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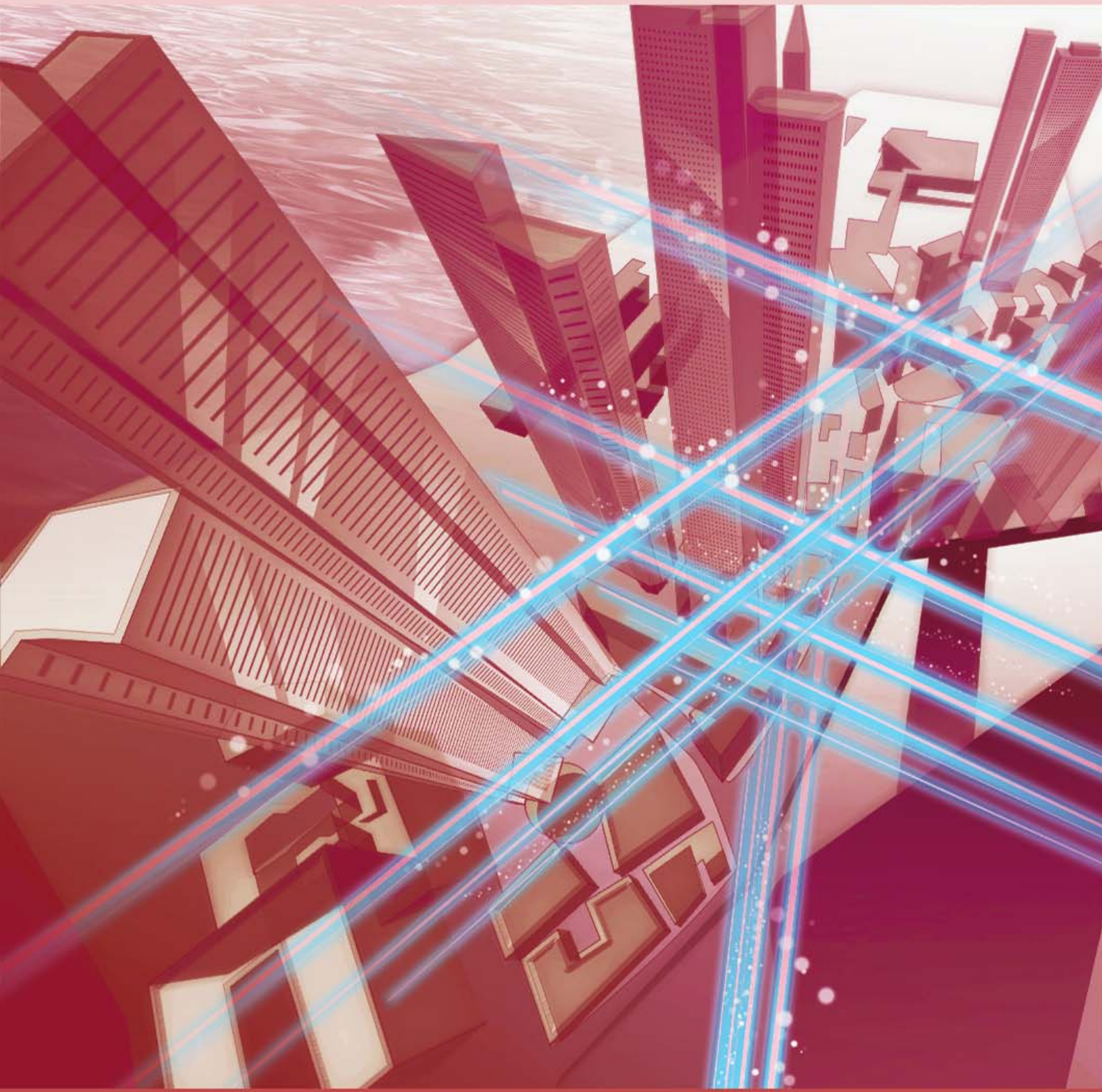

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Feature Articles: New Value Creation through Collaboration with B2B2X Partners

Global Standardization Activities

External Awards/Papers Published in Technical Journals and Conference Proceedings

Accelerating Digital Transformation to Create New Value

Ryuichi Sumi and Nobukatsu Takei

Abstract

NTT is working to accelerate digital transformation to create new value by leveraging research results that are the most advanced in the world. In particular, we believe that through collaboration with B2B2X (business-to-business-to-X) partners, we can combine the different strengths of NTT and our partners, which will lead to the creation of value that can transform the world. In this article, the process of value creation—from the significance of collaboration and generating ideas to technical verification and promotion—is explained.

Keywords: digital transformation, value creation, joint experiment

1. Efforts to utilize research results to benefit the world

At the NTT laboratories, researchers are working day after day on the world's most advanced and proprietary research. Although the primary goal of our research activities is to achieve excellent research results, at the same time, it is necessary to disseminate such research results so that they are widely recognized in the world and are actually utilized.

In addition to publishing research papers and standardization activities to disseminate research results, it is also important to commercialize results so that they are used commercially. Producers at the Research and Development Planning Department are working to overcome the barrier between the research phase and the commercialization phase, the so-called *valley of death*, and are actively helping to get research results into commercial projects.

The main activity for producers involves collaborating with industry partners to achieve business development through our efforts concerning business-to-business-to-X (B2B2X), which is a policy of the NTT Group. The Feature Articles in this issue introduce representative examples of new value creation achieved through collaboration with B2B2X partners by making use of the most advanced research results in the world [1–5].

2. Collaboration with B2B2X partners

The significance of collaboration using research results as the core is described as follows. The concept of such collaboration is shown in **Fig. 1**.

First, by matching partners who are in contact with users around the world, and the NTT laboratories, which have the world's most advanced research results, we can create new value that did not exist before. By combining the technologies of the NTT laboratories with the assets of our partners (such as technologies and fields of expertise), we expect to create new value such as determining convenient forms of usage, solving certain business problems of our partners, and developing products and solutions that are widely applicable throughout the world.

Second, from the viewpoint of the NTT laboratories, we can directly understand requirements in the field, which are fed back from our partners, thereby leading to a higher level of research. For example, performance targets to be achieved are clarified, and hypotheses can be verified through field verifications and analysis of actual data.

Third, the collaborations with global partner companies are increasing, and we expect to roll out our research results to such global businesses. Collaborating with global partners and NTT's global operating companies from the early stages of research

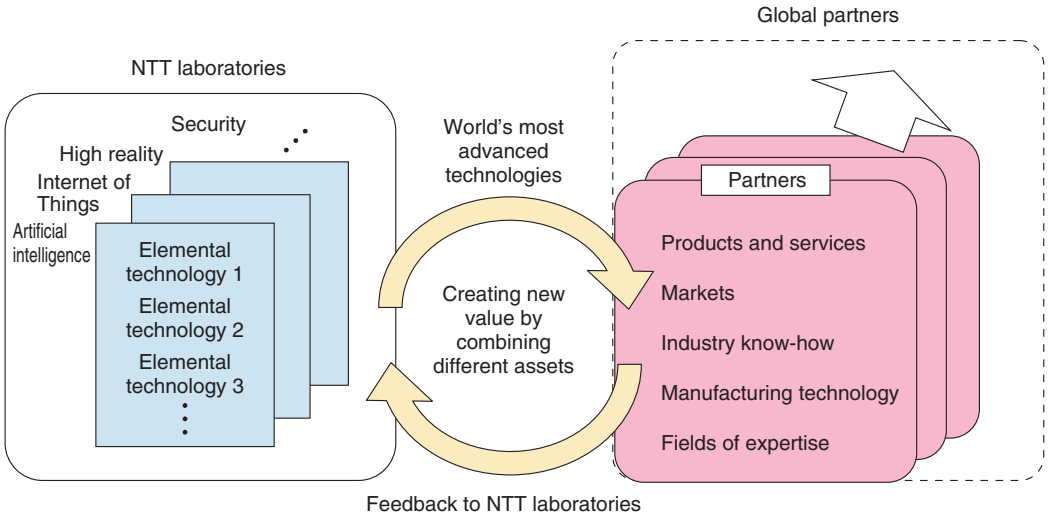

Fig. 1. Collaboration with B2B2X partners.

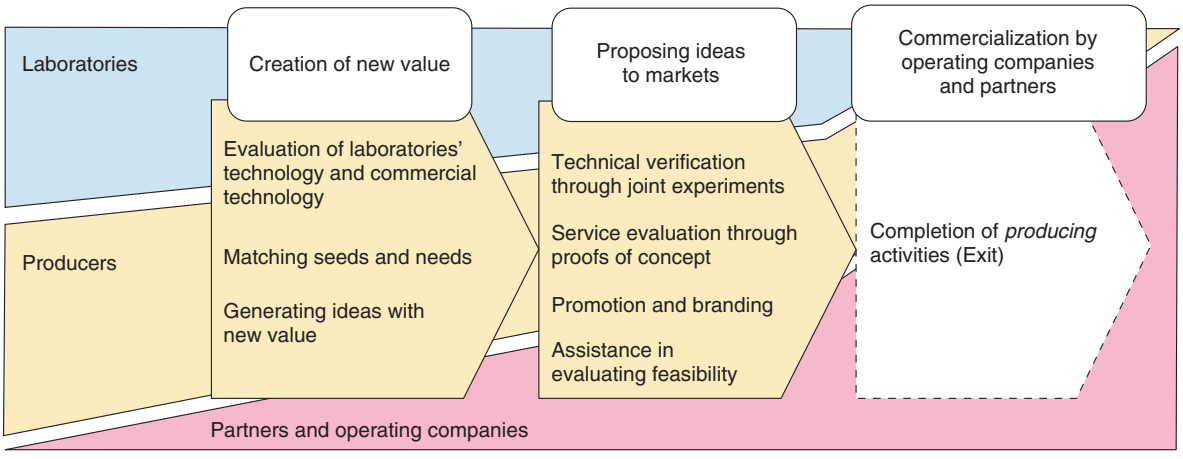

Fig. 2. Collaboration process with partners.

makes it possible to acquire new knowledge that cannot be obtained in Japan alone and to understand pressing issues in various parts of the world. As a result, new channels for disseminating our research results will be opened up around the world.

In these three ways, through business collaborations based on multiplying state-of-the-art technologies of the NTT laboratories and partners from different industries, assets not owned by NTT but owned by the different industries, and vice versa, react in a chemical-like manner that triggers the creation of new ideas aimed at the whole world.

3. Collaboration process with partners

The collaboration process with partners is shown schematically in **Fig. 2**.

In the first step, new value is created. In concrete terms, we investigate and evaluate laboratories' technologies and market technologies by exchanging opinions with the laboratories in regard to what technologies from among various themes being researched should be announced to the world at an early date and what dissemination channels are conceivable. In addition, by combining different elemental technologies, or combining the technologies of our laboratories

with the intellectual property of other companies and with the needs of users in the industrial world, we generate ideas with new value that did not exist in the world. To this end, from day to day, producers are building trusting relationships with their partners while constantly considering what value can be created by combining mutual technology assets.

In the second step, proposals are offered to the market. To confirm that an idea generated through joint examination with a partner is beneficial, joint experiments are conducted in the field, and the feasibility of the idea from a technical viewpoint is evaluated. For these joint experiments, the NTT laboratories and partners collaborate in conducting technical verifications; that is, the NTT laboratories provide technologies and demonstration equipment, while the partners provide business fields and subjects.

In addition, it is essential to visualize the idea through a proof of concept (PoC) and evaluate it from the viewpoint of services for users by actually *touching* it, or trying it out. For a PoC, ideas are put into concrete form such as software and hardware, although they are simply structured. In the meantime, usage scenarios of users are visualized, and usability when such ideas are commercialized is confirmed.

In the final step, commercialization is supported. If both the technical evaluation through the joint experiment and the evaluation of serviceability through the PoC are concluded successfully, the partner and the NTT operating company will then determine whether or not the idea will be established as a business. Once that judgement is made, the NTT operating company and our partner will continue to mutually work on profitability evaluations of the business, forms of commercial distribution, price targets for products, future market prospects, and other details. One such effort carried out by producers is to support the NTT operating companies and the partners in their efforts towards commercialization by, for example, proposing business models and coordinating the business formation.

4. Promotional activities for forming partnerships

To create collaborative partnerships, it is necessary to disseminate information to the outside. We actively disseminate information on key milestones such as the start of new collaborations and the results of joint experiments and PoCs via news releases from NTT and responses to media. In addition, research results are exhibited at NTT R&D Forum, CEATEC JAPAN, MWC Barcelona, AI EXPO TOKYO, Next-generation Agriculture EXPO, the International Modern Hospital Show, and other domestic and overseas exhibitions. At these venues, we strive to promote our research results and to create opportunities for new encounters.

It is also important to *brand* the new value created through collaboration as that of the NTT Group. Accordingly, producers are naming services that embody value and are actively registering trademarks.

5. Future development

Collaboration with partners with different backgrounds is a good way to create new value. From now onwards, we will put even more effort into global collaboration and will conscientiously spread our research results for the benefit of the world.

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Creation of New Value in Collaboration with Mitsubishi Heavy Industries

Katsushi Shindo, Sachio Yoshida, Yukiteru Nagatake, and Takuya Yamaguchi

Abstract

In collaboration with partner companies and organizations, the NTT Group is accelerating its efforts to promote the B2B2X (business-to-business-to-X) business model and thereby support the digital transformation of our corporate customers. This article describes a collaboration between NTT and our partner company Mitsubishi Heavy Industries, Ltd. (MHI). In particular, it explains how we are applying the results of research and development (R&D) done by the NTT laboratories in the information and communication technology (ICT) field to MHI's social infrastructure products such as those for the energy and environment fields and the transportation and shipping industries and also to MHI's factories and work sites in Japan and abroad. This partnership is aimed at rapidly creating new value through *social infrastructure* × *ICT* and utilizing R&D results in solutions to solve our customers' problems as well as social problems.

Keywords: digital transformation, photonic-crystal optical fiber, security technology for industrial control systems

1. Research and development collaboration on *social infrastructure* × *ICT*

With the joint aim of creating new value by integrating social infrastructure and information and communication technology (ICT), NTT and Mitsubishi Heavy Industries, Ltd. (MHI hereafter) started collaborating in April 2014 on research and development (R&D) focused on the following three themes (**Fig. 1**) [1].

Field (1): optical fibers and sensors

Studies are underway on the applicability of NTT's optical-fiber and laser technology and radiowave measurement technology cultivated in the field of telecommunications as well as biometric-information measurement technology to maintenance operations and manufacturing sites of MHI's products.

Field (2): big data

The two companies are examining the applicability of NTT's big-data processing and analysis technology to MHI's big data such as operational statuses of products and customers' opinions recorded at call centers.

Field (3): augmented reality and media processing

A study is being done on the applicability of NTT's augmented reality technology and media processing technology such as video and audio to improve remote communication and work efficiency between support staff and workers at MHI's domestic and overseas factories as well as at construction sites.

The security field was added in March 2016 as a fourth theme. Thus, as of September 1, 2018, we have been working on new initiatives with MHI in four collaboration fields.

Field (4): security

Security technologies for industrial control systems—combining control technology attaining high reliability and safety cultivated by MHI in the defense

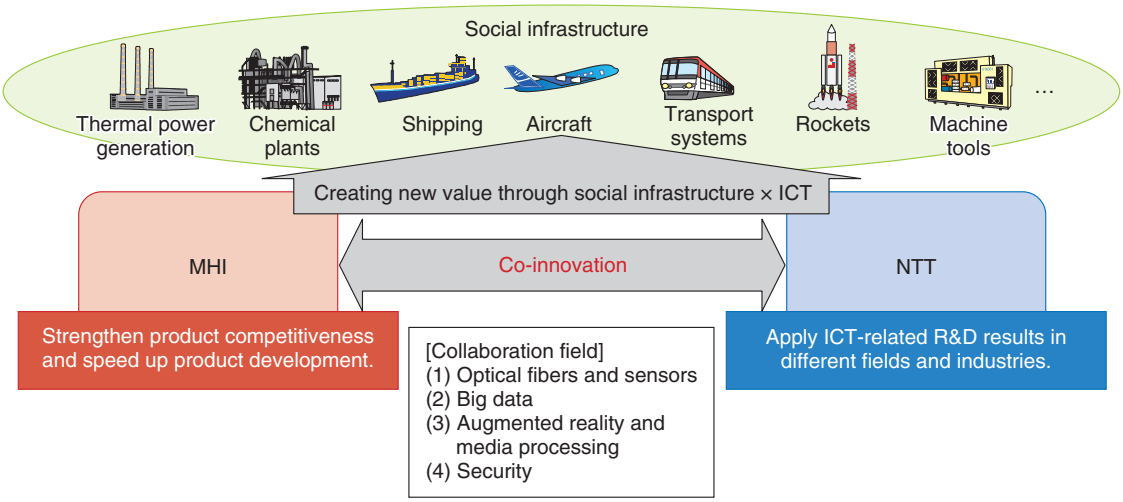


Fig. 1. New value creation through social infrastructure × ICT.

and space fields and NTT's state-of-the-art security technology—are being investigated.

This article introduces two collaborations. The first involves collaboration on R&D in the optical fiber and sensor field. Specifically, we introduce our R&D efforts concerning technology enabling transmission of a high-power single-mode laser beam over a longer distance, which was once considered impossible in the industry, while maintaining transmission quality suitable for laser processing [2]. This is enabled by fusing NTT's optical fiber technology and MHI's high-power laser processing technology.

The second collaboration is in the security field. We introduce the cybersecurity technology called InteRSePT®*1 for industrial control systems and outline our efforts to commercialize it [3–5].

2. Collaborative research on optical fiber technology for transmitting high-quality laser beam processing

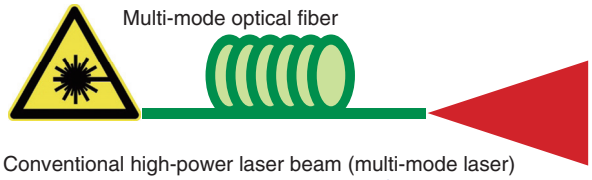
Optical fiber is an essential part of today's information and communication networks and is in wide use throughout the world. Applications of optical fiber range from endoscopes and gyros to transmission of laser beams for processing. With laser processing, it is necessary to transmit high-power laser beams with an output power more than 10,000 times stronger than that of the light used for normal optical communications. However, a nonlinear optical phenomenon imposes physical limits on the optical output and the distance that light can be transmitted by the optical fiber.

The current widely used laser beam (multi-mode laser beam) can be transmitted over several hundred meters by using existing optical fiber (multi-mode optical fiber). However, the multi-mode laser beam has been unsuitable for applications requiring higher processing accuracy. Meanwhile, a high-power (10-kW class) laser beam (single-mode laser beam) suitable for more precise laser processing can only be transmitted several meters with existing optical fiber (single-mode optical fiber). Therefore, it is not suitable for application to actual laser processing requiring optical fiber transmission of several dozen meters (**Fig. 2**).

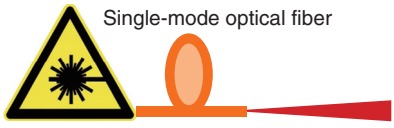
Photonic-crystal optical fiber (PCF: photonic crystal fiber)*2 [6, 7] technology previously developed by NTT was used in this collaborative research. In this technology, the light is confined to a region surrounded by an array of air holes and then propagated. NTT designed and developed a novel PCF optimized for transmission of a high-power single-mode laser beam, and NTT and MHI jointly demonstrated its high-power transmission capability [8] (**Fig. 3**). The results of this research were reported at the 89th Lecture Meeting of the Japan Laser Processing Society [9] held at Osaka University on May 23 and 24, 2018.

*1 InteRSePT®: Abbreviation of integrated resilient security and proactive technology, for industrial control systems and a registered trademark of MHI in Japan.

*2 PCF: Optical fiber that has a structure in which air holes are regularly and periodically arranged in a silica glass cross section.



Conventional high-power laser beam (multi-mode laser)
– Transmission distance over hundreds of meters
– Output light beam is wide, and processing accuracy deteriorates



High-quality, high-power laser beam (single-mode laser)
– Transmission distance up to several meters
– Output light beam is narrow, and processing accuracy is improved

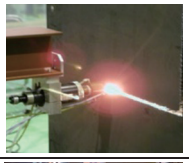
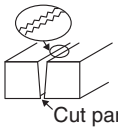
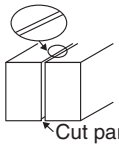
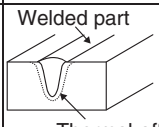
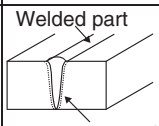
Example of processing		Multi-mode laser beam	Single-mode laser beam	Advantages of applying single-mode laser beam
Cutting		 Cut surface is rough. Cut width is wide. Cut depth is shallow. Cut part	 Cut surface is smooth. Cut width is small. Cut depth is deep. Cut part	• Fast processing speed • High processing accuracy • Less material damage • High energy efficiency
Welding		 Welded part Welding width is wide. Shallow penetration Thermal effect is wide. Thermal-affected zone	 Welded part Small welding width Deep penetration Thermal effect is narrow. Thermal-affected zone	

Fig. 2. Laser quality and transmission distance of laser processing as well as processing accuracy.

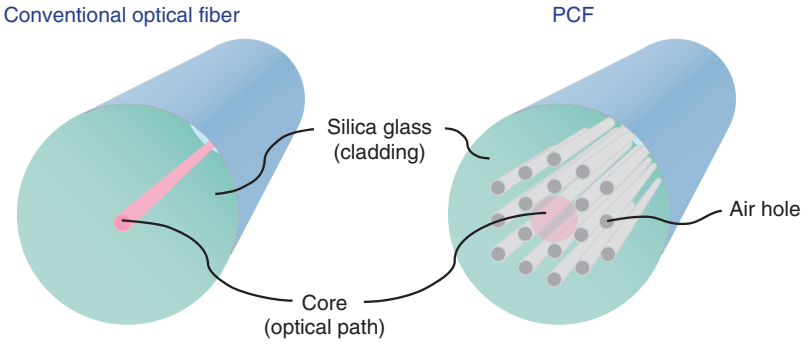


Fig. 3. Comparison of conventional optical fiber and PCF.

This technology can be applied to remote processing, remote welding, and thick plate cutting in the manufacture of existing automobiles, aircraft, and ships. It is also expected to contribute to expanding the application field of laser processing technology to various social infrastructure industries and thereby dynamically change the concept of manufacturing. While MHI continues to develop application technology for punching and welding of heat-resistant alloys, it aims to put this laser processing technology using PCF into practical use starting in 2019.

In addition to developing optical fibers, we will

promote collaborative R&D on potassium tantalate niobate (KTN: $KTa_{1-x}Nb_xO_3$) deflection elements and diffractive optical elements as basic technologies necessary for laser processing.

3. Cybersecurity technology for industrial control systems and efforts toward commercialization

Cybersecurity for industrial control systems is an important area requiring continued research. We report some key issues concerning cybersecurity for industrial control systems in this section.

3.1 Problems facing security of industrial control systems

As the era of the Internet of Things progresses, the threat of cyber-attacks on industrial control systems of critical infrastructures such as factory facilities and electric power systems is ever increasing. Critical infrastructures such as factories, power/energy systems, and transportation systems consist of both information systems and industrial control systems. As mentioned above, ensuring the security of industrial control systems is just as important as ensuring the security of information systems. The following challenges arise with industrial control systems that need to be addressed with certain countermeasures.

1) Handling problems without causing frequent stops: Since factory equipment and power-system facilities cannot be stopped easily, it is difficult to handle problems (such as application of security patches) involving stops and restarts like those commonly carried out for information systems.
2) Handling long-term renewal cycle of industrial control system equipment: The renewal cycle of industrial control system equipment can cover long periods of more than ten years. Meanwhile, the supported period of information system equipment is often shorter than that and does not match the renewal cycle of industrial control system equipment. Moreover, it often happens that new equipment and old equipment are used at the same time.
3) Handling real-time control: Delays in exchanging control signals may be directly related to a control malfunction, and any transmission delays must be smaller than the allowable level.
4) Lack of security engineers: Since security is often managed by departments other than the information systems department, and there tends to be less distribution of security know-how related to industrial control systems, there is often a shortage of engineers familiar with the security of industrial control systems.

3.2 Concept of InteRSePT®

In response to the four issues described above, MHI and NTT have developed a security solution for industrial control systems called InteRSePT®. InteRSePT consists of a security management system that monitors and responds to threats in an integrated manner and a real-time network monitoring system that detects unauthorized communications flowing through the network and implements interruptions of packets and other security measures as necessary (**Fig. 4**).

The function of each component is summarized below.

- The real-time network monitoring system is connected to the network of the industrial control system and monitors communication. It detects anomalies according to built-in detection and response rules and controls the transit and blocking of packets as necessary.
- The security management system monitors the entire industrial control system and detects and responds to threats by evaluating situations in an integrated manner based on NTT's proprietary know-how. It collects and analyzes control communication data and various kinds of sensor data in order to detect multiple anomalies that cannot be assessed based only on the rules of the real-time network monitoring system. The security controller also changes the communication control rules used by the real-time network monitoring system according to the operating conditions and detected anomaly information.

By carrying out this security processing on the InteRSePT side, we are providing the following solutions to the above-mentioned problems.

1) Downtime caused by the updates required for security measures is minimized.
2) Since the facility equipment (sensor and control equipment), which is the endpoint of the industrial control system, is not modified, the effect of security updates on the update cycle of the equipment can be minimized.
3) Equipment that can handle high-speed processing with low delay is adopted, and real-time control is supported.
4) It is possible to reduce the burden of security measures on engineers in charge of the industrial

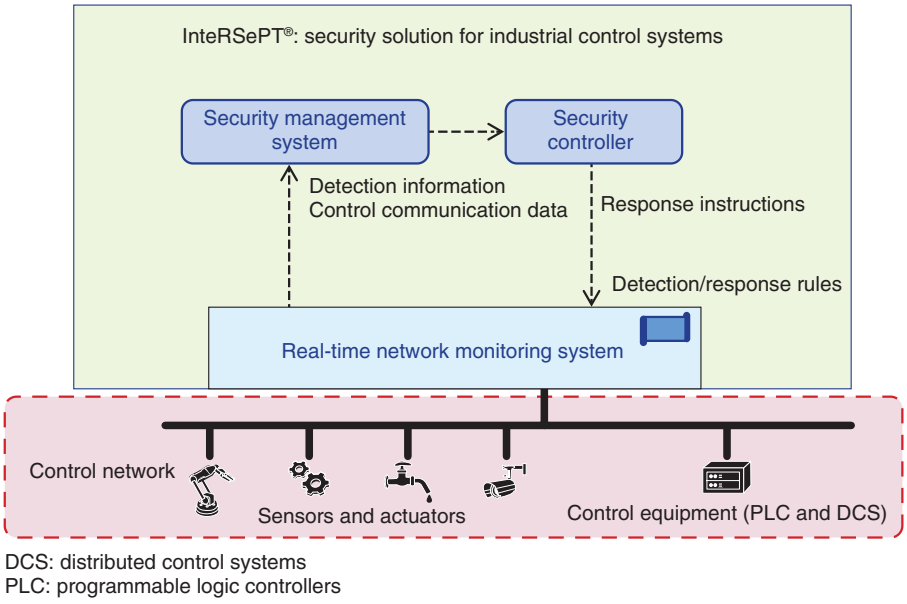


Fig. 4. Overview of InteRSePT®.

control system.

3.3 Expansion of InteRSePT

The NTT Group and MHI are currently collaborating on sales of security solutions using InteRSePT. Furthermore, we aim to respond to various requirements of industrial control systems and are therefore planning to strengthen InteRSePT as outlined below.

- Provide functions to make installation easier. We are considering providing support functions to further facilitate the introduction of InteRSePT, including a flexible network-control function to minimize changes of the existing environment.
- Expansion of compatibility with industrial communication protocols. We are planning to enhance compatibility to various industrial communication protocols used by industrial control systems.
- Provision of a total menu covering upstream to downstream. We are considering providing a service menu that can comprehensively handle tasks ranging from security consulting to system construction, migration, and operations monitoring.

4. Future development

In the future, we will continue to create technologies that will help solve common problems concerning social infrastructure through collaboration between NTT and MHI as well as through new research efforts. Moreover, we aim to apply developed technologies in various industries by promoting collaboration with MHI along with the NTT operating companies. We also plan to share acquired knowledge within the NTT Group.

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Trademark notes

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Collaboration with NYK Line in the Maritime Industry

Shigehiro Hori

Abstract

The maritime industry (shipping companies, shipyards, marine equipment manufacturers, etc.) in Japan and the rest of the world is going through a major transformation. The issues to be addressed include further strengthening environmental regulations, reforming an industry structure that is likely to be affected by global economic trends, building evolved ships with a view to future autonomous navigation, and finding a solution to the increasing shortage of human resources such as captains and sailors. The NTT Group aims to support the maritime industry in addressing these issues and is therefore applying its information and communication technology expertise cultivated in the telecommunications business to the maritime industry. In this article, maritime industry trends and specific efforts of the NTT Group in response to those trends are introduced, and future directions are presented.

Keywords: edge computing, IoT platform, shipping

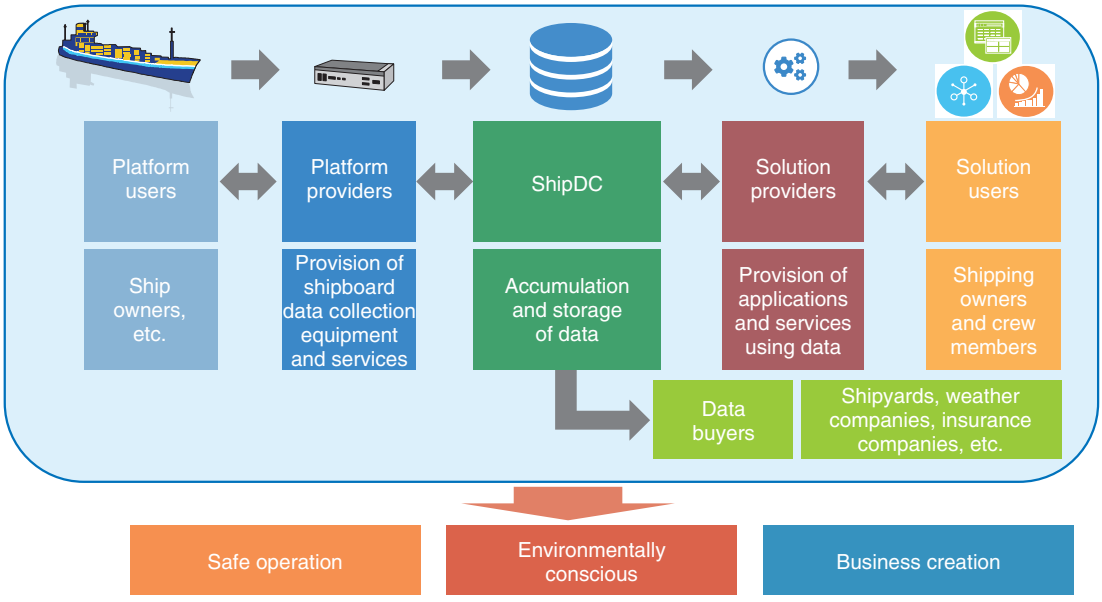
1. Issues concerning the maritime industry and necessity of digitization

Efforts to introduce the Internet of Things (IoT) in the Japanese maritime industry have mainly been promoted by the Internet of Ships Open Platform (IoS-OP), a consortium operated by the Ship Data Center (ShipDC) (a subsidiary of Nippon Kaiji Kyokai, known as ClassNK [1]), and in which 46 companies including NYK Line and NTT are participating. In addition to shipping companies, shipyards, and marine equipment manufacturers, information and communication technology (ICT) companies such as NTT are also participating in this consortium, and we are developing rules and contracts for sharing and utilizing ship data within the maritime industry. What is unique about this approach is that it is not manufacturer driven; instead, it is an industry-wide mechanism involving user companies such as shipping. ClassNK, the general incorporated foundation, handles the function of sharing data from datacenters, and by doing so, it plays the role of coordinating various interests in the ownership and utilization of data. This effort to promote data distribution by ClassNK is slightly different from the approach to IoT taken by other industries (**Fig. 1**).

One reason that Japan's maritime industry has built a platform called IoS-OP and is hastening data utilization is to meet the goals of the strict environmental regulations imposed on the maritime industry. At the 2018 72nd meeting of the Marine Environment Protection Committee (MEPC 72) of the International Maritime Organization (IMO), the "Initial IMO Strategy on Reduction of GHG Emissions from Ships" was adopted, which comprehensively establishes a greenhouse gas (GHG) emission-reduction target for international shipping and the measures to meet that target [2].

This strategy was the first in the world, in a single sector, to commit to the worldwide goal of zero emissions of GHG during this century. This is a long-term policy that sets out—through further promotion of energy conservation technology, implementation of economic incentive methods, and other measures—to improve fuel efficiency of international shipping as a whole by 40% by 2030 compared to 2008, to halve GHG emissions by 2050 compared to 2008, and ultimately, to meet the very high goal of zero emissions of GHGs during the 21st century.

In the maritime industry, although efforts to reduce



Source: Created using materials from ShipDC

Fig. 1. Role of IoS-OP.

the fuel costs of ships are being made, crude oil prices are on the rise, and the burden of fuel costs is expected to be further increased by the regulation of SOx (sulfur oxide) emissions taking effect in 2020. Consequently, the momentum behind improving ship operations and design is growing. In particular there is still considered to be room for improvement regarding ship design. To that end, it is essential to collect, share, and utilize actual data concerning ship operations by digitization such as IoT and artificial intelligence.

The governments of Europe and China have recently strengthened efforts toward environmental regulation. As for Japan, it is important to lead the world in developing technologies as well as promoting standardization and rule making.

2. The challenge towards digitization

At NYK Line, differentiation by technological capabilities has been identified as one of the themes in the medium-term management plan "More Than Shipping 2018—Stage 2, leveraged by creative solutions—" for fiscal years 2014 to 2018. They have promoted initiatives to create new business and to solve problems by harnessing their technological capabilities, front-line capabilities, and creativity.

Regarding those initiatives, NYK Line aims to further raise the level of safety and environmental responsibility efforts—which are essential from the viewpoint of shipping companies—and also focus on innovation by using the latest ICT such as IoT and big data. They are therefore advancing research on ways to achieve optimum operation through data utilization, fault prediction and prevention of ship equipment, and development of technologies for future autonomous-navigation vessels. One such initiative involves the development of a ship information management system (SIMS), which is a performance management system for monitoring oceangoing ship data in detail, such as the operational status and equipment status, and sharing information between ship and shore.

3. Joint experiment on utilizing edge computing

The use of edge computing technology (such as software distribution technology and data-exchange platform technology) and the know-how of the NTT laboratories in the next-generation SIMS of the NYK Group will make it possible to promptly utilize various data gathered onboard via various applications as well as to stably and efficiently share data, information, and applications between onboard and land offices. In this manner, we are promoting initiatives such as more advanced ship operations and maintenance

management.

In a joint experiment utilizing an experimental SIMS installed on an oceangoing ship, we successfully demonstrated a next-generation onboard IoT platform with a mechanism for distributing and managing the installation of new applications and updates of existing applications to the SIMS from land [3]. We are currently developing this platform with the aim of its commercialization.

4. Future development

We successfully demonstrated the next-generation onboard IoT platform as the infrastructure for digitization of ships. Going forward, we plan to utilize NTT's technology and expertise in many ways such as developing various applications using the platform, applying sensing technology for an entire ship, and implementing security measures for complete digitization, including encryption of data distribution on IoS-OP. We have thereby taken up the challenge of globally supporting the NYK Group and the entire maritime industry. As a final note, in pursuit of safe and efficient operation of ships, environmental efforts, and strengthening international competitiveness, we should all pay attention to creating innovation in the maritime industry.

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Trademark notes

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B2B2X Collaboration in the Primary Industry Sector: Agriculture, Forestry, and Fisheries

Yoshikazu Kusumi

Abstract

Primary industries in Japan such as agriculture presently face problems such as a declining working population, the aging population, and a decreasing area of agricultural land. Meanwhile, the world is said to be facing a global food crisis due to the future population explosion. Information and communication technology (ICT) is attracting a lot of attention as a way to contribute to solving these domestic and international challenges. The NTT Group is actively engaged in the primary industries by utilizing the ICT that we have developed in the telecommunications business. In this article, specific efforts and future directions of the NTT Group and partners in the primary industry sector are introduced.

Keywords: primary industry, food value chain, glocal

1. Introduction

In the Japanese agricultural industry, the working population has declined and continues to age. Specifically, the working population has decreased by nearly 60% in the last 30 years, and the proportion of employees aged 65 or over presently exceeds 60%. The number of new people working in agriculture has also not significantly increased due to the instability of incomes caused by fluctuations in yield and quality (which depend on the weather) and uncertainties such as natural disasters and damage caused by wild animals. A similar trend applies in the fishery and forestry industries. On top of that, the amount of agricultural land is decreasing. The area of agricultural land in Japan, which peaked at 6 million hectares in 1965, has since decreased to about 4.5 million hectares, and the amount of cultivated land that is abandoned continues to increase year by year [1]. As a result, the area of land per management entity in Japan is about 20 to 80 times less than that of Europe and the USA.

Concerns have arisen that on a global scale, the population explosion will result in a battle for food and water. Accordingly, it will be necessary in the future to increase the number of workers employed from the younger generation, enlarge the scale of agriculture, and dramatically improve agricultural productivity, while taking the global market into account in order to enable Japan's agriculture to flourish. Meanwhile, some bright signs are appearing such as an increase in the number of companies involved in production in the primary industries and an increase in agricultural exports. At the Japanese Government's Council on Investments for the Future, the agriculture, forestry, and fishery industries were touted as targets for reform to become part of Society 5.0 and the data-driven society, and becoming the world leader in smart agriculture was set as a top priority.

2. Efforts of NTT Group regarding *agriculture × ICT*

The NTT Group has also positioned agriculture as a priority area, and the NTT Research and Development Planning Department is serving as the coordinator for this effort. It has established a group-wide project called the Agriculture Working Group. This working group is conducting a wide range of studies

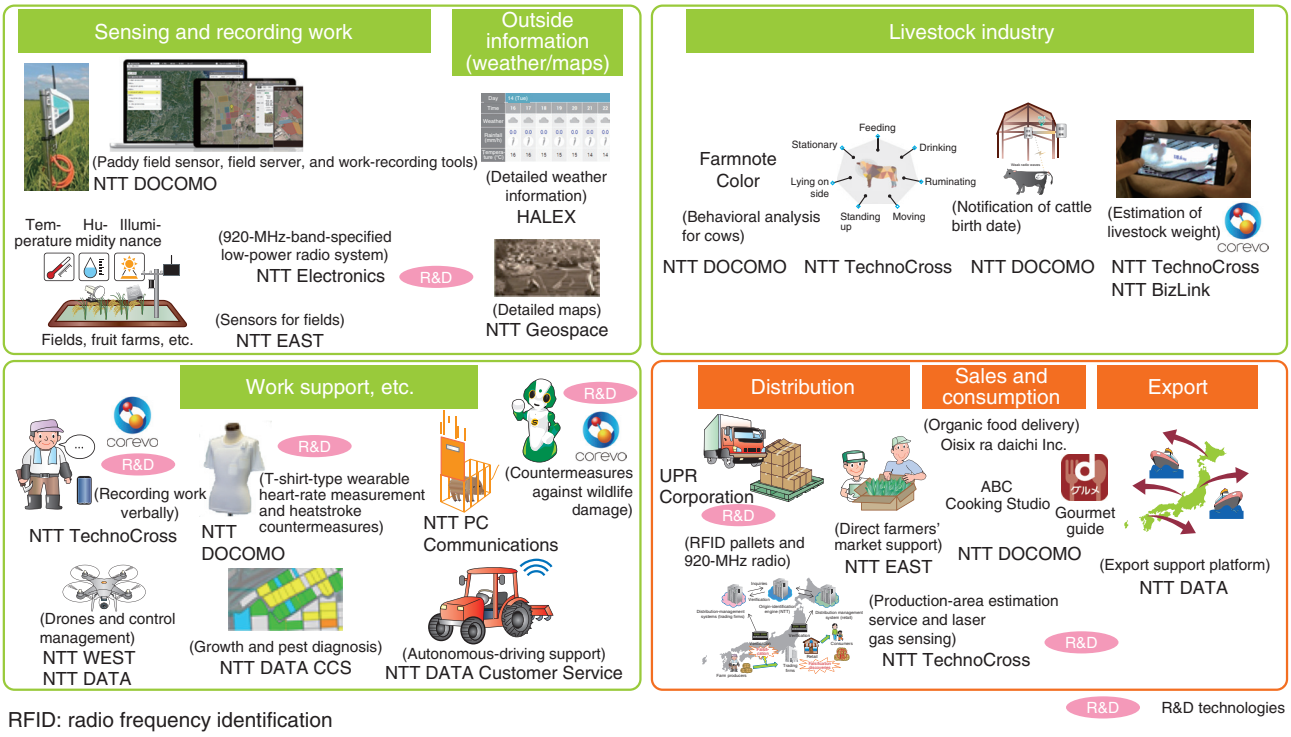


Fig. 1. Map of group solutions.

on, for example, overall strategy, business, services, and research and development (R&D) in collaboration with major operating companies such as NTT EAST, NTT WEST, NTT DOCOMO, and NTT DATA as well as with about 30 NTT Group companies with outstanding services and research laboratories with advanced technology. Two of the group companies participating include NTT Geospace, which handles essential map information for agriculture, and HALEX Corporation, which handles weather information.

We are also expanding our efforts to the fishery and forestry industries. We are utilizing the nationwide communications infrastructure and assets of group companies, network services, and artificial intelligence (AI) technology called corevo® to provide customers with technologies and solutions for the primary industries (**Fig. 1**). By combining these elements, for example, we can treat some areas of agricultural land—which is predicted to be large-scale and scattered in various areas—as one virtual farm, and we can centrally manage data concerning the environment and soil as well as growth conditions collected by deployed sensors and secure networks, and then analyze that data with AI.

We can use the results of the analysis to create an optimum cultivation plan for each product in question. Farm work can then be carried out efficiently according to that plan, while agricultural machines, robots, and drones work in cooperation. Furthermore, we aim to create a mechanism for solving problems including stabilizing income by, for example, visualizing the process from distribution to sales and consumption, import, and export, and producing saleable crops according to plans, based on demand.

3. Collaborations with partners

Since the NTT Group is not directly engaged in production activities such as agriculture, it lacks expert knowledge and know-how in that field. Accordingly, in line with NTT's B2B2X (business-to-business-to-X) business model, we are promoting strategic collaborations with various partners in industry, government, and academia. For example, we are working with Kubota Corporation, a manufacturer of agricultural equipment, to create information and communication technology (ICT) innovation in the field of agriculture and water-environment infrastructure. Specifically, we are making efforts to save

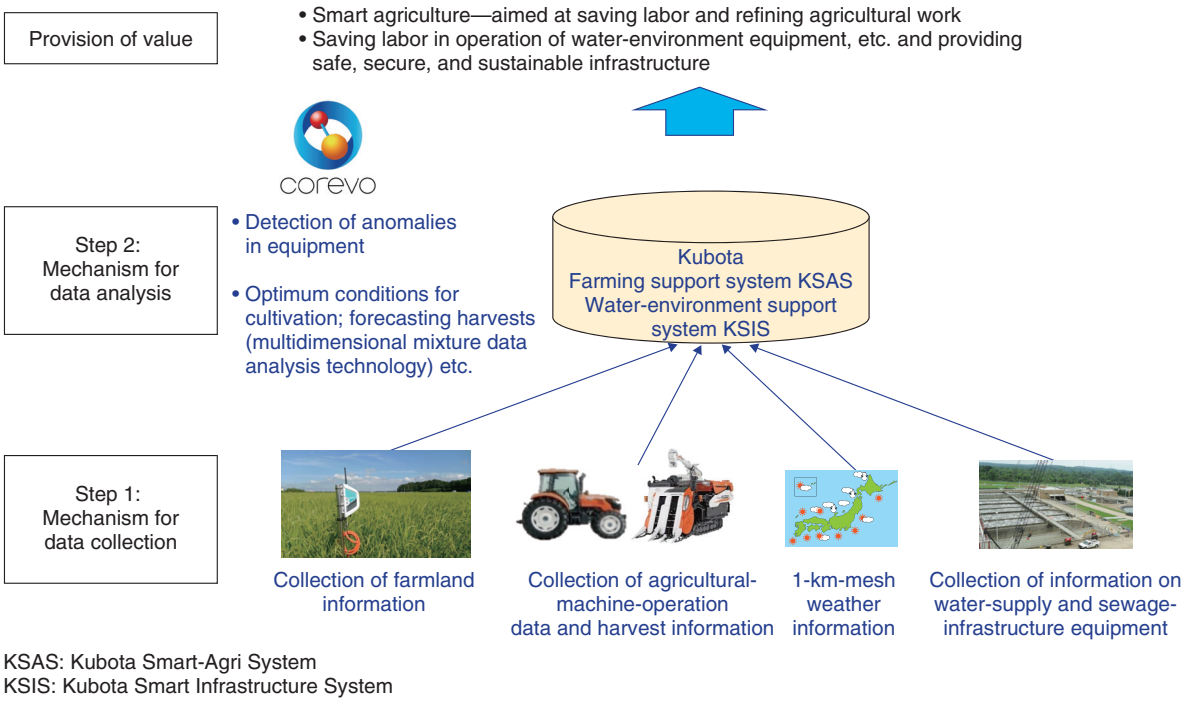


Fig. 2. Agricultural cooperation with Kubota.

labor—by implementing advanced operations of water-environmental equipment and smart agriculture in order to save labor and improve the precision of agricultural work—and create services that lead to safe, secure, and sustainable infrastructure (**Fig. 2**).

By utilizing paddy-field sensors, an energy-saving wide-area wireless service, and a 1-km-mesh weather forecast service, we are building a mechanism to gather and visualize information collected from farm land, agricultural machinery, water-supply- and sewage-related equipment, and other places (Step 1 in Fig. 2). This mechanism is used to collect and accumulate information in the company's farming support system called Kubota Smart-Agri System (KSAS) and in the water-environment support system called Kubota Smart Infrastructure System (KSIS), where it is analyzed by NTT's corevo AI technology (Step 2).

We are experimentally verifying a system we constructed to achieve more efficient monitoring and improved accuracy (**Fig. 3**). For example, by using multidimensional mixture data analysis technology developed by NTT Service Evolution Laboratories, we can efficiently extract meaningful lateral features from various kinds of data related to rice production, for example, farm temperature and humidity and the amount of solar radiation, and then forecast conditions and optimum harvest times for high-yield production of good-tasting rice.

Alternatively, to monitor the KUBOTA Submerged Membrane Unit (SMU)[*1] installed in private wastewater treatment facilities, we are using anomaly detection technology developed by NTT Software Innovation Center and the open-source machine-learning processing base called Jubatus[*2] [2] to analyze data such as pressure levels of submerged membranes and operating information. Such information was monitored by humans in the past but is now monitored automatically.

We are also working with the JA (Japan Agricultural Cooperatives) Group on initiatives in the area of livestock and farming. For example, the National Federation of Agricultural Cooperatives Associations (ZEN-NOH) is using a system called Mobile Gyuonkei (namely, attaching sensors to cows about to give

*1 KUBOTA SMU: A membrane bioreactor for water treatment systems using high-precision flat sheet membranes. The KUBOTA Submerged Membrane Unit® is a registered trademark of Kubota Corporation.

*2 Jubatus: An open-source online machine-learning framework for real-time distributed processing environments jointly developed by NTT Software Innovation Center and Preferred Networks, Inc.

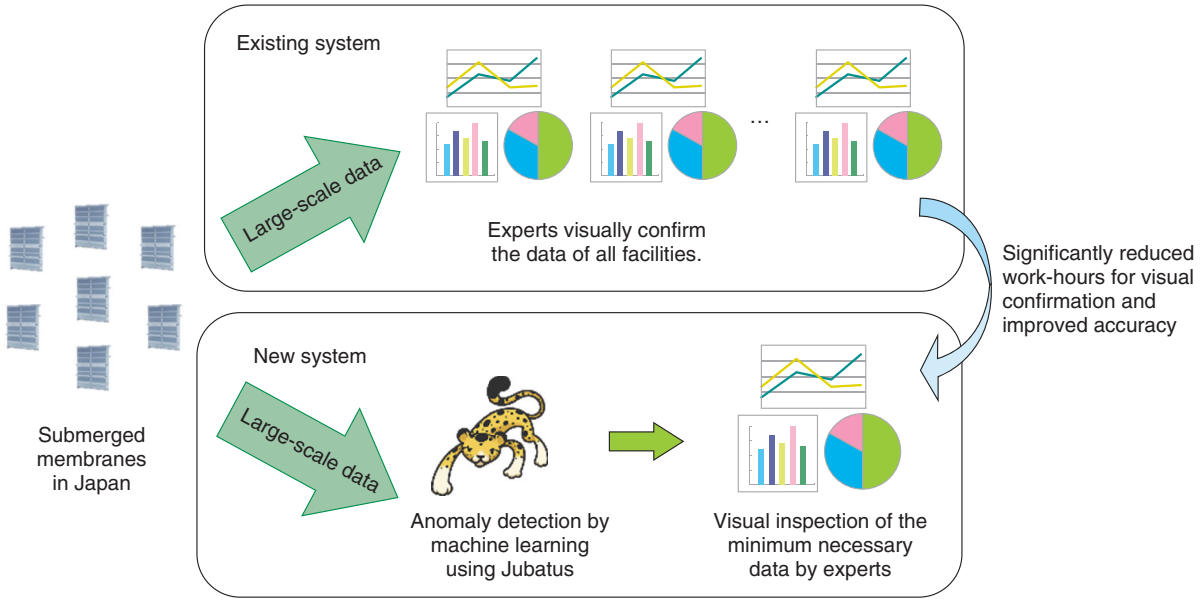


Fig. 3. Saving labor by using Jubatus in monitoring of submerged membranes.

birth to precisely measure their body temperature). This helps to ensure calving proceeds safely and without accidents and protects the interests of livestock farmers. Additionally, 1-km-mesh weather information is sent to a membership information service for producers and the JA Group called APPINES/AgriInfo. The information includes data on weather, temperature, humidity, rainfall, wind direction, and wind speed and is provided at 30-minute update intervals. Such extremely up-to-date and detailed meteorological information contributes to improving agricultural productivity.

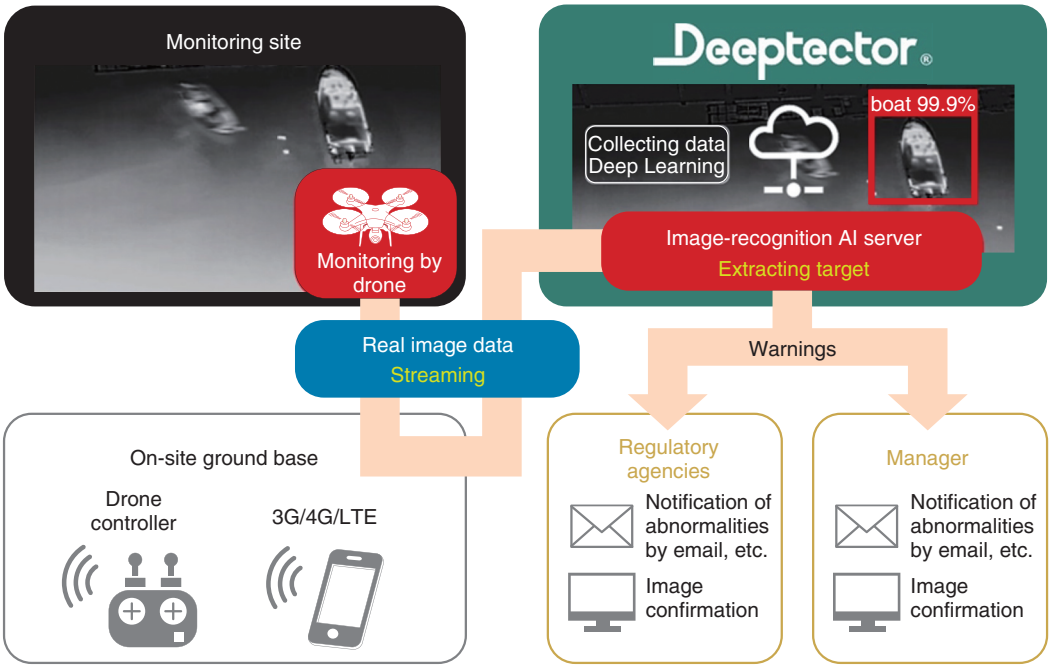
Furthermore, NTT and eight other NTT Group companies are participating in the Agricultural Data Collaboration Platform Council (WAGRI)*3 [3], in which more than 200 organizations from industry, government, and academia participate. We are utilizing various open systems and data possessed by WAGRI and also providing to WAGRI speech recognition technology equipped with a state-of-the-art speech recognition engine developed by NTT Media Intelligence Laboratories as well as weather and map services of the NTT Group in order to pursue digital transformation in Japan's agriculture industry.

Another new initiative is being implemented in the fisheries field. For example, in cooperation with regional fishery cooperatives, we are helping oyster farmers determine the optimum timing of their work by understanding the state of the ocean. This involves measuring the momentarily changing seawater temperature via a sensing network that can measure sea water temperature over a wide range. Moreover, we are helping to implement measures against the poaching of fish, which has been increasing in recent years, by collaborating with Mitsuiwa Corporation, which is proposing deterrence by drone monitoring, and advancing proposals to multiple fishery cooperatives. In particular, we have confirmed that by analyzing captured images and detecting and reporting poachers using image recognition AI called Deeptector®, we can greatly reduce the labor and cost burdens of conventional monitoring vessels and monitoring personnel and deter the poaching of fish (**Fig. 4**).

4. Future development

Until now, the NTT Group has focused on the agricultural value chain by working on production in farming. In the future, we will expand our efforts to the entire farming field, including distribution, processing, sales, and consumption. For example, we aim to develop a mechanism called the digital food value chain (which connects producers and customers

*3 WAGRI: A data sharing and provision platform for creating environments in which people working in agriculture can improve productivity and management by using data. The term WAGRI is a coined word combining *wa* (a Japanese word meaning harmony) and *agri* (agriculture).



LTE: Long-Term Evolution
3G/4G: third-generation/fourth-generation mobile communications

Fig. 4. Image of deterrence and monitoring of fish poaching by drone and Deeptector®.

with digital data) to promote *market-in agriculture* (which produces goods according to customers' requests). This mechanism will achieve planned and stable production as well as stable procurement, and enable concerned parties involved in farming to make profits without waste. Moreover, we will expand our efforts not only in Japan but also in a so-called *glocal* (global + local) manner. We are tackling agricultural problems on a global scale in ways such as expanding the digital farming system organized in Japan (local) to overseas production and utilizing blockchain and traceability technology for safe and secure importation of agricultural products produced outside Japan (global). Furthermore, we will promote prompt initiatives targeting the fishery and forestry industries through cooperation with the necessary partners. Aiming to become a value partner, in which the NTT Group is selected as a partner, we will continue to contribute to the sustainable development of primary industries with a global perspective (**Fig. 5**).

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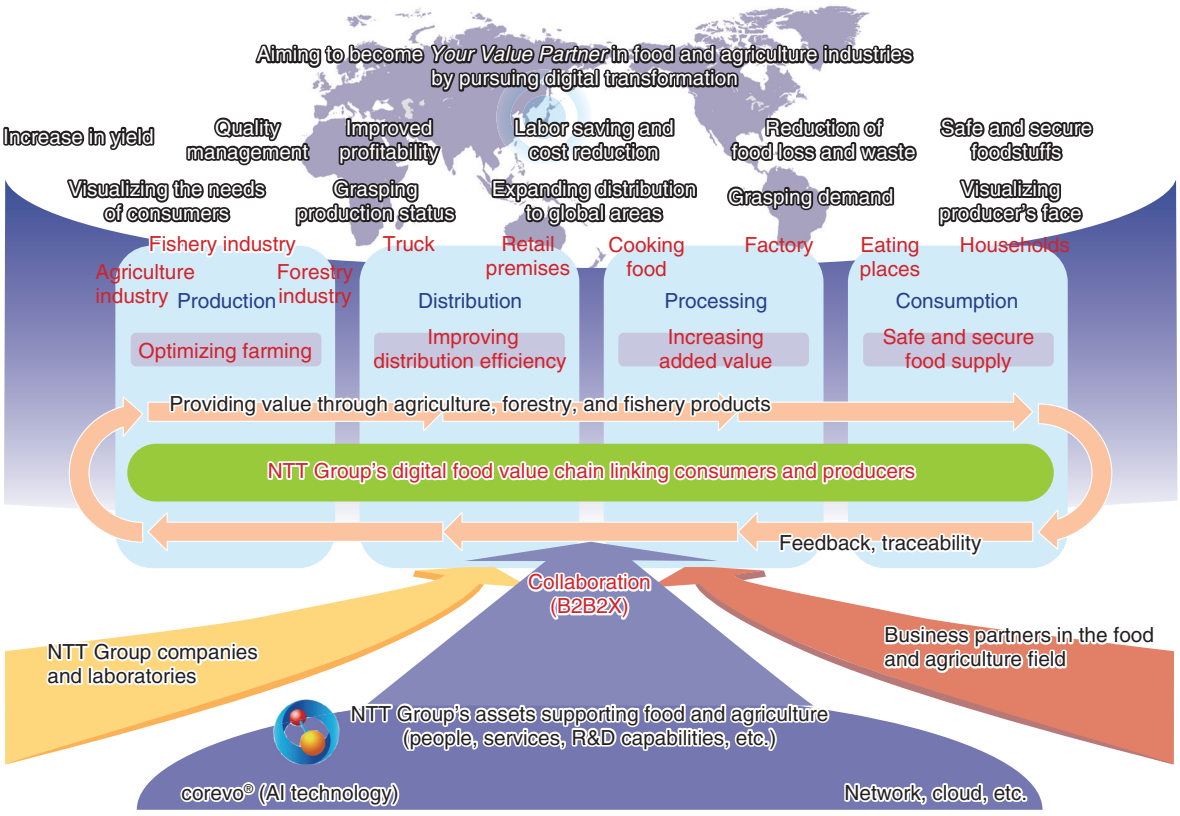

Fig. 5. Concept of *Your Value Partner* in the food and agriculture industries.

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A Kabuki and Information Communication Technology Collaboration: Kabuki × ICT

Soichiro Usui, Kazumasa Kimura, Shingo Kinoshita, and Kenichi Minami

Abstract

At NTT, we have been promoting various initiatives concerning the application of information and communication technology (ICT) to *kabuki*, the traditional Japanese performing art. Specifically, we have been conducting joint experiments with Shochiku Co., Ltd. since 2016 aimed at providing new ways to appreciate kabuki by using ICT. We have also been providing technology for *Cho Kabuki supported by NTT*, which has been performed since 2016 at the Niconico Chokaigi festival held by Dwango Co., Ltd. With the success of these achievements, NTT and Shochiku are planning to conduct commercial performances at the Minamiza Theatre in Kyoto starting in 2019. In this article, we introduce past initiatives concerning kabuki × ICT and outline future prospects.

Keywords: kabuki, ICT, collaboration

1. Initiatives involving joint experiments

In 2016, NTT and Shochiku Co., Ltd. initiated a joint experiment aiming to create a new way to appreciate *kabuki* using information and communication technology (ICT). The view at NTT was that it would be beneficial to collaborate with people engaged in high culture in order to provide deep excitement and new experiences through ICT looking ahead to 2020. At the same time, Shochiku was looking into creating new content to further disseminate the charm of kabuki while passing on traditional kabuki to the rapidly increasing number of inbound customers to Japan. NTT and Shochiku agreed to start collaborating in experiments, four of which have been done so far.

1.1 Kabuki in Las Vegas

At the venue of KABUKI LION SHI-SHI-O: The Adventures of the Mythical Lion, which was presented by Shochiku in Las Vegas, USA, in May 2016, we used ICT to encourage non-Japanese people to experience the charm of kabuki. At the same time, to provide kabuki-viewing experiences to many people beyond the barriers of time and distance, we conducted a variety of experiments at not only the Las Vegas performance venue but also at a remote location, namely, Haneda Airport in Japan.

1.1.1 Remote live transmission to Haneda Airport

Footage captured by nine 4K cameras installed at the kabuki performance venue in Las Vegas was encoded using high-compression HEVC (High Efficiency Video Coding) developed by NTT and then synchronized in real time using MMT (MPEG* Media Transport) technology to flexibly synchronize multiple streams of video and audio. Accordingly, we achieved the world's first live international transmission of 4K multiscreen videos. At Haneda Airport, by synchronously presenting 4K multiscreen videos as

* MPEG: Moving Picture Experts Group, a working group of ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission) in charge of developing international standards for compression of audio and video data.

Photo 1. Live viewing via 4K multiscreens.

an all-around view, namely, a front-stage view (three screens), an elevated-walkway (through the audience to the stage) view (one screen on the left side and three screens at the rear), and a ceiling view (two screens above), it was possible to reproduce the performance of kabuki actors across the board and provide an audience experience like being in a seat surrounded by the actual stage and elevated walkway (**Photo 1**).

Moreover, we used object extraction technology, which is an element of our immersive telecommunication technology called Kirari!, to enable the kabuki actor Ichikawa Somegoro VII (now Matsumoto Koshiro X) to give a remote stage greeting. In other words, we created an experience in which it appeared that Mr. Ichikawa was actually holding a press conference at the Haneda Airport venue in person, when he was actually in Las Vegas (**Photo 2**).

1.1.2 Interactive exhibition experiment outside the theater

In front of the theater in Las Vegas, we exhibited Henshin Kabuki (transformation kabuki), namely, an interactive-experience exhibition that combines advanced technologies of NTT with the motif of kabuki's unique makeup method known as *kumadori*. The mysterious world combining culture with technology that Japan boasts of has gained such a favorable reputation that people who wanted to try this interactive experience—who were mainly non-Japanese—lined up to give it a try (**Photo 3**).

With Henshin Kabuki, an image of the kumadori mask selected by the person trying the experience is first captured. The kumadori mask image is automatically recognized with high precision regardless of its direction and inclination by NTT's angle-free object-search technology. A kumadori pattern is then superimposed on the face of the person and displayed as augmented reality.

Furthermore, a demonstration was carried out of the concept of *amplified experience*—by which projection mapping with dynamic presentations such as pause and expressions specific to kabuki is performed on a giant three-dimensional (3D) facial object, and important elements in the production are extracted and made to stand out beyond reality—along with the key-point extraction and emphasis technology necessary for realizing that concept.

In addition, we changed the faces of 50 kumadori masks hanging on a wall surface, which typically do not move, so that they laugh, get angry, and form a variety of expressions by using NTT's Hen Gen Tou (deformation lamps) light projection technology.

We also applied Hen Gen Tou to offer new stage effects that give movement to background images conventionally used in kabuki. Additionally, we used interactive distribution technology for omnidirectional video in an experiment to transmit 4K omnidirectional

Photo 2. Remote stage greeting by Ichikawa Somegoro VII (now Matsumoto Koshiro X).

Photo 3. Ichikawa Somegoro VII (now Matsumoto Koshiro X) experiencing Henshin Kabuki.

video at low bandwidth while maintaining the quality of experience when viewing on site. In this manner, we have made efforts to expand the performance of kabuki both inside and outside the venue.

1.2 Kabuki Virtual Theatre

To expand the theatrical opportunities for kabuki fans in remote regions and to widely convey the appeal of kabuki, we set up Kabuki Virtual Theatres at the Kumamoto Prefectural Office in collaboration with NTT, NTT WEST, Kumamoto Prefecture, and

Photo 4. Kabuki Virtual Theatre.

Shochiku in March 2017 and at Paruse Iizaka, Fukushima City, in collaboration with NTT, NTT EAST, Fukushima Prefecture, and Shochiku in March 2018 as events to promote reconstruction efforts after the Kumamoto Earthquake and Great East Japan Earthquake, respectively.

1.2.1 Kabuki Virtual Theatre

Utilizing Kirari! technology made it possible to present performance images of KABUKI LION SHI-SHI-O as a new screening work full of realism that gave viewers the virtual sensation that the kabuki actors were performing right in front of them. In addition, in Fukushima, we experimentally demonstrated establishing an economical and versatile image-projection system. Visitors to the Kabuki Virtual Theatre really appreciated the wonder of kabuki and the latest technology as well as the increased opportunities to view kabuki remotely in rural areas (**Photo 4**).

1.2.2 Henshin Kabuki

An interactive-experience exhibition called Henshin Kabuki—which became popular in Las Vegas—was packaged in movable containers that allowed people in many different areas to experience the charm of kabuki. By utilizing the mobility of the containers, we were able to visit disaster areas in Kumamoto Prefecture and Fukushima Prefecture (**Photo 5**). A wide range of people, from young children to the elderly, visited the Henshin Kabuki container and responded very positively to the experience.

1.2.3 Kabuki Shout

In Fukushima Prefecture, we also exhibited Kabuki Shout—which lets people enjoy an experience like becoming a master of *omukou* (in which the kabuki audience shouts out to the actors)—by using NTT's acoustic processing technology (**Photo 6**).

An omukou shout is yelled toward the picture of an actor displayed on the big screen, and speech recognition is performed (even in noisy spaces) using NTT's intelligent-microphone technology. Real-time wave-field synthesis technology is then used to propagate the sound in three dimensions synchronously with the movement of the voice. In addition, when the omukou shout *hits* the actor's picture, the picture responds with various reactions depending on factors such as timing and kind of voice.

Highlighting in this way the feature of omukou shouts by applying the latest technology enables people to become familiar with kabuki in a new form.

1.3 Real and virtual collaboration dance Miyako Musubi Yume no Renjishi

In November 2017, as the third part of the joint experiment, we implemented a special project called Miyako Musubi Yume no Renjishi within the Hajimemashite Kabuki (Nice to meet you kabuki) event

Photo 5. Henshin Kabuki container.

Photo 6. Kabuki Shout.

Photo 7. Real and virtual collaboration dance using Kirari! technology.

being held by Kyoto City, with the aim of providing young people with opportunities to get to know traditional industries by experiencing the culture of Japan.

This experiment utilized object extraction technology and ultra-realistic media synchronization technology in the Kirari! set of technologies as well as dance performances by Nakamura Hashinosuke IV, Nakamura Fukunosuke III, and Nakamura Utanosuke IV, who performed at Miyagawacho Kaburenjo Theatre. The performances were transmitted in real time to the Pontocho Kaburenjo Theatre (1.5 km away) in such a manner as to create a virtual collaboration with Nakamura Shikan VIII performing at the Pontocho Kaburenjo Theatre (**Photo 7**). Thanks to the utilization of ICT in this way, we received comments such as "Amazing" and "Very impressed" from many young people after they watched the four artists performing in a perfectly synchronized manner as if they were all performing at the same venue.

2. Efforts concerning *Cho Kabuki supported by NTT*

Cho Kabuki was first performed in 2016 at the Niconico Chokaigi event held by Dwango Co., Ltd., and three works have been produced through 2018.

NTT and Dwango have been collaborating in business efforts related to video and social services since

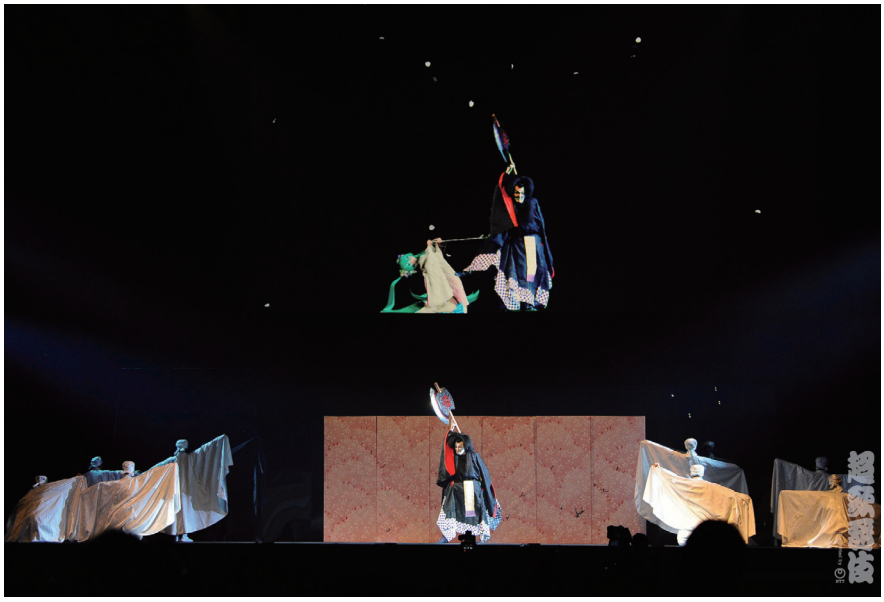


Photo 8. Shadow cloning using object extraction technology.

2013, and NTT has presented a research and development (R&D) booth at Niconico Chokaigi since 2014. We have also been providing extra sponsorship and technologies for Cho Kabuki since Niconico Chokaigi 2016.

NTT is taking up the challenge to create completely new kabuki productions using the latest technologies (including a technique called shadow cloning using Kirari!) and to broaden the ways of enjoying kabuki. We have advanced the technologies and stage effects each year in efforts to expand the younger generation of kabuki fans.

2.1 Shadow cloning using object extraction technology

We have been implementing a technique called shadow cloning with Cho Kabuki every year since its inception. This technique is used to create productions that were not possible in the past by extracting video images of kabuki actors in real time using object extraction technology and stereoscopically projecting the extracted video images to different places.

In 2016, shadow cloning was showcased for the first time in the play Hana Kurabe Senbonzakura to project multiple extracted videos of Nakamura Shido II, and we received a great response.

In 2017 in the play Kuruwa Kotoba Awase Kagami, it was possible to create the impression that Nakamura Shido and Sawamura Kuniya were fighting impressively in a virtual action scene between their respective avatars by simultaneously operating multiple object extraction systems.

In 2018, in the play Tsumoru Omoi Hana no Kaomise—Mata Kuru Haru Cho Kabuki no Nigiwai, the use of object extraction technology with improved extraction accuracy by machine learning enabled robust object extraction even in scenes where there was a change in the background that had never been done before. As a result, an action sequence with Nakamura Shido and the vocaloid Hatsune Miku performing a climax scene was successfully produced (**Photo 8**).

Shadow cloning continues to evolve year after year as a key technology underpinning a familiar stage effect of Cho Kabuki, and it has enabled us to provide new theater experiences every year.

2.2 New stage effects using double-sided transparent multilayer aerial-image display device

The paper-craft box for “Kirari! For Mobile” (multilayer aerial-image display technology) makes it possible to easily view 3D images in combination with smartphones. In the play Hana Kurabe Senbonzakura, this technology was used to enable viewers to enjoy Hatsune Miku performing in a box on the palm of the hand and to experience the flavor of Cho Kabuki.

The phrases in white and green at the top of the figure are omukou shouts by viewers of live streaming.

Photo 9. Double-sided transparent multilayer aerial-image display device.

In 2018, we extended this multilayer aerial-image display technology to develop a double-sided transparent multilayer aerial-image display device that enables three layers of aerial images to be viewed simultaneously from the front and back by controlling the optical path length for multiple display devices. In the play Tsunoru Omoi Hanano Kaomise—Mata Kuru Haru Cho Kabuki no Nigiwai, this technology was used to create a new effect that had previously been impossible; namely, Hatsune Miku appears as if on a float, the background of which is expressed in multiple layers, so it seems like she is parading around the stage (**Photo 9**).

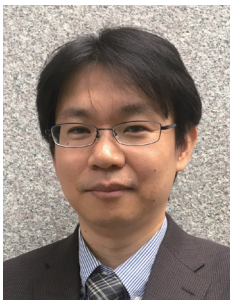
In addition to the above technologies, we used acoustic technologies, namely, virtual speaker technology and wave-field synthesis technology to create a powerful sound effect with high presence. Through these efforts, we received shouts from the audience and viewers of "Denwa-ya!" (telecom carrier) in the manner of an omukou shout, indicating that NTT has also succeeded in raising its presence among young customers.

3. Commercial performances of kabuki × ICT

Through the seven initiatives described so far, we have accumulated experience in the possibilities of kabuki × ICT. NTT and Shochiku will continue working to advance our efforts to utilize ICT in real kabuki performances, thereby raising our ability to attract customers, improve our business potential, and create new entertainment business opportunities.

After the reopening of the Minamiza Theatre in Kyoto in November 2018, NTT and Shochiku will spend the period from 2019 to 2021 co-producing performances such as kabuki that utilize ICT at the Minamiza Theatre and sequentially expand them to other theaters. As a first step, we are planning to co-produce a Cho Kabuki performance with Dwango at the Minamiza Theatre in August 2019.

Through the above efforts, as kabuki × ICT rises as a new genre, we will strive to expand our business by integrating kabuki and other forms of entertainment with ICT and to pursue the B2B2X(business-to-business-to-X) model through NTT Group companies. In addition, with an eye towards the imminent event in 2020, we will reflect the findings obtained during our efforts described in this report in the entertainment field as a whole.



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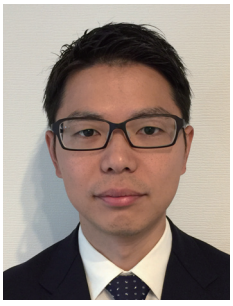

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Demonstration Trial of Nara Guide Bot—Kintetsu Railway and NTT Group's Jointly Developed Information Guidance Service for Train Stations

Hideo Fujii, Takashi Itoh, Mayuka Kitagawa, Yuto Mizoguchi, Takayuki Haseba, Yuriko Shimada, Taiji Nakamura, Takuya Murayama, and Satoshi Fukada

Abstract

There are many sightseeing spots along the railway lines of Kintetsu Railway Co., Ltd., including Nara and Ise-Shima, and the number of international tourists to these areas is rapidly increasing. In this article, we introduce a demonstration trial conducted at Kintetsu Nara Station of a tourist-guide service for inbound tourists. The service is called Nara Guide Bot and uses NTT's multimodal Agent-AI (artificial intelligence).

Keywords: AI, tourism, image recognition

1. Sharp increase in number of international visitors

The number of foreign nationals visiting Japan reached 28.69 million in 2017 after consecutively breaking the record for the preceding five years. The Japan National Tourism Organization (JNTO) reported in July 2018 that the number (estimated) of arriving visitors during the first half of 2018 (January to June) was 15.899 million, an increase of 15.6% over the same period in 2017. JNTO also announced that this number was the highest ever [1]. The 15-million mark was reached a month earlier than the previous year, which marked the fastest increase in Japan's history. Each prefecture in the Kansai region (western Japan) has also broken its record high. The (estimated) number of arriving visitors to Nara Prefecture in 2017 was 2.09 million, which is double that just two years earlier when it exceeded 1 million for the first time.

2. Seamless guidance information

Kintetsu Railway Co., Ltd. (Kintetsu) is working on seamless guidance for all customers, including inbound tourists, whose number is rapidly increasing as described above (**Fig. 1**).

Seamless guidance is a collective term for an information service provided by Kintetsu that is aimed at ensuring smooth use of railway services for all customers irrespective of age or language. Here, the meaning of *seamless* is considered twofold: first, customers moving smoothly and seamlessly to their destinations, and second, a system that is useable by all customers regardless of age or language. The use of smart devices such as smartphones and tablets has

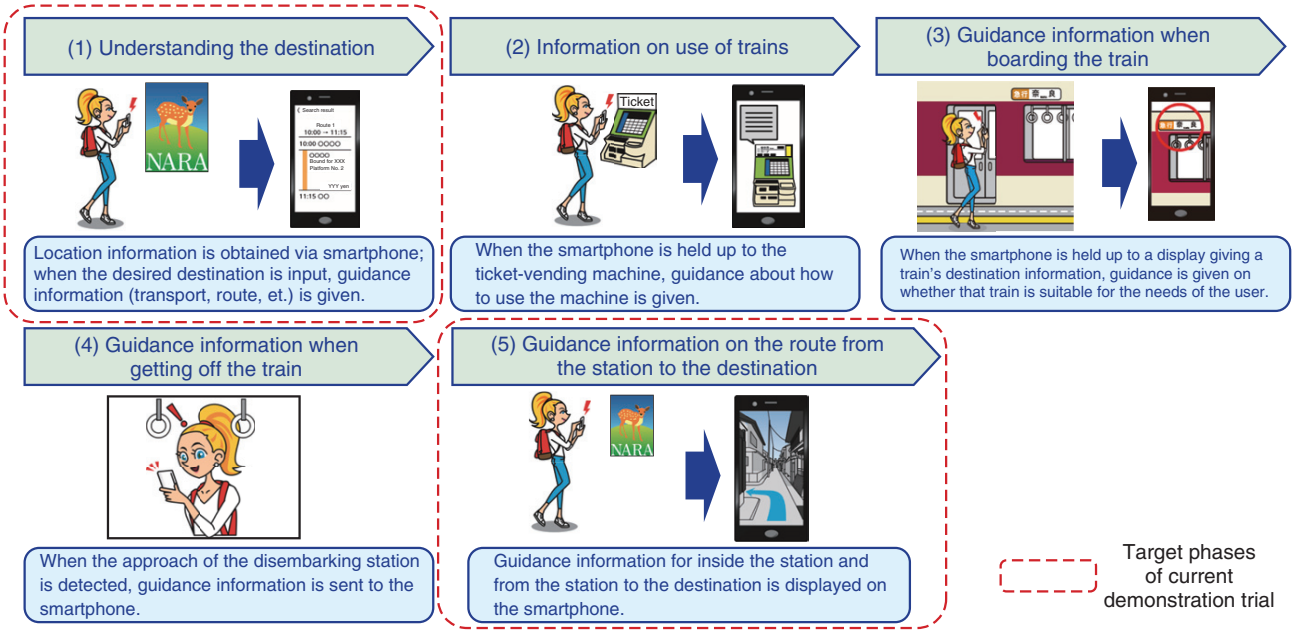

Fig. 1. Image of seamless guidance service.

increased around the world for all age groups, and we aim to create various services by utilizing such devices.

3. Present status of Kintetsu Nara Station

Kintetsu Nara Station is the station on the Kintetsu Line visited most often by inbound tourists to Japan. Multilingual concierge staff are currently employed to give these visitors the guidance they need verbally. Although enquiries from customers to staff members and concierge staff form general patterns, the number of enquiries continues to increase along with the increasing number of customers.

The results of observing and analyzing the trends of passengers using the Kintetsu Line for sightseeing—regardless of whether they are domestic or international visitors—revealed that many of them search for information on their own smartphones, record things by taking pictures, and try to make decisions by themselves. In other cases, passengers pointed to the screen of their smartphones while asking station staff for information.

4. Investigation of demonstration service

In cooperation with Kintetsu and NTT, NTT WEST investigated the demonstration service by carrying out the following actions.

(1) Interviewing staff at the foreign visitors desk/concierge at Kintetsu Nara Station
(2) Observing the behavior of inbound visitors to Japan
(3) Analyzing the contents of enquiries

The investigation indicated that there is a strong need for the concierge function, and it is expected to continue increasing as the number of tourists visiting Japan increases. Accordingly, we decided to create a demonstration service to solve problems revealed by behavior patterns of visitors from their arrival at the station to their reaching their desired sightseeing spot (**Fig. 2**).

5. Multimodal Agent-AI and demonstration service

Various artificial intelligence (AI) services are already available around the world. However, most of them have only a single means of inputting information (i.e., only text, images, or sound). This means that if a problem cannot be solved with one AI service, the user has to go to the trouble of activating and switching to another AI service.

Multimodal Agent-AI is an agent AI with multiple communication modes that utilizes NTT's corevo® technology. If a specific AI cannot answer a question, the system hands it over to another AI. Thus, it is

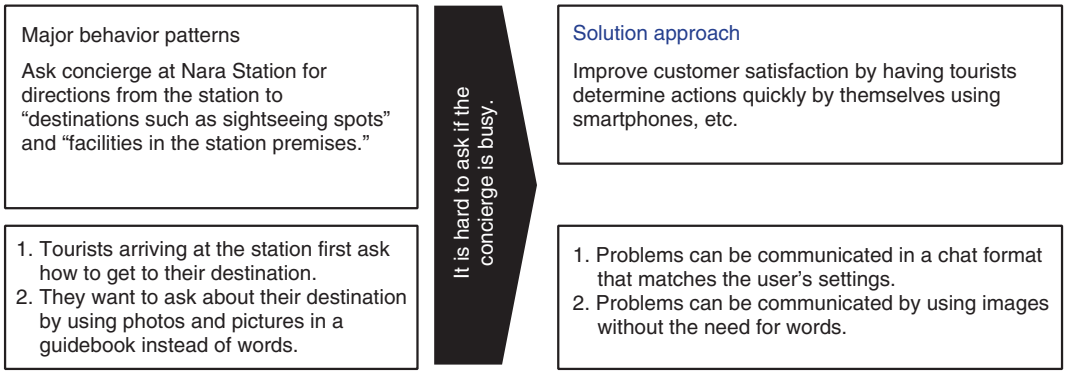

Fig. 2. Investigation of demonstration service.

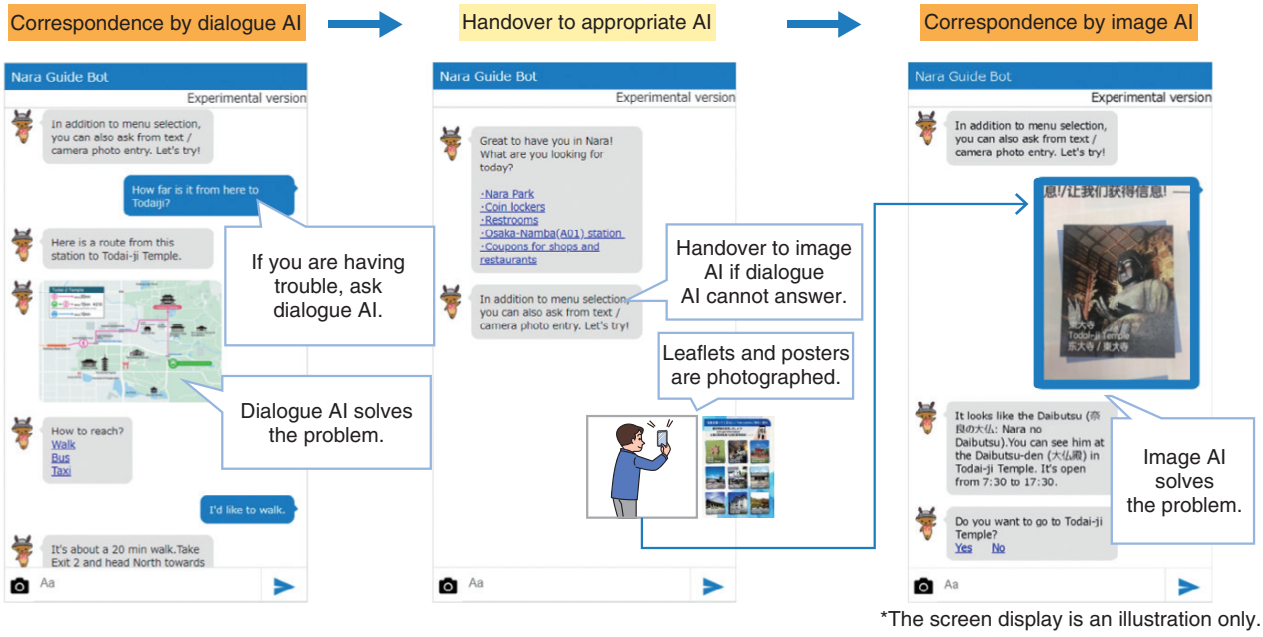

Fig. 3. Image of multimodal Agent-AI.

possible to provide useful information quickly while reducing the time and effort of the user operating the AI.

We used the results obtained from the investigation of the demonstration service to develop a chatbot using textual questions and image-type questions as a demonstration service system called Nara Guide Bot. With the multimodal Agent-AI, if a visitor finds it difficult to ask a question via text, the user can still send images of objects and photos and ask image-type questions by using the camera-interface AI (**Fig. 3**).

The camera-interface AI utilizes Point-and-Search Guidance, which is a service developed by NTT for displaying route guidance, detailed sightseeing information, and other information in the language set on the user's smartphone [2, 3] when the user holds up their smartphone and points it at information signboards, buildings, products, or other items. Angle-free object search technology [4] (one AI technology used in corevo) makes it possible to recognize the object with high precision even if the smartphone is held obliquely or if the target is blocked. In addition, we have developed text language processing and

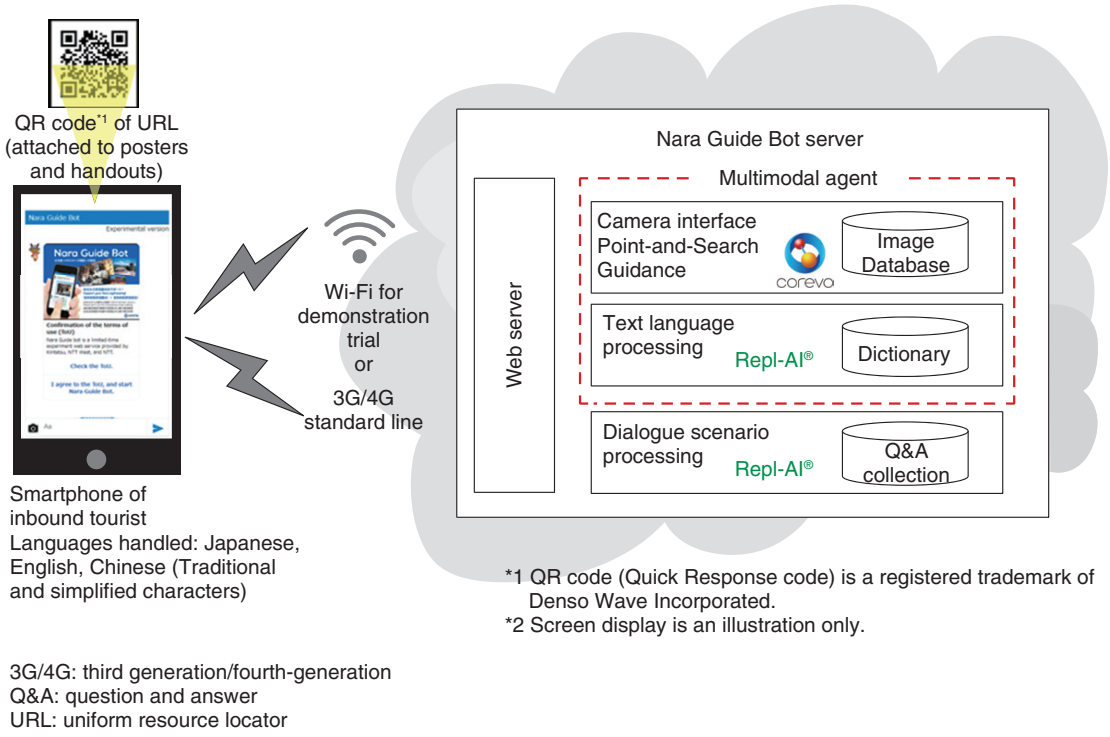

Fig. 4. Demonstration service system.

dialogue scenario processing, which are the basis of the chatbot, using the chatbot platform called Repl-AI® provided by NTT DOCOMO and Intermedia Planning, Inc. (**Fig. 4**).

6. Overview of demonstration trial

In the demonstration trial at the location and period stated below, multilingual staff briefly explained the service to actual inbound tourists before use. After the tourists had used the service, they were asked by questionnaire about its usability and their intention of using it (**Figs. 5** and **6**).

- Period: July 27 (Fri) 2018 to August 10 (Fri) 2018
- Location: Kintetsu Nara Station, East Gate, outer concourse

In addition, posters were hung, and leaflets were distributed in a corner of the East Gate, outer concourse, and the trend in use by inbound tourists was measured.

7. Results of demonstration trial

During the two-week period in which the demonstration service was open to the public, many travelers using Kintetsu Nara Station tried the Nara Guide Bot. We questioned over 400 inbound tourists by questionnaire; the results are summarized below.

(1) Regarding the usability of the service, over 90% of respondents said that the service was easy to use. The most common reason for this response was “Inquiries can be made using photographs,” which greatly exceeded the reasons “Inquiries can be made by text selection” and “Inquiries can be made via text input.” This result confirmed that the multimodal Agent-AI, which makes it possible to ask questions by sending images of objects and photographs, is effective from the viewpoint of inbound tourists.

(2) As for intention to use the service, more than 90% of respondents replied that they would use the service in the future, and this result confirmed the acceptability of the demonstration service.

(3) As for content, a large number of requests to expand the range of use were received from users. For example, in addition to route guidance starting from the station, route guidance

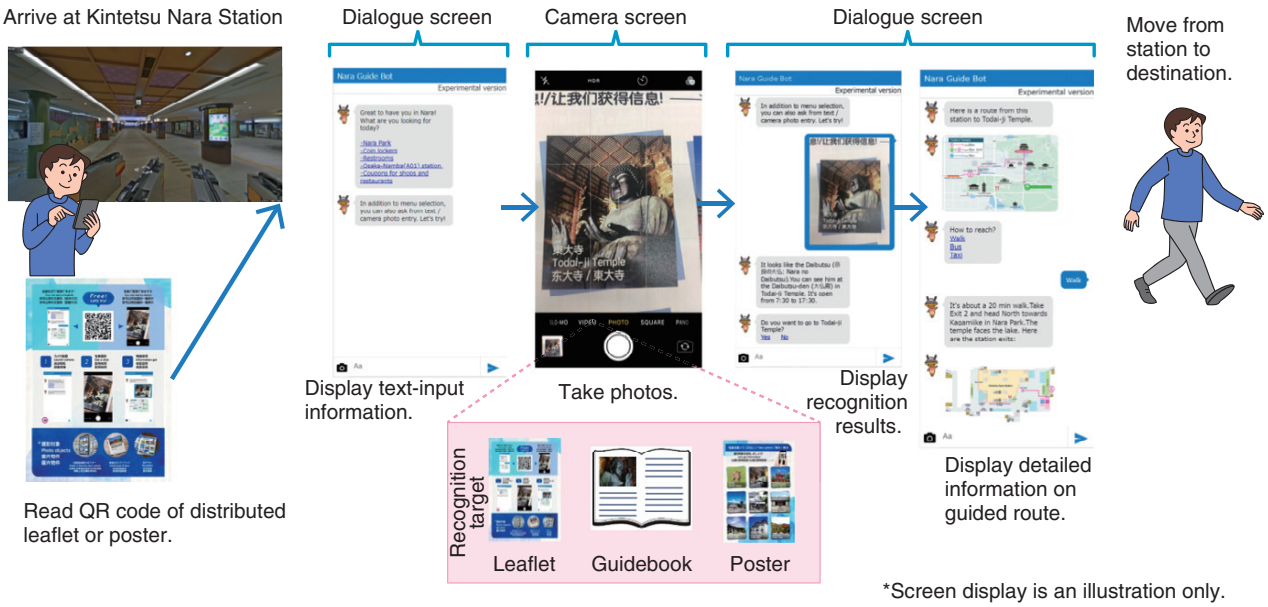

Fig. 5. Overview of demonstration trial.

Fig. 6. Demonstration trial at Kintetsu Nara Station.

starting from the user's current position while sightseeing was requested.

8. Future development

By utilizing the technology developed through this demonstration trial as the platform of seamless guidance provided by Kintetsu, we aim to create a new tourist information service with three key features: (i) provision of intuitive language-independent transport-usage guidance and tourist information, (ii) support of station staff and tourist information concierge, and (iii) proposal of a highly satisfactory tourist route through analysis of collected data. In addition, we will work toward practically applying solutions utilizing AI and other ICT (information and communication technology) tools such as Point-and-Search Guidance and chatbot, and contribute to solving social issues concerning the inbound tourist and transport industries.

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Trademark notes

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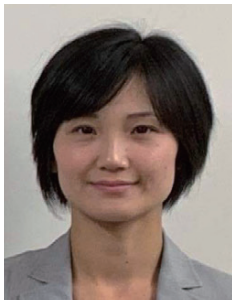

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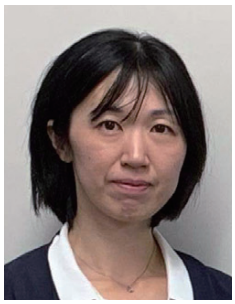

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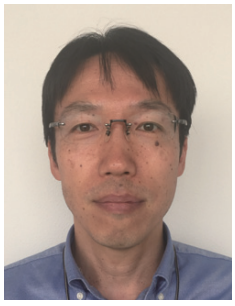

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Trends in Standardization of High-precision Time- and Frequency-synchronization Technology for Creating a 5G Mobile Network

Kaoru Arai and Makoto Murakami

Abstract

High-precision time- and frequency-synchronization technology has received worldwide attention in recent years for its importance in creating a future fifth-generation (5G) mobile network. Consequently, standardization of this technology is underway by ITU-T (International Telecommunication Union - Telecommunication Standardization Sector) Study Group 15. This article introduces the function of time- and frequency-synchronization technology in 5G mobile networks and describes standardization trends concerning technical requirements such as synchronization-network architecture and synchronization accuracy.

Keywords: 5G, time synchronization, PTP

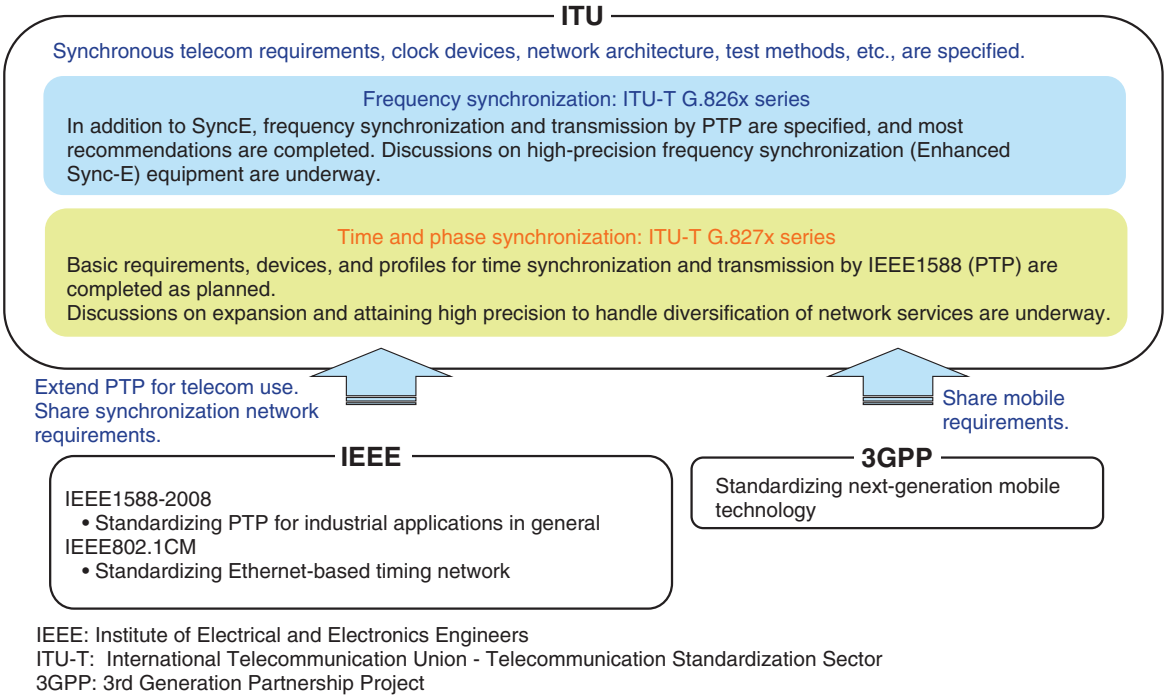
1. Time-synchronization technology in mobile communication

Synchronization technology is essential for data transmission between communication systems and has been introduced into many telecommunication operators' networks. Conventionally, network carriers offering services such as telephones and leased lines have established synchronous networks and have synchronized the clock frequencies of the devices, thereby multiplexing and separating data and providing high-quality services. Synchronization technology has been important even for packet-based asynchronous networks and is required for efficient data communication for fourth-generation (4G) and 5G mobile networks. Thus, synchronization technology is important in mobile communication as well as in fixed communication and is one of the basic technologies in realizing the network services of telecommunication operators.

Synchronization technology is mainly classified as frequency synchronization and phase/time synchronization. The state in which the clock frequencies of different systems match is called frequency synchronization, and the state in which the timings between the clocks agree is called phase synchronization. In particular, when the clock timing is synchronized with Coordinated Universal Time (UTC),[*1] that state is defined as time synchronization. Time-synchronization technology for communication services is currently used for time-division multiplex communication based on Long-Term Evolution (LTE), and fixing the time synchronization between UTC and mobile base stations contributes to improving the utilization efficiency of the frequency band at the base stations.

In the 5G era, more efficient use of bandwidth is necessary to handle the increasing amounts of data traffic, and advanced communication methods for improving communication quality are required in

*1 UTC: Time managed to continuously maintain the difference between global time (based on the earth's rotation) and international atomic time (based on the time standards of the standards agencies of each country) within 0.9 seconds by inserting leap seconds, etc.



IEEE: Institute of Electrical and Electronics Engineers
ITU-T: International Telecommunication Union - Telecommunication Standardization Sector
3GPP: 3rd Generation Partnership Project

Fig. 1. Relationships between standardization organizations concerning synchronization technology.

order to address the diversification of end applications. High-precision time synchronization for temporal coordination and control between base stations is also required. Representative example technologies are dual connectivity (i.e., communicating by using multiple base stations) and carrier aggregation (i.e., bundling a large number of carrier frequencies as one channel). Together with the standardization of such mobile technologies, standardization of the synchronization technologies that support them is under discussion.

2. Technology for achieving high-precision time/frequency synchronization

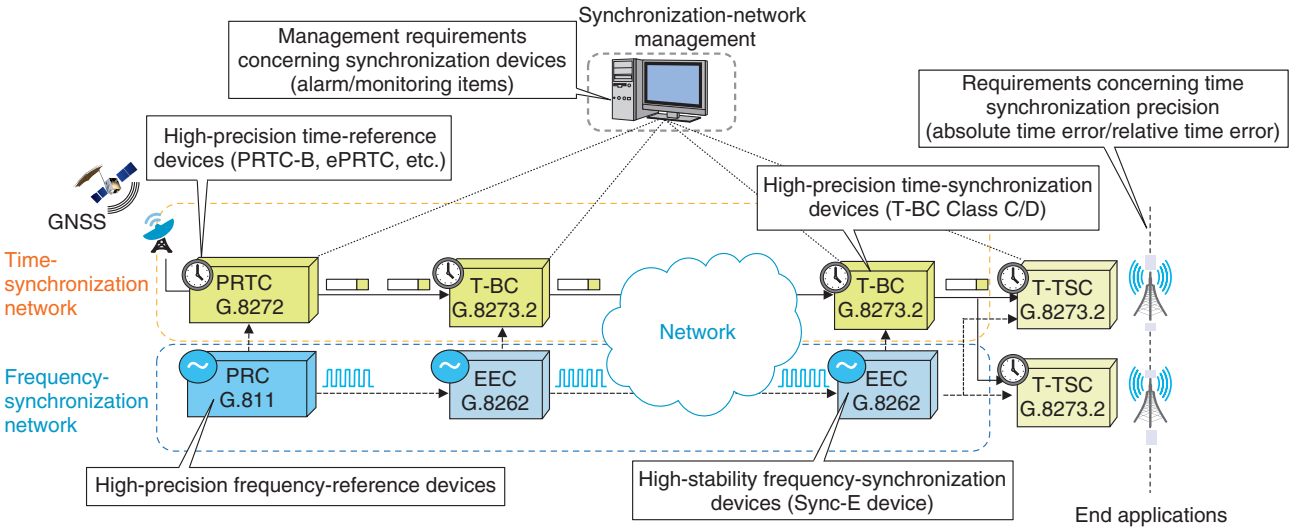
Precision Time Protocol (PTP)[*2] is a protocol for achieving time synchronization based on time-stamp information stamped on packets [1]. PTP has attracted attention in recent years because time synchronization with UTC is possible with microsecond- to nanosecond-order precision. Therefore, standardization of PTP as a candidate protocol for time synchronization of future 5G mobile networks is underway. PTP generally uses UTC information received from a global navigation satellite system (GNSS), typified by the GPS (Global Positioning System), as the time reference. It is possible to transmit and synchronize that time information—with the installation site of the GNSS antenna as the reference point—by utilizing the network.

Frequency synchronization, represented by Synchronous Ethernet (Sync-E) [2], is also commonly used as a backup for time synchronization. If PTP packets are missing (due to network congestion, etc.), and time synchronization is not possible, time synchronization can be maintained for a certain period of time by applying frequency synchronization.

3. Relationships between standardization organizations in terms of time/frequency-synchronization technology

Standardization bodies are addressing various issues related to frequency-, phase-, and time-synchronization technologies including PTP, and the relationships between these organizations in terms of these technologies are shown in **Fig. 1**. Study Group

*2 PTP: A protocol to calculate the time shift of a slave (subordinate device) relative to a master (superior device) based on time-stamp information and round-trip-delay information stamped in a dedicated time-synchronization packet and synchronize the calculated time with the master clock.



PRTC: primary reference time clock
PRC: primary reference clock
T-BC: telecom-boundary clock
T-TSC: telecom-time slave clock
EEC: synchronous Ethernet equipment clock

Fig. 2. Configuration of synchronization network and main standardization topics.

(SG)15 of the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) is standardizing specifications for frequency-synchronization technology such as Sync-E (ITU-T G.826x series) as well as time-synchronization technology that extends PTP (IEEE1588-2008, prescribed for general industrial applications by the Institute of Electrical and Electronics Engineers (IEEE)) to telecommunication operators (ITU-T G.827x series). The 3rd Generation Partnership Project (3GPP) has been specifying the technological requirements of the mobile field, and this information is being fed back to the ITU-T for their discussions. In addition, the ITU-T is standardizing synchronization equipment while referring to the draft timing requirements (IEEE802.1CM: Time-Sensitive Network for Fronthaul) for the Ethernet-based mobile fronthaul being discussed by IEEE.

4. Requirements concerning time and frequency synchronization for 5G mobile communication

At the ITU-T SG15 meeting in February 2018, a technical report (GSTR-TN5G) on transport networks for 5G was given consent. That report also includes network architecture and accuracy requirements concerning time- and frequency-synchronization technologies. The discussion topics concerning general network configurations and standardization for time and frequency synchronization are shown in **Fig. 2**. The time-synchronization network is configured with a primary reference time clock (PRTC)—a time-reference device that receives time from a GNSS, a telecom-boundary clock (T-BC)*3 for receiving, synchronizing, and transmitting time information from the PRTC, and a telecom-time slave clock (T-TSC)*4 for supplying the time from the T-BC to the end application.

The frequency-synchronization network supporting time synchronization consists of a primary reference clock (PRC)—a frequency-reference device—and a synchronous Ethernet equipment clock (EEC), which synchronizes and distributes frequency by Sync-E. In addition, the synchronization-network management system monitors and controls these time- and frequency-synchronization devices.

Accuracy is cited as the main requirement of time synchronization [3]. In addition to the absolute time error defined in terms of error with respect to UTC, in

*3 T-BC: A device that calculates time information from PTP packets and attains time synchronization. The time information can then be relayed from a time source.
*4 T-TSC: A device that terminates PTP packets and supplies time information to the end application.

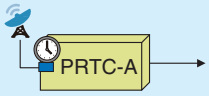
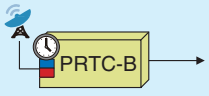
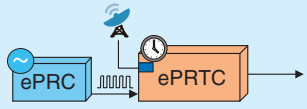
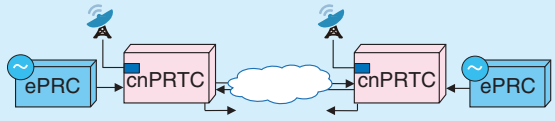
Table 1. Requirements concerning mobile applications and time-synchronization accuracy.

Category	Applications	Time alignment error
A+	MIMO or TX diversity transmission, at each carrier frequency	65 ns
A	Intra-band contiguous carrier aggregation with or without MIMO or TX diversity	130 ns
B	Intra-band non-contiguous carrier aggregation with or without MIMO or TX diversity, and inter-band carrier aggregation, with or without MIMO or TX diversity	260 ns
C	TD-LTE	3 μs

Source: IEEE802.1CM Draft 2.2; Draft standard for local and metropolitan area networks—excerpt from Time-Sensitive Networking for Fronthaul

MIMO: multiple-input multiple-output
TD-LTE: time-division duplexing LTE
TX diversity: transmit diversity

Table 2. Classes of PRTC.

PRTC type	Performance	Device configuration
PRTC-A (G.8272)	Maximum time error: 100 ns	
PRTC-B (G.8272)	Maximum time error: 40 ns Error reduction of GNSS signal reception by high-precision receiver	
enhanced PRTC (ePRTC) (G.8272.1)	Maximum time error: 30 ns Time synchronization is maintained when GNSS reception is impossible by frequency-reference device (ePRC) (within 100 ns over 14 days).	
coherent network PRTC (cnPRTC) (G.8275 et al.) Under discussion	Maximum time error: ? Reliability improved by mutual monitoring and comparison through the network High precision achieved by mutual synchronization	

recent years, relative time error between base stations is also being considered under the assumption of 5G applications. The time-synchronization accuracy requirements of major mobile applications being discussed and regulated by the 3GPP and IEEE are listed in **Table 1**. Up to now, standardization has been advanced with the aim of achieving absolute time-synchronization accuracy of 3 μs for TD-LTE (time-division duplexing LTE) [4]. However, in recent years, higher precision (namely, a minimum of 65 ns) is being required as a relative time error for carrier aggregation and other technologies. Therefore, to ensure high-precision and stable operation of various synchronous devices for providing time information to base stations, high reliability as well as management capabilities are required. In the following section, standardization trends concerning these topics are introduced.

5. Quality improvement of time-synchronization devices

Here, we report on efforts to improve the quality of time-reference and time-synchronization devices.

5.1 Time-reference device (PRTC)

Currently, the ITU-T specifies multiple types of PRTC, which is a device that receives time from a GNSS, according to the levels of accuracy and reliability as listed in **Table 2**. In contrast to PRTC-A

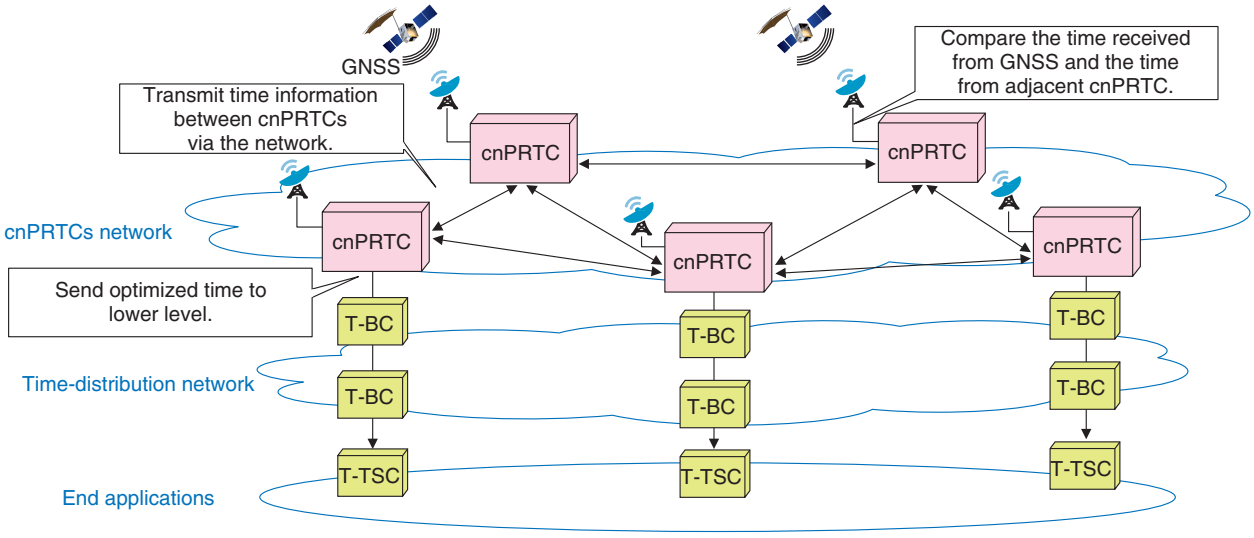


Fig. 3. Concept of cnPRTC.

(G.8272), which specifies a maximum time error in relation to UTC of 100 ns, PRTC-B (G.8272), for which a highly accurate receiver is mounted, specifies a reduced error of 40 ns. In addition, ePRTC (enhanced PRTC, G8272.1) has a function for maintaining time synchronization (*holdover*) with high precision by using a frequency-reference device (PRC) when a GNSS signal cannot be received. Currently, the specified holdover requirement is that time synchronization must be maintained within 100 ns over two weeks.

More recently, discussions have begun on a device concept called coherent network PRTC (cnPRTC) as a solution utilizing networks to minimize the effect when a GNSS signal cannot be received. As shown in **Fig. 3**, a cnPRTC optimizes error while comparing time information from a GNSS received from its own base station and information from neighboring devices, synchronizing those bits of information, and detecting abnormalities in GNSS reception. Details of the monitoring network architecture and mutual comparison methods will be discussed from now onwards. To improve the reliability and quality of future synchronization networks, NTT also proposes concepts concerning equipment in cooperation with other telecommunication operators.

A PRTC is an important device in a time-synchronization network. However, depending on the environmental disturbance and antenna installation conditions, the desired quality may not be able to be secured, especially when the GNSS signal is received as a reference. Consequently, developing a method for achieving stable reception of the GNSS signal has become a major issue among ITU-T participants. Therefore, the ITU-T is working on creating a technical report (GNSS-TR) on basic know-how and general measures against error factors concerning GNSS—to be published in the future.

5.2 Time-synchronization device (T-BC)

The T-BC (G.8273.2) receives time information from a PRTC and transmits and synchronizes it, and the issue of reducing the time error per device is being discussed. The ITU-T specifies the maximum absolute time error per device as a performance index of a T-BC, and that error is classified according to the accuracy class of the device, as listed in **Table 3**. Currently, although Class B is specified, new classes must correspond to the high accuracy requirement for 5G. At the ITU-T SG15 meeting in February 2018, agreement was reached on specifying the new classes of C and D. It was agreed at the meeting in October 2018 to specify the maximum time error per node to 30 ns for Class C. Opinions were expressed that class D should be set to 15 ns per node, and the specification of numerical values is planned from the viewpoints of both use cases of telecommunication operators and performance of the equipment. Specific requirements are also being fine-tuned in cooperation with other telecommunication operators based on the functionality and performance of a new clock-supply module for high-accuracy time synchronization

Table 3. Maximum absolute time error per node of T-BC (October 2018).

Class	Maximum absolute time error (ns)	
A	100 ns	
B	70 ns	
C	30 ns	Newly agreed
D	15 ns?	Under discussion

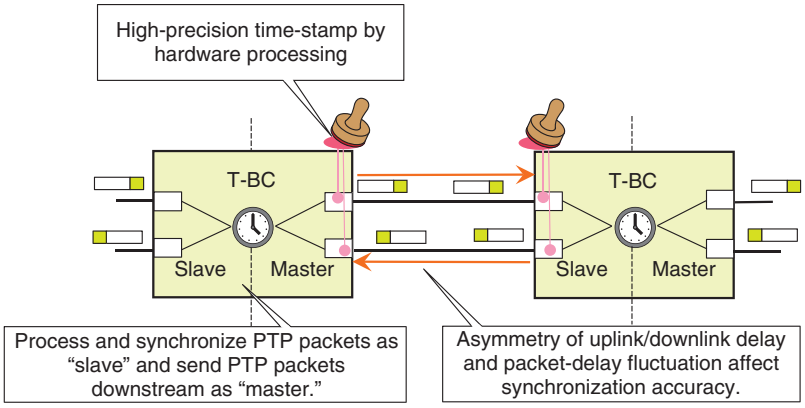


Fig. 4. Function of T-BC.

developed by NTT [5].

Also, the performance of the PTP itself within the T-BC is being studied with the aim of improving time-synchronization accuracy. As shown in **Fig. 4**, the error factors of the PTP for the T-BC include time-stamp-embossing error caused by internal clock frequency and asymmetry in uplink and downlink delay.

As an example of a time-stamp-embossing error, when the internal clock frequency of the device is 125 MHz, the error of one time-stamp becomes a maximum of 8 ns. Therefore, in the case of T-BC class D (equivalent to the level of several nanoseconds), it is necessary to improve the time-stamp performance within the device.

The delay asymmetry of the uplink and downlink is being considered in order to achieve high accuracy from the viewpoints of intra-device delay and fiber-transmission delay. With regard to intra-device delay, although the PTP has a function for eliminating delay fluctuation in the device by means of a hardware time-stamp function, ways to further improve synchronization accuracy by taking into account the delay-fluctuation factor at the device level are being discussed. However, in the current situation, intra-device delay primarily depends on the implementation, and specifying the delay values as standards is an important task facing the ITU-T. Regarding fiber-transmission delay, parameters of optical fibers (such as wavelength dispersion) have been discussed by ITU-T SG15 in cooperation with members studying issues related to optical fiber, and the goal is to promote understanding with the participants responsible for synchronous systems.

6. Quality improvement of frequency-synchronization devices

Efforts are underway to increase the accuracy of frequency synchronization by improving the quality of the relevant devices. Those efforts are described in this section.

6.1 Frequency-reference device (PRC)

When the time-synchronization signal is interrupted, it is necessary to keep the time according to the frequency-synchronization signal and internal clock. Frequency-synchronization accuracy is determined by the performance of the PRC (shown in Fig. 2). The conventional PRC (G.811) recommendation is

intended for use with synchronous network services such as telephone and leased lines, and it was last updated in 1997. However, in anticipation of the use of frequency synchronization in the mobile field, based on the latest technology of clock devices such as atomic clocks, enhanced PRC (ePRC) was given consent as a new recommendation (G.811.1) in June 2017. The frequency accuracy of an ePRC was specified to be improved tenfold over that achieved by a conventional PRC. For example, if the frequency accuracy is increased tenfold by switching from PRC to ePRC, the holding time when the time signal is interrupted is also extended tenfold, so sufficient time is available to restore the time signal.

6.2 Frequency-synchronization device (EEC)

An EEC (G.8262) is a frequency-synchronization device equipped with Sync-E, and discussions have been held on developing a high-quality enhanced EEC (eEEC). Consent was obtained for the new recommendation (G.8262.1) at the meeting in October 2018. The stability of timing devices such as oscillators incorporated in the eEEC was the main issue being discussed, and the eEEC was being considered in reference to the effects of the temperature characteristics of an actual device. As a result, the holdover performance when the input signal of frequency synchronization is lost was specified to be more stable than the conventional EEC.

7. Enhancement of synchronization network management

In addition to the synchronization devices described above, the management of synchronous networks has also been a recent topic of discussion. The ITU-T has already standardized the OAM (operations, administration, and maintenance) of main-signal systems such as Ethernet. However, with the recent increased importance of time-synchronization technology, the need for stable maintenance and operation of synchronization-system devices is increasing. The ITU-T discusses specific quality-monitoring items, measurement items, as well as alarms and events regarding synchronization devices based on maintenance requirements received from telecommunication operators. In addition to developing the new clock-supply module [5], NTT has also proposed technologies (such as ones for quality monitoring and alarms) included with the developed equipment and has reflected those technologies in the relevant document. That document is scheduled to be prepared as an auxiliary document (G.Suppl.SyncOAM) for the recommendations of existing synchronization technologies.

8. Future development

Time-synchronization technology is an important technology for the 5G era, and it is necessary to keep track of standardization trends in the future in a timely manner. NTT will continue to actively contribute to standardization activities while advancing research and development of high-accuracy synchronization technology.

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He received a B.S. and M.S. in applied physics from Tokyo University of Science in 2010 and 2012. Since joining NTT Network Service Systems Laboratories in 2012, he has been researching and developing network systems such as clock supply systems and leased line systems. He has been participating in ITU-T SG15 activities concerning synchronization technologies since 2014.

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He received a Ph.D. in electrical engineering from the University of Tokyo in 2009. He initially engaged in the research and development (R&D) of long haul transmission systems using optical amplifiers and coherent modulation/demodulation schemes at the emergence of those technologies. After completing development and deployment of a commercial optically amplified submarine system, he continued R&D of wavelength division multiplexing systems to further increase the fiber transmission capacity. From 2001 to 2003, he worked for NTT Communications, where he was involved in the construction and operation of international communication networks mainly in the Asia-Pacific region. Since 2003 he has been an active participant in ITU-T SG15 as head of the Japanese delegation and has also been involved in R&D and standardization of large-capacity optical transport networks. He is currently the chairman of the transport networks and EMC (Electro-Magnetic Compatibility) Working Group in the Telecommunication Technology Committee (TTC) of Japan. He received the Accomplishment Award from the ITU Association of Japan in 2015 and the Distinguished Service Award from TTC in 2015.

External Awards

TTC Information and Communication Technology Award, TTC Chairman's Prize
Winner: Kenjiro Arai, NTT Network Service Systems Laboratories
Date: June 19, 2018
Organization: The Telecommunication Technology Committee (TTC)

For his contribution to the standardization and actualization of IP interconnections.

DICOMO 2018 Paper Award
Winner: Motohiro Makiguchi and Hideaki Takada, NTT Service Evolution Laboratories
Date: September 4, 2018
Organization: Information Processing Society of Japan (IPSJ), Multimedia, Distributed, Cooperative, and Mobile (DICOMO) 2018 Symposium

For "Tabletop Type Glassless 3D Screen System Using Optical Linear Blending."
Published as: M. Makiguchi and H. Takada, "Tabletop Type Glassless 3D Screen System Using Optical Linear Blending," Proc. of DICOMO 2018, 3C-1, pp. 509–513, Fukui, Japan, July 2018 (in Japanese).

JSAP Poster Award
Winner: Nahoko Kasai, NTT Basic Research Laboratories/Tokyo Metropolitan University; Aya Tanaka and Tetsuhiko Teshima, NTT Basic Research Laboratories; Koji Sumitomo, University of Hyogo; Hiroshi Nakashima, NTT Basic Research Laboratories
Date: September 18, 2018
Organization: The Japan Society of Applied Physics (JSAP)

For "Neuronal Growth Control Using Chemical Modification of Nanopillars."
Published as: N. Kasai, A. Tanaka, T. Teshima, K. Sumitomo, and H. Nakashima, "Neuronal Growth Control Using Chemical Modification of Nanopillars," Proc. of the 79th JSAP Autumn Meeting, 20p-PA3-8, Nagoya, Aichi, Japan, Sept. 2018.

CSS 2018 Incentive Award
Winner: Nariyoshi Chida, Yo Kanemoto, Kazufumi Aoki, and Jun Miyoshi, NTT Secure Platform Laboratories
Date: October 24, 2018
Organization: IPSJ Special Interest Group on Computer Security Group (CSEC), Computer Security Symposium 2018 (CSS 2018)

For "A Formal Grammar-based Approach toward Attack Scenario Reconstruction."
Published as: N. Chida, Y. Kanemoto, K. Aoki, and J. Miyoshi, "A Formal Grammar-based Approach toward Attack Scenario Reconstruction," Proc. of CSS 2018, 2B3-2, Nagano, Japan, Oct. 2018 (in Japanese).

MWS 2018 Outstanding Paper Award
Winner: Toshinori Usui, Yuto Otsuki, Yuhei Kawakoya, Makoto Iwamura, and Jun Miyoshi, NTT Secure Platform Laboratories
Date: October 24, 2018
Organization: IPSJ CSEC, Anti Malware Engineering Workshop 2018 (MWS 2018)

For "Automatic Enhancement of Script Engines by Appending Behavior Analysis Capabilities."
Published as: T. Usui, Y. Otsuki, Y. Kawakoya, M. Iwamura, and J. Miyoshi, "Automatic Enhancement of Script Engines by Appending Behavior Analysis Capabilities," Proc. of MWS 2018, Nagano, Japan, Oct. 2018 (in Japanese).

RIEC Award
Winner: Nobuyuki Matsuda, NTT Basic Research Laboratories
Date: November 29, 2018
Organization: Research Institute of Electrical Communication, Tohoku University

For his achievements in researching advanced control of photonic states for quantum communications.

Papers Published in Technical Journals and Conference Proceedings

Future Nationwide Optical Network Architecture for Higher Availability and Operability Using Transport SDN Technologies
Y. Uematsu, S. Kamamura, H. Date, H. Yamamoto, A. Fukuda, R. Hayashi, and K. Koda
IEICE Transactions on Communications, Vol. E101-B, No. 2, pp. 462–475, February 2018.
An optical transport network is composed of optical transport

systems deployed in thousands of office buildings. As a common infrastructure to accommodate diversified communication services with drastic traffic growth, it is necessary not only to continuously convey the growing traffic but also to achieve high end-to-end communication quality and availability and provide flexible controllability in cooperation with service layer networks. To achieve high-speed and large-capacity transport systems cost-effectively, system configuration, applied devices, and the manufacturing process have recently begun to change, and the cause of failure or performance degradation has become more complex and diversified. The drastic traffic growth and pattern change of service networks increase the frequency and scale of transport-capacity increase and transport-network reconfiguration in cooperation with service networks. Therefore, drastic traffic growth affects both optical-transport-system configuration and its operational cycles. In this paper, we give an overview of the operational problems emerging in current nationwide optical transport networks, and based on trends analysis for system configuration and network-control schemes, we propose a vision of the future nationwide optical-transport-network architecture expressed using five target features.

Simulation of Water Absorption and Desorption Behavior for Anti-corrosion Coatings in Existing and New Accelerated Corrosion Tests

T. Miwa, Y. Takeshita, A. Ishii, and T. Sawada

Progress in Organic Coatings, Vol. 120, pp. 71–78, February 2018.

A cyclic corrosion test (CCT) that ensures compatibility with acceleration of corrosion and approximation of actual outdoor corrosion is in high demand, and many kinds of CCTs have been developed. We have proposed a new CCT for evaluating corrosion resistance of anti-corrosion coatings. In this work, we measured the water diffusion coefficients of three kinds of anti-corrosion urethane/epoxy coatings at 20–60°C and calculated their activation energies. In addition, the water absorption/desorption behaviors of the coatings in several CCTs, including our new CCT, were simulated.

Regulated Transport Network Design Using Geographical Resolution

S. Kamamura, A. Fukuda, R. Hayashi, and Y. Uematsu

IEICE Transactions on Communications, Vol. E101-B, No. 3, pp. 805–815, March 2018.

This paper proposes a regulated transport network design algorithm for IP over a dense wavelength division multiplex (DWDM) network. When designing an IP over DWDM network, the network operator should consider not only cost-effectiveness and physical constraints such as wavelength colors and chromatic dispersion but also operational policies such as resilience, quality, stability, and operability. For considering the above policies, we propose to separate the network design algorithm based on a geographical resolution; the policy-based regulated intra-area is designed based on this resolution, and the cost-optimal inter-area is then designed separately, and finally merged. This approach does not necessarily yield a strict optimal solution, but it covers network design work done by humans, which takes a vast amount of time and requires a high skill level. For efficient geographical resolution, we also present a fast graph mining algorithm, which can solve NP-hard subgraph isomorphism problems within the practical time. We prove the sufficiency of the resulting network design for the above policies by visualizing the topology, and also prove that the penalty of applying the approach is trivial.

Distributed IP Refactoring: Cooperation with Optical Transport Layer and Centralized SDN

S. Kamamura, A. Fukuda, H. Mori, R. Hayashi, and Y. Uematsu

IEICE Transactions on Communications, Vol. E101-B, No. 7, pp. 1661–1674, July 2018.

By focusing on the recent swing to the centralized approach by the software defined network (SDN), this paper presents a novel network architecture for refactoring the current distributed Internet protocol (IP) by not only utilizing the SDN itself but also implementing its cooperation with the optical transport layer. The first IP refactoring is for flexible network topology reconfiguration; the global routing and explicit routing functions are transferred from the distributed routers to the centralized SDN. The second IP refactoring is for cost-efficient maintenance migration; we introduce a resource portable IP router that can behave as a shared backup router by cooperating with the optical transport path switching. Extensive evaluations show that our architecture makes the current IP network easier to configure and more scalable. We also validate the feasibility of our proposal.

End-to-End Redundancy and Maintenance Condition Design for Nationwide Optical Transport Network

Y. Uematsu, S. Kamamura, H. Yamamoto, A. Fukuda, and R. Hayashi

IEICE Transactions on Communications, Vol. E101-B, No. 11, pp. 2267–2276, November 2018.

To achieve high end-to-end availability in nationwide optical transport networks across thousands of office buildings, it is important to properly make each function redundant, and execute protection switching, repair failed functions, and recover redundancy to prevent multiple simultaneous failures. High redundancy leads to high system cost and high power consumption, and tight conditions for recovery lead to high maintenance cost. Therefore, it is important to optimize the balance between redundancy and maintenance conditions based on appropriate availability indicators. We previously proposed a resource-pool control mechanism for a nationwide optical transport network that can optimize the balance. This paper proposes an end-to-end availability evaluation scheme for a nationwide optical transport network with our mechanism, by which network operators can design the pool-resource amount of each function and the maintenance conditions for each network area properly to satisfy the end-to-end availability requirement. Although the maintenance conditions are usually discussed based on failure-recovery times, they should be discussed based on cost- or load-based volumes for this design. This paper proposes a maintenance-operation-load evaluation scheme, which derives the required number of maintenance staff members from failure-recovery times. We also discuss the design of the pool-resource amount and maintenance conditions for each network area of a nationwide network based on the proposed evaluation schemes.

Accelerating a Lloyd-type k-Means Clustering Algorithm with Summable Lower Bounds in a Lower-dimensional Space

K. Aoyama, K. Saito, and T. Ikeda

IEICE Transactions on Information and Systems, Vol. E101-D, No. 11, pp. 2773–2783, November 2018.

This paper presents an efficient acceleration algorithm for Lloyd-type k-means clustering, which is suitable to a large-scale and high-dimensional data set with potentially numerous classes. The algorithm employs a novel projection-based filter (*PRJ*) to avoid unnecessary

distance calculations, resulting in high-speed performance keeping the same results as a standard Lloyd's algorithm. The *PRJ* exploits a summable lower bound on a squared distance defined in a lower-dimensional space to which data points are projected. The summable lower bound can make the bound tighter dynamically by incremental addition of components in the lower-dimensional space within each iteration although the existing lower bounds used in other acceleration algorithms work only once as a fixed filter. Experimental results on large-scale and high-dimensional real image data sets demonstrate that the proposed algorithm works at high speed and with low memory consumption when large k values are given, compared with the state-of-the-art algorithms.

Automatic Driving Support Scheme Considering Signal and Traffic Conditions

K. Mizutani, M. Yoshida, T. Hata, and I. Shake

Transactions of the Society of Instrument and Control Engineers, Vol. 54, No. 11, pp. 793–801, November 2018 (in Japanese).

Currently, vehicle communication infrastructures are conducted in several locations, and they provide some traffic and signal information for vehicles. With this information, automatic driving technologies are widely studied, and they focus on the avoidance of stopping by red light signals and car crashes. They have deep insight for all research fields; however, there are no proposals for realizing both types of avoidance at the same time. In this paper, we propose an action determination learning scheme for realizing driving support considering both types of avoidance. Our scheme is based on Deep Reinforcement Learning, which is similar to the latest crash avoidance scheme. A simulation evaluation revealed that the numbers of both crashes and stopping by red light signals becomes lower as time goes on, and effective parameter tuning is revealed at the same time.

Quantum Remote Sensing with Asymmetric Information Gain

Y. Takeuchi, Y. Matsuzaki, K. Miyanishi, T. Sugiyama, and W. J. Munro

arXiv:1811.05586 [quant-ph], November 2018.

Typically, the aim of quantum metrology is to sense target fields with high precision utilizing quantum properties. Unlike the typical aim, in this paper, we use quantum properties for adding a new functionality to quantum sensors. More concretely, we propose a delegated quantum sensor (a client-server model) with security inbuilt. Suppose that a client wants to measure some target fields with high precision, but he/she does not have a high-precision sensor. This leads the client to delegate the sensing to a remote server who possesses a high-precision sensor. The client gives the server instructions on how to control the sensor. The server lets the sensor interact with the target fields in accordance with the instructions, and then sends the sensing measurement results to the client. In this case, since the server knows the control process and readout results of the sensor, the information of the target fields is available not only to the client but also to the server. We show that by using an entanglement between the client and the server, an asymmetric information gain is possible so that only the client can obtain the sufficient information of the target fields. In our scheme, the server generates the entanglement between a solid state system (that can interact with the target fields) and a photon, and sends the photon to the client. On the other hand, the client is required to possess linear optics elements only including wave plates, polarizing beam splitters, and single-photon detectors. Our scheme is feasible with the current technology, and our results pave the way for a novel application of quantum metrology.

Analysis of Communicative Phrase Prosody Based on Linguistic Modalities of Constituent Words

K. Takada, H. Nakajima, and Y. Sagisaka

Proc. of the 13th International Conference on Knowledge, Information and Creativity Support Systems, Pattaya, Thailand, pp. 217–221, November 2018.

In this paper, phrase prosody is analyzed based on linguistic modalities of constituent words for communicative speech synthesis. Since Japanese final particles and auxiliaries play crucial roles to indicate speaker's intention and attitudes as modality differences, Japanese phrase sets showing different degrees of the speaker's judgment were employed. Communicative/reading speech data were compared over 5 kinds of modality of epistemic judgment (uncertainty of what the speaker said) and 8 kinds of modality of evaluative judgment (what the speaker wishes listeners to be). These modality differences were quantified in 6-point Semantic Differential (SD) scales. The corresponding phrase communicative/reading prosody differences were measured by the F_0 rising in the phrase final mora. Statistical analysis showed a negative correlation value between the F_0 rising in the phrase final mora and the SD about judgment only in communicative prosody but not in reading prosody. These results support the communicative prosody control possibilities from the modality information embedded in constituent words.