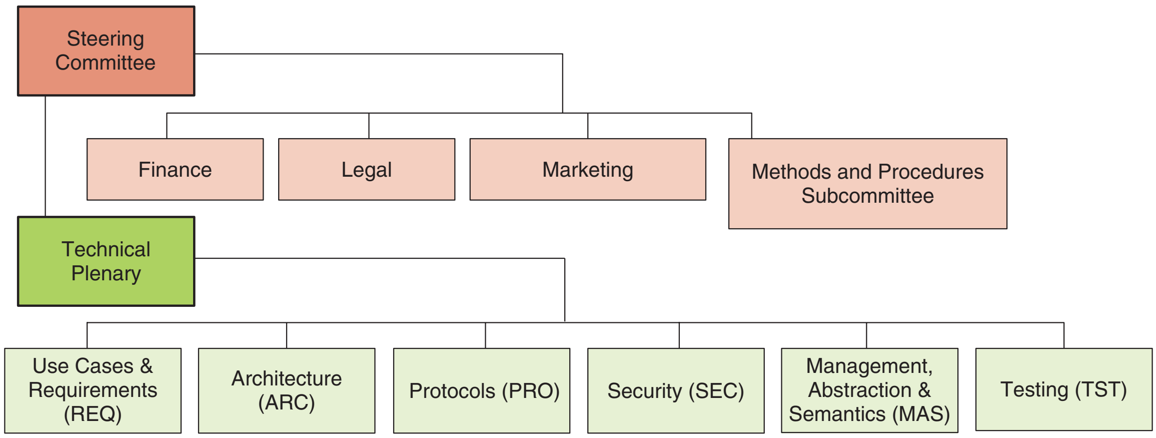

Fig. 1. oneM2M organization.

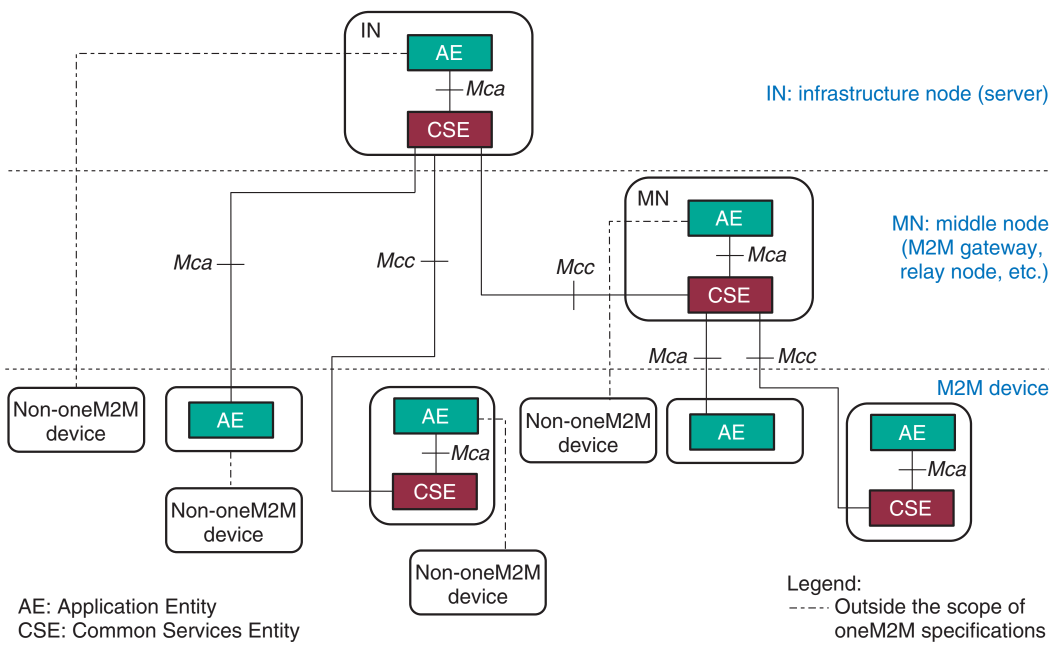

Fig. 2. Architecture of oneM2M specifications.

been narrowed down to CREATE, RETRIEVE, UPDATE, DELETE, and NOTIFY. Using only five operations in this way achieves a simpler protocol design than a web service, in which developers can define any operations.

Multiple types of oneM2M resources have been specified such as <contentInstance> for storing sensing data, <container> for storing those instances, and <subscription> for receiving notifications of information updates. The main types of resources are listed in **Table 1**.

Specific communication methods used under the above architecture can be selected from a variety of protocols and message encoding schemes (called serialization). Release 1 of oneM2M allows for protocol selection from HTTP (Hypertext Transfer Protocol), CoAP (Constrained Application Protocol), and MQTT (Message Queue Telemetry Transport) and serialization from XML (Extensible Markup Language) and JSON (JavaScript Object Notation).

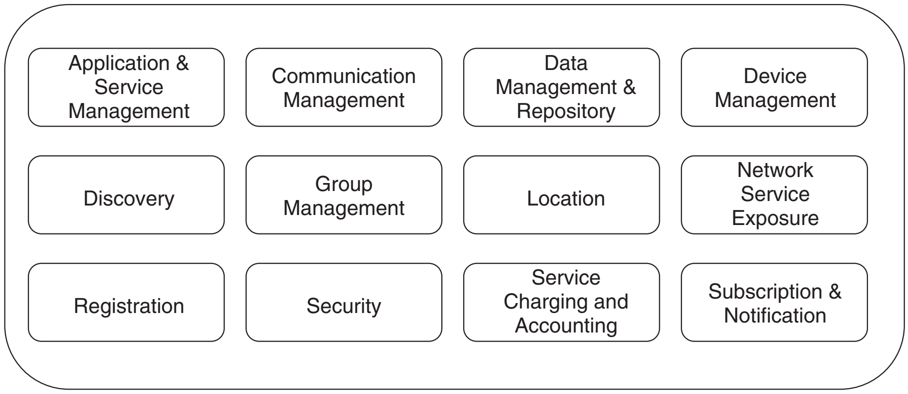

Fig. 3. Common functions of CSE.

Table 1. Principal types of resources.

Resource name	Role/Feature	Release
<CSEBase>	The root of the tree consisting of all resources. Each resource is registered under this root.	R1
<container>	Acts as a container for data buffering	R1
<contentInstance>	Generated directly under <container> for storing data	R1
<subscription>	Generated directly under a target resource to receive notifications in the event of resource changes, etc.	R1
<accessControlPolicy>	Policy governing access control	R1
<flexContainer>	Used for customizing attributes—introduced to handle diverse types of attributes in interworking	R2
<timeSeries>	Though similar in role to <container>, it includes a function for detecting missing time series data.	R2
<timeSeriesInstance>	Generated under <timeSeries>. Though similar in role to <contentInstance>, it can save data-generation time as an attribute.	R2

This approach enables the selection of a communication method appropriate to requirements at the time of system development while simplifying migration in the event that a superior communication method becomes available in the future.

In addition, oneM2M provides a framework for linking to and operating with other standard protocols [3–6]. A type of AE called an Interworking Proxy Application Entity (IPE) can communicate with another standard protocol. An IPE creates a resource on CSE as reflecting information on the other protocol so that other AEs on oneM2M can read that information. Conversely, the IPE can monitor for resource updates performed by oneM2M AEs and notify and interact with the other standard protocol accordingly. In short, an IPE enables oneM2M to link up with another standard protocol.

3. Extensions in Release 2 and Release 3

In this section, we describe the main elements included in these releases.

3.1 Release 2

Release 2 of oneM2M contained specifications for the home and industrial domains and for interworking, and it introduced semantics technology.

Specifications for the home domain included an information model for home appliances. Specifications for the industrial domain introduced the <timeSeries> and <timeSeriesInstance> resources for handling time series data. In addition, more options for communication methods were added to enable high-immediacy communications and more efficient communications. Specifically, Websocket was added as a protocol, and CBOR (Concise Binary Object

Representation) was added as a binary format for serialization.

Release 2 also presented interworking specifications with AllJoyn, OIC (Open Interconnect Consortium), and LwM2M (Lightweight M2M) and introduced the <flexContainer> resource to enable efficient representation of diverse types of data.

In terms of semantics technology, Release 2 introduced the <semanticDescriptor> resource that enables the meaning of data to be described using RDF (Resource Description Framework). This information can be used to search for resources.

3.2 Release 3

Scheduled for release in March 2018, Release 3 is focused on efforts to promote the adoption of oneM2M. Thus, key items—a developer's guide and test specifications—have been revised and improved. Release 3 also includes more extensions to home-domain specifications. Of these, interworking between oneM2M and healthcare devices specified by OMA GotAPI* (DeviceWebAPI) was approved. Specifically, a data model for representing target devices on oneM2M was added, and its correspondence with the data model on the OMA side was specified. These additions to oneM2M specifications were achieved through a collaborative effort among NTT Network Innovation Laboratories, NTT Service Evolution Laboratories, and NTT DOCOMO.

4. Trends surrounding oneM2M

We introduce here three major trends surrounding oneM2M: interoperability test events, certification, and open source software (OSS).

4.1 Interoperability test event

An interoperability test event is an event in which each company brings its own implementation and conducts interoperability tests. This is an open event lasting about four or five days, and even non-oneM2M members can participate. It has been held twice a year since 2015. In this event, a participant performs an interoperability test with a predetermined partner according to oneM2M test specifications [7] in a session lasting one to two hours. This session is repeated about four times a day. Taking part in this event enables a participant to efficiently improve the quality of its implementation. It also enables discrepancies with or ambiguities in oneM2M specifications to be identified and mutual operability to be verified. NTT has participated in all five past events.

4.2 Certification

Certification is an activity that assesses (through testing) whether a product complies with standards and specifications and if so, gives permission to display that fact. Being a partnership project, oneM2M is not a corporate entity, so it itself cannot act as a certification body. It has therefore been decided to consign the work of certification to an outside institution. Several discussions have been held with regard to this matter, and with an eye to commencing oneM2M certification as early as possible, it was agreed in April 2016 that certification work would be rolled out in stages beginning with regional certification (Phase 1) followed by global certification (Phase 2). Taking the lead in Phase 1, Korea's Telecommunication Technology Association (TTA) began certification activities targeting Asia in February 2017. As of December 2017, 11 products of 8 companies had been certified. Global certification targeting the entire world as Phase 2 is scheduled to begin in the middle of 2018 using the Global Certification Forum (GCF) in the United Kingdom as the certification body.

4.3 OSS

Implementations of oneM2M through OSS projects are also progressing. Some examples of CSE implementations are OM2M of the Eclipse project, Mobius of the OCEAN project, and IoTDM of the OpenDaylight project. In addition, OS-IoT promoted by the Alliance for Telecommunications Industry Solutions (ATIS) is a software library for developing AEs for embedded devices.

5. Future plans

At the time of this writing, Release 3 of oneM2M was scheduled for release in March 2018. In addition, procedures for transposition of oneM2M specifications as the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Recommendations are proceeding, and the plan is to reach a consensus in this regard in ITU-T Study Group 20. This endorsement as ITU-T Recommendations should further advance the awareness and spread of oneM2M.

The formulation of oneM2M Release 4 specifications

* OMA GotAPI: Generic Open Terminal API Framework (GotAPI) standardized by the Open Mobile Alliance (OMA).

will begin in earnest following the release of Release 3. As of December 2017, improving access control and simplifying the oneM2M platform had been approved as items to be taken up. It is also being proposed that more attention should be given to the smart city domain [8] as an application of oneM2M, in view of the high affinity of this field with the oneM2M platform.

NTT Network Innovation Laboratories considers oneM2M to be promising as an IoT platform standard. Going forward, it plans to make contributions and proposals and lobby the oneM2M partnership project with the aim of making oneM2M into specifications that can be effectively used by the NTT Group.

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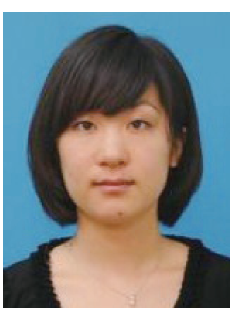
Trademark notes



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Examples of RT-BOX Deterioration and New Inspection Method

Abstract

Maintaining outdoor equipment is necessary in order to provide communication services without interruption. This article describes the deterioration that can occur in certain outdoor facilities and how we are working to improve the inspection and maintenance process. This is the forty-fifth article in a series on telecommunication technologies. This contribution is from the Materials Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: RT-BOX, corrosion, inspection manual

1. Introduction

Modern information and communication services are supported by a variety of facilities including radio towers, utility poles, conduits, manholes, and tunnels. Among these, the remote terminal box (RT-BOX) and remote subscriber module (RSBM) are important facilities for accommodating and multiplexing public and leased circuits and connecting them by optical fiber to central offices. In particular, the RT-BOX as an outdoor facility is continually exposed to diverse environmental conditions including wind, rain, and airborne salt, making periodic inspections all the more important.

The Materials Engineering Group of the Technical Assistance and Support Center has surveyed instances of deterioration in RT-BOX facilities and made technical contributions toward the formulation of a new inspection manual. In this report, we introduce examples of RT-BOX deterioration and describe a new inspection method.

2. Examples and causes of RT-BOX deterioration

The RT-BOX uses dedicated housing installed with air conditioning equipment in order to protect telecommunications equipment from the surrounding environment (**Fig. 1**). This housing consists of painted steel in which seams and gaps are sealed by caulking. Here, the deterioration and peeling of paint or caulking due to environmental effects such as ultraviolet radiation and outside air temperatures will expose the steel material to rainwater, water vapor, and other elements, thereby accelerating corrosion. Such a situation will reduce the ability of the RT-BOX to safely house the telecommunications equipment, so some sort of repair work will be needed such as reinforcement of the housing or replacement of components or materials.

Examples of deterioration in steel, paint, and caulking commonly seen in RT-BOX housing are shown in **Figs. 2–4**. The tendency of paint to deteriorate at corners and uneven sections of the RT-BOX housing can be seen. This is because applied paint easily thins out at corners and uneven sections and because stress concentrates at such locations along with the expansion and contraction of steel due to outside air temperatures. Furthermore, the deterioration or peeling of caulking can drive the corrosion of steel as described above, so special attention is needed here.

We can also show an example of deterioration caused specifically by the structure of the RT-BOX housing. Here, moisture generated by the outdoor unit of the air conditioning equipment in the RT-BOX turned into pooled water and was not appropriately discharged. This water then entered the housing from the seam between this outdoor unit and the outer wall,

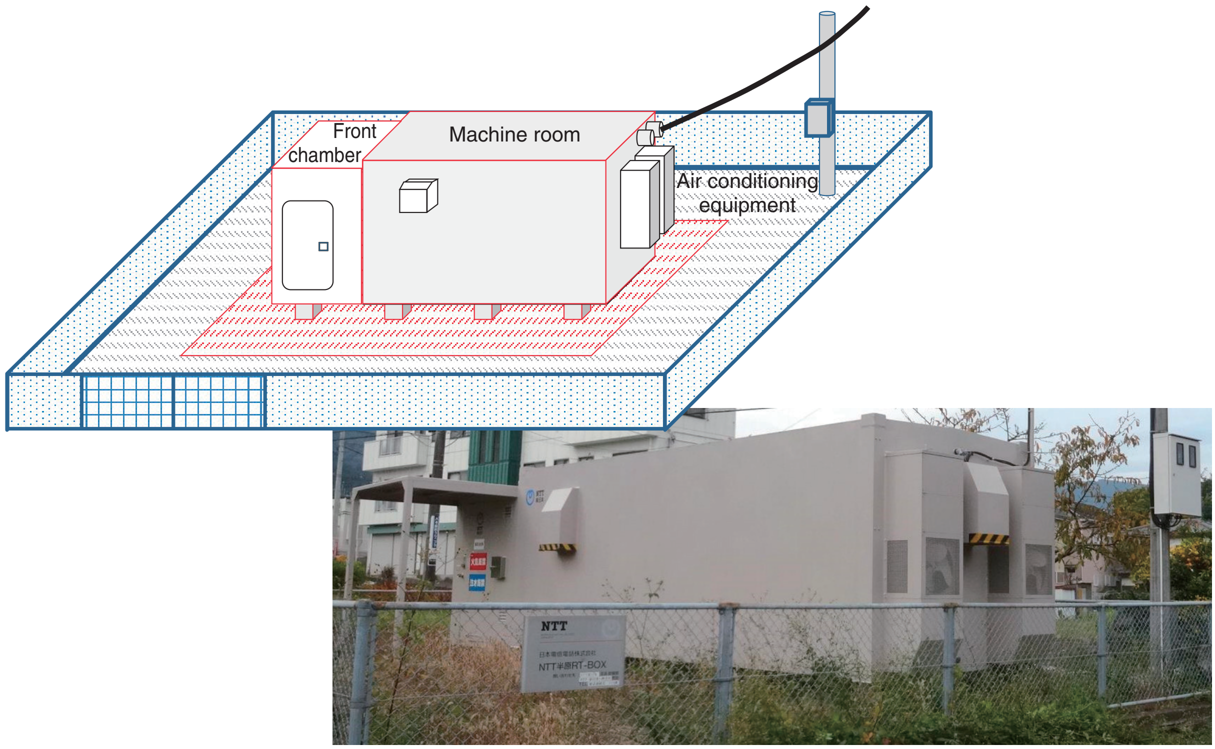


Fig. 1. External view of RT-BOX.

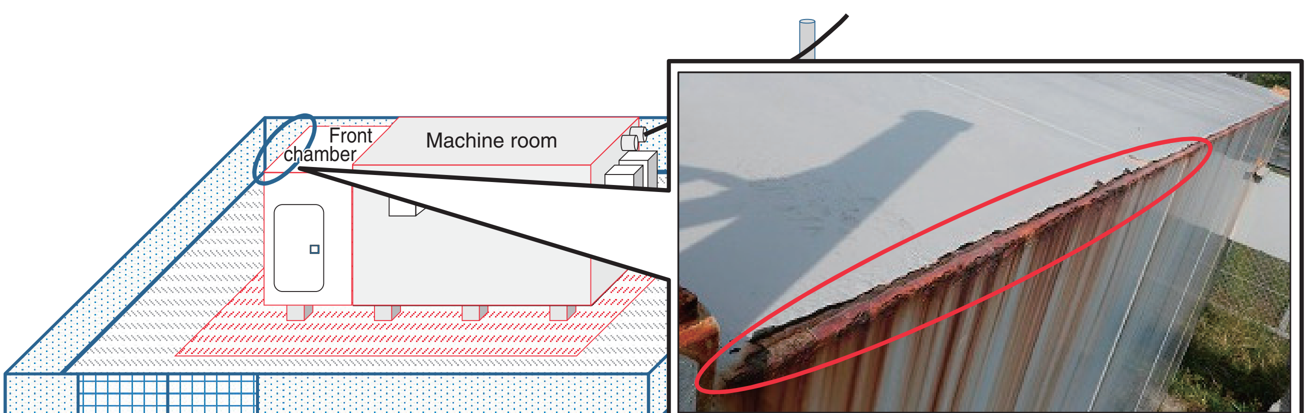


Fig. 2. Example of deterioration in RT-BOX steel.

and the interior portion of steel at the lower side of the RT-BOX corroded (**Fig. 5**).

3. New RT-BOX inspection method

Similar to other NTT facilities, the RT-BOX is a target of inspections. The facility inspection manual ver. 4 (March 2015) describes a method for inspecting an RT-BOX. The instructions given in the manual, however, are somewhat vague and difficult to understand. They fail to specifically indicate what, where, and with what criteria to inspect. One example of such instructions is "Check for external deformation, rust, and damage." Simply specifying "external" here

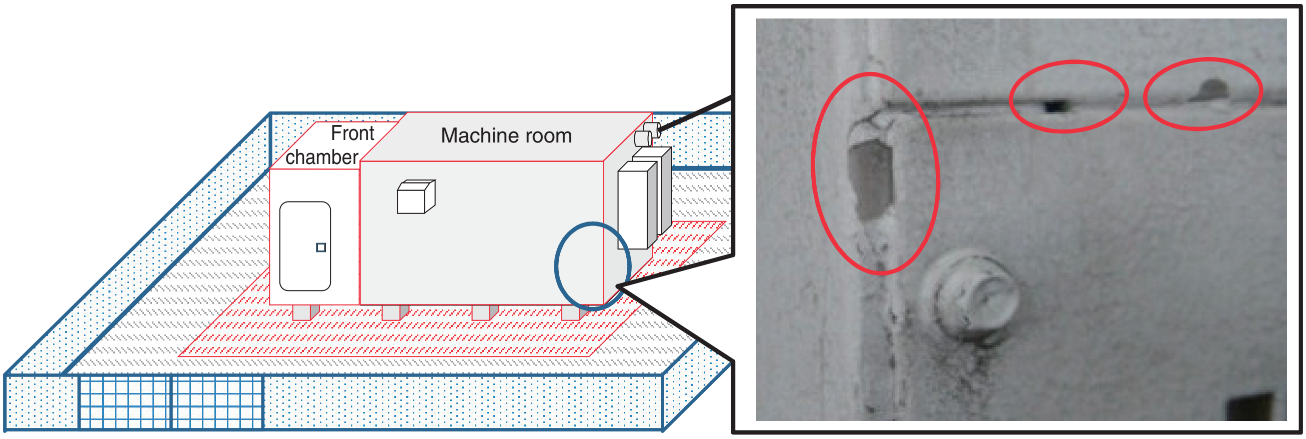


Fig. 3. Example of deterioration in RT-BOX paint.

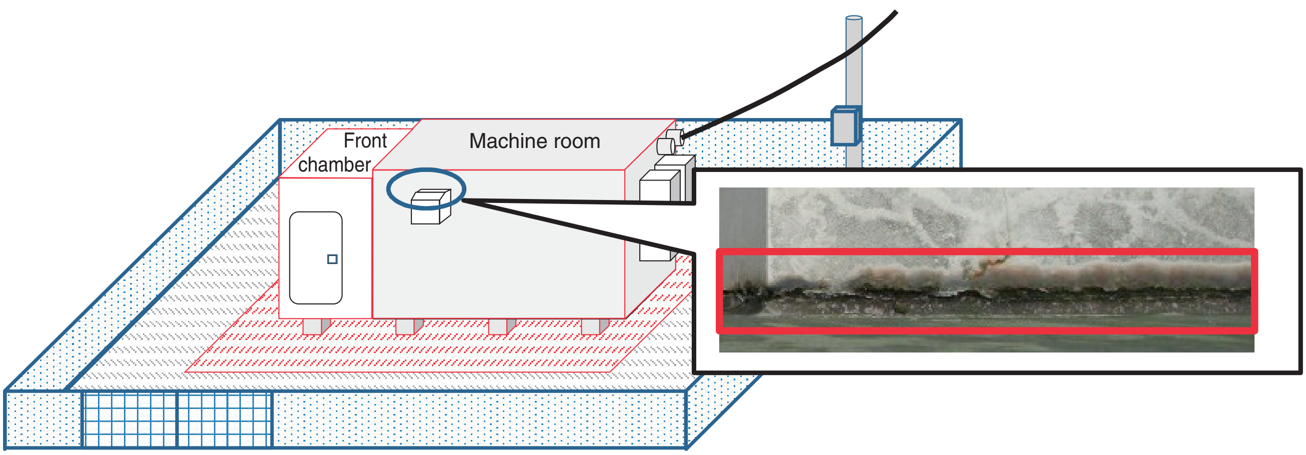


Fig. 4. Example of deterioration in caulking.

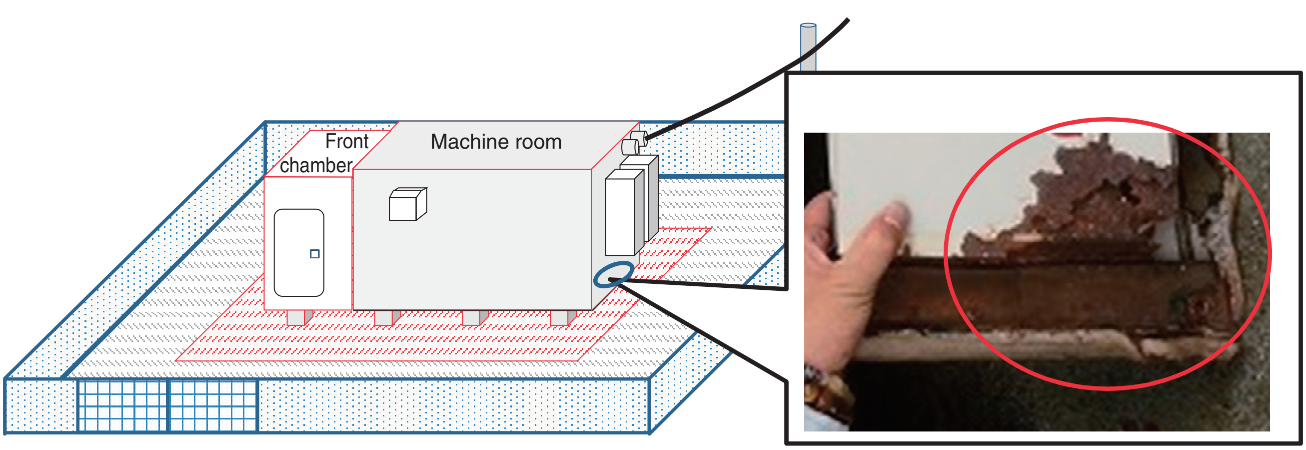
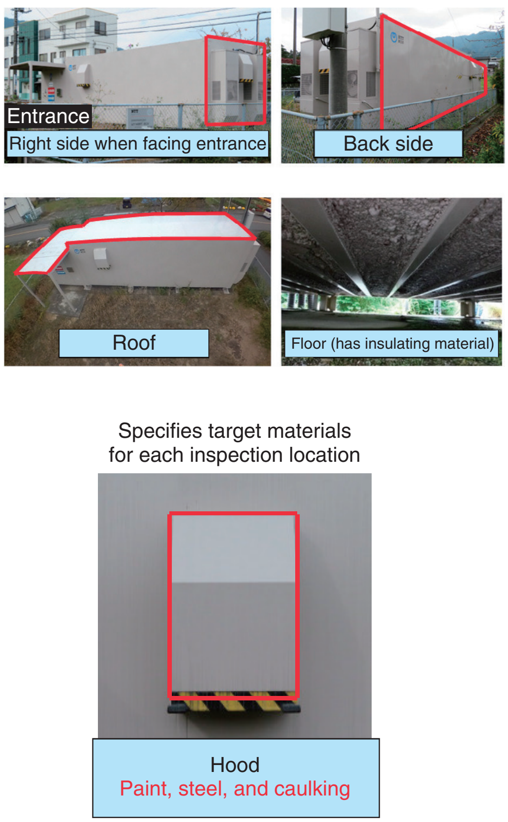


Fig. 5. Example of deterioration of inner steel due to pooled water from RT-BOX air conditioning equipment.

Points out specific inspection locations



Clarifies inspection criteria

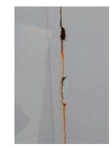
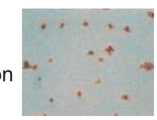
Degree of deterioration			Description
Housing deterioration	Degree S	• Red rust • Dripping rust stain • Perforation	■ Red rust (rust points aggregate and become larger) Applicable to cases in which rust points on steel panels aggregate and become a large mass of red rust  ■ Dripping rust stain Traces of dripping water that includes red rust  ■ Perforation State in which corrosion of steel panels has progressed and a perforation is observed 
	Degree A	• Rust points	■ Rust points State in which rust points have appeared on steel panels, often on the paint's surface 
	Degree B	• Deformation, repair traces	■ Deformation, repair traces Applicable to cases in which bumps or traces of repair on wall surface are observed on steel panels 
	Degree C	• No anomalies	■ No anomalies Applicable to cases in which no rust, rust stains, or deformation can be observed on steel panels

Fig. 6. Concept of new inspection manual.

is quite ambiguous with no clear indication of where to look. Moreover, deformation, rust, and damage each have inherently different causes and cannot be lumped together, but criteria related to the progress of deterioration specific to each are unclear.

With the objective of protecting the equipment-installation environment within the RT-BOX machine room, we proceeded to formulate a new inspection manual. Here, of the components and materials making up an RT-BOX, we focused on steel, paint, and caulking as materials whose deterioration could have an effect on the environment in the machine room, and based on knowledge of deterioration mechanisms accumulated by the Technical Assistance and Support Center, we compiled specific inspection locations and criteria (**Fig. 6**).

Clear specification of inspection locations in the above way enables thorough inspections to be performed. In addition, providing a table of deterioration samples for each of the steel, paint, and caulking materials enables scoring of the degree of deterioration observed. This mechanism makes it possible to assess the overall degree of RT-BOX deterioration based on the scores of each inspection location and to assign priorities to RT-BOX repair work.

4. Conclusion

In this report, we presented examples of RT-BOX deterioration and introduced a new inspection method. Based on the respective deterioration mechanisms of the paint, caulking, and steel making up an RT-BOX, we established inspection locations and criteria and introduced a system for scoring inspection results. Going forward, we plan to contribute to activities aimed at spreading the use of this new RT-BOX inspection method.

Event Report: Tsukuba Forum 2017

Wataru Yamada, Keiji Okamoto, Koji Ieda, and Tomoyuki Nomura

Abstract

Tsukuba Forum 2017 was held on October 19 and 20. The theme of the forum was *Creating Access Network Together with Essential Partners ~Advanced IoT/5G Technology and Safe Construction and Operation of Facilities*. This article gives a brief overview of the speeches and exhibits presented at the forum.

Keywords: Tsukuba Forum, access network, 5G, IoT, safe construction and operation

1. Introduction

The Tsukuba Forum is Japan's largest integrated symposium on technologies related to access networks. The 2017 event was the 28th one held since the first event in 1990. The theme of the 2017 event was *Creating Access Network Together with Essential Partners ~Advanced IoT/5G* Technology and Safe Construction and Operation of Facilities*. This theme expresses the desire to create an access network that leads society to sustainable development for everyone who uses the network together with those who create, maintain, and support it. In addition to NTT Access Network Service Systems Laboratories (AS Labs), 113 organizations (**Table 1**) participated and presented the latest research and development (R&D) and technological trends.

2. Overview of speeches

The keynote speech and a special speech were given at the Tsukuba International Congress Center on the first day. They were relayed from the main convention hall of the International Congress Center, which was the main venue, to a venue at the NTT Tsukuba R&D Center. Live streaming and video-on-demand distribution services through a video portal site were also offered.

2.1 Keynote speech

Mr. Yoshihiro Kuroda, Representative Member of the Board, Senior Executive Vice President and Senior Executive Manager of the Plant Headquarters from NTT WEST, gave a keynote speech entitled "Activities of the NTT WEST Group" (**Photo 1**). He introduced the group structure together with the roles of the NTT WEST Group companies. He also explained areas of interest, the situation with competing companies, and sales and profit information. In fiscal year (FY) 2016 (April 1, 2016–March 31, 2017), NTT WEST achieved a record operating profit of 95.1 billion yen and is aiming for 100 billion yen in FY 2017 based on three strategies: strengthening profitability in business markets, increasing the profit from fiber optic services, and expanding the business growth in each Group company.

In terms of strengthening profitability in the business market, yearly growth is expected as a major pillar of earning. The sales target is more than 600 billion yen, with over 35 billion yen in profit in FY 2017. Regarding the expansion of profit from fiber optic services, Mr. Kuroda reported that the number of subscribers of these services had reached 9 million in August 2017 and that subscriptions through a wholesale business model called Hikari Collaboration Model will be about 50% of the total number in

* IoT/5G: Internet of Things/fifth-generation mobile networks

Table 1. List of exhibitors.

■NTT Group companies
- NTT EAST CORPORATION
- NTT EAST-MINAMIKANTO CORPORATION
- NTT EAST-KANSHINETSU CORPORATION
- NTT Infrastructure Network Corporation
- AIREC ENGINEERING CORPORATION
- NTT RENTAL ENGINEERING Co., Ltd.
- NTT Broadband Platform, Inc.
- NTT GEOSPACE CORPORATION
- NTT WEST CORPORATION
- NTT FIELDTECHNO CORPORATION
- NTT Communications Corporation
- NTT World Engineering Marine Corporation
- NTT DOCOMO, Inc.
- DOCOMO CS, Inc.
- NTT FACILITIES, INC.
- NTT Electronics Corporation
- NTT Advanced Technology Corporation
- NTT-AT Techno Communications Corporation
- NIPPON CAR SOLUTIONS Co., Ltd.

■Information & Telecommunications Engineering Association of Japan (ITEA)
- EXEO TECH CORPORATION
- KYOWA EXEO CORPORATION
- Nippon COMSYS Corporation
- MIRAIT Corporation
- TOSYS CORPORATION
- NDS Co., Ltd.
- C-Cube Corporation, Ltd.
- Hokuriku Denwa Kouji Co., Ltd.
- NIPPON DENTSU Co., Ltd.
- MIRAIT Technologies Corporation
- SOLCOM Co., Ltd.
- Shikokutsuken Co., Ltd.
- Seibu Electric Industry Co., Ltd.
- SYSKEN Corporation
- DAIWA DENSETSU CORPORATION
- TTK Co., Ltd.
- TSUKEN CORPORATION

■Communication Line Products Association of Japan
- AICHI CORPORATION
- ASABA MANUFACTURING CO., LTD.
- OCC Corporation
- Okano Cable Co., Ltd.
- Kando Co., Ltd.
- KYOEI HIGH OPT Co., Ltd.
- JFE Metal Products & Engineering Inc.
- JAPAN RECOM Ltd.
- SHODENSHA CO., LTD.
- SWCC SHOWA CABLE SYSTEMS CO., LTD.
- Suzuki Giken Co., Ltd.
- SUDA SEISAKUSYO Co., Ltd.
- Sumiden Opcom, Ltd.
- Sumitomo Electric Industries, Ltd.
- 3M Japan Limited
- SEIWA GIKEN, Inc.
- SENSHU ELECTRIC CO., LTD.
- DYDEN CORPORATION
- DAITO DENZAI Co., Ltd.
- Tadano Ltd.
- Tsushin Kogyo Electric Wire & Cable Co., Ltd.
- TOSHIN ELECTRIC Co., Ltd.
- TOTSU-SOKEN CORPORATION
- SEI Optifrontier Co., Ltd.
- NISHI NIPPON ELECTRIC WIRE & CABLE CO., LTD.
- NIPPON CONCRETE INDUSTRIES CO., LTD.
- Nippon Seisen Cable, Ltd.
- Nippon Tsushin Denzai Co., Ltd.
- Fujikura Ltd.
- Fujikura Dia Cable Ltd.
- Furukawa Electric Co., Ltd.
- MASARU INDUSTRIES, LTD.
- Dainichi Corporation

■Communications and Information Network Association of Japan (CIAJ)
- Anritsu Corporation
- FXC, Inc.
- NEC Corporation
- NEC Networks & System Integration Corporation
- NEC Magnus Communications, Ltd.
- Oi Electric Co., Ltd.
- SEIKO SOLUTIONS, INC.
- NAKAYO, INC.
- Hitachi, Ltd.
- Viavi Solutions Japan K.K.
- FUJITSU LIMITED
- HellermannTyton Co., Ltd.
- MARUBUN CORPORATION
- Mitsubishi Electric Corporation
- Yokogawa Test & Measurement Corporation / Yokogawa Solution Service Corporation
- ASAKURA FACTORY Co., Ltd.
- IWABUCHI CORPORATION
- OTANI KOGYO CO., LTD.
- Sankosha Corporation
- SANRITZ ELECTRONICS CO., LTD.
- SANWA DENKI KOGYO CO., LTD.
- TAIEI Manufacturing Co., Ltd.
- Takacom Corporation
- Takachiho Sangyo Co., Ltd.
- TOMEI TSUSHIN KOGYO CO., LTD.
- NAGAMURA MANUFACTURING CO., LTD.
- NISSHIN ELECTRIC CO., LTD.
- Hakusan Inc.
- HACHIKO ELECTRIC CO., LTD.
- Fukuoka Tsushin Kozai Seisakusho Co., Ltd.
- MIYOKAWA Manufacturing Co., Ltd.
- WATANABE CO., LTD.
- Japan Telecommunications Equipment and Materials Manufacturers Cooperative Association

■Other companies
- NTEC
- SUNREC CO., LTD.
- HARADA CORPORATION
- MIKI Inc.
- MAEDA ROAD CONSTRUCTION Co., Ltd.

FY 2017.

Efforts are underway to expand the business growth of each Group company, and the goal was set to achieve 150 billion yen in sales through undertaking outsourced work, developing real estate, and strengthening new business endeavors in areas such as the cloud, networks, datacenters, content, and games. In addition, the activity status of the global business and the preparation status for various sports events to be scheduled in the future were introduced.

Next, the state of facilities was discussed. Investments in facilities have been reduced over the years, shifting from the legacy system to growth fields. Data traffic is increasing by 1.5 times annually, and 60% of it is occupied by video traffic. Several solutions were introduced to address this situation, including simplifying networks, using a large-scale network, and implementing traffic management. In addition, in preparation for the major sports event scheduled for 2020, the NTT WEST Group is dealing with security issues in collaboration with organizations inside and outside the group. Another major management task is improving operational efficiency while promoting network migration, which will lead to cost reductions. Smart operation was also mentioned in the example of a remote technician taking the initiative to support on-site work by consolidating skills and know-how. As part of efforts to strengthen security and safety, it was announced that NTT WEST is preparing for an anticipated Nankai Trough earthquake by taking the lessons learned from the Kumamoto earthquake into consideration.

New business models, namely game services, power consumption visualization, and cloud services

Photo 1. Mr. Yoshihiro Kuroda, NTT WEST Senior Executive Vice President, delivering keynote speech.

Photo 2. Mr. Masaaki Moribayashi, Senior Vice President of NTT Communications, delivering special speech.

promoted by the NTT WEST Group companies were also introduced. Activities for expanding business opportunities in cooperation with partner companies were described, using examples of the actual alliances. Through such efforts, the NTT WEST Group companies are contributing to solving various social issues.

Finally, several new initiatives were introduced in the IoT and edge computing fields; trials are underway in collaboration with various partner companies.

2.2 Special speech

Mr. Masaaki Moribayashi, Senior Vice President, Cloud Services, NTT Communications (NTT Com), gave a special speech entitled "NTT Com's Cloud and Data Center Strategy" (**Photo 2**).

The speech opened with a statement that NTT Com aims to increase the proportion of employees who work outside Japan as global activities grow, as well as to increase global business revenue from the current 27% to 40% in FY 2020. One of the strengths in promoting globalization is that NTT Com offers all resources, from networks to solutions—especially in cloud colocation networks at the global level—and can provide integrated services.

With regard to datacenter business, it was stated that the submarine cable network and datacenters are designed and provided in a unified way, and that great effort is made to thoroughly pursue reliability and performance. The Hong Kong Financial Data Center was cited as an example, where the cable landing station and the datacenter are integrated. In the past, carriers have invested in submarine cables for the ever-increasing Internet traffic, but it was recently revealed that a large amount of the investment comes from over-the-top (OTT) service operators. Furthermore, while Internet traffic was once concentrated in the United States, it is now concentrated in Asia. NTT Com's datacenters were mainly located in Japan in 2013. However, the locations outside Japan now account for about 70% of the total size, and thus, the annual capacity growth ratio of the company's datacenters is number one in the world. Mr. Moribayashi then announced NTT Com's plans to connect the company's datacenters operating throughout the world with a closed 10-Gbit/s network and to provide services while connecting not only to its own company but also to other companies' cloud facilities.

As for the cloud service business, it was noted that private clouds are dominant in the domestic services and that NTT Com aims to provide private clouds for enterprises and a hybrid type cloud that combines the good points of both private and public cloud services. It was also explained how seamless service can be provided by setting a cloud and a network for each site and by managing customers' ICT (information and communication technology) environments while reducing operational costs by applying unified management to multiple clouds.

Lastly, two examples of collaboration with partner companies were introduced, namely, technology developed with McLaren-Honda and the enterprise resources planning service developed with Virtustream Inc.

Photo 3. Workshop leaders (from left to right: Mr. Soichi Nakajima, Digital Telco Lead Analyst of IDATE DigiWorld; Mr. Shuichi Yoshino, project manager of NTT Network Innovation Laboratories; Mr. Hiroyuki Nakamura and Dr. Atsushi Nobiki, project managers of AS Labs).

2.3 Workshops

A series of workshops was held in the afternoon of the first day and on the second day. They included lectures given by an analyst from IDATE DigiWorld and by three project managers from NTT Network Innovation Laboratories and AS Labs (**Photo 3**).

(1) Workshop 1

Mr. Soichi Nakajima, Digital Telco Lead Analyst from IDATE DigiWorld, gave a lecture entitled "The State of the World OTT Markets Today and Scenarios for the Digital Economy 2025."

He first explained the market size of OTT services throughout the world. The OTT market accounted for only one-tenth of the telecommunications market in 2010, but with its annual growth rate of 11.4%, it is expected to account for half of the telecommunications market in 2020. A revenue analysis of OTT operators indicated that cloud services make up a large part of the charging model, while search engines account for the major part in the advertising revenue model. However, the revenue from advertising automation is growing. In addition, Mr. Nakajima showed that competition in the OTT market has been decreasing as a result of the oligopoly structure. He also explained the different strategies of the representative players such as Google and Facebook.

Next, four scenarios were introduced as economic phenomena of the next ten years, centered on whether the *intensity of personal data usage* and the *openness of technology & data* are expected to be high or low. It was predicted that the future market will be different according to each scenario. The four scenarios are as follows:

1) Club scenario: high intensity of personal data usage and low openness of technology & data, just like the current service image of Amazon.
2) Tech scenario: high intensity of personal data usage and high openness of technology & data, just like the current service image of bitcoin.
3) Low cost scenario: low intensity of personal data usage and high openness of technology & data, just like the current service image of Uber.
4) Shield scenario: low intensity of personal data usage and low openness of technology & data, just like the current service image of Apple.

(2) Workshop 2

Mr. Shuichi Yoshino, Executive Research Engineer, Senior Manager of Research Planning Section/Wireless Systems Innovation Laboratory from NTT Network Innovation Laboratories, gave a lecture entitled "IoT Initiative at NTT Labs. to Create Value in Various Fields." He introduced the requirements and functional architecture of the IoT and explained that information communication will enter the "autonomous and real-time" era in which social and industrial activities will be controlled and advanced through IoT-based networking in various fields such as healthcare, manufacturing, and agriculture. In addition to technical requirements such as real-time property and security, he said that non-technical requirements such as the establishment of a social consensus on data use, usage in the medium term, and business development will be necessary for the IoT.

Next, three technologies for the IoT were introduced using case studies:

1) Sense, Connect & Drive: This features examples of technology that contribute to improving safety by analyzing and visualizing biological information utilizing "hitoe," vehicle information, and environmental information, and instantaneous high-resolution data transfer technologies for moving obstacles and other things using a millimeter-wave band high-speed radio communication system.
2) Data & Software Logistics: This features examples of implementation in the manufacturing industry and automated driving support using the merits of edge computing, and promotion of commonalities in the interfaces of various kinds of collected data based on oneM2M specifications as IoT data-exchanging technology.
3) Analytics & Prediction: This focuses on development of person-tracking technology by establishing image analysis technology using deep learning, as well as technology to process it at high speed, and R&D of anomaly detection technology to automatically detect attacks on systems and networks connected with various devices by monitoring the behavior of networks and devices.

(3) Workshop 3

Mr. Hiroyuki Nakamura, Senior Research Engineer, Supervisor of Wireless Access Systems Project/Wireless Entrance Systems Project from AS Labs, gave a lecture entitled "Wireless Access Technologies to Provide Various Services in Future Networks." He first stated that the social background has evolved from wired to mobile and has changed to a mobile-centered lifestyle, and he showed an image of a network meeting the requirements of an access network in the IoT/5G era. He also described some contributions made to the development of wireless systems for the telecommunications business and the efforts of the AS Labs towards the era of full-scale deployment of 5G. The main issues with wireless systems for the telecommunications business were defined as improving maintainability and operation, reducing equipment costs, and system utilization. The efforts made in using satellite communications systems and terrestrial radio systems to offer telephone services in mountainous areas and on remote islands and to provide essential services in the event of a disaster were also described.

Next, Mr. Nakamura explained the future of wireless access in the 5G/5G+ era, which is focused on integration of cellular/unlicensed bands, along with five key technologies: 1) unlicensed band/cellular linking technology, 2) high-capacity radio relay technology, 3) unlicensed band radio access communication technology, 4) technology to model propagation of radio waves spanning frequencies, and 5) radio environment information platform technology. Some trials in an actual environment and examples of initiatives were also mentioned.

(4) Workshop 4

Dr. Atsushi Nobiki, Executive Research Engineer, Access Media Project from AS Labs, gave a lecture on the latest R&D trends in optical fiber and cable technology.

He outlined optical fiber technology over the past 40 years and showed that the research theme has shifted from backbone network technology to access network technology. He explained that in the environment surrounding optical communications in Japan, the future direction of optical fiber and cable technology is to maintain and operate a huge number of optical communication facilities with fewer personnel. It is therefore necessary to improve the operational process of existing facilities (operational innovation) and to enhance operability by deploying highly functional facilities (facility renovation). For operational innovation, it is necessary to perform 1) remote maintenance, 2) automatic inspection and analysis, 3) proactive maintenance, and 4) efficient field work with skill-free tools (one-man operation). For facility renovation, it is necessary to apply 5) optical fiber technology for extra-large capacity transmission and 6) network function redeployment. Additionally, specific technologies were introduced as recent R&D topics.

3. Overview of exhibits

In addition to exhibits from AS Labs, exhibits on the latest technologies of the co-hosting organizations and the NTT Group companies were held (**Photos 4** and **5**). As a first attempt at the forum, we held a joint exhibit on safety technology aimed at eliminating injuries at facility construction and operation sites. This exhibit was held in the special exhibition zone II (**Photo 6**).

3.1 AS Labs

The exhibition area was divided into five zones in which a wide range of R&D results of AS Labs were exhibited (**Fig. 1**). Information on recommended exhibits was displayed to visitors in an easy-to-understand manner (**Photo 7**).

Photo 4. Main venue.

Photo 5. Outdoor exhibition zone.

Photo 6. Special exhibition zone II.

(1) Special exhibition zone I

Special exhibition zone I featured advanced IoT/5G technologies. We exhibited cutting-edge efforts related to wired and wireless flexible access infrastructure technologies that support rich living for the IoT/5G era. Recommended exhibits in this zone were network technology for the IoT/5G era, P-MP (point-to-multipoint) wireless entrance systems with massive MIMO (multiple-input multiple-output), optical networking technologies for 5G mobile networks, the elastic lambda aggregation network, a cooperative wireless LAN (local area network) technique using a distributed smart antenna system, and 920-MHz-band wireless technology for underground infrastructure monitoring.

(2) Special exhibition zone II

Special exhibition zone II featured safe facility construction and operation. In this zone, we exhibited the latest technology and the evolutionary direction of facility construction and operation for improved safety by the co-hosting organizations, NTT Group companies, and NTT laboratories. Recommended exhibits in this zone were those centered on safe construction and operation, IoT technology to drastically reform construction work, optical fiber sensing of conduits attached to a bridge, advanced optical sensing technology for remote visualization of outside plants, technology for optimizing the inspection cycle of manhole covers, technology for inspecting manholes without entering them, promotion of the use of long-life conduits attached to a bridge, ideas for innovating maintenance activities, and a hydrogen embrittlement susceptibility test for rebar in concrete poles.

(3) Zone I

The topic of this zone was facility renovation; technologies that economically customize and bring maximum value to existing facilities were exhibited. In particular, we introduced a wireless system for disaster recovery, space-division multiplexing based optical fiber technology for realizing ultra-large capacity optical communication, the flexible access system architecture called FASA designed to meet various demands, and reach and split ratio expansion technologies using digital signal processing in optical access networks.

Special exhibition zone — **I: Advanced IoT/5G Technologies**
II: Safe Facility Construction and Operation

This exhibition presents cutting-edge developments in flexible wired/wireless access infrastructure technologies that will help build a social infrastructure that supports rich lifestyles in the IoT/5G era. Also exhibited here are the latest facility construction and operation technologies for improving safety developed by the co-hosting organizations, NTT Group companies, and NTT laboratories.

Zone I — **Facility Renovations**

This exhibition introduces technologies that bring new value to existing facilities by maximizing and economically customizing them.

Zone II — **Operation Innovations**

This exhibition is about technological innovations that drastically improve the inside and outside central office maintenance and operational tasks.

Zone III — **Display of model network**

This zone visually introduces an overall picture of access network technologies (those already deployed) in a physical sequence from an NTT central office to a customer's premises.

Fig. 1. Summary of NTT exhibition.

Photo 7. NTT exhibition zone.

(4) Zone II

The theme in this zone was operation innovations; the exhibits featured innovative technology to drastically improve the maintenance and operation of in-house and outdoor facilities. In particular, user interface augmentation technology, unified network management technology, and new manhole covers were some of the recommended exhibits.

(5) Zone III

In this zone, an overall picture of the access network technologies was displayed as a model network from inside the NTT central office to a customer's premises in an easy-to-understand way with actual equipment.

3.2 Information & Telecommunications Engineering Association of Japan (ITEA)

ITEA's efforts to promote secure, safe, and reliable information communication infrastructure facilities were presented. These efforts include maintaining the technology and know-how that have been cultivated up to now; building, maintaining, and improving the quality and efficiency of optical access networks; and promptly restoring facilities in the event of a major disaster.

3.3 Communication Line Products Association of Japan

The latest efforts and technologies of all the member companies were displayed. The technologies were related to offices and datacenters, safety and workability, as well as outdoor facilities, including optical and metal cables, connectors, and related components.

3.4 Communications and Information Network Association of Japan (CIAJ)

Together with the Japan Industrial Association for Telecommunications Equipment and Materials

(Zentsukyo), exhibitors who belong to CIAJ presented various products and solutions related to communication networks to achieve a safe, secure, and prosperous society.

3.5 NTT Group companies

To provide the best and most trusted services as a value partner, the NTT Group companies displayed the latest technologies that can contribute to solving the social issues through development of new businesses and services with partner companies.

3.6 Demonstrations and technical seminars

Demonstrations and technical seminars by exhibitors were held at the AS Labs main venue and in the outdoor venue, with many participants in attendance (**Photo 8**).

Photo 8. Technical seminar held by an exhibitor.

3.7 Stamp rally

A digital stamp rally using smartphones was carried out to allow visitors to navigate throughout the exhibition hall of AS Labs. Those who gathered the eight-stamp set in the venue were awarded an original utility pole number tag. When we gave the souvenirs to the participants, we received comments such as “I got a chance to see exhibitions that I would not normally visit” and “I gained a wide range of information.”

4. Conclusion

Despite the unfortunate rain, about 9700 people attended the event. We welcomed many customers from overseas and successfully held a forum. We received high interest in various exhibitions, including the latest R&D and future trends of AS Labs. Visitor questionnaires were distributed, and the results indicated that 97% of customers achieved the purpose of their visit. With the participating corporations including the co-hosting organizations, Tsukuba Forum 2017 was a successful event and a place to share innovations of access networks through exhibition of advanced technologies aiming at the IoT/5G era and R&D achievements aimed at solving issues of network operation.

Acknowledgments

We thank the Information & Telecommunications Engineering Association of Japan, the Communication Line Products Association of Japan, and the Communications and Information Network Association of Japan for their support of Tsukuba Forum 2017.

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He received a B.E., M.E., and Ph.D. from Hokkaido University in 2000, 2002, and 2010. Since joining NTT in 2002, he has been researching the propagation characteristics of wide band access systems. From 2013 to 2014, he was a visiting research associate at the Centre for Telecommunications Research at King's College London, UK. He received the Young Researcher's Award, the Communications Society Best Paper Award, and the Best Paper Award from the Institute of Electronics, Information and Communication Engineers (IEICE) in 2006, 2011, and 2014, respectively. He is a member of IEICE and the Institute of Electrical and Electronics Engineers (IEEE).

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He received an M.E. in human sciences in 2016 from Waseda University, Tokyo. From 1996 to 1998 he taught access technology as a Japan Overseas Cooperation Volunteer in the Republic of Honduras. After that, he worked mainly on network system development at NTT WEST and NTT Network Service Systems Laboratories. He has been with NTT Access Network Service Systems Laboratories since July 2017.

External Awards

IPSJ Yamashita SIG Research Award
Winner: Takeshi Mishima, NTT Software Innovation Center
Date: March 13, 2018
Organization: Information Processing Society of Japan (IPSJ)

For "Database Live Migration Middleware in Cloud Environment."

Database-as-a-service has been gaining popularity in cloud computing because multitenant databases can reduce costs by sharing off-the-shelf resources. However, due to heavy workloads, resource sharing often causes a hot spot. Unfortunately, a hot spot can lead to violation of service level agreements and destroy customer satisfaction. To efficiently address the hot spot problem, we propose a middleware approach called Madeus that conducts database live migration. To make efficient database live migration possible, we also introduce the lazy snapshot isolation rule (LSIR) that enables concurrently propagating syncsets, which are the datasets needed to synchronize slave with master databases. Unlike current approaches, Madeus is pure middleware that is transparent to the database management system and is based on commodity hardware and software. To demonstrate the superiority of our approach over current approaches, we experimentally evaluated Madeus by using PostgreSQL with the TPC-W benchmark. The results indicate that Madeus achieves more efficient live migration than three other types of middleware approaches, especially under heavy workloads; therefore, it can effectively resolve hot spots.

Published as: T. Mishima and Y. Fujiwara, "Database Live Migration Middleware in Cloud Environment," WebDB Forum 2016, Kanagawa, Japan, Sept. 2016 (in Japanese).

Papers Published in Technical Journals and Conference Proceedings

Shape Parameter Estimation for Generalized-Gaussian-distributed Frequency Spectra of Audio Signals

R. Sugiura, Y. Kamamoto, and T. Moriya

Proc. of the 2017 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), pp. 736–740, New Orleans, LA, USA, March 2017.

We have devised a method for estimating, from a single frame of audio frequency spectra, a shape parameter of multivariate generalized Gaussian distribution which has variance represented by an all-pole model and no covariance. Based on powered all-pole spectrum estimation (PAPSE), which is an extension of linear prediction, the proposed method simultaneously estimates the shape parameter and the maximum-likelihood variance, allowing more accurate representation of the probability density functions of the spectra. This paper shows an integration of the estimation into an audio codec for an example of its application, which resulted in the enhancement of the objective and subjective reconstruction quality. Since this estimation method provides us with simple parameters which reflect some acoustic features of signals, the method may also be useful in other audio signal processing problems.

Overlapping of Back Vowels /o/ and /u/ by Young Seoul Korean Speakers: Focusing on the Effect of Preceding Consonantal Type and Utterance Unit on Overlap in Formant Distribution

T. Igeta, S. Hiroya, and T. Arai

Journal of the Phonetic Society of Japan, Vol. 21, No. 2, pp. 53–60, August 2017 (in Japanese).

This study investigated overlapping of /o/ and /u/ in young Seoul Korean speakers' lenis/aspirated CV (consonant-vowel) syllables and discusses its results with previous studies' observations of overlapping in speech units of different length. Male speakers showed no overlapping in the lenis CV context, but did in the aspirated CV context. Females showed overlapping in both contexts, with greater overlapping in the aspirated. By comparing with previous V and read speech studies, it suggests that overlapping may be related to coarticulation and clarity reduction for males. For females, there is a possibility that the presence of C reduces overlapping in V.

CLEAR: Conditionally Lossless Encoding under Allowed Rates for Low-delay Sound Data Transmission

R. Sugiura, Y. Kamamoto, N. Harada, T. Kawanishi, and T. Moriya

The 143rd Audio Engineering Society International Convention, 9899, New York, NY, USA, October 2017.

We present in this paper a near-lossless full-band stereo compression scheme called Conditionally Lossless Encoding under Allowed Rates (CLEAR), aiming at its use in real-time transmission of sound data and sounds to be mixed or processed after being transmitted. Using a uniform quantizer with MPEG-4 Audio Lossless Coding (ALS) and adaptive pre- and post-processing, CLEAR controls the encoding bit rate with maximum fidelity of reconstructed signals. Objective experiments show an enhancement in signal to noise ratio (SNR) and from conventional low-delay codecs with compatible perceptual quality. Additionally, companding-based perceptual weighting designed for CLEAR is shown to make an improvement in Perceptual Evaluation of Audio Quality (PEAQ).

Impact of Articulator Velocity-controlled Rhythm in Perceiving Speech

S. Hiroya, N. Lavan, S. Chen, and S. K. Scott

Neuroscience 2017, Washington, D.C., USA, November 2017.

In this study, we developed a method that can convert temporal patterns of speech based on articulator velocity. The velocity was calculated from articulatory data, which were collected using the electromagnetic articulography (EMA) system. The bell-shaped velocity profile of natural speech was converted to an emphasized, uniform, and reversed velocity profile, without altering sentence duration. The result of speech intelligibility (percent keywords correct) showed natural = emphasized > uniform > reversed. Also, results showed natural > emphasized > uniform > reversed. These results indicate that speech intelligibility is affected by the non-biological articulator velocity profile such as uniform and reversed, but naturalness of speech rhythm is affected by any manipulation of velocity profiles.

Display Technologies of Sensory-motor Information Utilizing Touch and Somatic Illusions

T. Amemiya

The Japanese Journal of Psychonomic Science, Vol. 36, No. 1, pp. 135–141, December 2017 (in Japanese).

Touch, the sensation processed by the somatosensory system, is closely related to the body state. Due to the spatiotemporal characteristics of the somatosensory receptors and the structural constraints of the body, we have sometimes experienced sensory illusions in touch as well as in vision. In this paper, I introduce several techniques to generate illusory sensations which can be exploited to develop information displays. I review the previous findings of our experiments of the changes in haptic perception or body image using the techniques.

Multi-access Edge Computing: A Survey

H. Tanaka, M. Yoshida, K. Mori, and N. Takahashi

Journal of Information Processing, Vol. 26, pp. 87–97, February 2018.

Multi-access Edge Computing (MEC) can be defined as a model for enabling a business oriented, cloud computing platform within multiple types of access networks (e.g., LTE, 5G, Wi-Fi, FTTH, etc.) at the close proximity of subscribers to serve delay sensitive, context aware applications. To extract the most potential, MEC has to be designed as infrastructure to support many kinds of IoT applications and their ecosystems, in addition to having a sufficient management mechanism. In this context, various research and standardization efforts are ongoing. This paper provides a comprehensive survey of the state-of-the-art research efforts on the MEC domain, with a focus on the architectural proposals as infrastructure, the issue of the partitioning of processing among user devices, edge servers, and a cloud, and the issue of resource management.
