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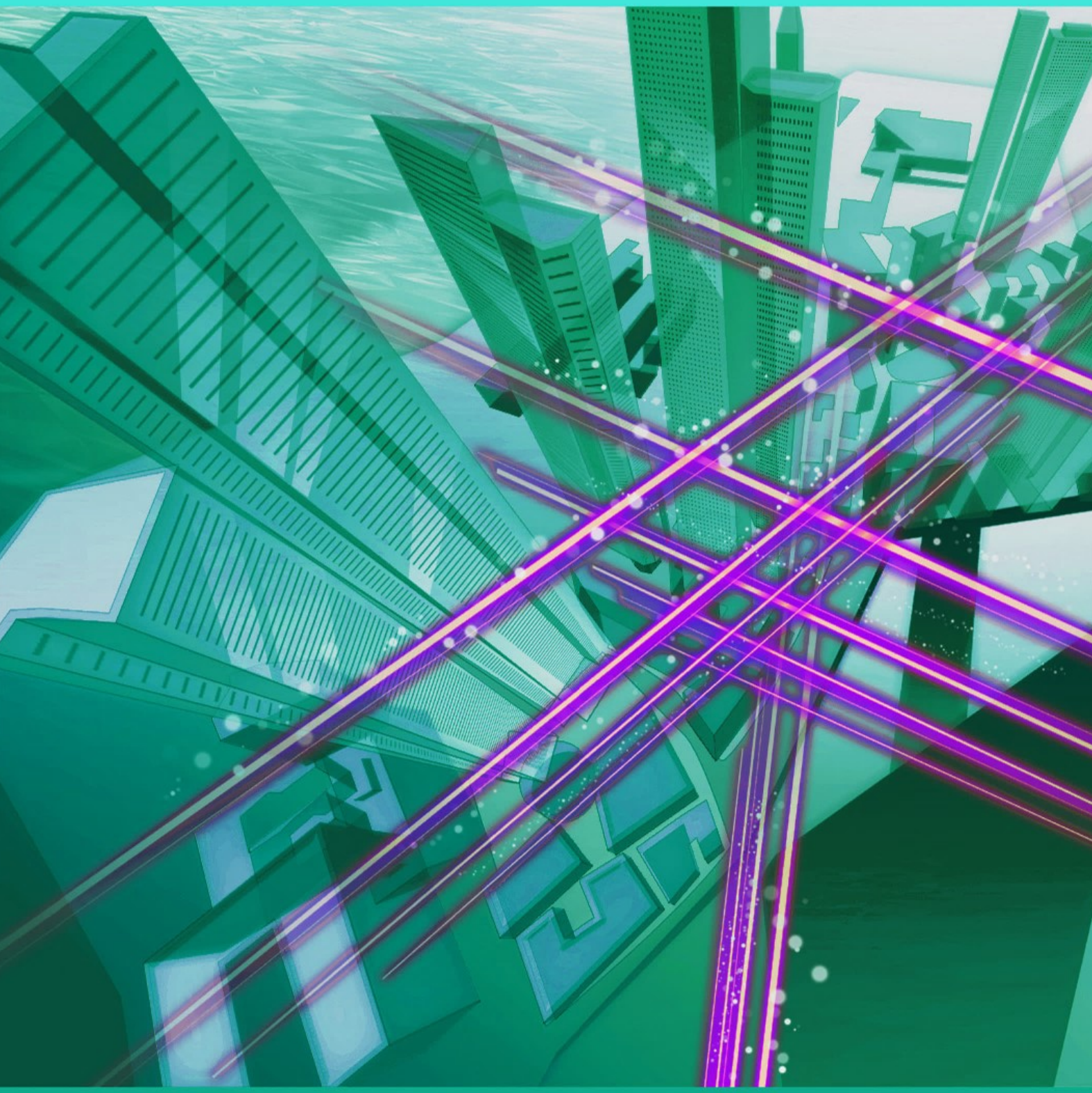

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Come as You Are and Identify Your Standpoint

Shigeto Furukawa
Senior Distinguished Researcher, NTT Communication Science Laboratories

Overview

In 2017, The Lancet, a medical journal, reported that hearing loss is a risk factor for dementia; and thus, interest in hearing is increasing worldwide. It is often thought that hearing loss is equated with the inability to hear low-level or high-frequency sounds; however, the root of the problem is not limited to that inability. We asked Shigeto Furukawa, a senior distinguished researcher at NTT Communication Science Laboratories, who researches the auditory mechanism based on biological responses that seem unrelated to hearing (such as the pupil) and analyzes information about how sounds are heard subjectively, about his latest research activities and the role of researchers.

Keywords: hearing, auditory mechanism, brain stem

Understanding hearing from biological responses

—Tell us about your current research.

Although my research area has been written as "elucidation of the neural mechanism of sensory perception," I am now mainly studying the auditory mechanism (**Fig. 1**). Recently, I have been particularly interested in how we hear. For example, different people often hear the same sound differently, and even the same person hears the same sound differently depending on the situation. Moreover, so-called "hidden hearing loss" is a problem concerning how to hear, and it is manifested as deteriorated hearing that registers no abnormality in a hearing test.

It is often said that signals obtained from the eardrum and inner ear (lower-order processing) are recognized, understood, and interpreted in the brain (higher-order processing), especially in the cerebral cortex. However, various processes are also performed in the brainstem between the ear and cerebral cortex ("intermediate processing"). It is the brainstem that retrieves basic information, such as pitch, and selects information that reflects the degree of importance. The brainstem also plays an important role in unconscious actions such as looking back in response to a voice spoken from behind.

—The function of the brainstem is key to elucidating the auditory mechanism.

We are therefore focusing on the intermediate processing carried out in the brainstem. The auditory and brain mechanisms are often analyzed by inserting an electrode into the brain of a test animal and measuring the electrical activities in the brain. However, we cannot insert an electrode into the human brain in this manner, so we analyze the brain in an indirect way

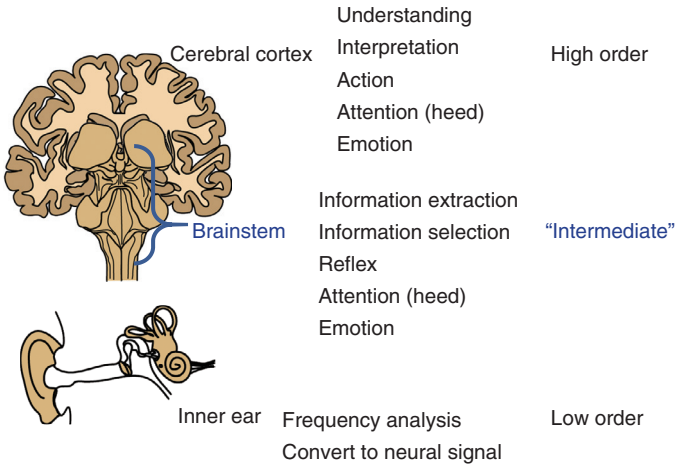


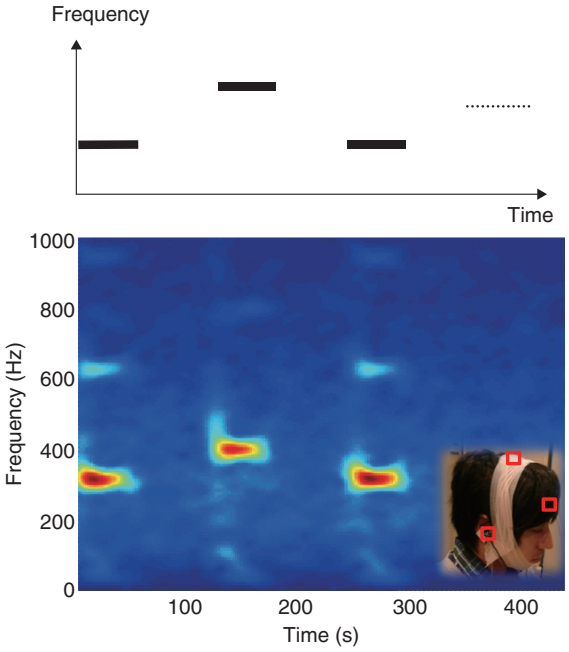
Fig. 1. Processing flow of auditory information.

using non-invasive measurement techniques, such as electroencephalograms (EEG) and eye movements, and computer modeling.

For example, an EEG of a person hearing a sound often includes the frequency components of a pattern that is similar to the sound presented (**Fig. 2**). These frequency components are thought to originate from the brainstem, so analyzing them is a means to investigate brainstem activity. Moreover, it has been shown that pupil size is linked to arousal level and attention-related neuronal-cell activity in the brainstem. On the basis of these measurements and analyses, it is possible to access the functions of the brainstem without having to pierce the brain with electrodes. Although we are still far from elucidating the auditory mechanism of the brainstem, we hope that by combining various measurement methods and modeling, we will be able to reveal—from outside the body—the mechanism of hearing that occurs naturally at an unconscious level.

—What applications can be considered in the future?

Let's consider listening to music as an example. Liking or not liking a song differs from person to person, and even if the same person listens to a song, his/her enjoyment of the song changes from time to time. By measuring the biological response of people listening to a song, it may be possible to objectively measure how each person feels at that time. Although it seems that making that possibility a reality is a long way off, I am researching the idea that we can obtain hints by elucidating the relationship between attention and hearing.



EEG signal (bottom graph) contains the same frequency components as that of the stimulus sound (top graph).

Fig. 2. Brainstem-derived EEG (frequency-following response).

Let me introduce some of the research my team is working on regarding attention. For example, I'm considering whether the sound a person is paying attention to can be determined by measuring the pupil. In fact, it has recently been reported that the

pupil changes with perceived brightness as well as physical brightness. We have found that this phenomenon can also be applied to auditory attention (**Fig. 3**). In an experiment, a participant listened to a sound through headphones while looking at a screen divided in half; bright (left) and dark (right). Different sounds were emitted from the left and right speakers of the headphones. We found that when the participant was told, "Pay attention to the sound from the left speaker without moving your eyes," the size of the pupil changed according to the brightness of the screen on the side of attention (left), despite the fact that the participant did not move his/her eyes. In this example, when the left side of the screen was bright, the pupil diameter decreased. In other words, the participant's attention directed toward the sound can be detected visually from the outside as a change in pupil size. By using this phenomenon, it may be possible to determine to which speaker a person is paying attention when multiple people are in conversation.

Regardless of the intent of the individual, some attention is directed according to external stimuli. This attention is called "exogenous attention," the study of which is more challenging. If someone is asked, "What are you paying attention to?", they will become aware of their attention, and it will be impossible to measure their spontaneous attention correctly. Owing to this fundamental difficulty, exogenous attention to sound has not been extensively investigated. We believe that measuring pupil and eye movements can also be used to assess exogenous attention. Although not well organized yet, these measurements are providing new insights.

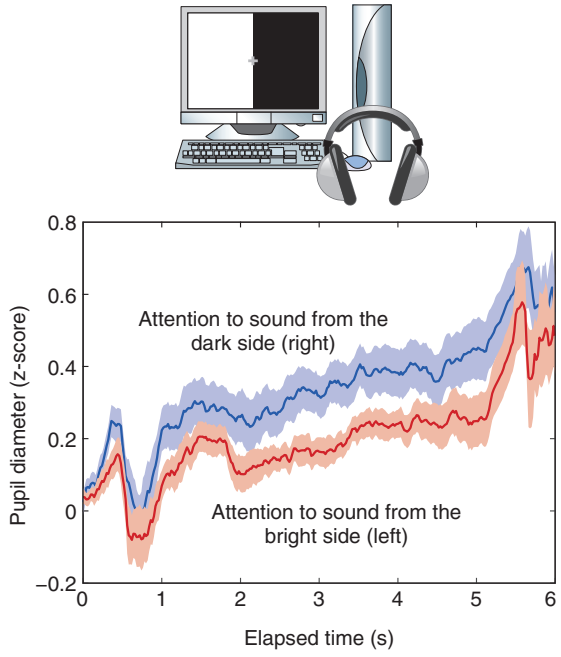


Fig. 3. Change in pupil diameter when attention is paid to a sound to one ear while looking at the center of a screen divided into light on the left and dark on the right.

Explore essential problems with an open mind because the basic research field has a high degree of freedom

—Why did you decide to become a researcher?

According to my parents, I wanted to be a doctor when I was a child, and I seemed to have longed to become a researcher since I was young. As I went through high school and university, that longing faded; however, as I watched others get office jobs at companies before graduating from university, I realized that I wanted to do something different. I think that my consciousness of becoming a researcher was greatly influenced by my supervising professor at that time. The department in which I was enrolled (sanitary and environmental engineering) is strongly focused on solving social problems; in fact, when I first enrolled, I was interested in environmental issues. However, over time, I gradually became unable to identify the social issues I wanted to address. There was a reluctance to plant the seeds of research by saying, "There is a problem" when there was no such problem, so I became fascinated by pure science. One trigger of my interest in hearing came from entering a lab studying noise at university, even though the mainstream research undertaken in the department was on sewerage, water treatment, and air pollution.

—What is the moment like when you are glad that you have studied something?

Because the human brain is complex, examining neural responses gives mixed results. Even if we make a hypothesis, it is often not possible to clearly show from experimental results whether the hypothesis is correct. However, during the trial and error used as an analysis method, even the mixed data of complex neural responses of the brain may reveal something useful depending on one's ingenuity. I feel most satisfied when I could make such revelations. What you see at that time of a revelation is something

seen for the first time in the world. Even if similar research has been reported, you are the only one possessing the data that you measured on site, and you are the one who chooses the analysis method.

—What do you do to devise research and analysis methods?

It is often said that you should first set a goal, break down the challenges posed by that goal, and finally address what you need to do from then onwards. I'm not saying that process is wrong, but I'm not too concerned about following those steps. As for basic research, if you come across something interesting during one of the steps, you have to have a sense of following it up by taking a detour. Something unexpected always happens at the research lab. I think that applying one's way of thinking at such times will lead to unique research.

When I reflect back, my activities sometimes diverge too much or sometimes I am too particular about what is in front of me and being too committed to not knowing if it makes sense. Such a commitment is an important quality for a researcher to have; even so, I think it is necessary to pursue one's research while continuously questioning whether a small thing is just a small thing or whether it has importance.

The field of basic research has a high degree of freedom. However, the fact that you are responsible for deciding what to research is actually a great deal of pressure. You can either apply your expertise to academic research that focuses on details or you can aim for major easy-to-understand results that meet the expectations of top management. Although both approaches must sometimes be taken by researchers, I think that to ultimately contribute to the company, society, or learning, I must pursue things that are important.

However, some things are important regarding solving social problems, while others are essential regarding understanding the principles of the universe. Although some problems are apparent because of one's uniqueness and expertise, some of the problems faced by many people in society are vague but essential and lying dormant. Therefore, I don't think too much about the problems I need to solve and want to keep an open mind.

You can identify your standpoint only when you look back later

—Please give a word to junior researchers.

As I continue my research, there are times when I find it tough. When I was conducting physiological experiments with animals, it was physically tough, and when I was doing detailed tasks like looking at cells, I was worried that I would not be able to see the way ahead. When you reach an impasse like that, you can do something else or seek a way around it. For example, an idea may be revealed by discussing certain topics with the research community and colleagues. Even in simple discussions like chats, knowing what other people are interested in can confirm your standpoint. If you know that you are such a person without deciding what you should be, you will know the best way to live your life.

You may be able to identify your standpoint and way of life only by looking back later. Your work as a researcher will vary. In addition to writing papers, the role of a researcher includes teaching people and running organizations such as research institutes and academic societies. Even if you think that it is troublesome at the time, you may realize who you really are one day while fulfilling the roles as requested. Although it may seem that there is nothing you can control, because researchers ought to have a strong personality, your standpoint won't change so easily even though you let it be.

In interviews with young people, I tell them that people do not change much, so it is better to accept them. No matter what you do, you will have a sense of self-worth. Advice to researchers such as, "That's wrong, so go in a different direction." will not work. I tell them to concentrate on whatever is going well, and you'll eventually get some interesting results over time. I think a good approach is to consult with others and help each other while being yourself; in this way, each of us will be able to exert our abilities.

—What is the role of researchers in society?

In one sense, a researcher conducting basic research is like a monk. Monks practice their religion, but that practice does not immediately help grow vegetables and fill bellies. However, believers donate to monks because they appreciate something in that practice. Basic research (i.e., "practicing") conducted by researchers may not be immediately useful to the world. However, if something overlooked or that was

vague is elucidated and made concrete by research, some people will come to consider making that research useful. Also, when confronting the world's problems, we might find clues to solving them by taking a step back and looking at them abstractly. Both the practice of monks and basic research are exactly transitions between the abstract world and the real world, and I think our responsibility lies in that transition. Some monks, such as novices, set themselves apart from the world, while other monks live in society and connect with the world. I think that researchers can also take either path. I believe that it is better for each of us to contribute to society through our research while thinking about our own path.

—Please tell us about your future prospects.

Up until now, the main target of auditory research has been the accuracy of correctly hearing information contained in sound and the mechanisms that support that process. I think that rather than the accuracy of hearing, the content and quality of perceived sounds in daily life could become part of the research. Assessing subjective hearing is not straightforward. I believe that it is necessary to investigate and understand the perception, behavior, sensory nervous system, autonomic nervous system, and their close interactions. Fortunately, devices that measure biological responses, such as eye movements, pupils, and brain activity, are rapidly evolving. As seen in the boom in artificial intelligence, machine-learning technology has made remarkable progress, and neuroscience has benefited from the analysis and modeling that it enables. I didn't talk about this technology in this interview, but I'd like to try applying such new technology to clarify the previously unknown mechanism of hearing. We have already obtained interesting results concerning this mechanism. We also want to develop technologies to evaluate and design sounds that are easy for humans to hear. While I want to achieve results that have a social impact, I also want to work on research that will be of interest to me only. That may sound selfish, but if you don't find yourself interesting, being a researcher will be boring.

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■ **Interviewee profile**
Shigeto Furukawa
Senior Distinguished Researcher, Human Information Science Laboratory, NTT Communication Science Laboratories.

He received a B.E. and M.E. in environmental and sanitary engineering from Kyoto University in 1991 and 1993, and a Ph.D. in auditory perception from University of Cambridge, UK, in 1996. He conducted postdoctoral studies in the USA between 1996 and 2001. As a postdoctoral associate at Kresge Hearing Research Institute at the University of Michigan, USA, he conducted electrophysiological studies on sound localization, specifically the representation of auditory space in the auditory cortex. He joined NTT Communication Science Laboratories in 2001. Since then, he has been involved in studies on auditory-space representation in the brainstem, assessing basic hearing functions, and the salience of auditory objects or events. As the group leader of the Sensory Resonance Research Group, he is managing various projects exploring mechanisms that underlie explicit and implicit communication between individuals. He is a member of the Acoustical Society of America, the Acoustic Society of Japan, the Association for Research in Otolaryngology, the Japanese Psychonomic Society, the Japan Audiological Society, the Japan Neuroscience Society, and the Japanese Society for Artificial Intelligence.

R&D on Security Contributing to Creation of New Value

Shinichi Hirata

Abstract

NTT Secure Platform Laboratories is engaged in research and development of security technologies required for a *smart world*. In this article, an information sharing platform of secure data utilization required for a smart world is described, and the efforts of NTT Secure Platform Laboratories to support that world are introduced from two aspects: security that protects the smart world and security that creates the smart world.

Keywords: data utilization, cryptography, security operation

1. The *smart world*

As typified by the key phrase *digital transformation*, digital data are being used by people in various real-world settings, e.g., social activities, and the way people live their lives and work is changing rapidly.

A large amount of digital data is acquired from physical spaces and used in various settings concerning social activities. Our aim to make use of digital data is threefold: (i) process this large amount of data in cyberspace in sophisticated ways, return the data to the physical space, and use them there; (ii) make it possible for all people to live safely and in their own way through those data-related activities; and (iii) enable society to work smoothly. We call this world view a *smart world*. It is assumed that a smart world will enable two types of optimization: *personal optimization*, namely, fulfilling safe and healthy living through a personalized and customizable living environment, and *social optimization* such as creating industrial systems that can achieve total optimization based on forecasts and work environments that are suitable for the requirements of workers (i.e., work hours, places, etc.). We are striving to create security technologies necessary for safe and secure use of large amounts of digital data, which is indispensable for a smart world.

2. Recent trends in security

Society has started to make the major changes needed to achieve a smart world; however, should we not determine the nature of threats present in today's cyberspace before achieving this?

In information technology (IT), the following threats are noteworthy: business-email compromise (BEC), namely, stealing management information from a company using email, etc. and exploiting that information to threaten or defraud people or businesses; supply-chain attacks targeting vulnerable parties (customers, contractors, etc.) in the product lifecycle (design, manufacture, use, and disposal) of information devices; and activation of fake news exploiting social networking services.

BEC involves attackers who infiltrate corporate-information systems and spoof corporate transactions and management information. In particular, an attack attempts to steal money or confidential information of a company by impersonating the compromised company and exchanging fake information with related parties such as customers of the compromised company.

According to a report by the FBI Internet Crime Complaint Center released in April 2019, there were 351,937 BECs in the USA in 2018 (up 17% from the previous year), and the damage amounted to $2.7 billion (up 46% from the previous year) [1]. Moreover,

as an attack that attempts to steal confidential information from systems and networks and stop certain functions, a supply-chain attack penetrates the product-design, manufacturing and distribution processes then distributes hardware, firmware, software, etc. that can attack third parties throughout the market. It has become clear that such attackers have successfully distributed firmware and software, including backdoors, to commercially available personal computers and smartphones.

In operational technology (OT) (i.e., control networks) and the Internet of Things (IoT), the number of attacks on critical infrastructure has increased. These attacks target control networks operating inside public facilities that support people's lives (such as electric, gas, water, communications, broadcasting, and transportation) by targeting these facilities. Actions that lead to suspension or destruction of these facilities are expected to disrupt the lives of the public, for example, by stopping power transmission from power plants and eventually causing large-scale blackouts. The common trend in the above security-threats is that cyberattacks have recently impaired the security of the general public and nations. In other words, they are evolving into attacks targeting larger victims.

3. Security technologies for protecting a smart world and for creating a smart world

What security technologies must we provide for the coming smart world? We are focusing on two key phrases: *protecting a smart world* and *creating a smart world*. Security technology for protecting a smart world protects various networks and IT systems (such as IT, IoT, and Internet service providers) and users from cyberattacks. Security technology for creating a smart world create a smart world by promoting secure data utilization by applying cryptography and supporting active use of data to activate corporate activities and ensure safe daily living. These two key phrases are positioned as the two pillars holding up our research and development (R&D) on security.

4. Security technology for protecting a smart world

As described above in "Recent trends in security," it is expected that new cyberattack techniques will appear daily and the sophistication and expansion of these attacks will increase. The sophistication and increasing number of cyberattacks increase security risks facing companies and organizations. The elements that make up security risks are broadly divided into threats, vulnerabilities, and assets that companies and organizations should protect. However, even for major companies that value security, the cybersecurity budgets that individual companies and organizations can bear are limited to about 15% of their IT-system budgets, and that figure drops to 5% or less for small and medium-sized companies. To counter the spread of cyberattacks in the future, companies and organizations must drastically improve their ability to defend against and counter cyberattacks (**Fig. 1**).

To improve the defense and countermeasures against cyberattacks, we are developing the following technologies in response to the sophistication of cyberattacks: advanced technology for detecting malware in endpoint devices; advanced technology for determining malicious domains; and technology to counter attacks that exploit the psychological weaknesses of users. We are also developing the following technologies in response to increasing number of cyberattacks: technology for improving operational efficiency and labor-saving technology for security operations [2].

To counter cyberattacks in OT/IoT, under the assumption that various devices (such as IoT and control) are connected, it is necessary to (i) ensure security throughout the supply chain and the product lifecycle (spanning design, manufacturing, distribution, construction, operation, and disposal) and (ii) implement multi-layer measures through cooperation among industrial fields. Under the assumption that IoT is going to be applied, for example, to factories, buildings, agriculture, and monitoring and maintenance systems, we are advancing R&D on authenticity and integrity monitoring technology for IoT devices, which detects software tampering of IoT devices and control devices at the manufacturing, distribution, and operation stages, and cyber physical anomaly detection technology, which detects illegal behaviors during operations. Moreover, in line with advancements in the mobility field, such as sensor networks for cars and autonomous vehicles, we are pushing ahead with R&D on real-time anomaly-detection technology for in-vehicle networks and attack-detection technology on the cloud, which quickly and accurately detect and analyze attacks against vehicles and attacks by vehicles that have malfunctioning in-vehicle networks, as well as fake-sensor-data detection technology, which prevents

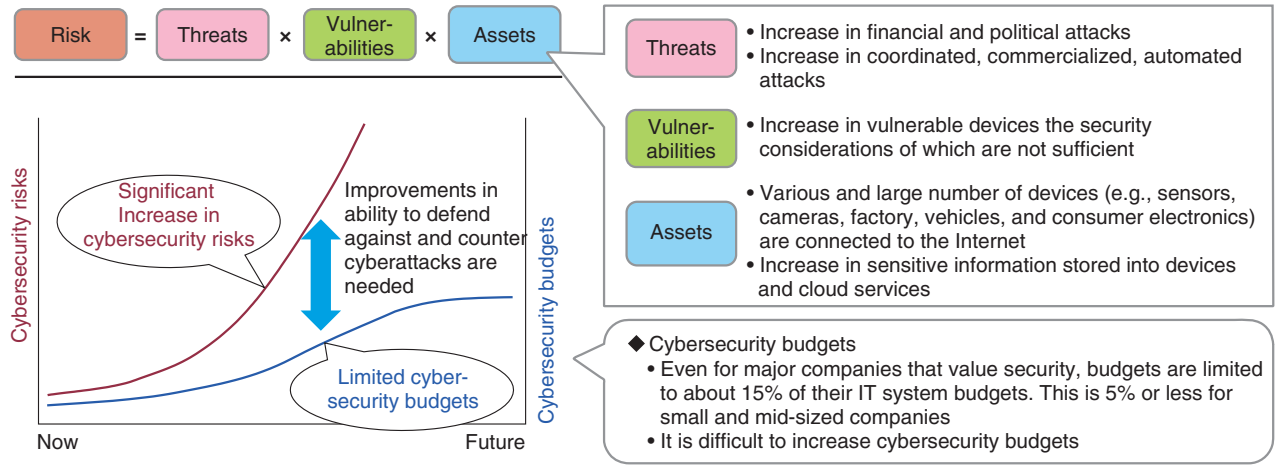

Fig. 1. Cybersecurity risks and budgets.

confusion regarding traffic information due to mixing of false sensor data. In addition to the above-mentioned technologies as countermeasures against cyberattacks on OT and IoT systems, we must develop integrated countermeasures and formulate rules based on the interdependence of IT security, functional safety, and physical security.

5. Security technology for creating a smart world

To create a smart world, it is essential to provide technologies that support safe data distribution and use, namely, solving problems caused by unauthorized use of data, data hoarding, and privacy breaches. These technologies are composed of a flexible and secure data distribution and analysis mechanism that can use data across fields and enable secure execution of all value-creation processes (from data generation, utilization, and analysis to disposal).

Data have thus far been held and used only within a single business entity. However, to create a smart world, the following mechanisms are required: for conducting advanced analysis (integrated analysis) by combining secured data to keep privacy and trade secrets while sharing them between organizations; and for solving various issues and returning the solutions to society on the basis of the results of cross-sector integrated analysis. These mechanisms will enable secure data utilization across industries and fields while creating unprecedented new value (**Fig. 2**).

We are working on secure computation technology to compute a function on encrypted data and anonymization technology that enables safe use of personal data as core technologies to enable such value creation [3]. When analyzing and utilizing data, the data generally have to be decrypted; thus, data utilization related to sensitive data (e.g., trade secrets and personal information) is not progressing. The above-mentioned secure computation technology supports the creation of a world that facilitates solving problems by taking into account the handling of information related to individuals and companies then sharing necessary data between organizations according to the purpose. In September 2019, we announced the world's-first secure computation technology enables model training with a deep neural network while training data are kept secret [4].

Anonymization technology makes it possible to create various anonymously processed information, including data concerning the proprietary technology of NTT Secure Platform Laboratories. With the enforcement of the revised Act on the Protection of Personal Information of 2017 in Japan, if personal information is processed as anonymously processed information, it can be provided to third parties without the consent of the individual. The anonymization technology of NTT Secure Platform Laboratories, which is in compliance with the above act, has been commercialized as anonymously processed information creation software by NTT TechnoCross Corporation.

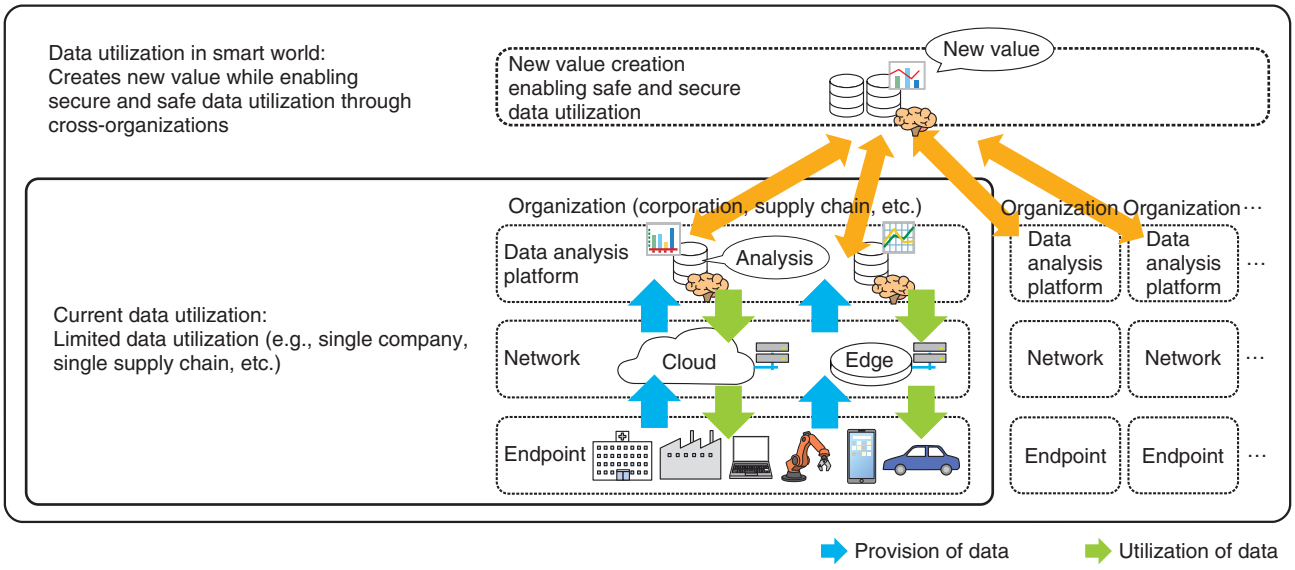

Fig. 2. Data utilization in a smart world.

6. Activities related to Center of Excellence (CoE)

We are actively involved in activities at NTT's CoE with the aim of creating technology that enable the competitiveness necessary for the NTT Group to support a smart world.

Through the activities of the CoE, our highly skilled human resources are taking the initiative in the academic and professional communities. Regarding cybersecurity, we are focusing on management of expert communities and global security contests as well as development of human resources in collaboration with universities. Regarding data security, with an eye on 10 to 20 years from now, we are also researching fully homomorphic encryption, which can be called the next generation of secure computation; post-quantum cryptography, which maintains security even if quantum computing becomes a reality; and quantum computing as the world's-most-advanced research for cryptography [5]. We are also focusing on consulting activities to use the knowledge thus far accumulated at NTT Group companies and supporting the development of safe and secure systems and applications that comply with privacy protection and legal systems.

7. Future developments

As described in this article, NTT Secure Platform Laboratories is engaged in various R&D activities related to security with the aim of becoming the source of the advancement and differentiation of the NTT Group's security technologies while striving to create a safe and secure smart world.

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He received a B.S. from Hokkaido University in 1990. He joined NTT in 1990 and has been engaged in R&D of cryptography, IC card technology, and authentication systems.

The Future of Data Distribution and Its Security Technology

Toshiyuki Miyazawa, Toshinori Fukunaga, Gen Takahashi, Ryo Kikuchi, Seiji Takahashi, and Satoshi Hasegawa

Abstract

With the acceleration of digital transformation, the value of data is ever increasing, while concerns about security risks and privacy are growing stronger. At NTT Secure Platform Laboratories, we intend to address these issues with cryptographic technology and create a world in which data owned by individuals and organizations are provided and used at the minimum level necessary according to the purpose to enable problem solving. In this article, specific initiatives undertaken at NTT laboratories to support secure data distribution in such a world are introduced.

Keywords: multi-party key sharing, secure-computation AI, anonymous processing

1. The Future of data distribution

With the acceleration of digital transformation (DX) in various fields, it is expected that the digitization of people, goods, processes, etc. of companies and organizations will progress and that advanced analytical processing will make it possible to address issues such as value creation and improving operational efficiency. While the value of data has increased in line with these trends, security risks and privacy concerns have also intensified.

With the globalization of corporate activities and the spread of the cloud and Internet of Things, various and diverse entities (people, terminals, organizations, etc.) have become interconnected. As various types of data are exchanged and shared by these entities, the risk of theft or leakage of the data affecting companies and individuals has also increased. Concerns about legal restrictions and privacy regarding using personal and corporate information for artificial intelligence (AI) and machine learning—which play important roles in DX—are also growing.

To eliminate such risks and concerns, NTT Secure Platform Laboratories wants to use cryptography to create a world in which data concerning products or individuals can be safely exchanged according to the purpose and enable problem solving (**Fig. 1**). The following technologies that support such secure data distribution are introduced in this article: (i) data encryption and related technologies for protecting all communications end-to-end; (ii) secure-computation AI for enabling advanced integrated analysis while protecting corporate secrets and privacy; and (iii) anonymization technology for processing personal data in a manner that does not identify individuals and encourages the use of that information.

2. Data encryption and related technologies

Important data used in data distribution can only be exchanged and shared between multiple entities (individuals, organizations, terminals, etc.), and it is important that information not be leaked to other entities. In consideration of the risk of information leakage from service providers recently, it has become increasingly necessary to keep data confidential even from the companies that provide data-distribution services and their system administrators.

To satisfy this requirement, it is desirable that (i) a secret key to the encryption is shared between trusted

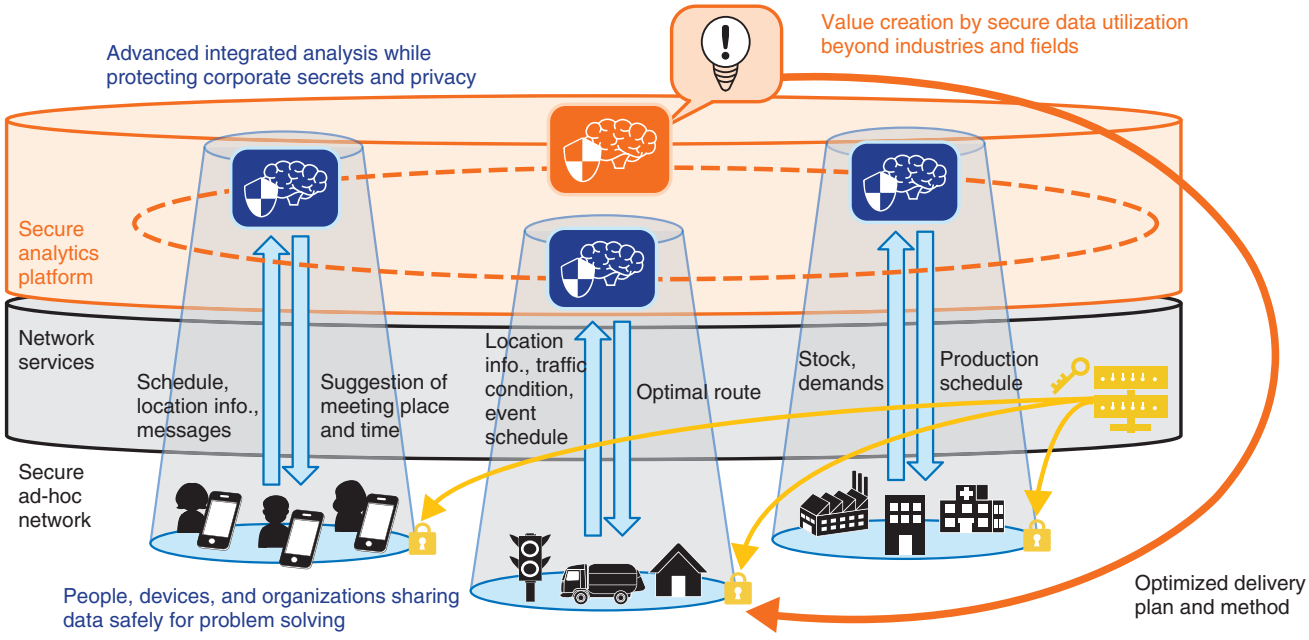

Fig. 1. Secure data distribution.

entities and the data to be exchanged and shared are encrypted with the secret key and (ii) the shared data can be searched. However, enabling these processes faces two major technical challenges. The first challenge is efficient key sharing among multiple entities. It is required to share keys among many entities; however, it is inefficient and impractical to repeatedly execute a key-sharing protocol between two parties using multiple systems.

In light of the above-described circumstance, NTT is studying technology that enables efficient sharing of keys among multiple entities via a key-mediation server installed by a service provider. The key-mediation server guarantees in principle that the shared key cannot be reconstructed. We developed a method for enabling efficient key sharing for a fixed period regardless of the number of entities. This method enables exchange and sharing of data concealed from information-distribution service providers by using only an arbitrary number of entities involved in communication at that time.

The second challenge is to search for encrypted shared data by using the computer resources of the data-distribution service provider. Since data-distribution services are often provided in cloud form, it is desirable to search for shared data by using the computer resources of the data-distribution service provider; however, if the encrypted data are decrypted for such a search, the data cannot be concealed from the service provider. With this issue in mind, NTT is studying a method of enabling this concealed search by encrypting the search index separately from the data and searching with the encrypted search index. As mentioned above, the processing is complicated because shared data are frequently re-encrypted every time an entity is added or deleted. We are thus devising a method of doing this efficiently.

For technology related to the two above-mentioned challenges, we have also developed technology for efficiently re-encrypting data with a new key without encrypting the shared key (encrypted when the shared key was updated) each time an entity is added or deleted. Combining the above-mentioned method and technology, we have already commercialized communication services such as telephony and online chat that do not leak data to service providers [1].

3. Secure-computation AI

It is generally necessary to restore (decrypt) the original data during processing for data utilization, even if they were encrypted during communication or storage. Data owners know that this processing may leak information, so many users and organizations are reluctant to use data related to trade secrets and personal privacy. This is considered a major obstacle,

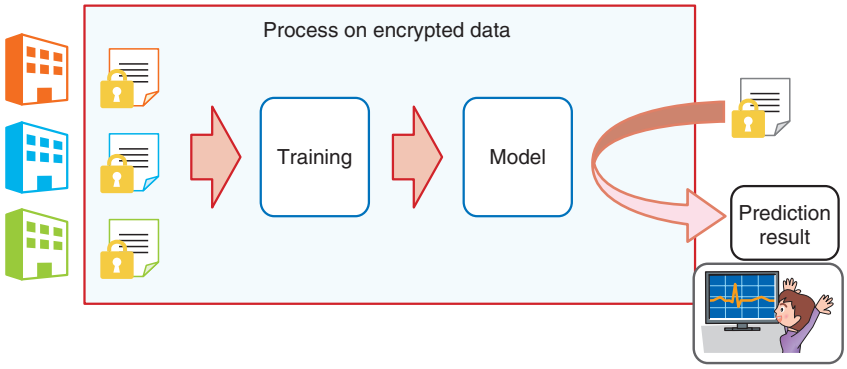

Fig. 2. Secure-computation AI.

especially when data are to be provided, actively used, and transferred from their owner to another party or even distributed within the same organization.

To help eliminate such obstacles, NTT is leading the world in research and development (R&D) of secure-computation technology that can process data while encrypting them. With this technology, data encrypted using the confidential-data-sharing technology standardized by the ISO (International Organization for Standardization) can be analyzed without first restoring them to the original form. This is expected to contribute to the creation of a world in which information (such as confidential information of companies and information concerning personal privacy) can be safely and securely provided and used. This technology has reached the practical stage.

NTT is currently researching and developing secure-computation technology that enables more advanced analysis. We have recently developed a world-first technology that can process a standard algorithm used for deep learning, which has begun to be used in the AI field, without restoring encrypted data to the original data [2]. In other words, all the steps necessary for data utilization in deep learning, namely, data provision, data storage, learning processing, and prediction processing, can be carried out on data in the encrypted state (**Fig. 2**). We believe that this technology will allow data owners to provide data with peace of mind when using the data with AI, leading to an increase in the amount and types of data while enabling advanced analysis with improved accuracy. For example, the technology is expected to make the following possible: (i) by learning personal-location information and schedules in conjunction with weather and corporate-event information, etc., it will be possible to anticipate the most appropriate purchases and staffing resources for restaurants; and (ii) by learning medical data (such as X-rays, magnetic resonance imaging, computed tomography scans, and micrographs) while keeping them concealed, it will be possible to quickly and accurately determine whether malignant tumors are present in test results.

In the future, we plan to demonstrate the effectiveness of deep learning using secure computation by conducting proof experiments in cooperation with partners who have AI expertise.

4. Anonymization technology

The use of personal data has recently become the focus of attention, and the market for such use is about to be activated in earnest. Under such circumstances, NTT is researching data-processing technology that promotes safe use of personal data.

According to the revised Act on the Protection of Personal Information of 2017, “anonymously processed information” (namely, personal information processed in a manner that a specific individual cannot be identified and the personal information cannot be restored) can be provided to third-parties and used for tasks other than the specified purpose without the consent of the person in question. For example, by allowing manufacturers to use anonymously processed information made from purchase-history data possessed by retailers, the manufacturers could develop new products in accordance with consumer attributes and purchasing habits.

If only anonymity is to be enhanced, the characteristics of the original data will be greatly impaired, and the data will be less useful. Accordingly, to satisfy

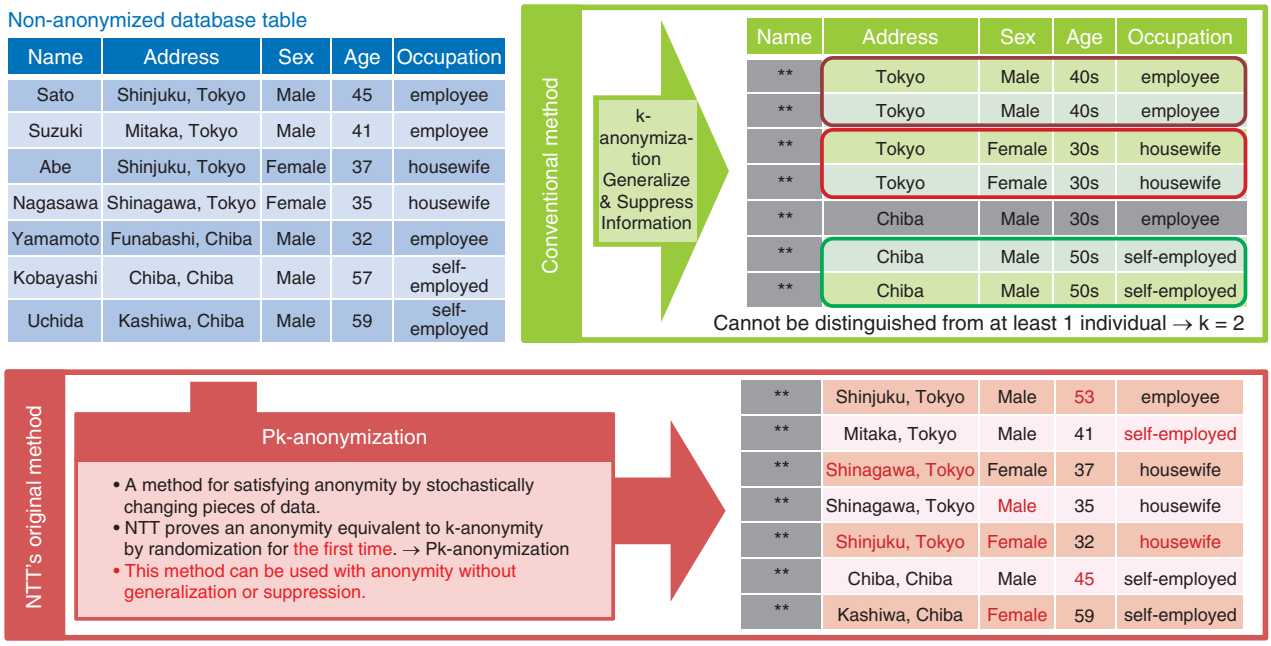

Fig. 3. Pk-anonymization.

both the data owner's need to reduce the risk of leaking personal identification and the data user's need to obtain data that retain the characteristics of the original data, optimal anonymous processing is needed. NTT has thus developed anonymously processed information-creation software for creating anonymously processed information that balances anonymity and usefulness. This software has been available in Japan from NTT TechnoCross since 2018, and its market development is progressing mainly in the medical and financial fields.

This software features various anonymization and evaluation techniques to comply with Processing Standards Nos. 1 to 5 for anonymously processed information specified by the Personal Information Protection Committee. One of these techniques is NTT's original anonymization technique called "Pk-anonymization," which ensures high usability without changing the data granularity by using a perturbative method. As the conventional technology, K-anonymization secures k-anonymity* by abstracting data by for example, changing "33 years old" to "30s" and "Chiyoda ward, Tokyo" to "Tokyo"; however, it is affected by information loss. In contrast, when Pk-anonymization (which disturbs data) is introduced, no information is lost, and more accurate and broader analysis is possible (**Fig. 3**).

With the aim of creating a world in which data are more actively used, NTT is working on reducing the risk of leaking personal identification as well as of inferring personal attributes. For data utilization, it is problematic that when calculation results such as statistical information are used, for example, if the average test scores of two people are used, a person who knows the score of one of them can estimate the score of the other. Privacy concerning such calculation results is called "output privacy," which has been widely studied in statistics. NTT is focusing on output privacy of machine learning, which is a promising data-analysis technology, and continuing to research risk-analysis and protection technologies related to machine learning.

5. Future directions

To enable secure data distribution, as introduced at the beginning of this article, NTT is designing and developing various encryption technologies in addition to those introduced in this article. Examples of these efforts are (i) development of cryptosystems and evaluation of their security in anticipation of the creation of quantum computers (the R&D of which is

* K-anonymity: The characteristic that the corresponding individual cannot be identified from the processed data with a probability of 1/k or more.

accelerating) and (ii) cryptographic program obfuscation, which makes the processing content of a program cryptographically non-analyzable and enables distribution of secure programs [3]. On the basis of our expertise in cryptographic theory and technology, we will conduct R&D on data security that contributes to the resolution of problems of NTT Group's customers and social issues.

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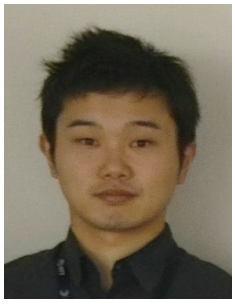

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The Forefront of Cyberattack Countermeasures Focusing on Traces of Attacks

Makoto Iwamura, Yo Kanemoto, Yuma Kurogome, Kazufumi Aoki, Yuhei Kawakoya, Shingo Orihara, and Jun Miyoshi

Abstract

Cyberattacks have become more capable of infiltrating corporate networks with malware by skillfully deceiving the target, and it is becoming increasingly difficult to prevent infections before they occur. Regarding web servers that are open to the public, the frequency of attacks increases and alerts occur more frequently as attack techniques become well known. It is thus becoming difficult to determine which attack to respond to. In this article, the forefront of cyberattack countermeasures focusing on traces left by attacks is discussed to address this issue.

Keywords: cyberattack countermeasures, malware analysis, alert triage

1. Current status of endpoint defense

Targeted attacks aimed at companies and the malware (malicious software) used in those attacks are becoming more sophisticated daily, and it is becoming difficult to prevent intrusions before they occur. Under such circumstances, a technique called endpoint detection and response (EDR) is attracting attention. EDR takes measures to be taken after an intrusion into account under the assumption that an intrusion by malware will be allowed.

Conventional security products prevent infection by detecting the apparent characteristics of malware (such as patterns included in executable files of the malware) as rules before the malware is executed. However, malware that changes its apparent characteristics and escapes detection by security products has started to be used in recent targeted attacks. The apparent characteristics of malware can be changed relatively easily. On the contrary, post-infection behavior is closely related to what the malware is intended to do, and it is considered difficult to change that behavior compared to changing the apparent characteristics. EDR is used to combat such targeted attacks by detecting the behavior of malware after it has begun to spread and leave traces behind.

A rule that detects traces that remain when a computer is infected with malware is called an indicator of compromise (IOC). Depending on the EDR product used, malware infection can be detected with a user-created (“custom”) IOC. Traces left by malware infection and how to generate an IOC to detect them are described in the following sections.

2. Traces of malware infection and their detection

Let us suppose that a file named “mal_a.txt” remains as a trace when malware infects a terminal. To detect that trace, it seems appropriate to prepare an IOC whose file name is “mal_a.txt.” However, when the same malware infects another terminal, if the file name becomes “mal_b.txt,” it cannot be detected by the original IOC. In this case, a little ingenuity is

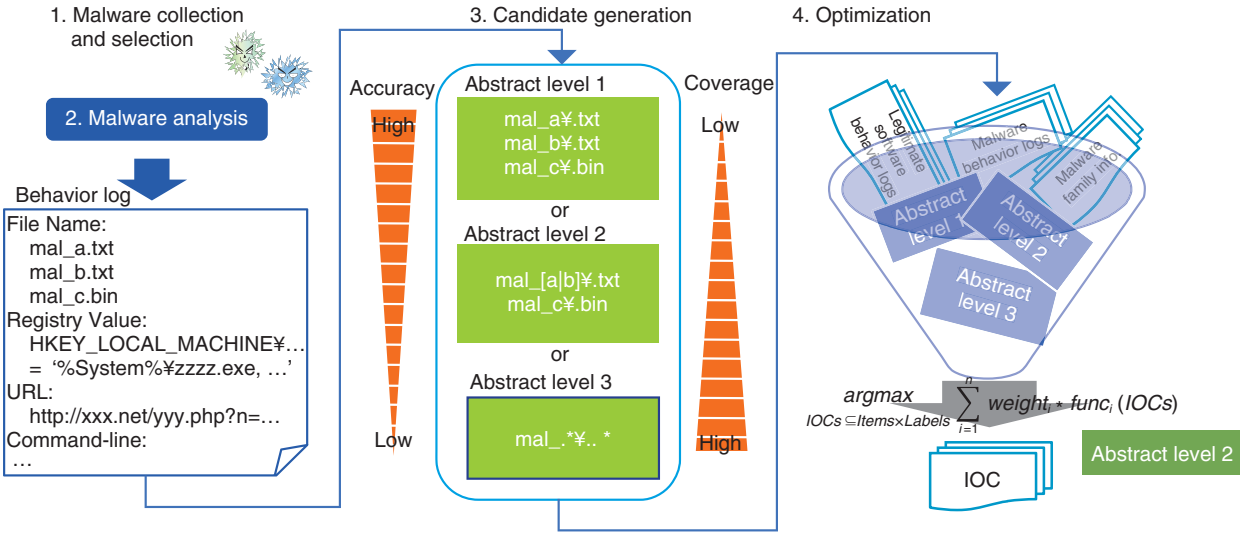

Fig. 1. Automatic generation of IOC.

applied and an IOC is created whose file name is "* .txt" (where * is an arbitrary character string). That IOC will cover both "mal_a.txt" and "mal_b.txt" and might cover other traces that may appear in the future. However, normal applications that are not malware are also running on terminals monitored using EDR. If a normal application creates a file called "leg.txt," the IOC "* .txt" will detect that file as a trace of malware. Although it is harder to change post-infection behavior than the apparent features of malware that prior technology focuses on, an IOC must be expressed in a manner that does not cause false detection while increasing coverage so that it can follow the changes in traces.

One more point must be taken into account when considering what is required of an IOC. Let us suppose an IOC detects that the malware has actually infected a terminal. Much of the subsequent work is left to security engineers, i.e., people. It will be possible to determine, for example, the path the malware entered by, whether it has sent confidential information to the outside, whether any other terminals are infected, and clarify those findings from remaining logs. It may be necessary at times to know what the IOC has detected, improve the IOC, and test other devices. All this is required for an IOC to make it easy for people to see and interpret. Detection criteria are very complex for certain types of machine learning, and some algorithms are difficult to understand, let alone improve. In the field of security, in which people exist in a series of work flows, the interpretability of an IOC also becomes important.

3. Automatic generation of IOC

NTT Secure Platform Laboratories is researching and developing malware-analysis technology that comprehensively identifies the behavior of malware that has various anti-analysis functions. The automatic IOC generation technology [1] introduced here generates an IOC with high detection accuracy, coverage, and interpretability by using the behavior logs extracted with that malware-analysis technology as input. Specifically, an IOC is generated by the following procedure (**Fig. 1**).

(1) Malware collection and selection: Collect and select malware according to the environment to be monitored by the IOC.
(2) Extraction of a behavior log with malware-analysis technology: Analyze malware in a virtual environment dedicated to malware analysis and extract a behavior log of the malware. Our malware-analysis technology is used for this task.
(3) Generation of IOC candidates with multiple abstractions from malware-behavior logs: Generate regular expressions with various abstractions that can be candidates of an IOC from past malware-analysis knowledge.
(4) Calculation of optimal IOC set based on detection accuracy and ease of interpretation: For each of the above-generated IOC candidates,

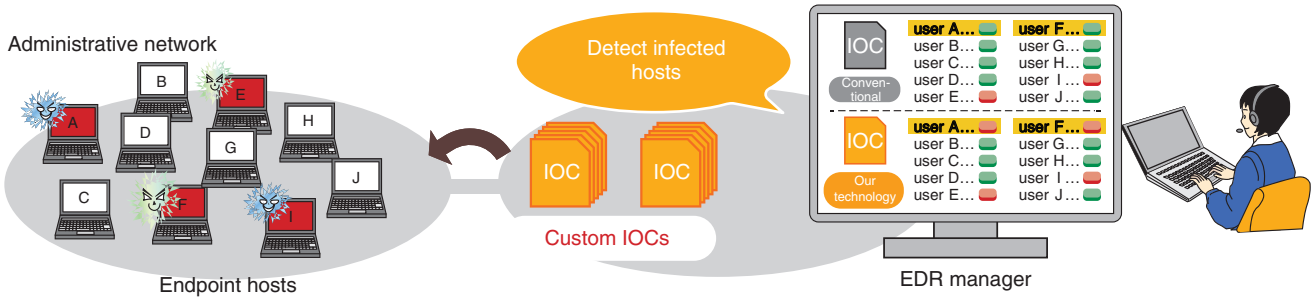

Fig. 2. Use of custom IOCs.

consider detection accuracy and ease of interpretation on the basis on the behavior logs of legitimate software and malware and calculate the optimal IOC for each malware family.

By adding the generated IOC to EDR products on the market, it will be possible to detect malware-infected terminals that have been conventionally difficult to detect (**Fig. 2**). Currently, we collect and select about 10,000 samples per week, and we have started distributing the IOCs generated from the results of analysis of that collection of malware to the NTT Group. In the future, we will continue to respond to malware other than those with executable file formats (such as script format).

4. Current state of public-server defense

Whenever a new vulnerability is discovered on a server or application, cyberattacks target that vulnerability. Cyberattacks that exploit vulnerabilities of servers and applications have exceeded 10 million per day worldwide. To detect and block these attacks, it is becoming common to deploy security devices such as an intrusion prevention system (IPS)[*1] or web-application firewall (WAF)[*2]. Ideally, these security devices should correctly detect and block all attacks. Realistically, however, it is difficult to do this. The reason is that quality of service will degrade due to false blocking. If the security device is not tuned sufficiently by the operator, normal communication may be detected and blocked. Due to this risk, it is difficult to block all attacks without tuning by the operator. Therefore, only detection, such as intrusion detection system (IDS)[*1], is conducted in most cases.

5. The need for more-efficient security operations

A computer-security-incident response team (CSIRT) or security operation center (SOC) analyst responds to cyberattacks occurring in a company or organization. CSIRTs and SOC analysts analyze data daily for security breaches on the basis of alerts sent from security devices.

In particular, WAFs and IDSs that detect server attacks report thousands or tens of thousands of alerts every day, and violations are analyzed on the basis of the knowledge and experience of the analysts. As a result, if the alerts are not prioritized to the more-important ones, it will not be possible to handle all alerts generated in a limited time span.

This prioritization is something that can only be done by a few analysts with knowledge and experience, and now that attacks are growing in scale, it is not practical to analyze all attacks entirely manually because not everyone can do that analysis. Moreover, the attacker can adopt a tactic that requires only a single instantaneous attack of choice to achieve the purpose of the attack while launching many meaningless attacks. Such a tactic paralyzes corporate security monitoring, preventing CSIRT and SOC analysts from noticing the real attack in a timely manner.

6. Alert-triage technology

At NTT Secure Platform Laboratories, we have

*1 IPS/IDS: A system that protects applications from attacks that exploit vulnerabilities; IDS refers to a usage mode that performs only detection, while IPS refers to a usage mode that blocks detected attacks.

*2 WAF: A system that protects applications from attacks in a similar manner to IPS/IDS. It has a detection capability specialized for web applications.

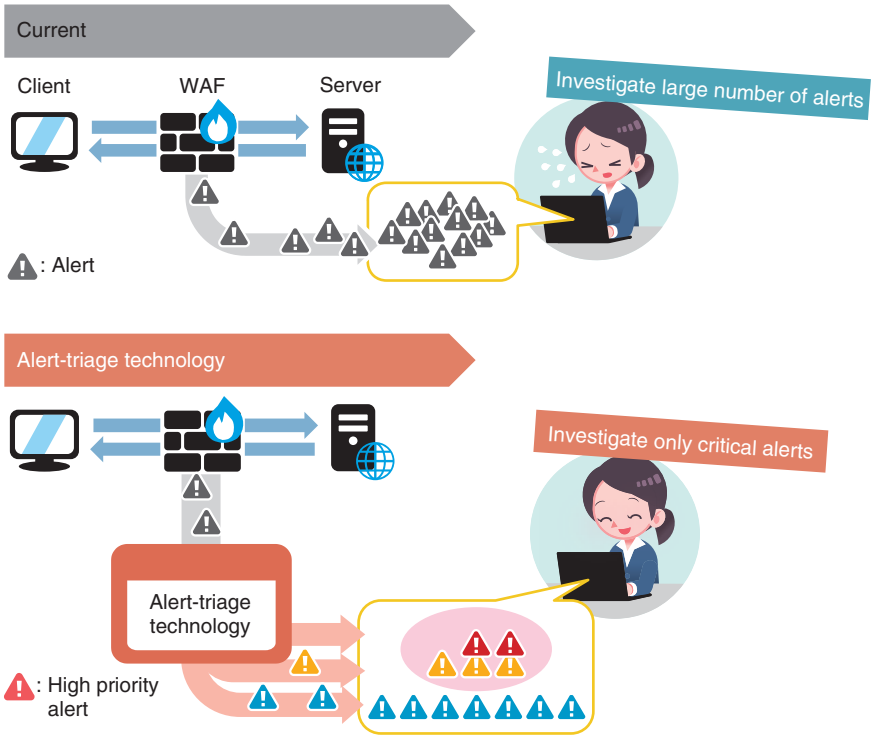

Fig. 3. Alert-triage technology.

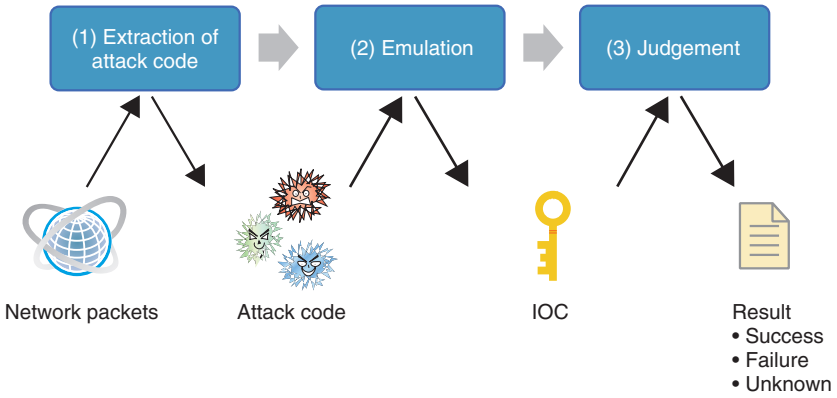

Fig. 4. Basic functions of alert-triage technology.

developed an alert-triage technology [2, 3] that automatically determines the success or failure of an attack on a server (from a network communication) from the trace of the attack and determines whether the alert associated with that attack should be given priority. This is the world's first technology for performing triage (prioritization) by focusing on the success or failure of an attack. This technology enables a server administrator or SOC analyst to concentrate on attacks that require immediate response (**Fig. 3**). The basic functions of this technology are listed as follows (**Fig. 4**).

(1) Extracting the code or command that the attacker wants to execute on the server if the attack is successful
(2) Executing the extracted attack code or command

Time	Alert	Source	Destination	Attack result*	Response priority*
Dec. 2, 2019 21:38:12	Remote code execution attack detected	x.x.x.x	y.y.y.y	Failure	Low
Dec. 2, 2019 21:43:03	SQL injection attack detected	x.x.x.x	y.y.y.y	Success	High
Dec. 2, 2019 21:43:15	Cross-site scripting attack detected	x.x.x.x	y.y.y.y	Undeterminable	Medium

* Information added by our technologies

Fig. 5. Examples of the alert triage.

on an emulator simulating various servers and extracting the trace of the attack (i.e., IOC)

(3) Checking whether the IOC extracted from the emulator was occurring in the actual communication and judging that the attack was successful if it occurred or failed if it did not occur.

When an alert occurs, it is possible with this technology to add information to the alert that (i) the attack was successful, (ii) the attack failed, or (iii) the success or failure of the attack is undeterminable (**Fig. 5**). If the alert has information that indicates the attack was successful, the response priority is high, and the alert should be checked first, even if other alerts are checked later. Conversely, if information is added to the alert that the attack failed, the priority of the response is low, and the alert could be checked later. This technology makes it clear at a glance which alerts should be prioritized, and we believe that if a large event or forum suffers an increasing number of alerts or if an attacker carries out a campaign, the effect of alert-triage technology will be more pronounced.

According to our evaluation using a real network environment, about 52% of alerts were correctly judged as failed attacks, and the priority of response to those alerts was reduced. Moreover, it was possible to raise the priority of related critical alerts to just 0.1% of successful attacks lost in a large number of alerts. An example of another favorable result is that it was also possible to recognize an attack as successful at the reconnaissance stage (at which the damage was still minimal) and, by notifying the operator, to take measures before the attack damage spread.

7. Future developments

Under the supposition that it is practically difficult to prevent cyberattacks in advance, a technology that determines the success or failure of a malware infection at an endpoint terminal or an attack on a public server—by focusing on the traces left during the attack—was introduced in this article. For future work, we will advance our research on technology for automating the response after detection of an attack to counter cyberattacks—which are expected to become increasingly sophisticated and numerous.

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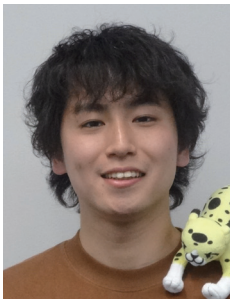

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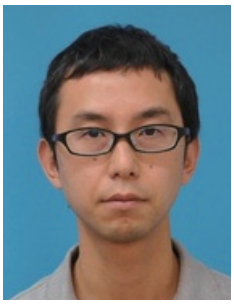

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Cutting-edge Research on Cryptography Theory in Response to Changes in Computing Environments

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Abstract

Triggered by the case that a government employee successfully forged a bank card in 1982, NTT established the first research group on cryptography around the same time. NTT Secure Platform Laboratories has contributed to building a firm theoretical ground for cryptography while developing cryptographic technologies that can respond to the changes in evolving communication and computing environments. In this article, research activities of NTT Secure Platform Laboratories on cryptography and information security technologies—in preparation for the emergence of rapidly developing quantum computers—are discussed.

Keywords: quantum computer, post-quantum cryptography, attribute-based encryption

1. Background

The notion of security in cryptography is defined on the basis of the amount of computational resources (i.e., memory and computational speed) that an attacker can have. In the 1990s, when the Internet began to spread, a public key of Rivest–Shamir–Adleman (RSA) encryption, having about 512 bits, was considered secure. In 2001, when the Electronic Signature Law was enacted in Japan, public keys are required to be 1024 bits, and in the revision to that law, which has been being considered since 2008, they will soon be required to be at least 2048 bits.

Many cryptosystems are moving toward the more efficient *elliptic curve* approach. More advanced public key cryptography (such as identity-based cryptography based on pairing groups over elliptic curves), efficient digital signature schemes protecting privacy of the signer, and highly efficient non-interactive zero-knowledge proof systems have been developed. Cryptography naturally has the ability to control access to information through key-management methods. Regarding conventional cryptographic communication, the sender and receiver of information have a one-to-one relation. In the more complex scenario of encrypted communication, however, encrypted data are stored in the cloud and the embedded information is accessible by multiple recipients satisfying the condition specified by the sender. Some advanced cryptosystems, such as attribute-based encryption (ABE), have been developed for such purposes.

It has been shown that if a general-purpose quantum computer is developed that can handle a large number of qubits with sufficient precision so that Shor's algorithm can be executed, it will be able to break efficient public-key cryptographic schemes, such as RSA encryption and Diffie–Hellman key exchange, currently in wide use [1]. Even if such advanced quantum computers do not become viable for several decades, it is necessary to develop cryptographic techniques that are secure against the threat such computers pose—so-called *post-quantum cryptography*—without waiting for quantum computers to become a reality. In fact, much research and development (R&D) and standardization of post-quantum

cryptography is already underway. As well as the motive of the providers of cryptographic systems, there are two practical reasons for such effort. The first is that a new encryption method takes a very long time from development to deployment in the real world. That is, updating a system that appears to be working to a new system that is not compatible is not something that every user can do in a short time. The other reason is the concern that current privacy will be compromised by future advances in attack techniques in a manner called *long-term security compromise*. It is a concern that even encrypted communications may be intercepted and stored for long periods, and their content may be exposed by quantum computers created in the future. In other words, for content that would be difficult to leak after several decades, a quantum-computer attack is a threat that must be addressed in the present. Post-quantum cryptography is not executed on a quantum computer; instead, it is executed on current computers. It is therefore necessary to consider security in terms of post-quantum cryptography in the current computer environment.

The activities of NTT Secure Platform Laboratories (SC Labs) regarding quantum information processing technology are first described. The latest topics concerning post-quantum cryptography are then discussed. Finally, SC Labs' latest research results on ABE, which is one of the functions of conventional public-key cryptography, are presented.

2. Quantum information processing

2.1 Quantum information processing technology at SC Labs

In October 2019, news circulated that quantum computers had finally achieved "quantum supremacy," namely, capabilities beyond those of conventional computers [2]. SC Labs has been researching and developing quantum computers that process information on the basis of the principles of quantum mechanics.

Quantum computers implemented to date can still only process data on the order of tens of qubits, and many issues on how to achieve scalability remain unresolved. In other words, R&D on how to construct quantum computers and achieve scalability is the litmus test for verifying the current security level of cryptography. Quantum information technology has also created new security technologies. The properties of quantum states differ from those of ordinary data, for example, a state is destroyed when measured unnecessarily, and it cannot be copied. By making good use of these different properties, new security technologies can be developed.

2.2 Path to developing the quantum computer

The foremost barrier to constructing quantum computers is their vulnerability to errors. Regarding qubits, it is difficult to reduce errors in the manner of digital data, which is the main information-processing unit used today; accordingly, if the scale of a quantum computer is increased, the computational result will be buried in the noise, and correct calculation will become difficult. The only solution to this problem thus far has been *quantum error correction*. When quantum error correction is applied, if the control of qubits is achieved below a specific error rate within a technically feasible range, the logical error rate of the quantum information in the encoded quantum state can be reduced, and the handling capability of the error can be extended.

Another issue is to increase the size of the qubit. Increasing the scale of qubits while accurately controlling individual qubits at high speed is contradictory and has rarely been achieved with unstable quantum states. A breakthrough in quantum engineering is expected to increase the number of qubits while maintaining accuracy of controlling individual qubits. At SC Labs, we (a subgroup) are participating in the Ministry of Education, Culture, Sports, Science and Technology (MEXT)'s Q-LEAP project, which is involved in the development of superconducting quantum computers. As part of Q-LEAP, we are working on advanced control technology that enables quantum error correction and R&D aiming at expanding the scale of quantum computers.

3. Toward quantum-secure networks

An example of a new security technology that uses quantum information processing is *quantum cryptography* (or *quantum key distribution*). Eavesdropping can be detected if the quantum state is destroyed when measured unnecessarily, so, secure key distribution is possible in principle. However, there are three problems with the current technology: (i) vulnerability to loss, (ii) practically limited communication distance (up to about 100 km), and (iii) inability of networking. The solution to these problems is using a *quantum repeater*, which makes it possible to control quantum states of light and matter with high precision and to correct quantum errors in a manner that can withstand losses. In fact, a quantum repeater

is therefore a technology that is fairly comparable with constructing small to medium-scale quantum computers. To implement a quantum repeater, we have to conduct almost the same R&D as that for implementing quantum computers. At SC Labs, we are working on controlling the quantum states of light and atoms with the high precision required for quantum repeaters while increasing the scale of the quantum states that can be handled. SC Labs is also participating in the CREST project of the Japan Science and Technology Agency (JST), in which we are engaged in R&D using cavity quantum electrodynamics—which enables high-precision interaction between light and atoms.

4. Toward quantum-resistant (post-quantum) cryptography: Secure implementation and contribution to standardization

In addition to conventional cryptographic techniques such as RSA cryptography and elliptic-curve cryptography, post-quantum cryptography, which is considered to be durable against quantum cryptography, has been studied for decades. For the most basic functions, namely, encryption and signature schemes, theoretical schemes based on problems that are difficult to solve with quantum computers have been known for a long time. However, the performance of these schemes, such as processing speed and communication traffic, is remarkably inferior to that of RSA cryptography and elliptic-curve cryptography, so these schemes have been determined impractical, and implementations of post-quantum cryptography are scarce.

As the emergence of quantum computers has recently become a visible threat, this threat has finally started to be seriously considered. Proposing and implementing faster and higher-performance post-quantum-cryptography technologies have become important research topics. In particular, in *lattice-based cryptography*, which is regarded as promising for post-quantum cryptography, new schemes have been proposed and implemented by adding several ideas and optimizations to conventional schemes that have strong security foundations, and they have demonstrated performance comparable to that of RSA encryption. Implementation experiments on virtual private network software have also begun [3].

While theoretical security foundations have been thoroughly investigated, vulnerabilities concerning implementation (such as side-channel attacks and fault attacks) have not been considered. Moreover, efficient new schemes often require *sampling from discrete Gaussians distributions* and *rejection sampling*, which are *not* used in the conventional cryptographic schemes; thus, secure implementations of them are new challenges. To address these implementation issues, SC Labs assessed security against implementation attacks, especially against the lattice-based signature scheme, and discovered numerous vulnerabilities [4, 5, 6, 7, 8]. For example, in a previous study [4], which targeted multiple implementations of the BLISS scheme, a fast lattice-based signature, we showed that measuring power consumption and processing time when a signature is generated makes it possible to completely recover the secret key by using algebra and number theory. We are proposing countermeasures and implementation schemes to overcome the above-mentioned vulnerabilities and are verifying their security. We also proposed and implemented lattice-based signature schemes that provide strong security against implementation attacks while maintaining the highest level of performance [9, 10, 11].

The above-mentioned studies had a significant impact on the ongoing post-quantum cryptography standardization process launched by the National Institute of Standards and Technology (NIST) in 2016 (hereafter, NIST Post-Quantum Cryptography (PQC) standardization). In particular, the implementation vulnerabilities of the BLISS scheme [4] are being considered as implementation threats in the design policy of a candidate called Dilithium. According to reported results [4], almost all lattice-based signatures in the NIST PQC standardization avoided sampling from discrete Gaussian distribution. Even after the start of the NIST PQC standardization, SC Labs contributed to the successful results regarding safe implementation of Dilithium and Falcon [6, 8, 10, 11] and to completely defeating and eliminating a scheme with weak security foundations [12].

5. Recent topic 1: Quantum computers and cryptography

5.1 Method for evaluating security of symmetric-key cryptography using a quantum computer

A general-purpose quantum algorithm for secret-key cryptography is not currently known. Therefore, attacks that apply the Grover algorithm or the quantum-random-walk algorithm are known to be best. At SC Labs, we developed methods for evaluating security based on analyzing the internal details of

symmetric-key cryptographic schemes. For example, we improved the multi-collision-finding algorithm of hash functions, which was achieved in collaboration with NTT Communication Science Laboratories [13].

Furthermore, anticipating the availability of quantum computers in the future, some adversaries may be now eavesdropping and collecting information. We are also devising safety-assessment methods for estimating the effect of such adversaries [14, 15].

5.2 Technique for security proofs in the presence of quantum computers

Many previous security proofs did not assume that an adversary has a quantum computer. As a result, even if the security is proven, there is a chance that the adversary can breach the security by using a quantum computer. Under such a circumstance, many security-proof techniques that take into account quantum computers have been developed since 2010. SC Labs is also researching such security proofs. Some examples of this research are methods for enhancing the security of post-quantum public-key cryptography [16, 17], quantum security of hash functions [18], quantum security of symmetric-key cryptography with the Feistel structure [19], and general lower-bound evaluation of attacks on hash functions when precomputation is allowed [20].

6. Recent topic 2: ABE

Although public-key cryptography can be divided into several main themes, this article focuses on one, *attribute-based cryptography with practical efficiency*. For public-key cryptography, a sender of information encrypts the information with a recipient's public key into a ciphertext and only the recipient who has the corresponding private key can decipher the ciphertext to access the information. ABE schemes allow the sender to freely specify the recipient without limiting the information to a single recipient. More specifically, a policy is embedded in the ciphertext, and attributes of the recipient are embedded in the secret key. A recipient can then receive information only if their attributes match the policy in the ciphertext. Therefore, the logic is embedded in the ciphertext and secret key, and it is possible to restrict information exchange.

Many ABE schemes have been proposed; nevertheless, they are insufficient in terms of implementing them in actual systems. One problem is scalability of attributes. Many ABEs require that all attributes used are determined at the initialization of a system, that is, we can thereafter no longer add attributes. To attain scalability, it is desirable to be able to add attributes at any time. Another problem is data size. In the case of some methods, the size of the ciphertext increases in proportion to the size of the embedded policy and number of attributes used. This dependence has been undesirable because it occupies storage. Therefore, various performance criteria have been considered in regard to actual use; however, an ABE scheme that reaches practically desirable levels in relation to all those criteria had not yet been proposed. Given this situation, we developed an ABE scheme that possesses all the properties desirable in terms of practicality.

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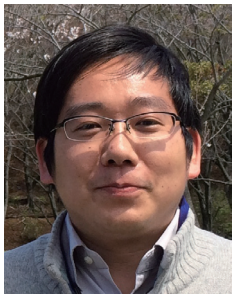

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Working toward Sharing Social Infrastructure

Motoyuki Ii

Abstract

This article introduces initiatives for sharing the social infrastructure within the NTT Group, including concrete measures to resolve societal issues and other initiatives. It was prepared based on a keynote speech given by NTT Senior Executive Vice President Motoyuki Ii at the Tsukuba Forum 2019 held on October 31 and November 1, 2019.

Keywords: sharing of social infrastructure, smart infrastructure, smart energy

1. Introduction

As human economic development has progressed, the burden on the environment has continued to increase. With advances in information and communication technology (ICT), increasing amounts of energy and resources are being consumed. The NTT Group has an obligation to work actively on reducing this burden on the environment while also contributing to economic development (**Fig. 1**). Three key points in this area are that (1) the NTT Group overall must change its mindset; (2) the NTT Group must show these changes by concrete action; and (3) technical innovation will support this action. These three points form the basis for this lecture.

The main economic model has been linear economy, in which products are made from materials, sold and used, then discarded. Taking automobiles as an example, the number of cars has increased as the economy brought prosperity, going from one car per household to one car per person. As a result, we are using more materials and energy, building more roads, and continuously increasing the load on the environment. The same applies to home appliances. As people have become richer, households have air-conditioners and several televisions. The situation is the same in our field, i.e., ICT. As ICT becomes more abundant, the amount of information being circulated increases, and the amount of energy needed increases. Such activity is definitely not environmentally friendly. However, life is more convenient, and society is safer and more secure. So what approaches are there to reducing the burden on the environment?

1.1 Circular economy

The idea of the circular economy is now considered obvious in Europe, particularly in the Netherlands. This is a recycling-based economic system; re-using items or returning them to usable base materials. If that is not possible, then burning them to produce energy. We need to adopt technology to reduce the load on the environment and develop the economy by providing things as services and not owning them, or sharing them and not having exclusive ownership. Companies and private citizens will need to work toward a circular economy, sharing rather than owning assets, and using as many renewable sources of energy as possible (**Fig. 2**).

1.2 Peer-to-Peer (P2P) sharing economy

The P2P sharing economy is being advanced mainly by individuals. More people register to provide services in various categories, and users can use these services without owning anything. Such an economy has begun in many sectors of society, and re-using things and using renewable resources are advancing.

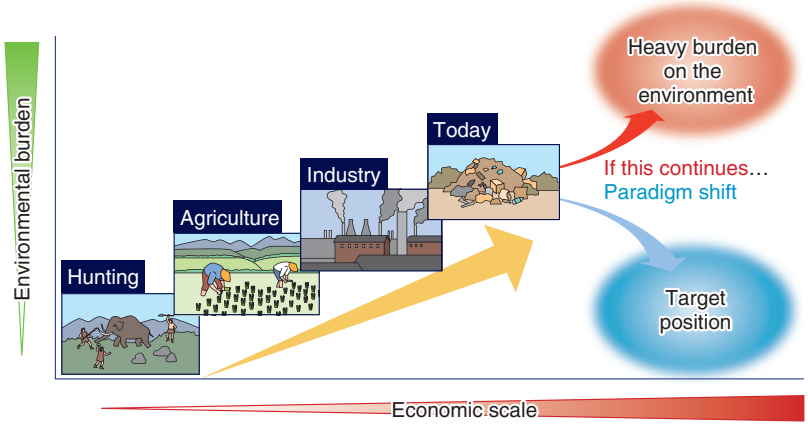


Fig. 1. Achieving both economic development and reduced environmental load.

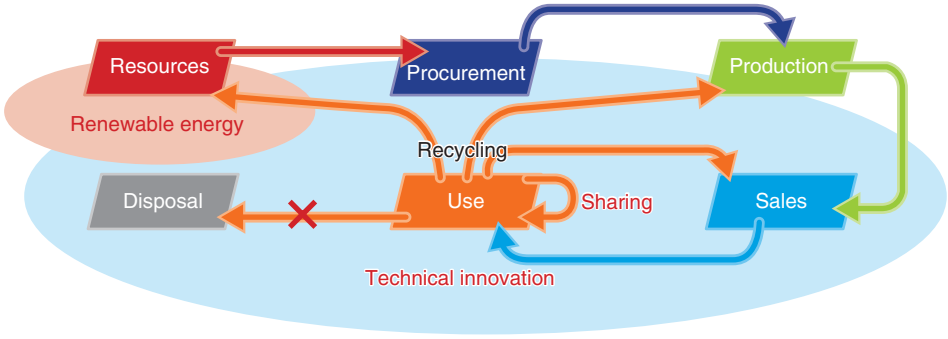


Fig. 2. Economic model for the future.

The background to this sharing economy is, of course, sharing rather than owning. A value is emerging that it is better to share with everyone because it is a waste to throw things away, and an economy is emerging in which buyers and sellers can trade one-to-one, immediately and every day. However, in the prevalent model in the field of communications, facilities, such as antennas, conduits, and power supplies, are equated with services, which has led providers to exclusively own facilities. In the mobile communications field, the ability to install antennas in good locations is an advantage for companies, so there is a tendency for companies to install them in similar locations. We argue that competition regarding facilities and services are the same, but this has increased the burden on the environment. We will need to change this approach by separating facilities and services, sharing as many facilities as possible, and competing in terms of services (**Fig. 3**).

1.3 Sharing social infrastructure in ICT

What does the social infrastructure mean in ICT? A social infrastructure is defined to include facilities such as antennas, conduits, and power supplies for telecommunication companies. Physical equipment, such as computers, servers, and storage, and even data in cloud technology are included. To share these assets, they must be created and used jointly, or made open and used in a reciprocal manner. Therefore, so-called infrastructure sharing must be considered to include the use of data (**Fig. 4**). If our efforts thus far have been egocentric, our mindset needs to be

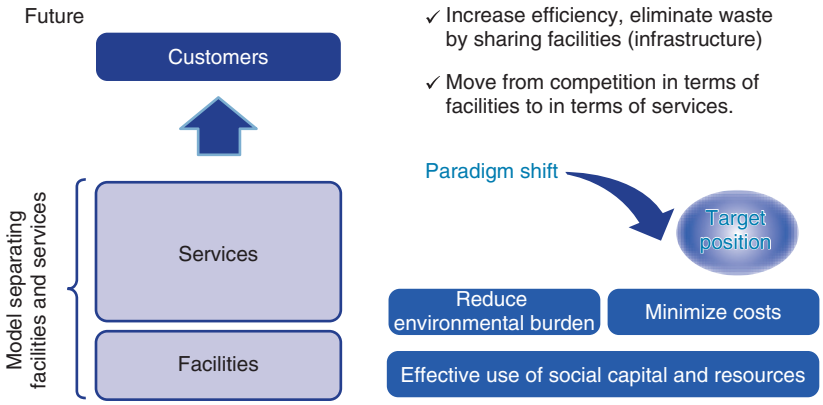


Fig. 3. Sharing economy.

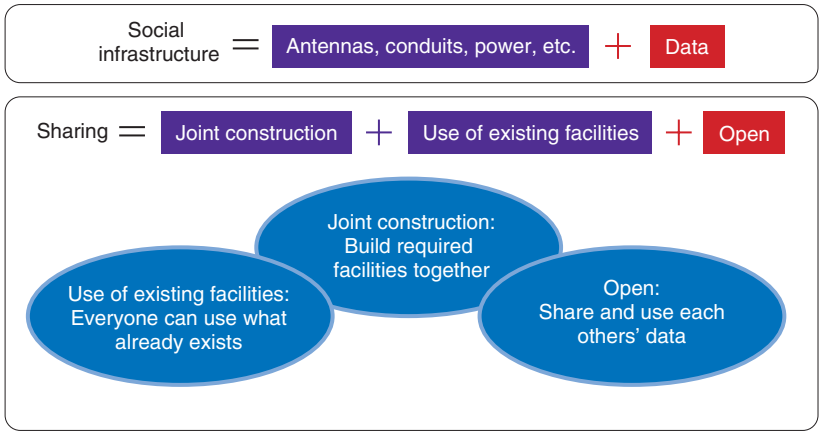


Fig. 4. Shared use of social infrastructure in ICT.

changed to be eco-centric, moving from a linear economy to a circular economy, and from owning to sharing at the business level.

2. Concrete initiatives at NTT

The NTT Group has qualities of both a public and private organization, and is required to bear some responsibility toward society as a whole. To find solutions for various issues in society through our business activities, we need to collaborate with partners. As a result, we are oriented toward forming a *smart world*, or *Society 5.0*, as it is being called in Japan, and to contribute to the United Nations' Sustainable Development Goals (SDGs). Below we introduce our three businesses working toward such collaboration: Mobile Communications, Smart Infrastructure, and Smart Energy.

2.1 Mobile Communications business

Social issues in this business are reducing the capital cost of facilities, accelerating infrastructure building for national deployment of fifth-generation mobile communication systems (5G), and securing space to build 5G base stations. Our theme is, "Do we really still need to compete in terms of facilities in these areas?" Would it not be better to share as much infrastructure as possible, reduce costs, and use space, which is a societal resource, more effectively?

(1) Building sharing (indoor/outdoor)

JTOWER is a company that is neutral with respect to mobile carriers, and is working to build antennas collaboratively. As a pure holding company, NTT has investment and business ties with JTOWER. This is

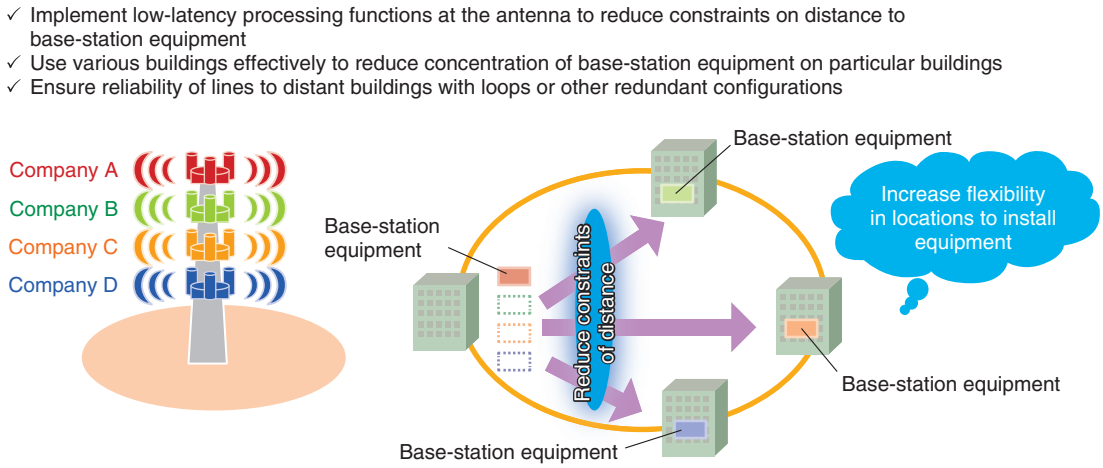


Fig. 5. Promoting building sharing.

the first step. We would like to expand the sharing model and overcome barriers among mobile carriers in the 5G era.

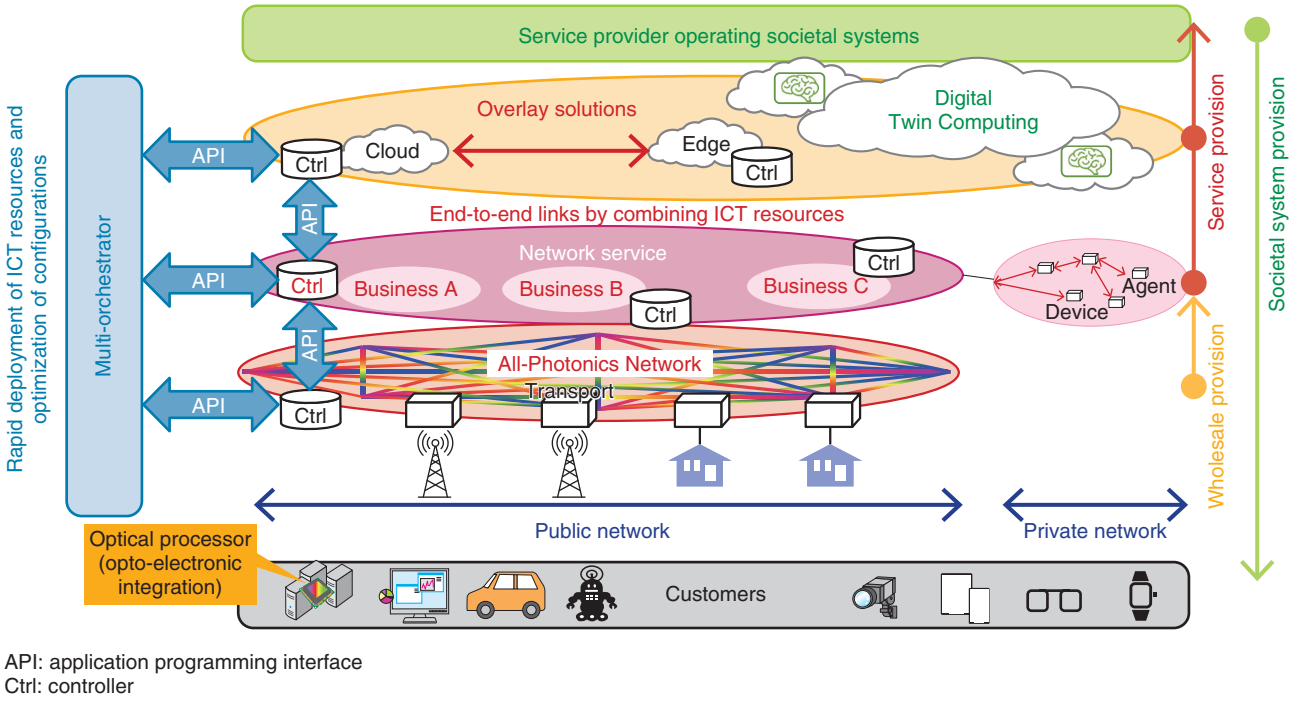
As 5G is introduced into buildings, factories, and other workplaces, construction of many antennas in buildings will be necessary. If every company does this, the number of antennas, cabling, power supplies, and other facilities will be unwieldy. This has led to initiatives toward in-building system (IBS) sharing to simplify and share antennas and other facilities, at least within buildings. This would help reduce costs and energy consumption. There will be a need for neutral companies to carry such efforts into the future. In particular, JTOWER is working with tenants, shopping malls, and other commercial buildings on IBS sharing. Since companies are building their own separate antennas, integration of these facilities is necessary.

There is also increasing need to build 5G antennas outside (towers). Density is lower in rural areas, so 5G business would not be profitable, while sharing business will have great financial significance. In urban areas, there is little space for building facilities, so it makes sense to share the small available space. Even if JTOWER does not build all facilities, it would be beneficial for carriers to open access to their own towers and other facilities. When 5G frequencies were first allocated, the Ministry of Internal Affairs and Communications (MIC) divided Japan into a mesh of approximately 4500 10-km^2 sections. Each carrier was asked what percentage of these sections they would cover by 2024, and the requested frequency allocations were granted giving priority to carriers that declared to provide 5G services covering more of these sections. Four carriers overlapped in most of these approximately 4500 sections, so we believe that it will be an issue whether these carriers will have separate facilities or share facilities.

Each company is also currently building their own mobile front-haul (MFH), which connects base stations to each of their antennas, and mobile back-haul (MBH), which connects base stations and base stations to their core communications networks. We would like to share these facilities in the future. However, for the MFH, dark fiber is used to send radio-frequency signals between base stations and antennas. If technical innovation produces a low-latency transmission scheme, it will be possible to overcome constraints on distances to base stations and bring signals to neighboring buildings. This will allow base-station equipment to be installed in various buildings, contributing to sharing buildings and using them more effectively. If such networks can be given loop topology, redundancy will also increase. As building resources are limited, it will be necessary to promote building sharing by sharing and introducing new technologies, which requires technical innovation (**Fig. 5**).

(2) Promoting interoperability of base-station equipment

The Open Radio Access Network (O-RAN) Alliance is an industry consortium gathering carriers and vendors from around the world. Until now, vendors have built base-station equipment using their own interfaces, creating an environment in which products of a company can only be connected with each other.



API: application programming interface
Ctrl: controller

Fig. 6. Vision of future networks.

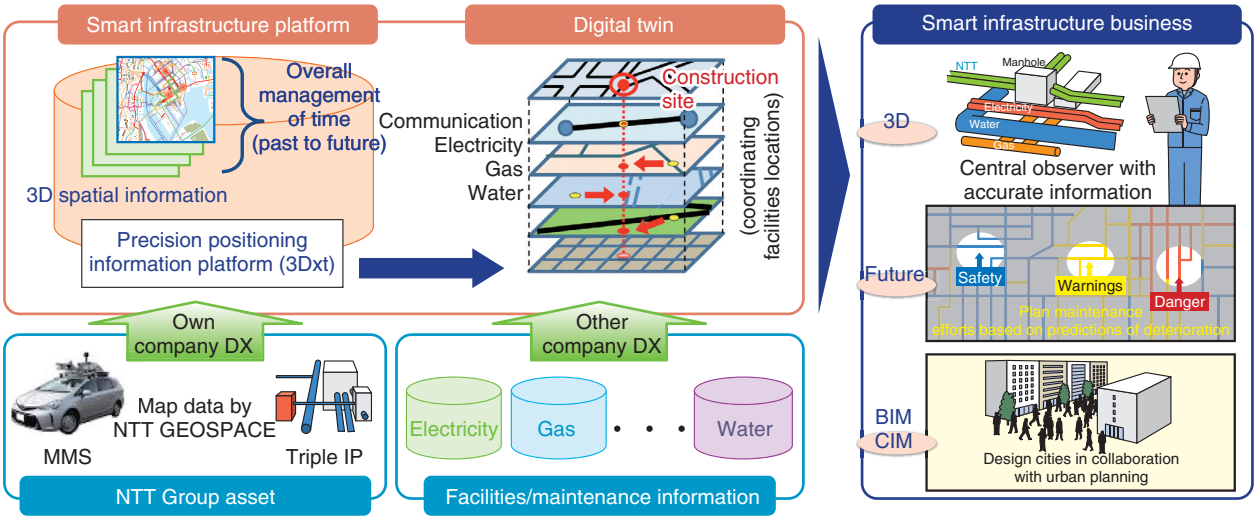
This has made sharing difficult, so the O-RAN Alliance is defining open interfaces. For the next stage, Advanced 5G, if vendors make their products based on open interfaces, a testbed will be prepared to check these interfaces and interconnectivity and interoperability can be checked with each product, there will be an environment in which products from different vendors can co-exist. This kind of initiative will contribute to sharing.

(3) Vision for networks in the future

A three-layer model (**Fig. 6**) describes network issues. The bottom layer is the transport layer, consisting of communication media such as fiber or wireless. The middle layer is the network-service layer, provided by each carrier providing various services to customers. The top layer contains overlay solutions, creating various services using the cloud. For example, services created by GAFA (Google, Apple, Facebook, and Amazon) are at this layer. Actual services are provided by combining network resources with overlay-solution resources using multi-orchestration. Note that "sharing," as we mentioned so far, applies to the most basic transport layer, including antennas and transmission channels. However, service competition will occur in the top overlay-solution layer. We can provide new value to users by combining sharing and competition.

2.2 Smart Infrastructure business

By infrastructure, we refer to underground facilities such as conduits and cable tunnels, and the related data. The underground facilities of service providers, such as those for gas, water, and electricity, as well as communication, have become very old. Personnel who build and maintain such facilities are also getting older, and facilities are managed separately by each company. This is inefficient and places an extra burden on the environment. Such conditions have led to the idea of *smart infrastructure*, in which companies can share data and find various efficiencies that can reduce the burden on the environment, even if they do not share all their facilities. To achieve this, it will be necessary to layer databases of the facilities held by each company on a single map. Companies do not know what facilities others have or what is buried at a certain depth. They each carry out work, such as digging up roadways, at different times. The first requirement is therefore to share the data. The data must be opened, and all facilities must be made *visible* based on this open data. A platform to accomplish this is needed. When real facilities are converted to digital data and used to layer the digital world over



Share infrastructure information, use as digital twins.

BIM: building information model
CIM: construction information modeling/management
DX: digital transformation
IP: Internet protocol
MMS: mobile mapping system
3Dxt: 3D xenon transient

Fig. 7. Smart infrastructure concept.

the real, it is called a digital twin. The success of this effort will depend on the quality of digital twin creation to reveal how the facilities are deployed underground. This will require three-dimensional (3D) technology, prediction technology, and so on. Achieving such a system will enable companies to coordinate to build and maintain underground facilities, rather than doing it separately as they have been (**Fig. 7**). For example, when repairing a road, a database will enable the repair work to be observed centrally by representatives from a different company. Currently, an initiative is being promoted called i-Construction, in which excavation equipment is operated based on data regarding objects buried at the site. Assuming the data are correct, this will help avoid incidents such as accidental cutting of service lines. We expect that the time is coming when it will be standard to simulate work in cyberspace before working in the real world.

Maintenance has been conducted by replacing components based on fault criteria such as inspections or years of service life. By digitizing facility information, prediction technologies can be used to predict what will occur based on the data, potentially reducing the need for inspections (**Fig. 8**). We feel that if companies having a societal infrastructure, such as communications cables, gas and water lines, or electrical conduits, are able to conduct work on them efficiently by coordinating with each other in some way, it would lessen environmental burden. To achieve this, NTT changed the ownership of NTT InfraNet from NTT EAST to our holding company, changed the management structure, and increased capitalization to conduct a smart maintenance business and build a database, as described above, for the NTT Group and for other companies. This was our first initiative. When building smart cities, operators and the types of pipes and wiring will be decided in the design stages, and it will be possible to examine entire urban areas in cyberspace, including aspects such as scenery.

2.3 Smart Energy business

Communications and energy are inextricably linked. We feel a great responsibility as a communications operator and have been developing ICT rapidly and are continuing to build datacenters, thus dramatically increasing energy consumption. We have our own initiatives to reduce the burden on the environment by supporting efforts to shift from using fossil fuels to renewable energy sources. There have also been repeated large-scale disasters recently, which have damaged communications and other societal infrastructures worldwide. Providing emergency

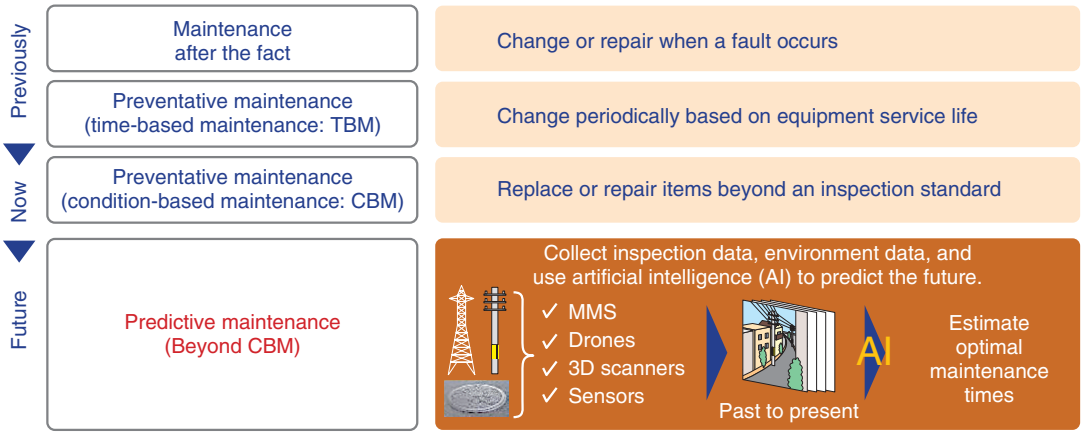


Fig. 8. Utilization for smart maintenance.

power supplies at such times is becoming an important issue. To find solutions to such societal issues, we have created a new subsidiary called NTT Anode Energy Corporation to share NTT's communications infrastructure and buildings (central offices) and contribute to building a sustainable society.

Currently, only 16% of the energy used in Japan is renewable, and even for 2030 targets, we have given only relatively passive figures of 22 to 24%. There are countries in Europe achieving this in the 30% range, and some are declaring that they will increase this rate to over 40%. It will be difficult to achieve 100% renewable energy, but increasing this amount is necessary.

However, renewable energy has its weaknesses compared with fossil fuel or nuclear power generation. For example, the amount of power generated from solar power fluctuates greatly depending on the weather. Wind power is similarly unstable, varying with the strength of the wind. There are also issues with supply and demand. Urban areas have very high demand for electrical power, but rural areas have environments that can actually supply renewable energy, while themselves consuming less electricity. This balance of supply and demand has not been achieved, and connecting everything with power lines would be costly, even for just transmission and distribution lines. A mechanism to maximize the utilization of renewable energy is needed. One solution is distributed energy. The supply-and-demand balance issue can be resolved to a certain extent by consuming the energy near where it is generated. In many regions, renewable energy has been introduced as a backup for alternating current (AC) power, but when there is sufficient AC power available, this produces excess supply, so power generation is stopped. It would be good if the excess could be stored in batteries and used when needed. However, such initiatives are not currently being undertaken, and in reality, all the renewable energy that could be generated is not being used. We will need to somehow overlay the renewable-energy distributed-energy system on the existing AC power system and maximize utilization of renewable energy.

Some possibilities in such situations include placing batteries in the many buildings owned by NTT or possibly building DC (direct current) transmission and distribution networks though the conduits that we also have between buildings. Communication operators are also well situated to show expertise in controlling and managing the energy network. ICT technology will be needed for controlling supply and demand such as electricity discharge/generation management and visualization. This will need to be automated and *autonomized* with artificial intelligence, using appropriate triggers.

3. Conclusion

The NTT Group will continue in its efforts toward a sustainable environment, and we hope everyone involved will support and collaborate with us in these efforts.

Motoyuki Ii
Senior Executive Vice President, NTT.

He received an M.S. in engineering from Keio University, Kanagawa, in 1983 and joined Nippon Telegraph and Telephone Public Corporation (now NTT) the same year. In June 2011, he became senior vice president of NTT EAST and executive manager of the Plant Planning and Strategy Planning Departments of the Network Business Headquarters. In June 2014, he became senior vice president of NTT EAST and senior executive manager of the Corporate Sales Promotion Headquarters. In June 2015, he became executive vice president and representative director of NTT EAST. In June 2016, he became its senior executive vice president. In July 2017, he became senior executive vice president and representative director of the Business Innovation Headquarters. In June 2018, he became senior executive vice president, chief technology officer, and chief information officer of NTT. In June 2019, he reached his current position as senior executive vice president of NTT.

In June 2000, he completed the Master of Science in Management course at Stanford Graduate School of Business, USA.

Pioneering a Prosperous Future with Regional Innovations

Naoki Shibutani

Abstract

This article introduces the NTT EAST Group's latest efforts in agriculture to make Japan more prosperous through the revitalization of small and medium-sized enterprises and primary industries in Japan's regions. It also introduces the importance of *collective impact* in creating new value with a variety of stakeholders and a concept for creating an open social platform. This article is an edited version of the keynote speech given by NTT EAST Senior Executive Vice President Naoki Shibutani at Tsukuba Forum 2019, held on October 31 and November 1, 2019.

Keywords: regional innovation, open social platform, data-driven society

1. Do innovations occur in Japan?

Japan is ranked sixth in the World Economic Forum's global competitiveness ranking. However, from indicators of the country's suitability for innovative business, Japan is ranked 14th, a low standing among developed countries. The world's gross domestic product (GDP) has grown over the last 30 years. As part of this trend, Japan's GDP has grown 120%. However, the GDP of European Union countries have at least doubled, while the GDP of the United States has grown 330% and China's has grown more than tenfold. Considered in this light, Japan has become a country that really does not grow.

Can the people of a country without economic growth be happy? Japan is ranked 58th in the World Happiness Report. This suggests that the Japanese, faced with social issues such as a low birthrate, aging society and pension crisis, have a hard time feeling happiness that comes from having children with peace of mind and leaving a legacy to the next generation. Many of the top spots in the happiness ranking are occupied by small countries such as those in northern Europe. However, these countries also enjoy growing per-capita GDP. Japan, on the other hand, does not have a view that tomorrow will be better than today or a future 20 years down the road will be better than tomorrow.

2. Have innovations by GAFA (Google, Amazon, Facebook, and Apple) brought happiness?

What innovations should occur in Japan? Revenues of GAFA, which have created innovations that dominate the world, have certainly been increasing sharply. However, there is a book, titled *Hired: Six Months Undercover in Low-Wage Britain* about the experience of working in an Amazon.com warehouse and as an Uber driver. I went to Seattle earlier this year and observed an Amazon warehouse. I saw how artificial intelligence (AI) efficiently controlled workers and systems. Amazon workers have heavy workloads at low wages, for which Amazon is being criticized by the mass media. Labor's share of the economy in the United States has been trending downward. The theory is that large companies, such as GAFA, have kept profits to themselves instead of returning them to their workers.

3. Open social platform

GAFA adopt a business model based on the

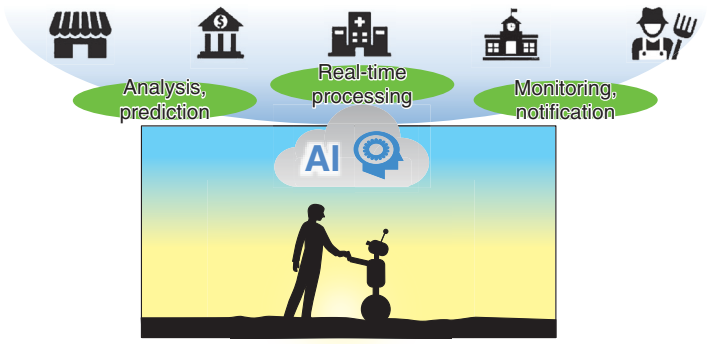


Fig. 1. Shift to AI that supports humans.

monopolization of collected data. In this model, world data are sucked up using a variety of methods such as social networking services and advertising models, and the data are used to improve the company's products and content. Many people worldwide are now raising their voices in concern over this business model.

At NTT, our business model does not monopolize data. Instead, we create data lakes that gather data from all sorts of places and willingly share them with the rest of society. Together with all of you, we want to create a society that can become more prosperous. If we create a model with which data are used by all of society, then Japan will once again draw the attention of the rest of the world.

4. Leverage AI so that people can do more creative work

How to promote a set of ethics of AI and people co-existing, instead of people being used by AI, is being debated (**Fig. 1**). If we can create AI that plays a supporting role in helping people when they are in trouble instead of AI being used in place of people, then I believe we can achieve social innovations that command the attention of the world.

4.1 Japan's renaissance will be difficult without regional revitalization

I will now explain NTT EAST's efforts to reinvigorate Japan based on our partnerships with our customers. Japan's working population is continuing to decline; therefore, we must consider how to move Japan forward.

Japan's per-capita productivity is ranked 20th among Organization for Economic Cooperation and Development (OECD) countries, an extremely low position. However, if we look at just the productivity of Tokyo, we see that its productivity exceeds that of sixth-ranked United States. This fact shows that without thinking about how to revitalize Japan's regions, it will be difficult for Japan to grow again.

4.2 Innovation by improving the productivity of small and medium-sized enterprises (SMEs)

Another challenge is the disparity between SMEs and large companies. The productivity of large companies is high. In the past ten-odd years, however, the productivity of SMEs has not grown. SMEs make up 99.7% of all companies in Japan. We must think about how to create digital transformations in SMEs and improve their productivity.

More than half of all owners of Japanese SMEs are over the age of 70. Increasingly, they are shuttering their companies, not because of stalled business leading to bankruptcy but because there are no successors to take over the businesses, despite them still being profitable.

Another challenge facing regional SMEs is that they have no information technology specialists who can use technologies to reduce workload and improve productivity. If AI can handle the heavy labor of a job, many farmers and manufacturers may be able to continue their business. However, it is currently difficult to extend a helping hand to these SMEs.

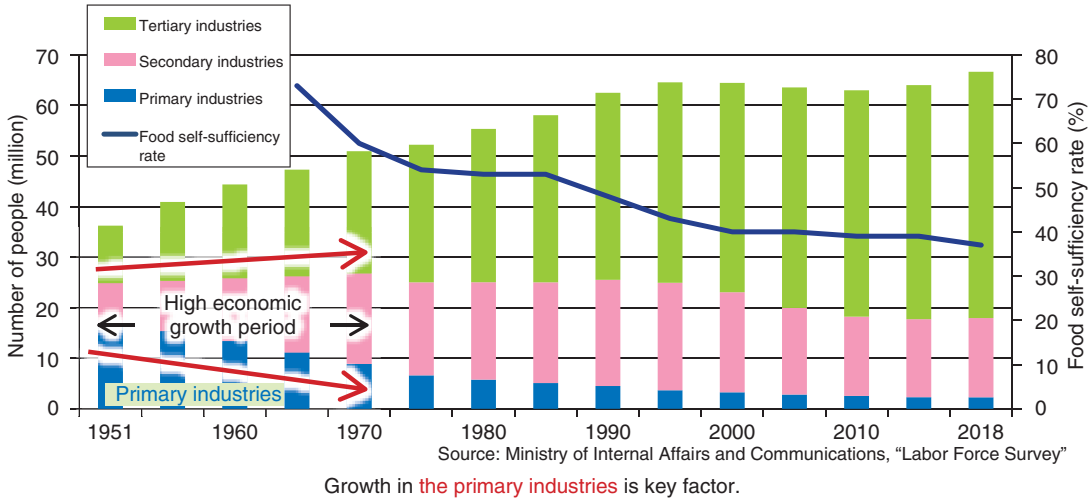


Fig. 2. Industrial structure balance and food self-sufficiency rate.

5. Creating regional employment by revitalizing primary industries

I would like to reiterate the general social trend taking place throughout Japan. Japan's population is falling, and in 2065, there needs to be 1.3 persons of working age to support one elderly individual. We must work to grow Japan and create a path to double its per-capita income.

Looking at the number of workers in each sector of the economy (**Fig. 2**), we see that young people are heavily employed in the service sector, whose customers are mainly based in Japan. The primary industry sector, i.e., industries concerned with providing the raw materials for manufacturing such as agriculture, fishery, and forestry, is shrinking yearly. While Japan's regions depend heavily on such industries, the country has not focused on how to strengthen them, particularly regarding agricultural production, livestock husbandry, and fisheries. How to reinvigorate these industries will be the key to regional revitalization.

Over the past 50 years, the number of agricultural workers has fallen 80%. What's more, 80% of these workers are over the age of 60, and abandoned farmlands are increasing rapidly. If we can effectively use land and improve productivity, then not only the manufacturing industry but also primary industries can become export industries and serve as another pillar of Japan's economy. We therefore seek to revitalize Japan's regions through improving SMEs' productivity and reinvigorating primary industries.

5.1 Regional circular symbiotic communities for Japan

At NTT EAST, we aim to support the creation of region-based circular symbiotic communities to improve SMEs' productivity and reinvigorate primary industries. For example, we can collect and convert manure from cows and wood chips from the timber industry into locally produced, locally consumed energy such as heat produced by biomass plants. For example, using this energy, caviar can be cultivated by aquaculturists, and the remains of the fish can be composted. To promote such communities, we seek to engage in leveraging digital technologies for Japan's regions.

5.2 Example of effort in the agricultural field

Based on the awareness of the issues described above, we at NTT EAST began to focus on agriculture. Agriculture faces a variety of challenges, such as a lack of workers, damage by wildlife, and natural disasters. However, there are countries that have succeeded with agricultural innovations. Even though the Netherlands has just one-tenth the surface area of Japan and its population is only 16 million people, its agricultural sector has expanded dramatically after World War II. The country is now the second-largest agricultural exporter in the world. The Dutch have created next-generation greenhouse horticulture with 5 times the crop yield per area than that of Japan. The Netherlands have established a region called Food Valley, like Silicon Valley for technology in the United States (**Fig. 3**). With Wageningen University,

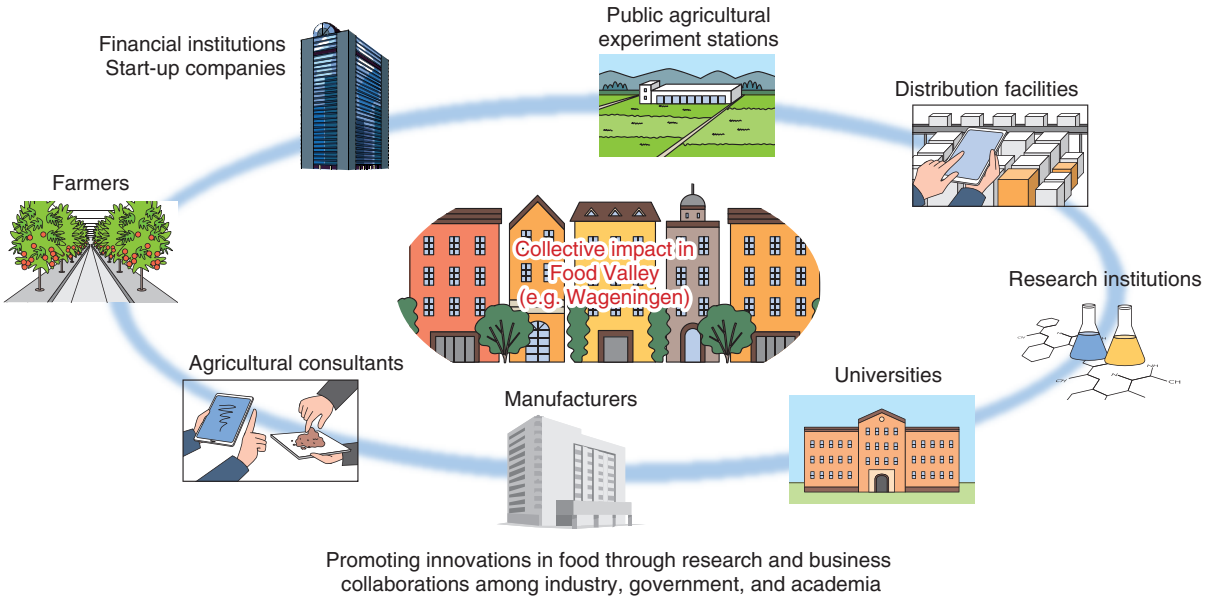


Fig. 3. To establish next-generation protected horticulture (Netherlands).

the world's most advanced university in the agricultural field, at the center, Food Valley is creating a system that connects stakeholders from a variety of organizations, such as public agencies, research institutes, manufacturers, and farmers. This region is formed by holistically researching and solving problems from a variety of angles. Questions include how to create high-quality seeds with biotechnology, how to improve the crop yield and production efficiency, and how to optimally distribute crop products to markets.

6. Collective impact

An idea that has gained attention is *collective impact*, which means building up an entire industry by bringing together the strengths of companies, government agencies, and research institutes, and sharing goals, as done in the Netherland's Food Valley, because the efforts of individual companies alone have their limits. In short, it is a philosophy that believes that combining powers results in transformations that impact society. We see countries such as the Netherlands that have succeeded with collective impact. We believe that the same can happen in Japan.

7. Two digital transformation approaches for advancing agriculture

As I have explained above, NTT EAST has begun efforts to revitalize SMEs and primary industries through digital technologies. I would like to introduce two real-world examples of efforts that we have been engaged in regarding agriculture (**Fig. 4**). There are two approaches to digital transformation, Mode I and Mode II. Mode I is a forward-casting approach based on the current method of agricultural practices. With this approach, productivity improves through digital technologies. Mode II, on the other hand, is a backcasting approach. It defines a completely new future condition as the starting point and considers what should be done to achieve that future. An example is completely changing the current agricultural methods by, for example, optimizing the Netherland's next-generation greenhouse horticulture for Japan. By adopting both Mode I and Mode II, regional revitalization can blossom, attracting industries and employing young people.

7.1 Mode I: Yamanashi model

I would like to introduce our effort in Yamanashi as an example of the Mode I approach. Shine Muscat grape farmers in Yamanashi actively partner with the JA (Japan Agricultural) cooperative Yamanashi Fruits. There is a farming couple who are both over

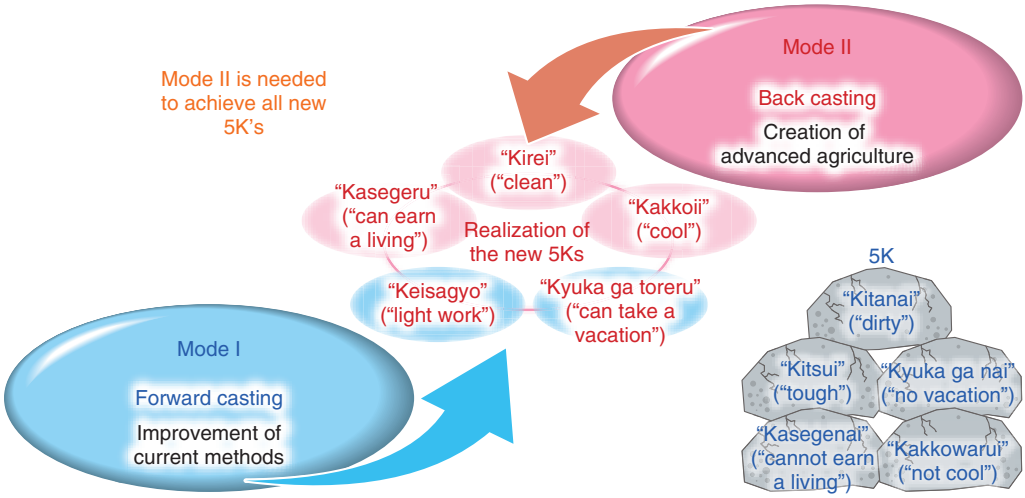


Fig. 4. Two approaches for advancing agriculture.

the age of 70 operating ten plastic greenhouses. Because Yamanashi is extremely hot in the summer, air conditioning must be used when the temperature exceeds 35ºC or all Shine Muscat grapes will become damaged. Therefore, the wife must visit the ten greenhouses every day to manage the air conditioning, a really laborious task. If we can just lighten this task, farming can continue for generations.

To assist such farmers, we are carrying out remote monitoring and data gathering by attaching Internet of Things (IoT) devices externally to existing facilities. With JA Yamanashi Fruits as the center, we are gathering cultivation data from many farmers and participating in ventures with the University of Yamanashi. By using temperature, carbon dioxide, and cultivation data to improve the quality of the Shine Muscat varietal and determine the timing of shipments, we have been able to develop a data-driven approach for improving crop yield and providing guidance in agricultural management (**Fig. 5**).

7.2 Mode II: Next-generation greenhouse horticulture model

As an example of the Mode II approach, we established a company called NTT AgriTechnology on July 1, 2019 to be fully engaged in agriculture. I now introduce NTT AgriTechnology Senior Vice President Daiki Endo's to give his thoughts and the company's specific efforts.

[Daiki Endo, Senior Vice President, NTT AgriTechnology]

My parents were rice farmers. Looking at the lack of workers due to the aging of society, including my relatives, I wondered if I could be involved in farm management in the future. I wanted to study onsite what leads to profitable and leading-edge agriculture, so I wanted to be a trainee at Salad Bowl.

Salad Bowl is an agricultural production corporation at the leading edge of agriculture and operates several large Dutch-style horticultural facilities in Japan. The structure and facilities of the greenhouses have unique characteristics and are well-lighted. The company is practicing a variety of labor-efficient Dutch methods and achieving originality by combining Dutch expertise and Japanese techniques.

In the Netherlands, agricultural technology is centered on supplementing many insufficient components such as sunlight and carbon dioxide. However, in highly humid Japan, instead of adding (supplementing), components must be removed. Salad Bowl has been successful in applying expertise in multiple domains in a Japanese manner to this difficult problem as it operates several cultivated fields.

What can NTT EAST offer to this enterprise? One key is improving productivity and reducing energy costs. Liquid petroleum gas and electricity are used to control the environment. I believe NTT EAST's IoT technology and information and communication technology (ICT) have a role in visualizing and improving the efficiency of these resources.

In fact, NTT EAST is conducting field tests at Salad Bowl's cultivated fields. We are estimating the crop yield for the next day after taking images of a field. If the amount of harvest is known, then the number of

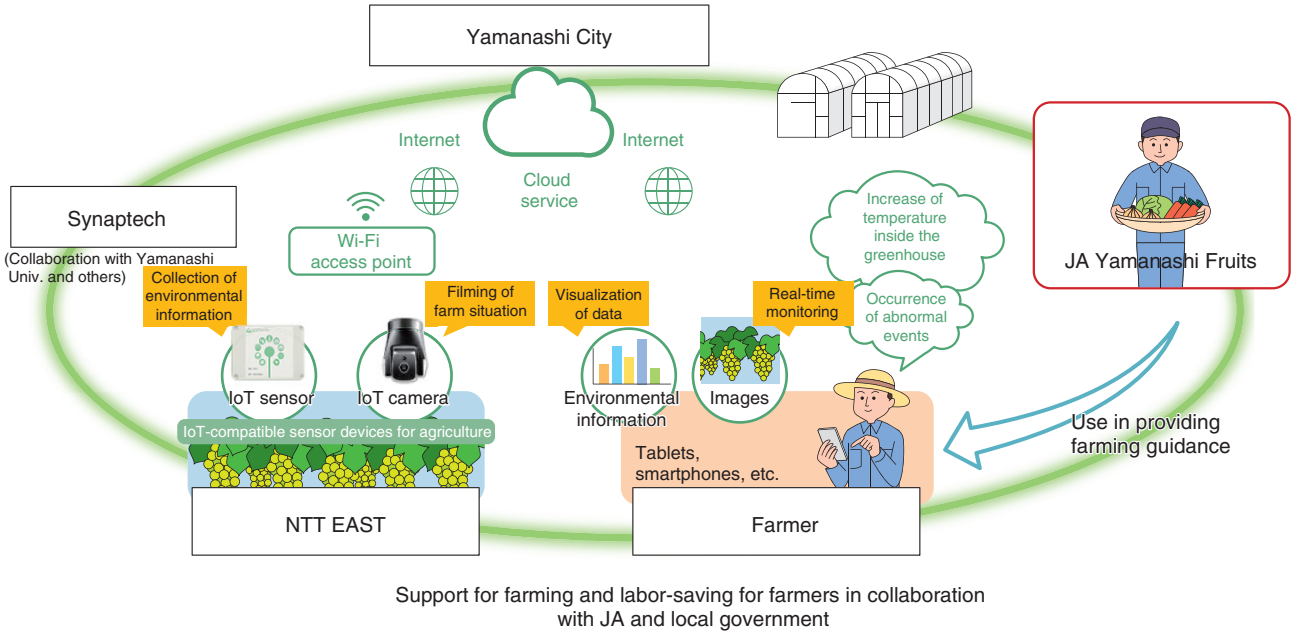


Fig. 5. Collaboration with Yamanashi City and JA Yamanashi Fruits.

workers can be assigned accordingly. By delivering information on tomatoes to the market in advance, for example, the appropriate amount of the produce can be sold without excess inventory. IoT and ICT make this possible.

We have received requests not only from Salad Bowl but also various regions and municipalities. Therefore, NTT EAST established NTT AgriTechnology to engage in agriculture and provide field-tested solutions. By forming an even stronger partnership with Salad Bowl than before, we are contributing to the adoption of large-scale greenhouse horticulture nationwide and promoting community development through building greenhouses.

8. Aiming for regional revitalization and community development through "Agriculture × ICT"

Summarizing Mode I and Mode II, we at NTT EAST, who are not experts in agriculture, want to form lasting partnerships with farmers who wish to leverage digital technologies to bring about mutual benefits. Looking to the Netherland's success in agriculture, we at NTT EAST want to build up a region's industry together with universities and consultants in that region. In line with this goal, we wish to work with regional stakeholders to support a circular society that carries out local production of energy for local consumption.

9. Networks for supporting regional social innovations

Because we are a network company, we must create networks to support regional revitalization. We wish to build them together with NTT R&D and manufacturers. Leveraging data by data scientists is the current focus. However, it is difficult to collect data pre-formatted at a level where AI analysis is possible. We want to create a framework for data lakes where reliable data are gathered. For this goal, our mission is to collect data from every conceivable source, such as from 40 billion IoT devices and drones and satellites, and create edges for computing in regions so these data can be openly used for social innovations.

Data obtained from sensor devices, drones, and satellites have different characteristics concerning data-acquisition range, resolution, and freshness. A perspective on how to gather data by combining these characteristics is critical. Previously, satellites have used optical sensors to capture images; thus, images of ground surfaces could not be obtained in bad weather. However, ground-surface information can now be obtained regardless of the weather by using microwave radar. By launching several hundred

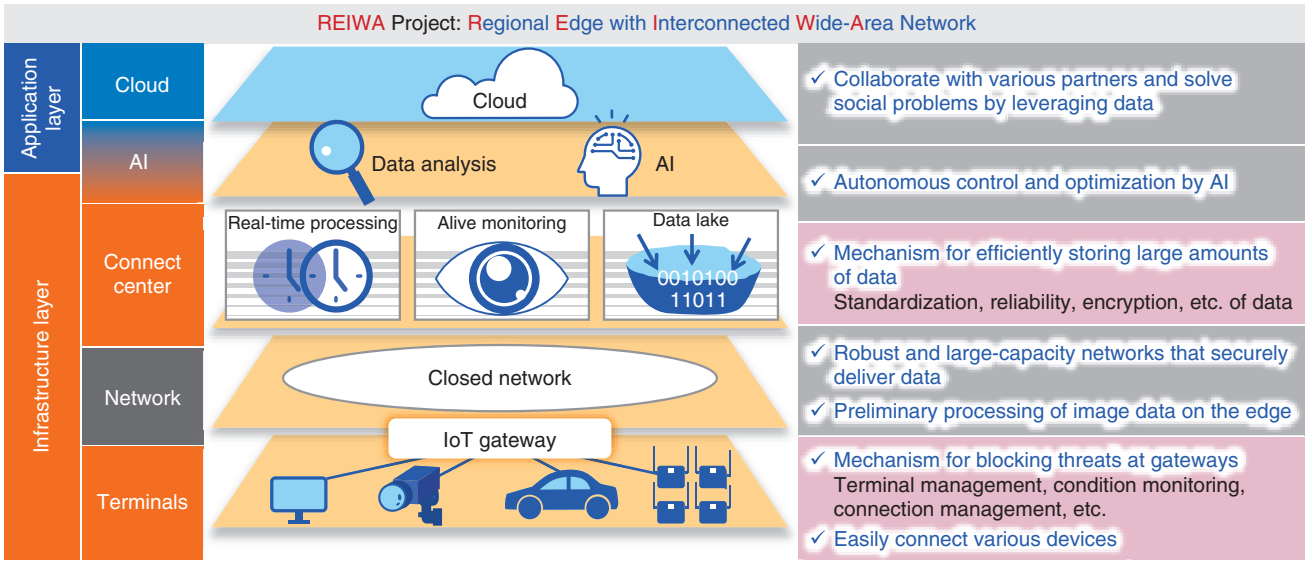


Fig. 6. Social infrastructures that guarantee the reliability of data.

low-earth orbit satellites, whose cost has fallen sharply, and obtaining images with microwave radar in regular intervals, information can be obtained at very short cycles. NTT EAST became a member of the xData Alliance on October 24, 2019 and announced that we are fully participating in space ventures.

With regard to local fifth-generation mobile communications (5G), we cannot simply deploy local 5G. To solve a region's difficulties, we must build networks that use a best mix of all network types, including optical fibers, Wi-Fi, low power wide area, and local 5G.

10. Toward developing secure IoT

There are security issues with IoT technology (**Fig. 6**). Many IoT devices have low-spec processors and memory and are not updated, leaving them with many security holes. Their data handling is thus not reliable, and they cannot be used for mission-critical purposes such as medicine and automated driving where lives are at stake. Therefore, our mission is to make IoT technology trustworthy for handling data. It is critical to have an environment where data entrances and exits are robustly protected, even when a variety of devices are connected, clean up data while processing appropriately at edges, and enable the data to be used by data scientists in the upper layer. We wish to build next-generation edge networks that draw out wisdom from a variety of users for social innovations such as AI.

Specifically, through IoT gateways, we carry out alive monitoring of devices and use inference techniques to remove data determined suspicious when abnormal behavior is observed during monitoring. We wish to create a regional edge network with Innovative Optical and Wireless Network (IOWN) as a set. We want to engage in this effort with the help of researchers, developers, and manufacturers.

11. To bring about regional social innovations

Finally, NTT EAST is visiting municipalities, farmers, and universities to build partnerships to promote digital-technology-based regional revitalization and a circular society (**Fig. 7**). Thanks to our partners, this effort has been well-received. Many municipalities and JA said that until now, no large companies have worked with them in this field, so they are eager to work with us. There have been many companies that immediately disappear after reaping the benefits of a partnership. Therefore, they said they wanted us to put down roots in their communities. I want to answer with confidence that we are working on regional revitalization and industrial development with the support of everyone in the community. To strengthen Japan, it is necessary to solve challenges faced by regions and SMEs. We appreciate support

Fig. 7. To generate regional social innovations.

from research institutes and related companies concerning this endeavor.

Naoki Shibutani
Senior Executive Vice President, NTT EAST.
He received a B.E. from Kyoto University in 1985. He joined Nippon Telegraph and Telephone Public Corporation (now NTT) the same year. In June 2014, he became senior vice president of NTT EAST and executive manager of Plant Planning Department and 2020 Preparation Department. In July 2017, he also became director of Tokyo Olympic & Paralympic Promotion Office. In June 2018, he also became the representative director of NTT EAST, senior executive manager of New Business Development Headquarters of NTT EAST, and president of NTT VIETNAM. In July 2019, he also became senior executive manager of Digital Transformation Headquarters of NTT EAST.

Technical Trends in Infrastructure Maintenance Management

Minoru Tanaka

Abstract

In the Civil System Project of NTT Access Network Service Systems Laboratories, we are working to achieve permanent infrastructure by implementing smart operation of facilities. We introduce new maintenance management for conduits, manholes, and tunnels. This article is based on a lecture from a workshop held on November 1 at Tsukuba Forum 2019.

Keywords: degradation prediction technology, high-accuracy location information acquisition technology, 3D model management

1. Direction of maintenance management

NTT has constructed many infrastructure facilities, including underground conduits, manholes, and tunnels. Most of these facilities are over 30 years old and half are more than 50 years old. We have been using the plan-do-check-action cycle of inspection, planning, and repair to extend the life of these facilities.

The cycle involves regular inspections that reveal abnormalities, detailed inspections, selection of optimal repair methods according to the inspection results, and repair work. This approach, known as preventive maintenance and post-preservation, is taken only from the post-construction perspective. Repairs are made only after facilities have deteriorated, so it is a rather defensive approach to maintenance management.

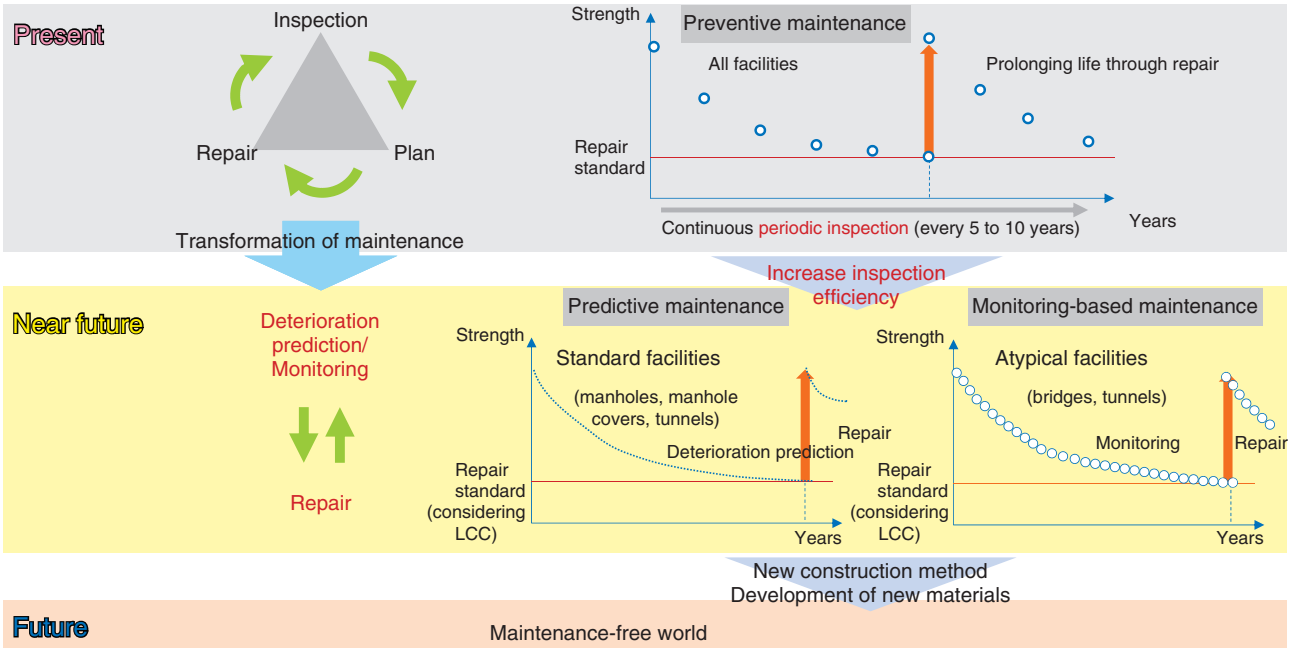
We ask the question, "What parts deteriorate, when do they deteriorate, and how do they deteriorate?" Knowing the condition of each facility can dramatically change maintenance work. This is a shift towards offensive maintenance. What is most important is technology for predicting deterioration. Deterioration can be accurately predicted by identifying which part is deteriorating and the mechanism by which it is deteriorating, and then estimating the deterioration period.

Accurately predicting deterioration makes it possible to manage the state of each facility and perform detailed maintenance tasks such as planned repairs. Although we can expect deterioration of facilities built in the era of mass construction, such detailed planning of repairs can facilitate a leveling effect on construction. That is to say, enabling fine control on the management side will make preservation work greatly different from the conventional approach of waiting until facilities have already deteriorated. Our objective is to change how maintenance work is done. Our approach is described in detail below.

1.1 Maintenance based on prediction and monitoring

It was not previously possible to predict where, how, and when a structure would deteriorate. The basic approach has been to conduct periodic inspections, decide on repairs according to how much the facility's functionality has decreased, and select the most appropriate repair method for the facility if repair is needed. After repair, however, the cycle of inspection and repair continues, so it has not been possible to determine the deterioration mechanism or supplement parts for which the deterioration-reduction mechanism cannot be identified.

We are currently conducting research and



LCC: life cycle cost

Fig. 1. Direction of maintenance management.

development (R&D) on clarifying deterioration mechanisms for infrastructure facilities and have been successful regarding various types of facilities. If mechanisms can be identified, periodic inspections would not be needed to determine what parts to repair and when to repair them. Instead, it is possible to predict deterioration and carry out predictive maintenance. We will be applying this approach to standard facilities such as manholes and manhole covers.

However, predicting deterioration in nonstandard facilities, such as specialized bridges and bridge-attached conduits, is difficult, so monitoring-based maintenance will be carried out. Concerning large-scale tunnels, we will move forward with a hybrid system that combines predictive maintenance and monitoring maintenance (**Fig. 1**).

1.2 Shifting maintenance management from defense to offense

We have thus far taken measures so that facilities older than 50 years can be used for 100 years or so. We also intend to evolve maintenance management from the conventional defensive approach to an offensive approach to further extend service life so that facilities can be used without concern for 150 or more years (**Fig. 2**). To achieve this goal, we must take a new technical perspective in developing management methods to replace the conventional inspect-and-repair approach from a post-construction perspective. To achieve an ultimate maintenance-free world, we are moving forward with new innovative R&D regarding construction and repair methods using new materials and inspection methods and creating new databases.

As described above, preventive maintenance based on deterioration prediction and monitoring-based maintenance serve as core technologies and are supported by databases. Because there is a huge amount of data and the role of the database as the foundation for advanced management through the use of various applications, there is a need to evolve from two-dimensional (2D) management on paper towards management in three or four dimensions with a time axis. Database evolution will result in changes in related tasks. For example, 3D management through visualization of underground spaces would make it possible to understand the situation of underground facilities as if a person were on-site and touching them. Previously, it was necessary to look at drawings on paper and imagine the required assembly, but now staff can easily share the same underground space without having such special skills. We call this digital

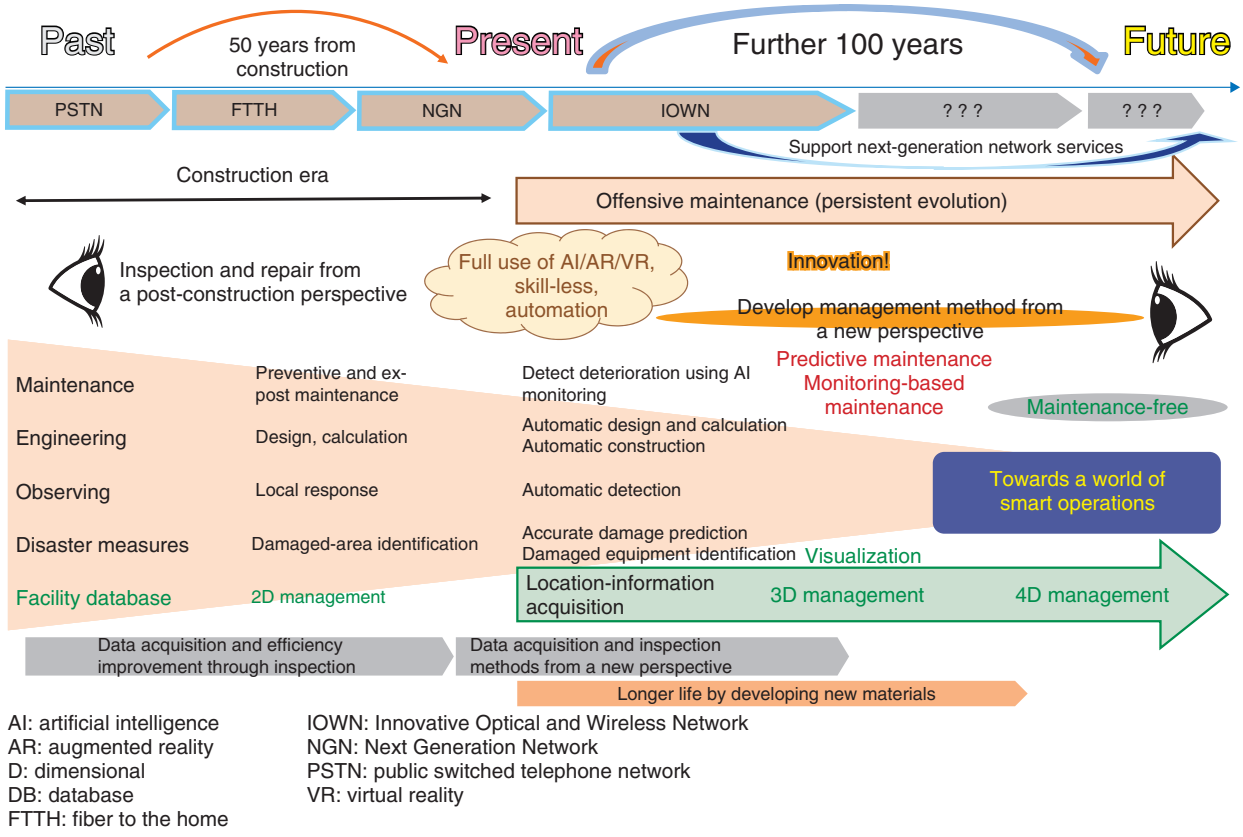


Fig. 2. Transform maintenance.

transformation (DX).

We are aiming to reduce manual work by combing artificial intelligence (AI), augmented reality (AR), and virtual reality (VR) with advanced database management. For example, the inspection of facility structures requires automation and autonomous operation with robots, etc., so we are pursuing R&D on automated inspection technology using unmanned aerial vehicles, etc.

Our R&D also includes application of AI to automatically detect deterioration using digital images taken during inspections as well as damage prediction for infrastructure facilities using a highly accurate 3D database. In engineering, AI-assisted design and assessment and automated machine construction at the worksite are also possible. AR can be used to increase efficiency in on-site inspections, and future advances will enable elimination of on-site inspections. Such 3D databases require highly accurate coordinates, so R&D on highly precise acquisition of location data from a global navigation satellite system (GNSS) is also in progress.

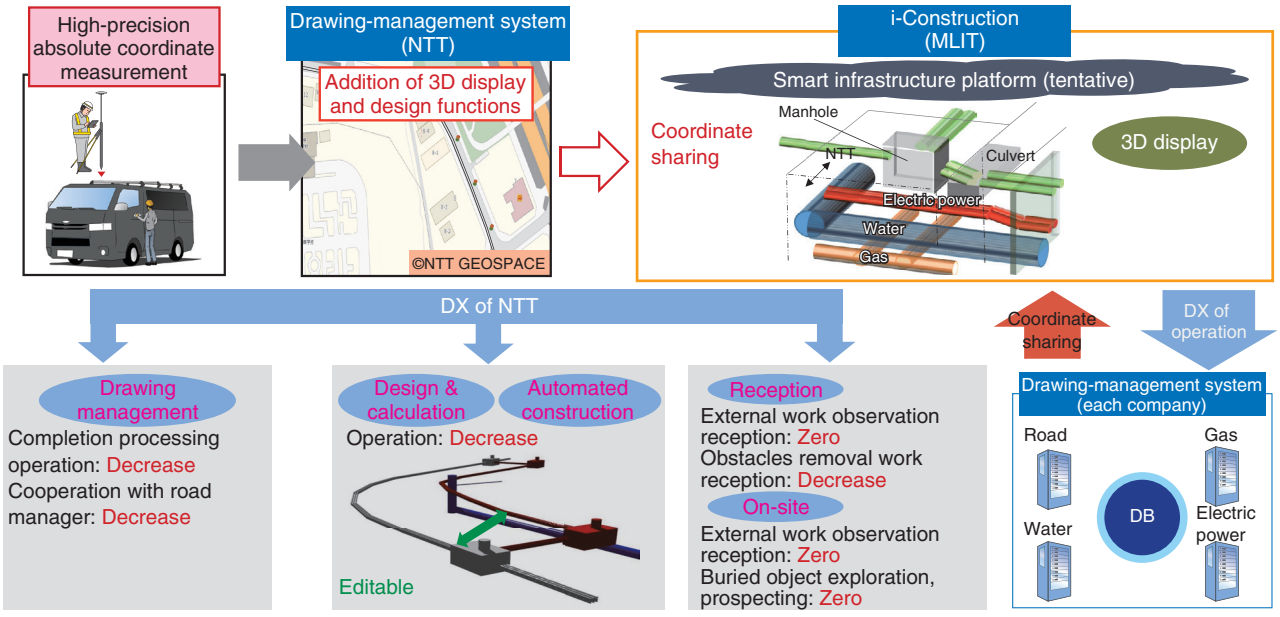
2. R&D on infrastructure

2.1 Infrastructure tasks (for conduits and manholes)

Correct and accurate location information is needed to increase the efficiency of conduit and manhole work, so technology for acquiring highly accurate absolute coordinates is important. Specifically, using a single-frequency GNSS to measure the location of newly constructed conduits and ground-penetrating radar for locating existing conduits are current R&D topics.

Highly accurate acquisition of absolute coordinates would enable sharing of precise facility location information with other lifeline providers in the implementation of the "i-Construction*" measures of the Ministry of Land, Infrastructure, Transport, and Tourism. Doing so would make it possible to automate the

* i-Construction: A measure initiated by the Ministry of Land, Infrastructure, Transport, and Tourism to improve productivity of the construction industry using information and communication technology.



MLIT: Ministry of Land, Infrastructure, Transport and Tourism

Fig. 3. Effect of acquiring high-precision absolute coordinates.

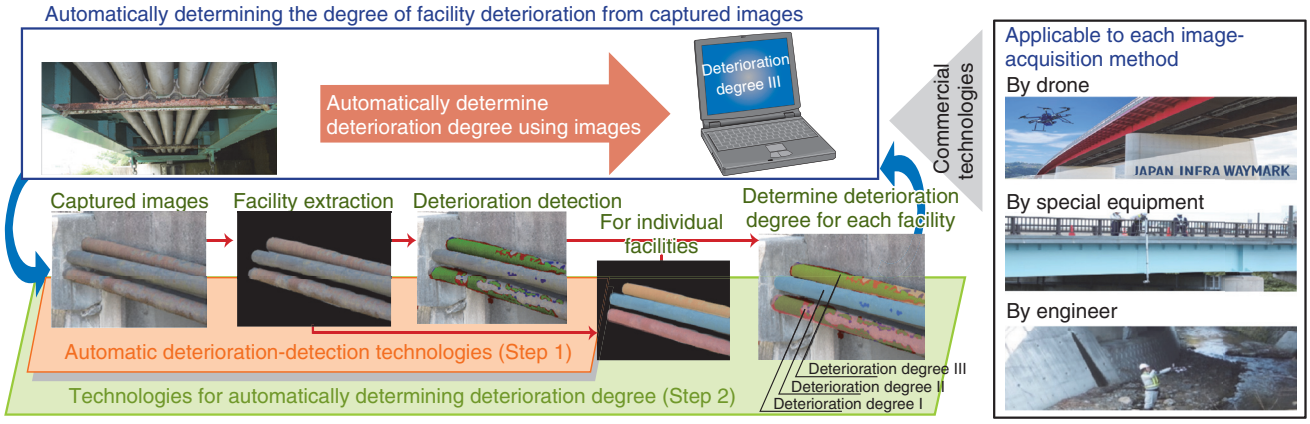


Fig. 4. Determining degree of deterioration with AI.

construction-completion processing, exclusive-use management, and design and assessment work. It would also lead to more efficient outside inspection work and acceptance of transfer work. In other words, it will lead to the promotion of DX in other companies as well (**Fig. 3**).

We have been working on using AI for detecting deterioration to improve the efficiency of bridge inspection, and this work is presented in this article as a case study (**Fig. 4**). Currently, various types of inspection images are acquired by drones, special equipment, or cameras operated by workers, etc. Skilled individuals who determine the degree of deterioration examine images. Our objective is to automate this process so that individuals who do not have specialized skills can do it.

The first step in the process is to distinguish NTT facilities from those of other companies in the obtained images. Then, the NTT facilities are examined for corrosion, and the parts where corrosion

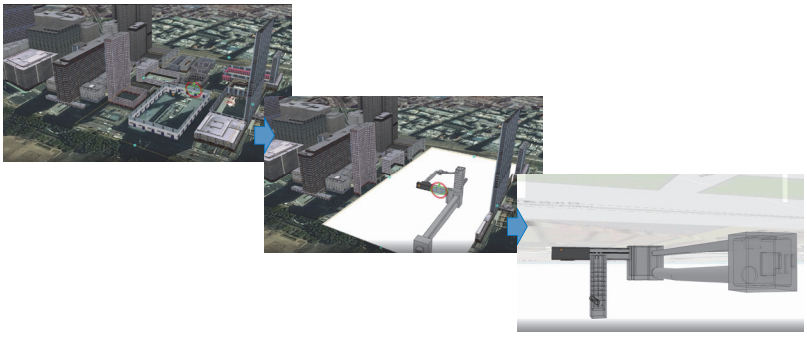


Fig. 5. Visualization image with 3D model.

exists are identified. It is now possible to detect corrosion with a high probability of success, and we are continuing this work with the goal of automating the determination of the degree of deterioration. Therefore, digital images can be used to determine what facilities are deteriorating, thus increasing efficiency.

2.2 Infrastructure tasks (for tunnels)

We are conducting R&D on using 3D models in managing tunnels. This technique visualizes the situation of underground spaces in a manner similar to the street-view function of satellite map services, making it possible to also reference the history of the inspection location (**Fig. 5**). Workers can view the facilities in 3D with a sense of themselves being in the tunnel. Also, a skeleton view of the tunnel makes it possible to know the placement of the reinforcement bars. For shield tunnels, it is possible to view the state of the primary lining, and any inspection point can be checked in cross-section. Although research is still in progress, it is possible to view from any angle, direction, or cross-section at any time. Implementing this technique will increase work efficiency.

To increase the efficiency of cable-tunnel management, we are currently focusing on three points: 1) full automation of monitoring and inspection using 3D models, 2) central management of facility information using 3D models, and 3) remote support for on-site personnel. Tunnels throughout the country will be monitored at a central monitoring center, and 3D information will be used for viewing facility information (**Fig. 6**). Also, data on environmental changes, such as temperature and oxygen concentration, in tunnels can be acquired from sensors in real time. Cameras can be used for central monitoring of sites where work may be dangerous and the status of facilities can be checked during natural disasters. The ability to quickly dispatch monitoring capabilities to disaster sites with robots and drones is also desirable.

Unified management of facility information with 3D models is another method of increasing efficiency. Facility-location data are managed as absolute coordinates, making it possible to visualize the situation in cable tunnels in a manner similar to the street-view function of mapping programs, obtain historical data on inspection points and the placement of reinforcement bars, and browse shield segment arrangements. Real-time monitoring with cameras is also possible.

Remote support for workers is important because the interior of tunnels is very complicated, especially in Tokyo. Workers who go into tunnels to inspect or repair must be kept informed of environmental conditions, such as temperature, humidity, and oxygen concentration, via real-time communication using tablet devices, etc. Workers can also access the results of past inspections and repair history and determine their current position and the route to the destination from a navigation display on the screen. Emergency evacuation guidance can also be given, the escape direction can be displayed, and communication with the monitoring center is possible, providing support for workers in real time.

3. Future development

Our objective is to make daily progress in increasing the efficiency of the maintenance management of infrastructure facilities. We also expect that the transformation of databases from 2D to 3D or even 4D will accelerate the DX of business. To continue providing a safe and secure infrastructure, the Civil System Project will promote R&D that creates value through advanced technology in fields such as materials,

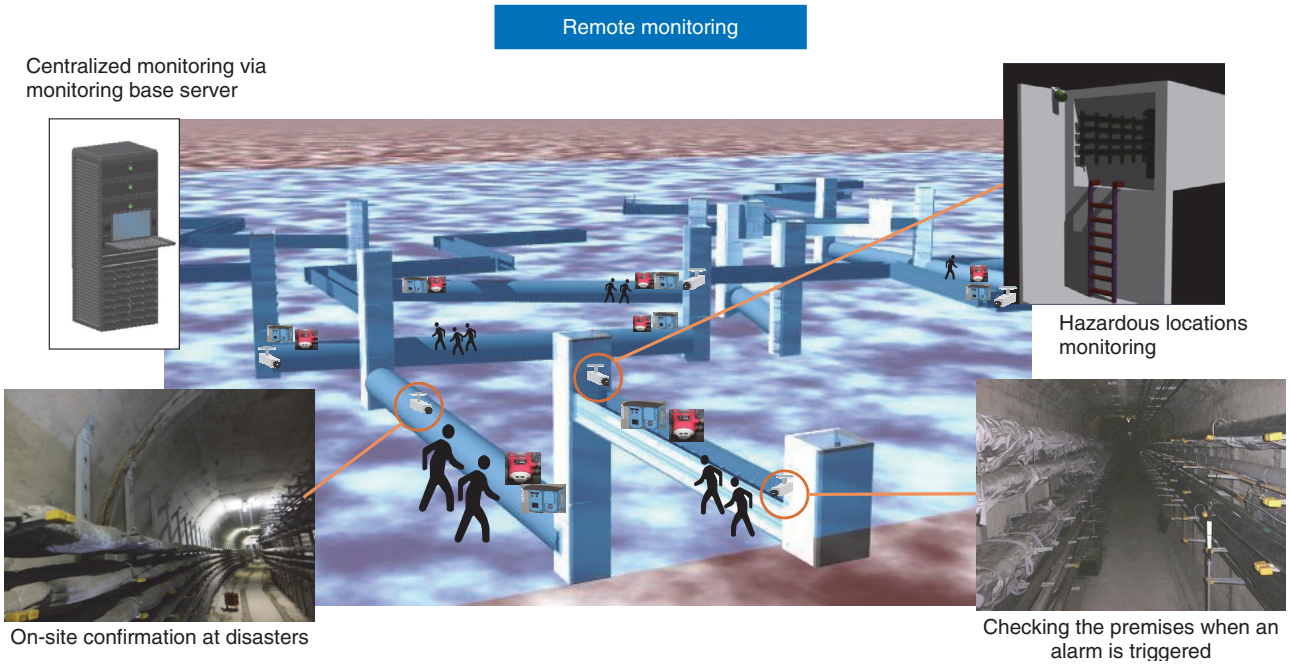


Fig. 6. Fully automated monitoring and inspection with 3D model.

information, telecommunications, and robotics, and fuse expertise in other fields. We will also contribute to the DX beyond NTT infrastructure facilities in businesses throughout the social infrastructure.

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Wireless Systems Technologies for Present and Future Services

Takeshi Onizawa

Abstract

The NTT Group provides a wide variety of services to its customers, and wireless technologies have an important role in supporting these services. Various methods of using wireless services are provided according to the characteristics of the frequency bands. This article introduces research and development directions in wireless technologies for supporting wireless services in the very high frequency (VHF), ultra-high frequency (UHF), microwave, and millimeter-wave bands. We also discuss the current state and future expansion of satellite communications and wireless local area networks (LANs).

Keywords: VHF/UHF/microwave/millimeter-wave bands, satellite communications, wireless LAN

1. Introduction

Needs and usage scenarios for wireless communication systems as a communications infrastructure continue to expand. In particular, traffic generated by mobile communications is increasing due to the widespread use of smartphones and tablet terminals. The development of wireless services and their spread is shown in **Fig. 1**. Past wireless services focused on telephone services such as subscriber systems and relay systems. This was followed by wireless services being more integrated into daily life as diverse wireless systems were developed and deployed independently such as cellular systems, satellite systems, and wireless local area networks (LANs). In the near future, we can expect the linking and fusing of these wireless systems. Current wireless systems will be enhanced by using a wide range of frequencies from low-frequency bands to high-frequency bands, i.e., from very high frequency (VHF) bands to millimeter-wave bands, by using new systems applying low-earth-orbit (LEO) satellite and radio-over-fiber (RoF) technologies, and by fusing these current wireless systems with high-density wireless LANs. To meet high expectations for these wireless services, NTT Access Network Service Systems Laboratories is researching and developing methods of exploiting the advantages of these systems. These wireless systems enable a highly convenient world in which all manner of things are connected through wireless technologies.

At the same time, our research and development (R&D) efforts have been focused on anti-disaster measures since the Great East Japan Earthquake of 2011. These include studies of wireless systems for dealing with disasters by quickly restoring and constructing the communications infrastructure after a wide-area disaster, which could greatly impact customers. We have been upgrading and enhancing various types of wireless systems for conventional anti-disaster systems and for the revised spurious-emissions standard.

To achieve even higher transmission speeds in the face of expanding usage scenarios for wireless communication systems, recent studies considered technologies for using even higher frequencies in the millimeter-wave band. One of these studies focused on the rapid traffic increase in urban areas. This study

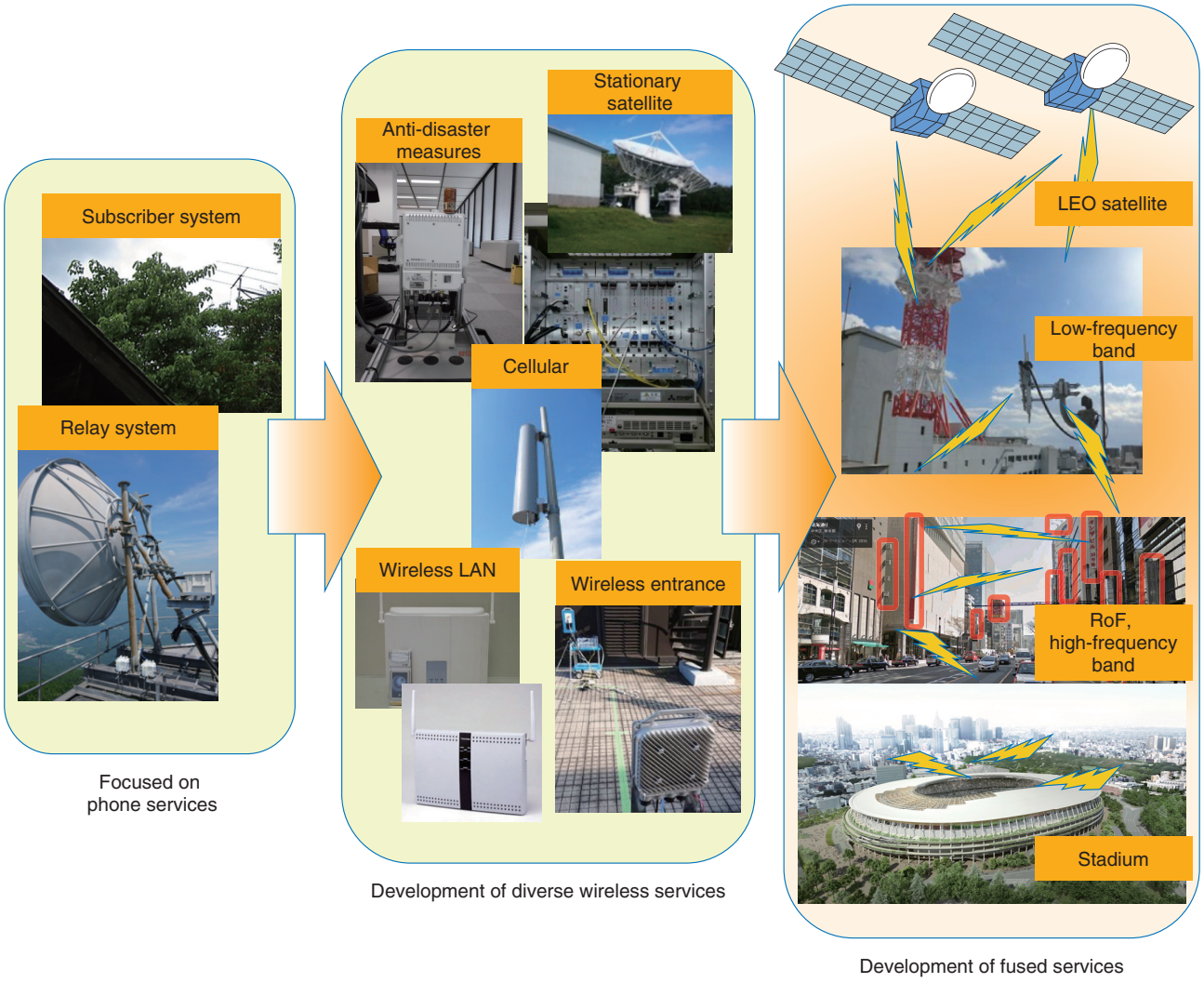


Fig. 1. Development of wireless services and their spread.

aimed at applying millimeter-waves to wireless entrance systems connected to remote base stations for small cells, large numbers of which will likely to be necessary in the future. Connecting wireless entrance systems to small-cell remote base stations in place of optical fibers will enable flexible base-station-deployment design. We are studying high-frequency-band analog RoF technology for softwarizing wireless transmit/receive functions for wireless central base stations. This study is proceeding in the direction of minimizing power consumption of remote base stations and inheriting the advantages of cellular stations such as compact and low-power characteristics.

Attention has also been on satellite communication systems in the wake of the Great East Japan Earthquake because of their inherent features such as wide-area and immediate communications. However, conventional satellite communication systems at that time suffered from old equipment and obsolete operational maintenance procedures. This led to the development of high-efficiency signal-processing equipment for disaster control and earth stations on remote islands where the laying of optical fiber is difficult. The grouping of this equipment into systems has also progressed. There have also been recent studies on

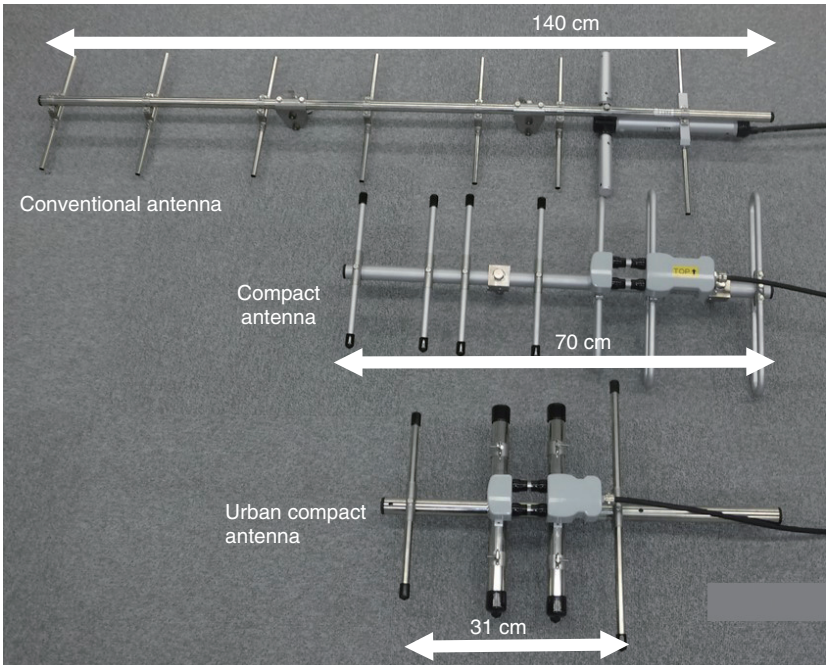


Fig. 2. UHF anti-disaster measures and downsized antenna.

applying LEO satellites to satellite communication systems to explore their use in future communications.

Wireless LANs are also making great progress beyond their conventional role of being just a means of communications in unlicensed bands. It is becoming a system that can significantly expand the reach of users. Therefore, various rich services, i.e., those that have high-efficiency and high-density performances, are being provided through the current and further development of wireless LANs.

In the following sections, we introduce our current R&D directions in these wireless technologies.

2. VHF/UHF /microwave-band wireless systems

We first introduce our R&D activities using the VHF, ultra-high frequency (UHF), and microwave bands. We describe anti-disaster systems using the UHF band for wide-area disasters that have attracted interest following the Great East Japan Earthquake. We used these systems including a microwave band system for the torrential rain that fell over western Japan in July 2018.

The NTT Group considers the construction of a network robust against disasters and the means of providing early restoration after a disaster as critical issues. Our wireless communication systems for anti-disaster measures are advantageous in terms of equipment mobility and early restoration. However, the problems of aging facilities and a lack of personnel with specialized skills are only becoming worse. Thus, the need has arisen for upgrading facilities and improving their operability and maintainability. Based on this background, we developed an anti-disaster wireless communication system with a range of several tens of kilometers using the UHF band. From lessons learned from the Great East Japan Earthquake, this system was also designed to provide a point to multi-point communication configuration, which can consist of multiple wireless terminal stations and a single wireless base station. It was also developed under a variety of requirements such as the provision of Internet-connection functions in addition to special public telephones and the capability to deal with wide-area disasters brought on by mammoth earthquakes and tsunamis. We improved the mobility and operability/maintainability of equipment such as through compact and lightweight designs. We developed in parallel with this system a compact antenna using a phased array method with a total length one-half that of conventional antennas as well as an even smaller antenna for urban use (**Fig. 2**).

Examples of UHF and microwave band systems

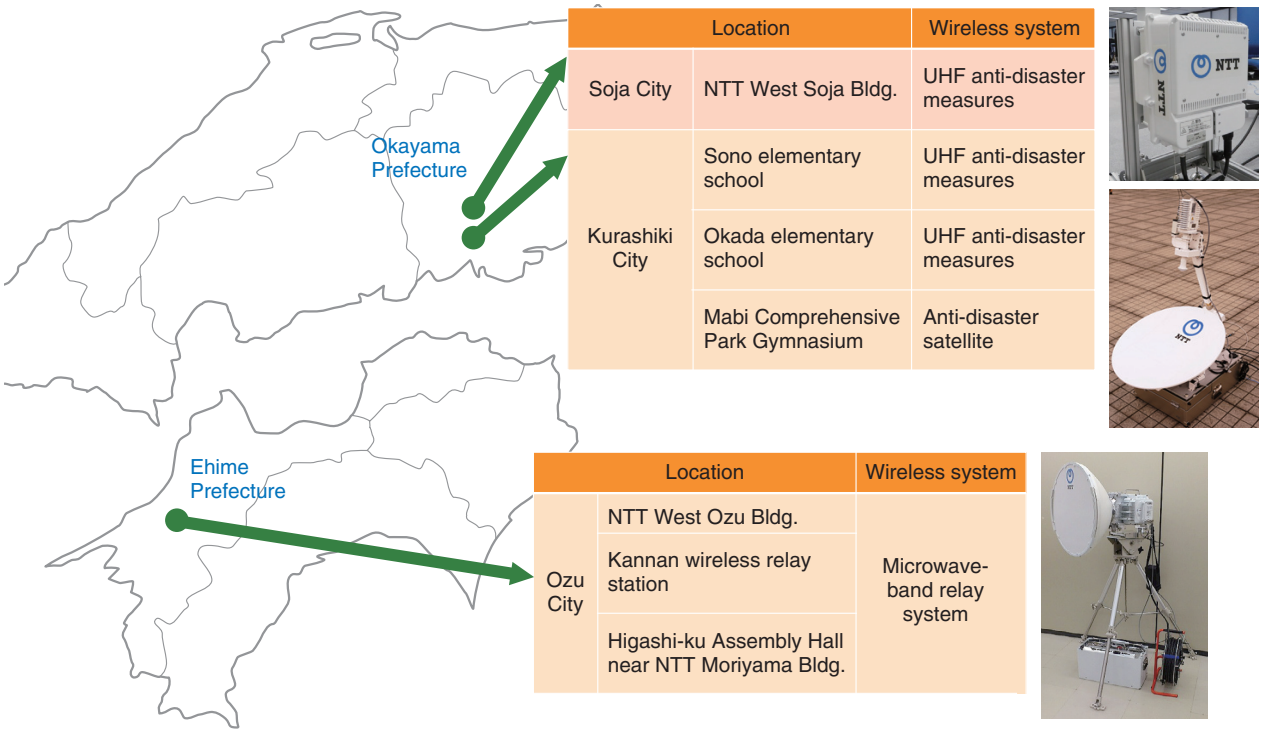


Fig. 3. Examples of wireless systems used during torrential rain in western Japan.

used in response to the torrential rains in western Japan are shown in **Fig. 3**. Specifically, UHF anti-disaster systems were used in Okayama Prefecture, and a microwave-band relay system was used in Ehime Prefecture.

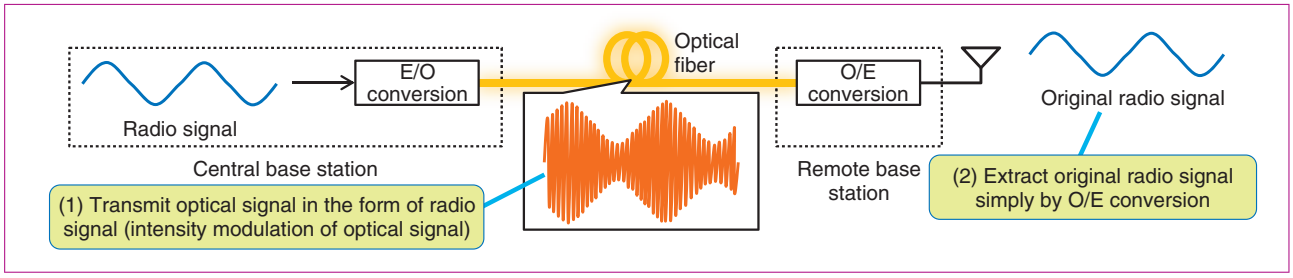
From the viewpoint of applying the VHF band to regions where wired equipment is difficult to install, such as national parks and super-rural areas outside mobile-phone coverage, the effects of long-delay waves must be clarified considering the need for long-distance signal propagation. For this reason, we are conducting basic studies on signal propagation by performing actual signal-propagation measurements to formulate a radio propagation model. We are also clarifying the feasibility of applying multiple-input multiple-output (MIMO) transmission technology to single-carrier systems in VHF band systems.

3. Millimeter-wave band wireless systems

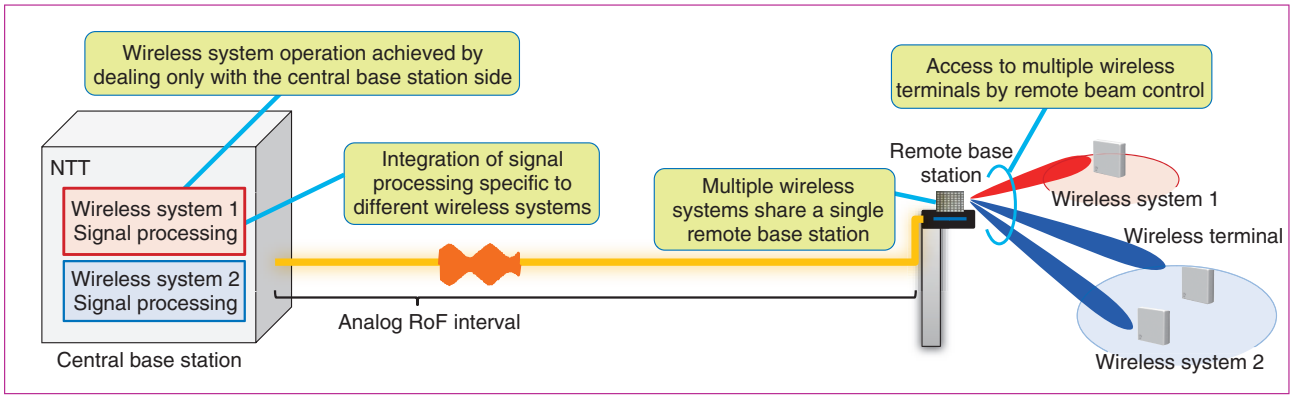
In this section, we introduce studies using the millimeter-wave band as an approach to using high-frequency bands. In particular, we describe wireless entrance technology and RoF technology as countermeasures to rising volumes of traffic in urban areas. Optical fibers are commonly used when connecting many small-cell remote base stations. However, it is expected that an even greater number of small-cell remote base stations will be used in the future, suggesting that wide-band and high-frequency wireless entrance technologies will become essential. We can expect efficient construction of the front-haul section through flexible use of wireless entrance technologies in combination with optical fibers. Therefore, we experimentally verified the performance of a wireless-entrance approach using millimeter waves. Assuming a front-haul interface based on a function assignment between a central base station and remote base stations and a transmission speed within 10 Gbit/s, we evaluated wireless transmission performance intervals of 20 and 50 m. The experimental results indicated that no major degradation in transmission performance could be found compared with using optical fibers.

R&D is also progressing in wireless systems using high-frequency-band analog RoF for directly converting millimeter-wave radio signals to optical signals for transmission through optical fibers. High-frequency-band analog RoF technology uses radio-signal-processing in a central base station and connects

(a) Analog RoF technology



(b) Function assignment between central base station and remote base station through analog RoF



E/O: electrical to optical
O/E: optical to electrical

Fig. 4. Wireless communication system using RoF.

antennas to a remote base station via optical fiber (**Fig. 4**). With this scheme, we can expect the remote-base-station side to take on a simplified and low-power configuration. When many remote base stations come to be deployed in the future, this scheme will make it possible to achieve remote beam control by implementing beam forming technology, which is essential to millimeter waves, only in central base stations. These millimeter-wave technologies are being investigated and developed for application in the beyond 5G (fifth-generation mobile communications) era.

4. Satellite communications

We now describe our R&D of satellite communication systems. In the aftermath of the Great East Japan Earthquake, attention turned to the distinctive features of satellite communication systems such as wide-area and immediate communications. Therefore, we developed high-efficiency signal-processing equipment for earth stations applicable to remote islands and anti-disaster approaches. Satellite communications are in the midst of a great transformation on a global scale. We are investigating the application of communications not only to stationary satellites used in conventional communication systems but also to LEO satellites. To explore the expansion of satellite communications, we are studying a MIMO transmission technique for applying MIMO technology to LEO satellite systems. A model of MIMO transmission using a LEO satellite is shown in **Fig. 5**. The basic results of this study indicate that transmission capacity can be increased when using multiple antennas on a LEO satellite to achieve large-capacity performance for downlinks. We intend to continue our R&D efforts in this area to find new uses of space.

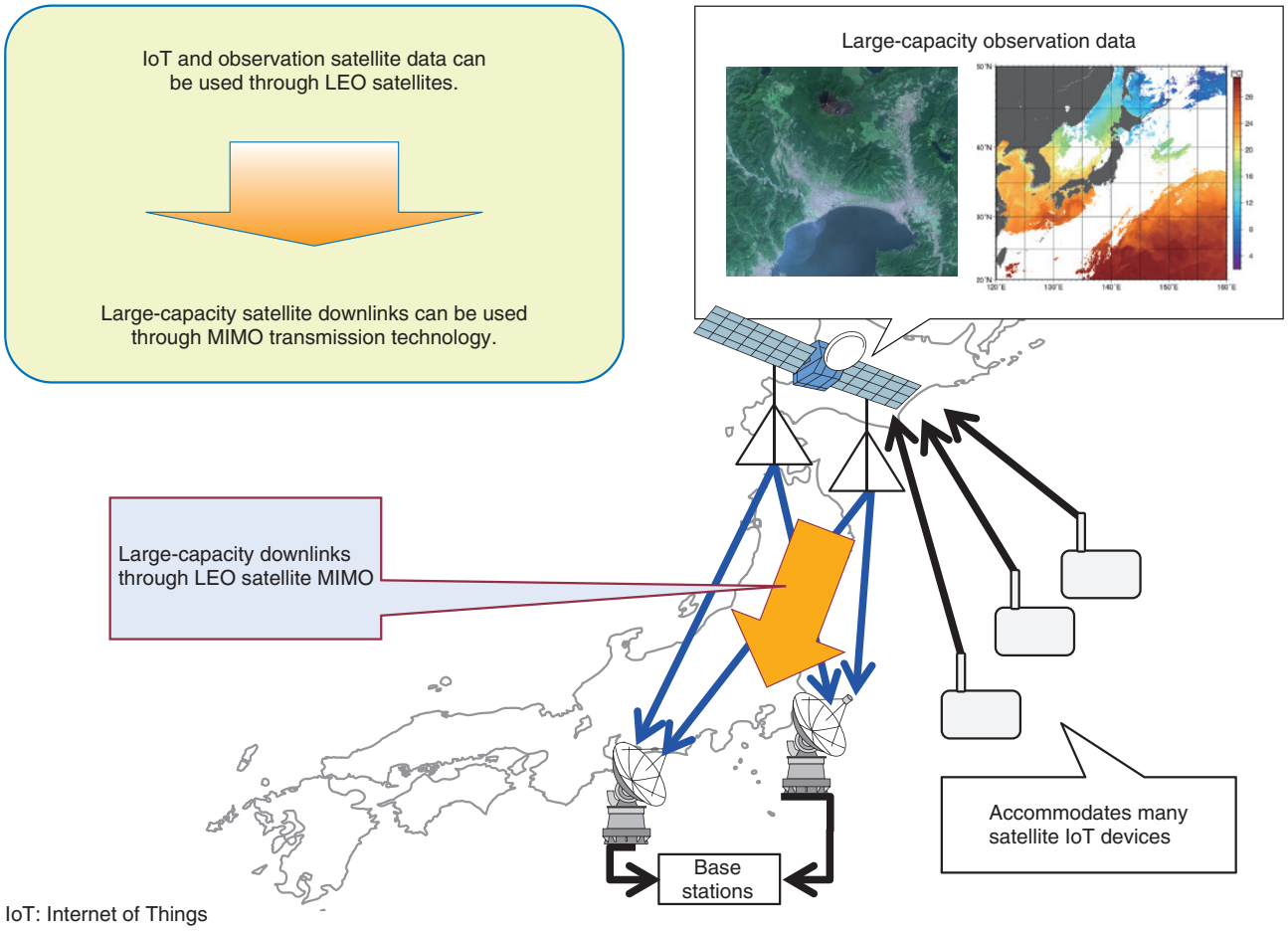


Fig. 5. LEO satellite MIMO transmission.

5. Wireless LANs

In this section, we describe recent R&D activities focusing on wireless LANs. While participating in the IEEE 802.11 committee and a variety of organizations such as the Association of Radio Industries and Business (ARIB), we have been promoting R&D of wireless LANs not only in terms of technology but also of standardization and regulations. Wireless LANs are dramatically advancing not only as means of communications, as in conventional LANs using unlicensed bands, but also in regards to usage scenarios. A wireless LAN is a system that greatly extends the user's reach. In addition to advanced specifications such as high-quality, large-capacity, and low-latency transmission, wireless LANs are contributing to a variety of services through new deployments in non-communication areas such as positioning, visualization of radio quality, and object detection by radio waves. Recent verifications involving crowds of around 10,000 people at large stadiums or exhibit halls have demonstrated the huge potential of all-member new-experience-type events, which use a large-scale Wi-Fi network environment to enable a simultaneous content-sharing experience.

6. Future outlook

For future study, we plan to continue our R&D activities to provide our customers with wireless services, which are all the more convenient, while supporting a wide variety of existing wireless services.

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He received a B.E., M.E., and Ph.D. from Saitama University in 1993, 1995, and 2003. Since joining NTT in 1995, he has been engaged in the R&D of personal communication systems and high data rate wireless LAN systems, future wireless access systems and radio propagation. He is now in charge of management strategies of wireless communication systems. He received the Best Paper Award, Young Investigators Award, and Achievement Award from the Institute of Electronics, Information and Communication Engineers (IEICE) in 2000, 2002, and 2006, respectively. He received the Maejima Hisoka Award in 2008. He also received the Best Paper Award in International Symposium on Antennas and Propagation (ISAP) in 2016. He is a senior member of IEICE and a member of the Institute of Electrical and Electronics Engineers (IEEE).

Compact Silica-based 16 × 16 Multicast Switch with Surface Mount Technology for PLCs

Ai Yanagihara, Keita Yamaguchi, Takashi Goh, and Kenya Suzuki

Abstract

We propose an electrical interconnection structure in which electrical connectors are directly soldered on a silica-based planar lightwave circuit using surface mount technology. A compact 16 × 16 multicast switch (MCS) having five electrical connectors was successfully demonstrated. We reduced the chip size to half that made with conventional wire bonding technology. We obtained satisfactory solder contacts and excellent switching properties. These results indicate that the proposed structure is suitable for large-scale optical switches including MCSs, variable optical attenuators, and dispersion compensators.

Keywords: optical switch, planar lightwave circuit (PLC), surface mount technology (SMT)

1. Introduction

Optical network automation is useful for accommodating increases in mobile and/or datacenter traffic and network restoration after serious disasters. In mobile and datacenter applications, hot and cold spots appear in different areas of networks at different times, which results in poor network resource utilization. Additional bandwidth or link assignments to hot spots will contribute to improving resource utilization, leading to a reduction in the capital expenditure for additional investment. Rapid network restoration after disasters is also required. Optical links should be changed from dead paths to live ones as fast as possible. Network automation is achieved by software-defined networking and reconfigurable optical add/drop multiplexing (ROADM) with colorless, directionless, and contentionless (CDC) functions. Multicast switches (MCSs) are enablers for the CDC-ROADM system [1–3]. Large-scale MCSs, such as those with 16 degree ports and 16 transponder ports, are important for handling a large number of signals to make the network more flexible.

Silica-based planar lightwave circuits (PLCs) are suitable for large-scale optical switches because they have many advantages, such as low propagation loss, high extinction ratio, and facilitation of density integration [4–6]. M-degree ports and N-transponder ports (M × N) MCSs are composed of M × N switch elements. Each switch element consists of Mach-Zehnder interferometers (MZIs), which are driven by a heater on one of its arms through the thermo-optic effect [7]. To supply the switching power to heaters from a driving circuit on a printed circuit board (PCB), the switch elements are equipped with electrical wires and electrical pads. Although we need to densely integrate switch elements to fabricate large-scale MCSs, the large area of the electrical wiring limits their number. Thus, we need to reduce the area of the electrical wiring to enable high-density integration of the switch elements. Several compact optical switches that overcome this problem have been reported. One uses the interposer for electrical interconnection [8]. This is suitable for silicon photonics but not appropriate for larger silica-based PLCs because such PLCs have a larger chip size and the difference in the thermal expansion coefficients between a PLC and the interposer cannot be ignored.

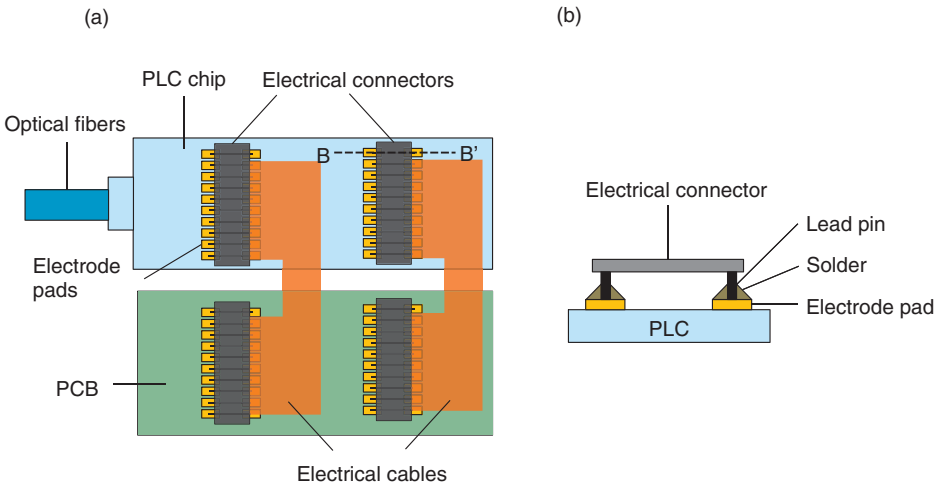

Fig. 1. (a) Top-view schematic of our proposed structure and (b) cross-sectional schematic of B-B' in (a).

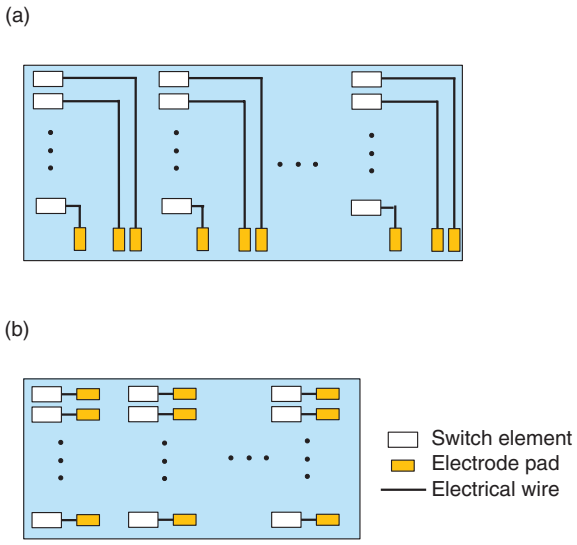

Fig. 2. Conventional (a) and proposed (b) structures of electrical wiring in the PLC chips of an M × N matrix or MCS.

In this article, we propose an electrical interconnection structure in which electrical connectors are directly mounted on a PLC using surface mount technology (SMT). We fabricated a 16 × 16 MCS with our proposed structure. The chip size of the PLC was successfully reduced to half that of a conventional chip using the bonding wire method. We obtained excellent switching performance.

2. Proposed structure

Figure 1(a) shows a top-view schematic of our proposed structure. The electrical connectors are directly mounted on the silica-based PLC chip. The lead pins of the electrical connectors are soldered to the electrode pads on the PLC surface, as shown in **Fig. 1(b)**, which is a cross-sectional view at B-B' in Fig. 1(a). The PLC and PCB are connected to each other with electrical cables, such as flexible print circuits (FPCs). **Figure 2** shows the designs of electrical

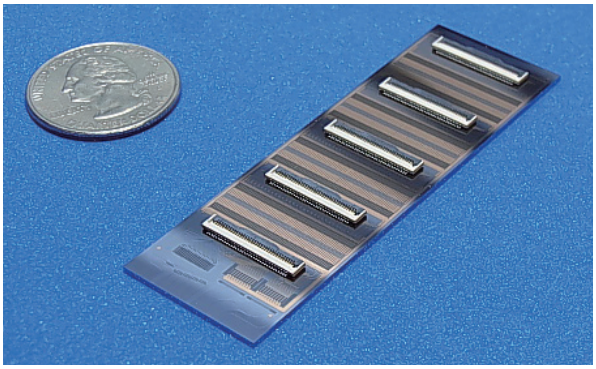

Fig. 3. Photograph of fabricated 16 × 16 MCS.

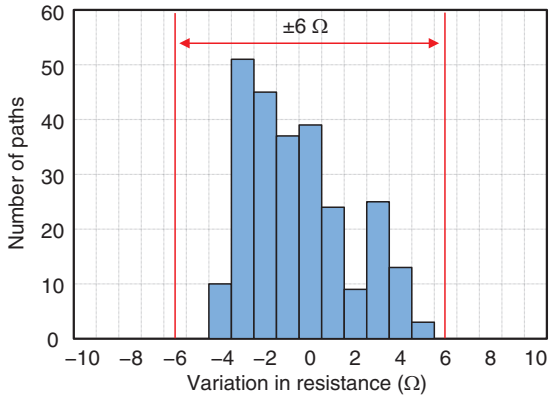

Fig. 4. Variation in measured resistance.

wiring in the PLC chips of an M × N matrix or MCS, which are for a conventional electrical connection structure and our proposed structure, respectively. Conventionally, as shown in Fig. 2(a), a PLC and PCB have been connected electrically using a general wire bonding method. Electrode pads are arranged on the edge of both the PLC and PCB to bond them with gold wire. In this design, long electrical wirings are arranged from each heater to each electrode pad on the edge of the PLC. Thus, the arrangement of the electrical wiring on the PLC becomes complicated and its area increases with the number of switch elements, which limits the miniaturization of the chip. On the other hand, the arrangement of electrical wiring with the proposed structure is simple, as shown in Fig. 2(b). As the electrode pads can be placed near the switch elements, the length of electrical wiring can be shortened. Therefore, this structure enables us to reduce the area of the electrical wiring and integrate the switch elements more densely. The proposed structure also offers advantages such as automatic fabrication because the electrical connectors can be mounted on the PLC using general SMT widely used in the assembly of electrical devices. The proposed structure also makes it possible to mount the connectors automatically at the wafer level, making it suitable for mass production.

3. Experiment

3.1 Fabrication

Figure 3 shows a photograph of the 16 × 16 MCS chip with the proposed structure. The chip was fabricated using the conventional silica-based PLC fabrication process. The 256 switch elements, consisting of MZIs and heaters, are regularly arranged in the PLC, and each heater is connected to the electrode pad with electrical wires. The electrical wires are shorter than those in a conventional PLC switch with wire bonding because the electrode pads are placed near the switch elements. Therefore, the area of the electrical wiring in the chip is greatly reduced. The chip size is 23.5 × 72 mm. We estimated that it is two times smaller than a conventional 16 × 16 MCS with wire bonding. After PLC fabrication, five electrical connectors are mounted on the PLC chip with solder using SMT at the 6-inch wafer level. After AgSnCu (Ag: silver, Sn: tin, Cu: copper) solder paste has been patterned on the electrode pads by screen printing, the electrical connectors are mounted and soldered by the standard reflow process. As there are 256 heaters in the 16 × 16 MCS chip, we mount five electrical connectors on it. Since general electrical connectors have approximately 50 to 80 pins, we can construct a large-scale MCS by increasing the number of mounting electrical connectors. Therefore, our structure is scalable for constructing much larger MCSs.

3.2 Electrical characteristics

We measured the resistance of the 256 switch elements by connecting the PLC and PCB with an FPC, as shown in Fig. 1(a). **Figure 4** shows the variation in the average resistance of the 256 heaters. This variation includes the variation in the heaters, electrical wires on the PLC, soldered connection parts between the electrode pads in the PLC and PCB and the lead pins of the electrical connectors, and the contacts between the FPC and electrical connectors. The variation in the average resistance was less than ±5 Ω and 3σ (σ: standard deviation) was 6.8 Ω. In our switch module, the variation needs to be less than ±6

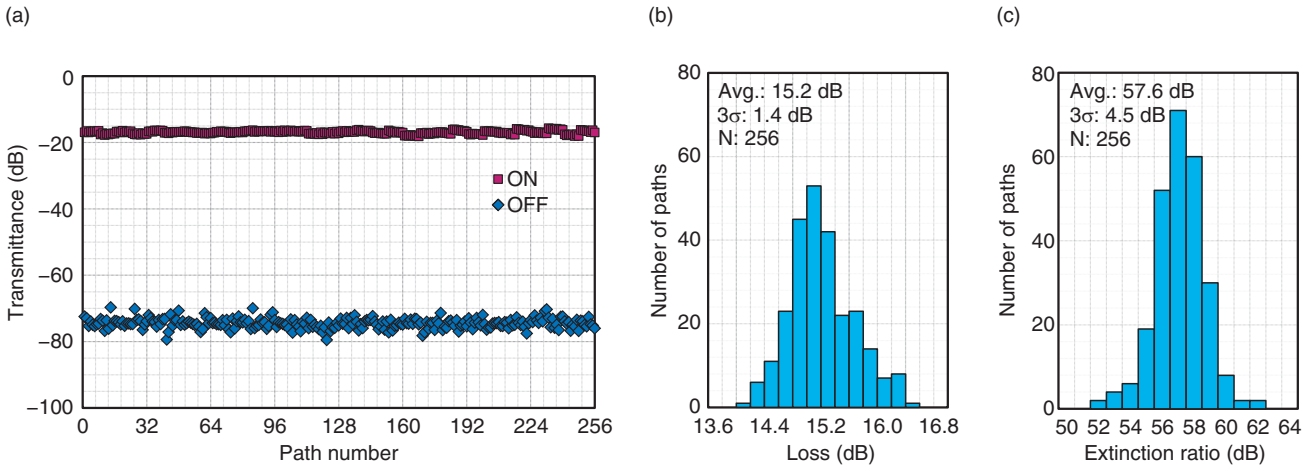

Fig. 5. (a) On-state and off-state transmittance for all 256 paths, and histograms of (b) insertion loss and (c) extinction ratios.

Ω to satisfy the need to keep the variation in insertion loss of all switch elements within ±0.1 dB. Thus, this result indicates that satisfactory connections were obtained for all soldered parts. We estimate that this variation in the resistance resulted in the variation in the length of the electrical wires. Thus, this variation in switch resistances can be reduced by changing the width or length of the electrical wires.

3.3 Optical characteristics

We evaluated the switching characteristics of all 256 connections from 16 degree ports to 16 transponder ports at the wavelength of 1550 nm. By measuring transmission changes with electric power applied to the heater, we obtained clear switching characteristics for all 256 paths. **Figure 5(a)** shows the measured on- and off-state transmittance for all 256 paths. The average switching power per switch element was 0.24 mW. It was clearly observed that all the paths operated correctly, proving that our proposed structure works well. **Figures 5(b)** and **(c)** show a histogram of the insertion loss and extinction ratios for all 256 paths. The average insertion loss and standard variation were 15.2 and 1.0 dB, respectively. The insertion loss includes intrinsic loss of 12 dB. Thus, the excess loss is as small as 3.0 dB on average. The average and variation in the extinction ratio were 53 and ±5 dB, respectively. As described above, all the paths operated correctly, proving that the proposed structure works well.

4. Conclusion

We demonstrated a compact 16 × 16 MCS using our new electrical interconnection structure based on SMT. Five connectors are soldered directly to the PLC by the standard reflow process used for electric devices. We successfully reduced the chip size to 23.5 × 72 mm, which is two times smaller than a conventional chip with wire bonding. We obtained satisfactory solder contacts and excellent switching properties. These results indicate that our proposed structure is suitable for large-scale MCSs and this new electrical interconnection method with SMT can be applied to other silica-based PLC devices.

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Activities of the APT/TTC Bridging the Standardization Gap Working Group—Holding of Ideathons in Cooperation with Universities in Southeast Asia

Hideyuki Iwata

Abstract

The Bridging the Standardization Gap (BSG) Working Group of the Telecommunication Technology Committee (TTC) of Japan has been implementing and promoting the spread of information-and-communication-technology-based solutions to address social issues in rural areas of Asian countries with support provided by the Asia-Pacific Telecommunity (APT). It has launched a platform designed to share data obtained at pilot sites in a number of countries, related to several fields including agriculture, fisheries, the environment, medical care, education, and disaster prevention. It held events at which ideas were proposed on how to create new industries through the utilization of data across different industries. This article presents an overview of these events.

Keywords: TTC, BSG, APT, ideathon

1. First ideathon

The first ideathon was held at the University of Malaysia Sarawak in Kuching, Malaysia, on December 5 and 6, 2018.

1.1 oneM2M Workshop (pre-ideathon workshop)

On November 28, before the ideathon was held, a lecturer from the University College of Technology Sarawak in Malaysia, held a workshop for 70 students at the University of Malaysia Sarawak. He gave an overview of oneM2M*, demonstrated how to set up a oneM2M-compliant server and connect Internet of Things (IoT) devices to this server.

1.2 Ideathon@Malaysia

This ideathon was held over two days and was attended by 76 students in 20 teams from the University of Malaysia Sarawak, and University College of Technology Sarawak (**Photo 1**). The teams were then further divided into three groups and gave presentations and demonstrations in each group. The top team in each group gave additional presentations in the plenary session, then the teams were ranked.

The titles of proposals and the areas targeted by the participating teams are shown in **Table 1**.

Since Kuching is a provincial city in Borneo, there were few proposals addressing the problem of traffic congestion. The most common topics were disaster-response solutions to floods and forest fires and medical issues, including problems with water quality.

* oneM2M: A global organization that was established in 2012 by major standards development organizations aiming at developing the requirements and specifications for machine-to-machine (M2M) and IoT technologies.

Photo 1. Scene from the awards ceremony at Ideathon@Malaysia.

Table 1. Titles of proposals and target areas at Ideathon@Malaysia.

No.	Title of proposal	Area	Group	Award
1	Smart Indoor Hydroponic Planting	e-Agriculture	QBF Ultimate	
2	Smart Shopping System	Smart city	4896	
3	IoT-based Water Quality Buoy Using oneM2M	e-Environment	Morphling	
4	Smart Badminton Stadium with Automatic Lighting System	Smart city	Keeper of the Light	
5	Health-monitoring System Using Motion and Pulse Sensor	Smart city	DGB	
6	Parking Slot Availability Indicator	Smart city	Smart Park	
7	Forest-fire Detector	e-Disaster	G-TECHNOVATORS	
8	Drainage-system Sensors for Flood Prediction	e-Disaster management	IDealTech	
9	Flood Detection with Rain Sensor	Disaster	SMART LRB	1st Prize
10	Narcolepsy Life Saver	e-Health	MedIT.com	
11	Water-pollution Detection System	e-Health	Mind Bender	
12	Vehicle RFID	Smart city	EE Prodigy	
13	Smart Greenhouse	e-Agriculture	iGreen	
14	JAMS: Just Another Metering System	Smart city	TheBitJunkeys	2nd Prize
15	Rainwater-collection System to Reduce Floods	e-Traffic, disaster	Alpha Minds	
16	iWater Cleaner	e-Environment	Fantastic Four	
17	Smart Waste-management System	Smart city	HOTS	
18	A+I: Mood-detecting Sensor	Smart city	LOTS	
19	Forest-fire Detection Using ATIS	e-Agriculture	ZIPs	
20	Life-saving System: e-Health, e-Traffic Management, Smart City	Health, transportation, smart city	Sffic	3rd Prize

2. Second ideathon

The second ideathon took place at Ateneo de Manila University, Manila, the Philippines, on March 6–8, 2019.

2.1 Technical Specifications Workshop

On March 5, the day before the ideathon was held, Dr. Daniel of Ateneo de Manila University explained and demonstrated to 26 students how to connect oneM2M-compliant IoT devices to a oneM2M-compliant server.

Photo 2. Scene from Ideathon@Philippines.

Table 2. Titles of proposals, target areas, and awards at Ideathon@Philippines.

No.	Title of proposal	Area	Group	Preliminary award
1	Potential of Smartphones in Disaster and Emergency Situations	Disaster	TriLocate	
2	Smart Analytics and Early-warning System that Forecasts Future Red Tide and Fish Kill Incidents	Aqua culture, disaster	Red Alert!	Round 2 /3rd Prize
3	Fastest Route Cleared Smart Traffic-light Control System to Emergency Vehicle Driver	Smart city, medicine	Lifeline	
4	Provide Commuters with Accurate Estimates of Wait Times and Optimization of Train Use	Smart city, transportation	Moving Stations	
5	Redistribute Foot Traffic to Save Time and Resources	Smart city	BOMS	Round 2
6	Food-supply Monitoring and Tracking System	Agriculture, health, logistics	Food Enthusiasts	Round 2 /1st Prize
7	Real-time City-wide Pedestrian Traffic Monitoring and Mapping System	Disaster, smart city	Fast Pass	Round 2
8	Improve Security, Portability, and Overall Efficiency of Medical Procedures	Smart city, health	MED ID	Round 2 /2nd Prize
9	Monitor Pollen and Dust Distribution	Smart city, health	polleNATION	
10	Provide New Innovative Sets of Data Concerning Human Activities within Homes	Smart home	Home Vita	
11	Monitor Trash in Drainages	Disaster	Image Pulse	Round 2
12	Patient-monitoring System	Health	MonitAir	
13	Solve Problems of Environmental Pollution through Smart Trash Collection	Smart city	Waste Watch	
14	Monitor Health and Status of Its Users Using Smart Watch	Smart city	Ligaw	Round 2
15	Intersection Data Collection and Processing System to Solve Traffic Problem	Smart city	IDCPS	
16	Track-energy Consumption by Providing Real-time, Aggregate and Pre-appliance Data and Heuristics	Smart home, energy	Smartr	

2.2 Ideathon@Philippines

Before the final ideathon (Round 2), an elimination round (Round 1) was held at Ateneo de Manila University with 34 students in 16 teams from the university, and 7 teams were selected (**Photo 2**). The final ideathon (Round 2) was held with judges from Japan, Malaysia, and the Philippines.

The titles of proposals, target areas of the participating teams, and awards presented at Ideathon@Philippines are shown in **Table 2**.

Photo 3. Scene from the awards ceremony at Ideathon@Indonesia.

Since this region is prone to natural disasters, many proposals addressed disaster-related issues and issues related to a shortage of medical facilities and institutions. Also, many of the proposed solutions required the involvement of the entire city.

3. Third ideathon

The third ideathon was convened at the Bandung Institute of Technology, Bandung, Indonesia, on November 8–9, 2019.

Three people from the Telecommunication Technology Committee (TTC) Bridging the Standardization Gap (BSG) Working Group, two from Malaysia, and two from the Philippines participated in and supported the event. Twenty faculty members and students from the Bandung Institute of Technology also assisted.

3.1 Workshop on oneM2M

Vice-Chair Kazunori Tanikawa of the TTC BSG Working Group gave an overview of oneM2M to enable the participants to use the internationally standardized platform for providing information and communication technology (ICT) solutions. Also, the University College of Technology Sarawak handed out oneM2M-compliant IoT tool kits and gave a tutorial on how to connect them to a oneM2M-compliant server.

3.2 Ideathon@Indonesia

This ideathon was attended by 57 people in 19 teams. Before the final ideathon (Round 2), an elimination round (Round 1) was held by the local operating organization, and 10 of the 19 teams were selected. Six people from the TTC BSG Working Group and two from the local operating organization were judges and evaluated the presentations (**Photo 3**).

The titles of proposals, target areas of the participating teams, and awards given by Ideathon@Indonesia are shown in **Table 3**.

The theme of many presentations was how to resolve traffic congestion, which is a common social issue in Asian cities. In addition, since Indonesia is studying how to transfer the capital from Jakarta to Kalimantan (Indonesian part of Borneo), there was a proposal on how to control peatland fires, a problem affecting Kalimantan.

4. Future prospects

In planning ideathons, we hoped to see proposals aimed at creating new industries by combining data across different industries. However, most proposals presented in these ideathons were related to solving impending social issues with ICT. Since our prior explanation seems to have been insufficient, it will be necessary to clarify the themes we would like participants to address in upcoming events. We plan to hold ideathons in other countries in the Asia-Pacific region and aim to expand these activities so that they will become common events in Asia.

Cultivation of human resources skilled in ICT is essential if we are to make regional economies thrive. Together with universities in Japan, we will contribute to this initiative through these activities.

Table 3. Titles of proposals, target areas, and awards given by Ideathon@Indonesia.

No.	Title of proposal	Area	Preliminary	Award
1	Independent Household Waste Processing and Online-based Waste Management	Environment		
2	E-MONEY with Tracking System in Toll Roads	Safety, transportation		
3	Peatland Humidity-control System for Forest-fire Handling	Environment	Round 2	
4	Firetruck Routing System	Transportation, safety	Round 2	
5	Coal Mining Supervision for Borneo 2025	Safety, efficiency, mining industry		
6	Smart Zebra Cross	Smart cities, road safety, IoT	Round 2	1st Prize
7	Smart Electricity	Smart cities	Round 2	
8	Integrated Waste-quality-monitoring System for Borneo: Integrating the Eco-friendly Trash Can and GoTrash Application	Environment, health, smart cities	Round 2	3rd Prize
9	WeHelp: Disaster-management App	Safety	Round 2	2nd Prize
10	Smart Traffic Light Using IoT and Cloud Computing for Protanopia	Smart city, cloud computing, IoT		
11	Borneo in 2025 Be a Smart City in Public Transportation	Smart city, transportation		
12	Traffic Control and Monitoring	Transportation		
13	E-Commerce for Fisherman	E-Commerce		
14	Kalimantan (Borneo) Smart-city Car Limiter 2025	Traffic, environment, health		
15	UAV Swarming Usage to Conserve Borneo's Forest	Environment	Round 2	
16	Waste Management	Environment		
17	Integrated Household Photovoltaic in a Smart City for New Capital Issue	Smart city, green energy	Round 2	
18	Crowd Estimation for Smart Transportation	Smart city, transportation	Round 2	
19	Smart Building	Smart city	Round 2	

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He has been a delegate of the International Electrotechnical Commission (IEC) Subcommittee 86A (optical fiber and cable) since 1998 and of the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Telecommunication Standardization Advisory Group (TSAG) since 2003. He is a vice-chair of the Working Group on Policy and Strategic Coordination and the Expert Group on Bridging the Standardization Gap in the Asia-Pacific Telecommunity Standardization Program (ASTAP). He received an award from the IEC Activities Promotion Committee of Japan in 2004, the ITU Association of Japan (ITU-AJ) International Activity Encouragement Award in 2005, an ITU-AJ International Cooperation Award in 2012, an award for contributions to an ICT development project at the APT ICT Ministerial Meeting in 2014, the ITU-AJ Accomplishment Award in 2018, and TTC Chairman's Prize in 2019.

Troubleshooting Facsimile Communication by Analyzing IP and POTS Protocols

Technical Assistance and Support Center, NTT EAST

Abstract

This article presents an investigation on a problem in which a part of a fax image is blanked out using various measurement tools. This is the fifty-seventh article in a series on telecommunication technologies.

Keywords: fax, packet capture, key telephone system

1. Introduction

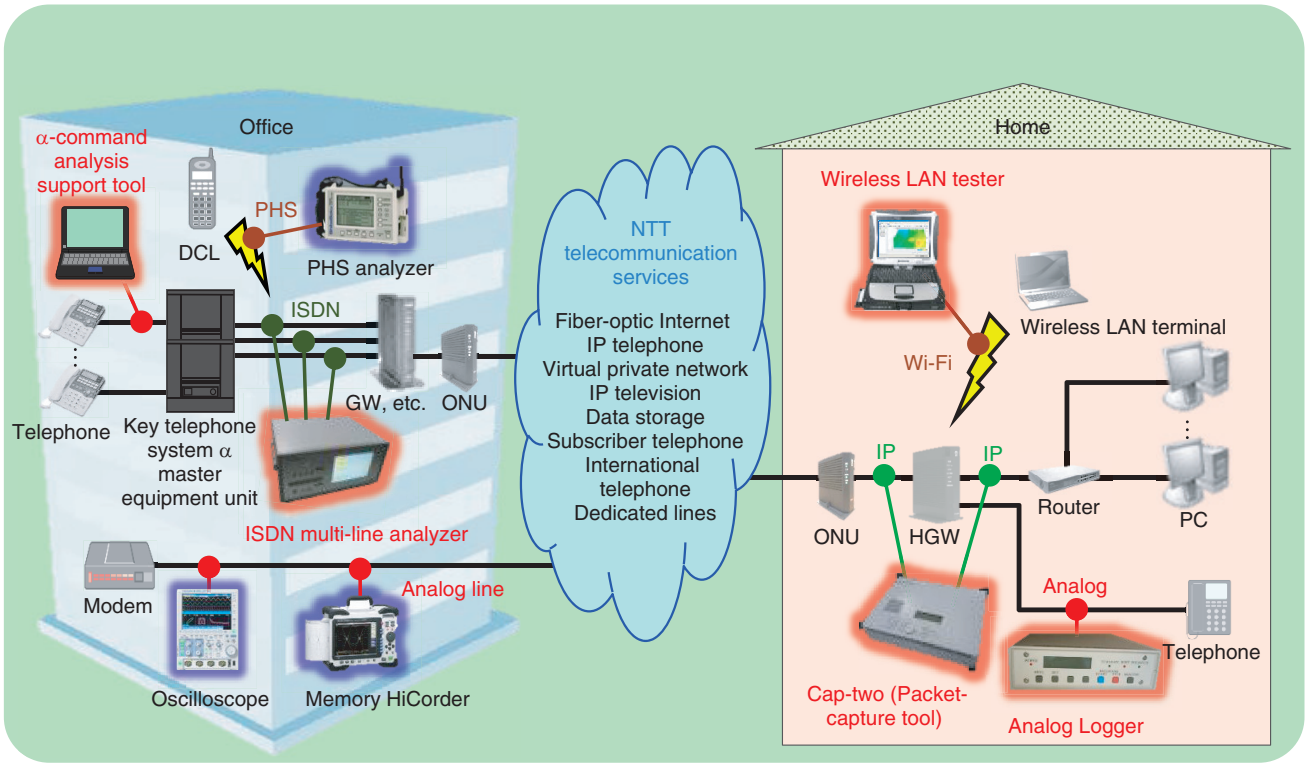
Along with the widespread use of fiber-optic broadband services, use of services and configurations of customer's network have become complicated. Thus, several problems have occurred due to setting mistakes or protocol failures. The Network Interface Engineering Group at the Technical Assistance and Support Center (TASC), NTT EAST, is in charge of technical support for Internet protocol (IP) services and public switched telephone network (PSTN) services such as plain old telephone services (POTS). Our mission is to quickly solve a problem in the field by finding the cause of the problem and suggesting appropriate measures to prevent such a problem for re-occurring.

To accomplish our mission, we developed and installed several tools for solving problems in our telecommunication services. For IP-related services, IP-packet capture and analysis tools are used to obtain IP packets in an IP section. For PSTN services, however, a signal-analysis method involving an oscilloscope, analog-waveform recorder (Memory HiCorder), and integrated services digital network (ISDN) protocol analyzer are used. In an investigation of terminals, especially for key telephone systems, we developed a signal-analysis tool for our key telephone system, i.e. α series key telephone system (**Fig. 1**).

In this article, we introduce a facsimile troubleshooting case in which a fax image is blanked out. First, we present the details of the problem then explain how to investigate it using our tools. Second, we present the results of analyzing the data obtained from these tools. Finally, we explain the cause of the problem derived from our investigation.

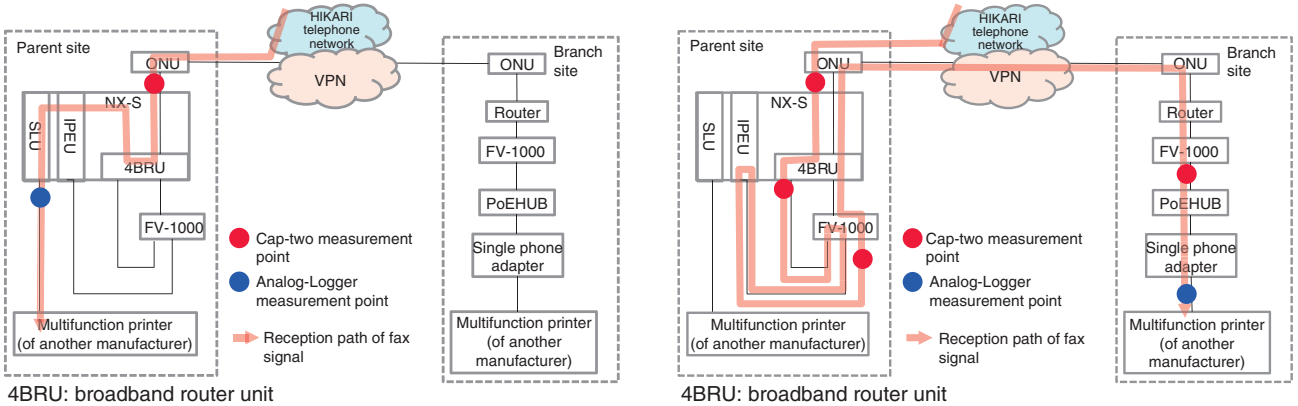
2. Summary of problem and investigation method

The configuration of the network in customer premises we investigated is shown in **Fig. 2**. The network had two parts, the parent office and branch site. These sites connected to each other with a virtual private network (VPN) service to extend the network, and each site connected to a HIKARI IP-telephone line to use public telephone services. A multifunction printer manufactured by another company was connected to each part and provided facsimile and printer functions. However, regardless of site location or line



DCL: digital cordless telephone
GW: gateway
HGW: home gateway
LAN: local area network
ONU: optical network unit
PC: personal computer
PHS: personal handy-phone system

Fig. 1. Effective maintenance-support tool for troubleshooting.



4BRU: broadband router unit
IPEU: IP extension unit
SLU: single phone-housing unit

(a) When receiving a call at the parent site

(b) When receiving a call at the branch site

Fig. 2. Configuration of customer network and measurement points.

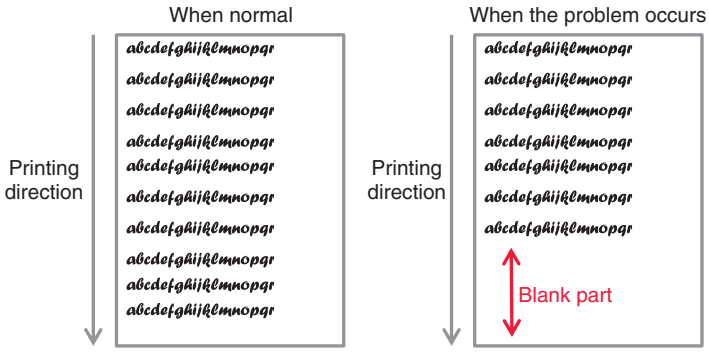


Fig. 3. Output of multifunction printer when a problem occurs.

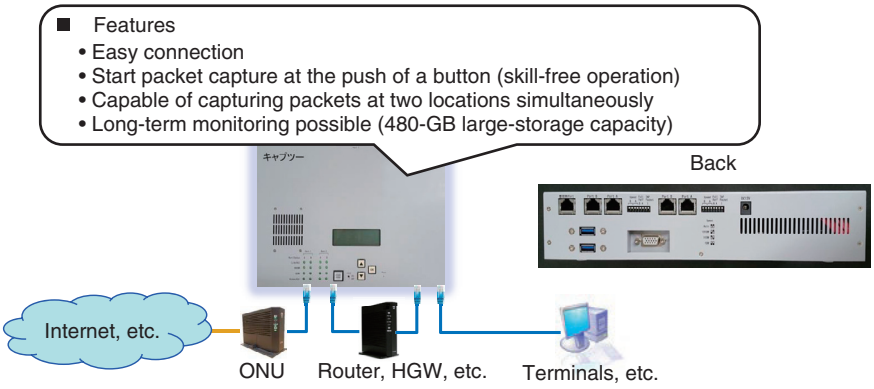


Fig. 4. Packet-capture tool Cap-two (developed by TASC).

used (internal or external), the received faxed image was sometimes partially blank, as shown in **Fig. 3**.

According to a declaration from the customer, the problem (i.e., a partially blank fax) occurred about once a week, and its cause could not be found out even though the manufacturer of the multifunction printer investigated it. Moreover, NTT had been confirming and changing the settings of the optical network unit (ONUs), key telephone system (αNX-typeS), and VPN-terminating equipment (FV-1000) connecting each site as well as replacing terminals, etc. However, the problem was not resolved, so we conducted an on-site investigation.

In the investigation, measurement tools (listed below) were installed along the receiving paths of the fax signal arriving by an external line to acquire and analyze IP packets and signals passing along each path. As a result, the fax communication was correct at each measurement point (Fig. 2). Since occurrence of the problem was rare, we decided to carry out long-term measurement by using our tools.

(1) Collection of IP packet data from network

For collecting IP-packet data from the customer's network, we used a packet-capture tool called Cap-two (**Fig. 4**), which is a dedicated device for easily collecting IP packet data without requiring any special skills.

(2) Collection of electrical signals (waveform data) from analog lines

To collect waveform data from analog lines, we set an analog-waveform recorder, called Analog Logger, on the analog telephone line. The features of the logger are shown in **Fig. 5**.

Analog Logger is a dedicated device for collecting electrical signals (waveform data) from analog lines. It has a registered jack (RJ) connector that can be easily inserted and connected to the analog line and can be used for automatic measurement without requiring any skills.

(3) Analysis of fax signals

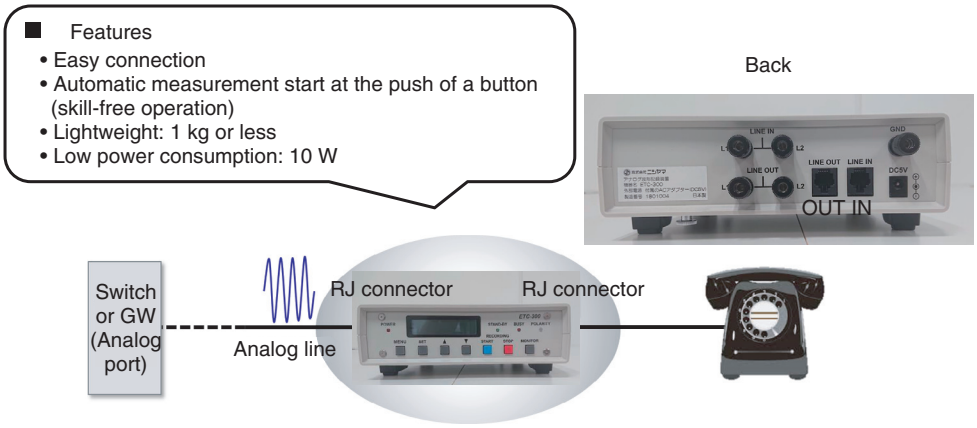


Fig. 5. Analog Logger (developed by TASC).

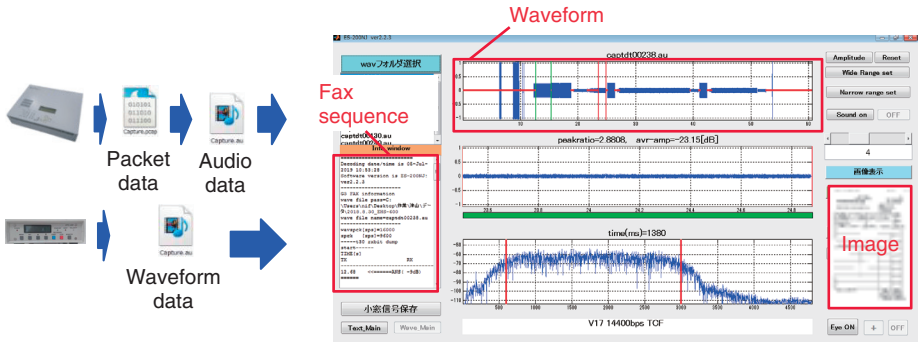


Fig. 6. Facsimile Communication Analyzer (commercial software).

The commercially available software Facsimile Communication Analyzer ES-200 (by Egretcom) was used to analyze the fax signals. This software can analyze a facsimile sequence and decode a facsimile image from audio files (wav files/au files) that record the facsimile signal in the line, as shown in **Fig. 6**.

We obtained two types of waveform data from the measurement. One is the data converted from IP packets obtained from the IP section, and the other is the data from the analog lines. By comparing these data using the software, we can evaluate the facsimile sequence and decoded facsimile image obtained from both IP and analog sections.

In this investigation, we sent the measurement tools (Cap-two and Analog Logger) to on-site service personnel, and these tools were installed and operated by those personnel. After the blank-fax problem occurred, the tools were sent to the TASC for analyzing the measured data.

3. Estimation of the cause of blank-fax problem

One month after installation of the tools, we recognized that the problem occurred twice (i.e., two blank faxes were received). The fax sequence as shown in **Fig. 7** were checked when the problem occurred. As a result, the following four points were clarified.

(1) After successfully completing the call setup and pre-message procedure, the sender divides the image information and sends it.

(2) After all the split-image information is transmitted, the partial page signal - end of procedure (PPS-EOP) signal is transmitted from the sender.

(3) The multifunction printer is disconnected after it does not respond to the PPS-EOP signal.

(4) The multifunction printer outputs a blank fax.

When the received image was decoded from the

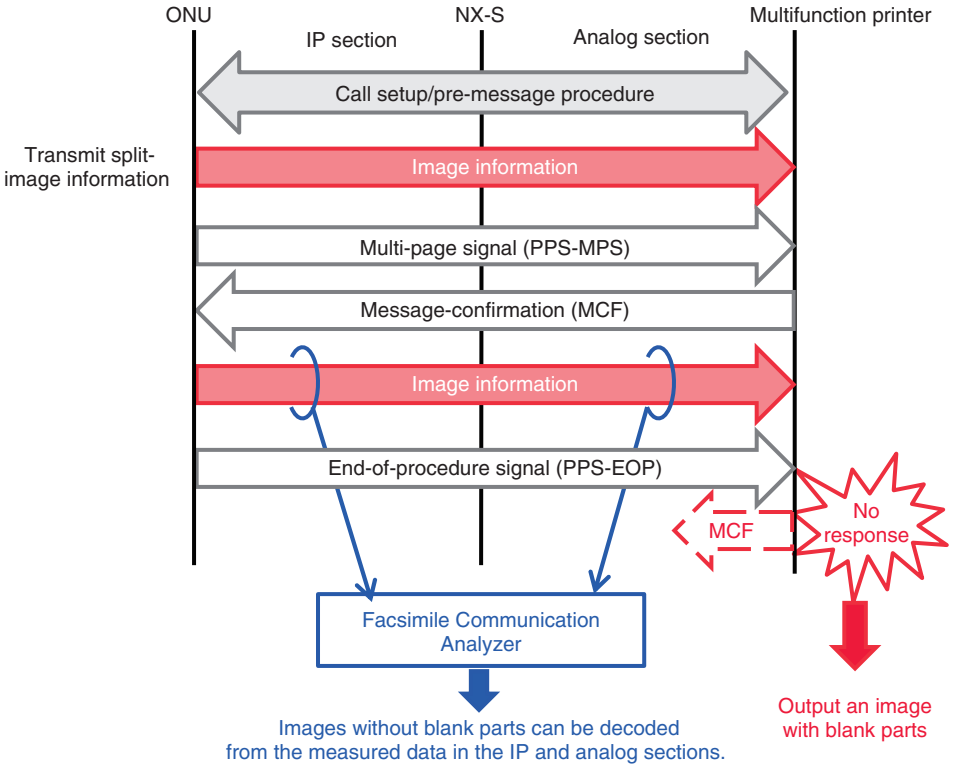


Fig. 7. Sequence of fax signals when blank-fax problem occurs.

packet and waveform data measured in the IP and analog line sections, respectively, the images received in both sections were successfully decoded. It is therefore concluded that no abnormality occurred in the fax signals transmitted via the sections subject to maintenance by NTT. Moreover, the multifunction printer did not respond to the proper signal it should be responding to; therefore, it is confirmed that the blank facsimile image occurred due to the setting/function of the multifunction printer. According to the results of the investigation, the customer requested the manufacturer of the multifunction printer to reinvestigate the problem. After reinvestigation was carried out, the blank-fax problem was eliminated.

4. Conclusion

In this article, a troubleshooting case of facsimile communication was presented as an example of problems in a complicated customer's network. It was shown that by using Cap-two and Analog Logger (developed by the TASC) and commercially available software (Facsimile Communication Analyzer) to analyze the fax signal, it was possible to identify the cause of the problem in the network combined with IP and analog system. The TASC will continue to solve problems in the field by supporting service personnel with our technical knowledge and developing useful tools.

Event Report: Tsukuba Forum 2019

Tomoyuki Nomura, Yusuke Koshikiya, Motoharu Sasaki, and Ikuko Takagi

Abstract

Tsukuba Forum 2019 was held on October 31 and November 1. The theme of the forum was "Supporting the present, shaping the new era—World-leading technology for creating services and field front-line technology for transforming operation/maintenance." This article gives a brief overview of the speeches and exhibits presented at the forum.

Keywords: Tsukuba Forum, overview of speeches, overview of exhibits

1. Introduction

The main theme of Tsukuba Forum 2019 was "Supporting the present, shaping the new era—World-leading technology for creating services and field front-line technology for transforming operation/maintenance." It was held with the intention of creating a smart world with NTT as *Your Value Partner* as it looks back on network access technologies that have supported society to date and pioneers new access networks of the future. In addition to NTT Access Network Service Systems Laboratories (AS Labs), 105 organizations, including co-hosting organizations and NTT Group companies (**Table 1**), participated. They introduced and exhibited the latest research and development (R&D) and technological trends.

2. Overview of speeches

The two keynote speeches were given at the Tsukuba International Congress Center on the first day. They were relayed from the main convention hall of Tsukuba International Congress Center to a venue at the NTT Tsukuba R&D Center. The speeches were received by a large audience.

2.1 Keynote speech 1

Mr. Motoyuki Ii, senior executive vice president and representative member of the Board of NTT, gave a speech titled "Towards Social Infrastructure Sharing" (**Photo 1**). For details, see the article in this issue [1].

2.2 Keynote speech 2

Mr. Naoki Shibutani, senior executive vice president and representative director of NTT EAST, gave a speech titled "Shaping Prosperous Future through Regional Innovation" (**Photo 2**). For details, see the article in this issue [2].

3. Workshops

On the second day of Tsukuba Forum 2019, workshops were held at AS Labs. A business unit manager of NTT Advanced Technology and two project managers from AS Labs conducted the workshops (**Photo 3**).

3.1 Workshop 1

Mr. Kazuo Kitamura, business unit manager of the AI and Robotics Business Headquarters, Robotics Solutions Business, NTT Advanced Technology Corporation, gave a lecture titled "WinActor Business

Table 1. List of Tsukuba Forum 2019 exhibits.

■NTT Group companies
NIPPON TELEGRAPH AND TELEPHONE EAST CORPORATION
NTT EAST-MINAMIKANTO CORPORATION
NTT EAST-KANSHINETSU CORPORATION
AIREC ENGINEERING CORPORATION
NTT RENTAL ENGINEERING CO., LTD.
Nippon Telematique Inc. (NTI)
NIPPON TELEGRAPH AND TELEPHONE WEST CORPORATION
NTT Communications Corporation
NTT PC Communications Incorporated
NTT World Engineering Marine Corporation
NTT COMWARE CORPORATION
NTT Electronics Corporation
NTT Advanced Technology Corporation
NTT-AT TECHNO COMMUNICATIONS CORPORATION
NTT TechnoCross Corporation
NTT Infrastructure Network Corporation
NIPPON CAR SOLUTIONS CO., LTD.

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

■Communication Line Products Association of Japan
AICHI CORPORATION
ASABA MANUFACTURING CO., LTD.
IWABUCHI CORPORATION
OCC Corporation
Okano Cable Co., Ltd.
KANDO Co. Ltd.
FUJIKURA HIGH OPT Co. LTD.
JFE Metal Products Corporation
JAPAN RECOM Ltd.
SHODEN SEIWA CO., LTD.
SWCC SHOWA CABLE SYSTEMS CO., LTD.
Suzuki Giken Co., Ltd.
SUDA SEISAKUSHO Co., Ltd.
Sumiden Opcom, Ltd.
Sumitomo Electric Industries, Ltd.
Corning International K.K.
DYDEN CORPORATION
DAITO DENZAI CO., LTD.
TADANO LTD.
Tsushin Kogyo Electric Wire & Cable Co. Ltd.
TOTSU-SOKEN CORPORATION
SEI Optifrontier Co., Ltd.
NISHI NIPPON ELECTRIC WIRE & CABLE CO., LTD.
NIPPON CONCRETE INDUSTRIES CO., LTD.
Nippon Tsushin Denzai Co., Ltd.
Fujikura Ltd.
Fujikura Dia Cable Ltd.
Furukawa Electric Co., Ltd.
MASARU INDUSTRIES, LTD.
DAINICHI CONCRETE INDUSTRY CO., LTD
Milliken Japan G.K.

■Japan Telecommunications Equipment and Materials Manufacturers Cooperative Association (Zentsukyo)
Asakuraseisakusho Co, Ltd.
OTANI KOGYO CO., LTD.
Sankosha Corporation
SANWA DENKI KOGYO CO., LTD.
SANRITZ ELECTRONICS CO., LTD.
TAIEI Manufacturing Co., Ltd.
Takacom Corporation
TAKACHIHO SANGYO CO., LTD.
Chuko Electric Co., Ltd.
TOMEITSUSHINKOGYO CO., LTD.
NAGAMURA MANUFACTURING CO., LTD.
NISSHIN ELECTRIC CO., LTD.
HACHIKO ELECTRIC CO., LTD.
MSK Technologies Co.,Ltd
WATANABE CO., LTD.

■Other Corporations
Anritsu Corporation
NEC Corporation
NEC Magnus Communications, Ltd.
NTEC
FXC Inc.
Oi Electric Co., Ltd.
OPT Gate Co., LTD.
SUNREC CO., LTD.
SHOSHIN Corporation
Seiko Solutions Inc.
HARADA CORPORATION
Hitachi, Ltd.
FUJITSU LIMITED
HellermannTyton Co., Ltd.
MAEDA ROAD CONSTRUCTION Co., Ltd.
MARUBUN CORPORATION
MIKI Inc.
Mitsubishi Electric Corporation
Yokogawa Test & Measurement Corporation / Yokogawa Solution Service Corporation
RIKEN KEIKI Co., Ltd.

Overview."

Mr. Kitamura first gave an overview of WinActor. WinActor is a client PC (personal computer)-based robot process automation (RPA) tool developed by NTT research labs in 2010 with its unified management support system technology. It was commercialized by NTT Advanced Technology and released in 2014. As of the first half of 2019, over 4000 companies have adopted this software, giving it the largest RPA tool market share in Japan. Over 700 companies are currently sales partners of this software.

Next, Mr. Kitamura described WinActor's three major features: simplicity, support, and scalability. New functions to strengthen the product and promote simplicity include a new service called *Cast on Call*, which provides ready-made scenarios for task automation, contour matching, and enhanced virtualization support. Version 7, slated for release in 2020, will feature a refreshed user interface (UI) and multilingual support. Mr. Kitamura also discussed personnel training to bolster support and gave examples of WinActor's management functions and enhancements for achieving scalability. He argued that to further strengthen collaboration with work applications for digital transformation (DX), the key issues are how to migrate WinActor to the cloud and implement on-premise and cloud collaboration and how to use artificial intelligence (AI) in areas where human judgment is required, which is not stereotypical, thus considered an area RPA tools are poor at.

Finally, Mr. Kitamura stated that NTT Advanced Technology is further pursuing customer's DX by increasing customer value when using WinActor together with all NTT's partners through the

Photo 1. Keynote speech delivered by Motoyuki Ii, senior executive vice president and representative member of the Board, NTT.

Photo 2. Keynote speech delivered by Naoki Shibutani, senior executive vice president and representative director, NTT EAST.

Photo 3. Workshop leaders (from left to right: Kazuo Kitamura, business unit manager, NTT Advanced Technology; Minoru Tanaka, project manager, AS Labs; and Takeshi Onizawa, project manager, AS Labs).

Technology Partner Program established in July 2019.

3.2 Workshop 2

Mr. Minoru Tanaka, executive research engineer and supervisor of the Civil System Project, AS Labs, gave a lecture titled "R&D Trends in Technologies for Maintaining and Managing Telecommunication Infrastructures." For details, see the article in this issue [3].

3.3 Workshop 3

Mr. Takeshi Onizawa, executive research engineer and executive manager of the Wireless Entrance Systems Project, AS Labs, gave a lecture titled "Wireless Systems Technologies for Present and Future Services." For details, see the article in this issue [4].

4. Two-day events

4.1 30th Tsukuba Forum Exhibit

The evolution and the future of access network

Photo 4. 30th Tsukuba Forum Exhibit.

Photo 5. Panel discussion.

technologies were showcased. Changes through the eras and transformation of systems were exhibited. Some visitors viewed the exhibit nostalgically, and many said, "I could easily understand how things changed" (**Photo 4**).

4.2 Panel discussion

Co-hosting organizations, NTT Group companies, and the NTT research labs united to introduce efforts and hold salon-style discussions on two themes: "Next-generation optical fiber cable technology" and "New wireless developments in the Reiwa era*." The panelists introduced examples from different companies. Many attendees commented, "I learned a lot" and "It was extremely interesting" after listening to discussions about specific challenges for the future and different companies' views (**Photo 5**).

4.3 Radio equipment supporting the local community and disaster preparedness

A video presentation on wireless facilities that support safe living in remote islands and mountain areas and prevent the isolation of affected areas during disasters was given.

4.4 Stamp rally

A digital stamp rally using smartphones was carried out for the third time at Tsukuba Forum 2019 to enable visitors to navigate throughout the exhibition hall of AS Labs. Those who gathered the seven stamps in the venue were awarded an original utility pole number tag. When the souvenir was handed to the participants, they remarked, "I look forward to this every year" and "I want to collect the utility pole number tag every year."

5. Overview of exhibits

In addition to exhibits from AS Labs, exhibits on the latest technologies of the co-hosting organizations and NTT Group companies were held (**Photos 6** and **7**).

5.1 AS Labs

The exhibition area was divided into three zones in which a wide range of AS Labs' R&D results were exhibited (**Fig. 1**). Recommended exhibits were marked and presented to attendees in an easy-to-understand manner (**Photo 8**).

(1) Future access network

Optical and wireless technologies that will make future access networks a reality were introduced. Recommended exhibits included presentations of analog radio-over-fiber technology to accommodate high-frequency multi-band radio systems, the direction of technological development to achieve future access networks, protocol-free wavelength-management-control technology, and optical-fiber environment monitoring.

(2) Pioneering technologies

State-of-the-art technologies to develop future access networks for a smart world were introduced. A recommended exhibit showed the information and communication technology (ICT) transformation of a conduit management system.

(3) Supporting technologies

Cutting-edge technologies to support a safe and secure society and current access networks were

* Reiwa is the name of the current Japanese imperial era, which began on 1 May 2019.

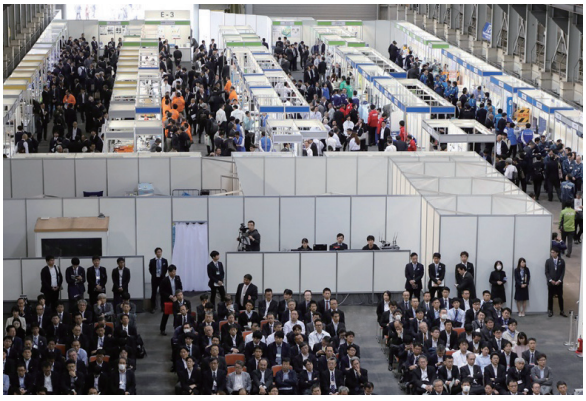


Photo 6. Main hall.

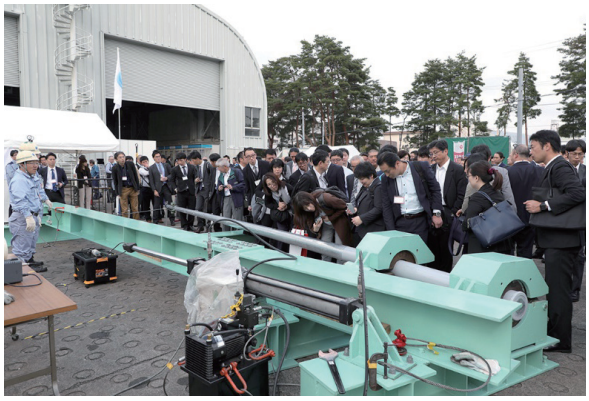


Photo 7. Outdoor exhibits.

Future access network

Introduces optical and wireless key technologies that will be responsible for future access networks.

Pioneering technologies

Introduces state-of-the-art technologies that will pioneer future access networks for achieving a smart world.

Supporting technologies

Introduces cutting-edge technologies that support a safe and secure society and the current access network.

Display of a model network

Introduces an overview of the access network technologies (those already deployed) in a physical sequence from an NTT building to customer's premise.

Fig. 1. Overview of NTT exhibits.

introduced. Recommended exhibits included UI extension technology to easily enable external collaboration, Internet of Things (IoT) wireless communication technology that extends the Wi-Fi standard (IEEE802.11ah), rule-learning-based failure location estimation and response support AI, optimal control technology that reflects human intentions, optimal wiring route configuration technology to avoid cable congestion, wiring technology with tolerance for demand fluctuation and that does not require operation, automatic failure recovery technology with auto-configuration and auto-wiring, multi-layer network autonomous control technology, automated manhole inspection technology using drones, technology for obtaining absolute coordinates of underground facilities, technology to visualize load and technology for understanding the relationship between unbalanced loads and structural degradation, and technology for making reinforced-concrete manholes maintenance-free.

(4) Display of a model network

This exhibit visually introduced the overall picture of access network technologies in a physical sequence from an NTT facility building to the customer's home.

5.2 Information & Telecommunications Engineering Association of Japan (ITEA)

This exhibit presented ITEA's efforts to develop secure, safe, and reliable information communication infrastructure facilities. These efforts include maintaining the technology and know-how that have been cultivated thus far; building, maintaining, and improving the quality and efficiency of optical access

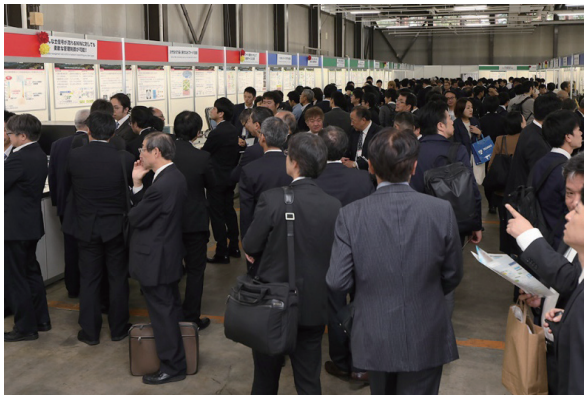


Photo 8. NTT exhibition zone.

Photo 9. Events of exhibiting companies.

networks; and promptly restoring facilities in the event of a major disaster.

5.3 Communication Line Products Association of Japan

The latest efforts and technologies of all the member companies were displayed. The technologies and products exhibited included optical and metal cables, connectors, and related components for outdoor facilities and technologies and products for datacenters and indoor facilities. Demonstrating safety considerations and diversity of needs, the offerings emphasized workability and drew the interest of many visitors.

5.4 Japan Telecommunications Equipment and Materials Manufacturers Cooperative Association (Zentsukyo)

With the slogan "Contributing to the development of an IoT society with reliable technologies and the art of manufacturing (*monozukuri*)," exhibitors belonging to Zentsukyo introduced their united efforts as an association to comprehend the expansion of the ICT market and environmental changes and respond to customers' demands with a sense of urgency.

5.5 NTT Group

Through their exhibits, NTT Group companies demonstrated collaborations with business partners as *Your Value Partner* through business activities. As *Your Value Partner*, NTT seeks to achieve a smart society through R&D and the use of ICT platforms. The exhibits introduced the NTT Group's latest technologies that contribute to solving social challenges.

5.6 Events of exhibiting companies

In the AS Labs main hall and in the outdoor venue, exhibiting companies gave demonstrations, which drew many visitors (**Photo 9**).

6. Conclusion

Tsukuba Forum 2019 was blessed with sunny weather on both days. It was a success, drawing about 9400 attendees, including many international visitors. They expressed great interest in the presentations of exhibiting companies, including the latest R&D and future trends of AS Labs. Visitor questionnaires were distributed, and the results indicated that 97% of customers achieved the purpose of their visit. Tsukuba Forum 2019 was a rich event that allowed NTT and participating organizations to share transformations in access networks through presentations of short-term efforts to support current access networks and pioneering medium and long-term efforts to create future access networks.

Acknowledgments

We thank the Information & Telecommunications Engineering Association of Japan, the Communication Line Products Association of Japan, and the Japan Telecommunications Equipment and Materials Manufacturers Cooperative Association (Zentsukyo) for their support of Tsukuba Forum 2019.

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Trademark notes

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

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He received a B.E. and M.E. in mechanical engineering and a Ph.D. in electrical engineering from Waseda University, Tokyo, in 2001, 2003, and 2015. In 2003, he joined NTT Access Network Service Systems Laboratories. He has been engaged in research on optical fiber sensing and maintenance technologies for optical fiber networks. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE). He was the recipient of the Institute of Electrical and Electronics Engineers (IEEE) Lasers and Electro-Optics Society Japan Chapter Young Scientist Award and the Young Researcher's Award from IEICE in 2004 and 2010, respectively.

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She received a B.E. in engineering and an M.E. in information science and electrical engineering from Tokyo University of Science, in 2010 and 2012. In 2012, she joined NTT Access Network Service Systems Laboratories. She has been engaged in research on operational software for business efficiency.

External Awards

Distinguished Achievement and Contributions Award
Winner: Yutaka Miyamoto, NTT Network Innovation Laboratories
Date: June 6, 2019
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE)

Dr. Miyamoto has long been engaged in research on the core technologies for high-speed, high-capacity optical transmission systems used in optical networks and has made many achievements. In particular, he has made outstanding achievements in research on the coherent, multicarrier, multilevel modulation/demodulation system.

Best Conversant Award
Winner: Keisuke Tsunoda, NTT Service Evolution Laboratories
Date: July 5, 2019
Organization: The Information Processing Society of Japan (IPSJ) Committee of DICOMO 2019 symposium

He was selected because he asked interesting and thought-provoking questions at the DICOMO 2019 symposium.

Best Poster Award
Winner: Takashi Kurushima, Yoshiki Sakamoto, Kimi Ueda, Hirotake Ishii, Hiroshi Shimoda, Kyoto University; Rika Mochizuki, Masahiro Watanabe, NTT Service Evolution Laboratories
Date: September 22, 2019
Organization: 3rd International Conference on Computer-Human Interaction Research and Applications (CHIRA 2019)

For "A Study on Legibility with Pairwise Comparison in Simultaneous Multilingual Display on Digital Signage."
Published as: T. Kurushima, Y. Sakamoto, K. Ueda, H. Ishii, H. Shimoda, R. Mochizuki, and M. Watanabe, "A Study on Legibility with Pairwise Comparison in Simultaneous Multilingual Display on Digital Signage," Proc. of CHIRA 2019, Vienna, Austria, Sept. 2019.

Award for Encouragement of Research in the 29th Annual Meeting of MRS-J Symposium L
Winner: Riku Takahashi, NTT Basic Research Laboratories
Date: November 29, 2019
Organization: The Materials Research Society of Japan (MRS-J)

For "Creation of Tough Hydrogel Architectures Towards Obtaining Hydrogel Fluidic Devices."
Published as: R. Takahashi, "Creation of Tough Hydrogel Architectures Towards Obtaining Hydrogel Fluidic Devices," 29th Annual Meeting of MRS-J, Yokohama, Japan, Nov. 2019.

The 2nd Hyogo-Kansai Caterpillar STEM award, Outstanding Achievement Award
Winner: Keiko Takase, NTT Basic Research Laboratories
Date: February 11, 2020
Organization: Caterpillar Japan

For her research on electrical control of spin-orbit interaction using semiconductor nanowire.

IPSJ Yamashita SIG Research Award
Winner: Yusuke Ichikawa, NTT Service Evolution Laboratories
Date: March 6, 2020
Organization: IPSJ

For "Evaluation of Dynamic Guide Signs Control Pedestrians in Public Facilities."
Published as: Y. Ichikawa, A. Hayashi, Y. Mihara, K. Shimizu, and H. Tezuka, "Evaluation of Dynamic Guide Signs Control Pedestrians in Public Facilities," IPSJ SIG Tech. Report, Vol. 2019-CDS-24, No. 31, 2019.

Papers Published in Technical Journals and Conference Proceedings

Topological Stack-queue Mixed Layouts of Graphs
M. Miyauchi
IEICE Transactions on Fundamentals of Electronics, Vol. E103-A, No. 2, pp. 510–522, February 2020.

One goal in stack-queue mixed layouts of a graph subdivision is to obtain a layout with a minimum number of subdivision vertices per edge when the number of stacks and queues are given. Dujmović and Wood showed that for every integer s, $q > 0$, every graph G has an s-stack q-queue subdivision layout with $4\lceil\log_{(s+q)q} \mathrm{sn}(G)\rceil$ (resp. $2 + 4\lceil\log_{(s+q)q} \mathrm{qn}(G)\rceil$) division vertices per edge, where $\mathrm{sn}(G)$ (resp. $\mathrm{qn}(G)$) is the stack number (resp. queue number) of G. This paper improves upon these results by showing that for every integer s, $q > 0$, every graph G has an s-stack q-queue subdivision layout with at most $2\lceil\log_{s+q-1} \mathrm{sn}(G)\rceil$ (resp. at most $2\lceil\log_{+s+q-1} \mathrm{qn}(G)\rceil + 4$) division vertices per edge. That is, this paper improves upon the previous results for graphs with larger stack number $\mathrm{sn}(G)$ or queue number

qn(G) than given integers s and q. Also, the larger the given integer s is, the more the previous results are improved.

A Method to Determine If a Test Case Is Necessary Using Support Vector Machine

S. Sunaga, K. Kikuma, K. Jimbo, K. Satoh, and K. Ueda

Proc. of the 2nd International Conference on Artificial Intelligence in Information and Communication (ICAIIC 2020), pp. 448–453, Fukuoka, Japan, February 2020.

Communication software used for the Next Generation Network (NGN) is required to be highly reliable, so it incorporates many methods to improve quality and prevent service interruptions during operation of public networks. However, the accumulation of quality improvement methods has resulted in problems with longer development times and increasing costs. The authors are working to solve such problems by automating development processes. In this paper, we propose a method of determining if a test case is necessary using a support vector machine. We vectorize know-how regarding the creation of verification test cases from experts who understand the requirement specifications. The support vector machine learns the vector as the training data. Then this is used to automatically determine if a test case is necessary. We evaluated the effectiveness of the method in automatically determining if a test case of particular requirements is necessary through practical experiments.