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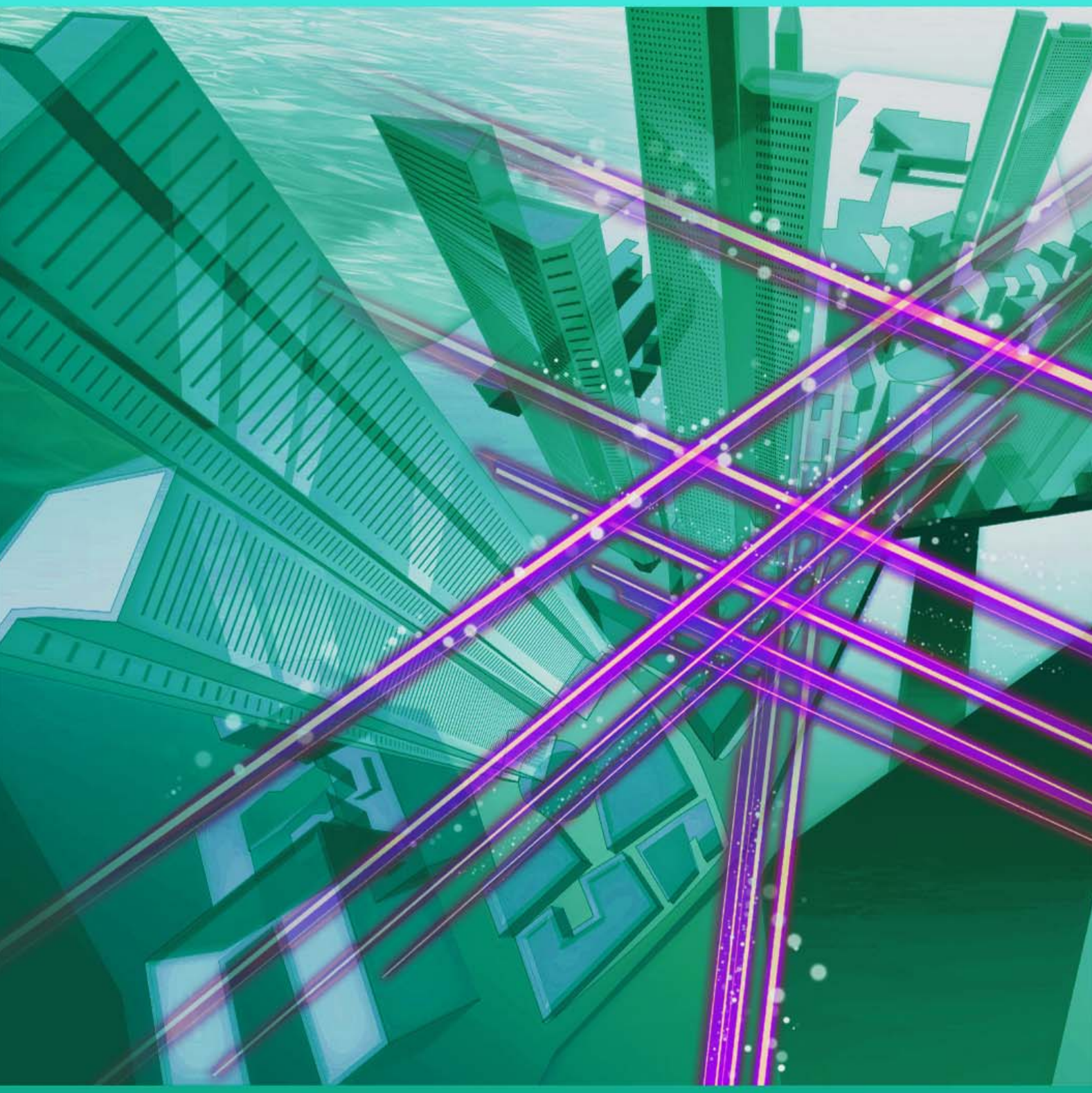

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"Managing from the Heart" Changes Society—Solving Regional Problems in the Spirit of "That's a Good Idea. Let's Give It a Try!"

Naoki Shibutani
Senior Executive Vice President, NTT EAST

Overview

NTT EAST is committed to achieving prosperous regional communities and sustainable development. On the basis of its original mission as a telecom carrier to *connect people*, it is now undertaking a new initiative as *an information and communication technology (ICT) solutions company moving together with regional communities* with the aim of solving the issues confronting its regional customers through the use of ICT. We asked Naoki Shibutani, Senior Executive Vice President, to tell us about the stance that NTT EAST needs to take to solve social problems and the progress it has made toward 2020.

Keywords: digital transformation, regional revitalization, ICT

Our basic stance: "listening to customers about every problem"

—Mr. Shibutani, may we begin by asking you about the business summary of NTT EAST?

The diffusion of optical circuits typified by our FLET'S Internet connection services has progressed in Japan, and the demand is currently slowing down. Accordingly, our sales are decreasing, but effective cost reductions are producing a steady rise in profits. For fiscal year 2018 (April 1, 2018—March 31, 2019), we expect to achieve an operating income of 233 billion yen, which is in line with our initial target. In particular, the target for our flagship FLET'S HIKARI fiber-optic broadband services was to obtain 400,000 new subscribers, and we are close to achieving that figure.

In addition, sales for high-value-added products such as Wi-Fi and cybersecurity services are gradually increasing, while the number of fixed-line (landline) subscribers is decreasing.

Operating income continued to increase for six straight years under our previous president, and it looks to increase in the first year of our current president as well. In short, we expect to achieve seven consecutive years of profitability, which means that our business conditions are right on track. Behind these achievements lie the tireless efforts of our employees. We have achieved great success in promoting activities to take work that we had previously been outsourcing and doing it on our own without fear of failing. This is enabling us to improve our skills and reduce costs and to create a mechanism that can contribute to profits by leveraging our unique strengths in the field.

—The NTT Group Medium-Term Management Strategy was announced in November 2018. What will you as Chief Digital Officer focus your efforts on?

The NTT holding company is promoting digital transformation (DX) as a pillar of the NTT Group, and at NTT EAST, we have begun to educate ourselves as a company about this next pillar of management. Here, DX can be broadly divided into our own internal DX and our customers' DX. To start this off, we are advancing DX within the company, and to this end, the facility department, sales department, administrative department, and other departments are using new tools in an attempt to make their respective business operations more efficient and to bring about change.

For example, there are successful cases of radically reducing workload by using text mining from artificial intelligence (AI) at call centers and using robotic process automation for large-volume delivery order processing. Our DNA is stamped with a culture of improvement and horizontal expansion in which we are constantly reviewing our work and trying to make it more efficient while striving to share these improvements with other departments. Our employees in the field are proactively disseminating best practices within the company. Of course, it's the head office that will take the lead in rolling out a major system, but in the field, it's on-site employees who understand the field best and thus make improvements in the system on their own. If some questions arise about using a certain tool, the DX team from the head office can provide some support. In this way, both the head office and personnel in the field are cooperating and making progress. I get a positive sense about such efforts, and I believe that the DX movement will facilitate the further evolution of our corporate culture.

Furthermore, with regard to our customers' DX, we gave thought as to what NTT EAST could do for the future of Japan while leveraging our strengths, and we came to the conclusion that solving social problems and engaging in regional revitalization were the paths to take. In short, we aim to provide help in solving regional problems.

Our customers that we are in contact with on a regular basis span various fields such as manufacturing and the agricultural and fishing industries, and they are located in multiple regions. A common topic here is that while great efforts are being made to connect one's work and company with the next generation of workers and to plant roots in a certain region, the aging society and the lack of people to inherit skills and know-how make this a difficult task. Moreover, while hearing often about new technologies such as AI and the Internet of Things (IoT), many of our customers don't really know how to use such technologies in their operations. We think that we can work closely with our customers in coming up with solutions to such problems regardless of the scale of their enterprise. For example, regarding AI and IoT, sensors and cameras could be used to accumulate data on the status of livestock or crops, and the results of analyzing such data by AI could be checked on the customer's home terminal. Such a capability could eliminate the need to make frequent visits to the farm for inspections, provide more sleep and leisure time, and enable appropriate delivery periods for farm products to be predicted. We have already begun to help with such familiar problems and are compiling case studies in which customers are very pleased with the results.

It is my hope that using new technologies in this way will help create a future that can make the companies of our regional customers strong and healthy. It is this idea that forms the pillar of solving regional problems. In general, this approach may be called "creating a smart world," but we call it "listening to customers about every problem" to lessen the sense of distance between us and customers, and we approach our work from this stance of listening to customers about their problems.

On the service and technology front, the telephone era has been succeeded by the Internet protocol (IP) era, and we are entering a period in which new targets must therefore be established. In this regard, we must upgrade the IP network to handle 4K/8K video. We also need to create mechanisms that will simplify the

use of AI and IoT and integrate them with the cloud, and we need to give substance to edge computing through real-world problem solving and case studies. There has been much talk recently about the fifth generation (5G), but this assumes the use of wireless communications for the most part. However, we can speculate on the possibility of achieving an even safer, more secure, and more convenient society by skillfully combining 5G with optical circuits based on FTTH (fiber to the home).

Objective: keep NTT EAST out of the news in 2020

—The 2020 events that are only a year away will be staged in the NTT EAST region. Please tell us what initiatives NTT EAST plans to take toward 2020.

Before taking up my present position, I was in charge of matters dealing with the Olympics and Paralympics. For this reason, I attended the Rio 2016 Olympics as part of an inspection tour and had the opportunity to speak with an on-site manager. He said "Keeping the name of our company out of the news during this Olympics and Paralympics period would be a great result!" I nodded in affirmation. This is because any appearance of the NTT EAST name in the news during the events in 2020 would likely be due to the occurrence of some incidents, a failure in broadcasting a certain event, or a failure to prevent a cyberattack. In other words, while we will make every effort to facilitate a successful event based on the catchphrase *Conveying dreams and inspiration to the world*, we will strive to remain in the background just as the manager at the Rio Olympics did. At present, we are focusing our efforts on down-to-earth tasks such as underground work and inspections for laying cable while making steady progress in the provision of facilities.

We are now proceeding with these preparations surely and steadily, which suggests that everything is on track, but the fact is, some things are not proceeding as planned. For example, there are about 40 venues including the broadcasting center that need work, but many of these venues are nevertheless carrying on business as usual. We can't very well interrupt events that are customarily held every year at these venues, since halting business operations because of construction work would have the unfortunate effect of reducing revenues at those facilities. Besides, the final work to be done after all electrical work has been completed at each facility is our responsibility. As you can probably infer from what I have said so far, we will be charged with completing all sorts of tasks in the two or three months preceding the actual games in July 2020, from installing LAN (local area network) cable to deploying mobile circuits for Wi-Fi and mobile phones, as well as setting up cybersecurity measures and checking terminal connections at all 40 venues. I can imagine a frenzy of activity, and just thinking about it is stressful. Circumstances are such that doing things as usual simply does not guarantee that things will go smoothly.

—This is obviously a big challenge that needs to be faced. How do you plan to deal with it?

Actually, I was the NTT Fukushima branch manager at the time of the Great East Japan Earthquake in 2011. So many things happened at that time that one day would hardly be long enough to tell you everything. But let me say here that I am providing my know-how in dealing with emergency situations to the Olympics and Paralympics team so that we can overcome any unforeseen problems, even those on the scale of that disaster.

The Great East Japan Earthquake was an unprecedented experience for NTT EAST. Amid conflicting information on the scale of the earthquake and damage to the nuclear power station, we found ourselves in an extreme situation in which we had to immediately

and accurately decide what damaged facilities to prioritize and how to restore them given the importance of communications as a social infrastructure. This was also a situation of extreme difficulty for myself as the top manager in charge of this area, but information from people directly affected by the disaster gradually began to come in. For example, there were restoration requests from prefectural and municipal offices whose communication cables had been severed by the earthquake, and amid the rapid spread of evacuation instructions, there were requests to secure emergency communications from local governments and hospitals in areas where evacuations had been delayed.

I wanted to restore communications for such people as soon as possible, but at the same time, I wanted to ensure the safety of our employees involved in restoration work at disaster-stricken locations still deemed to be dangerous. Filled with these emotions, I found it very hard to make each and every decision, but I don't know how many times I received encouragement from my fellow employees, who were also victims of this disaster themselves, to do as much as we could for everyone living in the affected regions.

These experiences taught me a valuable lesson: don't yell at times of an emergency. At such times, bad news is coming in constantly, and looking for people to blame or yelling things such as "Why wasn't that done earlier?" "You couldn't do it more like this?" or "Whose fault was that?" only makes matters worse. It gives rise to a situation that hinders the collection of information or the obtaining of critical information and that, in the end, is not helpful in relief and restoration efforts. It's exactly at the time of an emergency that one must remain calm and give priority to what you can do best; you can reflect on the effects of what you have done later.

In "managing from the heart," support and warmth become a driving force

—So creating a positive environment at the time of an emergency is extremely important! As an executive leading from the top, what else do you aim to provide?

I place great importance on "managing from the heart." I was the manager of the NTT EAST amateur baseball team when it won the prestigious Intercity Baseball Tournament two years ago for the first time in 36 years. However, in the first year that I became manager, we were eliminated in the preliminary

rounds, which was a crushing disappointment for the entire team. From my experience dealing with the Great East Japan Earthquake, I came to understand that one's mental attitude is important in shaking off adversity and using hard times as an opportunity to grow. A person is moved not by one's mind but by one's heart.

While there are some people who think that there is no power stronger than fear, I am not one of them. In contrast to using fear or pressure or anger, I am always trying to show that connecting with other people through the heart produces the best results. I believe that a smile and an open atmosphere can increase motivation. This holds for both business and baseball.

Returning to the baseball team, if the players were in a match that they felt likely to lose, they could be inspired to win simply by hoping for a mistake by the opposing team. However, negative feelings, in the end, would tend to come back at us. For example, saying something negative about the opposing team or jeering at them generated a bad mood, which came back to haunt us, causing us to lose an important match. After I told the players about this, they nodded in agreement and refocused their attention from the other team to themselves and began to cheer each other on, saying things like "Good pitch!" or "You struck out this time but that was a good swing—you'll do better next time!" Hearts connect under positive conditions. In this way, the players' got a boost with every match and started to do better, eventually rising to the top and winning the championship. Connecting in a heart-to-heart manner through positive conversation is no different from the way in which work should be done on a daily basis. I would like to get more people to agree with me on this "managing from the heart" approach.

—I've also become an advocate and fan of this approach. With that mindset and your diverse experiences, what kind of wisdom should NTT EAST apply to business from here on?

My desire to change the current state of affairs is quite strong. In this regard, I believe that there are two kinds of people: one that demonstrates his or her abilities in structured work and one that is especially skillful in applying all of one's abilities to assigned work in one's own way. I'm of the latter type. Since there is no framework, I can freely act according to current conditions and broaden my interactions with a wide array of people including customers. In this way, I encounter hardships all the time, but once a project is completed, I look upon that work as something that was enjoyable and worthwhile. This was true at the time of the Great East Japan Earthquake and during my work overseas.

When I think of my experiences in Japan and other countries, there are two things that come to mind with respect to the future of NTT EAST. The first is Japan's innovation dilemma that arises from the fact that Japan is a well-developed country without many serious problems. For example, the cashless society is progressing in various Asian countries due in part to a lack of confidence in their currencies, and it's exactly in regions where the transportation network has not fully developed that autonomous cars are rapidly progressing. Japan, meanwhile, has trusted institutions and a solid infrastructure. So the question for Japan is how to overcome its innovation dilemma originating in this environment.

The second thing that comes to mind is that human resource development looks to be an important key in overcoming this dilemma. In contrast to Japan where the lifetime employment system is still deep-rooted, societies in which changing jobs is a common and accepted practice can be found in the United States and other countries throughout the world. If the scope of our employees' experiences is too narrow, we won't be able to support a major social transformation, so I think it's necessary for us to fill that gap and reform ourselves. For example, I would like to help our young employees have intercultural experiences by sending them out into the world or by dispatching them out to the field such as to medical-care institutions, educational sites, rice-growing farms, sake breweries, and construction sites of partner companies. In this way, they will be able to gain experience by grasping real-world problems and to acquire practical skills in applying ICT (information and communication technology). This experience should prove useful in coming up with new ideas and creating new groundbreaking business opportunities.

—Mr. Shibutani, can you leave us with a message for all NTT EAST employees?

I was born in Kyoto, and in the Kansai (western Japan) dialect, we say "*E yan, yatteminahare*!" (That's a good idea, let's give it a try!) NTT EAST employees have a very strong desire to contribute to society and have a very self-sacrificing spirit. There are many people in general who are highly motivated and spare no effort when starting on a project, but when they take their first steps and confront a certain challenge, they often lose confidence and start to hesitate. There are also many managers who have been brought up in such an environment, and when they receive proposals from subordinates, they are apt to give reasons why those proposals are not feasible or to recount stories of their own failures in such work. In this way, they drain all the optimism from their subordinates and nip the bud of innovation without even noticing. They may have the best of intentions, but if so, I wish they would first respond on a more positive note by saying "*E yan*!" (That's a good idea!), or in the Kanto (Tokyo) dialect, "*Ii jan*." They could also say more encouraging things such as, "You could get better results by doing it this way," "I failed here, but making this improvement might work!" or "Now that I've laid the groundwork here, go ahead and give it a try." In other words, it's best to let people try something even if they fail. I believe that accumulating experience in this way is the best way to learn. My aim is to encourage people to take up challenging work by saying to them "*E yan*!"

—A very stimulating talk! To conclude, what would you like to say to our researchers?

Needless to say, all researchers are expected to come up with results appropriate to their research, but I am concerned that perhaps those results go only half way in making a connection with business. For this reason, I would like our researchers to choose between two things in their work. The first is to focus their energy on doing globally leading, cutting-edge research that can change the world and make history instead of short-term targets for the sake of commercial viability. As for the second, I would be delighted if our researchers could go out with us into the field to brainstorm with people actually engaged in

agriculture, fishing, and other industries on how best to use advanced technologies for the benefit of society.

Interviewee profile

■ Career highlights

Naoki Shibutani entered Nippon Telegraph and Telephone Corporation in 1985. He worked in NTT Department I beginning in 1999 and then served as NTT EAST Senior Manager of the Planning Department starting in 2001 (and was a guest researcher at the Center for Strategic and International Studies (CSIS), Washington, D.C.). In his career, he has also served as Department Manager of the Plant Planning Department, Plant Section, Network Business Headquarters; Manager of the Fukushima branch office; Senior Vice President and Executive Manager of the Plant Planning Department, Network Business Headquarters; and Senior Vice President and Executive Manager of the Tokyo Olympic & Paralympic Promotion Office. He assumed his present position in June 2018.

Research and Development of New Operating Techniques for Access Network Infrastructure

Takeshi Arai

Abstract

The team members of the Access Network Management Project at NTT Access Network Service Systems Laboratories have been engaged in research and development (R&D) related to the operation and management of access network infrastructure. This article reviews our recent R&D focused on innovating infrastructure maintenance and deployment. This includes techniques for carrying out facility inspections, condition sensing, and secure on-site work. It also introduces our vision for the future operation and management of access network infrastructure. This article is based on a lecture given during workshops at the Tsukuba Forum 2018 held in October 2018.

Keywords: access network media, access network inspection and management, Tsukuba Forum 2018

1. Introduction

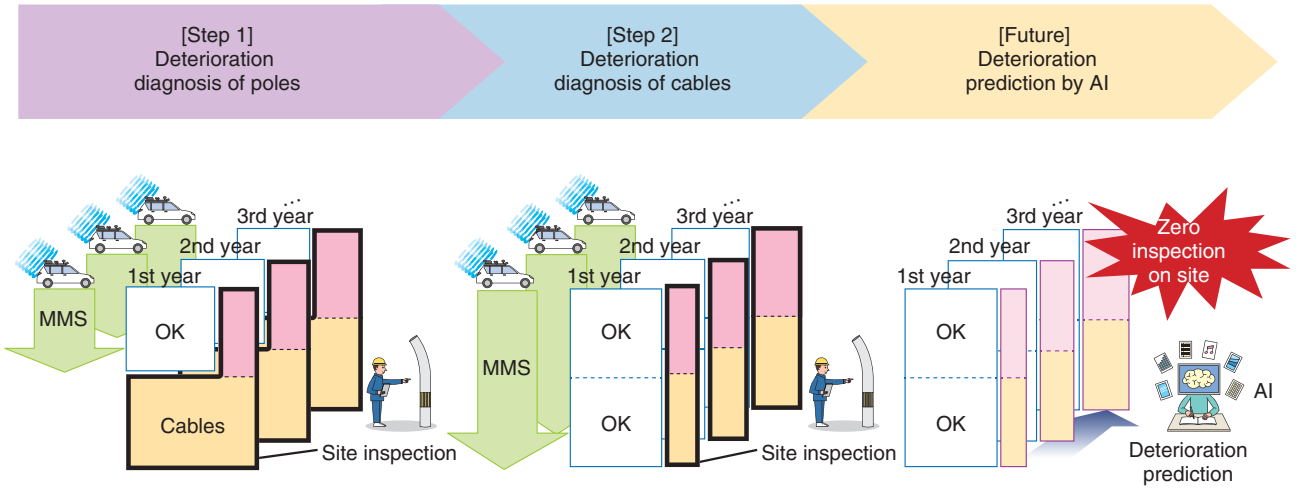
The NTT Group has deployed a huge number of network facilities that require continued maintenance. However, the number of NTT workers is expected to decrease by about 40 percent by 2025. To continuously provide safe and secure telecommunication services, we need to progress beyond the conventional manual-handling operation and management work. In regard to on-site work, the number of serious accidents related to insufficient skill has increased in recent years, and it is difficult to prevent such accidents due to the retirement of skilled workers. Therefore, there is an urgent need for the implementation of an accident-free deployment scheme to overcome skill insufficiency.

2. Innovative inspection

In this section, our research and development (R&D) of technology enabling efficient inspection of access network infrastructure is introduced. Our vision for inspection procedures of the future is *remote and predictive inspection*. The approach to realizing this vision has three steps, as shown in **Fig. 1**.

As the first step, we have designed an automatic diagnosis scheme for pole inspection. Pole inspection is the hardest aspect of infrastructure management since we have to thoroughly and manually check a large number of poles. With our diagnosis scheme, we plan to greatly reduce on-site work by categorizing poles into *safe* and *unsafe* groups and focusing inspection work on the unsafe poles.

The second step is to extend the target of the diagnosis scheme to cables, guy wires, and suspension wires to further reduce the amount of on-site work. However, on-site inspection work must still be undertaken for the unsafe facilities even if we achieve the above two steps. To realize our future vision where on-site work is unnecessary, we plan to employ artificial intelligence (AI) technologies to estimate the aging condition of a facility and predict its lifetime.



AI: artificial intelligence
MMS: mobile mapping system

Fig. 1. Roadmap towards smart maintenance.

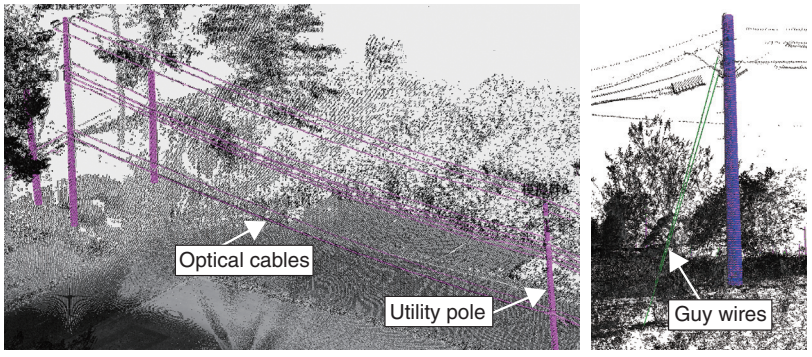


Fig. 2. 3D facility models captured with MMS.

2.1 Deterioration diagnosis of poles

The mobile mapping system (MMS) is a commercial technology that automatically captures outside objects as three-dimensional (3D) point cloud data while the inspector travels in a measuring vehicle and scans poles with a laser. We used the MMS to measure pole slopes and bends automatically by extracting each pole from the point cloud data. In addition, we also developed a Structure Deterioration Examination System, which incorporates an efficient data processing scheme to analyze a huge number of point cloud data. This system was put into practical use in 2018.

2.2 Deterioration diagnosis of cables

We also developed MMS-based measurement for cables and guy wires in addition to poles, as shown in **Fig. 2**. The point clouds of cables and guy wires were difficult to capture when they were interrupted by obstacles such as tree branches. To make them measurable, we collaborated with NTT Media Intelligence Laboratories and utilized their unique interpolation technique for our system. However, the interpolation section for drop cables is difficult to define because their start and end points are unclear. Thus, further R&D is required if we are to capture it completely. If our system could capture aerial facilities including drop cables, it would help us to find unsafe facilities remotely by measuring their slackness and

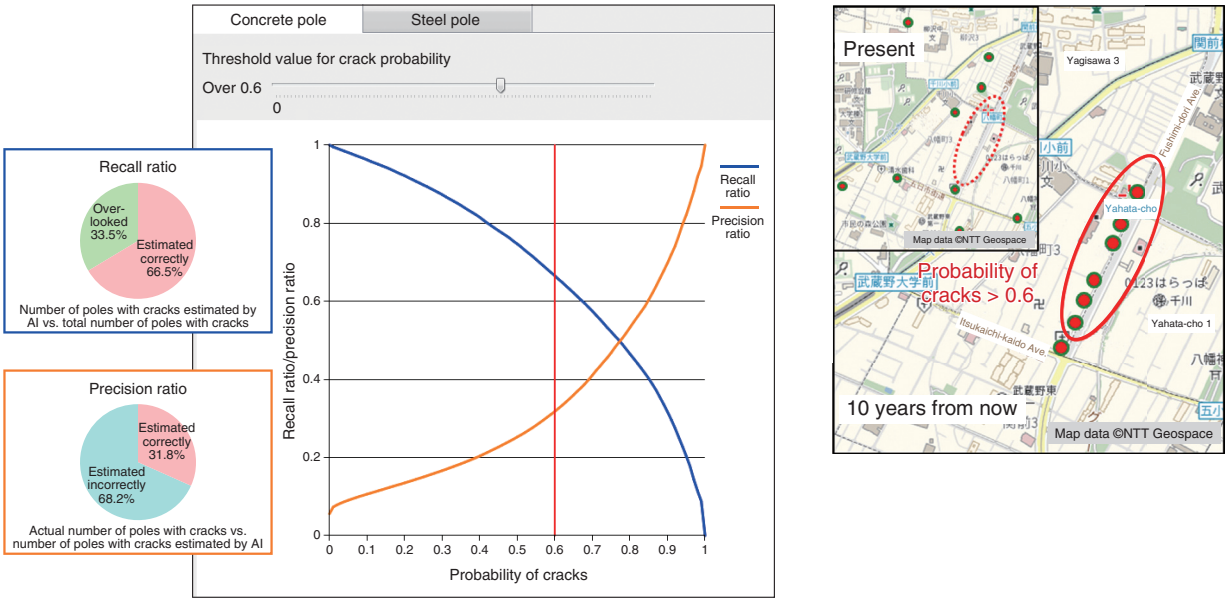


Fig. 3. Pole crack estimation using AI.

heights.

We also utilized the point cloud data as virtual reality (VR) space for remote inspection. In the VR space, which consists of 3D point cloud data, we can immediately reach the unsafe facilities, refer to the measurement results including pole slopes and cable heights, and check the on-site conditions with pictures. Moreover, facility alignment can be observed from a high vantage point by making the inspectors virtually giant.

While our MMS-based measurement is helpful for remotely inspecting facilities as described above, it cannot be applied in areas inaccessible to vehicles. In conventional on-site work, pole bends are measured with a measurement instrument called a Baum, which is a total station that has a concentric circle reticle. However, this tool is specially designed for use with poles and cannot be employed for other kinds of facilities. We plan to employ a fixed laser scanner, which can easily capture point cloud data in areas inaccessible to vehicles, to achieve automatic inspection work in a similar manner to the MMS.

2.3 Deterioration prediction by AI

Here, I explain our R&D aimed at facility aging prediction utilizing AI technology. Using AI that had learned pole data, we tried to predict the pole cracks that would occur in the next decade. However, the prediction accuracy was still imperfect. The AI estimation results are shown in **Fig. 3** for poles predicted to have a greater than 60% crack probability. The recall and precision ratios were about 70% and 30%, respectively, which were at insufficient levels for practical use. We are going to further carry out R&D designed to improve prediction accuracy.

The various facility data acquired with our system can be combined to provide some added value. For example, the locations of the unsafe facilities can be visualized on a map combining pole slope and bend data, where the on-site conditions can be observed with pictures. By combining the map with unbalanced load data, we can simulate balanced facility alignment by moving the pole locations virtually on the map. The simulation results can also contribute to achieving more efficient operation by utilizing them when planning construction work.

3. Condition sensing

In this section, our sensing techniques for access network infrastructure are introduced. The first technique is optical fiber identification for the efficient operation of fiber-to-the-home (FTTH) connection/disconnection work. When we connect or disconnect branched fiber for FTTH at the splitter, the fiber and its associated FTTH user must be carefully confirmed to prevent accidents, since the fiber information specified by a service order is not always correct. Our

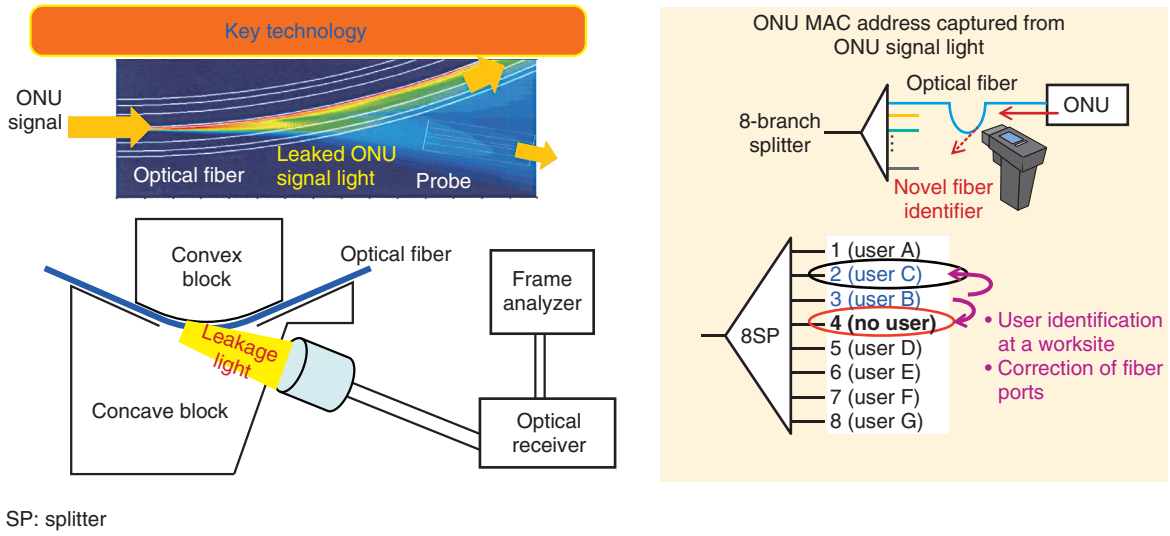


Fig. 4. Optical fiber identification technique.

technique enables us to easily identify an FTTH user on-site from the ONU MAC (optical network unit-media access control) address in the transmitted data frame by bending the branched fiber and detecting the light signal that leaks from that point, as shown in **Fig. 4**. This technique can be performed in-service by optimally designing the detection equipment. We believe that this technique will contribute to a reduction in back-orders by promoting efficient and secure on-site work.

The second technique is manhole identification to allow us to check for flooded closures. The conventional method involved measuring the distance between an NTT building (central office) and a flooded closure using optical time-domain reflectometry (OTDR). However, the OTDR results did not always agree with the actual distance due to extra fiber length in the closure, since OTDR estimates the distance from the fiber length. Therefore, OTDR could not always identify the location of the flooded closure precisely, and we were sometimes forced to check additional manholes to confirm their condition.

In contrast, our method identifies manholes by utilizing fiber vibration sensing technology. With this method, we cause the manhole to vibrate by hitting its cover with a hammer and then compare the detected vibration intensities for different manholes. This method can be efficiently carried out in combination with the conventional OTDR-based estimation technique.

4. Secure on-site work

Here, I introduce our efforts to promote secure on-site work. The first development is the secure deployment of road-crossing cable. Road-crossing cable deployment is dangerous work, where there is the risk of serious accidents caused by cable entanglement with moving vehicles. To avoid such accidents, we developed automatic cable lifting equipment, which remotely lifts drop cable by reeling in a rope bound to the cable. The equipment is as heavy as a safety block, and is at a sufficient level for practical use. We plan to further reduce the weight to improve usability.

The second development is a safety prechecking tool that utilizes augmented reality. This tool promotes secure work and assists fundamental actions by superimposing messages on the on-site view displayed on a tablet computer or smartphone, which automatically recognizes the on-site conditions, as shown in **Fig. 5**. In current deployment work, a voice-guided safety checking tool is already used; however, it is not always optimized for actual conditions. We believe that our newly developed tool will be helpful for promoting secure on-site work more effectively.

5. Future vision

In this section, I introduce our vision for the future operation and management (OAM) of access network infrastructure. Unlike network transmission and switching devices, most access network infrastructure,

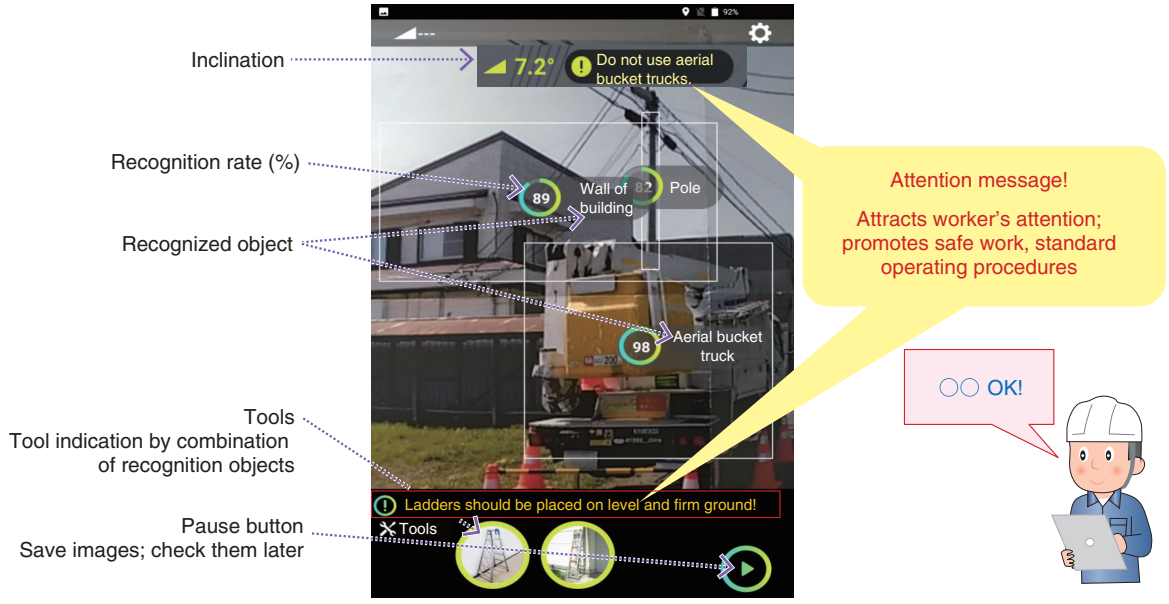
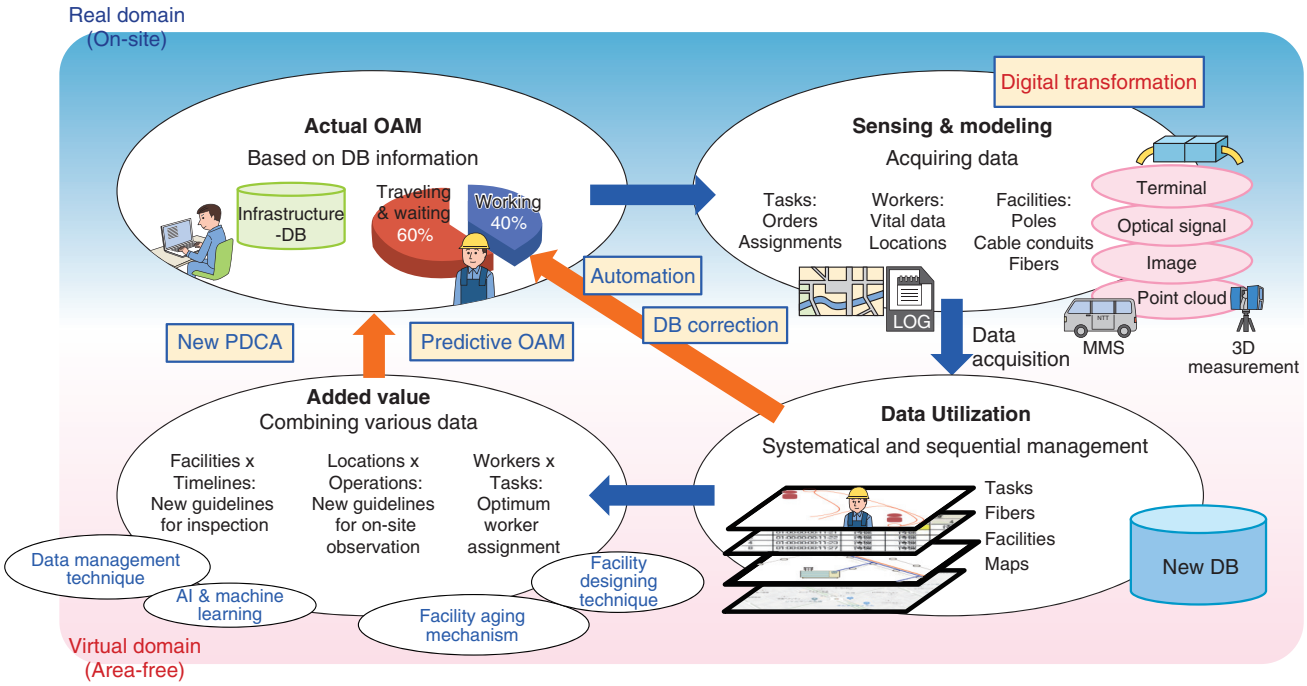


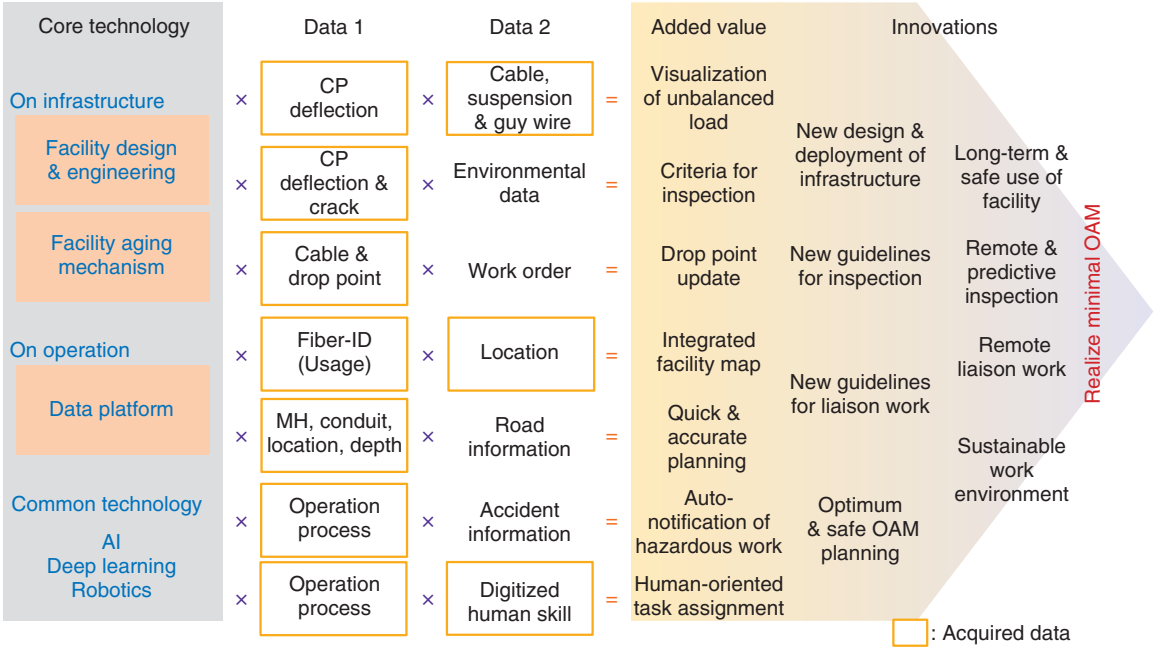
Fig. 5. Precheck with augmented reality technology.

including cables and poles, cannot be remotely monitored. Thus, a large number of resources are needed to manage them. To address this situation, we plan to acquire and digitize various kinds of facility data with MMS and other condition sensing technologies. An overview of our vision and the roadmap for future OAM are respectively shown in **Figs. 6** and **7**. Condition sensing through daily operation work helps improve the integrity of the current database, leading to further automation of operation work. Moreover, the various types of acquired data create added value that changes the operation scheme when the data are combined. For example, unbalanced load conditions in facilities can be visualized by combining our unique know-how for designing constructions, pole slope and bend data, and facility configuration data. This approach leads to the realization of minimal maintenance work such as load balancing by readjusting the cable tension without replacing the facility itself, resulting in a reduction in the investment cost needed for facilities. The combining of various data also has the potential to establish a new standard that will enable minimal on-site inspection. We will continue promoting further R&D to achieve minimal OAM.



DB: database
PDCA: plan, do, check, act

Fig. 6. Our vision for future OAM.



CP: concrete pole
ID: identification
MH: manhole

Fig. 7. Roadmap toward minimal OAM.

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He received a B.E. and M.E. in instrumentation engineering from Keio University, Kanagawa, in 1991 and 1993. He joined NTT in 1993. He is currently engaged in R&D focused on operating techniques for the optical access network.

Perspective on Optical Access Networks

Jun Terada

Abstract

Future optical access networks will require two important functions: high flexibility for mobile networks and Internet of Things networks, and low maintenance to reduce maintenance operations. This article presents the future direction of optical access networks and introduces FASA® (Flexible Access System Architecture), which is an important elemental technology. Optical-mobile cooperative control technology, a concrete example of applying FASA, is also introduced. Finally, FASA applications and standardization activities relevant to the architecture are explained. This article is based on a lecture given during workshops at the Tsukuba Forum 2018 held in October 2018.

Keywords: FASA, mobile network, low maintenance

1. Optical access networks

Recent decades have seen rapid growth in fiber-to-the-home (FTTH) services in Japan, with NTT EAST and NTT WEST having more than 20 million subscribers in total. The NTT Group now faces the challenge of determining how best to respond to changes such as the transition to the B2B2X (business-to-business-to-X) model, the increase in mobile traffic due to the momentous expansion of mobile phone base stations, the emergence of new uses such as the Internet of Things (IoT), and the difficulty in securing maintenance personnel. With today's expanding and diversifying networks, many terminals are connected at the same time, and maintenance personnel will be needed to support them. However, the working population in Japan is expected to decrease year by year and by 2060 to be only 60% of what it is today. Thus, a major issue will be whether there will be sufficient maintenance personnel to continuously and easily maintain the enormous amount of access network facilities. Because access network equipment will be distributed and installed in a great many homes, it will be very important for maintenance personnel to get to the homes quickly when maintenance operations need to be performed.

2. Vision of future optical access networks

Under these circumstances, we believe that *high flexibility* and *low maintenance* will be important key terms for future optical access networks. High flexibility means we must be flexible enough to handle mobile networks, IoT networks, and other networks that are expected to grow in the future. Specifically, we will need to meet new access network requirements such as low latency and massive device connectivity. Low maintenance refers to developing ways to reduce the amount of maintenance that access systems need. The key to putting these two objectives into action is the modularization and virtualization of access functions.

The technical points involved are the separation of transfer functions and service functions and the sharing of optical access networks by overlapping services. The basic idea is to disaggregate the service functions for providing various services onto the upper level, and to use simple general-purpose

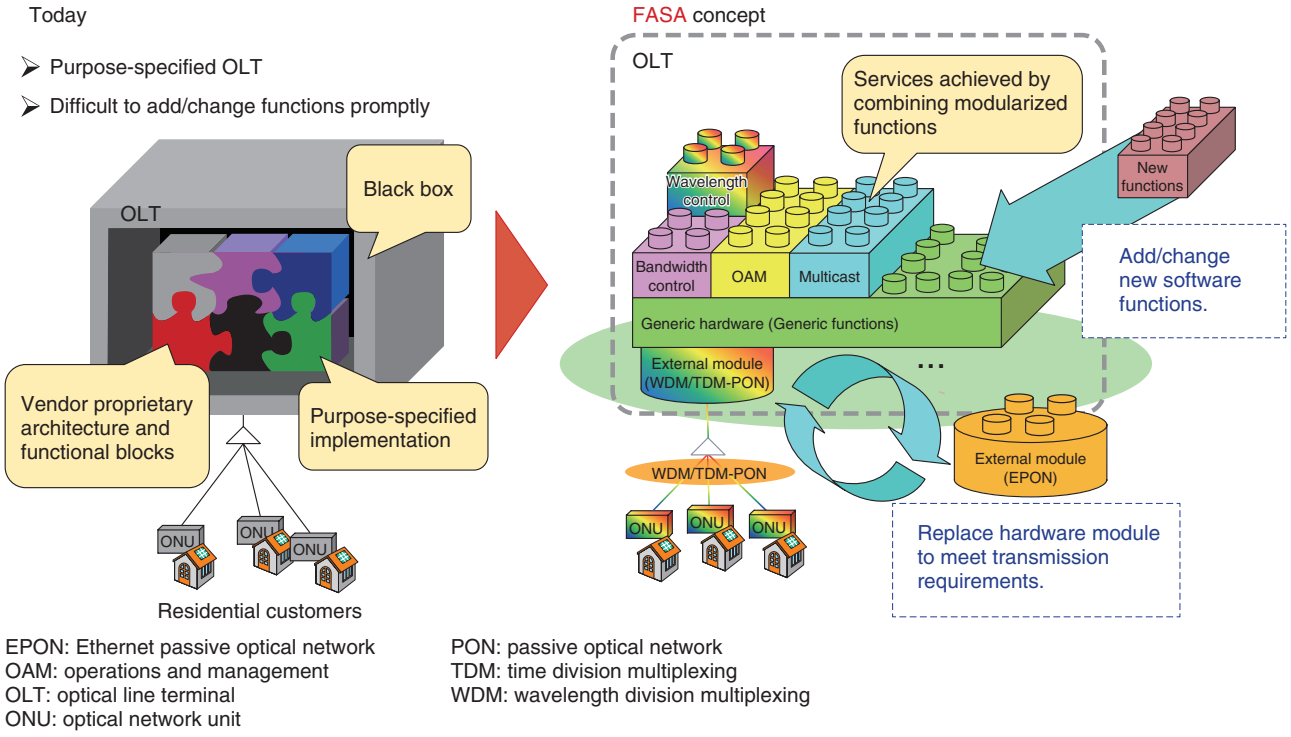


Fig. 1. FASA® concept overview.

hardware as much as possible. Functions can easily be added or removed by concentrating the service functions on the upper level. It is very difficult to change the entire system in order to add new functions in an access network, so it is desirable to disaggregate the service functions as much as possible. New network requirements can be met by adding functions only to the upper level of the systems.

3. FASA® initiatives

NTT Access Network Service Systems Laboratories announced the FASA®*1 (Flexible Access System Architecture) concept [1] in February 2016. This concept is designed to provide a variety of services quickly and economically and to enable continuous development over a long period of time. Current access networks have introduced different access systems for each service, making it difficult to add or change functions. For example, in the case of FTTH, equipment exclusive to both FTTH and NTT are installed and optimized for each.

In contrast, in the FASA concept, services can be achieved by using a combination of functional blocks (software) that are modularized and implemented on general-purpose hardware (**Fig. 1**). This makes it easy to add or change software functionality. Functions that can only be achieved with hardware, such as hardware modules that are compatible with transmission technology, can be handled by switching hardware.

The FASA concept is designed to achieve four goals:

(1) Faster service delivery: Supports operator specific modularized functions and simplifies installation of such functions
(2) Reduction of operating expenses (OPEX): Contributes to the reduction of OPEX by standardizing spare parts and maintenance work
(3) CAPEX (capital expenditure) reduction: Common, affordable hardware for a variety of services
(4) Service continuity: Enables hardware upgrades and replacements without impacting existing functionality

*1 FASA is a registered trademark of Nippon Telegraph and Telephone Corporation in Japan.

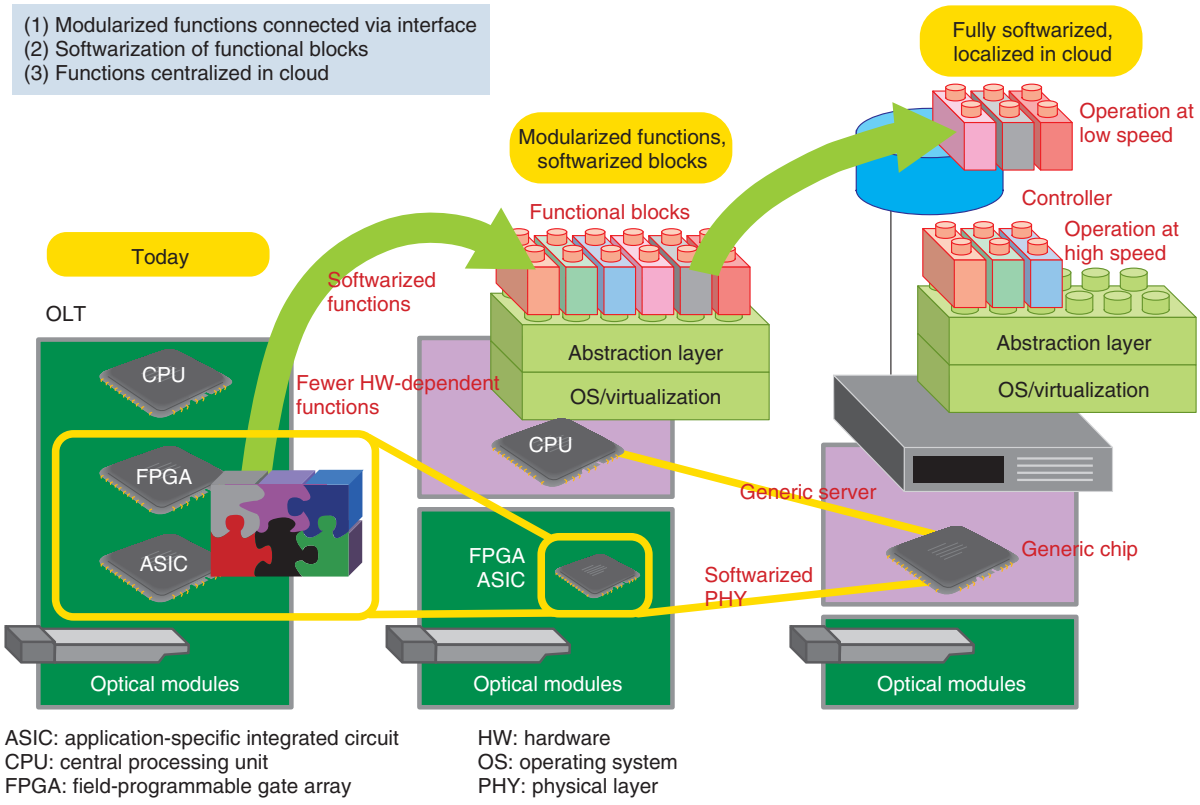


Fig. 2. Key features of FASA technologies.

4. FASA technical features

FASA has three main technical features (**Fig. 2**) as listed below. They are expected to be developed in a step-by-step process in order to achieve FASA utility.

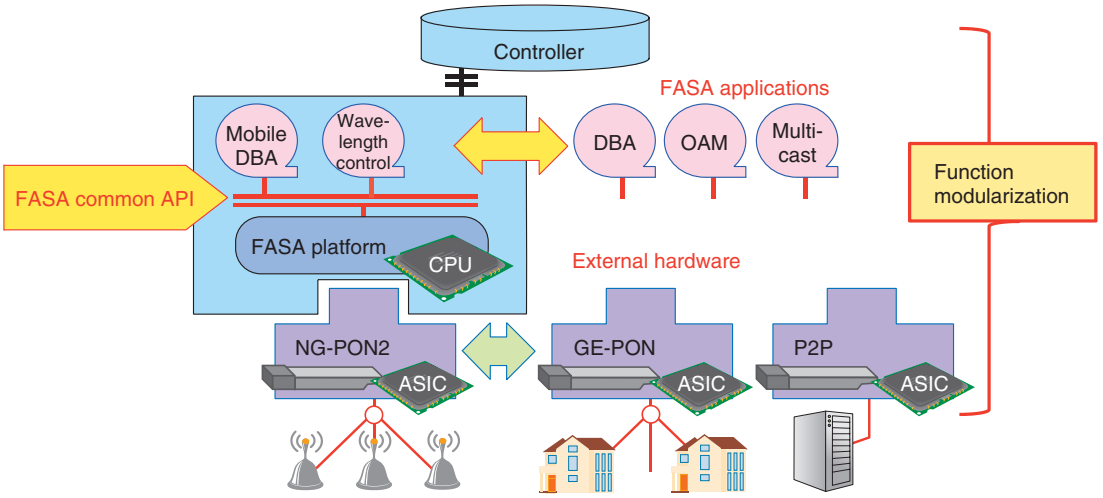
(1) Modularized functions that are connected via interfaces
(2) Softwarization of functional blocks
(3) Functions centralized in cloud

Complex configurations in present systems cause bottlenecks, and functions cannot be easily exchanged. With FASA, however, functions can be modularized (softwarized) from complex configurations and flexibly replaced via interfaces that are defined. Ultimately, we aim to centralize these functions in the cloud. NTT is promoting research and development (R&D) of the FASA common application programming interface (API) to enable various FASA applications to be operated on optical line terminals (OLTs), and R&D of the modularization of functions to enable add/change and dynamic combinations of functions in appropriate blocks, in order to flexibly add/change software functions.

The FASA White Paper was announced in May 2016 (June 2016 for English version) and updated in February 2017 (March 2017 for English version), and a standardization project was proposed to the Broadband Forum (BBF). For example, the dynamic bandwidth allocation (DBA) function can be implemented for mobile bandwidth control as an application that runs on the FASA platform and can be replaced with the DBA application for FTTH. This can be done through the FASA common API (**Fig. 3**).

5. Development direction

The underlying FASA platform and standardized communication protocols must be made available and maintained in an open environment, although features that achieve uniqueness can be developed quickly and flexibly by people who need them. Thus, an environment that can be used in the future is required. Furthermore, in order to reduce maintenance operations as much as possible, it is necessary to be able to concentrate the functions in the upper level as much as possible. To achieve these goals, the



GE-PON: Gigabit Ethernet PON
NG-PON2: Next-Generation PON Stage 2
P2P: point to point

Fig. 3. FASA common API.

platform and API must be open and standardized. We will work with operators not only in Japan but also globally to develop this system as a common architecture.

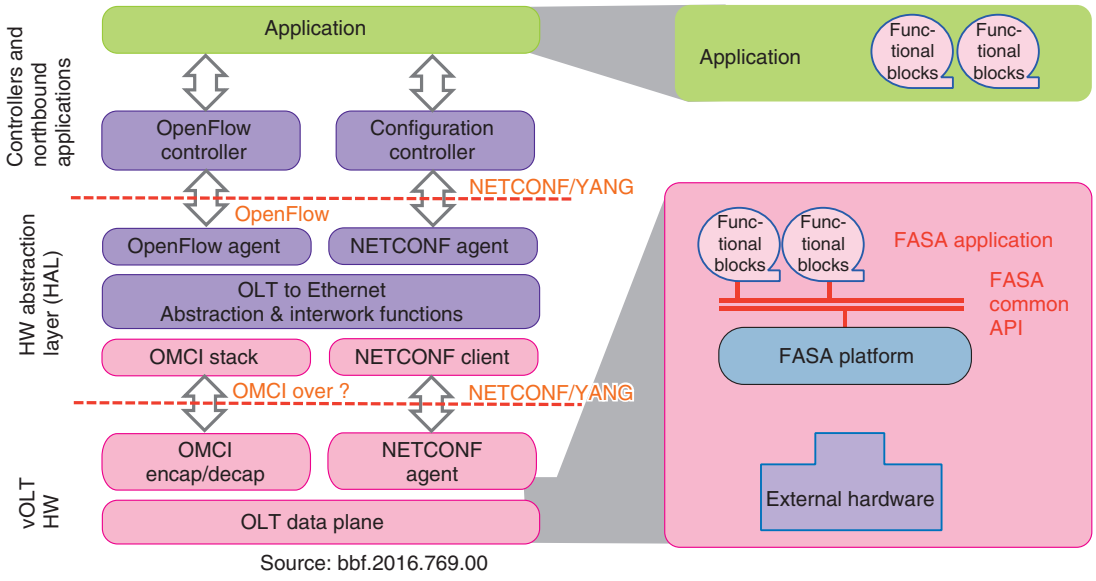
As an example, FASA and the SEBA[*2] platform released by the open source software organization Open Networking Foundation (ONF) are complementary, and we are aiming for virtualization that combines FASA and SEBA (**Fig. 4**). The goal is not only to provide flexible control and settings through virtualization but also to create architectures that can be flexibly changed, for example, by adding functions that require high-speed operation.

6. Optical-mobile cooperative control

When combined with FASA, the application area of optical access systems can be expanded to enable optical-mobile cooperative control. With the increasing number of base stations in future mobile networks, it has become a challenge to efficiently accommodate mobile base stations connected by optical fiber. Coordinated operation of optical access and mobile signal control enables optical access networks to achieve low latency and to be used in mobile networks, and to efficiently accommodate a large number of base stations. This was announced in a press release issued on February 14, 2018 [2], and it means that technology for efficiently accommodating mobile base stations using optical access has already been established.

The key point is the Cooperative DBA. A mobile base station functioning as a central unit (CU) notifies an OLT of user terminal scheduling information such as the amount of transmission data and accelerates the transmission permission of a passive optical network (PON) system to achieve low delay (**Fig. 5**). To enable PON systems to transmit upstream, the optical network unit (ONU) sends a transmission request to the OLT after the data arrive at the ONU, and the DBA controls the transmission timing of each ONU by shifting the timing with other ONUs. This increases the delay between the arrival of data and the actual transmission. Since the CU shares the radio frequency with multiple terminals, it performs upstream transmission scheduling in a manner similar to that of PON systems. This radio scheduling information is received by the OLT, and the PON upstream transmission permission is issued in advance in accordance with the radio upstream transmission timing to reduce the delay time. As a result, the uplink delay time, which used to be about 1 ms, has been reduced to less than 50 μs. This was demonstrated at the BBF meeting.

*2 SEBA: SDN (software-defined networking) Enabled Broadband Access platform on a variant of R-CORD (Residential Central Office Re-architected as a Datacenter).



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Encap/decap: encapsulation and decapsulation
NETCONF: Network Configuration Protocol
OMCI: optical network terminal management and control interface

YANG: A data modeling language for NETCONF. YANG is an acronym for Yet Another Next Generation.

Fig. 4. FASA and SEBA.

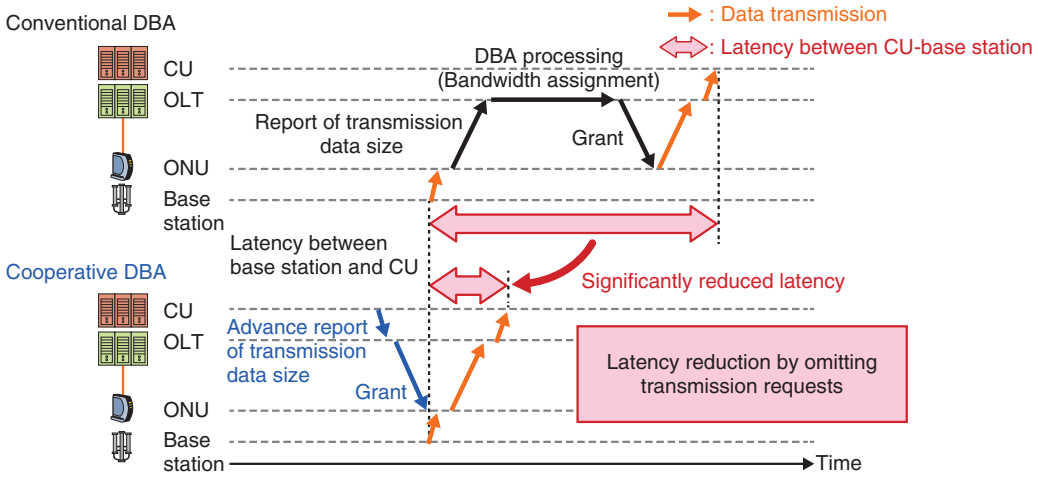
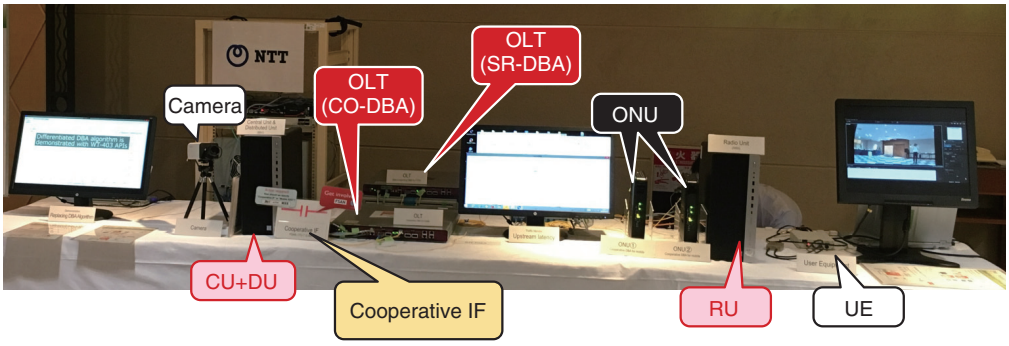


Fig. 5. Cooperative DBA.

In the demo, we compared the delay time between the conventional DBA for FTTH (SR-DBA: Status-Report-DBA) and the DBA for mobile (CO-DBA: Cooperative DBA) in the end-to-end configuration of a mobile system using an LTE (Long-Term Evolution) dongle. This demo was well received by BBF members (**Fig. 6**).

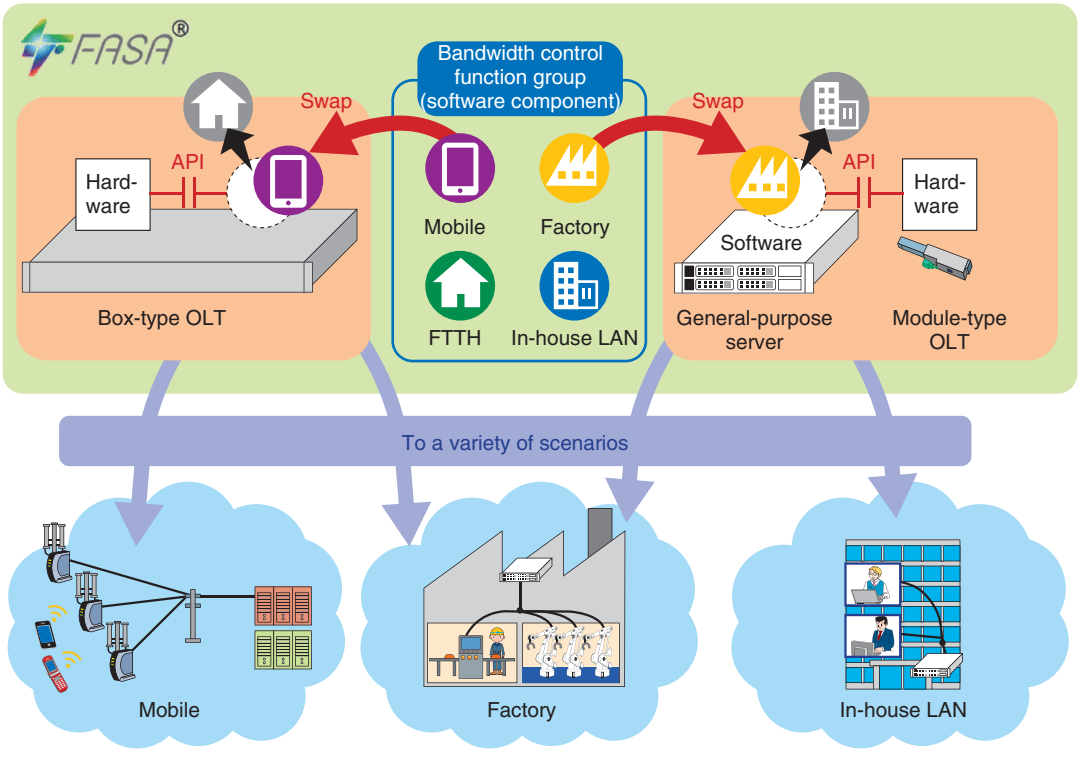
7. Demonstration of DBA function software modules

Among the various functions required for the access system, the DBA function provides high processing performance in real time, so it was considered difficult to replace it by software modularization. A



CU: central unit
DU: distributed unit
IF: interface
RU: radio unit
UE: user equipment

Fig. 6. Demonstration at BBF meeting.



LAN: local area network

Fig. 7. Experimental demonstration on replacing DBA function.

demonstration was conducted in which the DBA function was replaced with software modules in accordance with the usage scenario of the optical access system by two different OLT prototype models with defined APIs (**Fig. 7**). The box-type OLT shown in the figure is expected to be used in environments such as the central office of telecommunications carriers. It is expected to be used to provide conventional FTTH services and in 5G (fifth-generation) mobile systems, which require low latency, in combination with the aforementioned optical-mobile cooperative control.

The module-type OLT shown in the figure is a small module that does not contain all the conventional OLT functions—only those that the hardware is required to achieve. It is used in combination with

a general-purpose server with functions that can be achieved with software. It is possible to start on a small scale, so it is expected to be applied to local area networks in factories, universities, and office buildings.

8. Promotion of standardization

It is important for the Cooperative DBA to be able to cooperate without depending on the CU vendor and that it can be installed in commercially available OLTs. We are promoting two standardization projects to achieve this. One involves standardizing the cooperative handling of scheduling information between the CU and OLTs, which the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) and the Full Service Access Network (FSAN) Group are promoting. The other is a BBF project that involves standardizing the DBA algorithm and the IF (interface) between the common processors. Both standardization issues are being discussed with major international operators and vendors. We are working to expand this globally.

9. Future development

For future optical access networks, we plan to promote R&D to put the key terms high flexibility and low maintenance into action. R&D of optical access networks for 5G mobile systems will be carried out as FASA development continues in order to flexibly construct access network systems. We will participate in standardization activities at FSAN/ITU-T and BBF and start development activities at ONF to continuously develop software functions that can be changed flexibly. We will also promote R&D of optical access through discussions with various stakeholders.

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Simulation Technology for Analysis and Virtual Fabrication of High-speed Opto-electronic Modules

Hiromasa Tanobe and Atsushi Aratake

Abstract

In the last decade, demand for high-speed data transmission has been growing dramatically not only for datacenter traffic but also for mobile and fiber-optic access networks. To meet the demand, NTT Device Innovation Center (DIC) has been developing opto-electronic modules, including a receiver optical subassembly, transmitter optical subassembly, intradyne coherent receiver, and a coherent driver modulator. NTT DIC has been working to accelerate the deployment of these opto-electronic modules on actual fiber-optic networks and has developed technology enabling full-digital virtual fabrication of high-speed opto-electronic modules on computer. In this article, we describe the latest simulation technology, focusing in particular on the opto-electronic modules and their capabilities and performance.

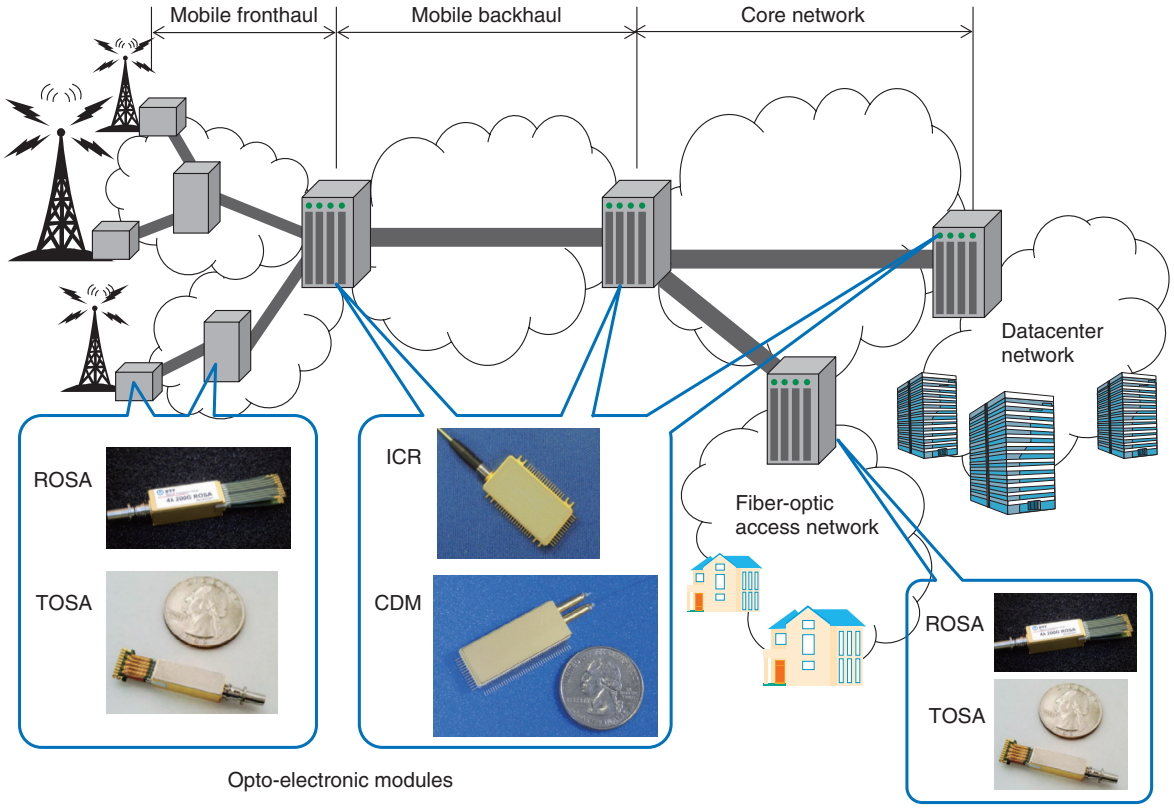
Keywords: opto-electronic modules, simulation, virtual fabrication, 5G mobile networks, fiber-optic access networks

1. Introduction

Fiber-optic data transmission technology is crucial for building both long-haul and short-haul transmission networks. For instance, as traffic on mobile and fiber-optic access networks continues to escalate, the capacity of both short- and long-haul fiber optic networks should be increased simultaneously. Recent aggressive investment in the fifth-generation wireless communication (5G) networks has become the key factor in regard to accelerating this undeniably strong trend in optical-fiber cable manufacturing and network expansion. According to an announcement made by the Georgia Department of Economic Development last year [1], the manufacturing capacity of optical fiber cables by a major global optical fiber manufacturer was predicted to double by the end of 2019 in order to cope with the rapidly expanding deployment of 5G mobile fronthaul and backhaul networks. The basic architecture of 5G mobile and fiber-optic access networks is shown in **Fig. 1**. In the next few years, optical transceivers with the capacity for high-data-rate transmission will be fully deployed on these networks.

Moreover, additional trends are occurring with the optical transceiver segments. A large number of million-scale optical transceivers are used in fiber-optic networks. Thus, optical transceivers are essentially key components enabling high-speed conversion between optical signals and electrical signals. Furthermore, with requirements to downsize optical transceivers, increase data rates, and reduce power dissipation, the optical transceiver has to simultaneously attain high speed, miniaturization, and integration. However, some natural laws that limit downsizing make these improvements difficult, especially in opto-electronic modules such as receiver optical subassemblies (ROSAs) [2], transmitter optical subassemblies (TOSAs) [3], intradyne coherent receivers (ICRs) [4], and coherent driver modulators (CDMs) [5], which are installed in the optical transceivers.

As data speeds increase, opto-electronic modules come under more stress and exhibit signal power loss and crosstalk aggression from densely packed opto-electrical and microwave parts due to natural electromagnetic effects. These natural electromagnetic



CDM: coherent driver modulator
ICR: intradyne coherent receiver
ROSA: receiver optical subassembly
TOSA: transmitter optical subassembly

Fig. 1. Basic 5G network architecture and various deployed opto-electronic modules.

phenomena degrade the signal integrity performance of the opto-electronic modules. Therefore, cut-and-try methods are commonly adopted in the actual development stage for downsizing. However, in view of the limited resources available for simultaneous development of various types of opto-electronic modules, it is imperative to break away from conventional development methodologies and to develop a novel procedure in the face of such inherently complicated limitations. This is our primary reason for pursuing the development of full-digital virtual fabrication on computer.

2. Preliminary analysis in signal integrity issues

Various optical transceivers and related opto-electronic modules such as ROSAs, TOSAs, ICRs, and CDMs, which were described in the previous section, are used in fiber-optic transmission networks. These opto-electronic modules are being miniaturized, and therefore, designers of optical modules need to concentrate on maintaining signal integrity performance in relation to electromagnetic issues.

The relationships between signal speeds and their quarter-wavelength in a microwave region are shown in **Fig. 2**. The quarter-wavelength rule is well known in the field of microwave design, and this must also be taken into account when building these opto-electronic modules. In the case of a 100-Gbit/s (25 Gbit/s x 4-lambda) TOSA [2], the package width is approximately a few millimeters, which is almost the same as the quarter-wavelength of 25 Gbit/s, as shown in Fig. 2. Generally, the TOSA is assembled with many different parts, including electro-absorption modulator integrated distributed feedback (EA-DFB) lasers, microwave components, and direct current (DC) power delivery parts. All the signal nets and DC power drains are accommodated densely in one

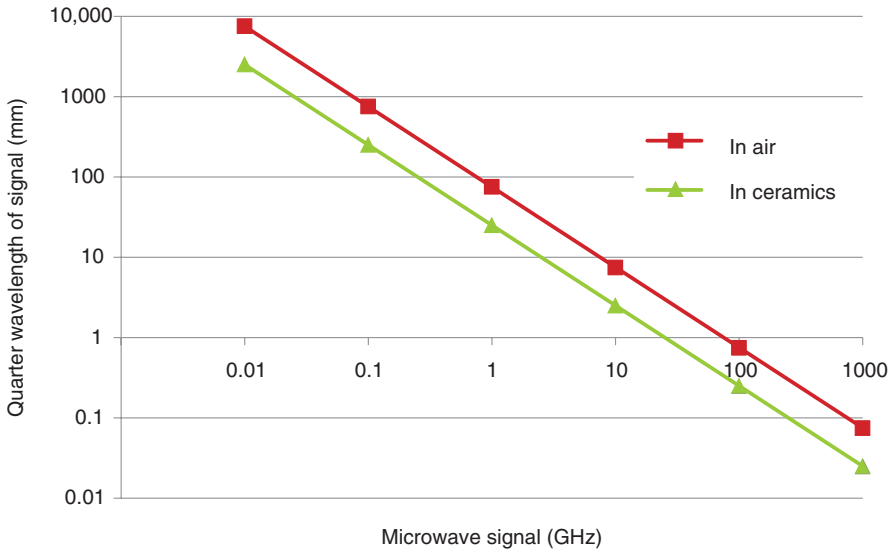
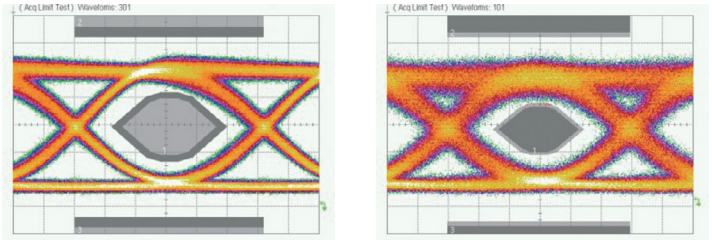


Fig. 2. Signal speed dependence of quarter-wavelength in microwave signals transmitted through air and through ceramic material.



(a) Only one lane activated (b) All four lanes activated

Fig. 3. Measured eye diagrams of 25-Gbit/s optical output signal corresponding to one signal lane under different operating conditions.

package. The high-density assembly easily induces crosstalk aggression due to coupling between adjacent signal nets, as well as microwave resonance and ground bouncing if quarter-wavelength microwave rules are not taken into account when designing the modules.

Eye diagrams when only a single lane or all four lanes were activated are shown in **Fig. 3**. In this case, each lane corresponds to a different signal net in the TOSA. As shown in the figure, there was relatively strong distortion when all four lanes were activated. However, the geometric structures in the open part of both eyes were almost the same. There were no crushing deformations in the center of the eye diagram even under the four-lane operating condition. The remarkable differences between the two cases were the eye opening ratio and the amount of amplitude distortion at high level, which determined the signal-to-noise ratio. Generally, under the condition of crosstalk aggression between different adjacent channels, eye diagrams of victim channels are distorted around the center of the eye diagram, and the shape changes from its original shape to a triangle or another geometrically complicated shape. Therefore, improving the eye diagrams in this TOSA was not as simple as just reducing the crosstalk between different adjacent channels. We had to take microwave resonance and ground bouncing into account while paying attention to quarter-wavelength rules caused by high density assembly in a small package.

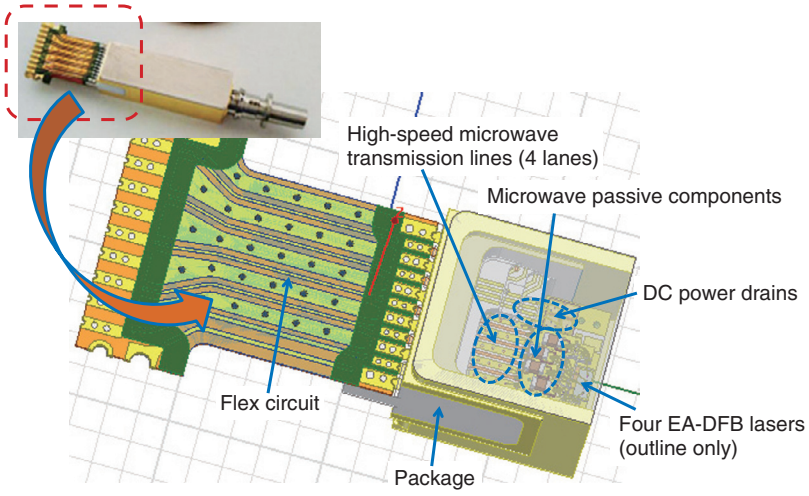


Fig. 4. 3D simulation model for 100-Gbit/s (25 Gbit/s x 4-lanes) TOSA.

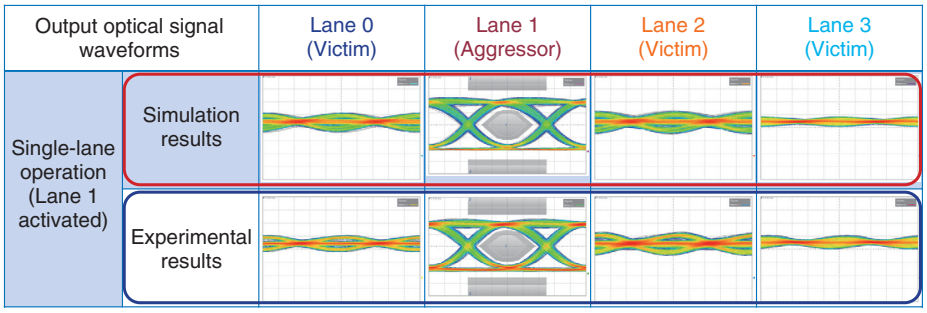


Fig. 5. Eye diagrams and cross-talk aggression optical signals in victim lanes.

3. Modeling and simulating

As discussed, there is a strong trend toward miniaturizing the size of optical modules. Thus, conventional deployment methodologies such as cut-and-try are not appropriate due to limitations of free space for assembly modifications in small packages. To achieve a breakthrough to meet this challenge, we built a novel full-digital optical module simulator by combining and modifying different commercial microwave simulators. This newly developed simulator is capable not only of showing dynamic characteristics in small-signal and large-signal analyses, including eye diagram output functions, but also of indicating areas of signal integrity degradation on a three-dimensional (3D) model.

A simulation model of the 100G TOSA is shown in **Fig. 4**. As demonstrated in this model, four lanes were tightly assembled in one package with many microwave passive components, DC power drain parts, and EA-DFB lasers.

Eye diagrams and crosstalk aggression optical signals at a victim lane are shown in **Fig. 5** with one lane activated in the TOSA. Eye diagrams with all four lanes activated are shown in **Fig. 6**. As shown in Figs. 5 and 6, all of the simulation results correlated relatively well with the experimental results. Moreover, this simulator identified the root cause of the signal integrity distortion in the 3D model. We confirmed that there was an area with ground-bouncing noise located in the deep part of the TOSA package on the 3D model. This area apparently had a unique structure, which broke the quarter-wavelength rules.

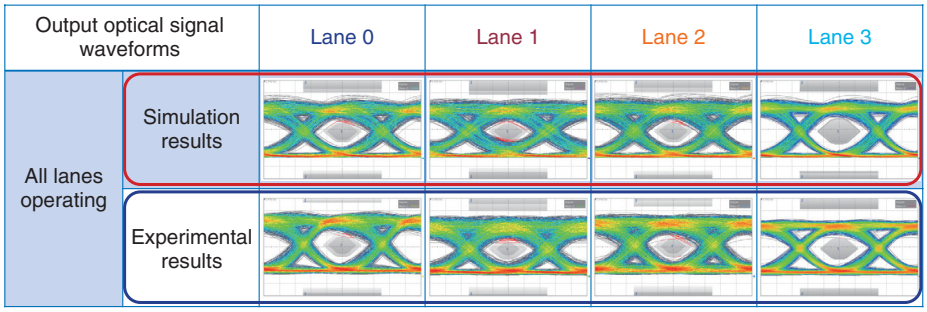


Fig. 6. Eye diagrams with all four lanes in operation.

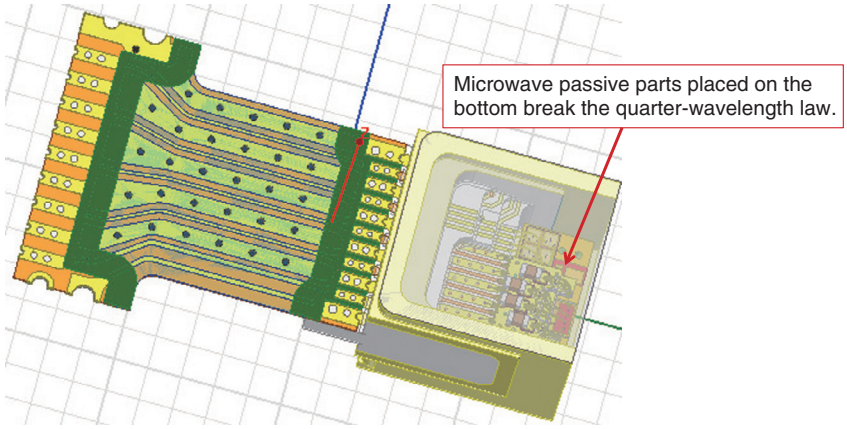


Fig. 7. Simulation analysis results showing parts that break the microwave quarter-wavelength law.

4. Virtual fabrication

As described in the previous section, this newly developed simulator successfully identified the root cause of signal integrity distortion in the TOSA. Moreover, the capabilities of the 3D-model simulating functions enable this simulator to virtually fabricate optical modules on a computer.

After the first simulation, we found that a microwave passive component, which broke the quarter-wavelength law, was initiating the ground bouncing, as shown in **Fig. 7**. With the conventional cut-and-try methodology, it is impossible to rapidly modify or replace the parts since the allocated place is nearly at the bottom of the TOSA. In contrast, our simulator rapidly and easily solved this problem. After the 3D modeling of a correct microwave part, we were able to fabricate a new TOSA virtually.

Eye diagrams of the original conditions and the virtually fabricated TOSA are shown in **Fig. 8**. A new piece of metal was placed on the ground-bounced microwave parts, and the microwave resonance between two microwave parts was successfully suppressed by the virtual fabrication. As can be seen in Fig. 8, large modification of the TOSA was not necessary to obtain the eye diagram. Thus, both the simulation technology and the virtual fabrication technology enabled us to minimize time and costs effectively during our opto-electronic module development at NTT Device Innovation Center.

5. Conclusion and future prospects

We described newly developed simulation technology used for studying and developing opto-electronic modules, focusing in particular on a 100-Gbit/s (25 Gbit/s x 4) TOSA. This simulation technology features not only dynamic performance analysis but also virtual fabrication on a computer. This technology is expanding the scope of our opto-electronic module

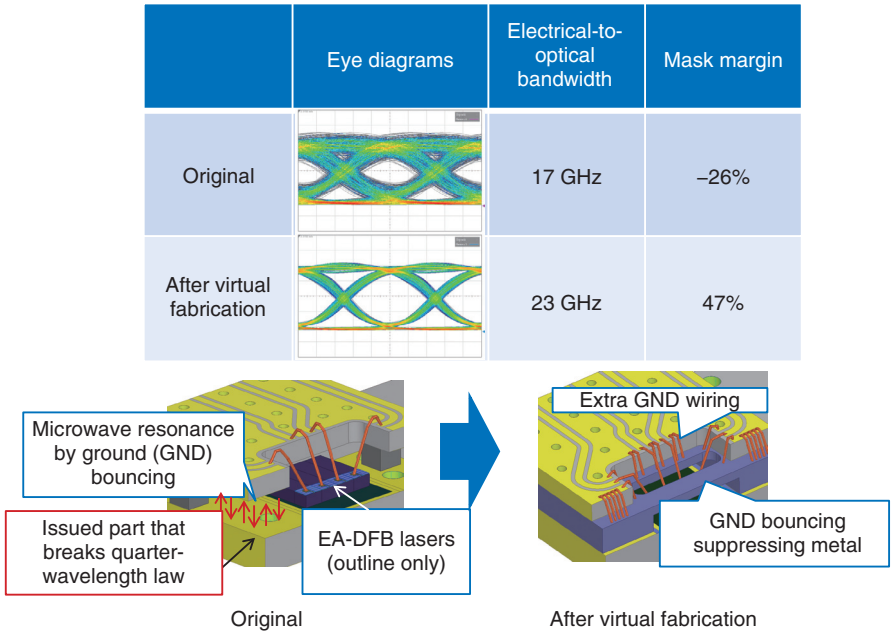


Fig. 8. Virtual fabrication of components and simulation results showing improved eye diagram.

development, which involves ROSAs, ICRs, CDMs, and other types of modules, and successfully shortening the development period. We also plan to build high-performance computing systems enabling the simulation and virtual fabrication of beyond-100-GHz-bandwidth opto-electronic modules.

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Results of the International Telecommunication Union (ITU) Plenipotentiary Conference 2018

Hideyuki Iwata

Abstract

The International Telecommunication Union (ITU) Plenipotentiary Conference was held from October 29 to November 16, 2018. This article introduces the results of the elections of senior officials and the member states of the Council of the ITU, and discussions of the main agenda items.

Keywords: ITU, ITU Plenipotentiary Conference, ITU Charter

1. Overview of the conference

The International Telecommunication Union (ITU) Plenipotentiary Conference was held at Dubai World Trade Centre, Dubai, United Arab Emirates, from October 29 to November 16, 2018. It was attended by over 2500 delegates from 182 states, including ministers in charge of telecommunications (**Photo 1**). Held every four years, this conference is the top decision-making body of the ITU with the participation of representatives from all ITU member states. From Japan, 39 delegates from both the government and the private sector took part in it, the delegation being headed by State Minister Yukari Sato and Vice-Minister for Policy Coordination Katsuya Watanabe, both from the Ministry of Internal Affairs and Communications.

2. Results of the elections of senior officials and member states to serve on the Council

The elections for the Secretary-General and Deputy Secretary-General were held on November 1. Houlin Zhao of China was re-elected Secretary-General with 176 votes out of 178 votes cast. Malcom Johnson of the United Kingdom was re-elected Deputy Secretary-General with 113 votes out of 178 votes cast. Mr. Brahima Sanou of Burkina Faso, current Director of the Telecommunication Development Bureau (ITU-D), received 65 votes.

The elections for Director of the Radiocommunication Bureau (ITU-R), Director of the Telecommunication Standardization Bureau (ITU-T), and Director of ITU-D were held on November 2. Mario Maniewicz of Uruguay was elected as the new Director of the Radiocommunication Bureau with 108 votes out of 176 votes cast in the second round of the election, while István Bozsóki of Hungary received 64 votes. Chaesub Lee of the Republic of Korea was re-elected Director of the Telecommunication Standardization Bureau with 174 votes out of 179 votes cast. Doreen Bogdan-Martin of the United States was elected as the new Director of the Telecommunication Development Bureau with 95 votes out of 179 votes cast in the first round of the election, in which the required majority was 89. She is the first female director in the ITU.

The elections for the members of the Radio Regulations Board and the member states of the Council were held on November 5. Akira Hashimoto, NTT DOCOMO Counsellor for Standardization, received 169 votes, which was the highest among all the candidates, and was elected as a member in the Asia and Australasia Region. Japan was elected a Council member state by receiving 166 votes, the second highest in the Asia and Australasia Region. Japan has now been elected a member state 12 times consecutively.

Photo 1. ITU Plenipotentiary Conference 2018.

3. Results of discussions of items on the main agenda

Discussions were held day in and day out, including on the weekend days. The discussions on the day before the final day continued up to 5:30 am the following day. The main results of the discussions are as follows.

(1) ITU Charter and Treaties

The Asia and Australasia Region and the Africa Region submitted a proposal that the ITU Charter and treaties not be revised unless absolutely necessary. The proposal was adopted without modification.

(2) Strategies and financial plan for 2020–2023

The Council submitted a plan that describes ITU activity policies for the four years starting in 2020. The Middle East and African Regions proposed to add the words, "online privacy," but this proposal was not accepted. Based on the strategies described in the plan, the activities that ITU needs to tackle in an effort to achieve the Sustainable Development Goals will be reorganized, and financial allocations and the activities of each sector will be defined.

(3) Internet-related issues

The Middle East Region submitted a proposal that the Digital Object Numbering Authority (DONA) Foundation* be referred to alongside the Internet Corporation for Assigned Names and Numbers (ICANN) and other Internet-related organizations and also submitted a proposal that was intended to transfer the role of ICANN to the ITU. From the viewpoint of ensuring technical neutrality and the clarification of the roles of different organizations, Japan, the US, and the European Region opposed the reference to DONA and were thus in conflict with the positions of the Middle East and African Regions. After a prolonged discussion, a modified resolution was adopted that made no reference to DONA and retained the current scope of ITU's role but gave due attention to the concerns of developing countries.

(4) Security-related issue

There was a conflict between two groups. The Middle East and African Regions want to actively promote the formation of international rules such as new treaties for ensuring cybersecurity, while Japan, the US, and the European Region want to respect the sovereignty of individual states and see the ITU's role as focusing on raising awareness about security and building security capabilities.

(5) International Telecommunication Regulations (ITRs)

The Middle East and Russian Regions made a proposal to revise the ITRs in 2020. The European

* DONA Foundation: A non-profit organization founded for the purpose of providing services such as technical coordination of Digital Object Architecture (DOA) for the promotion of the public interest, software development, and administration and operation of the Global Handle Registry.

Region submitted a proposal that seeks to terminate the review of ITRs, while the African Region, China, and the US proposed to continue the review of ITRs.

There was a dispute over whether it is necessary to revise ITRs and whether future review results are to be considered a prerequisite for revision of the ITRs. In the end, the issue of revising ITRs was not resolved, and a modified resolution was adopted to continue reviewing ITRs.

(6) Formulation of a new resolution about artificial intelligence (AI)

The Middle East Region proposed the creation of a new resolution about AI, while the European Region and the US proposed a resolution based on a neutral position. There was a dispute over whether to explicitly state that the scope, policy, and regulations of AI are outside the scope of the ITU, with a result that no resolution was created.

(7) Formulation of a new resolution about Over the Top (OTT)

The African, Middle East, European, and Russian Regions, and the US and Brazil proposed the creation of a new resolution about OTT services. The Middle East and Russian Regions proposed to study OTT for formulating regulations or international public policies, but Japan, the European Region, the US, and some other countries opposed the proposal. In the end, the relevant text was deleted, and a new resolution that emphasized continuation of the study within the scope of the ITU and coordination with related organizations and stakeholders was adopted.

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He received a Ph.D. in electrical engineering from Yamagata University in 2011. From 1993 to 2000, he conducted research on high-density and aerial optical fiber cables at NTT Access Network Service Systems Laboratories. Since 2000, he has been responsible for standardization strategy planning for NTT research and development. He has been a delegate of IEC Subcommittee 86A (optical fiber and cable) since 1998 and of the ITU-T (Telecommunication Standardization Sector) Telecommunication Standardization Advisory Group since 2003. He is a vice-chair of the Expert Group on Bridging the Standardization Gap in the Asia-Pacific Telecommunity Standardization Program Forum. In 2004, he received an award from the IEC Activities Promotion Committee of Japan for his contributions to standardization work in IEC.

Introduction of Salt-damage Maps

Technical Assistance and Support Center, NTT EAST

Abstract

Outdoor communication facilities are exposed to damaging weather and climate conditions and therefore require regular inspection and maintenance to ensure they operate safely and reliably. Such facilities also need to be placed in the optimum locations to reduce the potential damage from the exposure while best supporting telecommunication services. This article describes a map developed by the Technical Assistance and Support Center that illustrates the degree of damage from salt in different areas of Japan. This is the fifty-first article in a series on telecommunication technologies.

Keywords: salt damage, steel pole, corrosion

1. Introduction

Outdoor communication facilities are constantly subjected to the effects of the weather in various natural environments, and they are therefore at risk of deteriorating. Materials such as metals, concrete, and plastics are used for communication facilities, with metals being widely used for overhead structure supporting equipment such as suspension lines and metal fittings. Metal deteriorates due to corrosion in the form of rusting. Since such corrosion involves thinning of the metal, it greatly reduces the structural strength of the metal and may lead to serious facility failures and accidents. Accordingly, it is necessary to take appropriate measures such as confirming the amount of deterioration by inspection and implementing remedial measures.

Salt is known to be the main factor causing corrosion outdoors. It gets scattered on the land in the form of fine sea-salt particles carried on the wind blowing from over the sea. Although the concentration of scattered salt is low inland, the coastline is a salt-damage environment in which metals are easily corroded. Salt damage can be expressed in the form of a map (salt-damage map, hereafter) that illustrates the degree of salt damage in a certain environment.

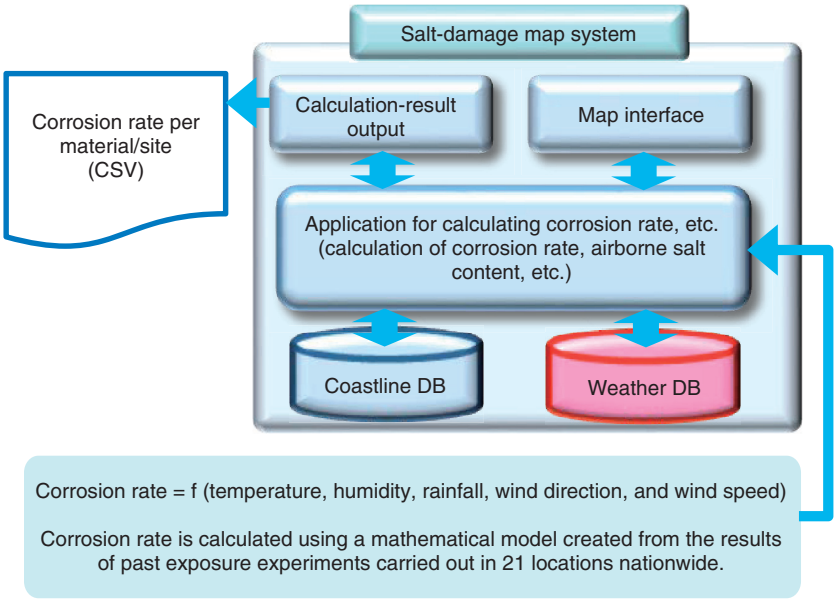
The Material Engineering Group of NTT EAST Technical Assistance and Support Center is investigating the cause of specific failures of communication facilities caused by various kinds of deterioration and striving to prevent the recurrence of such failures by applying our expertise. In this report, we introduce a salt-damage map as an approach to countering corrosion deterioration of communication facilities.

2. Overview of salt-damage maps

The salt-damage map system provided by the former NTT Energy and Environment Systems Laboratories to NTT EAST in 2011 is configured as shown in **Fig. 1**.

This system has a function for calculating the zinc corrosion rate at an arbitrary point and displaying it on a map. The calculation is based on the relationship between the corrosion rate and the distance from the coast and weather conditions modeled using the results of exposure experiments on galvanized steel (used as a corrosion countermeasure for communication facilities) that were conducted at 21 points nationwide by the Technical Assistance and Support Center since the era of the Nippon Telegraph and Telephone Public Corporation (the former NTT).

The corrosion rate of zinc plating is calculated using a mathematical model into which weather data such as temperature, humidity, and distance from the coast are input. To calculate the corrosion rate, weather



CSV: comma-separated values
DB: database

Fig. 1. Configuration of salt-damage map system.

data for the last 50 years or so (since 1969) collected by weather observation stations operated by the Meteorological Agency are used, and weather conditions supplemented by the weighted averages, that is, data weighted in regard to three weather observation stations located nearest to the point to be calculated, are applied. With the display interval taken as 100, 200, and 400 m for distances from the coast of up to 2 km, 2 to 4 km, and 4 to 5 km, respectively, the corrosion rate of zinc at a height 6 m from the ground is calculated and output as a result.

3. Refinement of salt-damage map using latest weather data

The weather observation stations providing the weather data used in a conventional salt-damage map are placed in about 200 locations and scattered at distances of more than 15 km on average; consequently, the weather data complemented by the weighted average for the three nearest weather observation stations contained large errors. In recent years, due to the development of meteorological technology, weather data throughout Japan can be obtained as a 1-km mesh. It was thus possible to refine the salt-damage map by recalculating it using weather data for 10 years beginning in 2007 (**Fig. 2**).

4. Plans to utilize the new salt-damage map

The salt-damage maps are expected to be useful in carrying out both engineering work and maintenance, as described in this section.

4.1 Engineering work

The application area of steel poles has been expanded in line with a revision to the application of concrete poles for single utility poles that was carried out in June 2017. In areas where concern about salt damage is high, steel poles completely coated in resin (known as uncorrodible (UC) steel poles) are used. The application area of UC steel poles is determined based on the existing facilities and past corrosion deterioration; however, the placement of these poles often varies depending on the people deciding where to put them.

The use of the salt-damage map to determine the application area of UC steel poles is an effective way to solve this problem. For example, rather than determining the application area by defining the area within 1-km or less from the coast as the salt-damage area, applying quantitative data and past findings will make it possible to determine the area according to the actual corrosion rate at the site (**Fig. 3**). As a result, it is possible to reduce the risk of mistakenly

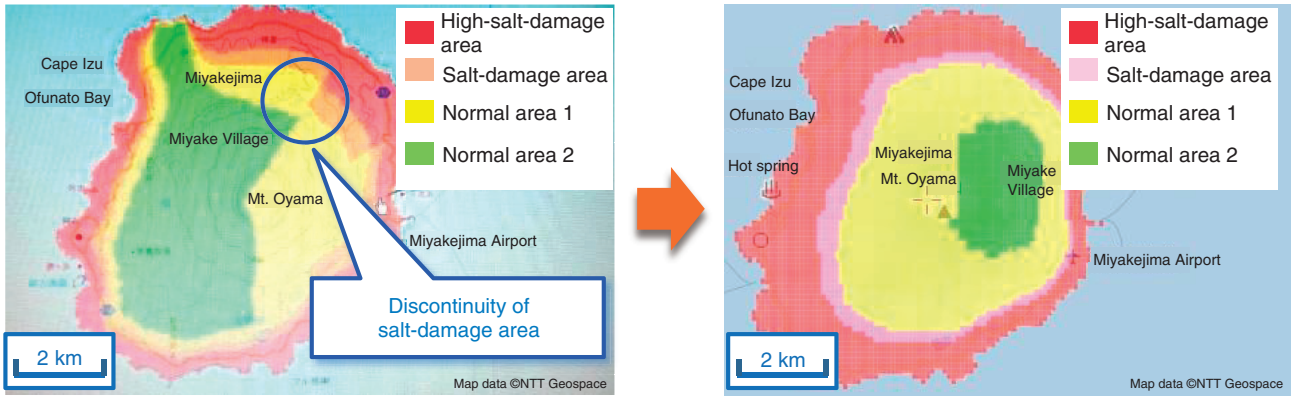


Fig. 2. Refinement of salt-damage map (Miyakejima, Tokyo).

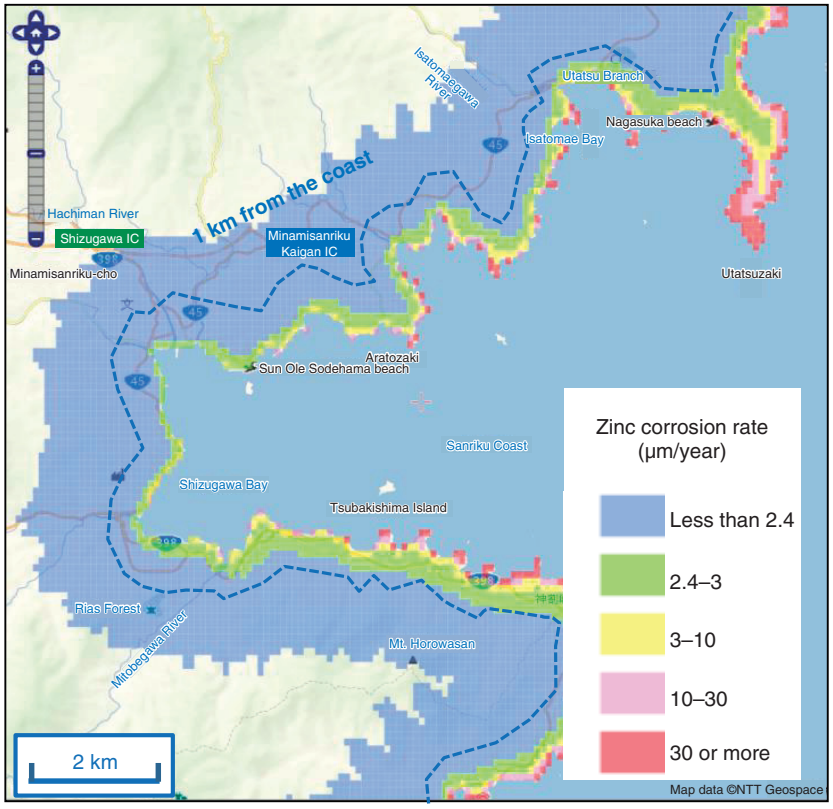


Fig. 3. Example of corrosion rate displayed on a map.

applying steel poles for general areas in salt-damage areas or applying UC steel poles in general areas.

Moreover, as for compensation for pole-relocation work, determination of the application area of UC steel poles affects the calculation of compensation for the relocation; accordingly, it is sometimes desirable to utilize a salt-damage map so that the application area can be determined more carefully.

4.2 Maintenance work

In areas of high salt concentration, zinc-plated overhead metal fittings may corrode about 10 years

Fig. 4. Examples of corrosion in high-salt-damage areas.

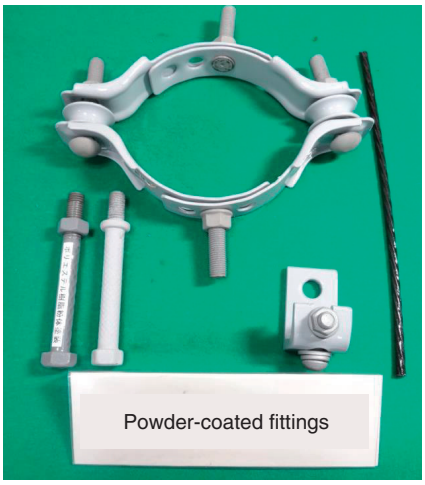


Fig. 5. Powder-coated overhead metal fittings.

after installation and reach the level for renewal (**Fig. 4**). In these high-salt-damage areas, powder-coated metal fittings are effective as countermeasures against corrosion (**Fig. 5**). Powder coating is a method of coating an object with a powdery paint without using a solvent, and it has been used since 2005 as an anticorrosion paint for ground-level and underground steel poles.

An example of determining the application areas of corrosion-resistant facilities and fittings using salt-damage maps is shown in **Fig. 6**. The region where zinc corrosion is 3 μm/year or more indicates where UC steel poles would be placed, and the region where zinc corrosion is 30 μm/year or more (high-salt-damage area) indicates where powder-coated fittings would be used. The areas with high salt damage that require such countermeasures may be known empirically by some people doing the actual work who are familiar with local circumstances. However, introducing the salt-damage map makes it possible to identify such areas more clearly and reliably without any omissions.

5. Implementation of trials to introduce new salt-damage maps

A trial utilizing salt-damage maps as part of a weather database for maintenance bases of access facilities is currently underway. After the results of the trial are confirmed, we plan to incorporate the new salt-damage maps as a function of the weather database in NTT's company-wide system. Moreover, we want to make it available to practitioners of telecommunication construction companies so that they can utilize the maps in various scenarios such as construction and management of facilities.

6. Concluding remarks

A new kind of salt-damage map that enables

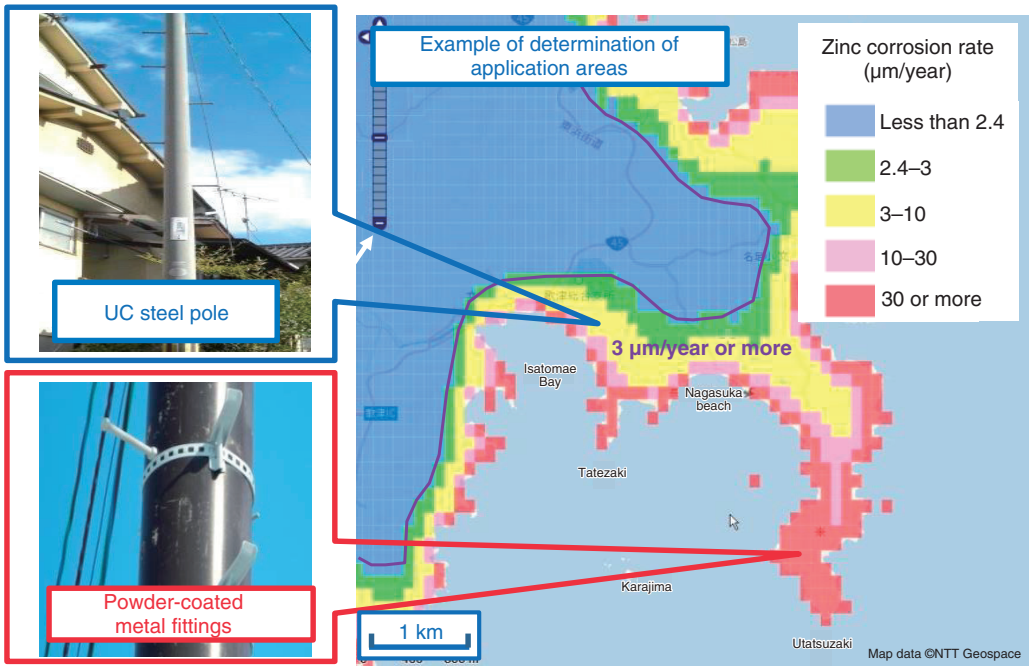


Fig. 6. Example of determining areas for application of corrosion-resistant fittings.

determination of application areas for corrosion-resistant fittings and facilities was introduced. The conventional way of determining salt-damaged areas involves the use of empirical judgment based on the corrosion situation of actual facilities and uniform judgment based on the distance from the coast. In future, it is recommended to use salt-damage maps in a comprehensive manner so that they can support proper introduction of corrosion-resistant fittings.

At the Technical Assistance and Support Center, we will continue to develop the salt-damage maps described in this report while also working on maps to visualize areas such as those affected by lightning damage and strong winds. From now onwards, we will continue to disseminate these maps as part of a weather database that will support the construction and operation of communication facilities, and we urge all stakeholders to take full advantage of that database.

Event Report: Tsukuba Forum 2018

Tomoyuki Nomura, Yusuke Koshikiya, Masashi Tadokoro, and Motoharu Sasaki

Abstract

Tsukuba Forum 2018 was held October 25 and 26. The theme of the forum was "*Enhancing social well-being, moving forward together—Address social challenges with advanced access network technologies and smart maintenance and operation*." This article gives a brief overview of the speeches and exhibits presented at the forum.

Keywords: Tsukuba Forum, access networks, maintenance and operation

1. Introduction

The Tsukuba Forum is Japan's largest integrated symposium on technologies related to access networks. The main theme of the 2018 event was "*Enhancing social well-being, moving forward together—Address social challenges with advanced access network technologies and smart maintenance and operation*." It was held with the intentions of moving forward together with customers as *Your Value Partner* by earnestly developing technologies that address a variety of social challenges. In addition to NTT Access Network Service Systems Laboratories (AS Labs), 108 organizations, including cohosting institutions 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 keynote speech and a special speech were given at the Tsukuba International Congress Center on the first day. They were relayed from the main convention hall of the International Congress Center to a venue at the NTT Tsukuba R&D Center. The speeches were received by a large audience.

2.1 Keynote speech

Mr. Hiroshi Tanabe, Executive Vice President of NTT EAST, gave a speech entitled "NTT EAST Business Trends and Activities for Network" (**Photo 1**).

First, Mr. Tanabe introduced NTT EAST's management trends as indicated by changes in operating revenue and operating income. He showed that in the last several years, NTT EAST continued to attain record profits and gave two major reasons for this. First, the earnings structure is steadily changing. Although income has come mainly from metal cable-based voice communication, it is shifting to income from optical fiber-based IP (Internet protocol) communication. Another reason is that NTT EAST has been able to continually improve operational efficiency by reducing expenses to a greater extent than the growth in revenue. In this way, the company has been able to secure profits.

Concerning revenue and income trends, Mr. Tanabe described in detail efforts to expand optical fiber services. The number of subscribers of FLET'S HIKARI has increased steadily since the service began. Mr. Tanabe stated that in addition to product capabilities such as cables, optical cords, and splitters developed by the NTT research laboratories, sales capabilities, including those of sales agents, have built a system in

Table 1. List of exhibitors.

■NTT Group
NIPPON TELEGRAPH AND TELEPHONE EAST CORPORATION
NTTEAST-MINAMIKANTO
NTTEAST-KANSHINETSU
NTT Infrastructure Network Corporation
AIREC ENGINEERING CORPORATION
NTT RENTAL ENGINEERING Co., Ltd.
NTT Geospace Corporation
Nippon Telematique Inc.
NIPPON TELEGRAPH AND TELEPHONE WEST CORPORATION
NTT FIELDTECHNO CORPORATION
NTT Communications Corporation
NTT World Engineering Marine Corporation
NTT COMWARE CORPORATION
NTT Electronics Corporation
NTT Advanced Technology Corporation
NTT-AT Techno Communications Corporation
NIPPON CAR SOLUTIONS CO., LTD.

■Information & Telecommunications Engineering Association of Japan (ITEA)
EXEO TECH CORPORATION
Kyowa Exeo Corporation
Nippon COMSYS Corporation
MIRAIT Corporation
TOSYS CORPORATION
NDS Co., Ltd.
C-CUBE Corporation
Hokuriku Denwa Kouji Co., Ltd.
Nippon Dentsu Corporation
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.
KYOEI HIGH OPT Co., Ltd.
JFE Metal Products Corporation
JAPAN RECOM Ltd.
SHODENSHA CO., LTD.
SWCC SHOWA CABLE SYSTEMS CO., LTD.
Suzuki Giken Co., Ltd.
SUDA SEISAKUSHO Co., Ltd.
Sumiden Opcom, Ltd.
Sumitomo Electric Industries, Ltd.
SEIWA GIKEN CO., LTD.
3M Japan Limited
DYDEN CORPORATION
DAITO DENZAI CO., LTD.
Tadano Ltd.
TSUKO Network Communication
TOSHIN ELECTRIC 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 Corporation

■Communications and Information Network Association of Japan (CIAJ)
Anritsu Corporation
FXC Inc.
NEC Corporation
NEC Networks & System Integration Corporation
NEC Magnus Communications, Ltd.
Oi Electric Co., Ltd.
Seiko Solutions Inc.
NAKAYO, INC.
Hitachi, Ltd.
Hitachi Information & Telecommunication Engineering, Ltd.
FUJITSU LIMITED
HellermannTyton Co., Ltd.
MARUBUN CORPORATION
Mitsubishi Electric Corporation
Yokogawa Test & Measurement Corporation / Yokogawa Solution Service Corporation
ASAKURA FACTORY Co., Ltd.
IRIICHI TECHNOLOGIES INC.
OTANI KOGYO CO., LTD.
SANKOSHA CORPORATION
SANRITZ ELECTRONICS CO., LTD.
SANWA DENKI KOGYO CO., LTD.
Taiei Seisakusho Co., Ltd.
Takacom Co., Ltd.
TAKACHIHO SANGYO CO., LTD.
TOMEI TSUSHIN KOGYO CO., LTD.
Nagamura Mfg. Co., Ltd.
NISSHIN ELECTRIC CO., LTD.
HACHIKO ELECTRIC CO., LTD.
MIYAKAWA ELECTRIC WORKS LTD.
MIYOKAWA Seisakusho
WATANABE CO., LTD.

■Other corporations
Nippon Telecommunication Engineering and Consulting
OPT Gate Co., LTD.
SUNREC CO.,LTD.
HARADA CORPORATION
MAEDA ROAD CONSTRUCTION Co.,Ltd.
MIKI INC.
MILLIKEN JAPAN G.K.

which customers can use FLET'S HIKARI with peace of mind. In addition, NTT EAST has improved productivity by introducing technologies such as fused optical core fibers, which has led to a decrease in the number of repair dispatches for failures per month year after year, and by visualizing the volume of work, such as onsite repair operations and line maintenance tasks.

On the other hand, because productivity improvement efforts are reaching their limits, Mr. Tanabe emphasized that NTT EAST is moving into an era in which productivity must be improved in a nonlinear and qualitative manner. He introduced three pillars of NTT EAST's efforts for efficient facility operations—smart onsite work, smart online support, and smart work methods—with specific examples.

As an example of smart onsite work, Mr. Tanabe described a new diagnostic technology that measures bending in utility poles by using a mobile mapping system (MMS). With the MMS, high-precision three-dimensional maps can be created by taking spatial measurements of facilities in an environment with a traveling car equipped with laser scanners, cameras, and GPS (Global Positioning System). As a result, The MMS makes it possible to inspect up to 200 poles in one day, in contrast to the maximum of 7 poles per day using commercial off-the-shelf measuring equipment. Mr. Tanabe emphasized that such an automated inspection system was found nowhere else in the world.

For smart online support, Mr. Tanabe gave the example of integrating internal and external office work. For example, a wide range of onsite work can be done by one worker by providing remote support

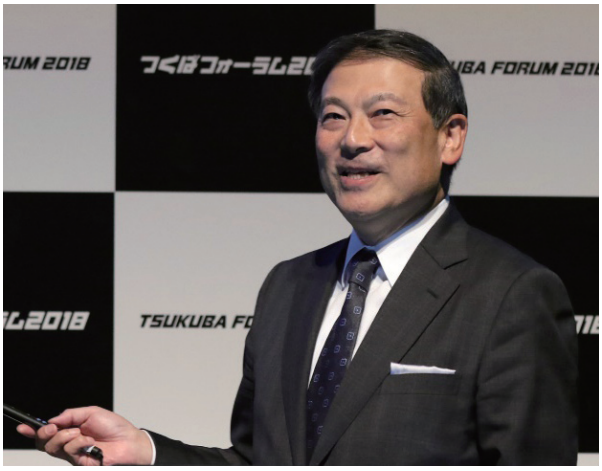


Photo 1. Mr. Hiroshi Tanabe, NTT EAST Executive Vice President, delivering the keynote speech.

Photo 2. Mr. Hiromasa Takaoka, NTT Communications Senior Vice President, delivering the special speech.

via video and giving guidance to the onsite worker. Mr. Tanabe stated that NTT EAST's strength will be in having workers who are capable of dealing with all onsite situations.

Furthermore, for smart working methods, Mr. Tanabe introduced the example of the variable working hour system in which workers in Hokkaido work different hours during summer and winter. He also presented a project by women employees—who have been increasing in number in recent years—to improve the onsite work environment, and activities to visualize and improve safety by reviewing one's actions through the introduction of stationary cameras in onsite environments.

In addition, Mr. Tanabe described NTT EAST's efforts to create disaster-resilient facilities. As efforts in the aftermath of the Great East Japan Earthquake in 2011, he introduced a wide range of countermeasures being undertaken by NTT EAST. These include measures to prevent electrical outages, such as installing emergency engine generators and backup batteries, and protective measures in the event of a tsunami, involving moving communication buildings to higher elevations.

Finally, Mr. Tanabe concluded his speech with powerful words. He stated that to support the success of various events to be held in Japan by 2020, NTT EAST is taking on the mission of steadfastly protecting the communications infrastructure. His speech was valuable for introducing a variety of specific efforts by NTT EAST.

2.2 Special speech

Mr. Hiromasa Takaoka, Senior Vice President of NTT Communications, gave a speech entitled "Digital Transformation of NTT Communications" (**Photo 2**).

First, Mr. Takaoka gave an outline of NTT Communications' Vision 2020. Vision 2020 represents NTT Communications' goal to become a global information and communication technology (ICT) provider recognized around the world through advanced services. The slogan of Vision 2020 is "Transform. Transcend." It means that NTT Communications' services and technologies will dramatically evolve and dynamically transform businesses, markets, and society (Transform), and create new value that exceeds expectations. By transcending the boundaries that limit people, they will realize a seamlessly connected world (Transcend). Mr. Takaoka stated that furthermore, NTT Communications is seeking to improve all processes by leveraging its knowledge and technologies accumulated to date in order to *go to market* as quickly as possible with advanced technologies and services. Among these efforts, digital transformation (DX) is a pillar to achieve Vision 2020. Mr. Takaoka said that it is a major push by NTT Communications to continue to provide new value by supporting customers as a DX Enabler™.

Mr. Takaoka then introduced NTT Communications' effort to build its Data Distribution Platform to realize Vision 2020. To realize an environment that can richly provide flexible and highly reliable

Photo 3. Workshop leaders (from left to right: Mr. Yukihiko Okumura, NTT DOCOMO 5G Laboratories Group Leader; Mr. Takeshi Arai, AS Labs Project Manager; and Mr. Jun Terada, AS Labs Project Manager).

services to customers according to their needs with the Data Distribution Platform, NTT Communications is working to connect globally deployed datacenters; to develop and utilize software-defined networking technologies and multi-orchestrator, which optimally combine a variety of software functions; and furthermore, to implement thorough security management. Diverse functions such as order management, customer management, and billing and settlement are necessary in order to achieve these extensive service line-ups. Mr. Takaoka stated that, as a result, it is necessary to collaborate with partner companies and develop useful functions. He said that such cooperation will be possible by precisely defining, adjusting, and releasing application programming interfaces (APIs), an effort to which NTT Communications is presently devoting its energy.

In addition, for security measures, as information distribution is becoming globalized, new demands are growing for personal information protection at national and regional levels. Responding to these needs is becoming more urgent. Besides datacenters, NTT Communications possesses network infrastructure. This makes it possible to visualize data storage locations and communication routes, making it possible for NTT Communications to provide strengthened security measures to customers.

Next, Mr. Takaoka introduced specific examples of DX. First, he presented an effort to automatically respond to customers' inquiries and issues. This system utilizes artificial intelligence (AI) technologies and big data analysis to provide automated handling, from responding to customers' voice inquiries to diagnosing problems.

Mr. Takaoka also stated that for the challenge of developing automated maintenance operations, NTT Communications has developed an automated system that orchestrates a series of work processes, from detection of network failures and repair to notification of customers. Using this system, the company was greatly able to improve the speed of responses compared with the previous system. Going forward, NTT Communications will leverage the technologies of this system, expand the range of automation with DX, and actively propose these DX technologies to corporate customers.

3. Workshops

On the second day of Tsukuba Forum 2018, workshops were held at AS Labs. An Executive Research Engineer from NTT DOCOMO and two Project Managers from AS Labs conducted the workshops (**Photo 3**).

3.1 Workshop 1

Mr. Yukihiko Okumura, the Group Leader of NTT DOCOMO 5G Laboratories' 5G Radio Access Network Research Group, gave a lecture entitled "Co-Creation of New Services and Resolution of Social Problems by Utilizing 5G." First, he presented the latest status of NTT DOCOMO's efforts to launch fifth-generation mobile communication networks (5G) services. Mobile communication speed has increased 400,000 times over the past 25 years to reach 988 Mbit/s. Mr. Okumura stated that the performance target of next-generation 5G is 20 Gbit/s, and furthermore, with the advent of 5G and the creation of new value, mobile traffic is expected to dramatically increase. NTT DOCOMO is seeking to begin commercial 5G services in the spring of 2020. With its mobile network as the core, the company seeks to

create new value and address social challenges with DX as the pillar, combining AI, augmented reality (AR)/virtual reality, and the Internet of Things (IoT). 5G will also have the three features of high-speed/high-capacity, low latency, and connections with numerous terminals. Moreover, 5G services are being expanded from urban to rural areas with appropriate functions and radio frequencies. Mr. Okumura explained that NTT DOCOMO will create new value by co-creating services and technologies with a wide range of partners.

Next, he discussed five examples of 5G applications that utilize high-speed communication, low latency, and high-resolution video to tackle a variety of social challenges: (1) remote operation of construction equipment to deal with the issue of a shortage of manpower in the construction industry, (2) remote operations using humanoid robots to confirm safety and restore services quickly after a disaster, (3) remote healthcare using high-resolution diagnostic imaging to reduce the disparity in medical care between urban and rural areas, (4) check-ups of expectant mothers using next-generation mobile medical clinic vans, and (5) surveillance of facilities with high-resolution video to ensure safety and security.

3.2 Workshop 2

Mr. Takeshi Arai, Project Manager of AS Labs' Access Network Management Project, gave a lecture entitled "Research and Development of New Operation Techniques for Access Network Infrastructure." First, Mr. Arai explained the background situation of network access facility operations. He stated that Japan's population of people in their productive years is declining, and that NTT facilities maintenance personnel responsible for access network operations are also aging. It is thus necessary to consider construction methods that prevent network access problems from occurring in the first place, even with lesser availability of workers' skills. He stated that NTT is seeking to eliminate inspections, which consume the most work during operations. As steps to reach this goal, he presented three steps in NTT's research to reduce inspections to zero: (1) practical application of MMS-based automatic utility pole diagnostic technology, (2) efforts to automatically inspect cables, guy wires, and suspension wires, in addition to utility poles, and (3), in the future, the use of AI to predict deterioration in facilities. Mr. Arai explained that creating added value from the multi-stratification of various kinds of data makes it possible to reduce operations efficiently.

Next, Mr. Arai introduced applications of sensing technologies. He discussed NTT's MAC (media access control) address capture technology for measuring networks beyond splitters and vibration sensing technology for identifying flooded manholes. He also presented safe work methods such as a method for safe road-crossing construction and the use of AR-based pre-work inspection. Concerning the direction of access network facility operations going forward, Mr. Arai stated that NTT seeks to eliminate inspections and reduce onsite observer work by establishing new inspection standards obtained by integrating multiple kinds of data, with the goal of minimal operations.

3.3 Workshop 3

Mr. Jun Terada, Project Manager of AS Labs' Optical Access Systems Project, gave a lecture entitled "Perspective on Optical Access Network." First, Mr. Terada stated that in regard to conditions for optical access, it is necessary to consider how to stably and continuously use and maintain the great number of facilities and deal with diverse uses of optical access in the 5G/IoT era. With this need in mind, he explained that high flexibility and low maintenance are key terms for optical access networks needed in the future. To achieve such a network, technologies to modularize and virtualize access functions are critical. Transport functions and service functions must be segregated, and the sharing of the optical network access by overlapping services is key. Next, Mr. Terada presented FASA®* (Flexible Access System Architecture), AS Labs' concept to realize these goals. FASA enables modularization of functions, establishment of common APIs, softwarization of functional blocks, and cloud operations. Furthermore, Mr. Terada introduced mobile base station accommodation passive optical network (PON) and virtual optical line terminal (OLT) as applications of FASA. This PON realizes low latency with corporative dynamic bandwidth assignment (DBA) implemented with FASA's technology. Virtual OLT is an SFP (small form-factor pluggable) OLT; it provides easy optical access service to areas where optical access is not yet available. Mr. Terada also discussed AS Labs' participation in international standardization activities, such as FSAN (Full Service Access Network), ITU-T (International Telecommunication Union - Telecommunication Standardization Sector),

* FASA is a registered trademark of Nippon Telegraph and Telephone Corporation in Japan.

Photo 4. Panel discussion.

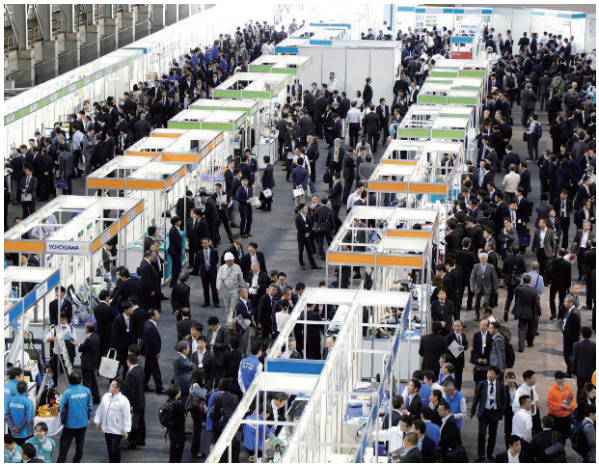


Photo 5. Main hall.

and BBF (Broadband Forum), and open development efforts at ONF (Open Networking Foundation).

4. Planned events

In addition to the speeches and workshops, various events were held that were well received by the visitors.

4.1 Panel discussion

For the first time at Tsukuba Forum, co-hosting organizations, NTT Group companies, and the NTT research labs united together on a special stage in AS Labs' main hall to introduce efforts and hold salon-style discussions on three themes: "Efforts to improve productivity with RPA (robotic process automation), "Moving toward true diversity from the advancement of women: What is universal ease of working?", and "Safety efforts supported by advanced technologies." The panel discussion drew standing-room crowds. Many attendees commented that they had learned a lot (**Photo 4**).

4.2 Video presentation

Steady efforts to support networks were introduced with panel exhibits and videos that presented outdoor test sites in Rumoi, Hokkaido, and Miyakojima, Okinawa, and a large-scale experimental facility in Tsukuba.

4.3 Stamp rally

A digital stamp rally using smartphones was carried out to enable visitors to navigate throughout the exhibition hall of AS Labs. Those who gathered the six-stamp set in the venue were awarded an original utility pole number tag. When we gave the souvenirs to the participants, we received comments such as "I was able to get an overall picture of all the exhibits by walking around the exhibition hall while collecting stamps."

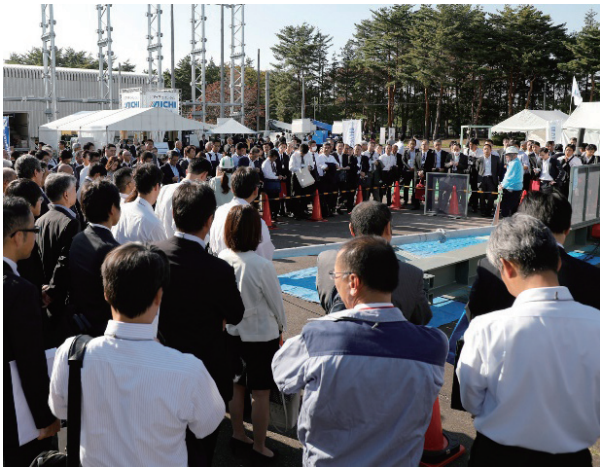


Photo 6. Outdoor exhibits.

5. Overview of exhibits

In addition to exhibits from AS Labs, exhibits on the latest technologies of the co-hosting organizations and the NTT Group companies were held (**Photos 5** and **6**).

Advanced Access Network Technologies

In anticipation of the 5G/IoT era, Tsukuba Forum 2018 introduces advanced access network technologies that can be adopted to provide services that meet diverse needs found in a variety of usage scenarios.

Smart Maintenance and Operation

To address social challenges that are becoming visible, such diversifying societies and the need to improve productivity, Tsukuba Forum 2018 introduces smart maintenance and operation technologies, including automation technologies and technologies to improve efficiency of operation tasks.

Display of a Model Network

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

Fig. 1. Overview of NTT exhibits.

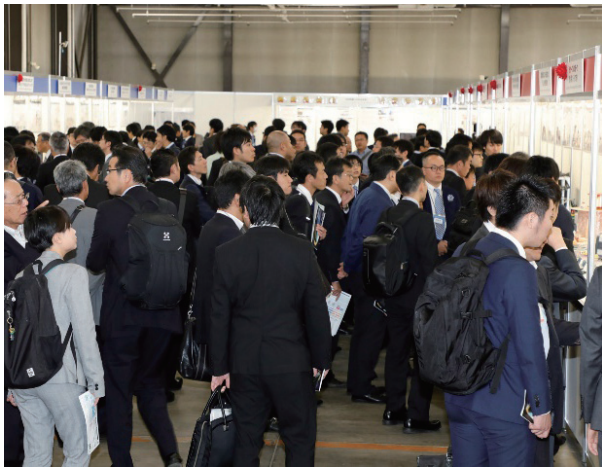


Photo 7. NTT exhibition zone.

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 7**).

(1) Advanced Access Network Technologies

In anticipation of the 5G/IoT era, AS Labs introduced advanced access network technologies that can be adopted to provide services that meet diverse needs found in a variety of usage scenarios. Recommended exhibits included a multi-path-tolerant GNSS (Global Navigation Satellite System) receiver that used time synchronization with world-class accuracy, strategic management-based wireless resource control technology to support diverse scenarios, development of underground and overhead cables to reduce the cost of parts and improve workability, software modularization technology for DBA in FASA, and technologies for ensuring low network latency.

(2) Smart Maintenance and Operation

To address the arising social challenges, the diversifying societies, and the need to improve productivity, Tsukuba Forum 2018 introduced smart maintenance and operation technologies, including automation technologies and technologies to improve the efficiency of operation tasks. Technologies presented as recommended exhibits included rule learning-based automatic failure point estimation technology, annotation/user interface extension technology for improving the efficiency of non-routine tasks, small antennas for the TZ-403D wireless access system for disaster recovery, new paint specifications for unpainted steel towers to achieve low-cost maintenance and longevity, in-facility position technology using time of arrival of radio waves, ICT conversion of a cable tunnel management system, technology for remotely visualizing facility conditions with optical fiber vibration sensing, wide-area active clamp noise filters, manhole inspection technology using autonomous drones, and pre-work inspection using AR technology to ensure work safety.

(3) Display of a Model Network

This exhibit visually introduced the overall picture of access network technologies in a physical sequence from an NTT communication building to the customer premises.

5.2 Information & Telecommunications Engineering Association of Japan (ITEA)

This exhibit presented ITEA's efforts to achieve secure, safe, and reliable information communication

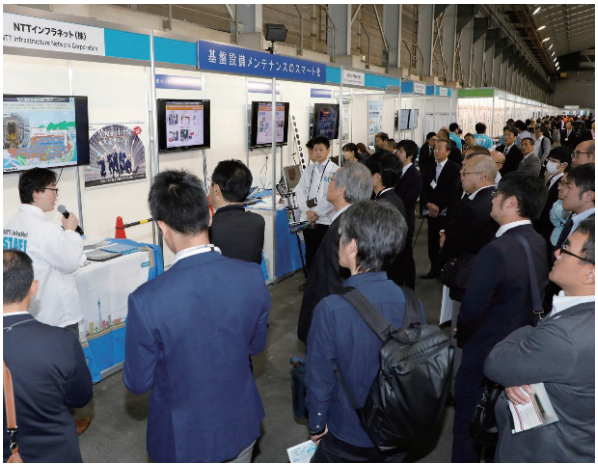


Photo 8. Events of exhibiting companies.

infrastructure facilities. These efforts include maintaining the technology and know-how that have been cultivated up to now; building, maintaining, and improving the quality and efficiency of optical access networks; and promptly restoring facilities in the event of a major disaster.

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 consideration of safety and diverse needs, the offerings emphasized workability and drew the interest of many visitors.

5.4 Communications and Information Network Association of Japan (CIAJ)

Together with the Japan Industrial Association for Telecommunications Equipment and Materials (Zentsukyo), exhibitors who belong to CIAJ presented various products and solutions related to communication networks to achieve a safe, secure, and prosperous society.

5.5 NTT Group

Through their exhibits, NTT Group companies demonstrated support for customers as well as their own transformation to achieve sustained growth going forward. They also introduced the latest technologies to contribute to realizing an abundant society by providing the best and most trusted services.

5.6 Events of exhibiting companies

In the AS Labs main hall and in the outdoor venue, exhibiting companies gave demonstrations that drew many visitors (**Photo 8**).

6. Conclusion

Tsukuba Forum 2018 was blessed with sunny weather on both days. It was a success, drawing about 10,200 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 98% of customers achieved the purpose of their visit. Tsukuba Forum 2018 was a rich event that enabled NTT and participating organizations to share transformations in access networks through presentations of research achievements in advanced onsite technologies and world-leading technologies, with an emphasis on cutting-edge access network technologies and smart operations and maintenance.

Acknowledgments

We thank the Information & Telecommunications Engineering Association of Japan, the Communication Line Products Association of Japan, and the Communications and Information Network Association of Japan for their support of Tsukuba Forum 2018.

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Mr. Nomura 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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He received an M.E. in engineering from the University of Tokyo in 2004. He joined NTT Access Network Service Systems Laboratories the same year. He has over 10 years of experience in R&D activities involving optical access networks including radio over fiber technology and Ethernet PON technology. His current research interests include the power saving technologies for PON and PON-based next-generation energy management and control systems for smart grids and smart communities to improve energy-use efficiency in local communities.

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He received a B.E. in engineering and an M.E. and Ph.D. in information science and electrical engineering from Kyushu University, Fukuoka, in 2007, 2009, and 2015. In 2009, he joined NTT Access Network Service Systems Laboratories. He has been engaged in research on propagation modeling for various wireless communication systems; propagation modeling of interference between mobile terminals for spectrum sharing wireless access systems, propagation modeling in VHF (very high frequency) bands for emergency wireless systems, and propagation modeling in high frequency bands for fifth-generation mobile wireless communication systems. He received the Young Researcher's Award and the Best Paper Award from IEICE in 2013 and 2014, respectively. He received the Best Paper Award at the International Symposium on Antennas and Propagation (ISAP) in 2016. He received the Young Engineer Award from IEEE Antennas and Propagation Society Japan chapter in 2016. He also received the Young Researcher Award and the Excellent Paper Award from IEICE Technical Committee on Antennas and Propagation in 2012 and 2018, respectively. He is a member of IEEE.

GPS Time Synchronization with World-class Accuracy Using Selected Satellites—Multipath-tolerant GNSS Receiver Dramatically Increases Accuracy in Severe Environments

1. Introduction

NTT and FURUNO ELECTRIC CO., LTD. (hereafter, FURUNO) have developed a receiver for the Global Positioning System (GPS) and other global navigation satellite systems (GNSS) that dramatically improves time synchronization accuracy in areas with severe reception conditions such as among buildings and in mountainous areas.

The integration of a new satellite signal selection algorithm developed by NTT into a time-synchronization GNSS receiver from FURUNO, in addition to signals from satellites in line-of-sight locations, has made it possible to use multipath signals (reflected or diffracted from buildings and other structures), which previously inhibited the accuracy of time synchronization. In a real multipath reception test environment, the time error was reduced to approximately one-fifth that of earlier values. This is a remarkable result in that it promises to enable time synchronization accuracy close to that obtained in open-sky reception environments with no obstructions, even in environments previously considered poor and unsuitable for accurate time synchronization, such as among buildings or in mountainous areas.

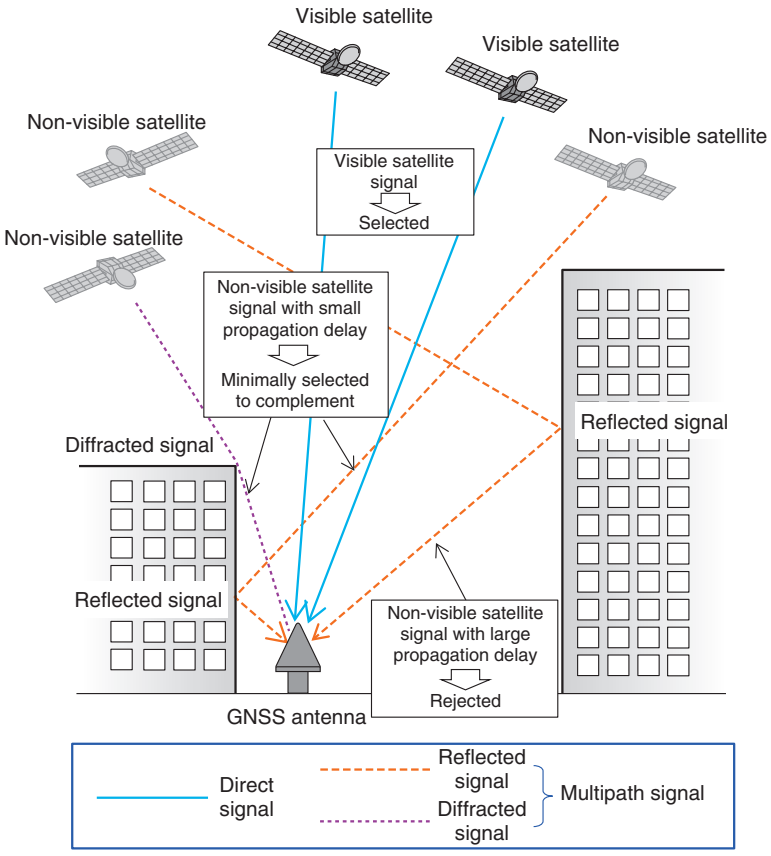
FURUNO plans to begin sales of their new GF-88 series time-synchronization GNSS receivers incorporating this new algorithm in April of 2019 and to deploy it widely in fields such as 4G/5G (fourth-generation/fifth-generation) mobile base stations, financial trading, power grids, and datacenters.

2. Background

Accurate time synchronization with Coordinated Universal Time (UTC),* using a GNSS such as GPS, is used in a wide range of fields for synchronizing mobile base stations, financial trading, earthquake measurements and other purposes. Particularly in recent years, mobile base stations based on TD-LTE (time division Long Term Evolution) and other TDD (time division duplex) methods are spreading globally and require transmitted signals to be synchronized accurately, down to the microsecond, to avoid interference of signals between cells.

However, in non-ideal reception environments such as in areas with many buildings or mountains where structures surround the antennas, the open area where signals from navigation satellites can be received directly is limited, and reception of multipath signals reflected from or diffracted by surrounding structures can significantly degrade the accuracy of time synchronization. Measures to improve time synchronization accuracy have been studied in the past, including placing antennas in locations where they can receive signals directly from greater numbers of visible satellites, and also filtering based on the elevation of the signal direction or a signal strength threshold to exclude signals from non-line-of-sight satellites that cannot be seen directly from the receiver location. Even so, these earlier methods were not always able to ensure adequate accuracy, and they also had issues

* UTC: Global standard time, managed based on international atomic time. Standard time in each country is set using UTC as the standard. Japan Standard Time is 9 hours ahead of UTC.



Prototype GNSS receiver

Inside the prototype GNSS receiver
(Dashed line indicating the FURUNO GF-8705 GNSS receiver module)

Fig. 1. Satellite selection algorithm and GNSS receiver prototype.

with reliability.

NTT has developed a new GNSS receiver algorithm for selecting suitable navigation satellite signals and conducted measurements to verify the effectiveness of this algorithm.

3. Research description and results

To compute the four parameters for position and time from navigation satellite signals, signals from at least four satellites must be received, but it is not always possible to receive four or more signals from visible satellites in so-called urban canyon environments obstructed by surrounding buildings. In this study, we have conceived a new satellite selection algorithm in which satellite signals suitable for improving the time accuracy are selected in an iterative selection process based on the estimated reception location and the signal arrival times.

As shown in **Fig. 1**, this algorithm first selects the signals from visible navigation satellites, and if there are fewer than four, it also selects the minimal number of signals with the smallest propagation delay from non-visible satellites. Thus, in poor reception environments, accuracy is improved by aggressively pruning unsuitable satellite signals. This could be called a *select few* satellite selection method. We developed a prototype by incorporating this algorithm into the GF-87 time-synchronization GNSS receiver from FURUNO and evaluated its performance in a test environment with multipath reception. We were able to demonstrate accurate time synchronization with a time error of approximately one-fifth that of earlier devices (**Fig. 2**).

Since this method is able to select the best satellite signals regardless of the number of visible satellites in the environment, antennas can be installed with less attention to the location, and significant increases in accuracy of time synchronization can be expected in a wider range of reception environments.

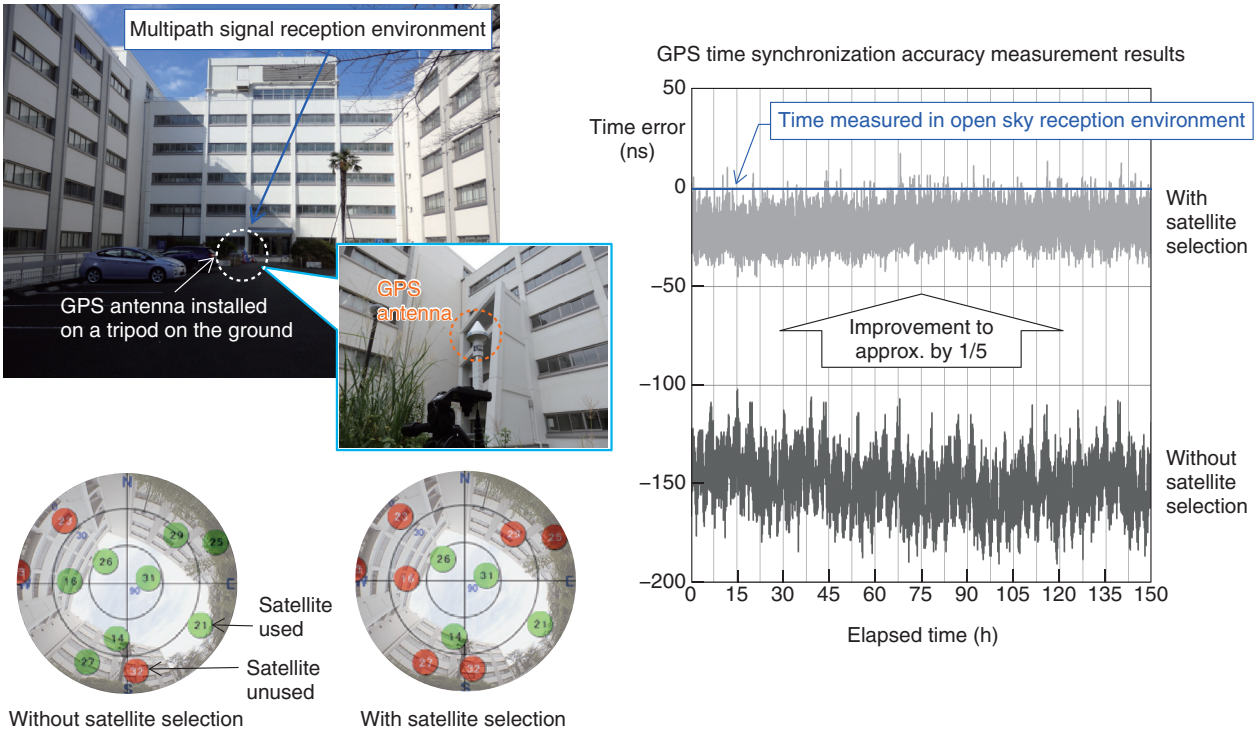


Fig. 2. Multipath signal reception environment and GPS time synchronization accuracy measurement results.

For Inquiries
Public Relations Office, Planning Department,
NTT Information Network Laboratory Group
http://www.ntt.co.jp/news2018/1810e/181023a.html

External Awards

2018 Specially Selected Paper
Winner: Yuhei Kawakoya, Makoto Iwamura, and Jun Miyoshi, NTT Secure Platform Laboratories
Date: December 15, 2018
Organization: Information Processing Society of Japan

For "Taint-assisted IAT Reconstruction against Position Obfuscation."
Published as: Y. Kawakoya, M. Iwamura, and J. Miyoshi, "Taint-assisted IAT Reconstruction against Position Obfuscation," Journal of Information Processing, Vol. 26, pp. 813–824, 2018.

IEEE Fellow
Winner: Seishi Takamura, NTT Media Intelligence Laboratories
Date: January 1, 2019
Organization: The Institute of Electrical and Electronics Engineers (IEEE)

For application of video coding.

The Asahi Prize
Winner: Tatsuaki Okamoto, NTT Secure Platform Laboratories
Date: January 1, 2019
Organization: The Asahi Shimbun Company

For his work in designing pioneering secret codes and developing safety theory.

Kenjiro Takayanagi Achievement Award
Winner: Seishi Takamura, NTT Media Intelligence Laboratories
Date: January 18, 2019
Organization: Kenjiro Takayanagi Foundation

For his pioneering research on video coding and its international standardization and dissemination activities.

The Itakura Prize Innovative Young Researcher Award
Winner: Yuma Koizumi, NTT Media Intelligence Laboratories
Date: January 22, 2019
Organization: Acoustical Society of Japan

For "DNN-based Source Enhancement to Increase Objective Sound Quality Assessment Score."
Published as: Y. Koizumi, K. Niwa, Y. Hioka, K. Kobayashi, and Y. Haneda, "DNN-based Source Enhancement to Increase Objective Sound Quality Assessment Score," IEEE/ACM Transactions on Audio, Speech, and Language Processing, Vol. 26, No. 10, pp. 1780–1792, 2018.

IEICE RCS Young Researcher Award
Winner: Riku Ohmiya, NTT Access Network Service Systems Laboratories
Date: February 1, 2019
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE) Technical Committee on Radio Communication Systems (RCS)

For "Three-dimensional Cooperative Carrier Sensing for Un-used Frequency Utilization."
Published as: R. Ohmiya, T. Murakami, K. Ishihara, T. Hayashi, and T. Yasushi, "Three-dimensional Cooperative Carrier Sensing for Unused Frequency Utilization," IEICE Tech. Rep., Vol. 118, No. 435, RCS2018-264, pp. 127–132, 2019.

JSPS PRIZE
Winner: Yoshitaka Taniyasu, NTT Basic Research Laboratories
Date: February 7, 2019
Organization: The Japan Society for the Promotion of Science (JSPS)

For his research on wide bandgap semiconductor ultraviolet light-emitting devices.

IEICE IN Research Award
Winner: Tomoki Ito, Information Technology Center, Nagoya University; Misao Kataoka, Hirofumi Noguchi, Yoji Yamato, NTT Network Service Systems Laboratories; Tsutomu Murase, Information Technology Center, Nagoya University
Date: March 4, 2019
Organization: IEICE Technical Committee on Information Networks (IN)

For "Network Architecture with Categorizing Metadata by Locality and Lifetime for IoT Database Management."
Published as: T. Ito, M. Kataoka, H. Noguchi, Y. Yamato, and T. Murase, "Network Architecture with Categorizing Metadata by Locality and Lifetime for IoT Database Management," IEICE Tech. Rep., Vol. 118, No. 245, IN2018-47, pp. 25–30, 2018.

The Awaya Prize Young Researcher Award
Winner: Atsushi Ando, NTT Media Intelligence Laboratories
Date: March 6, 2019
Organization: Acoustical Society of Japan

For "Question Detection from Acoustic and Lexical Features Using Feature-wise Pre-training."
Published as: A. Ando, R. Masumura, H. Kamiyama, S. Kobashikawa, and Y. Aono, "Question Detection from Acoustic and Lexical Features Using Feature-wise Pre-training," Proc. of Acoustical Society of Japan 2018 Autumn Meeting, 2-Q-5, pp. 1049–1050, Oita, Japan, Sept. 2018 (in Japanese).

IEICE OFT Young Researcher Award
Winner: Yuto Sagae, NTT Access Network Service Systems Laboratories
Date: March 20, 2019
Organization: IEICE Technical Committee on Optical Fiber Technologies (OFT)

For "A Study of Solid Type Low Latency Optical Fiber."
Published as: Y. Sagae, T. Matsui, K. Tsujikawa, and K. Nakajima, "A Study of Solid Type Low Latency Optical Fiber," IEICE Tech. Rep., Vol. 118, No. 40, OFT2018-2, pp. 5–10, 2018.

Papers Published in Technical Journals and Conference Proceedings

A Novel Non-supervised Deep Learning Based Network Traffic Control Method for Software Defined Wireless Networks

B. Mao, F. Tang, Z. Md. Fadlullah, N. Kato, O. Akashi, T. Inoue, and K. Mizutani

IEEE Wireless Communications, Vol. 25, No. 4, pp. 74–81, August 2018.

Software defined networking (SDN) has been regarded as the next-generation network paradigm, as it decouples complex network management from packet forwarding, which significantly simplifies the operation of switches in the data plane. The good programmability of SDN infrastructure also improves network feasibility. To alleviate the burden of the explosive growth in network traffic, in this article we propose a non-supervised deep learning based routing strategy running in the SDN controller. In our proposal, we utilize convolutional neural networks (CNNs) as our deep learning architecture, and the controller runs the CNNs to choose the best path combination for packet forwarding in switches. More importantly, in our proposal, the controller collects the network traffic trace and periodically trains the CNNs to adapt them to the changing traffic patterns. Simulation results demonstrate that our proposal is able to retain learning from previous experiences and outperform conventional routing protocols.

Exhaustive Graph Search and Applications Featuring Compressed Data Structures

T. Inoue

The Sixth International Symposium on Computing and Networking (CANDAR 2018), Takayama, Gifu, Japan, November 2018.

This talk presents exhaustive graph search techniques and their applications. Exhaustive graph search is a traditional but tough problem in computer science: finding all subgraphs in a graph under given constraints, e.g., paths, cycles, trees, degrees, size, and their combinations. Thanks to the recent advancement of algorithms and implementation techniques, exhaustive graph search has opened a new way to solve several network problems including configuration optimization, fault analysis, and reliability evaluation.

Measuring Lost Packets with Minimum Counters in Traffic Matrix Estimation

K. Watabe, T. Mano, T. Inoue, K. Mizutani, O. Akashi, and K. Nakagawa

IEICE Transactions on Communications, Vol. E102-B, No. 1, pp. 76–87, January 2019.

Traffic matrix (TM) estimation has been extensively studied for decades. Although conventional estimation techniques assume that traffic volumes are unchanged between origins and destinations, packets are often lost on a path due to traffic burstiness, silent failures, etc. Counting every path at every link, we could easily get the traffic volumes with their change, but this approach significantly increases the measurement cost since counters are usually implemented using expensive memory structures like a SRAM. This paper proposes a mathematical model to estimate TMs including volume changes. The method is established on a Boolean fault localization technique; the technique requires fewer counters as it simply determines whether each link is lossy. This paper extends the Boolean technique so as to deal with traffic volumes with error bounds that requires only a few counters.

Resource-efficient Verification of Quantum Computing Using Serfling's Bound

Y. Takeuchi, A. Mantri, T. Morimae, A. Mizutani, and J. F. Fitzsimons

Proc. of the 22nd Annual Conference on Quantum Information Processing (QIP 2019), Boulder, Colorado, USA, January 2019.

Verifying quantum states is central to certifying the correct operation of various quantum information processing tasks. In particular, in measurement-based quantum computing, checking whether correct graph states are generated or not is essential for reliable quantum computing. Several verification protocols for graph states have been proposed, but none of these are particularly resource efficient: Many copies are required in order to extract a single state that is guaranteed to be close to the ideal graph state. For example, the best protocol currently known requires $O(n^{15})$ copies of the state, where n is the size of the graph state [D. Markham *et al*., arXiv:1801.05057 (2018)]. In this paper, we construct a significantly more resource-efficient verification protocol for graph states that needs only $O(n^5 \log n)$ copies. The key idea that achieves such a drastic improvement is to employ Serfling's bound, which is a probability inequality in classical statistics. Utilizing Serfling's bound also enables us to generalize our protocol for qudit and continuous-variable graph states. Constructing a resource-efficient verification protocol for qudit and continuous-variable graph states is non-trivial. For example, previous verification protocols for qubit graph states that use the quantum de Finetti theorem cannot be generalized to qudit and continuous-variable graph states without hugely increasing the resource overhead. This is because the overhead caused by the quantum de Finetti theorem depends on the local dimension. On the other hand, in our protocol, the resource overhead is independent of the local dimension, and therefore generalizing to qudit or continuous-variable graph states does not increase the overhead. The flexibility of Serfling's bound also makes our protocol robust: Our protocol accepts slightly noisy but still useful graph states, which are rejected by previous protocols.

Quantum Remote Sensing with Asymmetric Information Gain

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

Physical Review A, Vol. 99, p. 022325, February 2019.

Typically, the aim of quantum metrology is to sense target fields with high precision utilizing quantum properties. Unlike the typical aim, in this paper, we use quantum properties for adding a functionality to quantum sensors. More concretely, we propose a delegated quantum sensor (a client-server model) with security inbuilt. Suppose that a client wants to measure some target fields with high precision, but he/she does not have any high-precision sensor. This leads the client to delegate the sensing to a remote server who possesses a high-precision sensor. The client gives the server instructions about how to

control the sensor. The server lets the sensor interact with the target fields in accordance with the instructions, and then sends the sensing measurement results to the client. In this case, since the server knows the control process and readout results of the sensor, the information of the target fields is available not only for the client but also for the server. We show that by using an entanglement between the client and the server, an asymmetric information gain is possible so that only the client can obtain sufficient information on the target fields. In our scheme, the server generates the entanglement between a solid-state system (that can interact with the target fields) and a photon, and sends the photon to the client. On the other hand, the client is required to possess linear-optics elements only including wave plates, polarizing beam splitters, and single-photon detectors. Our scheme is feasible with the current technology, and our results pave the way for an application of quantum metrology.

Verifying Commuting Quantum Computations via Fidelity Estimation of Weighted Graph States

M. Hayashi and Y. Takeuchi

arXiv:1902.03369 [quant-ph], February 2019.

The instantaneous quantum polynomial time model (or the IQP model) is one of the promising models to demonstrate a quantum computational advantage over classical computers. If the IQP model can be efficiently simulated by a classical computer, an unlikely consequence in computer science can be obtained (under some unproven conjectures). In order to experimentally demonstrate the advantage using medium or large-scale IQP circuits, it is inevitable to efficiently verify whether the constructed IQP circuits faithfully work. There exists two types of IQP models, each of which is the sampling on hypergraph states or weighted graph states. For the first-type IQP model, polynomial-time verification protocols have already been proposed. In this paper, we propose verification protocols for the second-type IQP model. To this end, we propose polynomial-time fidelity estimation protocols of weighted graph states for each of the following four situations where a verifier can (i) choose any measurement basis and perform adaptive measurements, (ii) only choose restricted measurement bases and perform adaptive measurements, (iii) choose any measurement basis and only perform non-adaptive measurements, and (iv) only choose restricted measurement bases and only perform non-adaptive measurements. In all of our verification protocols, the verifier's quantum operations are only single-qubit measurements. Since we assume no i.i.d. property on quantum states, our protocols work in any situation.
