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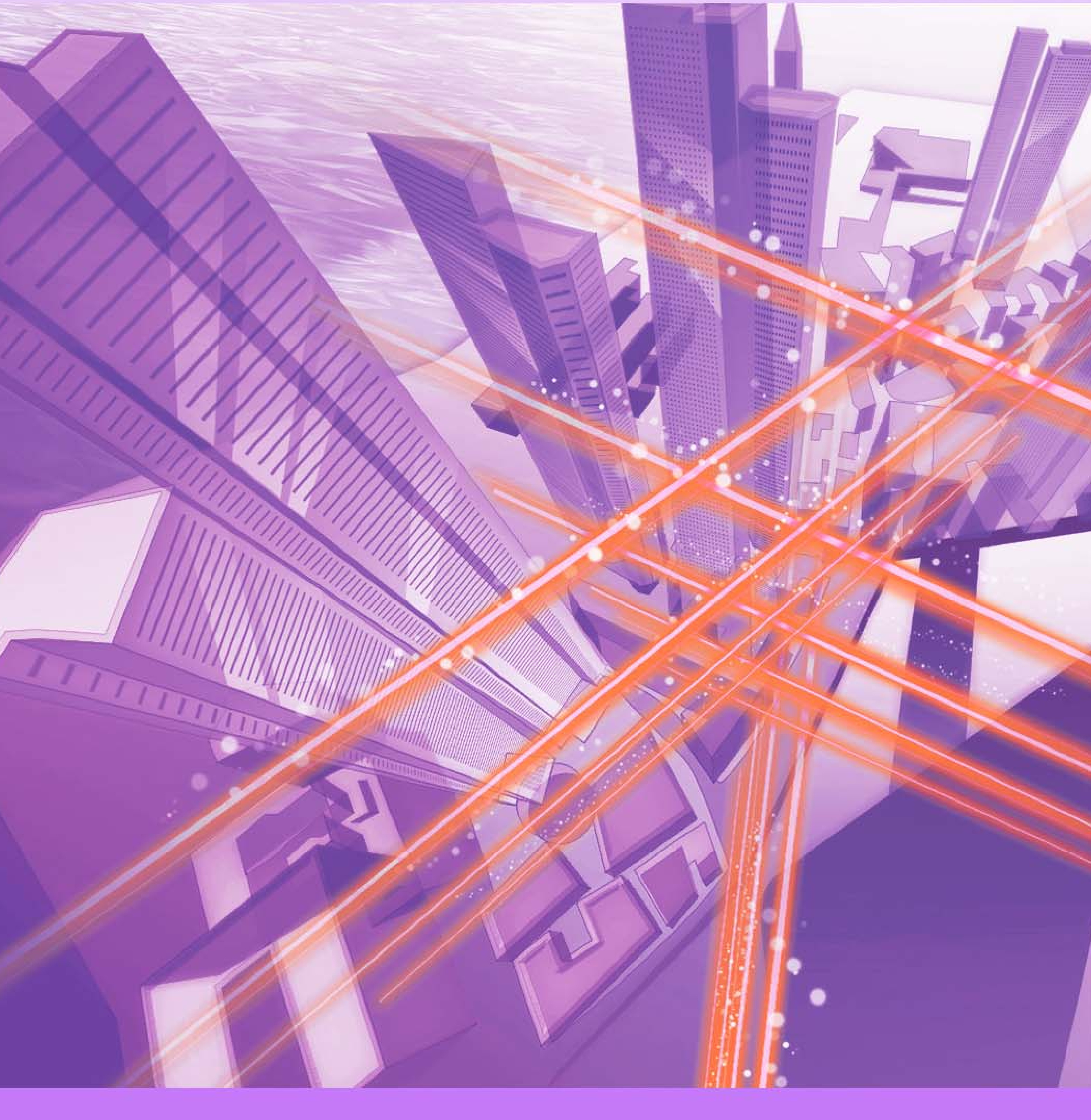

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Develop Your Technical and Social Perspectives While Nurturing Your Inspiration

Shinya Tachimoto
Senior Vice President, Head of NTT Information Network Laboratory Group

Overview

The NTT Information Network Laboratory Group aims to create a compassionate and flexible information-network infrastructure that connects everything. Researchers at the laboratory group are working diligently with pride, joy, and responsibility in creating technologies that will be implemented in society. We asked Shinya Tachimoto, senior vice president, head of the NTT Information Network Laboratory Group, about the capability required of top management of laboratories and the skills researchers should have in regard to research and development.

Keywords: NTT Information Network Laboratory Group, R&D, discussion

Continuity of research and development

—Could you tell us about the NTT Information Network Laboratory Group?

The NTT Information Network Laboratory Group is promoting research and development (R&D) of technologies to construct simple, smart, and sustainable networks that will contribute to the development of an information-network infrastructure that connects everything.

To make the Innovative Optical and Wireless Network (IOWN)—a future communication infrastructure proposed by NTT—a reality, while maximizing the potential of transport networks by promoting *all-photonics* technology, we are focusing on two initiatives: (i) R&D of flexible networks through Cognitive Foundation that enables prompt service provision and optimization of value chains and (ii) R&D of innovative environmental energy technology that contributes to achieving zero environmental impact.

The NTT Information Network Laboratory Group is engaged in such R&D at three laboratories: (i) the Network Service Systems Laboratories, which conducts R&D of a future information-network infrastructure and the network services provided on it; (ii) the Access Network Service Systems Laboratories, which conducts R&D on access networks that cover service areas by linking optical and wireless networks and the access services provided on them; and (iii) the Space Environment and Energy Laboratories, which conducts R&D on next-generation energy technology and sustainable system technology to achieve zero environmental impact, as well as environmental adaptation technology to adapt to global climate change and build a resilient society. With approximately 500 enrolled researchers, these three laboratories are positioned at the core of R&D on information and communication technology in Japan.

Together they aim to contribute to society through a wide array of research results, ranging from research on elemental technologies (including energy technology) to architectures of entire information networks and network operations.

The Musashino base in Tokyo, where the NTT Information Network Laboratory Group is located, has been a hub of R&D on telecommunication networks in Japan, starting from the Electrical Communication Laboratory of the Ministry of Communications to Nippon Telegraph and Telephone Public Corporation and NTT. Initially, the R&D was centered on telephony, and a telephone network was constructed on the basis of the results of that R&D, and many of the devices and systems configuring the network were based on specifications devised at the laboratory. As the era of telecommunication networks changes from telephony to the Internet, general-purpose products and open platforms have been used for the devices and systems that make up the network. Adapting to this trend, we have expanded our R&D to cover various network functions, services, and operations that use those products and platforms. As we head toward the IOWN era, the core technology of communication and information processing will shift from electronics to photonics. We want to take this opportunity to implement our research results into networks and systems and expand them globally. From the birth of R&D on telecommunication to the present and into the future, we have taken the challenge of developing new technologies while inheriting the results and expertise of the past and flexibly adapting our style of R&D and social contributions to the times.

—Could you tell us the important point for R&D activities adapting to the changing times?

I believe there are three approaches to R&D. The first is pursuing the advancement of technology from the perspective of a researcher. In other words, R&D is promoted on the basis of technological evaluation to steadily improve a technology, for example, to achieve 10% increase in performance or a decrease in cost. The second is R&D from the perspective of society. In other words, R&D is carried out by setting up one's own R&D theme according to his/her desire to change the society for the future, make society better, or solve issues facing society. The third is R&D driven by inspiration. In other words, R&D is launched by the inspiration through which one day one suddenly thinks of something that will be of great

use to society or one somehow combines two mechanisms from completely different fields and come up with a completely new mechanism.

I think that the technological and social perspectives can be cultivated to some extent through learning. For example, R&D from the technological perspective is the style of R&D that many researchers had been doing since university days; for instance, one could create the next "new" technology by reading papers or repeatedly examining ways to improve the shortcomings and issues that were clearly identified from the results of one's experiments. R&D from the social perspective involves considering how to use one's technology on the basis of daily life and information about the world. Even if a problem is in a completely different field, it may lead to an idea that your technology can be used to solve that problem. However, I think that the third one, inspiration, is often triggered by chance and is not something that can be acquired through learning. As well as increasing your knowledge base in preparation for inspiration, you should constantly ask yourself the question, "What if...?"

In many cases, it has been difficult to introduce research results in a timely manner because conventional information networks and the systems that compose them must be operated for a long time once they have been constructed for a specific service. However, as the world is ever changing and at a faster rate, it is important to have a vision of how to use the technology from the initial stage of research and to link that vision to development. This vision is exactly what IOWN is all about, and it is important to coordinate various research projects to develop a network to achieve this vision, which includes the All-Photonics Network. Networks will become virtualization-based in the future. By taking advantage of the flexibility that comes with virtualization, I believe that it will be possible to implement research results partially or temporarily and refine them in a timely manner while operating the system—something that has been difficult to do.

Discuss fully and make judgments and decisions that stakeholders are satisfied with

—Please tell us about the management of researchers based on your experience as an engineer.

I have been engaged in development activities for quite a long time. I majored in mechanical engineering and conducted R&D on robots at university. After joining NTT, I was initially engaged in the development of telephone-switching systems then the development of the asynchronous transfer mode in the 1990s and next-generation networks (NGNs) in the 2000s. In those days, I felt great joy and satisfaction when the results of my R&D were released to the world and used by people. As the senior vice president, head of the laboratory group, I am grateful to be able to think about—together with many other researchers—how to use our technology and consider future directions from a broader perspective than before while maintaining the same awareness and attitude toward contributing to society.

It is a real pleasure to be able to discuss matters of concern with researchers. In particular, it is very rewarding to be able to drive the process that guides our R&D in the right direction. Of course, there are responsibilities associated with my position, so I might ask myself if what I said is really correct or I might change my direction, if necessary, through information, people's reactions, and discussions. I think my job encompasses the whole process of setting those directions.

I think there are three points that must be considered when making such decisions and judgments. The first is the correctness of information. The second is whether the discussion was sufficient and a variety of viewpoints was taken into account instead of a particular opinion. The third is whether there is potential that the idea will be materialized and achieve results. At times, I am asked to make a black or white decision immediately; however, I always make a judgment or decision on the basis of these points. The environment surrounding R&D is constantly changing, so I try to discuss the best solution for each situation and make a decision that satisfies the stakeholders.

—Even though you are busy, you frequently hold discussions.

Discussions are carried out not only in large meetings but also in individual meetings on each research

topic. By understanding the details of a topic, I sometimes encourage researchers to adopt a different perspective. We also have inspirational discussions that I talked about earlier. Talking about the possibility of something might completely and unexpectedly lead to new development; conversely, it might cause confusion. Looking back on my research life, I believe that it is important for researchers to discuss each other's opinions and ideas, even if they are just random thoughts, and to think from different perspectives in response to those opinions.

To prevent the spread of COVID-19, remote work has become a mainstay, so it has become difficult to have opportunities for face-to-face discussions, and most discussions are held online. Inspirational conversations are transmitted differently when they are heard through a computer than when they are said face to face. Moreover, the way in which the message is conveyed and resonates differs considerably in comparison with that when we look each other in the eye or draw a picture on a whiteboard and post questions such as, "Well, what about this?" From a different viewpoint, this difference is an issue for consideration. The promotion of smooth communication in a remote society, such as the difference between online and face-to-face communications in how the message is communicated as a real feeling and how to eliminate frustrations, is a major theme for the future.

Talk about the world that our technology will make possible

—You make convincing judgments and decisions through discussions; that is, you value not only research results but also the process leading up to the decisions.

The hardest part of the discussion, judgment, and decision-making process is telling a researcher disappointing conclusions I have made. For example, researchers may have to interrupt their research or change their theme owing to changes in the environment. Doing so is difficult regardless of how big or small the subject is because the researcher has been working on it diligently. However, offshoots always grow from the hard work that has been put into a particular research theme. The technologies and materials that researchers have worked on and studied will be useful in certain ways in new fields, so I encourage researchers to connect them to those fields.

I certainly don't want to force researchers, who have strong individuality and various motivations, to go in a specific direction. Rather, I think it's important to let researchers look in different directions and be on the cutting edge of each direction. I think that's what's necessary in the future, so we'll lay the rails for the future in a certain way, but it is not forbidden to go off the rails because going off the rails can get you in the right position in the future. Therefore, I want to develop each offshoot, and I want all our researchers to do what they need to do now and grow the offshoots for the future.

—Please give a message to researchers and engineers inside and outside the company.

I hope that you will broaden the scope of your research by adding offshoots one after another, incorporating various styles and information according to the changes in society and the environment of the time while keeping your own style. I believe that this approach will broaden the scope of your life in the future.

I have learned a lot from the various comments on the news that flood the Internet. In the past, we did not have much exposure to anything other than the exemplary solutions organized through the mass media, but now, for better or worse, many people can speak freely on the Internet, and we are less likely to settle for such exemplary common solutions. In an uncertain world, I think it is important to understand where you stand in regard to the vast and multifaceted comments directed arbitrarily at will. It is very difficult to scrutinize and discern facts in the midst of divergent and untruthful information; even so, you can learn many things. For example, you may discover certain issues that we must solve as carriers and providers of information and telecommunications.

One of the major conditions for being recognized as a global researcher is that your achievements are technically superior. In addition to following the basic style of researchers, namely, communicating the excellence of your research and technology at academic conferences and in papers, you should always be aware of your contribution to society. While being recognized by experts for your technology, talk to the general public about the world in which that technology is implemented with words such as, "My technology can create such a world in the future."

Interviewee profile

■ Career highlights

Shinya Tachimoto joined NTT in 1990 and worked on the development of switching systems at NTT Exchange Systems Research Laboratories. He had a key role in NGN system development and network integration testing and was also responsible for developing mobile network service applications at NTT DOCOMO. He became a manager of the Second Division (currently Technology Planning Department) at NTT holding company in 2000, senior researcher at NTT Network Service Systems Laboratories in 2003, senior manager at the Core Network Development Department of NTT DOCOMO in 2009, project manager at NTT Network Service Systems Laboratories in 2014, and the vice president, head of NTT Network Service Systems Laboratories in 2018. He has been in his current position since July 2020.

Contemplate the Essence of a Problem from Multiple Perspectives

Kunio Kashino
Senior Distinguished Researcher, NTT Communication Science Laboratories and Bio-Medical Informatics Research Center, NTT Basic Research Laboratories

Overview

Auscultation (auditory diagnosis) has been used for centuries in the fields of health screening and medical care. It has the advantage of being repeatable and non-invasive while providing immediate results; however, because it is conducted in close proximity to the patient, it is challenging to perform on patients suspected of carrying infectious diseases. We interviewed Kunio Kashino, a senior distinguished researcher, who is working on *teleauscultation* with an eye toward addressing the above challenge and the future of health management, about the progress of his research activities and his attitude as a researcher.

Keywords: auscultation, telestethoscope, AI auscultation

Development of a telestethoscope that can collect and analyze biological sounds remotely

—Could you tell us about your current research?

When I was interviewed about six years ago, we talked about my research on scene analysis and media exploration based on media information, which I described as "creating a media dictionary." Since then, I have also started research on *teleauscultation* and *artificial intelligence (AI) auscultation* in July 2019 while concurrently working at the Bio-Medical Informatics Research Center.

We often see stethoscopes around doctors' necks when we are examined at medical institutions. According to medical professionals, sounds coming from inside the body (biological sounds) via stethoscopes contain a wealth of information. Last year, we developed a system called the "telestethoscope," which enables the collection and analysis of such sounds from a remote location (**Figs. 1** and **2**). The system consists of a wearable device worn by the patient and a receiving terminal (e.g. the tablet in the right photo in Fig. 1) operated remotely.

During auscultation, it is necessary to hear sounds at various places on the body. Accordingly, 18 acoustic sensors are installed in the wearable device of the current prototype telestethoscope. The 18-channel acoustic signals captured by these sensors are simultaneously collected with a 1-channel electrocardiographic waveform. On the screen of the receiving tablet, an outline of the torso is shown, and the part of the torso to be listened to can be specified by touching it on the screen or clicking on it with a mouse. The

Fig. 1.   Telestethoscope.

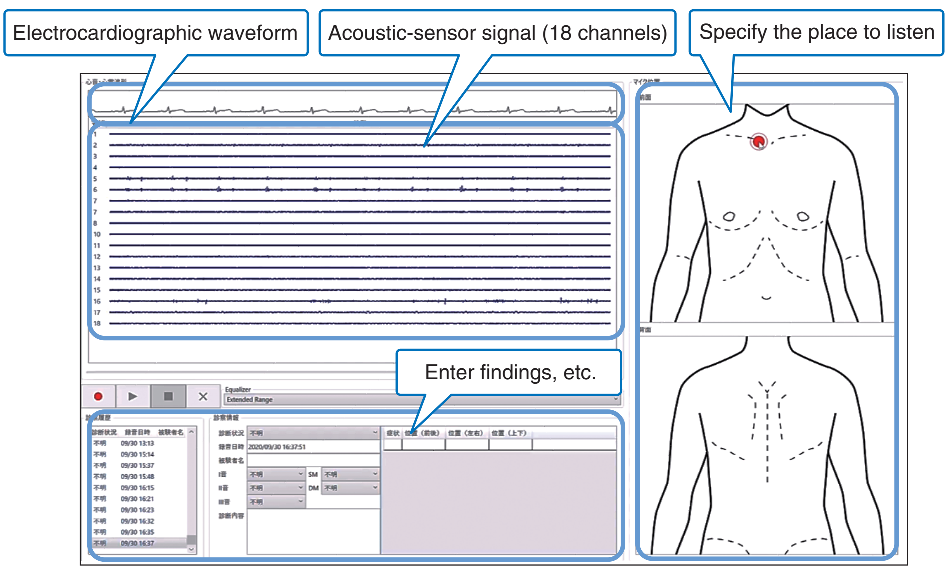
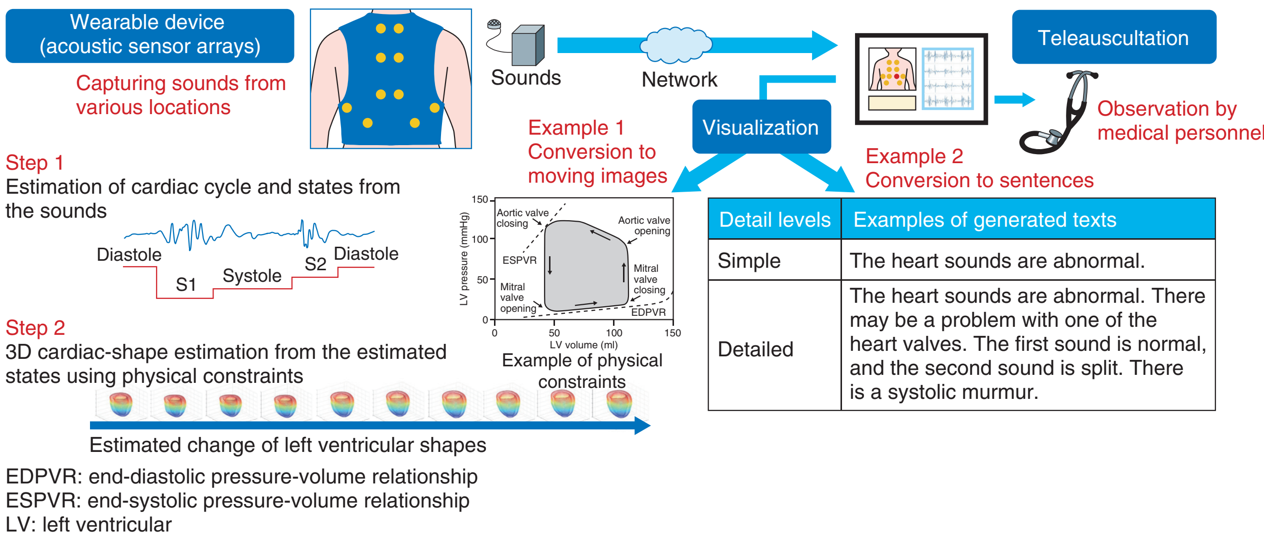


Fig. 2.   Screenshot of receiving tablet of telestethoscope.

sound emitted at that part (an estimated sound synthesized from signals from the multiple sensors) can then be heard. The acoustic signal waveforms captured by each sensor are also displayed on the screen, and it is possible to listen directly to those acquired raw waveforms. Taking computer analysis into consideration, the system is designed to obtain more information spatially and in frequency domains compared with ordinary stethoscopes, namely, not only the main frequency bands used in conventional auscultation but also other bands. All received signals are recorded so that they can be listened to at any time.

If this telestethoscope is put into practical use for medical purposes, it will enable medical professionals to conduct auscultation from a separate room without directly coming into contact with the patient or during online medical treatment (teleauscultation). Once we establish a technology for automatically analyzing the collected sounds, the telestethoscope will not only enable a medical professional to listen to the sounds from a sick person remotely but also enable a healthy person to use it on a daily basis for self-healthcare by using AI to analyze the sounds.

In fact, we are currently researching AI auscultation which analyzes internal bodily conditions on the basis of biological sounds (**Fig. 3**). An example of such research is translating the meaning of the captured biological sounds into words. We have developed a unique technology that directly translates bio-sound signals into a series of words. Unless you are an expert, you will not be able to clearly understand the meaning of your own biological sounds when you listen to them; however, by going through a "translator," so to speak, you will benefit from being able to



Detail levels	Examples of generated texts
Simple	The heart sounds are abnormal.
Detailed	The heart sounds are abnormal. There may be a problem with one of the heart valves. The first sound is normal, and the second sound is split. There is a systolic murmur.

Fig. 3. AI auscultation.

understand the state of your own body. In particular, by taking advantage of using sentences rather than just indicating words such as the name of a disease, this technology is designed to convert biological sounds to sentences with the desired level of detail on the spot, for example, the presence and degree of abnormalities and changes over time since the last checkup.

—Your research on telestethoscope and AI auscultation is generating high expectations. What difficulties are there in making them practical?

We have faced a few difficulties; for example, diagnostic-imaging technology is making remarkable progress year after year, and automated diagnosis using AI is being actively researched. In contrast, auscultation data are rarely collected and usually discarded without being recorded. Therefore, we had no choice but to start our research by collecting data and building the equipment to do so ourselves.

It has also been a very interesting challenge to reproduce the skills of medical professionals on a computer. There are aspects in common with auditory-scene analysis, which I have been working on for the past 30 years. When a person hears a sound, vibration generated somewhere by a physical cause is transmitted through a medium and shakes the eardrum. Auscultation is the problem of estimating the causes of the (mixtures of) vibrations transmitted. To solve this problem, it is necessary to use as much information as possible in addition to the vibration waveform. Just as medical professionals make judgements on the basis of their anatomical knowledge and medical experience, computers will need to fully use physical models of the body's organs and statistical models learned from a huge amount of case data. Although how to achieve this is a point of difficulty, it is also a point to which we can apply our ingenuity.

When we focus on sounds generated inside the body, however, we come across something new that we do not in typical computational auditory-scene analysis research. For example, research on acoustic signal processing has mainly focused on the scenario in which the medium for transmitting sound is a uniform substance such as air or water. However, in the body, sound is transmitted through multiple media with significantly different physical properties, such as bone, muscle, air in the lungs, fat, and liquid, are mixed in a small space. I think this mixed media makes teleauscultation or AI auscultation an even more challenging problem than conventional auditory-scene analysis.

The key to advancing research is to have an interest inherent in the research and maintain that interest

—What are some of the things that you keep in mind when you set research themes and problems?

It seems to me that the more complex the problem, the more important it is to think straightforwardly and simply. I also think that to find a problem, set a research theme, and solve the problem, it is important to contemplate what the real problem is. What is the essence of the problem? I also think that a researcher should take a balanced attitude among three perspectives, namely, a first-person perspective focused on yourself such as what you want to do and how you can increase your productivity as a researcher, a second-person perspective focused on other people that your research results directly target, and a third-person perspective other than these two perspectives. In particular, if you do not pay careful attention to the third-person perspective, you will tend to be dragged back by the first- or second-person perspective.

In a sense, what I said could be similar to a marketing strategy. Modern marketing emphasizes the importance of efforts to find latent needs that have not yet emerged from multiple perspectives, breaking away from conventional approaches such as product-centric perspective, namely, "We want to sell this product," as well as an existing-market perspective, namely, "This type of product is selling well." This way of thinking can also be applied to basic research. It is also about asking what kind of research can bring what kind of value to whom at what time from an objective perspective. Having said that, it is difficult to predict research value. Sometimes value in one's research may be discovered in a field where you do not expect. Therefore, I try to have both conviction and an eye for the unpredictable.

—So, what does it take to have strengths as a researcher?

From my viewpoint, it seems that all the researchers around me have unique strengths; however, they do not necessarily recognize their strengths as such. They just say they like what they are doing. Things that are not too tough for a person to do are often seen as that person's unique strength in the eyes of others. With that in mind, I think the key to advancing research is to have an interest inherent in the research itself. It may be important for researchers to be able to have the interest inherent in the problem and the way of solving it and maintain that interest.

As exemplified by teleauscultation and AI auscultation, it seems that auscultation is going against the times as diagnostic-imaging equipment is being developed and used in the medical field and its importance is increasing. However, I believe that by infusing new technology into auscultation, its usefulness will be reevaluated in the context of an aging society, new medical treatments, and self-healthcare. What's more, the extraordinary skill of estimating what is happening inside the body, which is invisible to the eye, from a one-dimensional waveform, has actually been used in the medical field for 200 years, so just thinking about it seems quite interesting to me.

The importance of teamwork

—Please give some words of advice to our junior researchers.

Through my recent research activities, I realized that I have a lot to learn from people with diverse experiences, not only members of my own research team but also non-researchers. Communicating with these people is invaluable. The Bio-Medical Informatics Research Center assembles people with various backgrounds from multiple NTT laboratories. Our team at the Center has been actively collaborating with external research institutes and medical institutions, so we are having more opportunities to meet with doctors and other medical professionals. These meetings are beneficial, and remind me of the importance of teamwork.

For teamwork to function properly, it is necessary to build relationships between members and enhance the strength of each member. It is important to create an atmosphere in which junior and senior people can respect each other's strengths and contributions, regardless of age or position. I want to ask all our employees, especially those in a higher position in the workplace in relation to younger employees, to always keep that in mind.

I think it is beneficial for researchers to not only develop their existing specialties but also diversify their specialties. For example, a person who studied sound processing at university then joined the company may also take up language processing, and if an opportunity to work on tasks other than research comes up, it would definitely be worth the experience. In my case, prior to joining the company, in addition to pursuing my doctoral research on acoustic-information processing, I was involved in agile development of commercial systems in an emerging industry at the time. After joining the company, I had the opportunity to learn about image processing and Bayesian inference theory. I also had many opportunities to work with people from NTT operating companies. Looking back on those experiences, I realize that they have all been useful in regard to my current work. I hope that you all will take advantage of every opportunity.

■ **Interviewee profile**

Kunio Kashino

Senior Distinguished Researcher at NTT Communication Science Laboratories and Bio-Medical Informatics Research Center, NTT Basic Research Laboratories, and Visiting Professor at National Institute of Informatics (NII).

He received a Ph.D. from the University of Tokyo in 1995. His research interest includes audio and video analysis, synthesis, search, and recognition algorithms and their implementation. He is a fellow of the Institute of Electronics, Information and Communication Engineers (IEICE), and a member of the Institute of Electrical and Electronics Engineers (IEEE), the Association for Computing Machinery, Information Processing Society of Japan, the Japanese Society for Artificial Intelligence, and the Acoustic Society of Japan.

NTT's Vision for the Future of Agriculture—Initiatives for the Entire Food Value Chain Using IOWN-related Technologies

Yoshikazu Kusumi, Takuya Murayama, and Kanji Yoshitake

Abstract

Since 2014, NTT has positioned agriculture as one of its priorities. By using the latest information and communication technology and collaborating with industry-leading partners, NTT has carried out group-wide initiatives to promote Smart Agri to solve problems in the entire food value chain, i.e., from production to distribution, sales, and consumption, in primary industries, such as agriculture, forestry, and fisheries. This article overviews the NTT Group's initiatives and describes the latest examples of initiatives that will lead to the digital agricultural revolution.

Keywords: IOWN, Remote World, food value chain

1. Overview of NTT Group's initiatives

Primary industries, such as agriculture, forestry, and fisheries, are indispensable for the survival of humankind. However, they face a variety of challenges, including resolving labor shortage, aging population, unstable income due to unseasonable weather, as well as ensuring food security to deliver safe and secure food and nutrition to the public in the face of the recent coronavirus pandemic. As a means to overcome these challenges, technologies such as AgriTech*1 and FoodTech*2 are attracting attention.

Since 2014, the Research and Development Planning Department of NTT has been leading the NTT Group's initiatives for primary industries. In collaboration with NTT laboratories, which develop advanced technologies, and about 30 NTT Group companies with outstanding services, we are promoting a wide range of initiatives with an eye on the entire food value chain, i.e., from production to distribution, sales, and consumption [1]. These initiatives include strategy formulation, research and development (R&D), development of services for commercialization, and dissemination of information on the results of such efforts. By combining NTT's Innovative Optical and Wireless Network (IOWN)*3 with group companies' nationwide telecommunication infrastructures, assets, and network services, we will enable innovations in food and agriculture and create new value (**Fig. 1**).

Specifically, we aim to build an ecosystem that makes it possible to optimize the entire food value

*1 AgriTech: Technology used in agriculture, horticulture, and aquaculture for improving yields, efficiency, and profitability.

*2 FoodTech: Technology that combines food and information technology (IT). Its wide range of applications includes reduction of food waste and loss by reviewing the supply chain—from production to processing, distribution, and consumption—of food by using IT, smart agriculture using Internet of Things and artificial intelligence, and *smart kitchens*, where the Internet and kitchen appliances are linked.

*3 IOWN: A next-generation communication infrastructure that NTT is promoting for practical use around 2030.

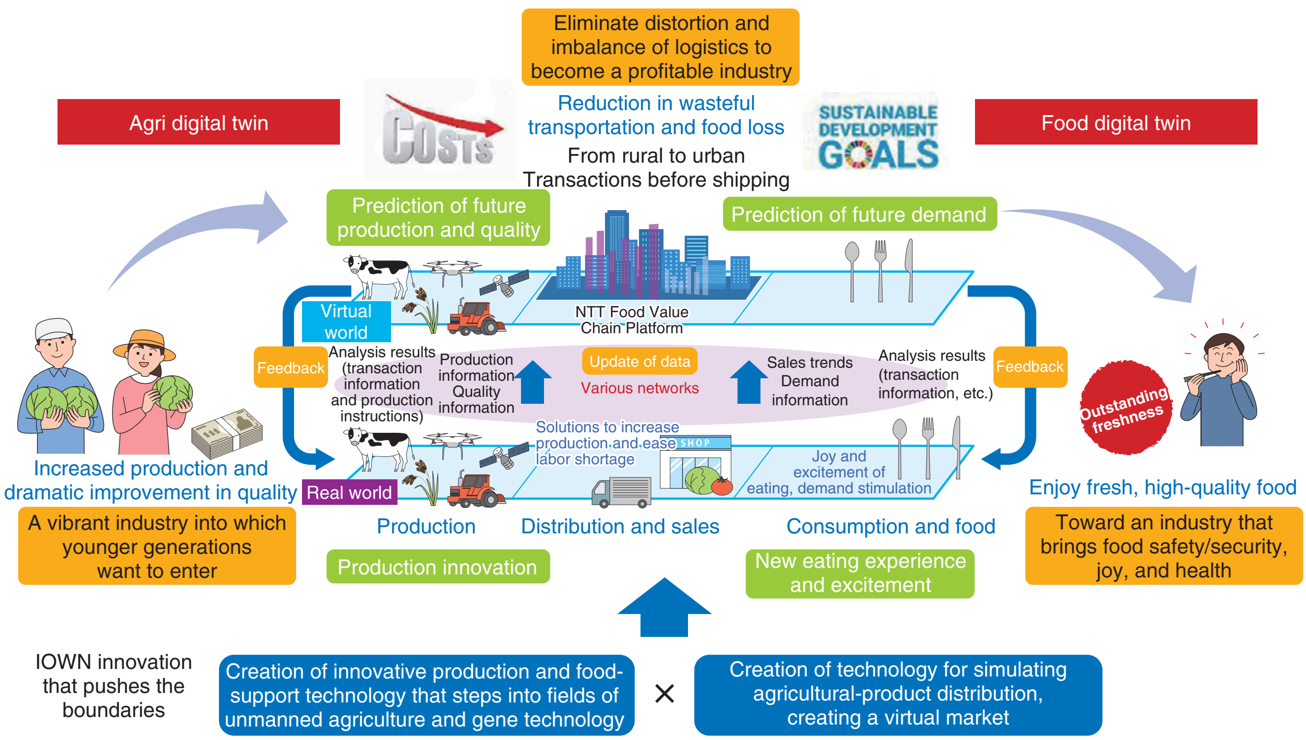


Fig. 1. A vision for food and agriculture.

chain. This will be enabled by combining multiple efforts such as (i) automating agriculture by remote-control robotics such as agricultural machinery and drones; (ii) digital transformation (DX) in the distribution of agricultural products by simulating real-world information on production and distribution sites in a virtual world and feeding back the results of supply-and-demand forecasts to the real world; and (iii) digital breeding by using bio-technology, micro-organisms, genetic technology, etc. to improve the potential of crops, thus dramatically improving productivity and quality.

The NTT Group's current capabilities include greenhouse farming (solar and artificial), outdoor cultivation (including organic farming), livestock, fisheries, weather, map, and topographical information as well as services and technologies that contribute to distribution, sales, and consumption, while meeting the United Nations' Sustainable Development Goals (SDGs) (**Fig. 2**). From among those capabilities, initiatives of NTT Group companies in the areas of plant factories using artificial light [2], food-waste recycling solution toward achieving the SDGs [3], fisheries [4], and organic farming using information and communication technology (ICT) [5] are introduced in the Feature Articles in this issue.

2. Example initiative 1

Regarding agricultural automation, NTT signed an industry-government-academia comprehensive cooperation agreement in 2019 with fellow signatories Hokkaido University, Iwamizawa City in Hokkaido, NTT EAST, and NTT DOCOMO. Since 2020, Kubota Corporation, a leading manufacturer of agricultural machinery, and other companies have signed up to this initiative, which has been further deepened by using the projects of the Ministry of Agriculture, Forestry and Fisheries and the Ministry of Internal Affairs and Communications. In 2019, we moved an unmanned agricultural machinery in the field (a farm) under remote monitoring using the fifth-generation mobile communication system (5G) and in 2020 carried out inter-field movements in which an agricultural robot moves between fields under remote monitoring, which had been considered extremely difficult [6]. This preliminary demonstration of the Remote World was conducted in Iwamizawa. Regarding the communication network used for that remote monitoring, the coverage area is small due to the frequency

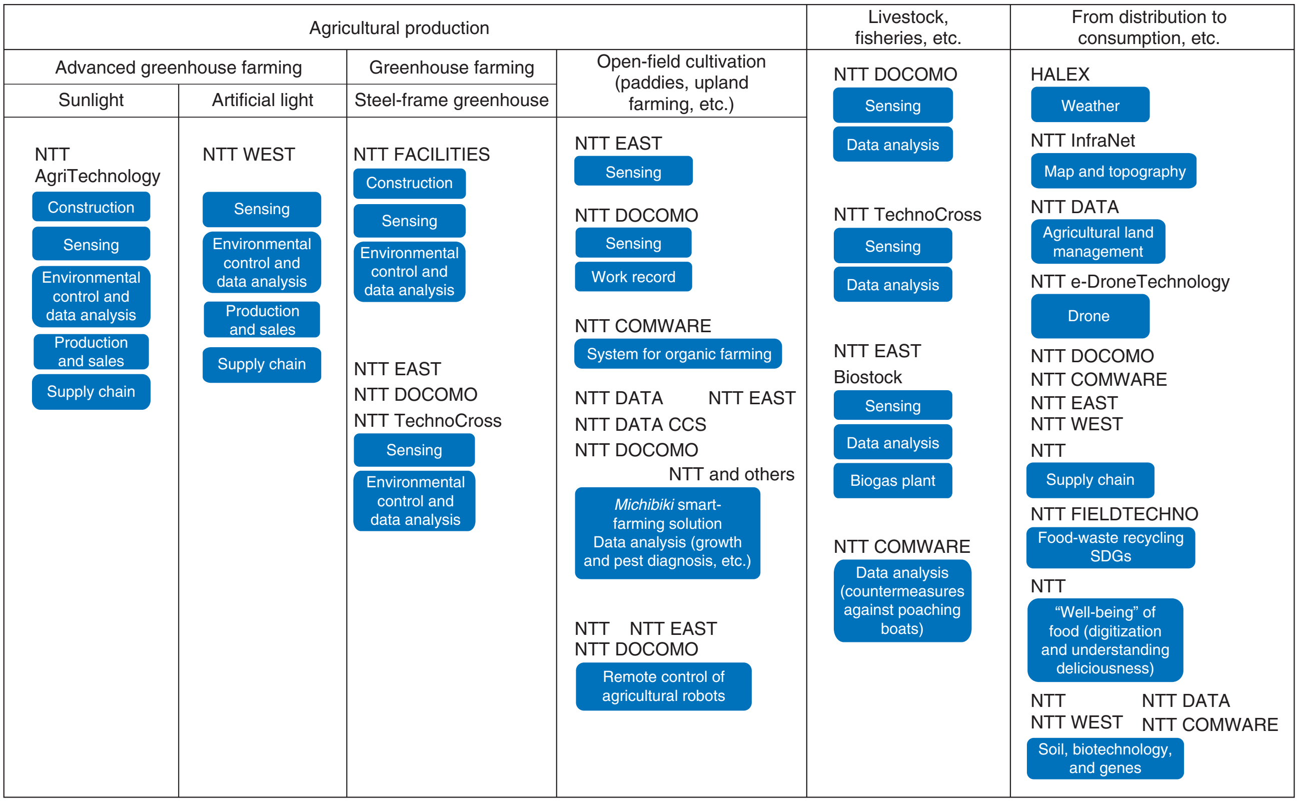


Fig. 2. Map of food and agricultural solutions (including R&D and field demonstrations in progress).

characteristics of 5G. Consequently, if an agricultural robot moves out of the area covered by the network system, it will not be possible to check the video while operating the robot from the remote-monitoring center or continue automatic operation.

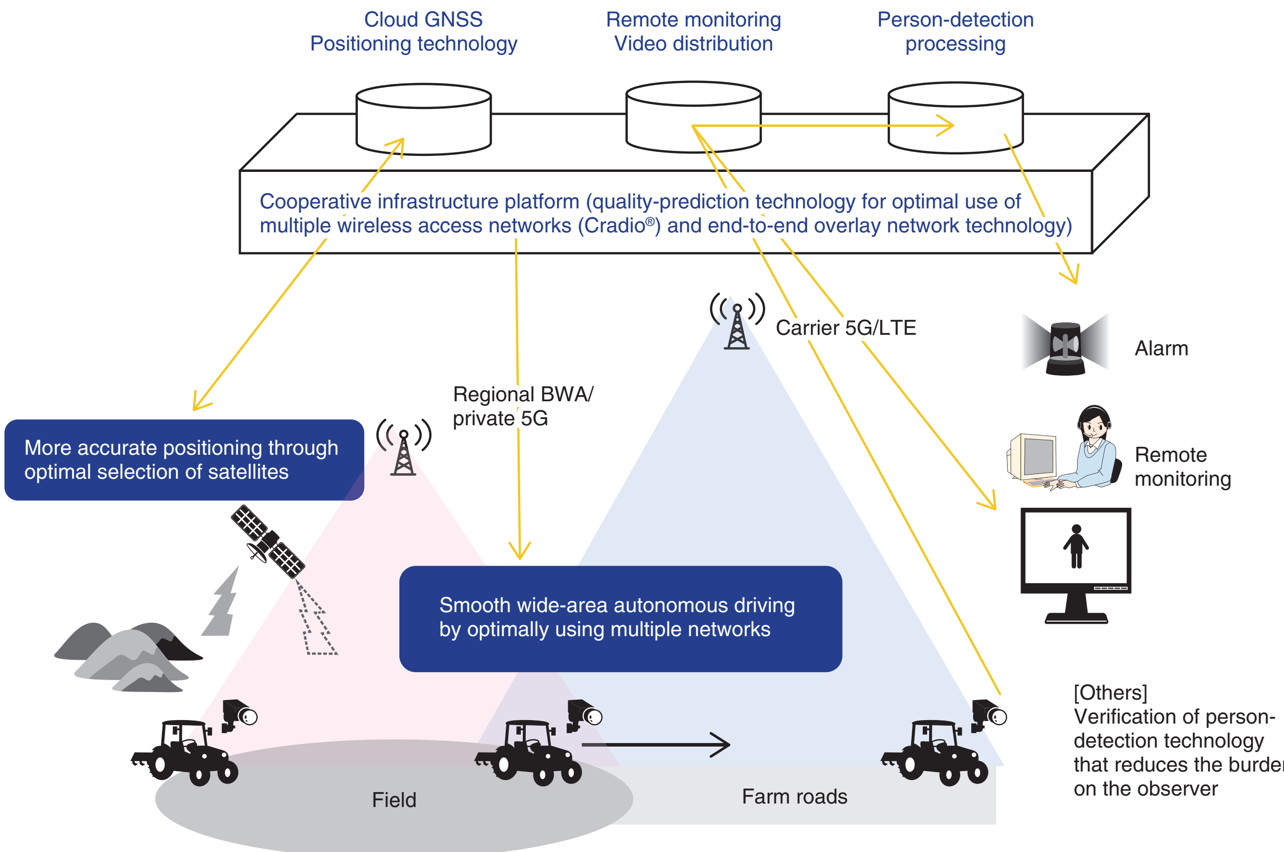
To solve the above-described problem, we verified the effectiveness of several technologies, including a cooperative infrastructure platform, which is an IOWN-related technology, for automatically selecting the most-suitable system from various network systems, such as 5G and broadband wireless access (BWA), in accordance with the operating conditions of the agricultural robot (**Fig. 3**).

We have also conducted non-technical studies in consideration of business operation, such as formulating safety guidelines in collaboration with national projects and sharing mechanisms for smart agricultural machinery. We plan to implement, at an early stage, the automation of agriculture centered on agricultural robots and launch the business of undertaking agricultural work.

We plan to enable innovations that will lead to a digital agricultural revolution in the Remote World we envision. For example, by using IOWN and related technologies that enable higher capacity of networks (more than 100 times current networks), agricultural cooperatives and contractors of agricultural work will be able to monitor and control a large number of robots—agricultural machines, drones, mowers, and harvesters—on wide-area farms from monitoring centers in remote locations and coordinate those robots. We will also model and systematize these technologies and expand them globally to contribute to solving the food shortage facing humankind (**Fig. 4**).

3. Example initiative 2

We are also working to reduce distribution costs, food loss, and ensure food security by optimizing the distribution of agricultural products. Currently, about 80% of fruits and vegetables are traded through more than 1000 wholesale markets throughout Japan, and most are shipped to markets in big cities such as Tokyo and Osaka. If too many products are gathered, the price will drop due to market principles, and



GNSS: global navigation satellite systems
LTE: Long Term Evolution

Fig. 3. Overview of demonstration of Iwamizawa Project.

Fig. 4. Image of future agriculture.

transferring the surplus to other markets will incur extra costs. There is also a serious shortage of drivers of trucks for carrying agricultural products. The recent increase in individual deliveries through online shopping and the spread of coronavirus infections are accelerating this problem. To solve these problems, we are planning to build a system that uses Digital Twin Computing, an IOWN-related technology, to predict future supply and demand by using the vast amount of data collected from the wholesale markets, and on the basis of the predicted information, purchases and sales will be completed in a virtual space before the agricultural products are brought to these markets. This system will enable the supply side to supply crops at the right time, place, and quantity, and the demand side to secure crops at the right time, place, and quantity. The system will also help solve social problems through initiatives that take into account the entire food value chain, such as solving driver shortages, reducing food loss and transportation costs, and ensuring food security as well as achieve the SDGs. Marketers, agricultural organizations, and local governments are also becoming more interested in this system, and collaborations and partnerships are expanding. This system is expected to lead to a digital agricultural revolution that will bring about a DX in distribution of agricultural products.

4. Concluding remarks

We believe it is now necessary in Japan to bring together the wisdom and technology of various fields in the primary industries, which are indispensable for the survival of humankind. We need to build a mechanism that accelerates the transformation of existing industries, creates new services, and fundamentally changes the industrial structure of the entire food value chain by taking both perspectives of agriculture with producers in mind and food with consumers in mind. By leveraging the unlimited potential of the ICT of the NTT Group and R&D capabilities of NTT laboratories, we will work with various partners to shape the future of food and agriculture. The NTT Group will continue to be a value partner of choice for all concerned and contribute to the development of primary industries.

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Future-oriented Agriculture—Strawberry Plant Factory Based on Regional Collaboration

Yoshikazu Takayama, Katsuhito Tsuzuki, Tsukasa Uekawa, Tomoyuki Nomura, Yuriko Maehara, Akiko Unami, Takashi Kawakatsu, Hiroki Kouyama, and Naoki Iwatani

Abstract

As a *social information and communication technology (ICT) pioneer*, NTT WEST is aiming to create *smart communities* to solve problems facing local communities and strengthen ties between individuals and society. Specifically, we are working on "Smart10x" initiatives to solve problems faced by local communities in ten fields by using the expertise and resources that exist in the community as well as those of NTT WEST and its group companies. This article introduces the "Collaboration Agreement on the Promotion of Agriculture and Regional Revitalization Utilizing ICT, Starting from Sakawa Strawberries," which was announced in April 2021, with regard to our initiatives for plant factories as future-oriented agriculture that is being promoted in the primary-industry sector.

Keywords: food and agriculture business, plant factory, regional revitalization

1. Background of the collaboration agreement

On April 24, 2021, the Sakawa Branch Strawberry Division of Japan Agricultural Cooperatives (JA) Kochi Prefecture (Sakawa Strawberry Division, hereafter), NTT WEST, the town of Sakawa, and Kochi Prefecture concluded a collaboration agreement to promote agricultural development and regional revitalization, particularly by leveraging the strawberry-cultivation technology of Sakawa Strawberry Division and information and communication technology (ICT) of NTT WEST and its group companies (NTT WEST Group, hereafter), as a way to explore the possibilities of "plant-based town development" advocated by the town of Sakawa.

In the Sakawa Strawberry Division, farmers are aging and their number is decreasing. Accordingly, while working on ways that will allow them to pass on skills, they aim to increase the number of new farmers and pursue sustainable agriculture by creating an environment that makes it easy for individuals to take up farming.

To become a *social ICT pioneer*, NTT WEST is taking the initiative in solving various problems brought about by changes in the environment surrounding society by using the power of ICT and collaborating with local communities (**Fig. 1**). As one of our initiatives, we had been considering the strawberry plant factory business as a means to solve social problems in the agricultural sector. Accordingly, we thought it was a good idea to grow Sakawa's delicious strawberries, which are highly evaluated by distributors, in a plant factory. Therefore, we consulted with the Sakawa Strawberry Division, leading to this collaboration.

The town of Sakawa is aiming to attract new farmers to support the Sakawa Strawberry Division and create a town in which children can learn about the

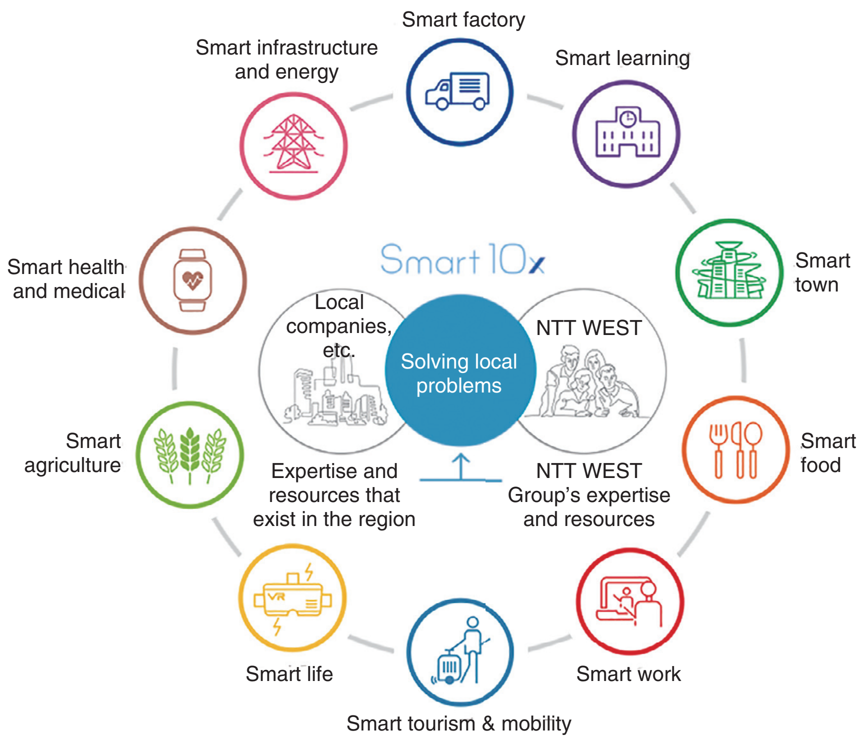

Fig. 1. NTT WEST "Smart10x" initiatives.

industries of Sakawa by using ICT in a manner that they can nurture their interests in such industries. Moreover, they want to make effective use of ICT in the "Sakawa Town, People, Work Creation Comprehensive Strategy" aimed at measures for addressing population decline, regional revitalization, and establishment of a virtuous cycle.

Against this background, we decided to close a collaboration agreement with the aim of contributing to the promotion of agriculture and plant-based town development by using ICT in the production of Sakawa strawberries. Targeting new agriculture and plant-based town development, NTT WEST will also explore ways to promote agriculture through digital transformation by promoting the use of ICT in agricultural fields and collaboration with plant factories in the Kansai (west Japan) region through regional cooperation. Kochi Prefecture is participating in this agreement to support the collaborative efforts of the Sakawa Strawberry Division, NTT WEST, and the town of Sakawa (**Figs. 2** and **3**).

2. Details of the collaboration

2.1 Specific actions to be taken

(1) Increase the number of new farmers of Sakawa strawberries
- Dissemination of information on Sakawa strawberries and the town of Sakawa through strawberry plant factories
- Production of strawberries using ICT

(2) Promote plant-based town development
- Consideration of the use of strawberries produced at plant factories for sale at roadside stations
- Study of ICT utilization to maximize the attractiveness and profit of roadside stations
- Expanding direct sales and revitalizing local communities by using closed-type plant-factory technology (**Photos 1** and **2**)

2.2 Agreement period

From April 24, 2021 to March 31, 2022.

2.3 Role of each party

(1) Sakawa Strawberry Division
- Various activities to increase the number of new

Fig. 2. Background and motivation for collaboration with the town of Sakawa.

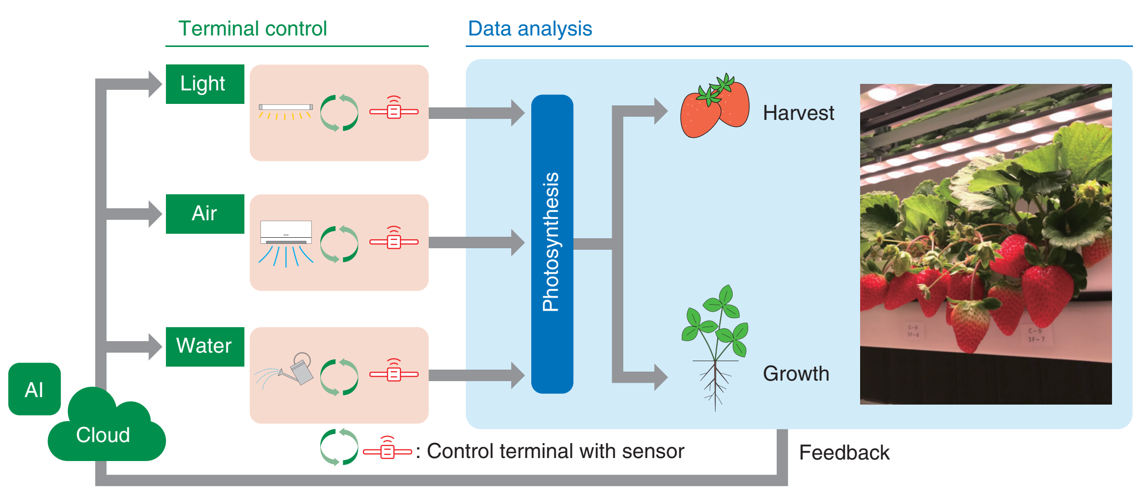

Fig. 3. Cultivation technology used in a strawberry plant factory.

farmers

- Pursuit of strawberry-cultivation technologies
- Provision of technological expertise on cultivation of Sakawa strawberries

(2) NTT WEST Group

- ICT-based support to increase the number of new farmers
- Regional revitalization through the promotion of strawberries produced in plant factories
- Studying the development of strawberry-plant-factory business in Sakawa

(3) The town of Sakawa

- Promotion and dissemination of plant-based town development
- Dissemination of the Sakawa strawberry brand
- Study of agricultural promotion and regional revitalization using plant factories

(4) Kochi Prefecture

- Support for initiatives from production to sales in line with the intentions of the producing

Photo 1. Strawberry cultivation field in Sakawa, Kochi Prefecture.

Photo 2. Strawberry plant factory operated by the NTT WEST Group.

region

3. Future developments

Under this collaboration agreement as a starting point, we will promote regional revitalization through cooperation in various fields, including the use of ICT, with a focus on Sakawa strawberries.

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Local Food Waste Recycling Solutions for Addressing the Sustainable Development Goals

Makoto Nakayama, Kento Miyaoku, and Fumihiro Nakanishi

Abstract

As a *social information and communication technology (ICT) pioneer*, NTT WEST and its group companies (NTT WEST Group, hereafter) aim to be a corporate group that is well-respected and trusted by the community by using the power of ICT to address local issues and create a sustainable society. NTT FIELDTECHNO, an NTT WEST Group company, whose core business is maintenance work in the regional telecommunication business, has enabled digital transformation of the food-recycling business by using ICT such as the Internet of Things and artificial intelligence. In partnership with Well Create Co., Ltd., which has excellent technical expertise in composting food residue, in April 2019, we started providing local food waste recycling solutions that contribute to the popularization of food waste recycling. This article introduces initiatives of NTT FIELDTECHNO concerning food waste recycling to address the United Nations' Sustainable Development Goals.

Keywords: food waste recycling, circular economy, organic agriculture

1. Status of food waste recycling and our solutions

1.1 Local food waste recycling solutions

The cost of introducing food waste recycling exceeds that of disposing of food residue as waste, and this has been a major factor preventing the spread of food waste recycling. To address this issue, the equipment for fermentation and decomposition of food residue provided by our local food waste recycling solutions uses microorganisms, which effectively decompose food residue such as vegetables. It can decompose and reduce the input food residue into a primary fermentation product that is five- to ten-times smaller in volume in a short time; consequently, it makes collection and transportation more efficient, thus reducing costs. We also provide a series of our solutions as a monthly service (including equipment rental to customers); therefore, an initial investment for introducing food waste recycling is not required on the customer's side, and their monthly food-residue processing costs are significantly reduced (**Figs. 1** and **2**).

Our local food waste recycling solutions will be provided by NTT FIELDTECHNO, which provides on-site telecommunication maintenance services throughout Japan. In addition to renting and installing the equipment for food-residue fermentation and decomposition to customers, the company offers a variety of services, including regular maintenance (**Fig. 3**).

When introducing these solutions, we want to ensure that customers can enjoy the cost benefits; accordingly, we will (i) provide consulting before introducing the solution and, if necessary, (ii) carry out tests on decomposition/fermentation of food residue and odors as well as trials using actual equipment. Cost simulations and tests on food-residue decomposition are provided free of charge, so customers can implement these solutions without any initial

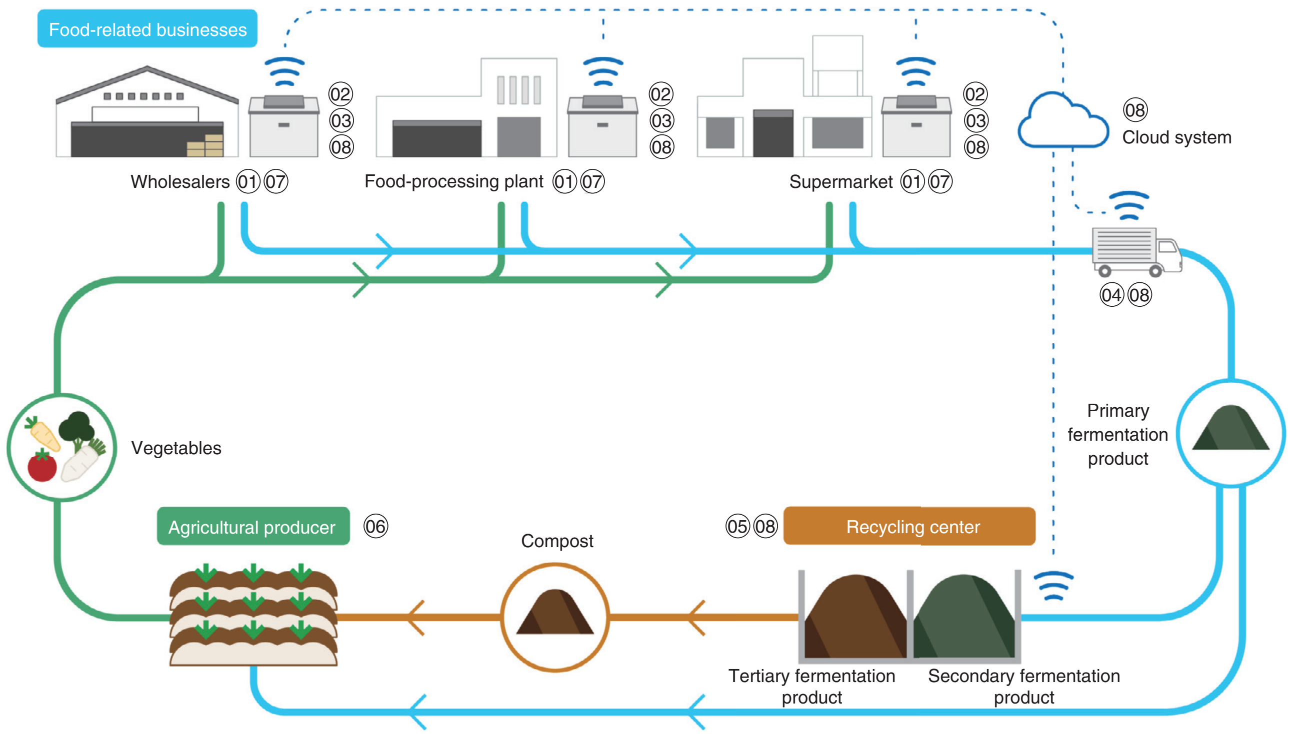


Fig. 1. Overview of our local food waste recycling solutions.

investment and reduce their monthly food-residue disposal costs. A trial (lasting about three months) using actual equipment is available for a fee.

1.2 Information and communication technology (ICT)-based food waste recycling

(1) Converting abandoned farmland into fields and improving fertility of farmland

In Japan's agricultural industry, the expansion of abandoned farmland, which has doubled in area in the past 20 years, is a problem. The main cause is the aging of farmers. However, it is also due to the deterioration of soil caused by the use of chemical fertilizers, which makes it difficult to grow crops, making farming less profitable. The abandoned farmland significantly affects neighboring farmers through growth of weeds and encroachment by pests such as insects.

To solve this problem of abandoned farmland, together with the Compost and Soil Research Institute, we are working on using recycled organic compost—made by adding locally available organic materials (e.g., cow and chicken manure, rice husks, and rice bran) to food residue generated from our local food waste recycling solutions—and digitizing our knowledge (temperature, humidity, pH adjustment, etc.) concerning such compost. NTT FIELDTECHNO has developed a system for collecting data on the extremely difficult process of manufacturing high-quality organic compost. The system uses Internet of Things (IoT) sensors and other technologies to create stable, high-quality compost and potting soil on the basis of the collected data. Therefore, it supports soil preparation, which is the foundation of agriculture (**Fig. 4**).

We are currently conducting a joint demonstration with a large-scale agricultural corporation in Okayama Prefecture regarding a project called "Restoring Abandoned Farmland and Fertilizing Farmland" by using high-quality organic compost. We are demonstrating and comparing methods of fertilizing soil in a short period at low cost at a leaf vegetable field by capturing aerial images with drones and collecting data on the physics, chemistry, microbial properties, etc. of soil with IoT sensors.

(2) Organic-farming support project

Our local food waste recycling solutions will also tackle other issues facing the agricultural industry to create a "food-recycling loop." For example, agriculture relies on intuition and experience, and expertise

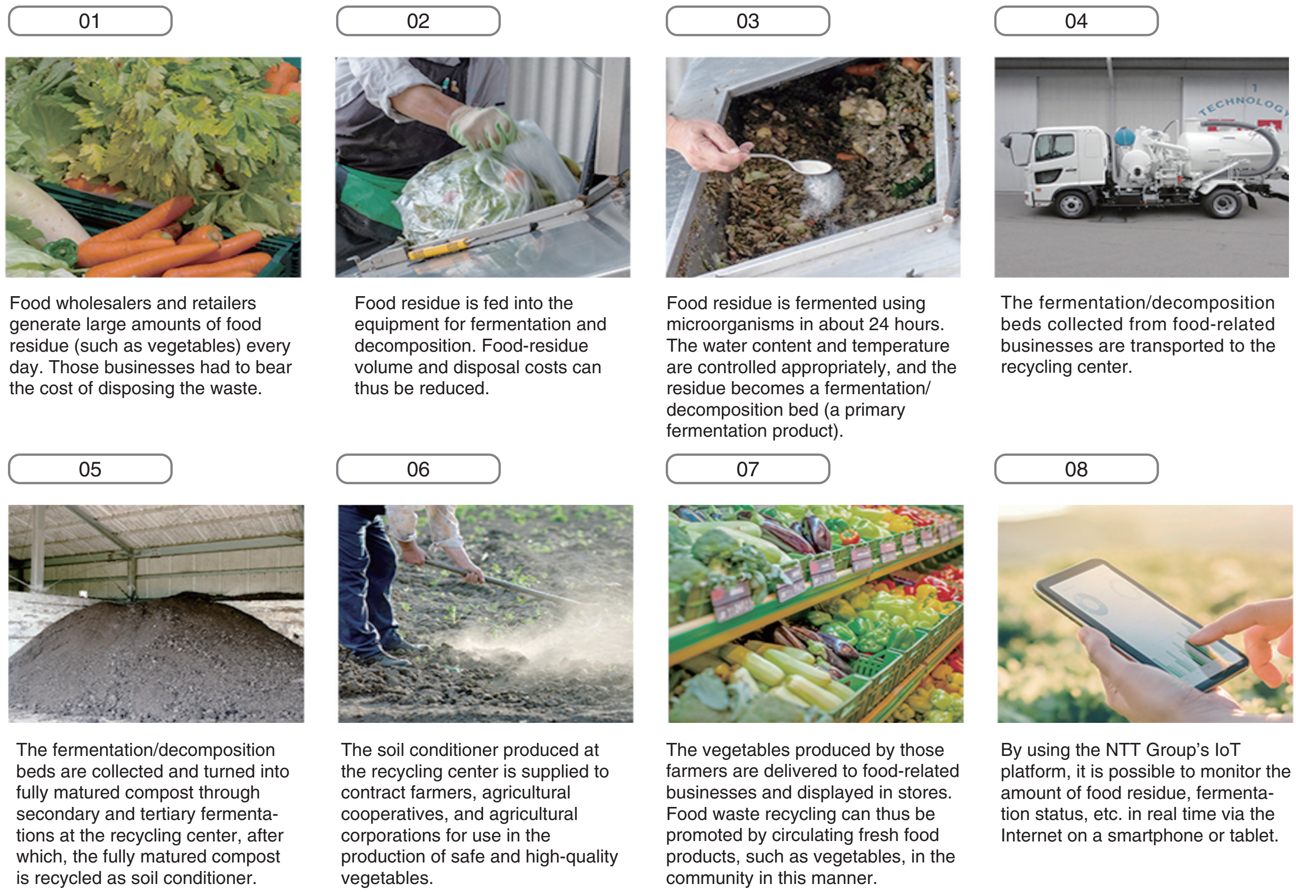


Fig. 2. The process of each solution.

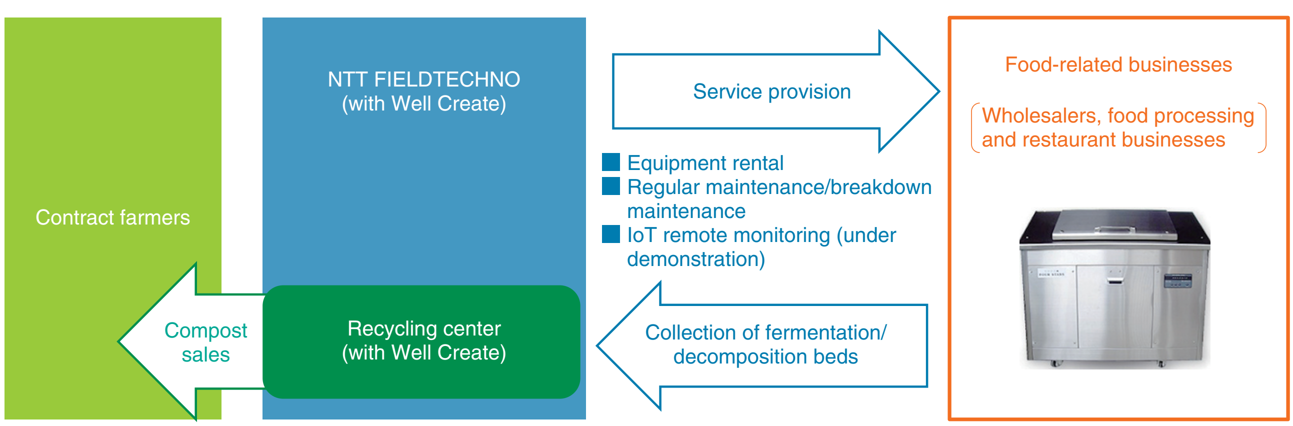


Fig. 3. Service-provision system.

is passed down through experience and transfer. With the ongoing aging of farmers and the increase in the number of farmers abandoning their farmlands, the loss of this expertise has become an urgent issue.

By using ICT, such as sensing and telecommunications that NTT WEST and its group companies (NTT

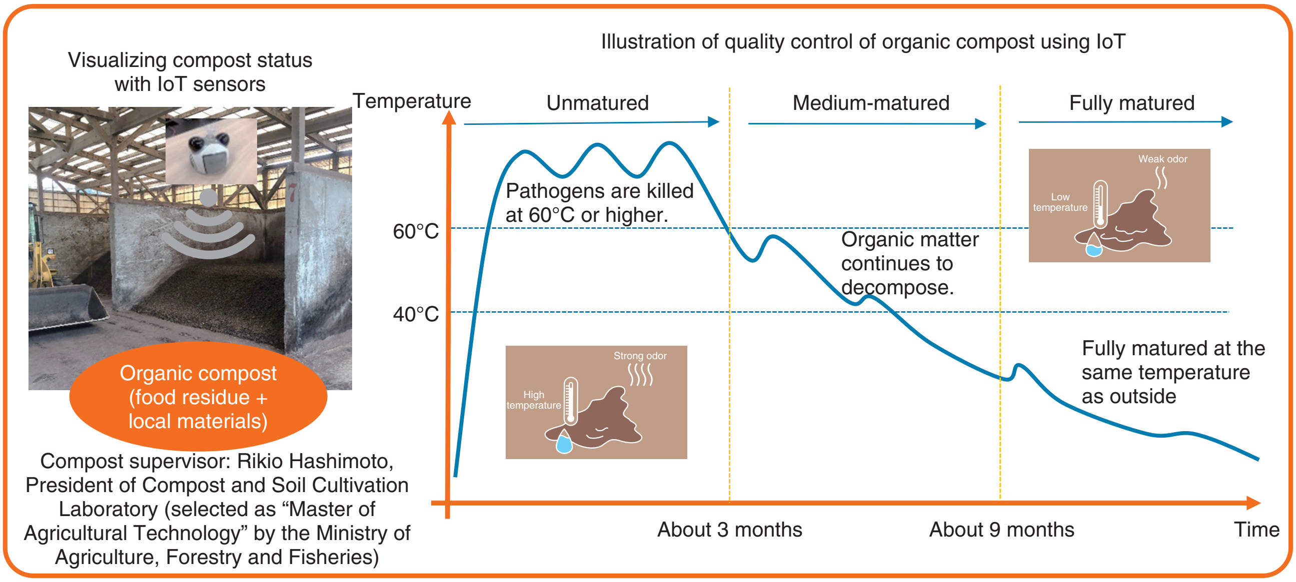


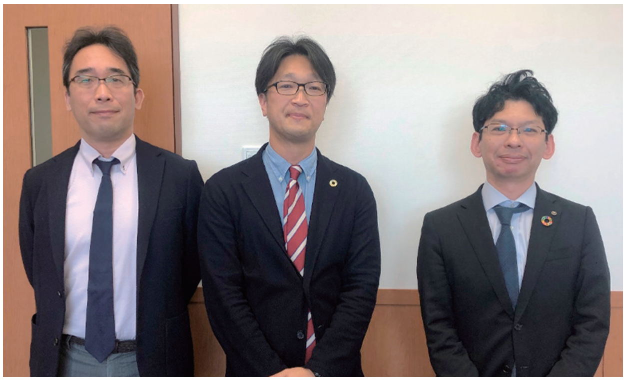
Fig. 4. Using data to manage the maturation of organic compost.

WEST Group, hereafter) possess, we will promote not only composting and soil improvement but also digitalization of farming expertise to support organic farming. We are in the process of digitizing all processes of organic farming, such as selecting varieties, raising seedlings, planting, irrigation, and evaluation of nutritional value of crops, for multiple organic farmers who are growing cherry tomatoes and leaf vegetables. Through these efforts, we are verifying improved profitability through labor saving and automation.

2. Future developments

The COVID-19 pandemic has gone on for over a year and has increased people’s frequency of eating and cooking at home. Under these circumstances, new food-distribution markets, such as ready-to-eat meals and home delivery of meal kits, are expanding, and options for selecting food and ingredients are increasing. Amid such changes in the environment, it is expected that consumers’ food needs will become more complex and diverse; as a result, their awareness of food safety, food loss, and sustainability will further increase.

The NTT WEST Group will build a resource-circulation smart value chain centered on the local food waste recycling solutions in light of these changes in market needs. In doing so, we want to provide consumers who are health conscious and nature-oriented with new value of a healthy and prosperous life within the circle of resource circulation and contribute to creating a sustainable society without food loss.



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“Fisheries +d”: NTT DOCOMO’s Solution Co-creation for the Fisheries Industry

Keiichi Yamamoto, Masako Nakashima, Yuko Yokoi, and Yutaka Okabe

Abstract

While there is no end in sight to the decline and depletion of natural fish and shellfish, the global fish catch is on the rise due to population growth and other factors. The need to reliably nurture marine resources while protecting the diversity of the oceans from pollution is growing in urgency. Accordingly, expectations regarding improvement and commercialization of sustainable aquaculture technologies are increasing. NTT DOCOMO is focusing on the fisheries industry as the main area for *industry creation* underpinned by its medium-term strategy through 2020 called “Declaration beyond.” Under this strategy, we have developed marine-monitoring technology and aquaculture-management solutions that use ICT (information and communication technology) buoys and cloud computing, thus contributing to regional revitalization in collaboration with partner companies. This article introduces the initiatives of NTT DOCOMO in the fisheries industry.

Keywords: fisheries, ICT, smart aquaculture

1. “Fisheries +d” initiatives began with support for post-disaster reconstruction

In April 2017, NTT DOCOMO announced its medium-term strategy, called “Declaration beyond,” and has been striving toward transforming itself from a mobile communications company to a “value co-creation company.” We believe that we can create new business and co-create new social value by combining the strengths of our partners in various fields, such as local governments, other companies, and research institutes, with NTT DOCOMO’s customer base, robust networks, information and communication technology (ICT), and other strengths. We refer to these initiatives with the suffix “+d” (plus d), in which d stands for NTT DOCOMO.

“Fisheries +d” initiatives for solving problems in the fisheries industry has started with providing reconstruction support following the 2011 Great East Japan Earthquake. As part of that reconstruction support, we began exchanges with seaweed and oyster farmers in the city of Higashi-Matsushima in Miyagi Prefecture and thought that we want to not only support reconstruction but also create sustainable services that are useful for people engaged in the fisheries industry through NTT DOCOMO’s main business. A service that uses ICT buoys was developed to meet this goal.

2. ICT buoys for visualizing sea conditions

One day, we heard from an oyster farmer in Higashi-Matsushima that “The sea conditions have changed since the earthquake, and our past experience and intuition are no longer valid.” Temperature and salinity (specific gravity) of the seawater at oyster farms are important factors in understanding sea conditions, and farmers used to measure them manually whenever they went to the oyster farms. To address this issue, we developed a service that uses

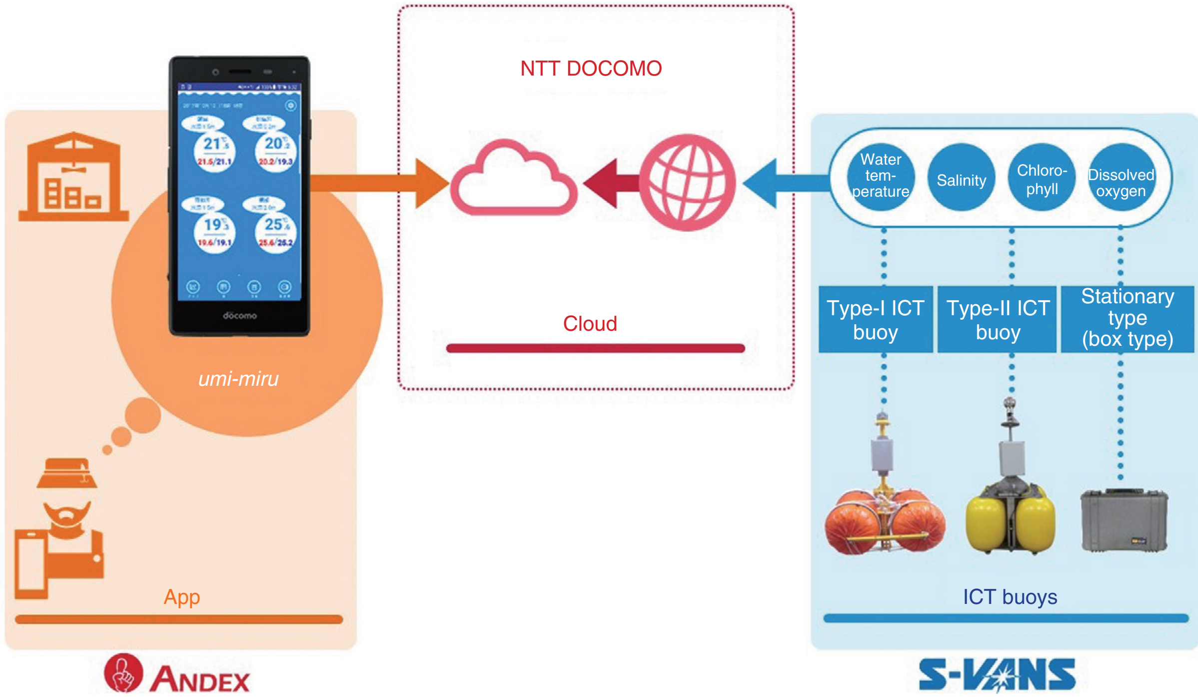

Fig. 1. Overview of ICT buoy solution.

ICT buoys equipped with sensors for measuring seawater temperature and salinity and communication modules installed at oyster farms. The sensor data—measured automatically every hour—are sent by the modules to the cloud, from which farmers can view the information via the app called "*umi-miru*" ("view the ocean" in English) installed on their smartphones. Together with our partners ANDEX and Sena and Vans Co., Ltd. (S-VANS), we began demonstration tests of this service in 2016 and launched a commercial service (**Fig. 1**) in October 2017.

Thanks to the introduction of ICT buoys, farmers have been able to continuously visualize sea conditions and support their experiences and intuition with data. Regarding edible-seaweed cultivation, we were able to confirm the effectiveness of ICT buoys for the "raising seedlings" process. Raising seedlings promotes the growth of seaweed through removing other seaweeds by exposing the seedlings (cells) of the seaweed attached to the seaweed net to the air. This is a key process that affects the taste, quality, and yield of seaweed. Seawater temperature and specific gravity had been measured at the seaweed farms before deciding on the work procedure for the day; however, thanks to the introduction of ICT buoys, past fluctuations in seawater temperature and specific gravity can be understood, so that work for the day can be determined on land. The farmers' experience thus far has made it possible to interpret the data and predict the optimum timing and duration of drying out the seaweed, and "Thanks to ICT buoys, we can now imagine the appearance of seaweed cells on land," said a seaweed farmer in Higashi-Matsushima.

Information of ICT buoys spread through connections between farmers, and their introduction has progressed in major seaweed-producing areas such as Ariake Bay in southwestern Japan. In the 2017 Fisheries White Paper published by the Fisheries Agency, ICT buoys were mentioned as an example of ICT utilization in the aquaculture industry. As a result, the introduction of ICT buoys has expanded to aquaculture sites other than seaweed. For example, three ICT buoys were installed in Tsushima, Nagasaki Prefecture, for pearl-oyster farming in March 2018 (**Photo 1**). They were equipped with seawater temperature, chlorophyll concentration, and turbidity sensors. This case is the first in which chlorophyll concentration is constantly monitored throughout the year at a pearl cultivation site. "With the introduction of ICT buoys, we now know the seawater temperature and chlorophyll concentration every hour, so we can clean and treat Akoya pearl oysters (Japanese pearl

Photo 1. ICT buoy in operation at the Tsushima Pearl Farming Cooperative.

oysters) according to the sea conditions. As a result, we can produce pearls of higher quality than ever before," said Mr. Hidaka, the head of the Tsushima Pearl Farming Cooperative. Since 2019, ICT buoys have been added and eleven ICT buoys are currently in operation at pearl-oyster farms in Nagasaki Prefecture.

Since 2019, we have also been receiving inquiries about ICT buoys from fish farming businesses concerning amberjack, red sea bream, and salmon. Regarding fish cultivation, sea conditions, namely, seawater temperature and dissolved-oxygen concentration, significantly affects the amount of feed intake and growth of cultured fish species. However, seawater temperature and dissolved-oxygen concentration are only measured during fish-feeding operations, and in many cases, feeding records are only managed analogically. When we visited aquaculture sites, we found that more than 90% of fish-farming companies are small and medium-sized, and fish-farming management is becoming more difficult due to sluggish fish prices and soaring feed prices. It is therefore difficult for fish farmers to invest in ICT, so we became acutely aware that ICT buoys alone cannot solve the problems facing fisheries sites.

3. From visualizing sea conditions to solving problems

NTT DOCOMO entered the fisheries industry with the goal of visualizing sea conditions by using ICT buoys; however, we have shifted to a policy of listening to the voices from fishery sites and working with our partners to provide solutions to the problems that we hear. In May 2020, we entered into a business alliance with the SABAYA Group (SABAYA Co., Ltd., SABAR CO., LTD., and FISH BIOTECH Co., Ltd.).

This business alliance aims to create a new market for safe, secure, and tasty farmed mackerel. In doing so, it hopes to encourage new entrants to the fisheries industry and contribute to revitalizing local communities and developing Japan's fisheries industry. As part of the alliance's efforts, a demonstration test to establish a new ICT-based mackerel farming model was launched in May 2020 at FISH BIOTECH's mackerel farm in the town of Kushimoto, Wakayama Prefecture. NTT DOCOMO has developed and has been providing an "aquaculture management cloud," a cloud environment that integrates the management of ICT buoys (stationary type) and mackerel farming. We have also conducted various ICT demonstration tests at the mackerel farming site in Kushimoto, including installation of cameras and other equipment and the use of underwater drones to check fish behavior and the presence or absence of leftover feed in fish ponds. Through these demonstration tests, we accumulated knowledge on how to deal with high seawater temperatures, which increases the mortality risk of mackerel as a result of infectious diseases and changes in the environment. We also confirmed the effectiveness of measuring fish length using ultrasonic underwater-visualization technology, improvements to the functions and user interface of the aquaculture management cloud, and the effectiveness of

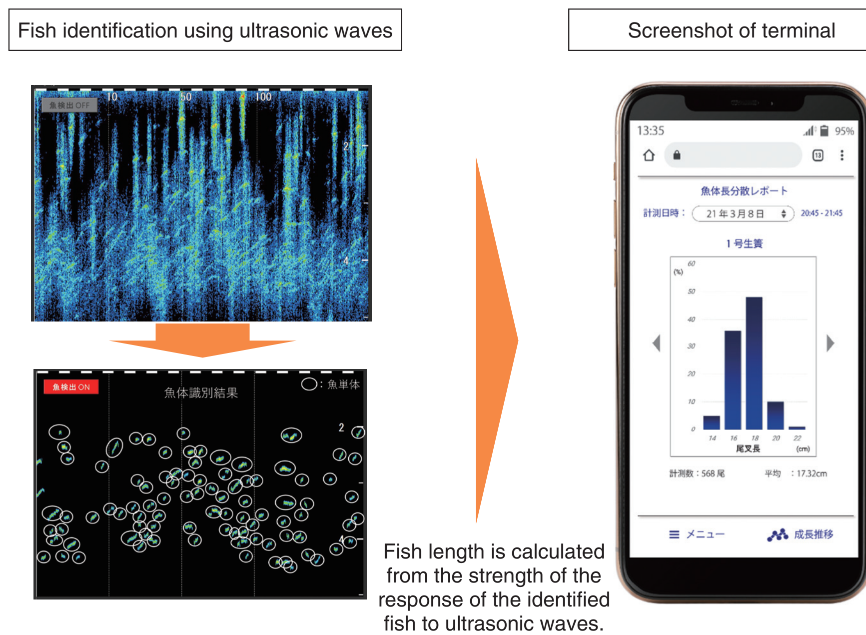

Fig. 2. Illustration of measuring fish length.

the "sea-condition simulation" service that we plan to launch.

Fish length measurement and sea-condition simulation using ultrasonic underwater-visualization technology are introduced in the following subsections as examples of co-creation with a partner.

3.1 Measuring fish length using ultrasonic underwater-visualization technology

On March 8, 2021, NTT DOCOMO and AquaFusion Inc. signed a business-alliance agreement to establish a new aquaculture-management model through development of an ICT service that uses ultrasonic underwater-visualization technology for automatically measuring fish length and weight. In the aquaculture industry, measurements of fish length and weight are key factors in efficient management of fish production. Until now, farmers had taken several farmed fish out of the fish tank with a scoop net and measured them one by one with a measuring instrument. However, physically handling the fish could kill them, and the growth of the fish extracted as samples varies, so it is difficult to accurately understand the growth process. Therefore, since October 2020, we have been verifying non-contact measurement of mackerel body length by using AquaFusion's ultrasonic underwater-visualization technology during demonstration tests of cultured mackerel with the SABAYA Group. On March 11, 2021, we announced that we have succeeded in measuring the average length of mackerel swimming in a fish tank with high accuracy (**Fig. 2**). From now onwards, we will verify the estimation technique of fish weight from fish length using artificial intelligence (AI).

The ultrasonic underwater-visualization technology automatically analyzes the response of an object to ultrasonic waves transmitted at high frequency to identify a fish. This technology represents the world's first use of CDMA (code division multiple access) for underwater ultrasonic measurement and enables ultrasonic transmissions of more than 40 times per second. Featuring resolution 100 times higher than conventional fish finders, it can identify individual fish even in densely populated environments such as fish ponds. The use of ultrasonic waves also makes it possible to measure fish even at night or when the sea is turbid, so the technology is independent of the measurement environment.

Linking fish-length measurement service provided by AquaFusion with NTT DOCOMO's aquaculture management cloud will make it possible to (i) accurately understand the growth process of fish as a function of the aquaculture-management cloud and (ii) provide ICT services for aquaculture with high added value, such as improving work efficiency and optimizing the amount of feed.

3.2 Sea-condition simulation

Sea-condition simulation is a service that is being tested in collaboration with Forecast Ocean Plus, Inc. and ANDEX (our partner in providing ICT buoys). Forecast Ocean Plus provides the information-consulting business for marine industries and public institutions and uses various prediction models resulting from the cutting-edge research of physical oceanography at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). NTT DOCOMO has been collaborating with Forecast Ocean Plus in developing a system that enables safe and efficient ship operation by equipping ships with terminals that can display tidal-current-forecast information provided by Forecast Ocean Plus.

We began considering collaboration in the aquaculture industry in 2018 and developed the "*umi-miru*" smartphone app for sea-condition simulation with ANDEX around the summer of 2019, when the horizontal resolution of the sea-condition prediction model reached 1 km (**Fig. 3**). With this app, hourly forecast for the next three to five days of sea-condition information, i.e., seawater temperature, current speed, and current direction, predicted by Forecast Ocean Plus can be displayed in the form of animation. Since 2020, we have been verifying the use of the *umi-miru* sea-condition simulation at several aquaculture sites, including the above-mentioned mackerel farm in Kushimoto. After sufficient evaluation and verification, we plan to improve the app and commercialize it. In the bays where many aquaculture sites are located, it is difficult to predict sea conditions due to inflow from rivers, etc. By using sea-condition information, such as sea temperature, from ICT buoys provided by NTT DOCOMO as input information for Forecast Ocean Plus's forecasting model, it is possible to improve the forecasting accuracy of sea conditions in bays.

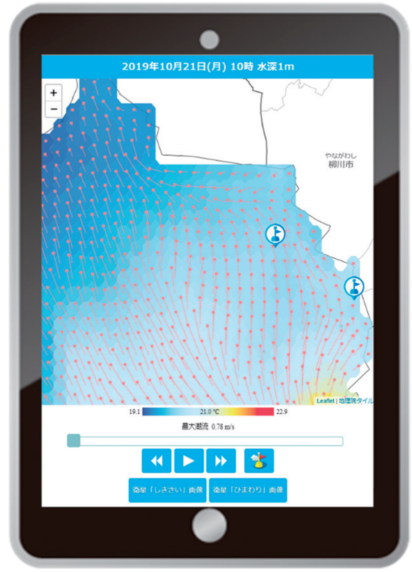

Fig. 3. Screenshot of the *umi-miru* smartphone app for sea-condition simulation.

4. Future developments

The Japanese fisheries industry is facing many challenges, such as a decreasing fish catches and an aging population of fishers and farmers. Working closely with our partners, NTT DOCOMO wants to contribute to revitalizing local communities and developing the Japanese fisheries industry by providing solutions to these challenges by using our experience and expertise in supporting the reconstruction from the 2011 Great East Japan Earthquake and in directly communicating with fishers and farmers.

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High-quality, High-yield Organic Farming with BLOFware®.Doctor

Hirofumi Umeshita, Shintaro Uno, Yutaka Kobayashi, Takeshi Saito, Masashi Kashima, and Marina Wada

Abstract

Organic farming has been gaining attention as a sustainable agriculture both in Japan and around the world; however, it faces problems such as inconsistent quality and yield, making stabilized production difficult. The organic cultivation theory called the "BLOF® (biological farming) theory" can solve these problems and achieve stable, high-quality, high-yield production in organic farming. NTT COMWARE has incorporated the expertise of organic cultivation based on the BLOF theory into its service system and started to provide a cloud-based farming-support service called "BLOFware®.Doctor." The service content and future development of BLOFware.Doctor are introduced in this article.

Keywords: smart agriculture, organic farming, BLOFware®

1. Environment surrounding organic farming

Accompanying the widespread adoption of the United Nations' Sustainable Development Goals, interest in organic farming as a sustainable agriculture to conserve the global environment has been growing around the world.

Organic farming is also being actively promoted in Japan, where the Ministry of Agriculture, Forestry and Fisheries (MAFF) has set a goal of increasing the area of organic farming to 25% (one million ha) of Japan's total farmland by 2050 [1, 2] (**Fig. 1**). However, the current area of organic farming as a percentage of total farmland is only 0.5% (237,000 ha, as of 2018) [3], therefore, increasing it to 25% in about 30 years is a very challenging goal. Organic farming generally requires more labor than conventional agriculture,*1 and its quality and yield are inconsistent, so it is difficult to stabilize production. To achieve the above-mentioned goal, it is important to establish and disseminate effective technologies to solve these problems facing organic farming.

2. Applying the BLOF® theory to solve the problems facing organic farming

The solution to the above problems facing organic farming is the "BLOF® (biological farming) theory,"*2 which is an organic-cultivation theory advocated by Masaaki Koiwai of Japan Bio Farm Co., Ltd. The BLOF theory enables stable production of organic crops with high quality and high yield by scientifically and logically preparing the soil (**Fig. 2**). To create optimal soil for growing crops, it is necessary to create ideal conditions with respect to the following three major soil components: (i) amino acids, which build cells; (ii) minerals, which are essential for maintaining life; and (iii) medium-matured compost, which promotes root growth.

Plants produce amino acids (organic nitrogen) necessary for growth by synthesizing carbohydrates created through photosynthesis and inorganic nitrogen absorbed from the roots; however, research has

*1 Conventional agriculture: Agriculture that uses chemical fertilizers and pesticides for pest control and weed control.

*2 BLOF® and BLOFware® are registered trademarks of Japan Bio Farm Co., Ltd. Other company names, product names, and service names mentioned herein may be the trademarks or registered trademarks of their respective owners.

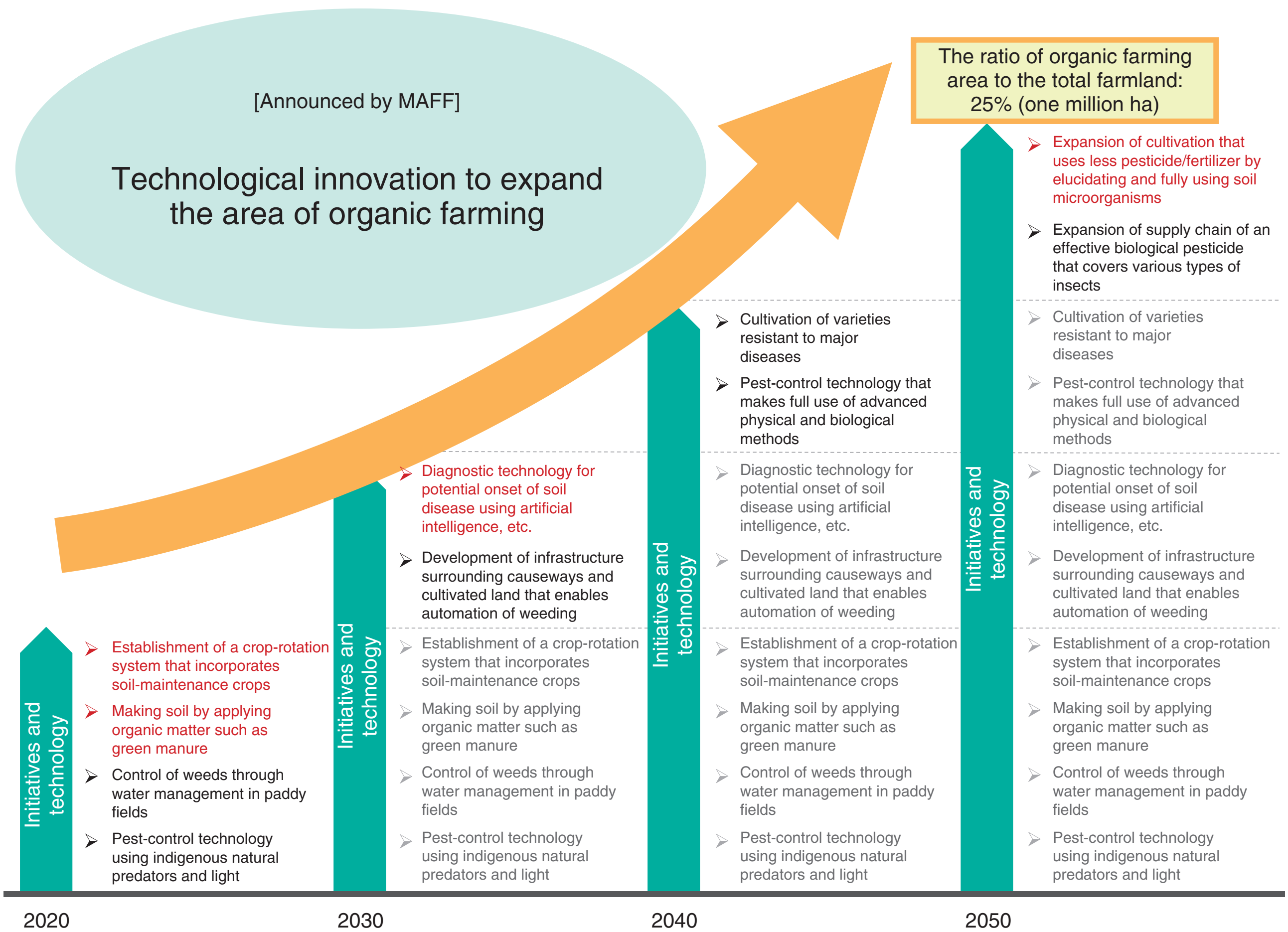

Fig. 1.   Efforts to expand the area of organic farming announced by MAFF [2].

shown that amino acids can be absorbed directly through the roots. The BLOF theory applies the results of this research and enables the provision of amino acids as fertilizer to be absorbed directly by the roots to achieve higher quality and higher yields than ordinary crops. Minerals in the soil that have been consumed by crops in large quantities to promote high quality and high yield can be appropriately replenished through fertilization*3 on the basis of the results of analyzing the current compositional balance of the soil; as a result, stable production is possible in the following years. By using medium-matured compost, it is possible to create soil with a fluffy, clustered structure. This type of soil allows the roots to grow deep into the ground, producing strong crops that do not attract pests and diseases without the use of pesticides.

The BLOF theory, which provides solutions to the problems facing organic farming and helps expand the area of organic farming, is evolving yearly. However, because it requires a high degree of specialized knowledge and skills to put it into practice, it has not been widely used.

3. Cloud-based farming-support service: BLOFware®.Doctor

In August 2020, through a business alliance with Japan Bio Farm, NTT COMWARE started providing the cloud-based farming-support service called BLOFware®.Doctor that incorporates the knowledge of the BLOF theory. During the development of BLOFware.Doctor, we adopted an agile methodology and worked with Japan Bio Farm from the concept-making stage. We conducted interviews with experts in the BLOF theory and farmers about a

*3 Fertilization: spreading fertilizer on soil (fields).

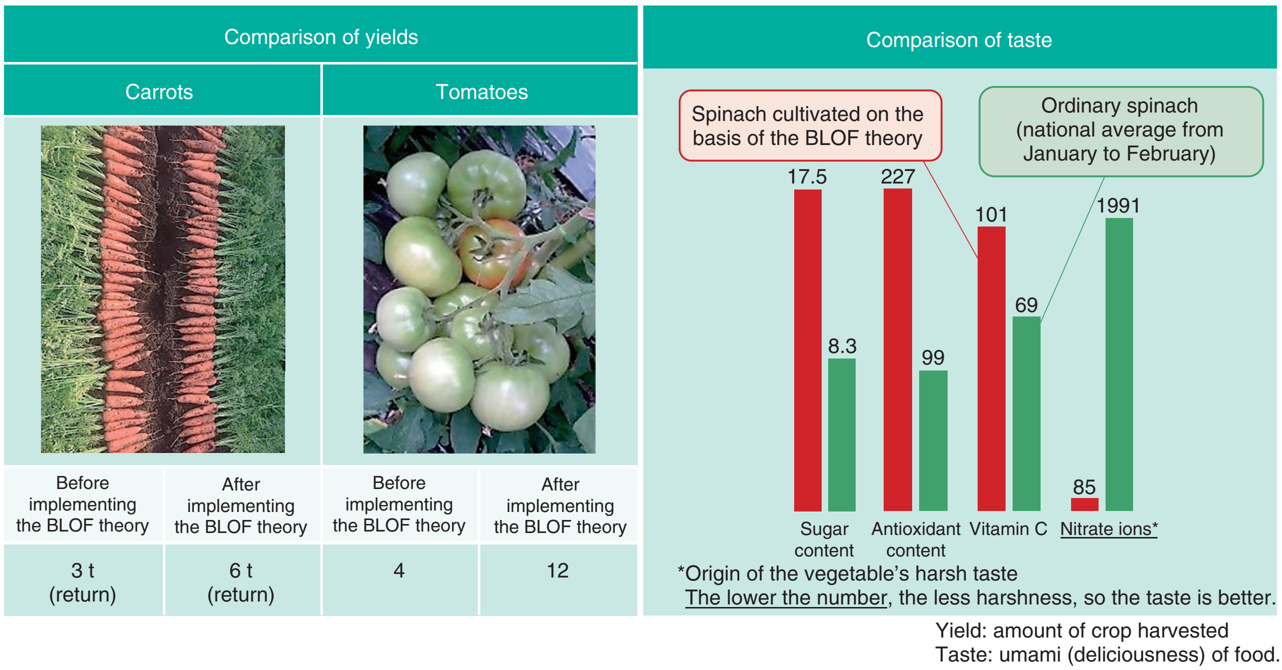

Fig. 2. Crops cultivated on the basis of the BLOF® theory.

prototype of BLOFware.Doctor and flexibly reflected the issues and requests we obtained from them in the specifications of the prototype. In this manner, we continued improving the prototype. In August 2019, we conducted demonstration tests on organic farming based on the BLOF theory by using the prototype of BLOFware.Doctor in cooperation with farmers and confirmed that BLOFware.Doctor can contribute to implementing organic farming based on the BLOF theory. After incorporating the requests from farmers concerning operability and functionality received during the demonstration tests, we launched the service on a full scale in August 2020.

We are collaborating with Japan Bio Farm regarding the provision as well as development of BLOFware.Doctor. By dividing the roles of the two companies according to their strengths, that is, NTT COMWARE took responsibility for construction and provision of the service system, while Japan Bio Farm took responsibility for provision of expertise and knowledge concerning the BLOF theory and user guidance, we are able to provide services that focus on helping farmers. BLOFware.Doctor allows farmers who have never been exposed to the BLOF theory to easily practice organic farming based on the BLOF theory on the basis of the following three points.

3.1 Point 1: The BLOF theory can be learnt from the basics

The first point is that it has a full range of features to help users learn the basics of the BLOF theory. BLOFware.Doctor provides a "growing map" that explains the basics of the BLOF theory in an easy-to-understand manner with photos (**Fig. 3**). The map can serve as a textbook of the BLOF theory that summarizes key points concerning work to be done in accordance with the growth stage of each crop, and it can be used for learning the BLOF theory and as a manual guide for actual farm work.

Japan Bio Farm also holds regular online seminars limited to users of BLOFware.Doctor. This is a special program that includes lectures on how to use BLOFware.Doctor and guidance on the agricultural work needed at that time of the year, so users can immediately put into practice what they learned in the seminar.

The growing map is available (via the cloud) for reference any time, and the seminars are archived for review at any time, so users can learn whenever they like, such as during their spare time. At organizations with multiple farmers, such as agricultural corporations, members can learn the same content, even if it is difficult for everyone to get together at the same time, which helps to establish a common language.

Fig. 3. Screenshot of growing map.

3.2 Point 2: Anyone can easily practice soil analysis and fertilizer planning

The second point is that soil analysis and fertilizer planning can be easily carried out by anyone. The two most-important steps in soil preparation, which is the core of the BLOF theory, are soil analysis, which analyzes the balance of soil components in the field in question, and fertilizer planning, which calculates how much fertilizer should be applied to the field. If these steps are not done properly, the effectiveness of practicing the BLOF theory will be greatly reduced.

BLOFware.Doctor is linked with the soil-analysis service provided by Japan Bio Farm. Users collect soil from their fields and send it to Japan Bio Farm, who analyze it and send the analysis results back to the users. The received analysis data can be easily imported into BLOFware.Doctor, so users can immediately proceed to creating a fertilizer plan.

Although Excel tools are available to assist in fertilizer planning for the BLOF theory, they require complex calculations and adjustments, which is one of the reasons that beginners stumble when practicing the BLOF theory. In response to the feedback from farmers, BLOFware.Doctor was designed so that anyone can easily create fertilizer plans by using graphs and easy-to-understand operations. Users can simulate the optimal amount of fertilizer by simply adjusting the amount of fertilizer they want to use in accordance with a guidance for optimal balance of soil components that is automatically displayed on their screen (**Fig. 4**). The calculation and adjustment logic is all built into the service system, so the user does not need to be aware of it. By applying fertilizer in accordance with the resulting fertilizer plan, it is possible to create the optimal soil for growing certain crops and achieve high-quality, high-yield production.

BLOFware.Doctor incorporates new knowledge on nitrogen content in the soil, whereas the only previously published information on fertilizer planning was related to the balance of mineral components. By simply entering the required information, the system automatically calculates the optimal amount of nitrogen and the amount of fertilizer needed to achieve it.

BLOFware.Doctor also incorporates a large amount of information that has never been made public before. For example, BLOFware.Doctor not only has separate functions for rice, vegetables, and fruit crops but also incorporates optimized calculation

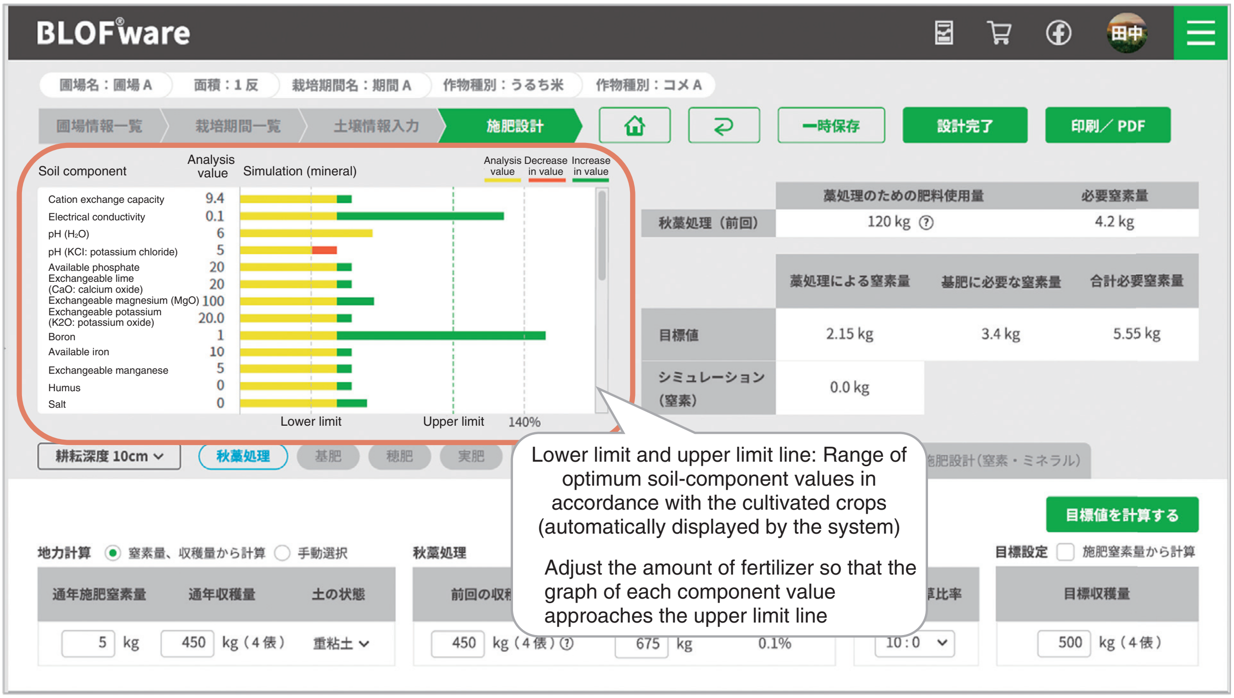

Fig. 4. Screenshot of fertilizer plan.

logic for each crop, such as carrots, onions, and spinach; in contrast, only common calculation logic for all crops was previously published. This information is unique to Japan Bio Farm and has not been published previously. Incorporating this information into BLOFware.Doctor makes it possible for a wide range of farmers to use advanced technology based on the BLOF theory while the core information is kept secret.

3.3 Point 3: Support is available when problems arise

The third point is that support is available whenever the user needs it. Although there are about 2000 practitioners of the BLOF theory, they are scattered throughout Japan. Consequently, it is often the case that newcomers to the BLOF theory have no one around them who practices it or no other practitioners to turn to for advice when in need. To address this issue, BLOFware.Doctor provides a support function, called "instructor's advice," which allows users to seek advice from instructors who are experts in the BLOF theory (**Fig. 5**). First, the user inputs questions and photographs of actual crops. The instructor returns advice based on the questions and photographs as well as information such as the results of soil analysis and a fertilizer plan for the user's fields. Therefore, the user can receive suitable advice based on his/her specific situation—just like a family doctor.

We have also set up a Facebook page exclusively for BLOFware.Doctor users as a platform to exchange information with other practitioners. That page will allow users to interact with each other and accumulate more knowledge.

4. Future developments

By providing BLOFware.Doctor featuring the three key points described above, we will help farmers succeed through the practice of the BLOF theory. Currently, only the rice-paddy version is available, but the vegetable and fruit-tree versions will be respectively available in the summer and fall of 2021.

We plan to make BLOFware.Doctor even easier to use by incorporating the voices of farmers and the latest knowledge about the BLOF theory and improving the instructor-advice function with artificial intelligence and chatbots. We also want to develop BLOFware.Doctor into a BLOFware series of services that provides comprehensive support for agriculture—from production to sales—to help farmers increase

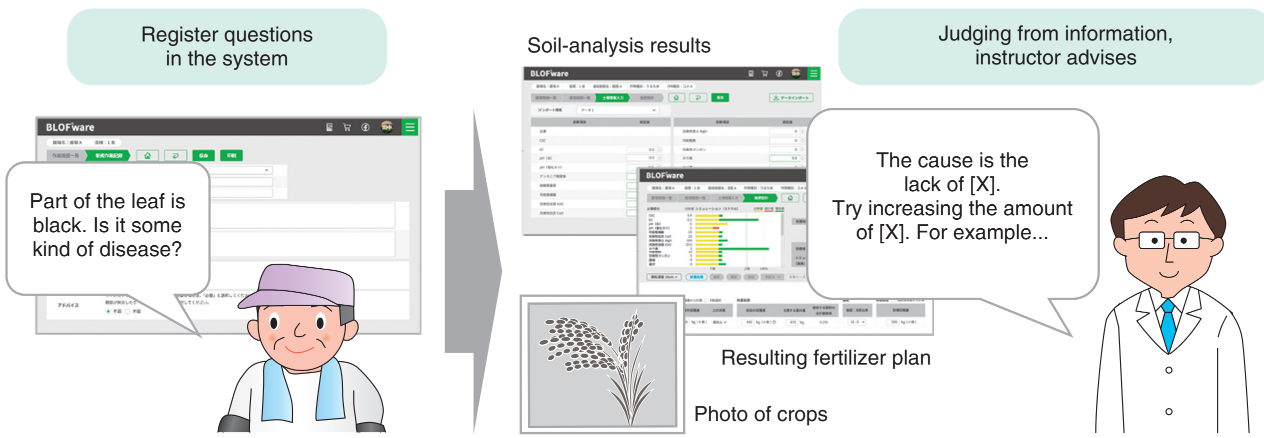

Fig. 5. Illustration of usage of "instructor's advice."

profits. In the future, we will consider global expansion of BLOFware.Doctor to contribute to solving the world's food crisis.

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Multi-radio Proactive Control Technology (Cradio®): A Natural Communication Environment where Users Do Not Need to Be Aware of the Wireless Network

Motoharu Sasaki, Toshiro Nakahira, Takatsune Moriyama, Tomoaki Ogawa, Yusuke Asai, and Yasushi Takatori

Abstract

To provide a natural communication environment where users do not need to be aware of the wireless network, we are researching and developing Cradio®—a set of multi-radio proactive control technologies that combines three advanced and coordinated technology groups: wireless sensing/visualization, wireless-network-quality prediction/estimation, and wireless-network dynamic control. This article describes the Cradio technology suite and our vision for the creation of a natural communication environment by combining these technologies with various social systems.

Keywords: Cradio®, multi-radio proactive control technologies, wireless communication

1. The prospects of wireless networks

1.1 Increasing communication volume and diversifying communication requirements

The concept of the Innovative Optical and Wireless Network (IOWN) has been proposed by NTT as a model for future implementation of networks [1]. The role of wireless communication is increasing dramatically in all aspects of our lives due to the growing volume of smartphone traffic and the development of Internet of Things (IoT) technology used to connect a variety of diverse objects to the Internet. It is therefore predicted that the volume of wireless communication will continue to increase. According to ITU-R*1 Report M.2370, mobile data traffic will reach 5016 EB/month in 2030, about 80 times higher than in 2020 [2]. In particular, the volume of machine-to-machine communication, which correlates with IoT, is expected to increase by about 124 times (622 EB/month). This shows that in addition to the increase in communication volume, there will also be greater diversity in the types of wireless terminals and usage patterns of wireless communication. Mobile communication will not just be used for smartphones but also for remotely controlling automated vehicles and drones and exchanging ultra-high definition video. This diversification of wireless terminals and usage patterns means that it is important to provide wireless network coverage not only in urban areas where the population is concentrated but also in suburban and rural areas. Therefore, we must respond to the

*1 ITU-R: The Radiocommunication Sector of the International Telecommunication Union (ITU).

increasingly diverse requirements for wireless communication quality suitable for various forms of use.

1.2 Diversification and increased frequency of wireless networks

To address these needs, studies are underway to develop various wireless communication standards. For mobile cellular communication, commercial fifth-generation mobile communication system (5G) services were launched in 2020, and progress is now being made in the research and development of 6G technology [3]. In addition to high-speed and large-capacity communications, low-latency and highly reliable communications, and multiple connections that exceed those of 5G, 6G includes new requirements that were not considered in 5G. There are also growing expectations for the use of private 5G, which enables the flexible deployment of private 5G systems within the buildings and premises of diverse entities such as businesses and local government bodies according to the needs of individual regions and industries [4]. In wireless local area networks (LANs), IEEE*2 802.11be is being standardized as the successor to the IEEE 802.11ax wireless communication standard, which is the technology behind Wi-Fi 6. When it finally comes out, IEEE 802.11be will support not only high-speed transmission with a maximum communication rate of 46 Gbit/s but also additional features such as multiple access points [5]. Development of the IEEE 802.11ay standard for WiGig (Wireless Gigabit) networks is also underway as a successor to IEEE 802.11ad, which uses the 60-GHz band [6]. For low-power wide-area (LPWA) networks, various demonstration experiments are being conducted with the aim of implementing Wi-Fi HaLow™ (IEEE 802.11ah), which is a wireless communication standard for IoT applications that also supports video transmission [7].

With developments such as these, the use of diverse wireless communication standards such as public cellular, private cellular, wireless LAN, and LPWA networks is going to become more widespread. These wireless communication standards use a variety of frequency bands ranging from 1 GHz to several tens of GHz, and studies related to 6G are even considering the use of frequencies above the 100-GHz band and into the THz band [3]. Although these high-frequency bands support higher communication bandwidths, their coverage areas are smaller due to increased radio-wave propagation losses. Therefore, to properly handle user requirements that change from time to time, from location to location, and from one application to the next, it is essential to properly use complex wireless networks that support a mixture of different wireless communication standards across a wide range of frequency bands with different propagation characteristics.

NTT aims to provide a natural communication environment where users do not need to be aware of how they are using wireless networks because they are always provided with the best possible communication environment to suit their ever-changing needs and radio-wave conditions in their current location. As a constituent part of IOWN [1], we are working on the research and development of Cradio®, a set of multi-radio proactive control technologies.

2. Cradio® (multi-radio proactive control technologies)

We designed Cradio to keep up with the constant evolution of user requirements and radio-wave conditions so that a natural communication environment can be continuously provided without users having to be aware of how they are using the wireless network. It is broadly composed of the following three technology groups (**Fig. 1**).

(1) **Understanding (wireless sensing/visualization):** Visualization of real-world conditions by wireless state measurement/visualization, wireless sensing, etc.

(2) **Prediction (wireless-network-quality prediction and estimation):** Prediction and estimation of constantly changing wireless communication quality

(3) **Control (wireless-network dynamic design/control):** Design of physical layouts in accordance with the local environment and requirements, derivation of optimum wireless parameters, dynamic control of network parameters and resources, etc.

By advancing these three wireless technology groups and linking them in real time, we aim to keep abreast of constant changes in radio-propagation conditions and the needs of users to provide a natural communication environment where users do not have to be aware of how they are using wireless networks.

With these three technology groups, Cradio has three means of addressing each of the issues that are liable to make it difficult for users to communicate comfortably at any time and in any location (**Fig. 2**). Wireless sensing/visualization technology addresses

*2 IEEE: The Institute of Electrical and Electronics Engineers

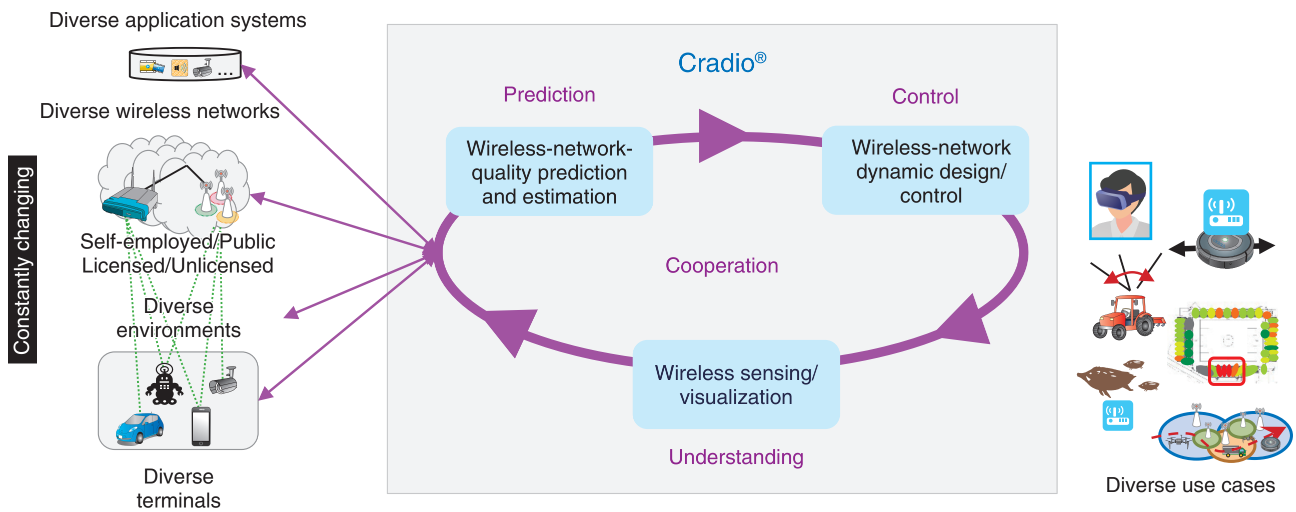

Fig. 1. Cradio concept.

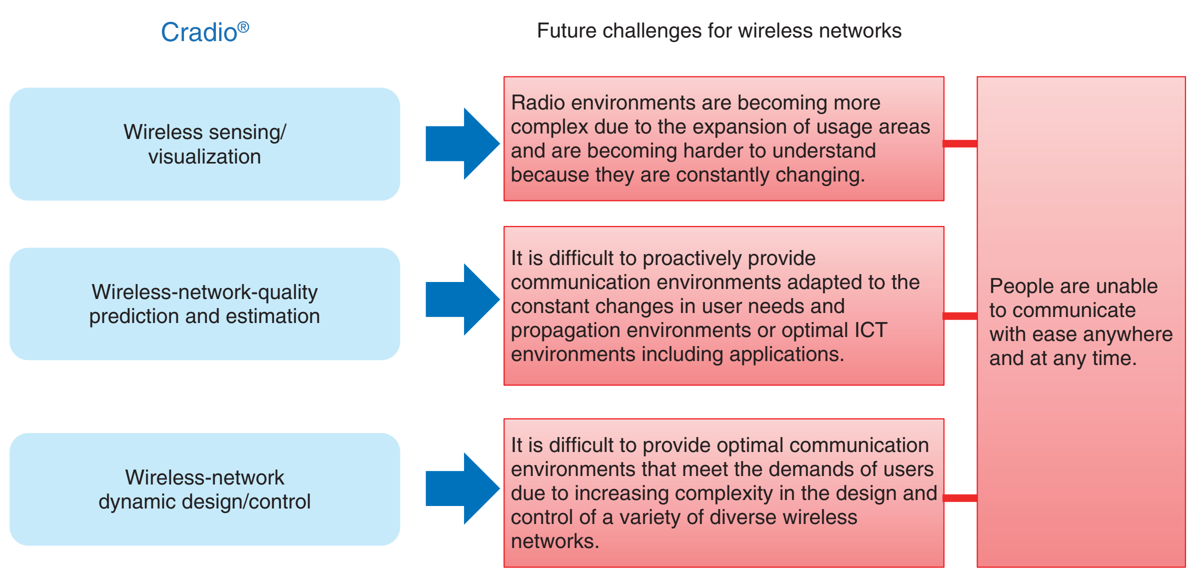

Fig. 2. How Cradio's technologies address future challenges in wireless networks.

the increasing complexity of the radio environment caused by the expansion of usage areas and the continuous fluctuations of these environments that are making them harder to understand. Wireless-network-quality prediction and estimation addresses the difficulty of proactively providing communication environments adapted to constant changes in user needs and propagation environments and optimal information and communication technology (ICT) environments including applications. Wireless-network dynamic design/control addresses the difficulty of providing optimal communication environments due to increasing complexity in the design and control used in a variety of diverse networks. These three wireless technology groups are explained below.

2.1 Understanding: Wireless sensing/visualization

Wireless sensing/visualization technology (**Fig. 3**) collects and analyzes information from various

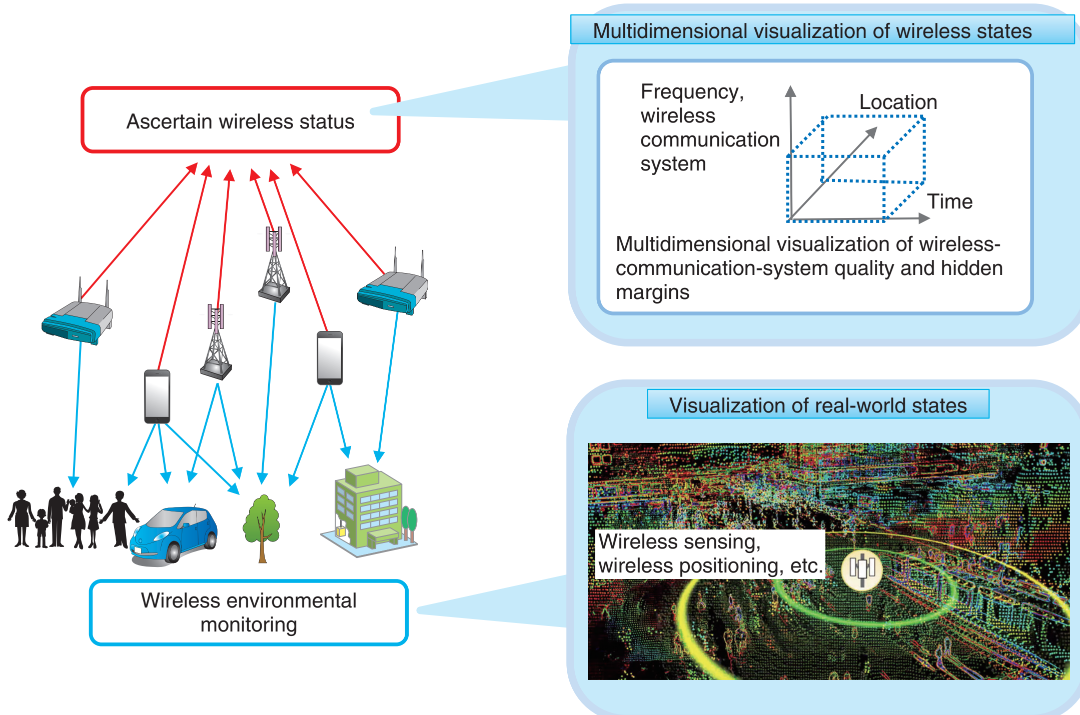

Fig. 3. Understanding – Wireless sensing/visualization.

wireless devices in various wireless communication systems to ascertain and visualize the status of wireless communication systems with regard to multiple dimensions, including frequency, method, location, and time. This makes it possible to clarify the communication quality of wireless systems, find hidden margins, and ultimately improve the efficiency of radio-wave utilization.

By using radio-communication technologies, such as wireless sensing and wireless positioning, it is possible to ascertain and visualize the real-world conditions around wireless devices. Therefore, it should be possible to quantify the position and state of everything that affects a wireless network. These technologies create an image of the real world that is important for ensuring the quality of wireless communication. This makes it possible to understand and visualize diverse environmental factors that affect wireless communication quality, including non-communication areas in wireless communication systems. It can also be expected to create added value as a new social infrastructure.

With the technology that we have used for ascertaining and visualizing the state of wireless LANs, it became possible to check the quality of a wireless LAN in real time [8]. In addition, wireless-LAN sensing technology [9] makes it possible to ascertain the impact of the surrounding environment on wireless-communication quality and create added value for wireless communication systems. We are currently working to expand the range of target wireless systems on the basis of these technologies and make further enhancements to these technologies.

2.2 Prediction: Wireless-network-quality prediction and estimation

Wireless-network-quality prediction and estimation technology executes deep learning on the basis of information obtained from wireless sensing and visualization technology to predict and estimate the quality of wireless communication, which changes from moment to moment in accordance with the surrounding environment and terminal position [10], thereby facilitating proactive optimization on the basis of future conditions (**Fig. 4**). The quality of wireless communication is affected by the radio-propagation environment between transmitters and receivers and varies in accordance with the usage conditions (resource availability) of the wireless communication system. Since these conditions

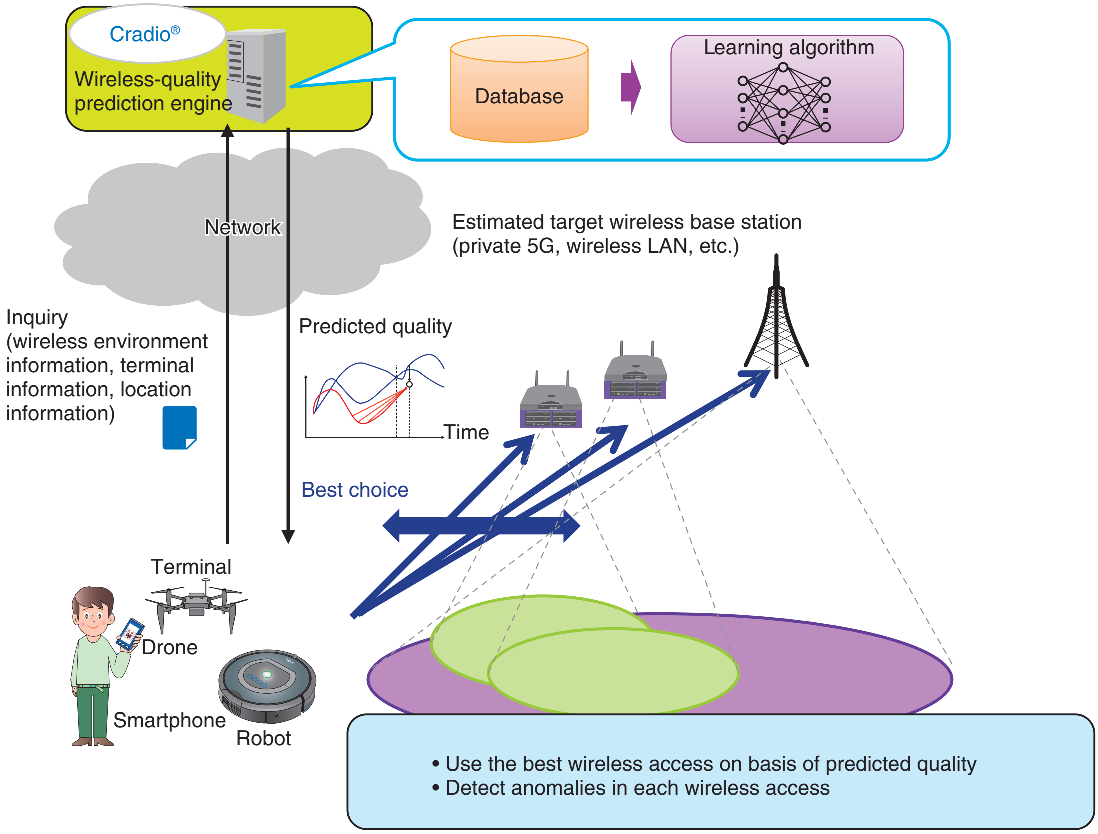

Fig. 4. Prediction – Wireless-network-quality prediction and estimation.

change from time to time, this prediction and estimation of wireless communication quality is not easy to do. With the above-mentioned wireless sensing and visualization technology, it is possible to ascertain and visualize the status of wireless communication in multiple dimensions on the basis of information collected from various devices and ascertain and visualize the real-world conditions surrounding wireless devices that affect the quality of radio communication. As a result, it should be possible to predict and estimate communication-quality parameters for each location, time period, and radio communication method with unprecedented accuracy. This will make it possible to make advance network-environment preparations in accordance with application requirements, avoid deterioration of communication quality and breaks in communication, and automatically select networks to connect to. Our aim is to provide proactive communication services that always deliver high quality of experience and quality of service.

We have conducted demonstration trials to predict the quality of communication between a cellular system and broadband wireless access in the control of self-driving agricultural machinery, which was able to execute network switching control to connect to a suitable network while continuing to provide the required communication quality [10]. We are currently investigating the enhancement of techniques for predicting and estimating the quality of general-purpose wireless networks by combining the various types of information mentioned above.

2.3 Control: Wireless-network dynamic design/control

In wireless-network dynamic design/control technology, on the basis of communication quality information obtained from wireless-network-quality prediction and estimation, we are carrying out switching/cooperation control of wireless-network dynamic configuration and switching/cooperation control of multiple wireless networks and control/optimization for the wireless connection of terminals (**Fig. 5**). As well as the optimization of various wireless parameters, this consists of comprehensive wireless-network

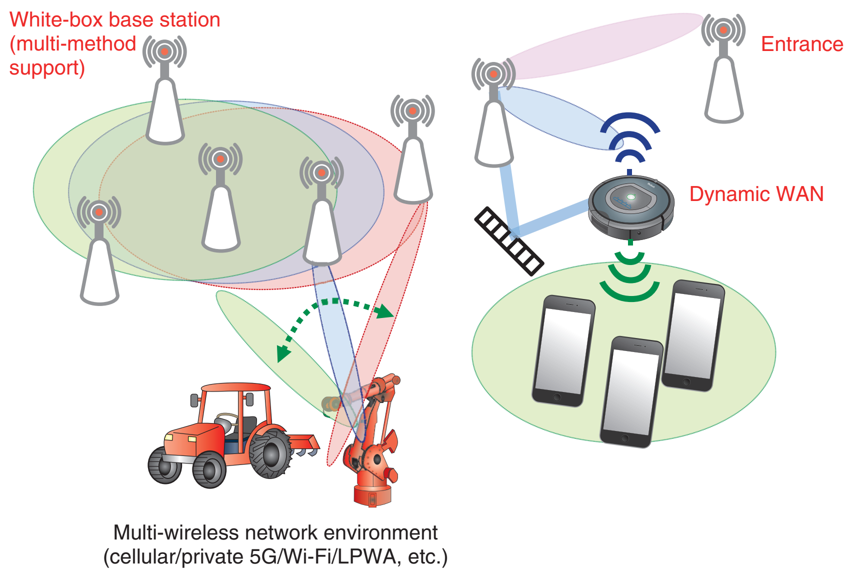

Fig. 5. Control – Wireless-network dynamic design/control.

design optimization and control measures such as the dynamic configuration of multi-radio networks with white-box wireless base stations that support multiple wireless communication standards, modification of the physical location and antenna direction of wireless base stations, and dynamic configuration of wide area network (WAN) entrances to adapt to these changes. Dynamic control can be considered not only for wireless networks but also for radio-propagation environments using equipment such as intelligent reflectors. This will make it possible to provide a world where wireless networks can be dynamically prepared wherever and whenever they are needed, facilitating a departure from the presumption of pre-prepared communication environments using conventional fixed wireless base-station locations and specified wireless communication standards. Using these technologies, our aim is to proactively and automatically configure optimal wireless networks to accommodate ever-changing user requirements and radio-wave conditions. This will lead to wireless networks that operate more efficiently and consume less power.

On the basis of wireless-resource dynamic control technology for wireless LANs that we have previously studied [11], we are working on practical technologies for the expansion and technical enhancement of target wireless systems, dynamic control of base-station placement (which have hitherto been fixed) [12], and implementation of distributed intelligent reflectors [13].

3. Cradio's potential for providing a natural communication environment

With Cradio's multi-wireless proactive control technology, it is possible to keep up with the constant changes of user needs and radio-propagation conditions through the advanced combination of wireless technologies such as the acquisition and visualization of diverse information in wireless networks, prediction and estimation of wireless-network transmission quality, and dynamic design and control of wireless networks. Cradio can also collaborate with various social systems and applications to create a natural communication environment where users do not need to be aware of the wireless network. By cooperating with various application systems outside the wireless layer, Cradio optimizes the wireless network in accordance with the status of applications that are in use and optimizes applications in accordance with the status of the wireless network (**Fig. 6**).

For example, by cooperating with and using information from social systems such as weather information systems and demographic systems involving various types of sensors and video information from cameras, we can expect to improve the accuracy of quality prediction/estimation and acquisition/visualization of information from wireless networks, including information about local conditions, such as

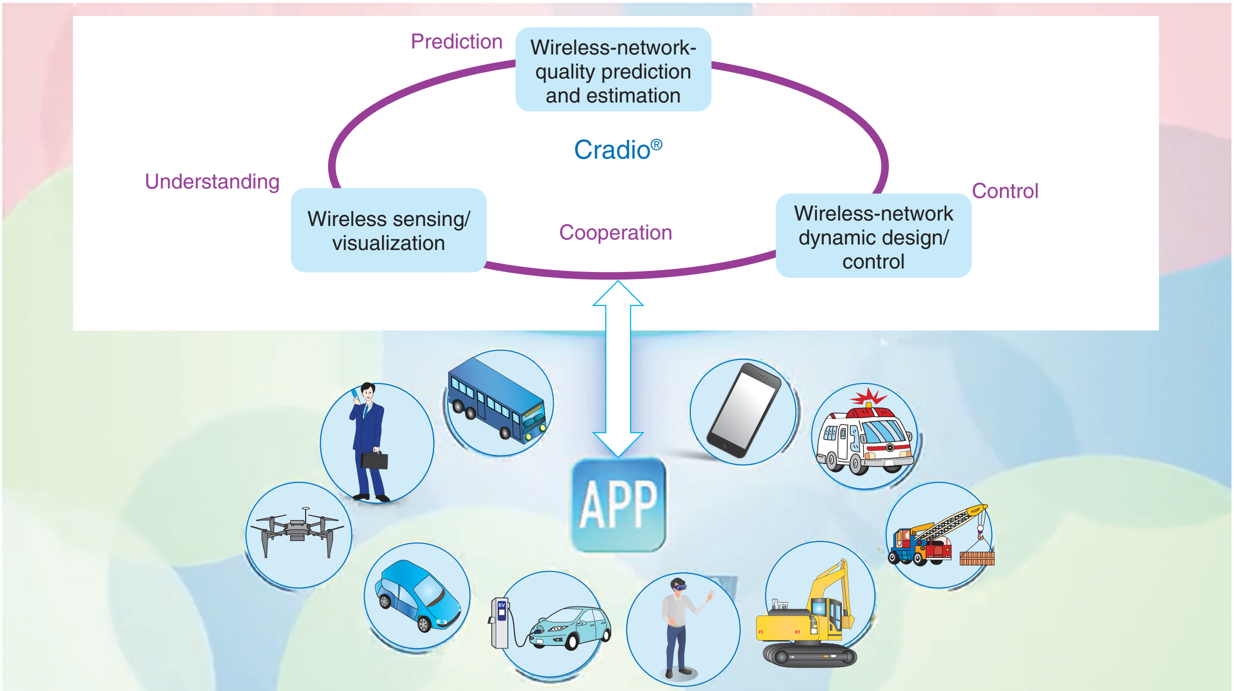

Fig. 6. Coordination of multi-radio proactive control technology (Cradio) with various applications and social systems.

rainfall, that can affect radio communication (especially at high frequencies), and the state of use of wireless communication systems (available wireless resources), and to use this information for the design and control of wireless networks [14]. In the above-mentioned example of autonomous vehicles, by using Cradio to predict and estimate wireless network quality in cooperation with automated driving management systems, it is possible for autonomous vehicles to select routes and adjust their driving speeds in accordance with the current quality of wireless communication. Video systems needed for the management of autonomous vehicles should be able to maintain the required video quality by dynamically adjusting the video codec rate. Therefore, all types of systems can be operated in a more advanced and flexible manner by cooperating with diverse social systems to obtain input information that can be used by Cradio and by cooperating so that information obtained with Cradio can be used outside the radio network layer.

Cradio's wireless technologies can provide higher value by coordinating with various systems and applications. We are currently conducting research and development aimed at implementing Cradio to provide wide-ranging value.

4. Future prospects

We described various components of Cradio and the natural communication environment that Cradio can provide through cooperation with diverse systems and applications. With the arrival of IOWN around 2030, we will continue to promote research and development aimed at implementing Cradio.

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Local Light Injection and Detection Technology for Optical-fiber Identification

Hiroyuki Iida, Takui Uematsu, Kazutaka Noto, Hidenobu Hirota, and Kenji Inoue

Abstract

We developed local light injection and detection technology that enables us to identify the target fiber below an optical splitter. This technology uses the basic characteristic of optical fibers of an optical signal propagating through the optical fiber leaks at fiber bends. This article gives an overview of this technology.

Keywords: fiber identification, PON, ONU

1. Cable installation work for open up fiber-to-the-home services

In 2021, the total number of fiber-to-the-home (FTTH) subscribers reached about 22 million for NTT EAST and NTT WEST in Japan. FTTH services have become an indispensable social infrastructure. For telecommunications carriers to continue to provide optical communication services with high quality and stability to their customers, it will become increasingly important to maintain the construction quality of optical fiber networks and improve the efficiency of maintenance operations. The most common construction work in optical fiber networks is to open the communication lines, which connects the optical fiber installed from the central office to the optical network unit (ONU) installed in the customer's premises. To achieve this connection, the target fiber must be identified.

2. Problem with conventional optical-fiber identification

Optical-fiber identification is widely used to specify the target optical fiber at the worksite [1]. Optical-fiber identification is achieved by detecting a test light injected from the appropriate central office and leaks from the bent fiber (**Fig. 1**). Optical access networks adopt the passive optical network (PON) system, in which one optical fiber is shared by multiple customers using an optical splitter. Although this architecture has advantageous in cost savings, optical-fiber identification cannot be executed below the optical splitter. This is because the test light launched from the central office is equally distributed among all branched fibers below the optical splitter. The optical fibers below the optical splitter support an enormous number of facilities, and facility management is complicated since it is difficult to identify the target fiber. Therefore, we developed technology to overcome this problem.

3. Local light injection and detection technology

The technology we developed consists of matching convex and concave blocks for bending the optical fiber and probe fiber with a gradient index (GRIN) lens (**Fig. 2**). Optical signals are input and output by setting the probe fiber in the path of light leaking from the fiber bend. We call this local light injection and detection [2]. Conventional optical-fiber identification is limited with regard to performance since it

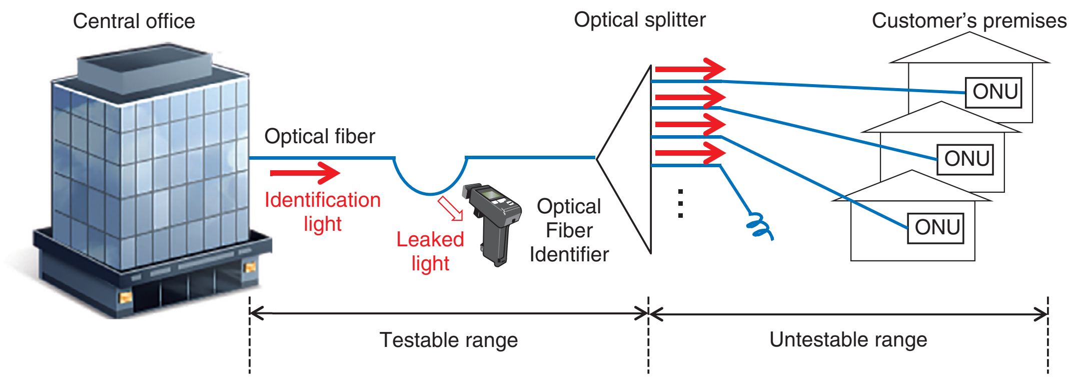


Fig. 1. Fiber identification in optical access networks.

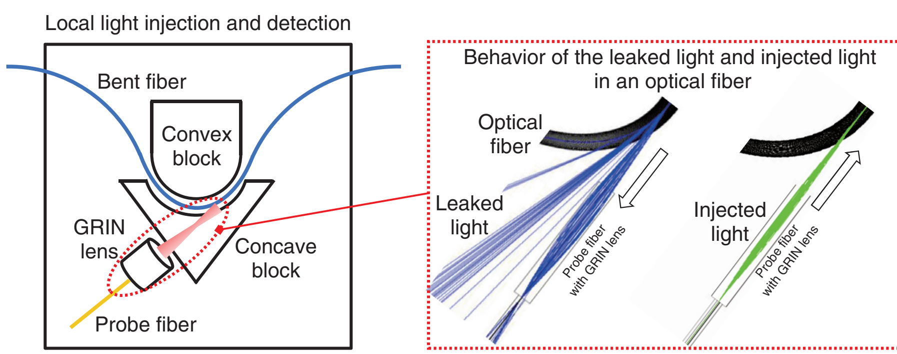
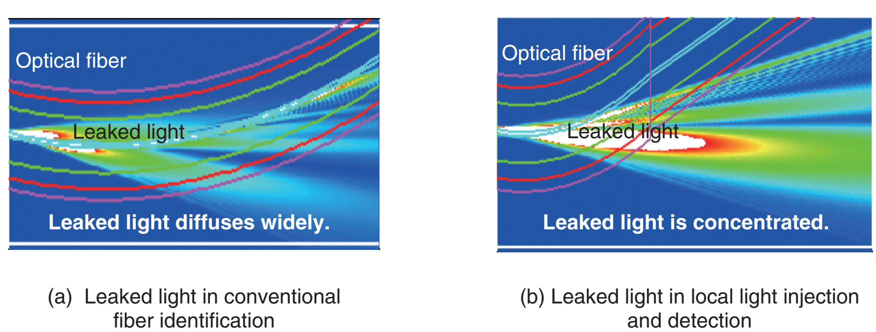


Fig. 2. Overview of our local light injection and detection technology.



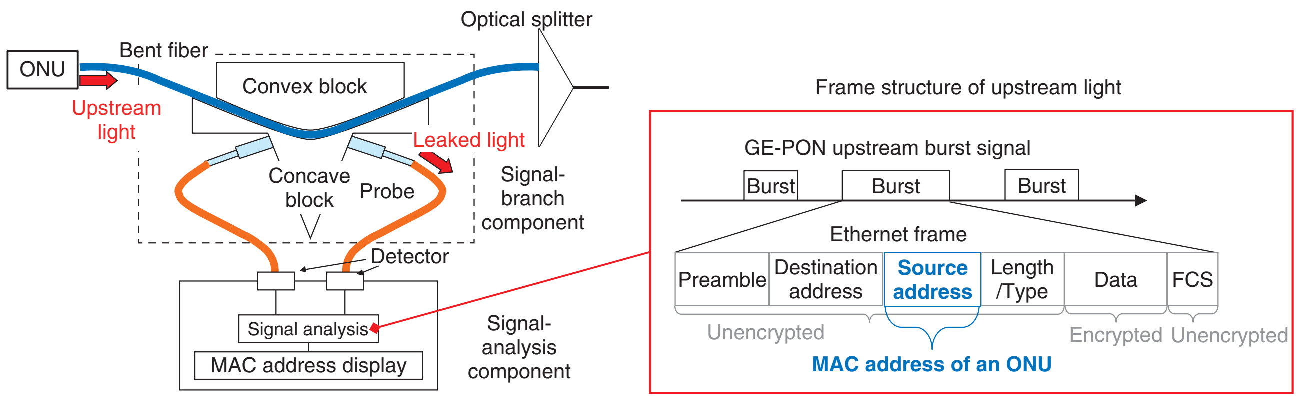
(a) Leaked light in conventional fiber identification

(b) Leaked light in local light injection and detection

Fig. 3. Contour map of leaked light intensity.

uses a low-speed signal of 270 Hz as the leaked light. In contrast, our technology can handle high-speed signals, up to 1 GHz, as the leaked light and can input optical signals to the bent fiber via the probe fiber. These unique functions are achieved by optimizing the input/output efficiency of the light leakage from the bent fiber.

The contour map of leaked light intensity from a typical bent fiber is shown in **Fig. 3**. In conventional optical-fiber identification, the leaked light diffuses in the free-air gap (Fig. 3(a)). Our technology generates strong leaked light by imparting the local bend



FCS: frame check sequence
GE-PON: Gigabit Ethernet PON

Fig. 4. Configuration of ONU MAC address capture device.

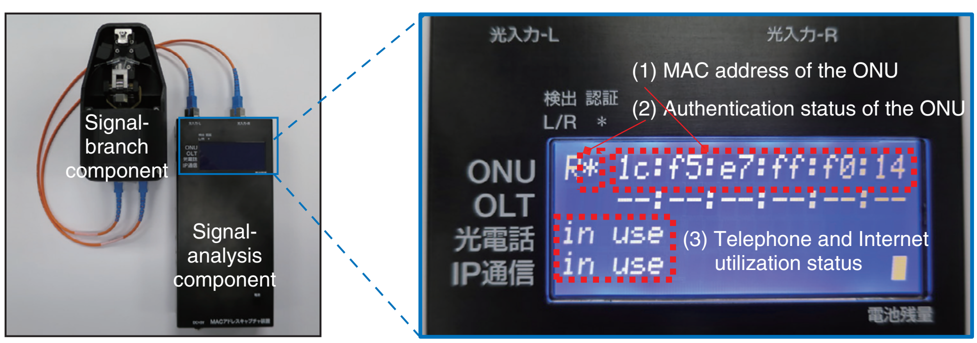


Fig. 5. Prototype of MAC address capture device and its display screen.

shape precisely designed with a bend radius on the millimeter order to the optical fiber (Fig. 3(b)). To receive leaked light with high efficiency, the probe fiber has a large core diameter and is equipped with a GRIN lens. Since the parameters of these optical devices are optimized for efficient reception of leaked light, our technology offers a 30-dB improvement in input/output efficiency compared with the conventional technology.

By drastically improving the efficiency of capturing/injecting leaked light, new applications can be developed. The following sections introduce specific applications.

3.1 Optical-fiber identification below an optical splitter by media access control address of the ONU

This section introduces one application of our local light injection and detection technology, which monitors upstream signals of the ONU from leaked light.

The upstream signal transmitted from the ONU in a customer's premises is received as leaked light (**Fig. 4**). The media access control (MAC) address of the ONU is stored as the source address in the ONU signal frame. The MAC address of the ONU connected to the target optical fiber can be captured by analyzing the leaked light [3]. Therefore, it is possible to confirm which ONU the target fiber is connected to, that is, to identify the optical fiber below an optical splitter.

The prototype ONU MAC address capture device and examples of its measurement results are shown in **Fig. 5**. The prototype device displays (1) the MAC address, (2) authentication status, and (3) utilization status of the ONU. The upstream signal of the ONU also contains frame information about the authorization

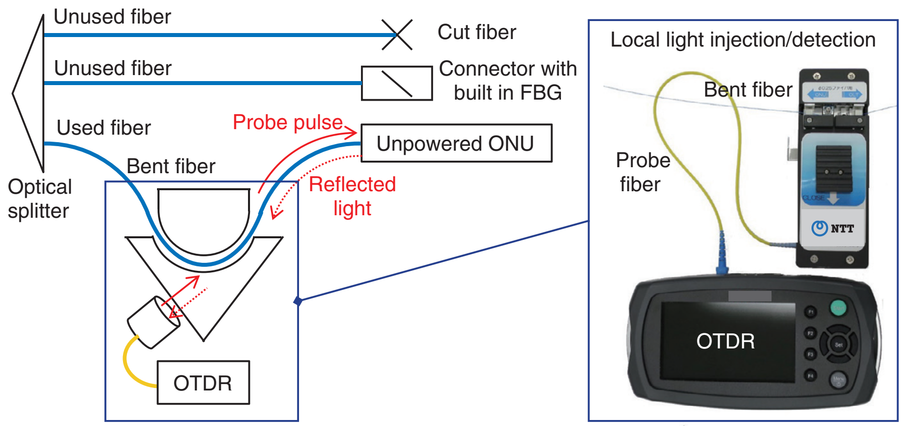


Fig. 6. Configuration of fiber-termination identification, and prototype of the local light injection and detection device.

and utilization status of the ONU, in addition to the MAC address of the ONU, which allows (2) and (3) to be displayed. Currently, field engineers have difficulty in checking whether an ONU has been certified and the status of its service utilization because it is necessary to confirm certification light emitting diode of the ONU on/off at a customer's premises or carry out a loopback test from the central office. With our technology, field engineers can check the status of the ONU in real time at worksites.

3.2 Fiber-termination identification by reflection analysis with optical time domain reflectometry

A second application of our technology is a test technique to determine whether an unpowered ONU is connected to the target optical fiber.

When installing optical fiber, field engineers must check whether the target optical fiber is used fiber or unused fiber. One method determines whether an optical fiber is used or unused by checking for the presence or absence of the ONU's upstream signal from leaked light. However, this method cannot accurately be used to determine whether the optical fiber is used fiber or unused fiber because it cannot distinguish unused fiber from fiber connected to an unpowered ONU. One solution is to use optical time domain reflectometry (OTDR). However, there is no port at which the probe pulse from the OTDR can be launched into the optical fiber.

To solve this problem, we developed a technique to determine whether an unpowered ONU is connected to an optical fiber without a test port by applying our local light injection and detection technology (**Fig. 6**). This technique enables test measurement by injecting OTDR probe pulses into the fiber under test through a fiber bend [4]. If the test measurement is to have sufficient accuracy, it is necessary to inject light into the bent fiber with high efficiency. Since the core diameter of an optical fiber is about 10 μm, highly accurate optical arrangements is required. Our technique offers high coupling efficiency, as we optimize the optical parameters such as beam waist and focal length of the GRIN lens, and the beam incident angle to the bent fiber. These characteristics have enabled high-efficiency light injection from the outside into the bent fiber.

Measurement results of the map of reflectivity ratios at $R_{1310\ nm}/R_{1550\ nm}$ and $R_{1650\ nm}/R_{1310\ nm}$ are shown in **Fig. 7**. Here, the reflectivity at x nm wavelength is defined as $R_{x\ nm}$. We measured the fiber under test with three termination cases: unpowered ONU, optical connector with built-in fiber Bragg grating (FBG), and a cut fiber. The measurement results yielded a map of reflectivity ratios of fiber termination at multiple wavelengths. As shown in the figure, the three termination cases occupy different regions on the map. Therefore, these cases can be identified by simple threshold determination on the map.

4. Future perspectives

We gave an overview of our local light injection and detection technology, which inputs and outputs optical signals by subjecting optical fibers to precise bending, and examined its applications. The upstream signal monitoring of the ONU and reflected light

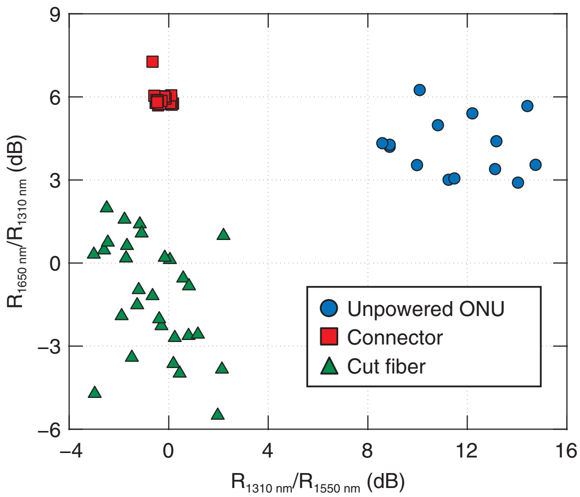


Fig. 7. Example of fiber-termination-identification results.

analysis of fiber termination, which were introduced as applications, make it possible to identify the optical fiber below an optical splitter and whether it is used fiber or unused fiber. Hence, field engineers can check the status of optical fibers in real time at the worksite. This technology will drastically improve the efficiency of construction work and be used commercially as a test tool for the construction and maintenance of optical fiber networks.

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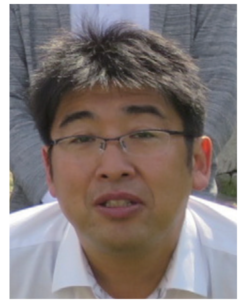

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Standardization Trends in the Disaggregation Technology of Access Systems at the Broadband Forum

Kota Asaka

Abstract

Research and development for introducing disaggregation technology into future access systems has been progressing to flexibly and quickly accommodate various services in such systems and achieve simple system operations. This article reports on the standardization trends in the disaggregation technology of access systems at the Broadband Forum along with relevant development trends at an open source software development organization of the Open Networking Foundation.

Keywords: disaggregation, access systems, Broadband Forum

1. Requirements of future access systems

The traffic of a broadband service over optical access systems, e.g., fiber to the home, has been rapidly increasing due to the expansion of remote work and education intended to prevent the novel coronavirus infection from spreading as well as wide dissemination of video streaming services [1]. Current standards of optical access systems have been developed as specifications with a transmission capacity of 40 or 50 Gbit/s to meet such a rapid and huge demand of traffic [2, 3]. Future access systems should provide a diverse range of services that have different system requirements (transmission capacity, latency, reliability, etc.) such as Internet of Things and edge computing, as well as accommodating a huge amount of traffic.

Given this background, the research and development of disaggregation technology has been progressing. Such technology can reconfigure the functions of an access system by combining general-purpose hardware components (i.e., server and switch) and open source software (OSS) that are loosely coupled via an open interface. However, a conventional system is achieved by using dedicated hardware equipment and software that are tightly coupled via a vendor's proprietary interface [4]. To achieve a disaggregated access system, specifying an open architecture and interface and developing OSS that can be flexibly and quickly replaced in accordance with system requirements are necessary to ensure interoperability and promote widespread dissemination.

2. Brief summary of Broadband Forum

The Broadband Forum (BBF) is an industry forum and has contributed to broadband-access industries and earned its high reputation for its efforts, especially in developing control/management specifications and interoperability test specifications of access systems, which have been published in more than 200 Technical Reports (TRs) [5]. BBF is composed of more than 150 companies/organizations, which include service providers (telecom carriers and multiple service operators), system vendors, ASIC (application specific integrated circuit) vendors, and others from around the world. Telecom service providers take a leadership role in designating technical topics and directions that are driving BBF. Each Work Area in the Technical Committee discusses corresponding technical specifications on the basis of these topics. BBF has been intensively engaging in the development of various specifications of access systems with

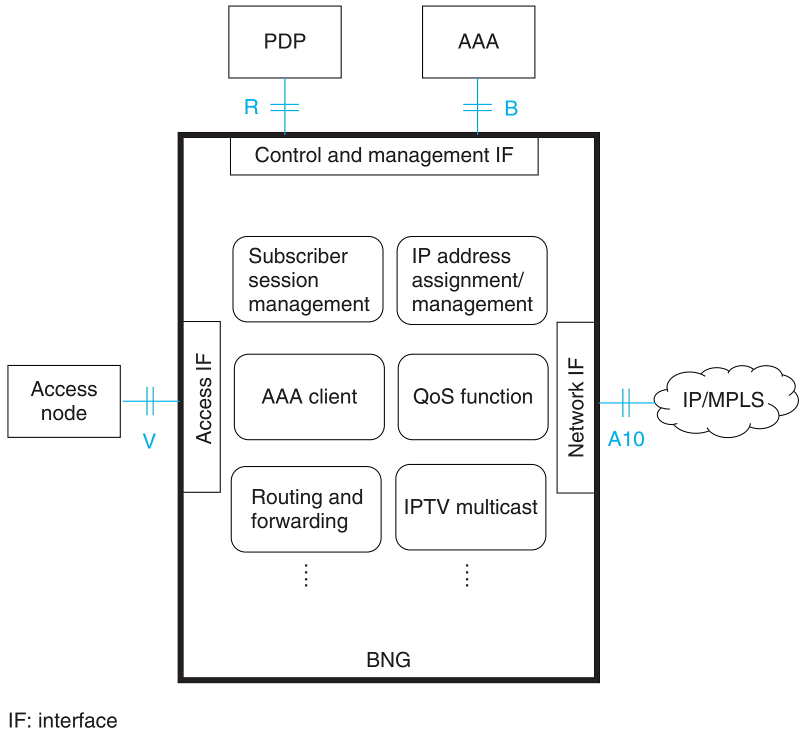

Fig. 1. Functional blocks and interfaces for a conventional BNG.

virtualization/disaggregation technologies, such as software-defined networking (SDN) and network functions virtualization (NFV), and it is recognized as the most active organization in these topics among access-systems-related standardization organizations and industry forums. In particular, BBF worked to provide a diverse range of specifications on the Network Configuration Protocol/Yet Another Next Generation (NETCONF/YANG)*1 model, architecture and interface of Cloud Central Office (CO)*2, disaggregated dynamic bandwidth-allocation function for optical access systems [6, 7], and a disaggregated broadband network gateway (DBNG). This article reports on the specifications on a DBNG, which was finalized in TR in June 2020. It also reports on the specifications on broadband access abstraction (BAA), which is one of the software components of Cloud CO and abstracts vendor's proprietary hardware specifications, such as an optical line terminal (OLT), along with relevant OSS development trends at the Open Networking Foundation (ONF).

3. Specifications of a DBNG

BBF recently specified a DBNG in TR-459 "Control and User Plane Separation for a disaggregated BNG" [8]. **Figure 1** shows the functional blocks and interfaces for a conventional BNG based on the information in TR-459. A BNG is an access point and connected to customer premises equipment at a subscriber's residence for wireline broadband services. It aggregates various traffic from access networks and forwards it to designated routes for metro/core networks depending on the service type. In addition to such functions, a BNG plays an important role in other functions that support broadband services, i.e., authentication, authorization, and accounting (AAA) of subscriber sessions, Internet protocol (IP) address assignment, and quality of service (QoS) control. A

*1 NETCONF/YANG: NETCONF is a configuration protocol of network equipment and was developed to remotely conduct configuration and management functions in distributed equipment from a centralized SDN controller. The YANG model is a common data-modeling language that abstracts a structure and configuration values of each piece of network equipment. Using NETCONF and the YANG model makes it possible to achieve interoperability between network equipment and a controller from various system vendors.

*2 Cloud CO: Next generation COs (telecom carrier central offices that contain network equipment) that use SDN/NFV, disaggregation, and cloud technologies.

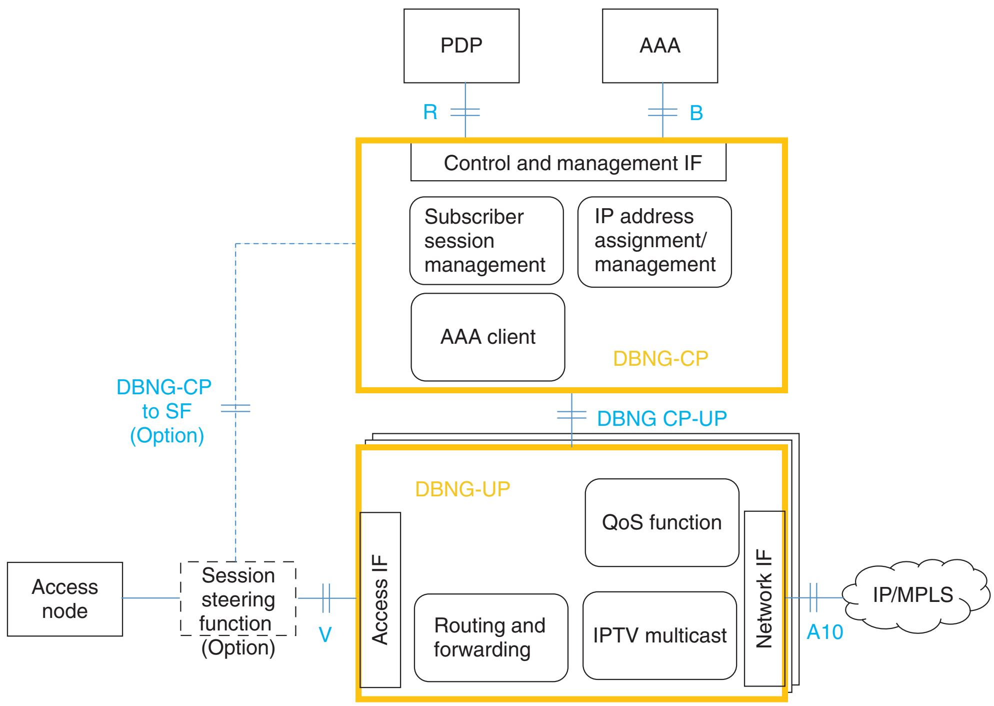

Fig. 2. Newly defined functional blocks and interfaces for the DBNG in TR-459.

BNG acts as a gateway between an access node and IP/multi-protocol label switching (MPLS). The interfaces between a BNG and each access node and IP/MPLS are defined as V-IF and A10-IF, respectively. Although the functional blocks inside a BNG are configured differently depending on the service to be provided by telecom carriers, it is composed of several functions. A typical example is shown in Fig. 1: subscriber session management, IP address assignment/management, AAA client, QoS function, routing and forwarding, and IPTV (television) multicast. These functions are managed/controlled by the policy decision point (PDP) and AAA controllers via the control/management interfaces inside the BNG. The interfaces between the BNG and each PDP and AAA are defined as R-IF and B-IF, respectively. Therefore, functions and external interfaces comprising a BNG are defined. However, software and hardware comprising a BNG are provided as integrated equipment, which has different implementation specifications from vendor to vendor. Therefore, operation of access networks is complicated because BNGs must be controlled/managed at each facility where BNG equipment is installed. There is also an apparent issue that usage efficiency of resources is low since telecom carriers are required to increase the number of BNGs on the basis of the unit of equipment to meet traffic demand.

To address these issues, BBF defined the DBNG in TR-459 to newly specify the functionally separated composition as well as interfaces, as shown in **Fig. 2**. This DBNG is achieved by separating various BNG functions by the functional groups of the DBNG-control plane (CP) and DBNG-user plane (UP), which are coupled via the newly created interface of the DBNG CP-UP. The DBNG-CP is specified for control-signal processing necessary for subscriber-session establishment while the DBNG-UP is designed for transmission/receipt processing of user data signals. By adopting such a control and user plane separation (CUPS) configuration, telecom carriers can expect much simpler operation of access networks. This is because they can remotely control/manage several DBNG-UPs independently located in multiple facilities from a DBNG-CP at another centralized facility. They can also expect higher usage efficiency of resources because increasing the number of DBNG-UPs at arbitrary facilities becomes possible, and the traffic steering function (SF), which enables traffic assignment to other facilities from the original one, is available as an optional specification. The interoperability between the DBNG-CP and

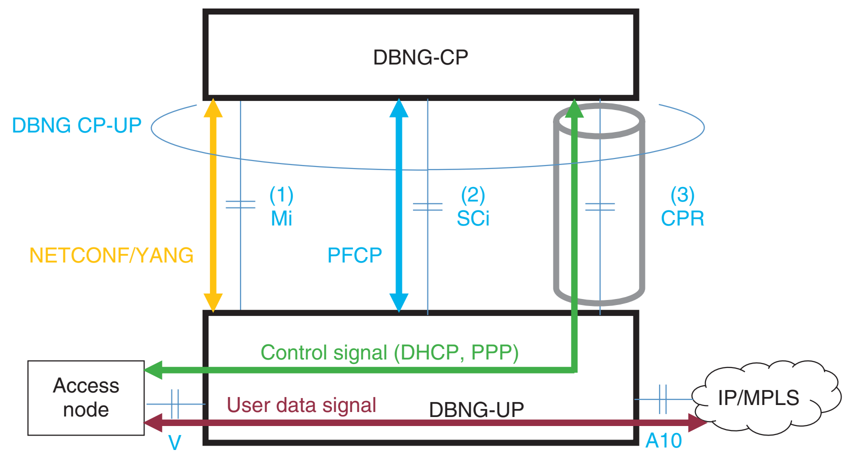

Fig. 3. Conceptual diagram of interfaces between DBNG-CP and DBNG-UP.

Table 1. Details of the interfaces between DBNG-CP and DBNG-UP.

No.	Appellation	Function	Protocol
(1)	Management IF (Mi)	• Pushing of DBNG-UP configurations from the DBNG-CP • Retrieving operational state and notification of alarm between the DBNG-CP and DBNG-UP	NETCONF/YANG
(2)	State control IF (SCi)	• Providing traffic forwarding rules to the DBNG-UP • Receiving acknowledgement from the DBNG-UP	PFCP
(3)	Control packet redirection IF (CPR)	• Providing a tunnel function for control signals between the DBNG-CP and DBNG-UP	DHCP, PPP

DBNG-UP can be established among different vendors by specifying the DBNG CP-UP interface.

Figure 3 shows a conceptual diagram of interfaces between the DBNG-CP and DBNG-UP defined in TR-459: (1) management interface (Mi), (2) state control interface (SCi), and (3) control packet redirection (CPR). The details of each interface are given in **Table 1**. (1) The Mi is an interface through which the DBNG-CP pushes configurations (i.e., a routing protocol setting) to the DBNG-UP. Retrieving the operation state and notification of alarm between the DBNG-CP and -UP can be achieved through the Mi, the protocol of which is specified as NETCONF/YANG. (2) The SCi is an interface through which the DBNG-CP provides traffic-forwarding rules to the DBNG-UP. The DBNG-CP also receives acknowledgement from the DBNG-UP via the interface. The protocol of the SCi is specified by extending the existing Packet Forwarding Control Protocol (PFCP), which had been globally deployed in mobile systems [9]. (3) CPR is an interface used for the control signals (Dynamic Host Configuration Protocol (DHCP), Point-to-Point Protocol (PPP), and others), which tunnel from V-IF (or A10-IF) to the DBNG-CP through the DBNG-UP. It provides a tunneling function when the DBNG-UP and DBNG-CP are connected via multi-hop networks due to CUPS.

BBF is planning to focus on the promotion and marketing activities of TR-459 as well as the development of detailed specifications of SF.

4. Specifications of BAA

BAA was specified in TR-384 "Cloud Central Office Reference Architecture Framework" and TR-413 "SDN Management and Control Interfaces for Cloud CO Network Functions" [10, 11]. **Figure 4** shows a conceptual diagram of BAA based on the information of TR-413. In conventional optical access systems, namely the passive optical network (PON), access equipment such as an OLT is implemented tightly coupled with a controller. Therefore, interoperability cannot be achieved, which results in complicated operations of access systems. To address

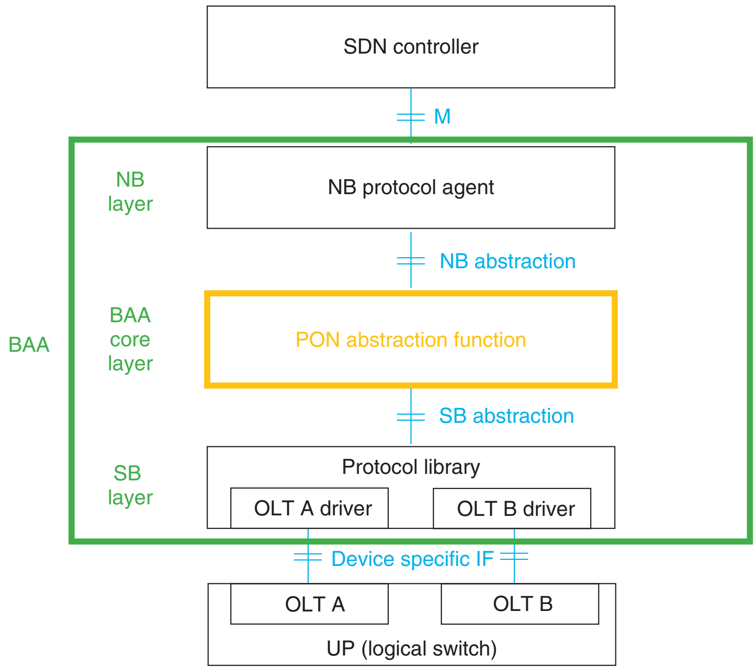

Fig. 4. Conceptual diagram of BAA.

this issue, BAA in Cloud CO was specified as an abstraction layer so that the SDN controller can control/manage various types of access-equipment hardware from a diverse range of vendors as an abstracted common logical switch through common commands. As shown in Fig. 4, BAA consists of a northbound (NB) layer, which functions as a protocol agent, BAA core layer, which has an abstraction function, and southbound (SB) layer, which works as a protocol library. The BAA core layer and each of the NB and SB layers are connected through NB and SB abstraction interfaces, respectively. BAA is also connected to an SDN controller via M-IF, and to the UP, such as OLTs, via device-specific interfaces. By introducing the above-mentioned configuration, BAA enables command conversion of control/management signals (commands) from the SDN controller to those for the abstracted logical switch. The converted commands are transformed to device-specific commands by a driver in the protocol library, then the commands reach the OLT equipment. Therefore, BAA enables the SDN controller to configure a flow setting of the UP and control FCAPS (fault, configuration, accounting, performance, and security) without having to take into account the difference in hardware-vendor specifications. This enables the establishment of interoperability among various vendors, which leads to simple operation of access systems.

In addition to the development of BAA specifications, BBF is engaged in OSS development to promote it in the near future [12]. Regarding related trends, ONF, which is an OSS development organization, has been leading the access virtualization project of SEBA (SDN Enabled Broadband Access). In this project, an access-abstraction technology of virtual OLT hardware abstraction (VOLTHA) had been proposed and developed in advance of BAA [13]. Although VOLTHA has almost the same functions as those of BAA, it can be applicable to the OpenFlow Protocol and whitebox OLTs [14, 15]. VOLTHA was commercially deployed by Türk Telekom and Deutsch Telekom in 2019 and 2020, respectively, but it is still being developed at ONF for function enhancement.

5. Future prospects

As the latest topic in future access systems, this article reported on the standardization trends in the disaggregation technology of access systems at BBF along with relevant trends in OSS development at ONF. Improvement in the technical maturity and function enhancement of related standardizations and OSS can be expected by reflecting the feedback from future discussions at BBF and ONF as well as telecom carriers who have commercially deployed the disaggregated technology in access systems. NTT will continue joining the discussion at BBF and ONF and contributing to global standardization activities and OSS development by providing requirements from telecom carrier's point of view.

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Grounding-system Evaluator for Preventing Lightening Damage to Telecommunications Center Buildings

Technical Assistance and Support Center, NTT EAST

Abstract

This article provides information on lightning damage to telecommunications center buildings and introduces the grounding-system evaluator developed by Technical Assistance and Support Center. The evaluator supports the investigation of the status of grounding systems, which includes telecommunication, power, and grounding installations. The evaluator also suggests methodologies for improving grounding systems in preventing telecommunication and power equipment from being damaged by lightning. This is the sixty-fifth article in a series on telecommunication technologies.

Keywords: lightning damage, grounding system, grounding-system evaluator

1. Introduction

When lightning strikes a telecommunications center building or nearby, it can cause damage or malfunction of telecommunication and power equipment. The damage may have a significant impact on the equipment in such buildings, and it can take a long time to restore telecommunication services. Therefore, it is important to prevent telecommunication and power equipment from being damaged by lightning.

Figure 1 shows the percentage of technical consultations classified by causes and damaged objects from the EMC Engineering group of Technical Assistance and Support Center (TASC) in fiscal 2019. Lightning-related technical consultations accounted for 26% of all consultations, and 30% of those consultations were related to lightning damage to telecommunications center buildings and radio relay stations. By analyzing the lightning damage in telecommunications center buildings, it was found that the damage was mainly caused by imperfections in the grounding systems, such as lack of wire connection and isolation.

The most important countermeasure against lightning damage to telecommunications center buildings is improving the grounding systems. However, to improve grounding systems, service personnel need to have correct knowledge on the grounding, investigation procedure, and how to solve the problems which are found in the investigation, such as lack of wire connection and isolation. To solve these problems, TASC prepared a document for providing "investigation and improvement methodologies and procedures for grounding systems in telecommunications center buildings." TASC also developed a grounding-system evaluator that supports the investigation of and improvement in such systems.

This article introduces this evaluator and a field case study.

2. Grounding-system evaluator

The grounding-system evaluator can visualize a configuration of the grounding system that includes the connection between the telecommunication and

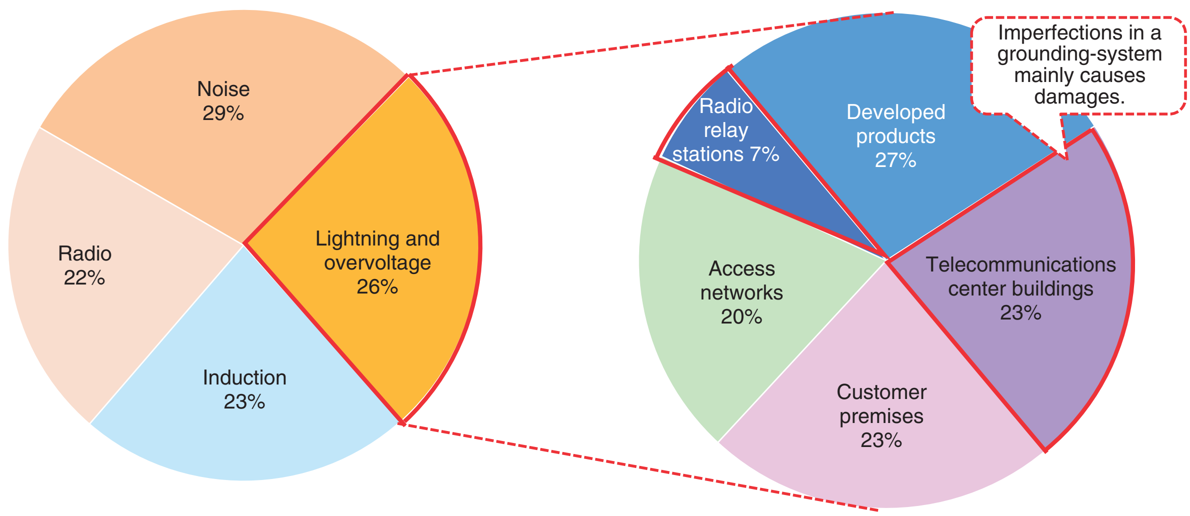


Fig. 1. Lightning-related technical consultations

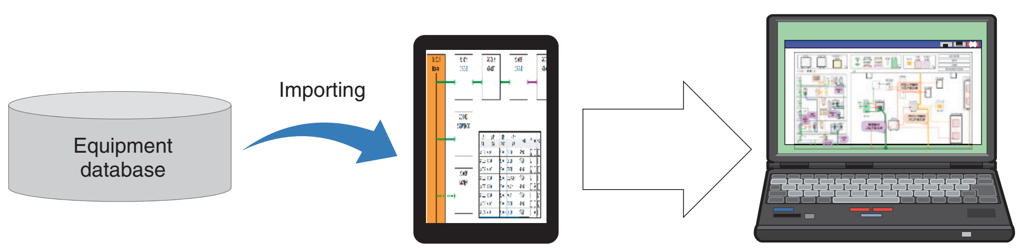


Fig. 2. Use of grounding-system evaluator.

power equipment and cable. It also points out imperfections in the grounding configuration in accordance with the above document. **Figure 2** illustrates the use of the grounding-system evaluator.

2.1 Configuration-visualization function

The configuration-visualization function is illustrated in **Figure 3**. The existing data of wiring connection, which are formatted by excel or csv, can be imported from the equipment database. This function enables users to reduce the time to input the grounding-system configuration and makes it possible to easily visualize the status/condition of telecommunication facilities, such as equipment, cables, and grounding cable, in telecommunications center buildings. It is also possible to visualize the results obtained through on-site investigations via a graphical user interface (GUI) and reflect them in the above visualization.

2.2 Function for automatically determining the status of a grounding configuration

The function for automatically determining the status of a grounding configuration is illustrated in **Fig. 4**. This function visualizes whether the status of the grounding configuration is correct. The evaluator investigates the 30 items for ideal grounding system described in the document of investigation and improvement procedures and methods written by TASC. If a fault is found, the evaluator shows the details of this fault. This means that users can easily find the areas to be improved. Thus, this function is not only useful for maintaining grounding systems but also makes design work more efficient.

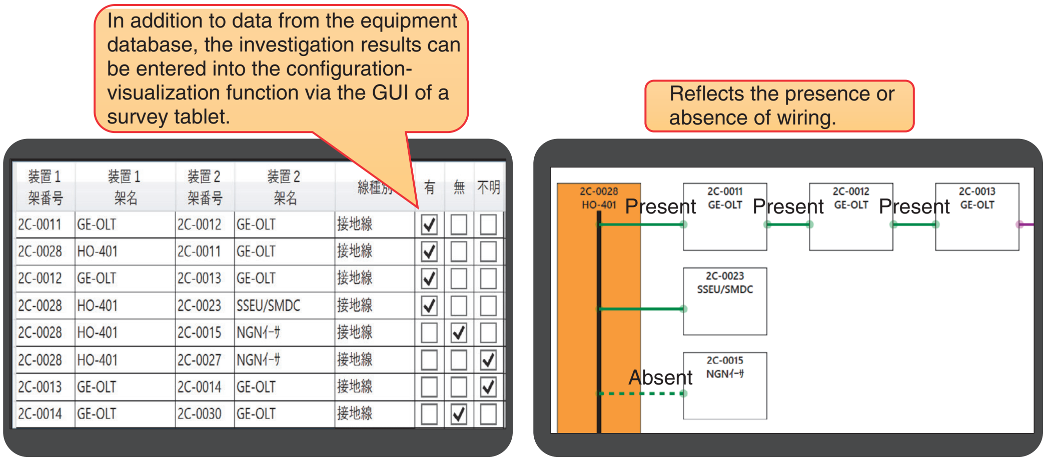


Fig. 3. Configuration-visualization function.

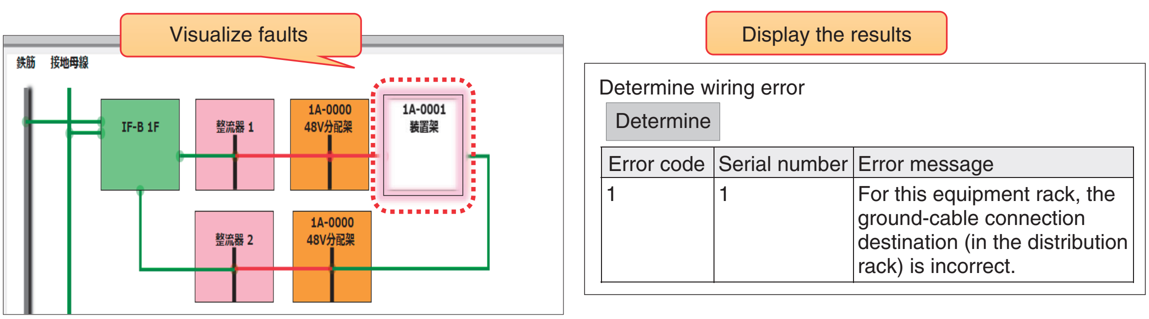


Fig. 4. Function for automatically determining the status of grounding configuration.

3. Case study of countermeasures TASC proposed against lightning-damage failure using the grounding-system evaluator

A case study of a countermeasures proposed by TASC using the grounding-system evaluator against lightning damage in a telecommunications center building is presented in this section.

3.1 Failure status

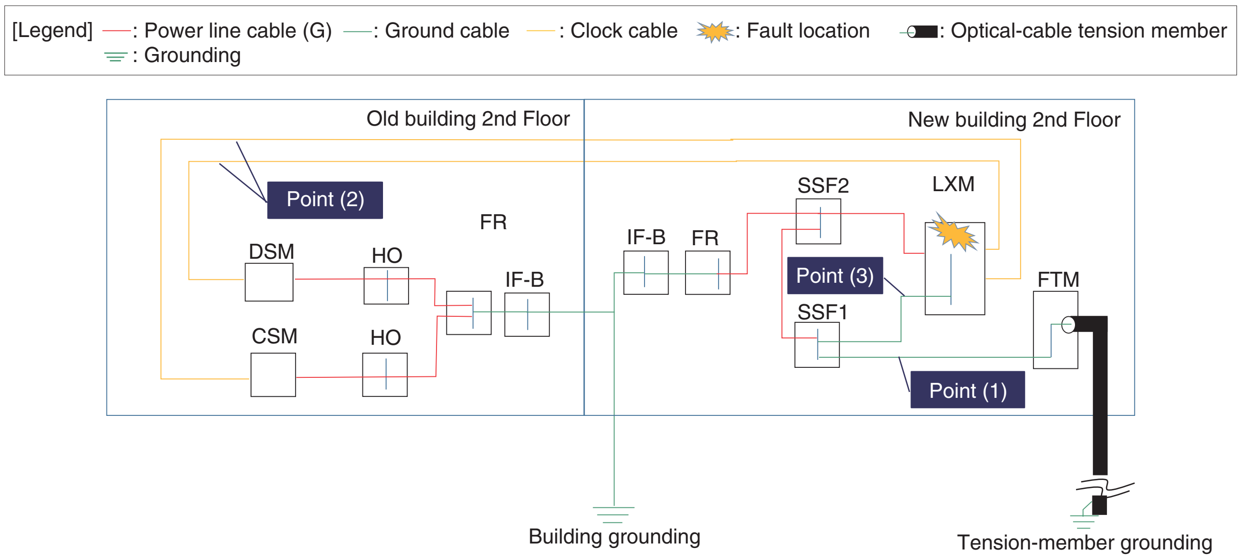
Due to lightning, the Subscriber Lines Cross-Connect Module (LXM) system failed and many customer services stopped for a considerable time. Although the system was recovered by restarting the LXM packages, TASC was asked to investigate the cause of the failure and propose countermeasures to prevent the lightning damage.

3.2 On-site investigation and simulation using the grounding-system evaluator

The status of a grounding-system configuration obtained from the on-site investigation is shown in **Fig. 5**, and points to be addressed are listed in **Table 1**. **Figure 6** shows the simulation results of the grounding-system evaluator, focusing on the fiber termination module (FTM) on the second floor of the new building and **Figure 7** shows details of wiring errors. The simulation results show that the wiring between the FTM and SSF1 (a power supply distributor) is incorrect, and the FTM should be wired to Interface – B (IF-B).

3.3 Estimation of causes

On the basis of the results obtained from the investigation, the estimated invading route of the lightning surge that caused the failure is shown in **Fig. 8** and **Table 2**. Due to the increase in the ground potential



CSM: clock supply module
DSM: dedicated service-handling module
FR: rectifier
HO: a power supply distributor

Fig. 5. On-site investigation of the building and identified configuration points.

Table 1. Wiring status of key points.

Wiring status	Content
Point (1)	The optical-cable tension member is connected to SSF-1 via the frame ground (FG) of the FTM.
Point (2)	LXM and CSM/DSM are connected by a clock cable across the building, but IF-C is not inserted.
Point (3)	The ground of LXM is connected to another rack (SSF1) instead of the rack receiving power supply (SSF2).

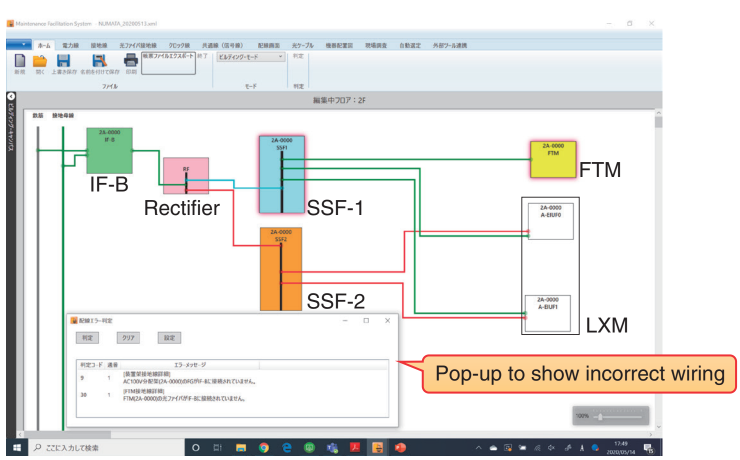


Fig. 6. Simulation based on on-site investigation results.

caused by the lightning strike near the telecommunications center building, a potential difference occurred between the building ground and tension-member ground. Thus, a lightning surge current was

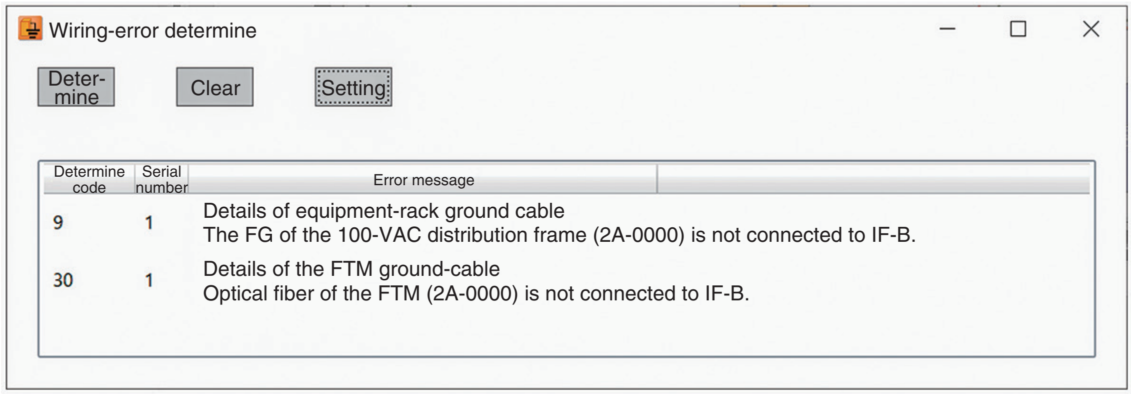


Fig. 7. Details of wiring errors determined using the grounding-system evaluator.

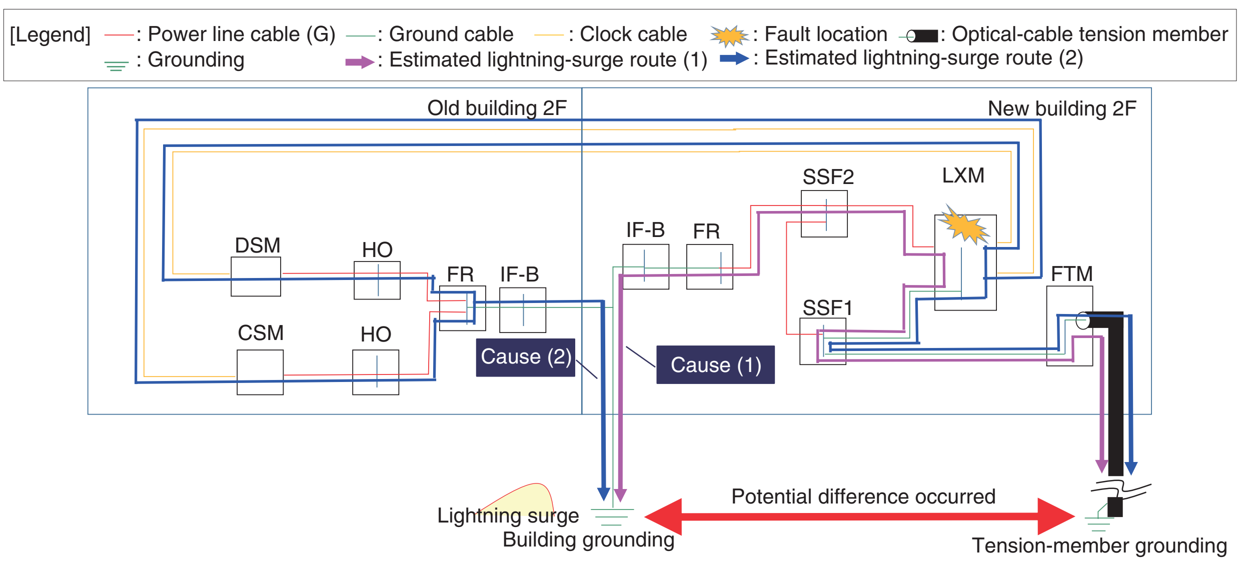


Fig. 8. Estimated lightning-surge route.

Table 2. Estimated lightning-surge route.

	Lightning-surge route
Route (1)	Building grounding ⇔ New building IF-B ⇔ SSF2 ⇔ LXM ⇔ SSF1 ⇔ FTM ⇔ TM grounding
Route (2)	Building ground ⇔ Old building IF-B ⇔ CSM/DSM ⇔ LXM ⇔ SSF1 ⇔ FTM ⇔ TM grounding

generated and propagated through cables, i.e., the lightning-surge current flowed from the ground cable into the LXM via the metal cables and flowed out to the ground cable and clock cable.

3.4 Lightening countermeasures

The countermeasures that were proposed against the above lightning damage in this case study are shown schematically in **Fig. 9** and described as follows.

Countermeasure (1): To pass the lightning surge

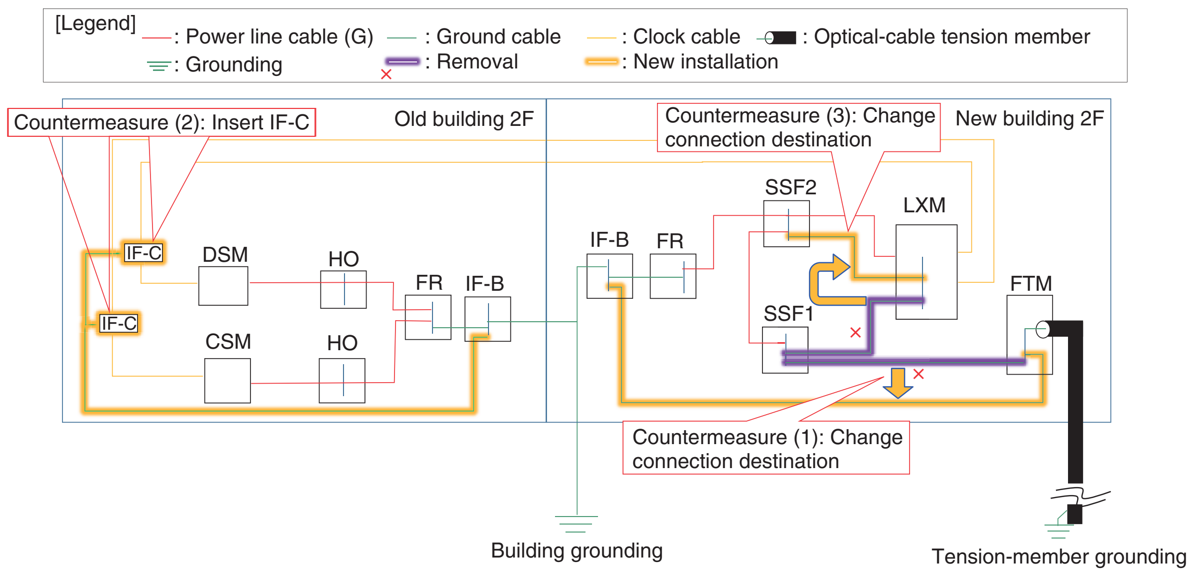


Fig. 9. The proposed lightning-damage countermeasures.

directly to the optical-cable tension member of the FTM, the ground cable between SSF-1 and the FTM should be removed, and the FTM should directly connect to IF-B in the new building.

Countermeasure (2): To pass the lightning surge flowing into the LXM from the clock cable, two IF-Cs are inserted into the clock cables crossing the buildings from the DSM and CSM, and the ground terminal of the IF-Cs should connect to IF-B in the old building.

Countermeasure (3): To make the SSF-2 and LXM equipotential, SSF-2 should connect to the LXM instead of SSF-1 and LXM.

4. Conclusion

This article described the grounding-system evaluator developed by TASC. By conducting a field-survey of lightning damage that occurred at a telecommunications center building, TASC could find the causes of the failure and proposed countermeasures to prevent lightning surge. The evaluator can visualize the configuration of a grounding system, which includes telecommunication equipment, power equipment, and grounding cables. It can also automatically determine the status of the configuration.

The EMC Engineering group in TASC is continuously engaged in technical support in the field regarding problems caused by lightning, malfunction of electromagnetic phenomena, interference of radio wave, induction from power line, and so on to ensure reliability of telecommunication services.

External Awards

The Young Scientists' Award, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology

Winner: Gento Yamahata, NTT Basic Research Laboratories
Date: April 14, 2021
Organization: Ministry of Education, Culture, Sports, Science and Technology

For his research activities of high-accuracy single-electron control using silicon quantum dots.

Young Researcher's Award

Winner: Takayuki Nakamura, NTT Network Service Systems Laboratories
Date: April 16, 2021
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE) Technical Committee on Network Systems

For "A Study on D-Plane Architecture and Configuration Method of a Data Network Slice Constituting an E2E Slice."
Published as: T. Nakamura, T. Narumi, M. Amasaka, and T. Sato, "A Study on D-Plane Architecture and Configuration Method of a Data Network Slice Constituting an E2E Slice," IEICE Tech. Rep., Vol. 121, No. 2. NS2021-12, pp. 65–70, Apr. 2021.

CHI 2021 Honorable Mention Award

Winners: Amanda Baughan, Nigini Oliveira, Tal August, University of Washington; Naomi Yamashita, NTT Communication Science Laboratories; Katharina Reinecke, University of Washington
Date: May 13, 2021
Organization: The Association for Computing Machinery (ACM) Conference on Human Factors in Computing Systems (CHI 2021)

For "Do Cross-cultural Differences in Visual Attention Patterns Affect Search Efficiency on Websites?"
Published as: A. Baughan, N. Oliveira, T. August, N. Yamashita, and K. Reinecke, "Do Cross-cultural Differences in Visual Attention Patterns Affect Search Efficiency on Websites?", CHI 2021, Virtual conference, May 2021.

Distinguished Service Award

Winner: Tsuyoshi Joucha, NTT Network Service Systems Laboratories
Date: May 21, 2021
Organization: The Telecommunication Technology Committee (TTC)

For his contribution to standardization activities adapted to the times as a member of the planning and strategy committee.

Distinguished Service Award

Winner: Seiichi Sakaya, NTT Network Service Systems Laboratories
Date: May 21, 2021
Organization: TTC

For his contribution to developing specifications concerning interconnections to support migration from public switched telephone networks to Internet protocol networks.

Information and Communication Technology Award, TTC Chairman's Prize

Winner: Kensaku Komatsu, NTT Communications Corporation
Date: May 21, 2021
Organization: TTC

For his achievements related to improving domestic technological capabilities by promoting international standardization of WebRTC and business promotion.

Best Paper Award

Winners: Atsushi Taniguchi, Takeru Inoue, Kohei Mizuno, NTT Network Innovation Laboratories; Takashi Kurimoto, Atsuko Takefusa, Shigeo Urusidani, National Institute of Informatics
Date: May 21, 2021
Organization: IEICE Technical Committee on Communications Society

For "Efficient Reliability Evaluation of Multi-domain Networks with Secure Intra-domain Privacy."
Published as: A. Taniguchi, T. Inoue, K. Mizuno, T. Kurimoto, A. Takefusa, and S. Urusidani, "Efficient Reliability Evaluation of Multi-domain Networks with Secure Intra-domain Privacy," IEICE Trans. Commun., Vol. E103-B, No. 4, pp. 440–451, 2020.

Best Paper Award

Winners: Naruto Arai, NTT Space Environment and Energy Laboratories; Ken Okamoto, NTT Information Network Laboratory Group; Jun Kato, NTT Space Environment and Energy Laboratories; and Yoshiharu Akiyama, NTT Advanced Technology Corporation
Date: June 3, 2021
Organization: IEICE

For "Method of Measuring Conducted Noise Voltage with a Floating Measurement System to Ground."
Published as: N. Arai, K. Okamoto, J. Kato, and Y. Akiyama, "Method of Measuring Conducted Noise Voltage with a Floating Measurement System to Ground," IEICE Trans. Commun., Vol. E103-B, No. 9, pp. 903–910, 2020.

Best Paper Award

Winners: Toru Mano, Takeru Inoue, NTT Network Innovation Laboratories; Kimihiro Mizutani, Kindai University; Osamu Akashi, National Institute of Informatics
Date: June 3, 2021
Organization: IEICE

For "Reducing Dense Virtual Networks for Fast Embedding."
Published as: T. Mano, T. Inoue, K. Mizutani, and O. Akashi, "Reducing Dense Virtual Networks for Fast Embedding," IEICE Trans. Commun., Vol. E103-B, No. 4, pp. 347–362, 2020.

Papers Published in Technical Journals and Conference Proceedings

Patentability Issues on AI-related Invention in Japan

Y. Nakajima and H. Shiomi

Journal of International Association for the Protection of Intellectual Property of Japan, Vol. 46, No. 2, pp. 71–89, March 2021.

Patent applications for artificial intelligence (AI)-related inventions are swiftly increasing not only in Japan but also in other countries around the world. There is a growing need for patent applications for AI-related inventions, even in industries and sectors that have not traditionally had much to do with the computer software-related inventions. In light of these circumstances, the Japanese Patent Office is making public and enriching case studies related to the requirements for describing AI-related technologies and determining inventive step in the Patent-Utility Model Examination Handbook. This article classifies AI-related inventions into four types according to their technical features, examines the requirements for novelty, inventive step, and description of each kind of invention, and points out the problems that may arise with each class in the future. The article also aims to highlight the different characteristics of AI-related inventions from general software-related inventions.

Flexible Assimilation of Human's Target for Versatile Human-Robot Physical Interaction

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IEEE Transactions on Haptics, Vol. 14, No. 2, pp. 421–431, June 2021.

Recent studies on the physical interaction between humans have revealed their ability to read the partner's motion plan and use it to improve one's own control. Inspired by these results, we develop an intention assimilation controller (IAC) that enables a contact robot to estimate the human's virtual target from the interaction force, and combine it with its own target to plan motion. While the virtual target depends on the control gains assumed for the human, we show that this does not affect the stability of the human-robot system, and our novel scheme covers a continuum of interaction behaviors from cooperation to competition. Simulations and experiments illustrate how the IAC can assist the human or compete with them to prevent collisions.

In this article, we demonstrate the IAC's advantages over related methods, such as faster convergence to a target, guidance with less force, safer obstacle avoidance, and a wider range of interaction behaviors.
