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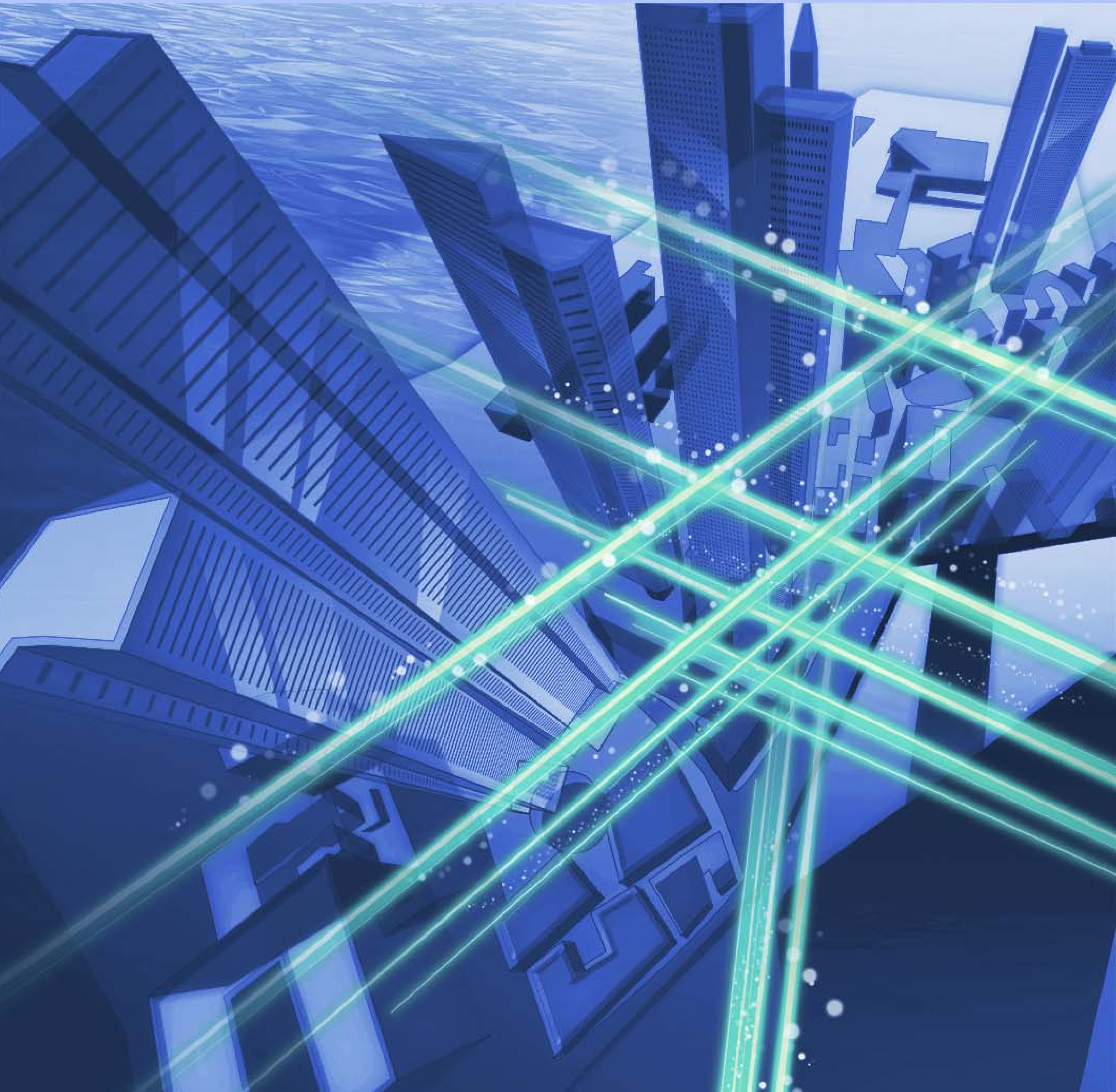

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I Wish to Contribute to the World through Research for the Rest of My Life

Hiroki Takesue
Senior Distinguished Researcher,
NTT Basic Research Laboratories

Abstract

As the miniaturization of complementary metal-oxide semiconductor electronic circuits that underpin computer technology approaches its limit, the end of Moore's Law—which suggests that the performance of digital computers increases exponentially over time—has become a reality. Therefore, research on new types of computers that use physical phenomena to efficiently (and at high speed) solve specific problems that digital computers cannot solve easily is being actively carried out. We interviewed Senior Distinguished Researcher Hiroki Takesue, who has published a series of world-leading results in this field of research, about his research achievements and his attitude as a researcher.

Keywords: coherent Ising machine, quantum random-number generator, photonic neurons, photonic spiking neurons

We demonstrated high-speed solution search of large-scale combinatorial optimization problems using the world's largest-scale coherent Ising machine

—It has been four years since we interviewed in 2018 after you received the Nishina Memorial Prize the previous year. How have your research activities been going since then?

One of my current themes, "implementing a large-scale coherent Ising machine (CIM)," has been an ongoing pursuit since 2018. Briefly, an Ising machine is a new type of computer that solves—through physical experiments—the problem of finding the minimum energy state in an Ising model, which is a theoretical model describing how a huge number of microelements called "spins" that can take on either of two values (up or down) interact with each other and behave as a whole. It can be applied, for example, to solve complex combinatorial optimization problems such as finding a one-stroke route that visits many points in the shortest time. A quantum annealer, which is a type of Ising machine and uses superconducting qubits as spins, has been developed. In collaboration with other research institutes under the Impulsing Paradigm Change through Disruptive Technologies (ImPACT) initiated by the Cabinet Office, Government of Japan, we have developed a CIM in 2016, which enables stable and fast calculation

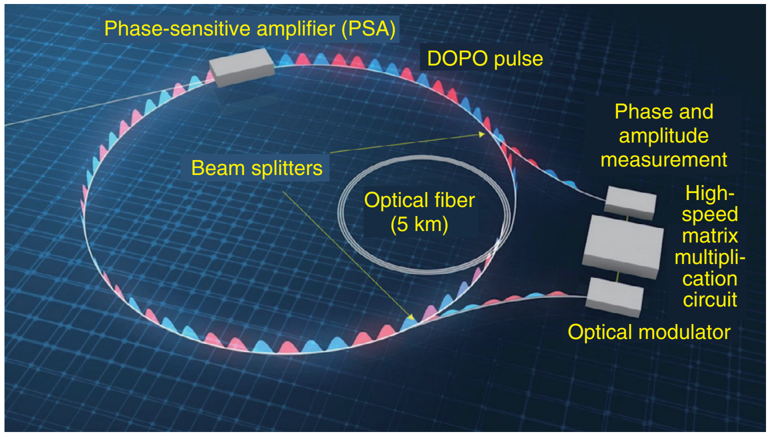

Fig. 1. Conceptual diagram of our CIM.

of the Ising model using a special laser light that takes on a phase (0 or π) as spins instead of unstable superconducting qubits. We call this CIM LASOLV™ because it solves ("SOLV") the above-described problem by using a laser ("LA") (**Fig. 1**).

In 2019, in collaboration with the National Institute of Informatics (NII), Stanford University, and the Ames Research Center of the National Aeronautics and Space Administration, we used a network of degenerate optical parametric oscillators (DOPOs) to experimentally evaluate the characteristics of a CIM. The results of this experiment revealed that the mechanism of the CIM's flexible connection among nodes (i.e., a square lattice where spins are arranged) plays an important role in solving complex graph problems at a high probability of success in obtaining correct solutions. In this experiment, we compared the success probabilities achieved with the CIM developed by NTT and that developed by Stanford University as well as a quantum annealer for solving the common combinatorial optimization problem and found that the CIMs outperform the quantum annealer in the case of graphs with high edge density [1].

In 2021, we constructed an ultra-large-scale CIM consisting of 100,000 DOPOs in collaboration with Prof. Kenichi Kawarabayashi and his colleagues from NII [2]. By increasing the scale of the optical system and the measurement-feedback scheme, we developed an ultra-large-scale CIM enabling 100,000 DOPO pulses with up to 10 billion couplings. This CIM can obtain the solution for a 100,000-node combinatorial optimization problem approximately 1000 times faster than by simulated annealing (SA) implemented on a central processing unit at equivalent accuracy. We also confirmed that by changing the operating conditions of the CIM, it is possible to obtain a broader distribution of solutions than that given by SA. Both these results have been published in the American scientific journal Science Advances.

—You've achieved one world's first after another.

In 2021, we were able to report the following additional results. First, by using a realistic optical device, we developed the world's-first high-speed quantum random-number generator (QRNG) that achieves a high degree of security [3] (**Fig. 2**). A QRNG is a device that uses the probabilistic nature of quantum measurement to create true random numbers. Random numbers produced by a QRNG can be made quantum mechanically secure in the sense that if an eavesdropper attempts to eavesdrop in a way that is quantum-mechanically possible, their unpredictability can be guaranteed. Together with the U.S. National Institute of Standards and Technology (NIST), we developed a theoretical method for efficiently guaranteeing random numbers from a small amount of experimental data. Then, by measuring the arrival time of light pulses called "time-bin qubits," we successfully generated a quantum-mechanically-safe random number composed of 8192 bits every 0.1 seconds. This achievement was published in the British scientific journal Nature Communications.

In collaboration with Kazuyuki Aihara, the deputy director of the International Research Center for Neurointelligence (IRCN) and special professor at the University of Tokyo, and other researchers, we succeeded in using DOPOs for generating artificial

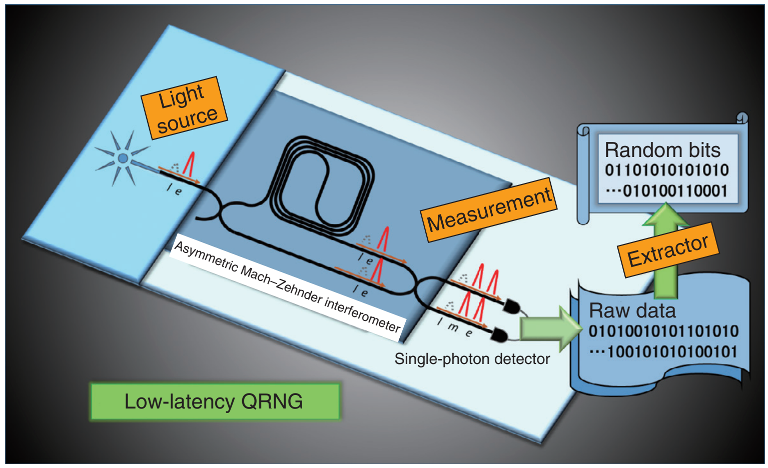

Fig. 2. Schematic of the developed QRNG.

photonic neurons that simulate the firing* signals ("spikes") of neurons [4]. The spiking dynamics of neurons are broadly classified into two classes in accordance with their response to external stimuli. We found that the DOPO neurons that we created have the property that both spiking modes can be freely controlled by a simple operation, namely, adjusting the light intensity of the optical pump to be injected. By controlling the spiking modes, it is possible to adjust the spiking frequency of artificial neurons, which is an important parameter of brain-inspired information processing.

Toward new information processing using the properties of light

—It is rare to produce three results per year for basic research, isn't it?

In addition to more than a dozen group members and members of other NTT laboratories, we have been collaborating with NTT Group companies and other companies and organizations, which has enabled us to obtain and publish world's-first results. Research activities are challenging, and not many companies in the world can take on the challenge of implementing in society the basic research results that were published in academic journals several years prior. We are very fortunate and proud that NTT allows us to take on such challenges.

The LASOLV Promotion Project, of which I am a member, is entering a phase in which we are trying to conduct a proof of concept as soon as possible. I want to further clarify the significance of our CIM in terms of basic research and implement it in a manner that people can benefit from it. As a researcher involved in basic research, I believe that such research is the stage at which "seeds" are created, and I understand the importance of creating such seeds. However, it is difficult to implement technology in society by only creating seeds. It is even more difficult in the case of technologies such as a CIM that spans a variety of disciplines, including quantum optics, photonics, computer science, and software. Through my activities in the LASOLV Promotion Project, I realized that by assembling researchers with various abilities and talents in different phases and technical fields, we can produce research results that are both socially and academically significant.

—It seems like these research results are going to have a great impact both academically and socially.

Although the academic and social significance of the results reported here somewhat overlap, we hope to contribute to the actualization and diversification of information processing using the analog, nonlinear, and quantum properties of light. Our long-term goal is to use DOPO-based spiking neurons as a neuron simulator with plasticity to test hypotheses concerning the function and information processing of the human brain [4]. As I said earlier, we also have

* Neuron firing: Sending an electrical signal from one neuron to an adjacent neuron when the input electrical signal to the former neuron exceeds a threshold value.

succeeded for the first time in the world in generating quantum-mechanically-secure random numbers in real time by using photons, and I believe this achievement is a major step forward in the practical application of QRNGs.

Since October 2020, I have also been the head of the Quantum Science and Technology Laboratory of NTT Basic Research Laboratories, and this lab is also actively researching quantum computers. We are often asked about the relevance of a CIM to quantum computing, but the principles and research approaches of the two are completely different. The so-called "quantum computer" is an attempt to create a quantum-computation algorithm with ultimate performance that is theoretically guaranteed then to achieve that performance experimentally. Although physical systems of CIMs have been constructed and empirically and experimentally demonstrated to be used for certain types of computations, the theoretical understanding of those systems is still in the early stages. Quantum computing is a field that is currently attracting a large amount of attention and is expected to progress as a technology of great importance to society. I believe that we can contribute to the diverse development of quantum technology by taking complementary approaches such as researching a CIM in parallel.

In our world, we have more unsolved problems than the number of researchers

—Could you tell us about your attitude as a researcher and the values that you have maintained?

Basically, I have been aiming for the "blue ocean," a field that has not been much researched by our predecessors. Many things in the world are still not understood, and compared with the number of unknown things, the number of researchers is insufficient. In other words, if you look carefully, you will see many areas of research that have not yet been explored. From that perspective, I believe that it is better to delve into untapped fields than to stay in a field of research that is well established because doing so will expand the opportunity for playing an active role.

I think a lot when deciding which theme to pursue; in the end, though, I decide according to whether a theme is interesting to me. To be honest, whether this theme will contribute to society is not the first thing I thought of; instead, I focus on what I intuitively feel is interesting. The significance of a research theme then becomes clear while conducting research on that topic of interest. That was also true in the case of a CIM.

I have had a memorable group meeting regarding a CIM. It was a meeting in which we reported on the generation of a large number of DOPO pulses, a basic CIM technique, by using nonlinear optical effects in a 1-km optical fiber ring. It was the first presentation about a CIM at NTT, and I remember that the theoretical researchers in our group relentlessly asked tough questions not only about the experimental results but also about the concept of the CIM. Although I was very excited by the results of an interesting experiment paving a new direction and was confident about the presentation, I was disappointed immediately afterward by the unexpectedly harsh reaction. However, many of the questions and comments I received at that time were highly relevant and have since become a major inspiration for my continued research on the CIM. I was also surprised and encouraged by the fact that, despite seeing this somewhat disastrous presentation, a colleague told me a short time later that he wanted to participate in this research. Come to think of it, perhaps the fact that a CIM was not an established field of study led to such diverse and meaningful responses.

—What is your attitude toward research activities in the future?

I am now at an age at which I think about how what I am pursuing can have a positive impact on society. When I joined the company, my goal was to first write a paper in English and present it at an international conference; however, as I achieved those goals, I gradually began to think that I would be happy to contribute in some way, such as writing an academic paper, that would have an impact on other researchers in the same field. I don't know to whom, or at what level, that contribution will be made, but now I'm wondering if my research can help people and society, hopefully directly.

Since joining NTT, I have always thought of myself as a young researcher, but now I am 50 years old. Since joining the company, I have been involved in four main themes. Although my current research is very fulfilling and interesting, I feel that it is time to look for a fifth theme so that I can progress further as a researcher. In a recent chat within our group, we learned that Dr. Shun-ichi Amari, who is a leading expert in the field of mathematical neuroscience, is still publishing papers as the first author at 86 years of age, and we talked about how great he is. I'd like to follow his example and continue to be a researcher as long as I can. My goal is to continue to contribute to others and society through my research.

As a senior distinguished researcher and the head of the Quantum Science and Technology Laboratory, I also consider it my mission to help junior researchers to be successful. Looking back on my life so far, I had several moments during my research life when I was unsure what to do, but could take a step forward with the help of those around me. I urge all young researchers to find their own "blue ocean," and I support them in these endeavors.

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■ Interviewee profile

Hiroki Takesue received a B.E., M.E., and Ph.D. in engineering science from Osaka University in 1994, 1996, and 2002. In 1996, he joined NTT Basic Research Laboratories, where he was engaged in research on lightwave frequency synthesis, optical access networks using wavelength division multiplexing, and quantum optics. He is currently pursuing research on communication and computation using quantum optics technologies. He is the recipient of several awards, including the ITU-T Kaleidoscope Conference 2nd Best Paper Award in 2008, The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology of Japan (The Young Scientists' Prize) in 2010, and the Nishina Memorial Prize in 2017. He was a visiting scholar at Stanford University, California, USA, from 2004 to 2005 and guest researcher at the National Institute of Standards and Technology (NIST), Colorado, USA, in 2014. He was selected as an Institute of Electrical and Electronics Engineers (IEEE) Photonics Society Distinguished Lecturer from July 2018 to June 2019. He is a guest professor in the Graduate School of Engineering Science, Osaka University and member of IEEE and the Japan Society of Applied Physics (JSAP).

Research on Display Image Optimization Based on Visual Models for Next-generation Interactive Media

Taiki Fukiage
Distinguished Researcher, NTT Communication Science Laboratories

Abstract
High-quality, low-latency, and energy-saving video generation is foreseen to become a requirement in next-generation interactive media. We spoke to Dr. Taiki Fukiage, a distinguished researcher who is aiming to establish an image-generation technology that is both human- and environment-friendly through the construction of visual models.

Keywords: visual model, vision science, media technology

What is "display image optimization based on visual models?"

—What kind of research are you doing?

My research would probably be best described as "media technology research based on vision science." I am engaged in research to improve media display technology and come up with entirely new display methods by taking advantage of the human visual characteristics elucidated by vision science. In this context, vision science is, roughly speaking, a field of study that elucidates how information seen through the eyes is processed in the brain and how it generates subjective perceptual experiences.

Applying vision science to media technology often necessitates predicting the perceptual experience that can be gained from any image or video. However, the main approach for research in the field of vision science thus far has been to break down stimuli into elements such as color, shape, and motion, and examine how each of them are processed. Thus, there are still no models to generically explain the way we see natural images and videos, as we see them in daily life. Therefore, the need to address the unsolved issues of vision science usually arises in considering technological applications.

To develop the relevant media technologies, we are conducting research by first figuring out the unsolved parts of vision science through experiments, and then building visual models to optimize the display images. To look into "how human visual information processing is carried out," we are working on both the scientific aspect of vision science for building models for visual systems and the technical aspect for optimizing the models by applying them to media display technology, enabling human- and environment-friendly video-generation technology (**Fig. 1**).

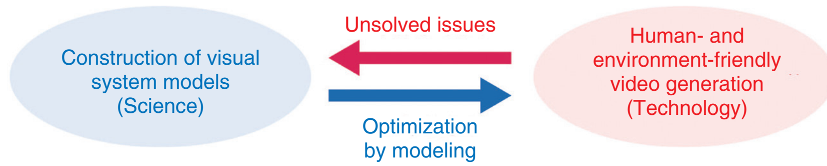


Fig. 1. Display image optimization based on visual models.

—Specifically, what media technologies are you researching?

I would like to tell you specifically about three media technologies.

HenGenTou (2015–2019)

Research on HenGenTou (deformation lamps) started before I joined the Laboratories and pertains to a technique that uses projection mapping to add movements to stationary objects. Previous research in vision science has shown that humans recognize the world around them by independently processing motion, shape, and color information, and subsequently integrating these different kinds of information. The research started from the idea that we could do interesting things if we took the process backwards. It is a technique that uses human illusion to make stationary objects appear to be moving; and I was very surprised myself when I saw it for the first time.

Creating the illusion that an object appears to be moving requires that the projection pattern be aligned exactly with the actual object. I was mainly responsible for the component pertaining to automatic calibration of position using computer vision technologies. Also, because it is an illusion-based technique, there is a limit to the amount of motion that can be added. If you try to make very large movements, the illusion would be seen as "a clearly different pattern is added on a stationary object." Therefore, we built a "projection dissonance model" that predicts "how much movement can be permitted" and worked on research that automatically gives the maximum movement within the permitted range.

Having visual impact and appeal, the technique has been commercialized in a variety of fields. For example, it has been used to add movements to point-of-purchase advertising at stores and applied to art works.

Hidden Stereo (2016–2017)

Hidden Stereo is a technology related to three-dimensional (3D) television. On a 3D television, where images appear in 3D with the use of special glasses, you can only see blurry images without the glasses on. Using the mechanism by which humans perceive depth, we developed a stereoscopic image-generation technology that enables users to see images clearly even without 3D glasses (**Fig. 2**).

To perceive depth, humans use a mechanism to resolve the images of the left and right retinas into elements such as orientation and fineness/roughness, and then detect the phase difference between the corresponding elements as disparity in order to perceive depth. The minimum necessary induction pattern for humans to feel depth is then created on the basis of this disparity detection mechanism, to create the image for the left eye by adding that pattern to the original image, and for the right eye by subtracting it. With 3D glasses, images appear three-dimensionally because left-eye and right-eye images are delivered respectively to the left eye and the right eye. But, without 3D glasses, the plus pattern for the left eye and the minus pattern for the right eye cancel each other out, leaving only the original image, so that one can see the image clearly.

This research was originally started from the idea that depth could be added to HenGenTou mentioned above. Their similarity is that HenGenTou add patterns to give movement, while Hidden Stereo adds patterns to give depth.

Intuitive image blending based on visibility (2020–2021)

"Intuitive image blending based on visibility" is our most recent research. There is demand for technologies for blending and displaying translucent images, such as for superimposing translucent images to render emotional scenes and stacking translucent information to prevent real-world scenery from being hidden in augmented reality (AR), virtual reality (VR), etc.

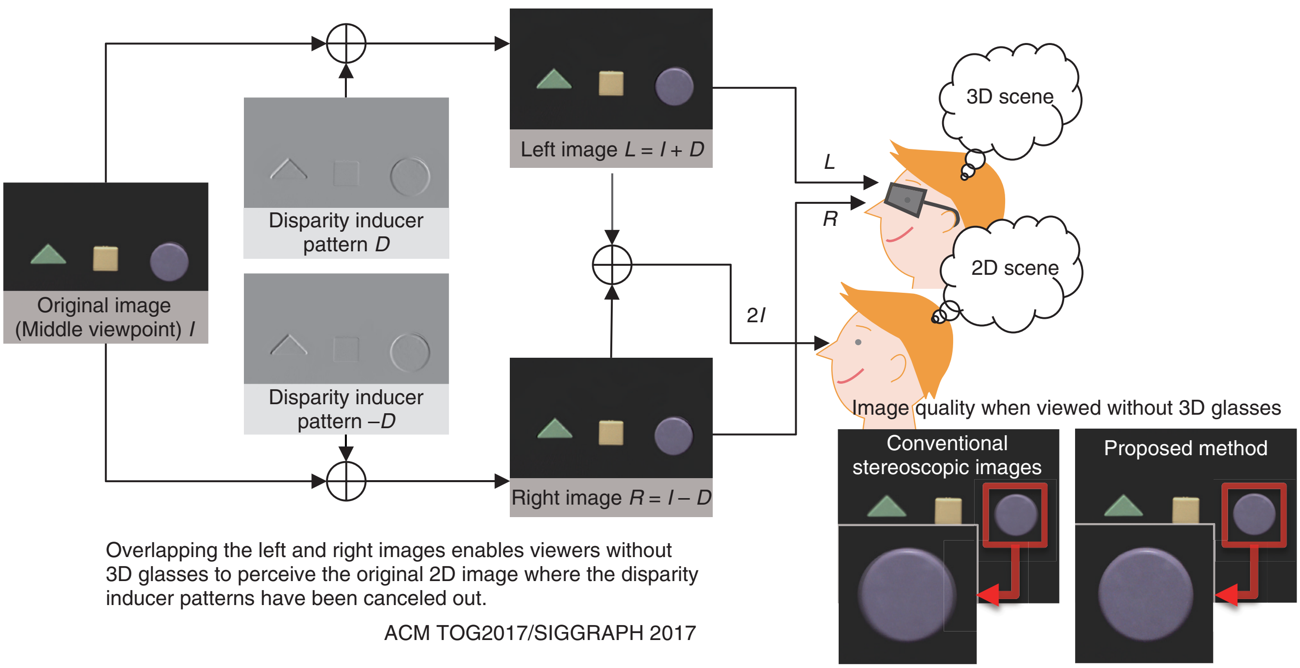


Fig. 2. Hidden Stereo.

This type of image blending requires setting the transparency level. However, even if the transparency is set uniformly to 0.5, visibility would completely differ depending on the combined images. It is difficult to get the desired results by simply synthesizing images by physically setting the transparency level.

Although models have been created to predict the visibility of individual elements, such as the color and coarseness of images, it has not been clear how to integrate these elements in order to predict the actual visibility of natural images. In this research, we are developing a "visibility prediction model" that can accurately predict visibility by measuring the visibility of blended images using a large number of natural images, and then automatically setting the optimum transparency level.

Aiming to establish video-generation technologies as well as contribute to vision science

—What are the directions of your future research?

Thus far, we have focused on applying the low-order visual science models, i.e., those near the entry point of the visual system, to media engineering. There are still many possible areas to explore in this field, but I feel that we have been able to clearly grasp what kinds of initiatives are doable.

Therefore, going forward, we will try to model the processing of higher-order information and optimize the models more aggressively. For example, previous studies have basically predicted the way we look through the central vision, near the so-called "central fovea," but we would like to also work on predicting the way we look through the "peripheral vision." In fact, a large part of the human vision involves peripheral vision. Furthermore, how information is processed for peripheral vision is considerably different from how it is processed for central vision. I believe that modeling this properly would lead to many new possibilities.

—What is your ultimate goal?

The three technologies presented here differ in the details, but their final goal is the same. There are two focal goals; the first is contributing to vision science. With a view to technological applications and a wide range of images and videos treated as stimuli, these studies may lead to the discovery of important visual functions that we have missed in the past.

And the second is contributing to technology. We aim to solve technical problems in the field of media engineering. Compared with previous displays, next-generation interactive media, such as AR and VR, require considerably more information and better quality, so it will likely become important to carefully distribute costs in consideration of human characteristics. On the basis of the constructed visual model, if we can determine the essential information necessary for eliciting natural human feelings, and then trim down unnecessary information, we will be able to achieve high-quality, low-latency, and energy-saving "human- and environment-friendly" video generation.

—Could you give a message to future business partners and young researchers?

NTT Communication Science Laboratories is a research laboratory that conducts basic research on an extremely wide range of fields. From only what I know, various studies are being conducted from brain science to computer vision, speech recognition, signal processing, and theoretical mathematics, the foundation of information processing. For many years, the fact that we have been conducting basic research without focusing on business applications is unusual for corporate research laboratories; but I think this is a major strength of NTT. In addition, while the degree of freedom for research is high, like that in universities and research institutes, we are not subject to many budget constraints. I would like to make use of this environment and pursue research with a broad perspective and free thinking, while creating technology seeds that will help society in the future.

If you want to become a researcher and are interested in the research topics mentioned above, I invite you to join our team and work with us. NTT hopes to provide an environment where you can maximize your full potential if you are engaged in your research and able to obtain competitive skills and knowledge while at university. It may also be important to find the topic that stimulates your curiosity the most. This is because a large part of research involves endless steady tasks that often do not go as planned; and I think curiosity will serve as the driving force for research during these seemingly fruitless times. As a researcher, I know that I still have a long way to go, and oftentimes I lose confidence. But ever since I was a student, I have had a strong interest in how humans perceive the world visually, and my curiosity about this problem has been the driving force for me to persevere in research.

■ Interviewee profile

Taiki Fukiage joined NTT in 2015, and is currently a member of the Sensory Representation Research Group, Human Information Science Laboratory, NTT Communication Science Laboratories. He has been a distinguished researcher at the Laboratories since 2020. He is conducting research on optimizing display images using visual models by leveraging expertise in the two fields of vision science and media engineering.

NTT's Vision for the Future of Agriculture, Forestry, and Fisheries—Simultaneously Improving Production Capacity and Sustainability

Yoshikazu Kusumi, Kanji Yoshitake, and Takuya Murayama

Abstract

The NTT Group has set agriculture, forestry, and fisheries as one of its priorities. In particular, we are working to implement Smart Agri—namely, optimizing the entire food value chain from breeding to production, distribution, sales, and consumption by using the Group's cutting-edge technologies, assets, and services and collaborating with forward-thinking partners. In response to growing concern about global environmental issues, we have begun new initiatives that will enable the agricultural industry to coexist in harmony with nature while improving its production capacity. This article describes issues concerning the agriculture, forestry, and fisheries industries and provides an overview of NTT Group's initiatives, specific examples, and future developments related to such industries.

Keywords: IOWN, coexistence with global environment, regional circular economy

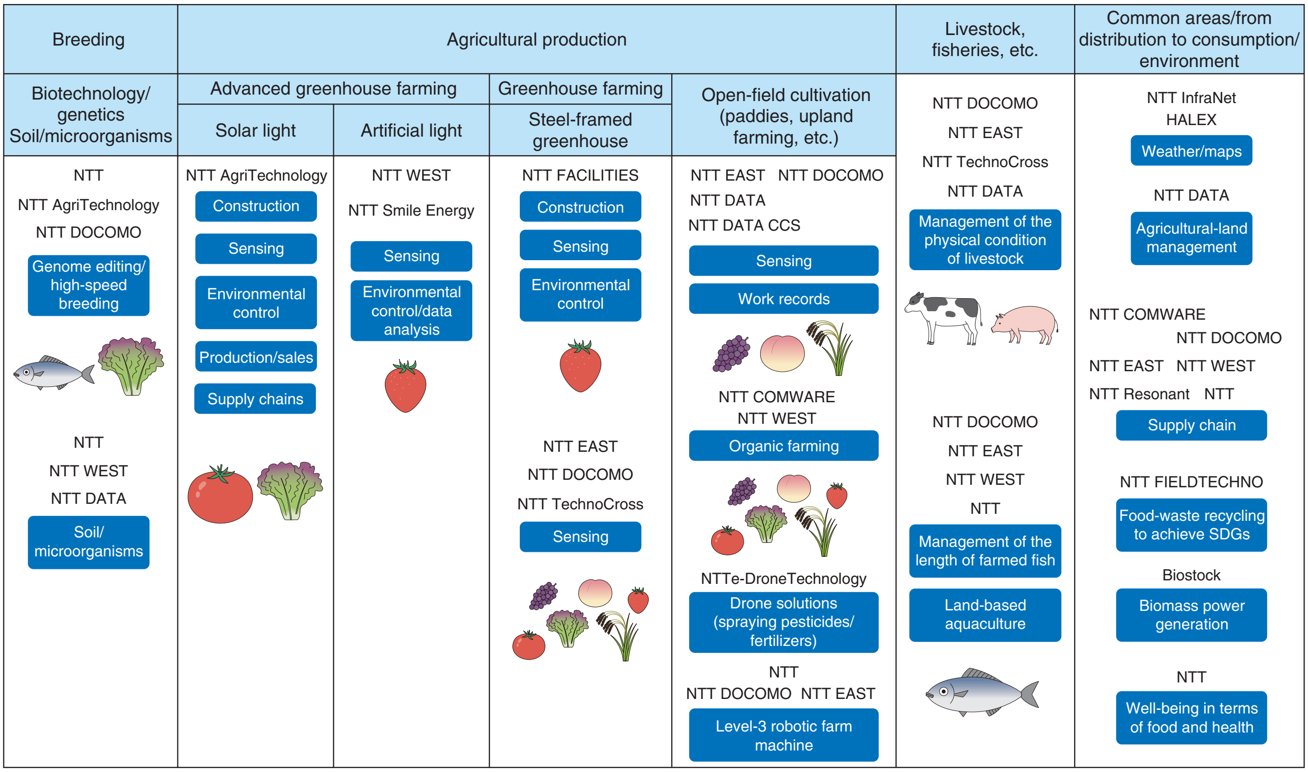
1. Issues concerning agriculture, forestry, and fisheries

The agriculture, forestry, and fisheries industries are indispensable for the survival of humankind; however, they face challenges such as a declining and aging workforce and decreasing production capacity and food self-sufficiency rate in Japan. This trend holds not only for agriculture but also for fisheries and forestry. It is particularly evident in the fisheries industry, in which the number of fishery workers has decreased from 392,000 in 1988, almost 30 years ago, to 152,000 in 2018, and over that period, fishery production has plummeted from 12.78-million tons to 4.42-million tons [1]. Once ranked first in the world in terms of fishery production, Japan has now dropped to eighth place. On a global scale, owing to the population explosion, demand for protein will exceed supply by 2030, resulting in a shortage of protein, including that from marine resources.

The agriculture, forestry, and fisheries industries are the only ones of the many industries that directly work with nature and enjoy its bounty. Accordingly, in addition to securing food by increasing production capacity, achieving sustainability is becoming increasingly necessary by maintaining and developing these industries in harmony with nature while taking environmental aspects into consideration.

2. Overview of NTT Group's initiatives

Against the above-described backdrop, the NTT Group is striving to strengthen the competitiveness and sustainable development of the agriculture,



SDGs: Sustainable Development Goals

Fig. 1. NTT Group's food and agricultural solution map (including research and development and field demonstrations in progress).

forestry, and fisheries industries through collaboration between NTT laboratories, which possess cutting-edge technologies, and approximately 30 group companies (**Fig. 1**) [2]. Combining NTT's Innovative Optical and Wireless Network (IOWN)*1 and the nationwide telecommunications infrastructure, assets, and services of NTT Group companies, we will create new value through innovation in the food and agriculture sector with forward-thinking partners.

For example, we want to build an ecosystem in which stakeholders in the food value chain can benefit by combining the following efforts: (i) digital breeding, which artificially modifies some of the properties of agricultural and fishery products by genome editing*2 and culture technology to dramatically and safely improve growth rates, carbon-dioxide absorption, etc. while giving due consideration to safety; (ii) ultra-labor saving and automation of agricultural work by using robotic farm machines and drones; (iii) digital transformation of agricultural-product distribution by which sellers and buyers make transactions in a virtual market built in cyberspace on the basis of supply-and-demand forecast information; and (iv) scientification of food and health to improve mental and physical well-being. Among the initiatives listed in Fig. 1, the Feature Articles in this issue introduce genome editing/high-speed breeding and soil/microorganisms [3], biomass power generation [4], drone solutions [5], and supply chains [6].

3. Specific examples of initiatives

3.1 Aiming to restore Japan's fisheries industry

The NTT Group has formed a capital alliance with Regional Fish Institute, Ltd. (RFI) [7], a venture

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

*2 Genome editing: A technique for altering a specific base sequence of a gene in an organism in a manner that improves the trait carried by that gene. It differs from genetic modification with which new characteristics are added to cells by introducing a gene extracted from another organism.

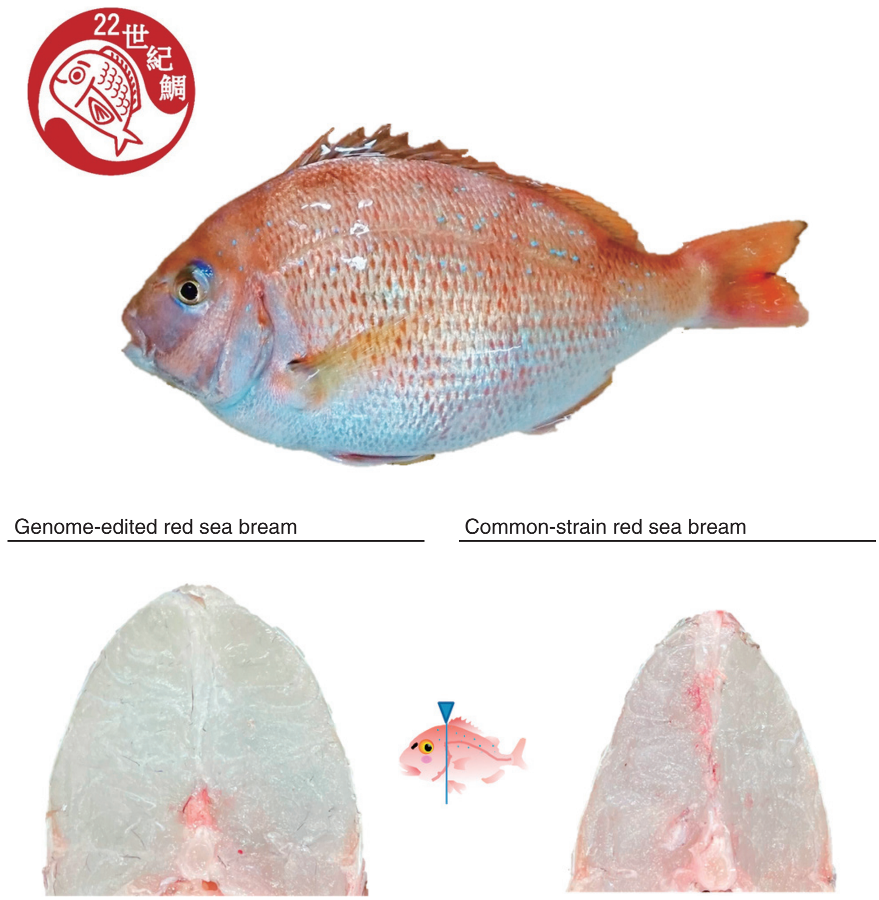


Fig. 2. Comparison of 22nd Century Bream and the common strain.

company originating from Kyoto University and Kindai University, with the aim of making Japan's fisheries industry the best in the world again and solving the global protein crisis. The alliance's land-based aquaculture business raises juvenile fish and shellfish in an Internet-of-Things-enabled environment using genome editing that deactivates a targeted gene in the DNA of those fish and shellfish in a manner that causes natural mutations through their natural resilience. When this technique was used to raise fish, the volume of the Japanese red sea bream increased up to 1.6 times more meat than the common strain while receiving 20% less feed, and the tiger pufferfish grew 1.9 times faster than the common strain while receiving 40% less feed and requiring much less rearing time. The seafood produced using this technique satisfy Japan's safety standards and have been branded and marketed as the world's first genome-edited animal foods under the names "22nd Century Bream" (**Fig. 2**) and "22nd Century Pufferfish." Through this initiative, we will add value to the Japanese aquaculture industry and transform it into a sustainable growth industry. In collaboration with RFI, we will create a future in which Japan's fisheries industry can solve the protein crisis, which is a global issue, as soon as possible.

3.2 Aiming for coexistence with the global environment

The agriculture, forestry, and fisheries industries enjoy blessings from the land, sea, and rivers; however, the global environment is becoming ever-more threatened every year as it faces issues such as climate change. NTT has announced a new environmental and energy vision called "NTT Green Innovation toward 2040" [8] to simultaneously achieve zero environmental impact and economic growth. As one of the efforts to reach this goal, NTT and RFI have started an experimental demonstration of carbon-dioxide conversion technology in which we apply

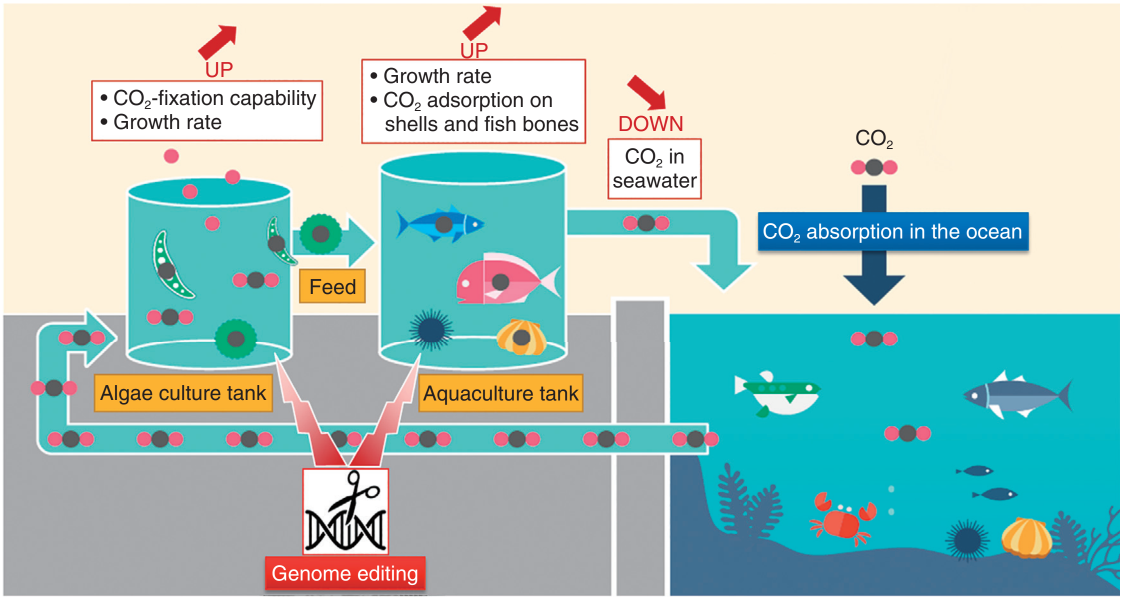


Fig. 3. Technology to reduce carbon dioxide in the ocean by applying genome-editing technology.

genome editing to algae, fish, and shellfish that can reduce the amount of carbon dioxide dissolved in the ocean (**Fig. 3**). In the normal food chain from algae to fish and shellfish, atmospheric carbon dioxide is absorbed into the ocean; however, the amount of carbon dioxide emitted into the atmosphere is increasing every year due to human activities, such as conversion of forests to agricultural land and urbanization, and the amount of carbon dioxide retained in the atmosphere cannot be reduced beyond the current level.

Accordingly, NTT will research and develop genome-editing technology for increasing the amount of carbon-dioxide fixation*3 in algae, and RFI will research and develop genome-editing technology for increasing the amount of carbon fixed in the bodies of fish and shellfish. By applying these two genome-editing technologies to the food chain from algae to fish and shellfish, we aim to establish a carbon-dioxide conversion technology that synergistically increases the total amount of carbon cycling in the ocean. In the future, this technology will be applied to increase production and improve the quality of fish and crops [9].

4. Future developments

To create a sustainable society in the future, we believe it is necessary to develop agriculture, forestry, and fisheries not only from the perspective of productivity improvement but also from the perspective of coexistence with the global environment. To make these efforts sustainable and effective, our future society will also require the formation of regional circular economy zones in which each region takes advantage of its unique strengths, makes the most of its local resources, and forms a self-reliant and decentralized society while helping and complementing each other among regions (**Fig. 4**).

As for the aforementioned land-based aquaculture for increasing carbon-dioxide fixation in the ocean, electricity (charges) consumed by temperature control and water circulation accounts for about 40% of the total cost, and how to reduce this cost is one of the keys to success. As a solution to this cost problem, we are investigating the use of recyclable energy sources that fully use resources and land that are not being used effectively in the region. Examples under investigation include (i) biomass power generation using waste, residue, and livestock manure generated on farms and (ii) solar power generation, for which installation sites are lacking in Japan, using abandoned farmland. These energy and heat sources can also be used in advanced greenhouse facilities and

*3 Carbon-dioxide fixation: A process in which inorganic carbon (such as carbon dioxide) is converted into organic-carbon compounds (such as sugars) and incorporated into the body of living organisms.

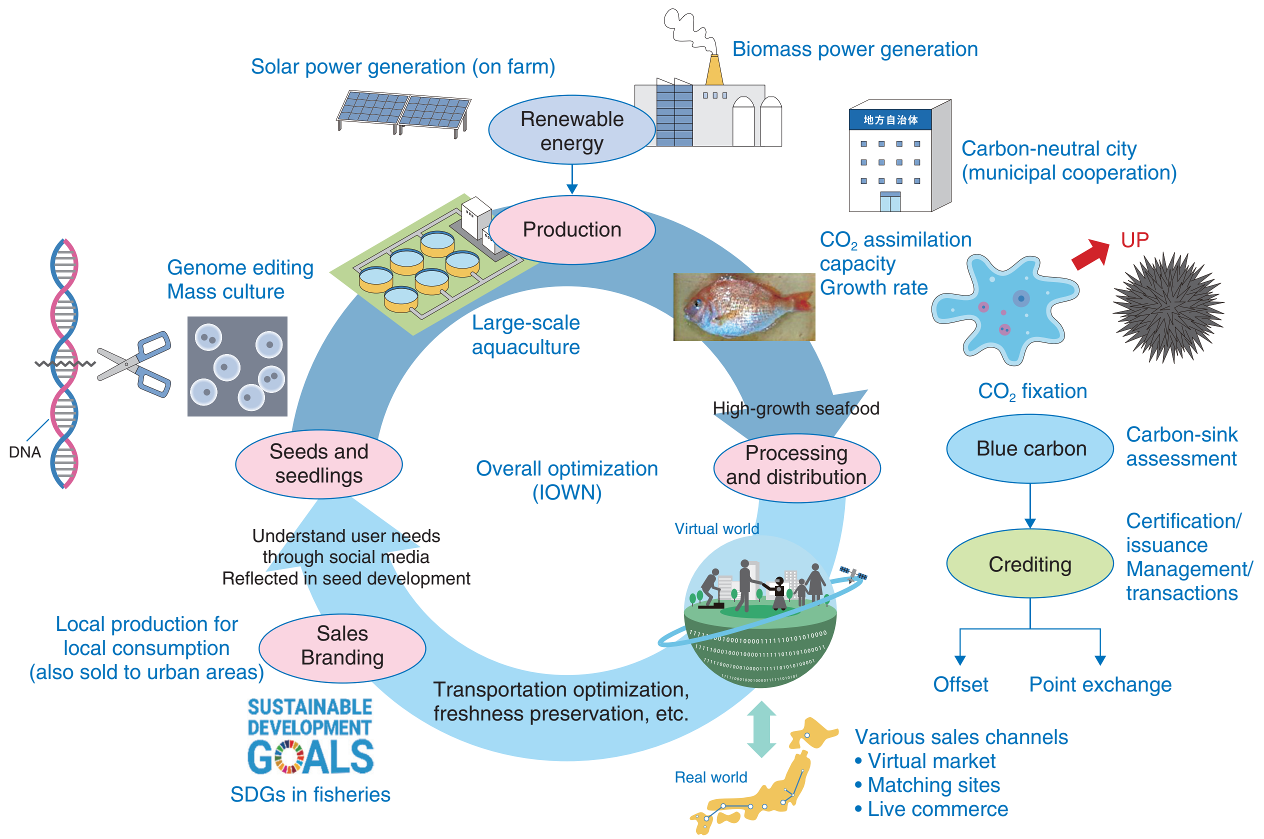


Fig. 4. A regional circular economy zone (centered around land-based aquaculture).

livestock sheds. It will also be possible to develop new business models, such as a new financial business based on agriculture and the environment by establishing a system in which, for example, credits obtained by reducing or absorbing greenhouse-gas (e.g., carbon dioxide) emissions can be exchanged for various points issued by private companies, and the points are used as local currencies in an economic zone while increasing incentives for implementing environmental initiatives. We aim to create a "sustainable regional circular society" through the overall optimization of information flow, logistics, and money flow generated by these activities using cutting-edge technologies and innovations such as IOWN.

The NTT Group will continue to deepen its efforts as a group of companies that support local communities. In particular, we will collaborate with various partners to integrate cutting-edge technologies and innovative business models while taking the challenge of developing agriculture, forestry, and fisheries industries in harmony with the global environment and creating regional circular economy zones.

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Yoshikazu Kusumi
Senior Manager, Strategic Business Creation Team, Research and Development Planning Department, NTT.

He received a B.S. and M.S. in nuclear engineering from Osaka University in 1993 and 1995. He joined NTT in 1995 and was assigned to the Long Distance Communication Business Division. He then worked at the Network Engineering Center, where he designed a network system for personal handyphone systems. He also worked at NTT Communications in the Carrier Sales Division, where he was in charge of wholesale business for foreign companies and later, planning global strategies. He is with NTT again, where he is responsible for ICT business creation for the agricultural industry.

Kanji Yoshitake
Senior Manager, Strategic Business Creation Team, Research and Development Planning Department, NTT.

After graduating from Tokyo University of Science in 1998, he was assigned to system engineering for public and educational institutions at NTT EAST. He then was engaged in service development work for routers, Wi-Fi, etc. He currently works at NTT and is responsible for creating an ICT business for the agricultural industry.

Takuya Murayama
Manager, Strategic Business Creation Team, Research and Development Planning Department, NTT.

He received a B.S. and M.S. in applied physics from Waseda University, Tokyo, in 2005 and 2007. He joined NTT in 2007. His research interests include lifelog systems and service design. He is a member of the Institute of Electronics, Information and Communication Engineers. He currently works at NTT and is responsible for creating an ICT business for the agricultural industry.

An Urban-circular Ecosystem in Which Food Waste from a Company Cafeteria Is Recycled Using an Ultra-compact Biogas Plant

Shogo Inoue

Abstract

Methanization, which can produce biogas, a renewable energy source, is attracting attention as an approach to recycle food waste; however, the installation cost and the labor required for operation and management are becoming issues. Therefore, Biostock CORPORATION, an NTT EAST Group company, developed an easy-to-operate container-type biogas plant equipped with a remote monitoring system. In collaboration with NTT EAST, the company installed a commercial version of the plant at a demonstration field called NTTe-City Labo to verify the plant as part of an urban-circular ecosystem that generates energy and fertilizer by using leftover food from the cafeteria of NTT EAST headquarters in central Tokyo and waste from NTTe-City Labo's farm fields.

Keywords: carbon neutral, renewable energy, food-waste recycling

1. Environment surrounding food-waste recycling

One of the keys to achieve carbon neutrality and a circular economy in the food and agriculture field is effectively utilizing the large amount of food waste generated every day. While it is important to reduce food loss by minimizing food waste as much as possible, it is effective to utilize food waste as a resource, rather than simply incinerating it.

The two most common approaches to recycling food waste have been conversion to animal feed ("ecofeed") and conversion to fertilizer ("composting"); however, the business environment surrounding both approaches has become increasingly difficult. The hurdle for ecofeed has been rising every year as sanitary standards have been tightened to counter swine fever and other infectious diseases affecting livestock. As a result, the number of processable waste has diminished, and investment in new equipment is often required to meet sanitary standards. Demand for compost is also an issue. Although some people prefer inexpensive compost due to rising chemical fertilizer prices, as the number of farmers continues to decline, chemical fertilizers—which have a higher fertilizing effect per unit amount and require less labor to apply—are gaining ground, and compost is generally oversupplied. It is thus becoming increasingly common that the more high-quality compost is produced, the more the compost business goes into the red.

In light of the above situation, a third approach to recycling food waste, *methanization*, has been attracting attention. Methanization is a technology for (i) fermenting and decomposing organic matter through the action of methanogens (microorganisms that produce methane) and (ii) extracting biogas (consisting mainly of methane) produced in that process. The collected biogas can either be burned in dedicated water heaters and boilers for use as hot water or it can be used to produce electricity through biogas generators; consequently, product demand after

Fig. 1. Container-type biogas plant.

recycling is not a concern. With the preferential treatment under Japan's feed-in tariff scheme and the strengthening efforts toward carbon neutrality in public and private sectors, the use of methanization has been rapidly increasing.

2. Issues facing methanization and biogas plants

To further expand the use of methanization, the cost of constructing facilities and the time and effort required for operating and managing them are issues that must be addressed. From both a technical standpoint to ensure stable fermentation of methane and an economic standpoint to increase efficiency of capital investment through economies of scale, it has been common to construct large methane fermentation facilities (biogas plants) with a daily throughput (biostock input) of 50 to 300 tons. Skilled operation managers are often assigned to each facility to monitor the activity of the methanogens and maintain stable fermentation.

Large-scale biogas plants have the advantage of being able to process large amounts of food waste at a time; however, they face two problems. First, as waste-treatment facilities, they can only be installed in a limited number of suitable locations. Second, large amounts of food waste must be transported to them every day, which incurs a high cost and emits carbon dioxide. To further promote food-waste recycling through methanization, it is required to (i) scale-down biogas plants and install them on-site at the location where food waste is discharged, for example, at food-processing plants and large-scale shopping complexes, and (ii) innovate a plant-operation system that enables an ordinary worker to operate the plant easily.

3. Overview and features of a container-type biogas plant and remote-monitoring system

With the above issues and requirements in mind, Biostock CORPORATION developed a container-type biogas plant in collaboration with Vioce Co., Ltd. (**Fig. 1**). This biogas plant has two key features. It is ultra-compact and easy to operate and is equipped with a remote monitoring system that allows unmanned operation.

Conventional biogas plants require large-scale construction at each installation site, and it generally takes about two to three years from the start of construction to the start of operation. In contrast, the components required for the container-type biogas plant—as its name implies—are housed in several 20-foot marine shipping containers, so it is remarkably compact. Components of the biogas plant are manufactured at factories. They are then transported to the installation site on a trailer and installed with a crane (**Fig. 2**). The only on-site work required is connecting electricity and water, so trial operations can begin in as little as two days. The portable nature of the plant also makes it suitable for remote islands and overseas locations where construction work is difficult to arrange.

The basic configuration of the container-type biogas plant is the same as a conventional biogas plant (**Fig. 3**). First, the organic waste (biostock) is homogenized in a conditioning tank. It then undergoes a fermentation process using methanogens in a fermentation tank, and biogas is extracted as a renewable energy source. The fermentation residue (digestive liquid) is used for agriculture or purified before being discharged. The container-type biogas plant differs from a conventional plant in that each component is

Fig. 2.   Installation work for the container-type biogas plant.

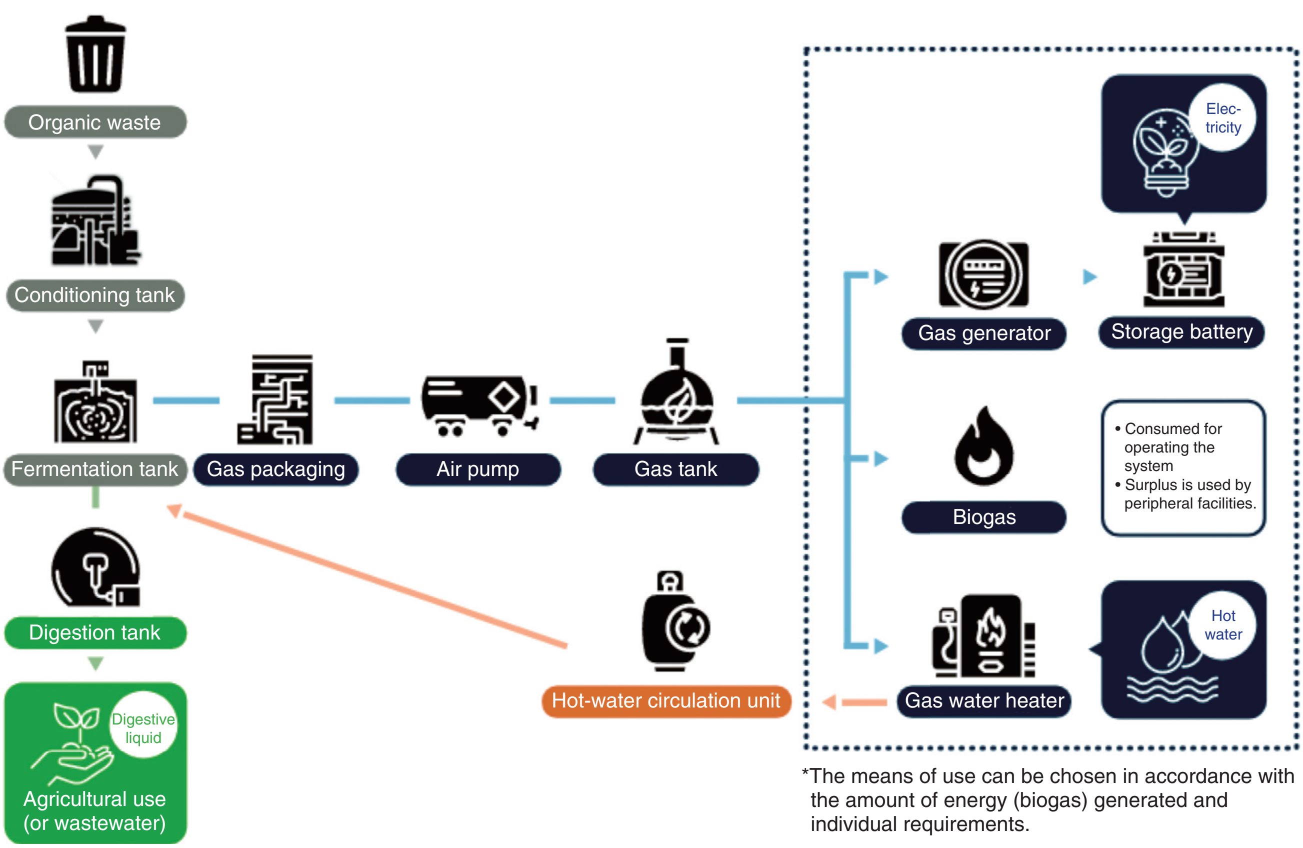

Fig. 3.   Configuration of the container-type biogas plant.

significantly scaled down. By selecting the optimum components in accordance with the volume of biostock to be processed, the increase in system cost can be curtailed, and the components are positioned so that they can be housed in 20-foot containers. This configuration allows the container-type biogas plant to operate with as little as 1 ton of biostock per day, whereas a conventional biogas plant typically

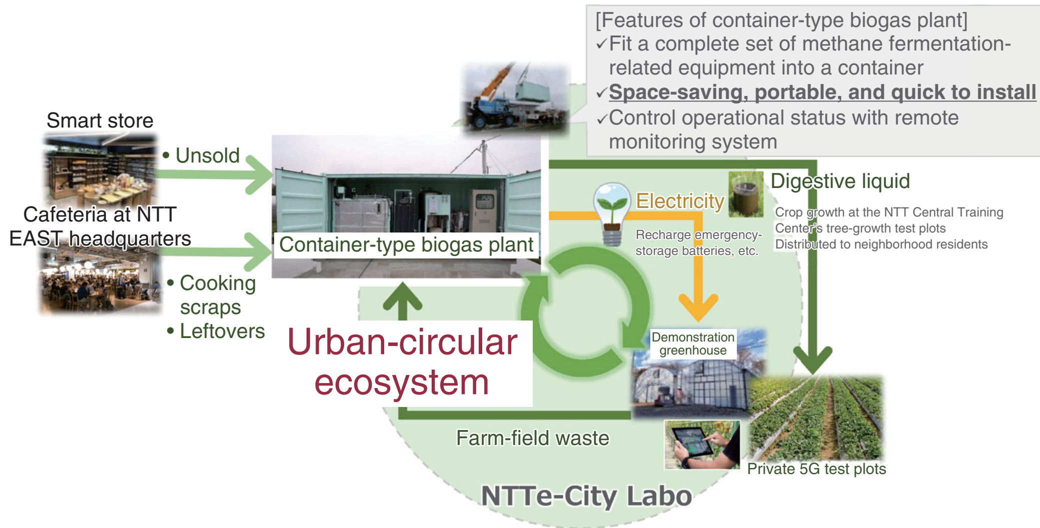

Fig. 4. Overview of the demonstration of an urban-circular ecosystem.

requires 50 tons or more per day.

The other feature of the container-type biogas plant is its remote monitoring system that enables on-site installation and unattended operation. Conventional large biogas plants generally require a dedicated operation manager at each plant. In contrast, thanks to automatic control and remote monitoring from Biostock by using numerous sensors, the container-type biogas plant can be easily operated and managed without a skilled operation manager at the site where the biostock is discharged.

Although systems for checking the operating status of a biogas plant via control panels at the site and, in some cases, alerts by email are conventionally available, Biostock's remote monitoring system differs significantly from those conventional systems in terms of economic efficiency, scalability, and security. The system is cloud-based, i.e., not on-premises software, and uses an Internet of Things (IoT) software package with a proven track record in the manufacturing industry. Thus, it is inexpensive and highly scalable. The system is also designed in line with NTT Group's security guidelines, which ensures it is safe and secure in response to, for example, cyberattacks in the industrial sector, which are expected to increase in the future. This system will be provided for not only container-type biogas plants supplied by Biostock but also biogas plants supplied by other companies and can be customized in accordance with user requests.

4. Demonstration of the container-type biogas plant at NTTe-City Labo

To verify the usefulness of the developed container-type biogas plant, in collaboration with NTT EAST, Biostock installed the plant at a demonstration field called NTTe-City Labo in February 2022 and started demonstrating an urban-circular ecosystem, of which the plant is a part, that generates energy and fertilizer by using leftover food from the cafeteria of NTT EAST headquarters in central Tokyo and waste from NTTe-City Labo's farm fields (**Fig. 4**).

Food scraps and leftovers from the cafeteria at the headquarters of NTT EAST in central Tokyo had been incinerated as general business waste. The container-type biogas plant will process such waste through methanization to achieve food-waste recycling. The collected biogas will be used to generate electricity for recharging emergency-storage batteries in the adjacent greenhouse built to demonstrate state-of-the-art agriculture. It will also be used to power an atmospheric water generator that can extract safe drinking water from the air in times of disaster. We also plan to promote the use of fermentation residue (digestive liquid) as fertilizer, which will be used to grow crops at the NTT Central Training Center (Chofu City, Tokyo). We are also investigating a scheme that uses the fertilizer in community farms and gardens.

Much of the food waste generated by businesses and households is still mostly incinerated without

ICT: information and communication technology

Fig. 5. NTTe-City Labo.

being recycled. Through the above demonstration, we intend to establish an urban-circular ecosystem, of which the container-type biogas plant is a part, that generates energy and fertilizer from urban food waste and use the demonstration as a model to roll out the system nationwide.

The container-type biogas plant installed at NTTe-City Labo is equipped with more sensors and IoT devices than a typical biogas plant; thus, it is possible to remotely monitor the plant and download real-time data, which had not possible without collecting samples and conducting chemical analysis on those samples. Therefore, we intend to implement data analysis that will contribute to the stabilization of fermentation (which is the key to the operation of biogas plants) and demonstrate stable operation through remote management. The results of these analyses and demonstrations will be useful in terms of research on further cost reduction of container-type biogas plants and accumulation of expertise for remote operation and management of these plants.

With the NTT Central Training Center at its core, NTTe-City Labo is a demonstration field where visitors can experience NTT EAST Group's solutions to local issues and where many cutting-edge technologies including the container-type biogas plant are being tested. An open laboratory for private fifth-generation mobile communication systems (5G) and a demonstration greenhouse for cutting-edge agriculture have been established at NTTe-City Labo. The container-type biogas plant installed there is expected to demonstrate effective use of food waste and local energy production for local consumption and showcase a solution for local issues and smart cities (**Fig. 5**).

5. Future initiatives and prospects

Starting with the delivery of the container-type biogas plant to NTT EAST, Biostock began marketing and selling container-type biogas plants that are space-saving, portable, and installable in a short time. We expect that container-type biogas plants will be an effective measure for addressing pressing issues concerning businesses that generate organic waste, such as carbon neutrality, decarbonization, and reduction of waste-disposal cost.

Food-processing factories generally produce one to five tons per day of food waste per factory, and it has been difficult to install a biogas plant inside a factory due to the insufficient amount of food waste to be processed and installation space; in contrast, a container-type biogas plant can be installed on-site at the factory without having to meet those requirements. By completing waste disposal, which was previously outsourced, within the factory, it is possible to reduce waste-disposal costs while improving the food-recycling rate. By collecting a renewable energy source, such factories can promote their contribution to achieving the United Nation's Sustainable Development Goals concerning food.

We also believe that container-type biogas plants can be an effective solution for municipalities struggling with increasing maintenance and operating costs of waste-treatment facilities and sewage-treatment plants. We have heard that many municipalities that separate and collect household food scraps for composting are finding it difficult to continue such operations due to cost burdens. We believe that introducing a container-type biogas plant and shifting to a hybrid process of methanization + composting will drastically improve the balance of payments. It can also be used as a decarbonization initiative in forward-thinking regions to achieve carbon neutrality by 2050.

In its 2021 edition of Annual Report on the Environment, themed "Socioeconomic Redesign toward Carbon Neutrality in 2050," Japan's Ministry of the Environment states that the three transitions, i.e., the transition to a decarbonized society, circular economy, and decentralized society, will be key. The container-type biogas plant is truly a solution that meets the needs of the times in terms of renewable-energy generation, recycling, and decentralization of waste disposal (cutting waste transportation). We will use the above demonstration as an opportunity to expand its use throughout Japan.

Shogo Inoue
Director, Head of Business Development, Biostock CORPORATION.

Development and Implementation of Connected Drones with Agriculture as a Starting Point

Akira Yamasaki, Yuji Sekiguchi, Shinya Suzuka, Susumu Kitagawa, Hodaka Sase, and Yoshito Tsutsumi

Abstract

In February 2021, the drone manufacturer NTT e-Drone Technology was established with a mission to promote the implementation of drones for creating a sustainable society. We, NTT e-Drone Technology, began operations by helping to build a regional hub by promoting the use of drones, starting with agriculture, which is a major industry in rural regions. Our efforts in the agricultural sector are primarily focused on in this article.

Keywords: drone, smart agriculture, IoT

1. Background to establishment of NTT e-Drone Technology

Established in February 2021 as a joint venture by NTT EAST, OPTiM Corporation, and WorldLink & Company Co., Ltd., NTT e-Drone Technology is a manufacturer of drones (**Fig. 1**). All three investors have been involved in smart agriculture for some time, saw the increasing use of drones in various agricultural operations (such as pesticide spraying, fertilizer application, sensing, and seeding) as a business opportunity, and decided to establish NTT e-Drone Technology. In close cooperation with the three investors, NTT e-Drone Technology is aiming for the implementation of drones that contribute to solving social issues, and starting with agriculture, we are engaged in a wide range of businesses from development of drones and contracting of their operation to development of human resources.

Unusually for an NTT Group company, NTT e-Drone Technology has the function of a manufacturer involved in the development of drones. We have been approached by a wide range of clients, from NTT laboratories to operating companies, and received inquiries both internally and externally. Our efforts in the agricultural sector, the theme of the Feature Articles in this issue, are introduced in this article, which are divided into current efforts and initiatives for the future.

2. Current efforts in the agricultural sector

2.1 Agricultural drone AC101

The AC101 2022 model drone, which was designed according to our motto "All for long and safe use," further strengthens the conventional airframe concept of "lightweight," "compact," and "energy-saving" to suit Japanese farm fields and offers a lighter, stronger, and more user-friendly airframe for first-time users (**Fig. 2**). In addition to those features, on the basis of numerous users' voices, such as "It will be problematic for agricultural equipment if parts supply is interrupted in two to three years," we guarantee seven-year support for the first time in Japan, which defies common practice in the drone industry. We also focused on the voices of those who wanted to "eliminate the trouble of recharging the battery" and "spray longer with a single battery charge," and designed the propeller to be made of carbon materials. The synergistic effect of a lighter airframe and user-friendliness

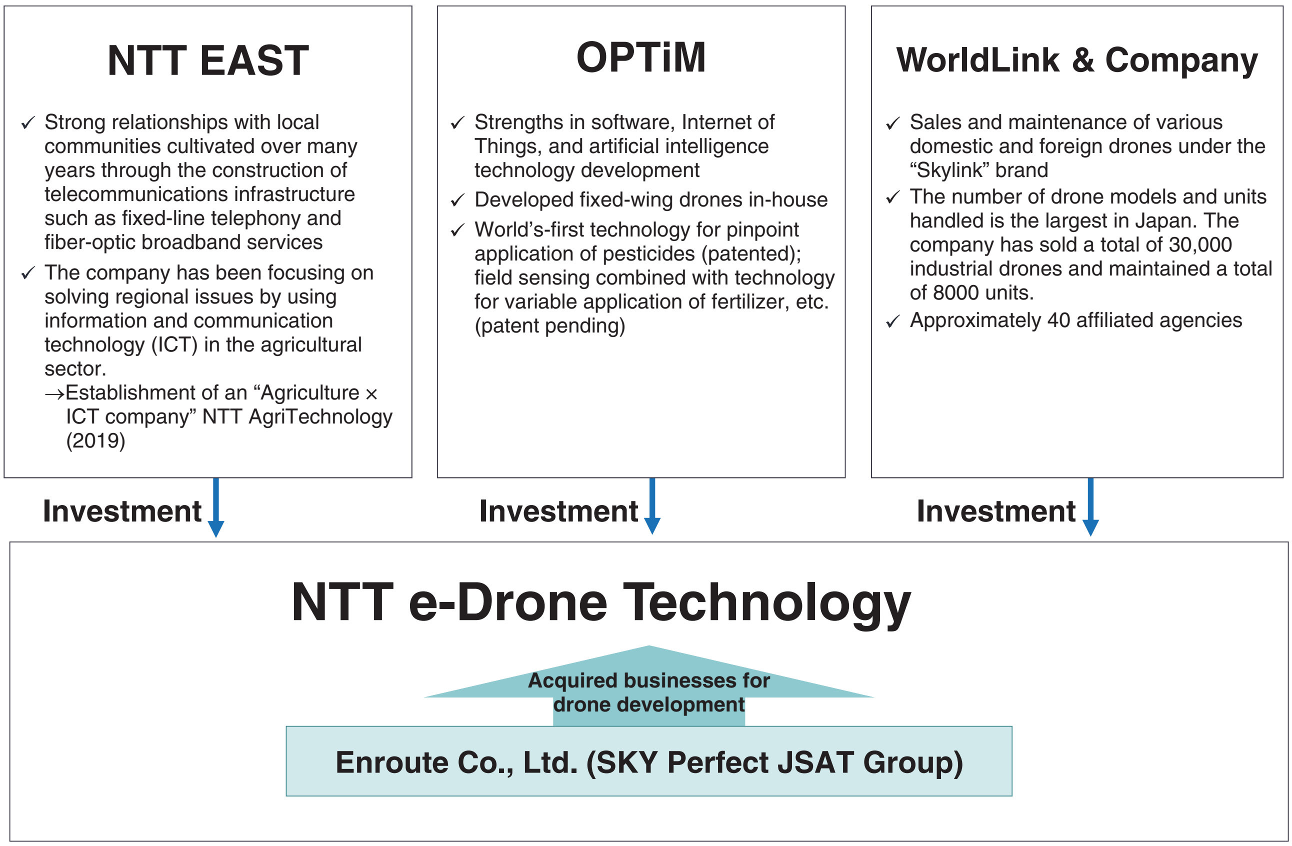

Fig. 1. Overview of NTT e-Drone Technology.

Fig. 2. Agricultural drone AC101.

makes it easier than ever to spray up to 2.5 ha on a single battery charge, even when hovering for slightly longer periods or when spraying over time in irregularly shaped fields.

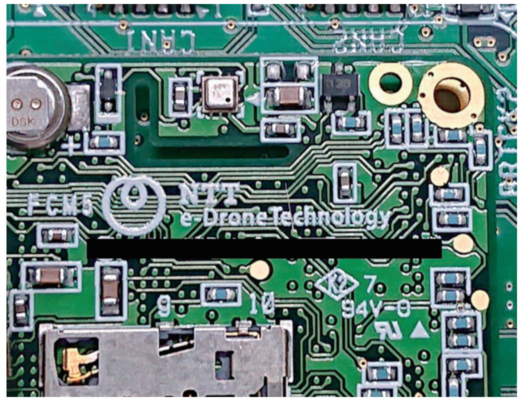

Fig. 3. NTT e-Drone Technology's flight controller (part of the printed circuit board).

2.2 Toward the widespread use of agricultural drone AC101

Since the company was established, we have held more than 100 events, such as demonstrations, and met with more than 2000 farmers, JA (Japan Agricultural Cooperatives) officials, and agricultural policy makers to exchange opinions on the use of drones in agriculture. We have received requests for remote control and fully automated navigation to save manpower and for expanding the range of crops that can be sprayed with pesticides by using drones. Japan's Ministry of Agriculture, Forestry and Fisheries is promoting the expansion of types of pesticides that can be sprayed by drones, and we are actively conducting test spraying and demonstrations with the AC101. Recently, test spraying of cabbage with the AC101 was conducted, which resulted in the purchase of the drone. We are also investigating using drones for pollination of apples. We will continue to promote the further popularization of the AC101 by answering requests from the field.

3. Initiatives for the Future—Development of connected drones and training of human resources

In July 2021, we announced a partnership with Auterion [1]. As a US, Switzerland, and Germany-based company, Auterion provides an open-software platform for drones that enables enterprises and government agencies to easily integrate airframes, payloads, and applications in a manner that meets their specific needs. Through this partnership, we are developing connected drones. These drones enable remote control of drones and real-time transmission of data acquired by drones to remote areas by making it possible for drones and the cloud to be constantly connected via wireless communication, i.e., LTE (Long Term Evolution), fifth-generation mobile communication systems (5G), and private 5G. We are developing connected drones because we believe they should be implemented as agricultural drones and drones for surveying, inspection, disaster countermeasures, and logistics. We have developed a prototype flight controller, a device for controlling a drone, and are developing it for mass production (**Fig. 3**). We are also developing efficient and highly functional applications for cloud computing through joint development with Auterion (**Fig. 4**).

Through the type of development described in this article, NTT e-Drone Technology intends to promote the implementation of drones to contribute to solving social issues. For our efforts in sectors other than agriculture, please check our official website and social media [2–5].

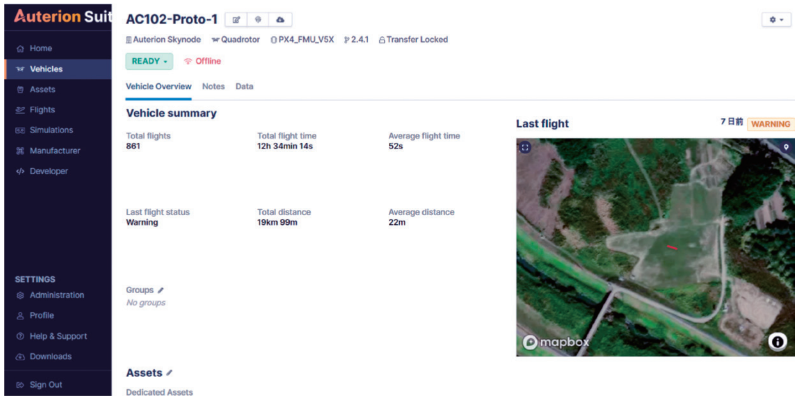

Fig. 4. Screenshot of image taken by drone and stored on the cloud.

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Authors (from left): Susumu Kitagawa; Hodaka Sase; Akira Yamasaki, Representative Director; Yuji Sekiguchi, Executive Officer of R&D Department; Yoshito Tsutsumi; and Shinya Suzuka; NTT e-Drone Technology Corporation

Data-driven Soil Cultivation Promoted by NTT DATA

Tomoo Oozeki and Kazuya Yamane

Abstract

To promote soil cultivation, we at NTT DATA are using information and communication technology to collect soil-diagnosis data and information on farming operations throughout Japan and compile a database of that information. This database will enable data-driven initiatives in the domain that has relied on past experience and intuition of farmers. The data in the database are normalized by conducting soil analysis using a nationally standardized method that makes it possible to understand not only the characteristics of individual fields but also regional characteristics. We have also developed and are testing a technology for measuring soil composition from satellite images as a means of reducing the time and labor required to collect soil samples for soil diagnosis.

Keywords: data-driven, soil cultivation, satellite image analysis

1. Soil cultivation using ICT

Because the amount of compost applied to rice paddies in Japan continues to decline and other issues, degradation of farmland soil has become an issue. Therefore, it is important to strengthen efforts to cultivate soil to improve crop yields by continuously implementing the following cycle: assessing the soil condition through soil diagnosis, planning farming operations in accordance with the assessed soil condition, implementing the planned operations, and verifying the yields. However, soil diagnosis, which should be conducted first, is only applied to certain fields, and farming plans for most fields are prepared according to the experience and intuition of farmers.

In response to this situation, the initiative described in this article used information and communication technology (ICT) to collect and compile a database of soil-diagnosis data and farming-operation information throughout Japan. The collected data can be analyzed by taking regional and crop characteristics into account, so farming operations can be suggested in accordance with the analysis results. Therefore, the use of ICT will enable data-driven initiatives in the domain that has relied on past experience and intuition of farmers.

2. Nationwide data collection and use of the data

When building a database, it is necessary to ensure data reliability. Soil diagnosis, which is a means of understanding the current status of soil cultivation, has been conducted by local soil-analysis laboratories in each region; therefore, analysis items have not been standardized and cannot be normalized by simply collecting data.

To address this issue, NTT DATA, in cooperation with the Japan Soil Association and organizations in 26 prefectures across Japan, established the Soil Diagnosis Database Construction and Promotion Council. As a result of the council's efforts to collect soil data from across the country using a unified method and consolidate soil-analysis laboratories, it is possible to uniformly handle soil-diagnosis data and analysis values across the country. In addition to soil-diagnosis data, information such as soil physical data, field yields, and farm work carried out can be collected as field records in a manner that allows the field conditions to be understood more clearly.

The soil-diagnosis database enables various analyses based on the collected data. For example, when soil diagnosis is conducted for a farm field, the analysis values can be automatically compared with

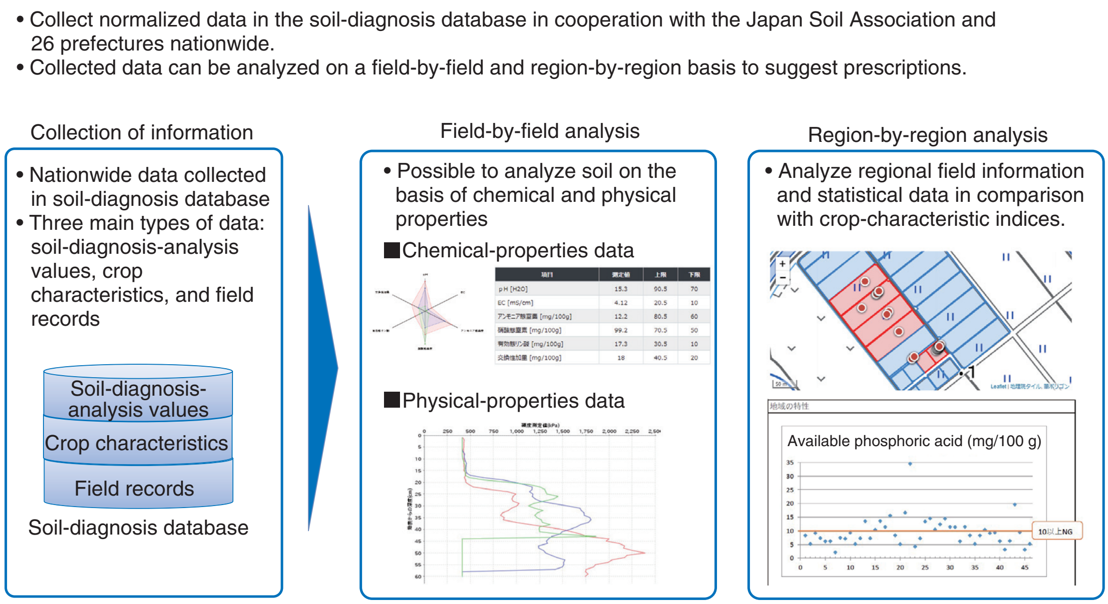


Fig. 1. Soil-diagnosis database.

multiple indices—defined by the council—in accordance with crop type so that issues in the field can be identified without relying on the experience and intuition of the farmer. By analyzing statistical information on regions and crop types, it is possible to (i) determine whether soil conditions are good or bad by taking regional characteristics into account and (ii) understand not only the characteristics of individual fields but also those of the region the regional organization of the council is in charge of. In 2021, we collected soil data from approximately 4000 sites nationwide and returned the results of analysis as prescriptions to the farmers and regional organizations that provided us with the soil data. We will continue promoting this initiative and rolling it out nationwide (**Fig. 1**).

3. Soil diagnosis using satellite images

The first step in soil cultivation is to assess the soil condition through soil diagnosis. This soil diagnosis requires a series of tasks that include collecting soil samples from the field, drying them, and sending them to an analytical laboratory. These tasks are labor-intensive, and during busy seasons, the analytical laboratory may require a long time to conduct the analysis, and the results may not be ready in time for the next planting. Even in our efforts to create data-driven soil cultivation, the large amount of time and effort required for soil diagnosis was problematic, so the number of diagnoses did not increase.

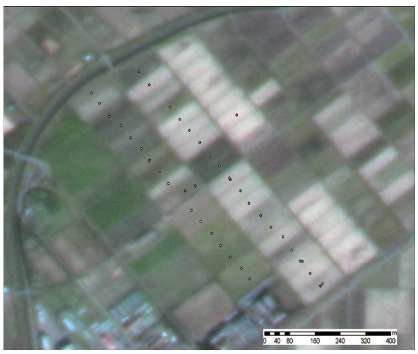
Accordingly, NTT DATA developed a technology for measuring soil composition from satellite images by using satellite-image analysis technology accumulated through the development and sale of the AW3D*. This technology uses satellite images acquired about once every three days, which makes it possible to acquire and analyze images at appropriate times in accordance with the farming conditions in the field. The analysis currently takes about a week for two component values, namely, humus content and inorganic nitrogen, on a 3 m × 3 m mesh. Using this technology makes it possible to easily obtain the composition values for any field in Japan. Because information is acquired over a wide area, intra- and inter-fields bias regarding soil composition can also be analyzed, which makes it possible to optimize fertilizer application in combination with other technologies such as variable fertilizer application. In 2021, we conducted demonstration tests of this technology in three fields in Miyagi and Niigata prefectures, and we hope to contribute to the promotion of

* AW3D: Three-dimensional map data jointly developed and marketed by the Remote Sensing Technology Center of Japan, which has many years of experience in satellite-image processing technology, and NTT DATA, which has high-speed, high-precision data-processing technology.

- Use satellite images to analyze humus content and inorganic-nitrogen values of soil over a wide area.
- Even inter- and intra-field bias regarding soil composition can be analyzed, enabling optimization of fertilizer application in combination with other technologies.

Acquisition of satellite images

- Farmers specify any date.
- Satellite-image acquisition and analysis in about one week



Analysis of satellite images

- Analyze information on a 3 m × 3 m mesh.
- Analyze humus content and inorganic nitrogen.

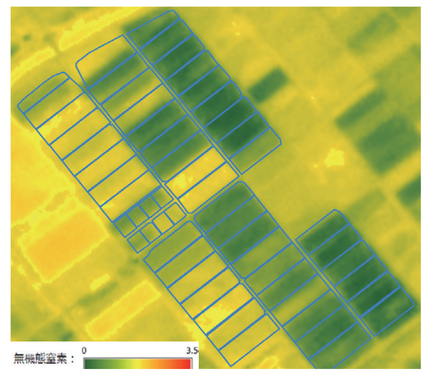


Fig. 2. Soil diagnosis using satellite images.

data-driven soil cultivation as we expand the geographical area in which it is tested (**Fig. 2**).

Authors (from left): Kazuya Yamane, Deputy Manager, Food and Agriculture Business Planning Group, Digital Business Promotion Department, NTT DATA Corporation; and Tomoo Oozeki, Senior Specialist, Food and Agriculture Business Planning Group, Digital Business Promotion Department, NTT DATA Corporation

Selling Agricultural Products to Consumers Online through Marchel by goo

Hiroshi Terasaki and Tatsuya Kusumi

Abstract

NTT Resonant offers a consumer-to-consumer online marketplace called *Marchel by goo*. This article explains recent trends in the creator economy and in domestic and international e-commerce services and introduces Marchel by goo with a focus on agricultural products. The actual voices of those involved in agriculture, the technical issues involved in operating the service, and its future prospects are described.

Keywords: consumer-to-consumer service, creator economy, e-commerce service trend

1. Marchel by goo

Marchel by goo is a service that offers a consumer-to-consumer online marketplace (**Fig. 1**). In contrast to other services that enable users to buy and sell used and new products, it values the process of creating a product, that is, the "story behind the product." Using Marchel by goo, sellers can post stories related to products by linking with various social-networking services (SNSs) such as blogs, Twitter, Instagram, YouTube, and TikTok. It can also be easily connected to *goo blog*, a blog service operated by NTT Resonant, allowing sellers to (i) select goo-blog articles that describe sellers' thoughts on products when they list products on Marchel by goo for sale and (ii) display the product being listed on Marchel by goo in the goo-blog article (**Fig. 2**). Sellers using goo blog are also able to send information to fans (readers) through blog articles. In addition, goo blog is a service that is visited by 28 million unique users each month, so Marchel by goo has the advantage of providing exposure of sellers to those users.

Believing that our service enables narrative branding by telling the story behind the product, rather than simply selling the product, we introduce this service to potential sellers by picturing it as similar to crowdfunding. With this perspective, we are currently focusing our efforts on the following areas: (i) industry-academia collaboration in cooperation with creators of fine arts to support students who have lost the opportunity to present their work during the COVID-19 pandemic, (ii) collaboration with traditional craftspeople who are finding it difficult to sell their work in physical stores, and (iii) collaboration with people in agriculture, which is what we focus on for the remainder of this article. We are jointly operating web pages dedicated to each organization and school we collaborate with to introduce the creators and promote sales.

Marchel by goo has been in service for two years, and we have seen a significant difference between sellers who blog and those who do not in terms of product sales and repeat purchases. For customers (buyers), purchasing a product from a creator they are completely unfamiliar with is considered a very high psychological hurdle. It became clear that getting to know a person (creator) through blogs and other SNSs tends to lead to purchases. We believe this tendency also holds in the creator economy, which is currently growing.

2. Creator economy

The term *creator economy* started to come into use

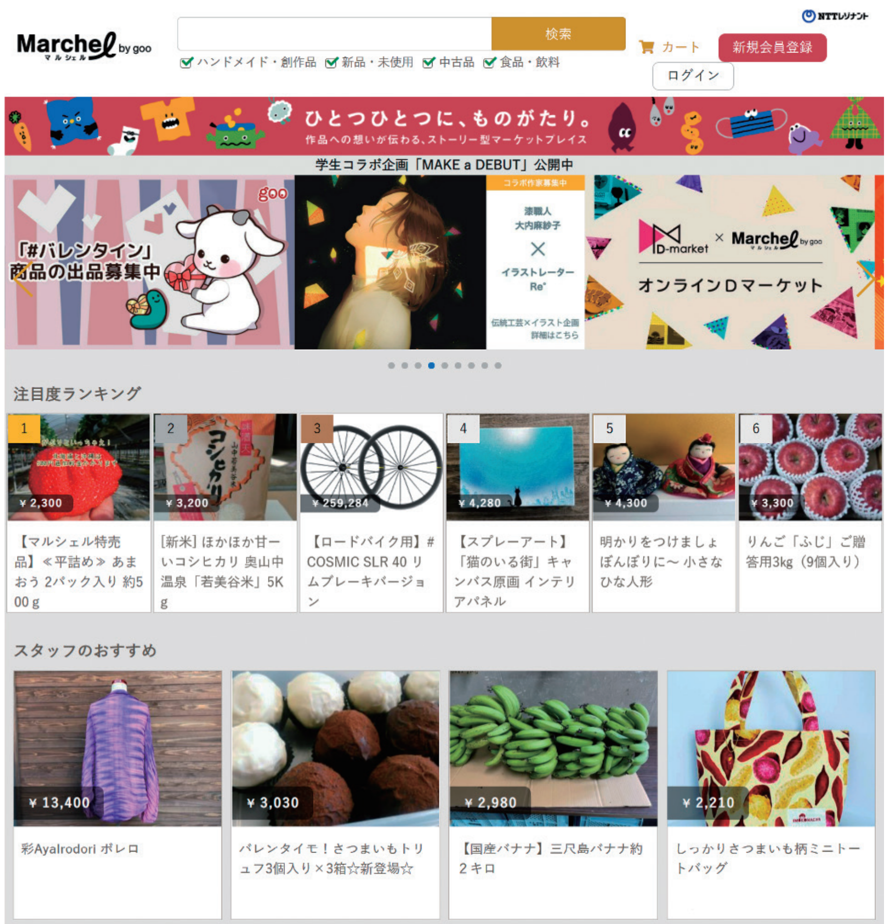


Fig. 1. Home page of Marchel by goo.

in the latter half of 2020. It is defined as an economic zone formed by individual actions and dissemination of information. Over the last few years, many words such as "diversity" and "side business" have been heard, and people have more diverse ways to earn personal income than before. YouTubers, gifting, video-game live streaming, online salons (private chat rooms), and other forms of income that were unthinkable a few years ago are now available. In addition to those forms, with the advent of non-fungible tokens (NFTs), the means of earning income can now easily cross the border and/or currency barrier through crypto assets. We believe the market for NFTs will grow as items that enable people to establish an identity in the illustration, music, and metaverse domains; however, we do not believe NFTs are something that will be sold as soon as exhibited. As mentioned earlier, self-promotion and self-branding is necessary. Nevertheless, it is easier than ever before to acquire fans and disseminate information through SNSs. Facebook and Instagram announced that they will invest a total of US$1 billion to support creators in 2022. For creators, the number of ways to earn rewards will continue to increase, and this trend will probably become more popular in Japan.

3. Collaboration with farmers

Considering farmers as creators, Marchel by goo is strengthening sales of agricultural products. Originally, articles by people involved in agriculture published on the goo blog had a powerful story to tell about their crops, so they were a good match for connecting with Marchel by goo. As we spoke with farmers, we realized that much room for development and improvement still exists in regard to sales of agricultural products.

We are currently working with the Ministry of

Fig. 2. Linkage of Marchel by goo with other services.

Agriculture, Forestry and Fisheries on its project to support female farmers, farmers in Niigata Prefecture, and certified professionals for promoting the sixth industrialization in the food and agriculture sector ("Food Pro."). Food Pro. is a group of experts involved in production (primary industry), processing (secondary industry), and distribution, sales, and services (tertiary industry). Together with small- and medium-enterprise management consultants, university professors, small and medium organizations, public officials, and people who want to promote local revitalization, we intend to implement nationwide distribution of agricultural products and support for farmers through Marchel by goo. We feel that it is essential to have the help of experts for new farmers and others who do not know how to sell their crops or who are not ready to take the first step into online sales.

3.1 Challenges identified while operating Marchel by goo with farmers

We had many opportunities to interview farmers about Marchel by goo and were able to identify certain challenges of handling agricultural products for online sales via any service (not just Marchel by goo).

(1) Problems with delivery

Due to higher delivery costs, inexpensive vegetables sold via Marchel by goo are priced higher than those sold in nearby supermarkets. This delivery-cost problem is not easy to solve; however, solving high delivery costs in a limited area could provide a significant competitive advantage. During our investigation, we found that there are many online-sales services that do not target the entire country but focus on certain parts of the country.

Another solution is to sell more expensive vegetables that are hard for the consumer to find nearby instead of selling inexpensive products. Crops produced by organic farming are often sold through direct-to-consumer distribution. Although the area devoted to organic farming is currently small in Japan compared with other countries, it has been reported that many consumers are willing to purchase organic food even at a slightly higher price because a certain level of added value is recognized by them. We believe the organic food market will expand further in the future.

Delivery slips can be converted to data and printed by those who are information-technology literate; however, many sellers are unfamiliar with the process, leading to problems due to errors while writing slips. To address this issue, some of our competitors established a system that allowed them to provide support to sellers locally. Another issue is the high hurdle to integrate delivery slips with major delivery companies via an application programming interface (API), which requires several thousand transactions per month.

In response to the above issues, Marchel by goo provides a mechanism for farmers to write about their commitment to their products in their blogs so that customers (buyers) can appreciate the high value of those products even if they are a little expensive. Therefore, the customers can empathize with the passion of the farmers and purchase the products. We are also striving to address the issue regarding delivery slips in consultation with a startup company.

(2) Number of orders and inventory control

Marchel by goo handles many small orders; however, many farmers want to sell their produce in large quantities. If a system to meet this demand was implemented, such as taking large orders and delivering them to each household, it would be worth the challenge since it would help solve the problem of high delivery costs.

(3) Self-branding

It seems that customers who buy vegetables from Marchel by goo tend to be more concerned with who they buy from than what they buy. In other words, rather than simply buying agricultural products, they also feel a sense of support for the farmers. Information disseminated by farmers is interesting and often includes content that leads to interesting education about food, such as advance preparations for growing crops, the growth process, and stories of hardship such as "Wild animals ate my vegetables!"

4. How to expand Marchel by goo on the technical side

4.1 Means of guiding customers to products they want

When a customer searches for a product on the web, if the product has a well-defined name (a proper noun), the customer can discover new or used products that match their purpose and budget through various e-commerce services that appear in their search results and can then proceed to purchase those products. On the contrary, products created by creators are difficult to categorize, since both the product name and its introduction are given in free-text. This situation makes it highly unlikely that a web search will lead to a product. Accordingly, we believe that rather than relying on web searches, it is more important to build so-called social currency, which helps people find products via word-of-mouth on SNSs, blogs, etc. and generates word-of-mouth by bringing creators and fans closer together.

It is also important to create a mechanism for visitors to Marchel by goo to become return customers. For example, a function that quantifies qualitative preferences and recommends products that co-occur with or deviate slightly from those preferences would lead to new purchases. We believe that we need a different method of making those recommendations from that used by a typical e-commerce service.

4.2 Cart abandonment and diversifying payment methods

For any e-commerce service, it is a common problem that customers put a product in their shopping carts but end up not purchasing it (so-called cart abandonment). One possible reason for this outcome is the time and effort required for settlement. Many e-commerce services accept payment by credit card. However, many more people than expected do not have a credit card; in fact, Marchel by goo has received many inquiries from such people. In response to this problem, a method of payment called "buy now pay later" (BNPL) is becoming popular in countries other than Japan. BNPL allows customers to pay for a product later at convenience stores, banks, etc. after they receive the product without the need to enter credit-card information at the time of purchase. Rather than fine-tuning the user interface (UI) to address the problem of cart abandonment, accepting BNPL will greatly improve the percentage of customers who reach the point of purchase as well as giving younger people an opportunity to purchase products. This type of post-payment settlement is also gradually spreading in Japan.

4.3 Touchpoints and work load of development

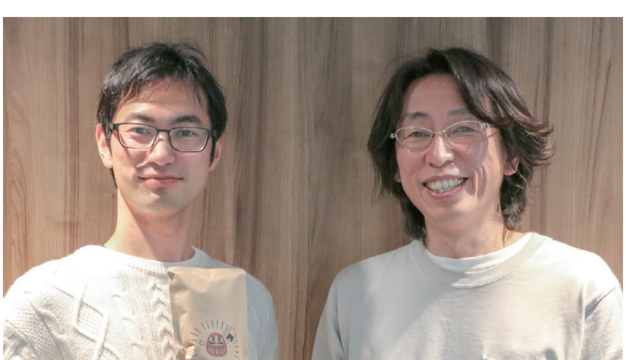
E-commerce services can be roughly divided into two parts: the front end, which includes product listings and product details, and the back end, which includes managing inventories, customers, and orders and processing payments. Marchel by goo operates both ends using a proprietary system, so it takes a long test period when part of the service is modified. For example, adding a new coupon function would require a major modification of the system that would involve modifying the entire system. The advantage of connecting the UI and back end with an API is that even if various smart devices or SNSs (in addition to personal computers and smartphones) are set up in the front end, as long as they are connected with an API, the back end will not require major changes.

Such an arrangement called *headless commerce* can greatly reduce development costs. It also provides peace of mind that the back-end system can be left to the experts. Although Amazon, Shopify, and others offer this arrangement, its initial implementation cost is still too high.

5. Future service expansion and concluding remarks

In addition to selling agricultural and processed products, Marchel by goo will start handling alcoholic beverages in 2022. We also plan to collaborate with illustrators, and we will promote business schemes for printing services, custom-made product sales, and collaborations with other companies. Considering recent trends, we believe that we need to catch up with the handling of digital content.

To generate a large number of transactions, we will continue to attract exhibitors and strengthen activities for increasing sales. We will also promote the provision of user experience that values the perspective of our service described at the beginning of this article. What is important to us is that our customers feel the value of purchasing products through Marchel by goo on the basis of "buying how" rather than "buying what" and "experiencing services" rather than "purchasing goods."



Authors (from left): Tatsuya Kusumi, Subsection Chief, NTT Resonant Incorporated; and Hiroshi Terasaki, Project Manager, NTT Resonant Incorporated

How ICT Contributes to Carbon Neutrality

Xiaoxi Zhang, Machiko Shinozuka, and Minako Hara

Abstract

To achieve carbon neutrality, we need to reduce greenhouse gas (GHG) emissions to net-zero at the global level by the middle of the 21st century. In September 2021, the NTT Group announced the new environmental and energy vision "NTT Green Innovation toward 2040," which formulates that the NTT Group will not only aim for carbon neutrality in 2040 but also contribute to reducing the environmental impact of society by simultaneously expanding the adoption of Innovative Optical and Wireless Network (IOWN) technologies and new information and communication technology (ICT) services. ICT can potentially contribute to reducing environmental impact in many sectors through optimizing production and consumption activities, improving energy efficiency, reducing the movement of people and goods, and so on. Therefore, ICT is expected to help us achieve a carbon neutral society. This article introduces our estimation model for analyzing the potential contribution of ICT usage to future environmental load reduction and economic growth. By covering the targeted 36 ICT services that are widely used or will spread in the near future in Japan, including those provided by NTT, this model will quantitatively analyze the environmental and economic impact of introducing these ICT services by 2030.

Keywords: ICT, carbon neutrality, GHG

1. Introduction

The impact associated with the progress of climate change has become more serious. The Paris Agreement, adopted in 2015, showed that the goal is to limit global warming to well below 2ºC, preferably to 1.5ºC, compared with pre-industrial levels [1]. The Special Report "Global Warming of 1.5ºC" and the IPCC Sixth Assessment Report published by the Intergovernmental Panel on Climate Change (IPCC) then indicated the importance of keeping the temperature rise at or below 1.5ºC to avoid significant risks [2, 3]. To achieve the 1.5ºC target, we need to reduce greenhouse gas (GHG) emissions to net-zero at the global level by the middle of the 21st century. Many countries set their GHG-emission reduction targets toward carbon neutrality in 2021.

In response to this situation, many companies have announced their ambitious GHG-emission reduction targets, and various climate-change measures are being taken to achieve them. The NTT Group announced the new environmental and energy vision "NTT Green Innovation toward 2040" in September 2021 [4]. Toward societal well-being, the NTT Group aims to increase its corporate value through environmental, social, and governance (ESG) initiatives and simultaneously achieve the conflicting objectives of zero environmental impact and economic growth by "Reduction of Environmental Impact through Business Activities" and "Creation of Breakthrough Innovation." The new environmental and energy vision formulates that the NTT Group will aim for carbon neutrality by 2040 and contribute to reducing the environmental impact of society by simultaneously expanding the adoption of Innovative Optical and Wireless Network (IOWN) technologies and new information and communication technology (ICT) services.

Although ICT use causes environmental load in its own sector (e.g., electricity consumption of ICT equipment), ICT can potentially contribute to reducing environmental impact in other sectors through optimizing production and consumption activities, improving energy efficiency, reducing the movement of people and goods, and so on [5, 6]. ICT is expected to contribute to achieving carbon neutrality by further reducing its energy consumption and reducing the environmental impact of society as a whole. This article introduces our estimation model for analyzing future environmental and economic impact of ICT usage. By covering the targeted 36 ICT services that are widely used or will spread in the near future in Japan, including those provided by NTT, this model will quantitatively analyze the environmental and economic impact of introducing these ICT services by 2030.

2. Estimation model

2.1 Previous studies and issues

Berkhout and Hertin recognized that the relationship between ICT and environmental impact is 'complex, interdependent, deeply uncertain, and scale-dependent' [7]. Several methods have been proposed for assessing the positive and/or negative environmental effects of ICT use [8–11]. For a single ICT service from a bottom-up approach, Recommendation L.1410 published by the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) proposed a method for the environmental lifecycle assessment (LCA) of ICT goods, networks, and services [9]. The method can identify the key factors driving carbon dioxide (CO_2) emissions from each life stage of ICT use. Since it requires a large amount of detailed micro-level data, it is more suitable for specifically analyzing individual ICT. However, it is difficult to determine the overall effects at a country level or for future forecasts. Bieser and Hilty used a macro-method based on 12 ICT use cases (such as e-health) [12]. They estimated the level of ICT adoption and the impact on GHG emissions of ICT adoption in each use case and compared them with a baseline. Hilty reviewed studies for more complex effects of ICT use, such as rebound effects and spillover effects, across industries [13]. With the above methods, however, it is difficult to determine the overall impact, especially when considering future impact.

To determine the overall impact at the macro-level, including complex effects, computable general equilibrium (CGE) analysis as a top-down approach is more suitable than the above bottom-up approach. However, few studies have analyzed the environmental effects of ICT usage from this approach, due to the complexity of expressing and assessing the effects of ICT introduction in the CGE model and the large amount of actual effect data required. We combined a bottom-up approach, which is mainly based on the LCA method, and a top-down approach, i.e., CGE analysis, and developed a dynamic CGE model to forecast macroeconomic and environmental impact [5]. The method has also been consented as ITU-T Recommendation L.1451 [10].

2.2 Estimation model

A CGE model replicates the input-output (IO) tables in a given region as a set of simultaneous equations and usually covers all goods and industry sectors in the evaluated region. Our CGE model is based on the AIM/CGE [Japan] of the Asia-Pacific Integrated Model [14]. Our CGE model is disaggregated into 49 sectors and 43 commodities on the basis of the IO table in 2005 [15]. Sectors are listed along the horizontal axis in Fig. 3, and equations used in our model are those from Masui [14]. **Figure 1** shows the structure of our CGE model. The final-demand sector (households) holds the production factors of capital and labor, which are provided to the production sector in exchange for income. The income received is used to purchase consumer goods or saved; thus, households maximize their utility in purchasing consumer goods, and savings are converted into capital in the next year. The production sector (enterprises) uses production factors (labor and capital) and intermediate inputs (e.g., energy and raw materials) to produce products and supply them to the market. Enterprises conduct production activities to maximize their profits on the basis of their production technologies. The supply and demand for goods and production factors are balanced in the market, and the price mechanism determines the levels of activity and value of goods, services, and production factors. Production efficiency in the production sector and consumption efficiency in the final-demand sector are expected to improve when ICT services are used in the production and final-demand sectors.

Figure 2 shows the process of capital accumulation and production in the model. The equilibrium calculation starts from 2005. The capital stock in 2006 depends on depreciation of existing capital and investment from 2005 and determines efficiency levels in 2006. Equilibrium for the current year is then calculated on the basis of the prepared efficiency levels, and the model runs year by year in this manner. New capital can be introduced in any sector but cannot be changed once introduced. Allocation of

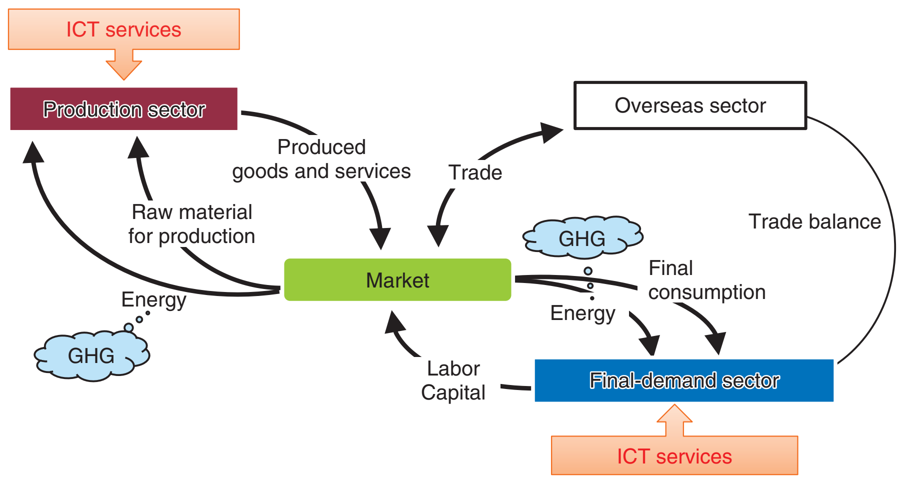


Fig. 1.   Structure of CGE model.

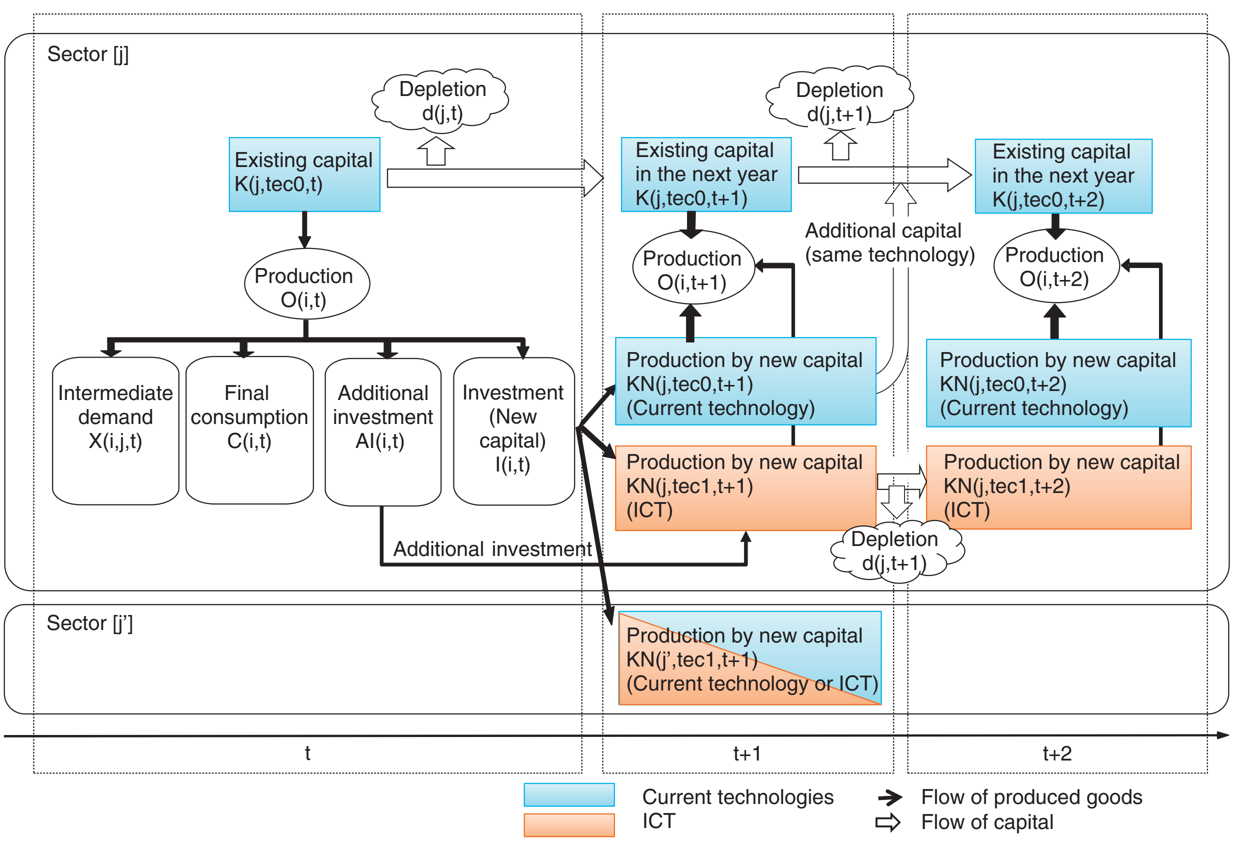


Fig. 2.   Process of capital accumulation in this model.

new capital is endogenously determined to achieve the maximum profit in the equilibrium calculation. Preconditions, such as future population change, expected economic growth rate, and share of power-generation technology, are set as given. In this model, by allocating the new production investment with

Table 1. Targeted ICT services, direct effects expected by ICT use, and future scenario for ICT services.

Industry category	ICT services	Effect expected by ICT use	2030 scenarios		
			Index of penetration	Baseline (keep in 2015 level)	ICT accelerated
(A) Finance	Online banking	Reduction in transportation use; reduction of branch banks	Internet banking accounts	82.09 million	146.46 million
	Cashless settlement	Cost reduction in management of store business; cost reduction in operation and management of automated teller machines (ATMs)	Utilization rate	0%	50%
(B) Public service	Electronic bidding	Reduction in transportation use	E-biddings	83,000	960,000
(C) Manufacturing	Supply-chain management	Suppression of overproduction; optimization of intermediate distribution and retail sales; reduction in factory and storage space	Utilization rate	40.00%	54.00%
	IoT technology for manufacture	Productivity improvement by visual control in production line; reduction of lead time	Utilization rate	0%	50%
	AI technology for manufacture	Productivity improvement by using machines to set up or inspect equipment instead of skilled technician; improvement in operation rate; prevention of human error	Utilization rate	0%	50%
(D) Distribution and services	Business-to-consumer e-commerce (EC)	Optimization of intermediate distribution and retail sales; increase in inventory space at net-retailers and goods distributed by parcel delivery; suppression of overproduction; reduction in volume of returned goods	EC rate	5.79%	12.20%
	AI technology for unmanned store	Labor saving by unmanned operation in store	Utilization rate	0%	10%
	AI technology for distribution	Productivity improvement in physical distribution	Utilization rate	0%	50%
(E) Medicine, Agriculture	Electronic prescription and medicine notebook	Reduction in paper use	Utilization rate	0%	50%
	Smart agriculture	Improvement of efficiency on farm work by visual control based on sensor data; labor saving by introduction of robots	Utilization rate	0%	50%
(F) Infrastructure	AI technology for electricity demand forecast	Improvement of generating efficiency by advanced electric power demand forecast	Utilization rate	0%	50%
(M) Common to many sectors	Teleworking	Reduction of transportation use; reduction of office use	Percentage of teleworkers	14.70%	34.00%

ICT services, new ICT services will be possible. New capital to provide ICT services will be allocated year by year. Expansion on the share of new capital to provide ICT services expresses the spread of such services.

2.3 Target ICT services and future scenarios

2.3.1 Evaluation of target ICT services and direct effects expected from ICT use

Thirty-six ICT services in six industry categories are covered in this estimation. **Table 1** shows representative ICT services in each industry category. ICT services that are commonly used, such as teleworking and online shopping, have relatively high penetration rates [16]. Even though newer ICT services, such as artificial intelligence (AI) and Internet of Things (IoT), have lower penetration rates than the older ICT services, they have started to be used in some industries such as manufacturing and distribution and services. Thus, their effects on GHG-emission reduction are expected to be great in the near future.

The direct effects expected from the use of these ICTs are surveyed using statistical data, forecast reports for future ICT, and use cases that have been introduced in factories or banking [17, 18]. The values of direct effects are estimated by the total amount of evaluated activity and amount reduced by ICT use. These effects are then fed back to the intermediate input coefficients of the CGE model.

2.3.2 Future ICT scenarios

Two scenarios until 2030 are presented to evaluate the impact of using ICT services: baseline scenario and ICT-accelerated scenario. For both scenarios, input data between 2005 and 2015 are set to be the same and are based on statistical data. From 2016, basic preconditions until 2030 (such as population changes and expected gross domestic product (GDP) growth rate) are set to be the same and based on Japan's Intended Nationally Determined Contributions [19].

To clarify the effectiveness of the treated ICT services, in the baseline scenario, all technology levels on energy efficiency from 2016 to 2030 are assumed fixed at their 2015 levels. In the ICT-accelerated scenario, future penetration rates of the most widely used ICT services are estimated to grow by linear approximation on the basis of past statistical data [e.g., 16], since linear approximation could best approximate the past data for them. Newer ICT services are boldly assumed to spread to high levels in our model, since penetration rates of most of these ICT services have not yet been predicted, and the purpose of this article is to show the potential impact of ICT use. For most of these new services, utilization rates are assumed to be up to 50%. Additionally, the spread of AI technology for distribution is not a strong prospect since it strongly depends on automated driving. The final three columns in Table 1 list the details of the future scenarios for the targeted ICT services. Investment values to the ICT sector between 2005 and 2020, such as equipment investment or software development, are from a market survey report on the ICT-related market [20], and the values until 2030 are estimated by linear approximation on the basis of the existing data.

2.4 Power consumption in ICT sector

To support these future ICT services, a large amount of ICT equipment will be needed such as sensors for collecting the data, edge computers, data servers, and fifth-generation mobile network equipment. Thus, the increase in power consumption by ICT equipment is a serious concern. We also investigated and analyzed power-consumption trends of ICT equipment use in the ICT sector in Japan up to 2030 on the basis of data between 2008 and 2018 and related reports on ICT-market forecasts [e.g., 21]. The ICT sector includes fixed/mobile networks, datacenters, and end-user devices. To determine the power-consumption trends of the ICT sector, we attempted to estimate the total power consumption of ICT equipment until 2030 by estimating the changes in the number of each type of ICT equipment and changes in the power consumption per unit of each type of equipment and multiplied the two values. The numbers of each type of ICT equipment are estimated to grow by linear approximation on the basis of past statistical data [21]. Regarding changes in the power consumption of various ICT equipment, since it is difficult to determine all details of all types of equipment, we investigated the relationship between the power consumption of ICT equipment and number of operating units, represented by servers. The results indicate that the power consumption per operating number of server devices was almost flat [22]. This is considered due to the fluctuation being offset by certain main factors such as the recent increase in the amount of communication traffic, improvement in the information-processing capacity of ICT equipment, and improvement in the energy-saving performance of equipment. On the basis of the results, three cases are assumed when estimating the power consumption in the ICT sector up to 2030. The power consumption per unit of ICT equipment is assumed to (1) remain unchanged, (2) be + 1%/year, and (3) be + 2%/year. By multiplying each case by the number of operating units of various ICT devices, the power consumption in the ICT sector by 2030 can be estimated. In accordance with the estimation results, the electricity consumption in the ICT sector in 2030 was estimated to be about 1.2 to 1.5 times higher than in 2020. In the CGE model calculation, the upper limit of 1.5 times is adopted, and the power consumption increase in the ICT sector is expressed as service demands for ICT in non-ICT sectors.

3. Estimation results and discussion

Compared with the baseline scenario, the results in the ICT-accelerated scenario showed a 1.3% increase in total GDP and 4.7% decrease in GHG emissions in 2030, which indicate the possibility of a decoupling of economic growth and environmental impact. The main reason is considered to be that electricity consumption in the ICT sector only accounts for a few percent of Japan's electricity consumption, and the increase in electricity consumption in the ICT sector was offset by the decrease in intermediate input in

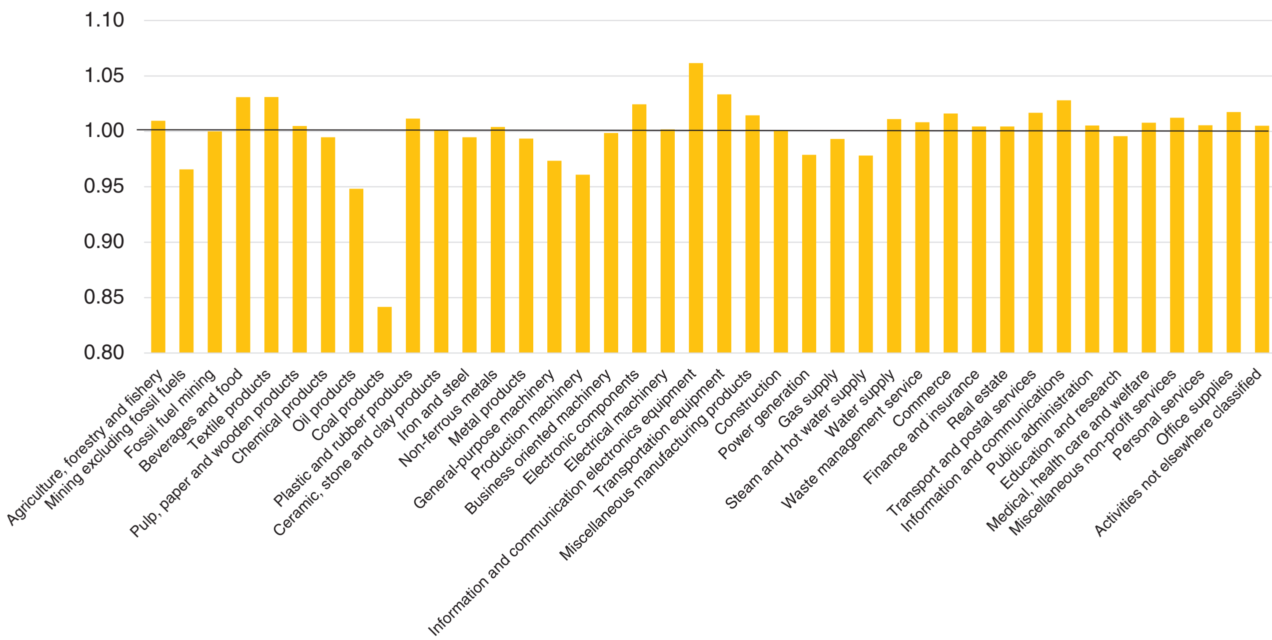


Fig. 3. Production amounts by sector in ICT-accelerated scenario in 2030 (value in the baseline in 2030 = 1).

other sectors due to the introduction of ICT.

Figure 3 shows the details of the production value by sector. In addition to the increase in the production value of information and communication equipment and the information and communication sector, the production value of many service sectors will also increase slightly. The reason is thought to be that the reduction in labor input by introducing ICT services such as AI improved production efficiency. Due to the increase in total GDP, household income and the production value of the beverage and food sector, which is directly linked to final consumption, also increased. There was also a decrease in the production value in the mining industry and sectors such as petroleum, coal, and production machinery. The GHG emissions by sector (**Fig. 4**) will decrease in the majority of sectors. It was found that the decrease in the demand of petroleum, coal, steel, and non-ferrous metals, and the transportation sector was significant due to the improvement in production efficiency and reduction in the movement of people and goods through the introduction of ICT. The above-mentioned tendency is also clear from **Fig. 5**, which shows the production amounts and GHG-emission change rate in the ICT-accelerated scenario compared with those in the baseline scenario by sector. The most promising is the lower right quadrant, where GHG emissions decrease as production value increases. However, as shown in the lower left quadrant, reducing the dependence on the coal and oil industries is also important for the future conversion to a decarbonization society.

The purpose of this type of scenario analysis is to show potential future scenarios rather than correctly predicting the future and present ways to move toward a more desirable future. In that sense, more scenario settings may need to be studied by taking into account the above concerns.

4. Conclusion

We developed a dynamic CGE model to analyze the future environmental and economic impact until 2030 brought about by popularization of 36 ICT services, considering both positive GHG reduction effects of ICT use in non-ICT sectors and GHG emissions caused by ICT equipment's operation in the ICT sector.

The model results indicate that besides the development of ICT-related sectors, the spread of ICT services, especially certain AI-based services, can improve productivity through labor-saving and better matching of supply and demand and contribute to increasing overall GDP. The results also indicate that GHG emissions will not increase, since the power consumption of ICT services is a relatively small part of overall power consumption, and the increase in

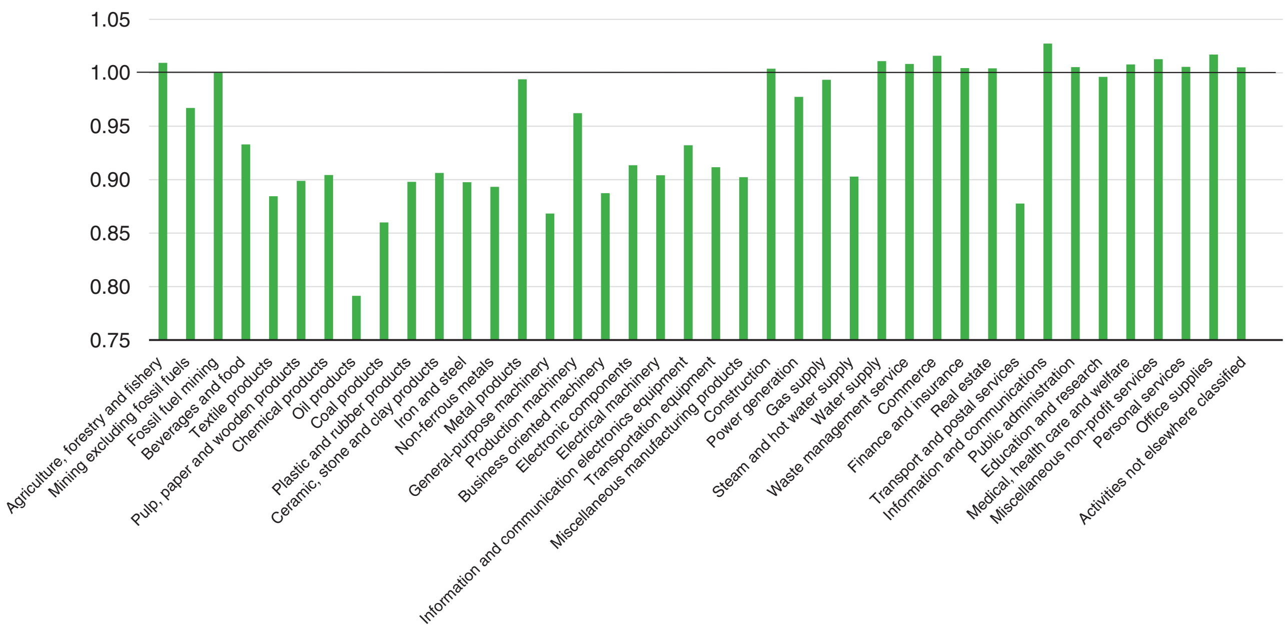


Fig. 4. GHG emissions by sector in ICT-accelerated scenario in 2030 (value in the baseline in 2030 = 1).

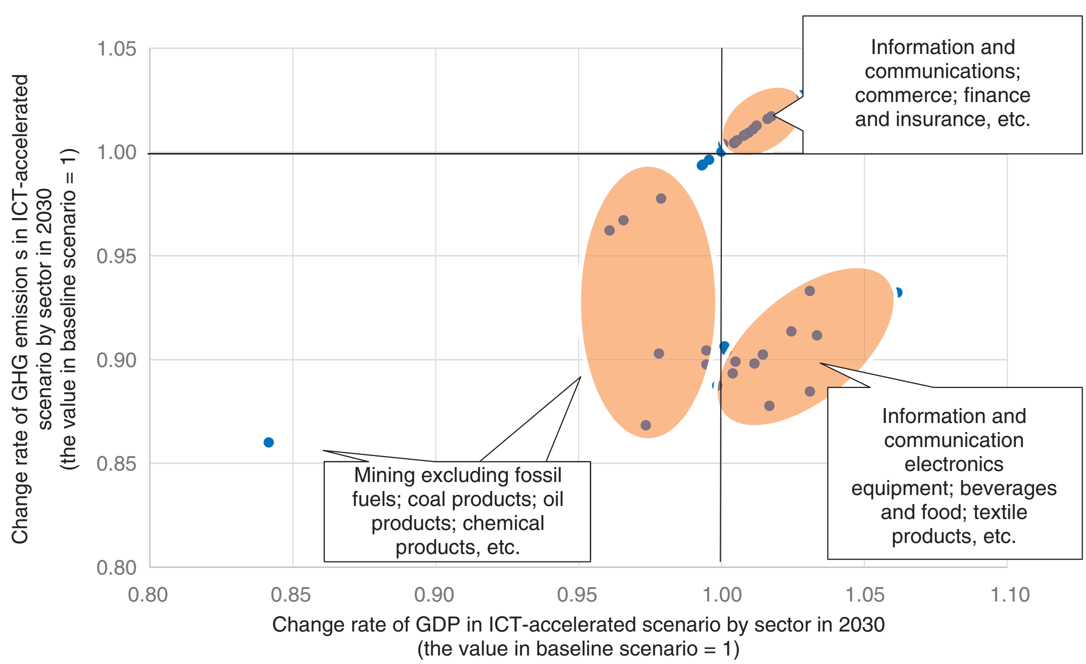


Fig. 5. Change rate of production amounts and GHG emissions by sector in ICT-accelerated scenario in 2030 compared with those in baseline scenario.

service demand for ICT may affect other inputs and offset them. Efficiency of logistics and manufacturing can greatly reduce the input of oil and coal products, thus drastically reducing GHG emissions. In 2030, compared with the baseline scenario, at least 1% additional GDP growth and 4% GHG-emission reduction can be expected by introducing targeted ICT in the ICT-accelerated scenario, which also means the feasibility of decoupling the economic and environmental effects of ICT use.

Due to the COVID-19 pandemic, the world is changing significantly and will continue to do so. The pandemic has triggered a major advance in ICT throughout the world. In Japan, "Remote World" supported by various digital technologies including IOWN, a new concept proposed by the NTT Group, is expected to lead us towards a lower-carbon society.

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Xiaoxi Zhang

Senior Research Engineer, ESG Management Science Group, Resilient Environmental Adaptation Research Project, NTT Space Environment and Energy Laboratories.

She received a B.S. and M.S. in social engineering from Tokyo Institute of Technology in 2007 and 2009. Since joining NTT in 2009, she has been engaged in research on risk-based management of telecommunication infrastructures and assessment of environmental impact of ICT use. She currently specializes in environmental and social future prediction simulations. She is a member of the Institute of Electronics, and Communication Engineers (IEICE) of Japan.

Machiko Shinozuka

Research Engineer, ESG Management Science Group, Resilient Environmental Adaptation Research Project, NTT Space Environment and Energy Laboratories.

She received a B.S. and M.S. in medical engineering from Keio University, Kanagawa, in 2013 and 2015. Since joining NTT in 2015, she has been engaged in research on assessment of the environmental impact of ICT use. She currently specializes in environmental and social future prediction simulations in terms of lifestyle. She is a member of IEICE.

Minako Hara

Group Leader, ESG Management Science Group, Resilient Environmental Adaptation Research Project, NTT Space Environment and Energy Laboratories.

She received an M.E. and Ph.D. in applied chemistry from the University of Tokyo. She joined NTT Energy and Environment Systems Laboratories in 2006 and studied environmental assessment and international standardization activities. She transferred to NTT WEST in 2016 and engaged in the formulation of the NTT WEST Group's environmental management strategy. She transferred to NTT Space Environment and Energy Laboratories in 2020 and later became a group leader. She is a member of the Society of Environmental Science, Japan and the Society for Environmental Economics and Policy Studies.

Optical Network Technology for Future Ultra-high-capacity Communications in the Beyond 5G and Big Data Era

Makoto Murakami

Abstract

The optical network is key to the ultra-high-capacity and highly reliable communications infrastructure for addressing the demand of rapidly increasing traffic and diversified services, which will be manifested with further development of 5G (fifth-generation) and beyond mobile communication services and applications including Internet of things, high-definition video, big-data analysis, and artificial intelligence. This article gives an overview and recent trends in standardization of optical network technology, mainly focusing on the ITU-T (International Telecommunication Union, Telecommunication Standardization Sector) Study Group 15.

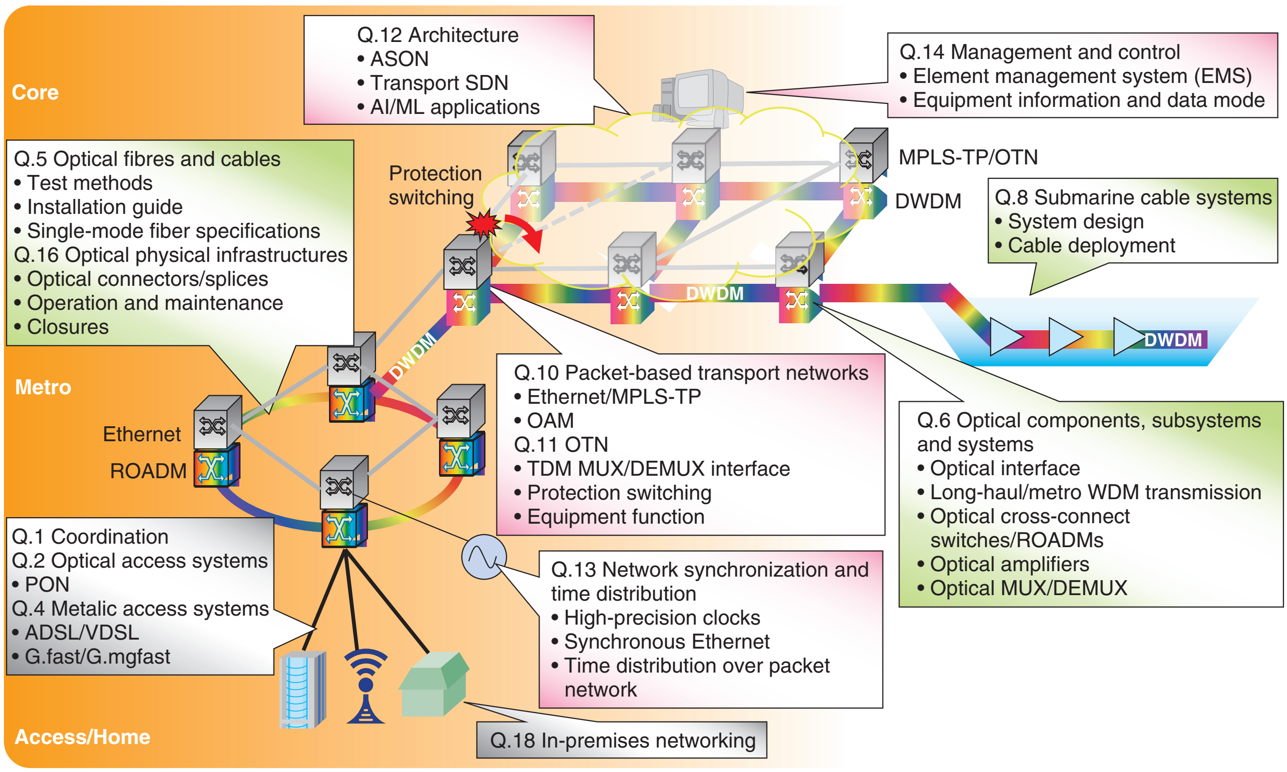
Keywords: optical network, standardization, ITU-T

1. Overview of standardization of optical network technology

The International Telecommunication Union (ITU) is one of the organizations of the United Nations that covers all member states including developed and developing countries and responsible for information and communication technology (ICT) matters. ITU Telecommunication Standardization Sector (ITU-T) is the sector responsible for international de jure standardization of the ICT infrastructure in ITU, while two other sectors, ITU-R (Radiocommunication Sector) and ITU-D (Telecommunication Development Sector), are responsible for radio-communication and telecommunication development, respectively. ITU-T consists of 11 Study Groups (SGs), and SG15 covers a wide area of technology relating to a very basic communications infrastructure of ICT services. ITU-T SG15 consists of 13 Questions, as shown in **Fig. 1**, and investigates all network areas including home, access, metro, and core, and various technical fields including optical physical infrastructures, optical and metallic cables, passive optical network (PON), optical wavelength-division multiplexing (WDM), time-division multiplexing (TDM), packet transport, network, synchronization, architecture, and management and control of the network.

Although ITU-T SG15 is the leading organization in optical network standardization, it has been common in international standardization that progress is not made with only an entity but collaborations among many standardization bodies. **Figure 2** classifies international and internal Japan organizations relevant to optical network standardization concerning each network layer.

At the physical media layer called layer 0, ITU-T SG15 collaborates with the International Electrotechnical Commission (IEC) Technical Committee (TC) 86 (fiber optics) in the field of optical components, optical fibers and cables, and physical infrastructures. While ITU-T SG15 basically focuses on telecom networks, IEC TC 86 covers more generic application areas including industries and vehicles, and many manufacturers worldwide participate to discuss



AI/ML: artificial intelligence/machine learning
DWDM: dense WDM
ROADM: reconfigurable optical add/drop multiplexer

Fig. 1. Network configuration and ITU-T SG15 technical fields.

detailed specifications and test methods. The Optical Internetworking Forum (OIF) mainly involves optical components and module manufacturers and develops multi-source agreements (MSAs), which are interoperable implementation specifications provided for industries.

At layer 1, which is supported by TDM technology, synchronous digital hierarchy (SDH) was conventionally used when telephone-based services were mainstream. The optical transport network (OTN) was then developed for data-centric services, and its standardization is basically discussed only in ITU-T SG15.

At layer 2, which is based on packet transport technology, the Institute of Electrical and Electronics Engineers (IEEE) 802.3 develops Ethernet standards, and the Internet Engineering Task Force (IETF) specifies Internet Protocol/Multi-Protocol Label Switching (IP/MPLS). ITU-T SG15 modifies their basic structures to add functions necessary for highly reliable and operational telecom network services, including enhanced operations, administration, and maintenance (OAM) and protection, to create carrier-grade Ethernet and the MPLS Transport Profile (MPLS-TP) [1]. For precision time distribution over packet networks, ITU-T SG15 standardizes specifications on the basis of IEEE 1588 from the aspects of telecom network operation. It also collaborates with the 3rd Generation Partnership Project (3GPP) on specifications for recent fifth-generation (5G) or beyond 5G mobile services [2].

In terms of overall network architecture, atomic function models are used to describe network configurations and behavior of signal accommodation and transport. For management and control of network equipment, information models based on Unified Modeling Language are developed in collaboration with Open Networking Foundation (ONF); data models, which depend on protocols, are based on Yet Another Next Generation (YANG) model description mainly developed in IETF. There are also collaborations with relevant standardization bodies, including

Fig. 2. Optical network technology and standardization organizations.

TM Forum, Metro Ethernet Forum (MEF), and Broadband Forum (BBF), through liaisons and joint meetings.

Since ITU-T and IEC are de jure standardization organizations participated by member states and responsible for standards obliged by the WTO (World Trade Organization) Agreement on Technical Barriers to Trade, standards committees were established in the Telecommunication Technology Committee (TTC) and Institute of Electronics, Information and Communication Engineers (IEICE) for internal discussions in Japan.

2. Access and home network

The PON is the main transport technology in the access network area, and various specifications have been standardized, such as B-PON (Broadband PON), G-PON (Gigabit-capable PON), XG-PON (10 Gigabit-capable PON), and 40G-PON (40 Gigabit-capable PON), which is based on time- and wavelength-division multiplexing in the upstream and downstream directions using 10-Gbit/s high-speed channels per wavelength. They are standardized as ITU-T Recommendations G.983.x, G.984.x, G.987.x, and G.989.x, respectively. Recent discussions include higher-speed PONs based on 25 or 50 Gbit/s, WDM-PONs for further increase in fixed capacity using multiple wavelengths, and Super-PONs (named in IEEE) to extend reaches to over 50 km with 64 branches. There are also discussions addressing mobile services, including radio-over-fiber for efficient mobile signal transmission, dynamic bandwidth allocation for lower latency, and PON slice networks for flexible services.

While optical access technology has prevailed worldwide, there is still demand for asymmetric digital subscriber line/very high-speed digital subscriber line (ADSL/VDSL) technology using metallic media, such as coaxial cables and telephone lines. Thus, G.fast, which enables high-speed metallic cable transmission ranging from 100 Mbit/s to 1 Gbit/s, has been standardized, and G.mgfast is currently being discussed for higher speeds of several gigabits per second. For home networks, G.hn series Recommendations have been developed for transceivers that transmit signals over metallic media using frequency bandwidths at around hundreds of megahertz and are mainly applied for high-quality video and smart grid services. Visible light communications are also discussed for services at speeds of hundreds of megabits per second over the range of several meters.

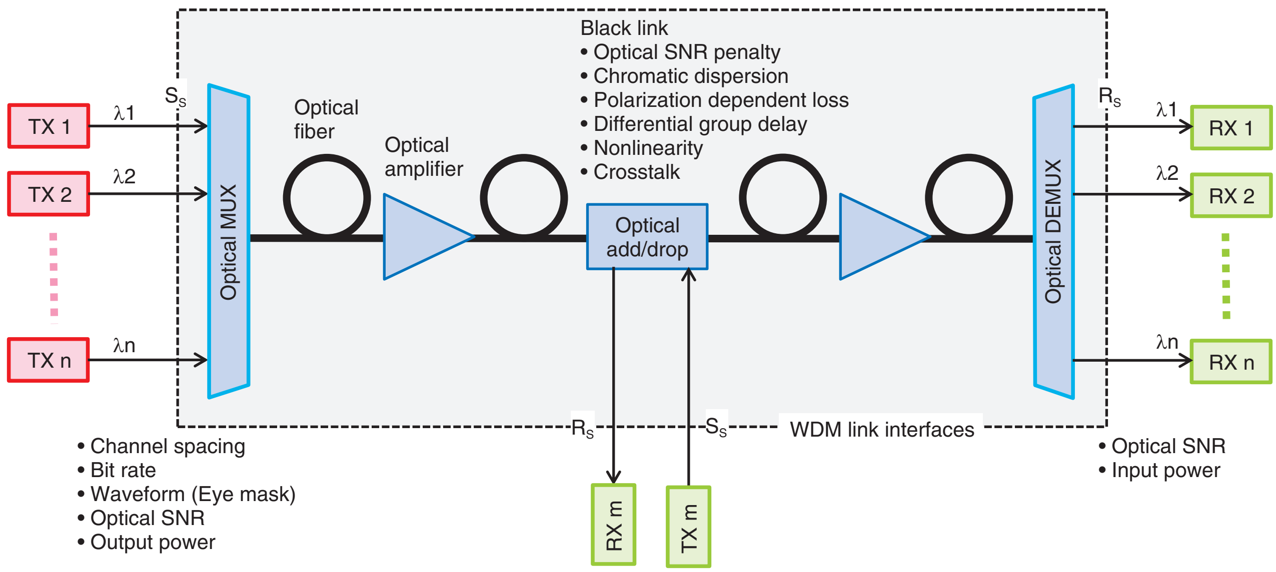


Fig. 3. WDM system configuration and interfaces.

3. Optical physical infrastructure, fiber cables, and WDM system

The physical infrastructure that protects network resources in various environments is significant for stable network operation. ITU-T SG15 mainly standardizes operation and maintenance issues, measurement methods including cable identification, and specifications of terminal boxes and closures installed in outdoor environments for optical-fiber distribution and connection. For further detailed specifications, such as mechanical characteristics, dust and water resistance, and robustness against temperature and humidity change, IEC TC 86 mainly investigates and standardizes them.

Optical-fiber and cable characteristics and their test methods have been standardized as G.65x series Recommendations: G.652 for basic single-mode fibers, G.653 for dispersion-shifted fibers, G.654 for cut-off shifted fibers, and G.655 for non-zero dispersion-shifted fibers. For future higher-capacity signal transmission, discussions on space-division multiplexing using multi-mode or multi-core fibers have recently started.

The progress of WDM transmission technology is key to achieve a very large capacity optical network, and various fundamental parameters have been specified for high performance and stable operation, including signal wavelength allocation, optical transmission bandwidth, signal bit rate per wavelength, modulation and demodulation schemes, and transmitter (TX) and receiver (RX) optical power level [3]. G.698.x series Recommendations define interoperable interfaces at single-channel connection points between TX, RX, and an optical link that includes optical fibers, amplifiers, and multiplexers/demultiplexers (MUX/DEMUX), as shown in **Fig. 3**. The parameters for TX and RX are set at reference points SS and RS without specifying the detailed configuration inside the optical link, which is called a black link approach. The optical signal emitted at the TX is specified by various parameters, some of which degrade during propagation in the optical link: decrease in the optical signal-to-noise ratio (SNR) due to optical amplifier noise accumulation, interchannel crosstalk in MUX/DEMUX, waveform distortion due to fiber chromatic dispersion and nonlinearity, and polarization-dependent differential group delay or polarization mode dispersion. After transmission, signal parameters including minimum optical power and SNR must satisfy the specifications defined for the RX.

G.698.2 is intended for an optically amplified WDM system typically applied to a metro area, which transmits 10 to 100 Gbit/s per-channel signals over several hundred kilometers. Further discussions on G.698.2 address capacity increase by applying higher-speed signals from 200 to 400 Gbit/s per channel. There is also discussion on a low-cost WDM system that transmits 25 Gbit/s signal per channel

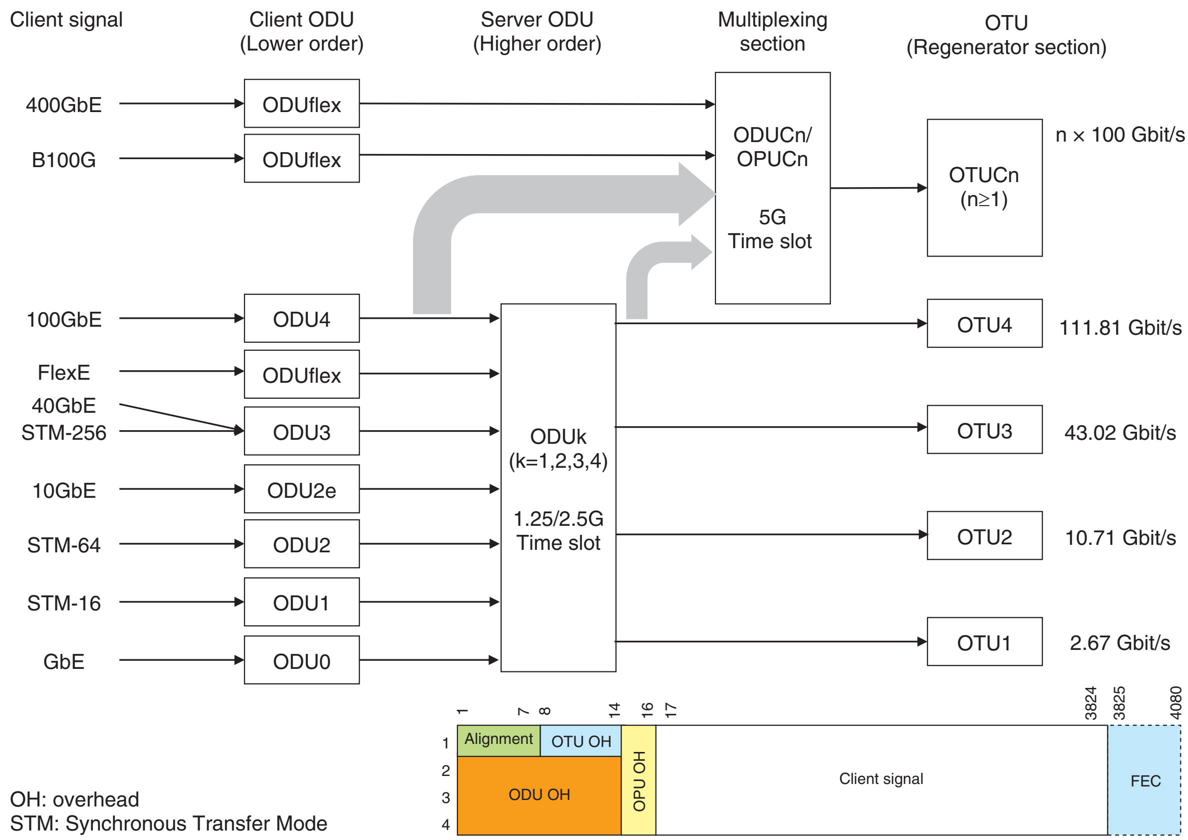


Fig. 4. OTN frame and multiplex hierarchy.

over 10 to 20 km for mobile front-haul applications.

For submarine cable systems, Recommendation G.977.1 has been standardized in view of recent demand for transverse compatibility between terrestrial terminal equipment and submerged plant consisting of optical-fiber cables and amplifiers, on conditions that they are installed by different manufactures. Discussions on new submarine-cable-system applications have recently started for scientific remote undersea sensing, which is relevant to the joint task force on SMART (Science Monitoring and Reliable Telecommunications) cable systems between ITU, World Meteorological Organization, the United Nations Educational, Scientific and Cultural Organization, and Intergovernmental Oceanographic Commission.

4. TDM system

The OTN can efficiently accommodate and multiplex various types of client signals in time division, and transmit them over long distances. OTN interfaces are specified in Recommendation G.709 including the OTN frame structure and multiplex hierarchy shown in **Fig. 4**. A client signal is contained in a container called an optical channel data unit (ODU) with additional overhead bytes for management and control then hierarchically multiplexed to compose a higher-order ODU. Finally, an optical channel transport unit (OTU) frame consisting of 4 rows by 4080 columns is created after adding Reed-Solomon (255,239) forward error correction (FEC) for transmission through an optical WDM system. The frame length of SDH, which was a core technology when telephone-based services were dominant, was fixed at 128 µs independent of the signal bit rate to send each byte repeatedly at 8 kHz. The OTN frame structure is fixed, and its size changes depending on the signal bit rate. The ODU size is defined to accommodate not only SDH but also various client signals including Ethernet. The G.709.x series Recommendations have been successively standardized to flexibly accommodate higher-speed client signals over 100 Gbit/s. Flexible OTN, defined in G.709.1 and G.709.3 for

	General/ Architecture	Interface	Equipment function	Equipment management	Protection switching
OTN	G.870 Terminology	G.709 OTN interface	G.798 OTN function	G.874 OTN management	G.873.1 Linear protection
	G.872 OTN architecture	G.709.1 Flexible OTN short-reach interface	G.798.1 OTN equipment type	G.875 OTN management information model	G.873.2 Ring protection
		G.709.2 OTU4 long-reach interface			G.873.3 Shared mesh protection
		G.709.3 Flexible OTN long-reach interface			
		G.709.4 OTU25&50 short-reach interfaces			
MTN	G.8310 MTN architecture	G.8312 MTN interface	G.8321 MTN function	G.8350 MTN management	G.8331 Linear protection

Fig. 5. OTN/MTN Recommendations.

short and long reach, respectively, transmits the signal over multiple wavelengths and uses a different ODU frame structure from the conventional OTN, which is 128 rows by 5140 columns. G.709.3 adopts higher-performance FEC depending on the signal bit rate and distance, such as staircase FEC or oFEC, which is determined by the Open ROADM MSA. Discussions on beyond 400G OTN have started to transmit the next generation higher-speed Ethernet over 400G, that is, 800 Gbit/s or 1.6 Tbit/s, discussed in IEEE.

For mobile signal transmission, a series of Recommendations for the metro transport network (MTN) has been standardized, which is engaged in transmitting the radio-access network traffic connecting distribution units and central units in the IMT (International Mobile Telecommunications)-2020/5G mobile front or middle haul. The MTN is based on FlexE, which has a TDM process between the media access control (MAC) and physical coding sublayer layers and can transmit Ethernet with a flexible granularity by using multiple physical interfaces. FlexE is originally specified in OIF, and the MTN is created by adding OAM functions necessary for highly reliable telecom network operation, including path and error monitoring, connectivity verification, delay measurement, and protection. The client signal in an MTN path has a 64B/66B Ethernet MAC frame and is processed at a unit of a 66B block. An MTN path is carried over 5-Gbit/s calendar slots in the MTN section layer.

The structure of Recommendations relevant to the OTN and MTN includes architecture, interface, equipment function and management, and protection, as shown in **Fig. 5** [4]. While pursuing higher-speed transmission, there is also a discussion on the OTN and MTN that accommodate lower-speed client signals below 1 Gbit/s. The discussion has started from clarification of the necessity of such an interface in view of actual service requirements because most low-speed circuit-based services can be covered by packet transport technology, and additional interfaces could significantly affect existing systems.

5. Packet transport system

ITU-T SG15 has developed the carrier-grade Ethernet to achieve high reliability and operability necessary for telecom network operators as well as traditional circuit-based TDM technology, such as SDH, while taking advantage of high efficiency and cost effectiveness inherent in the packet transport technology. A series of Recommendations, G.80xx, have been standardized to include overall architecture, service requirements, interfaces, OAM, equipment functions and management, and protection, similar to

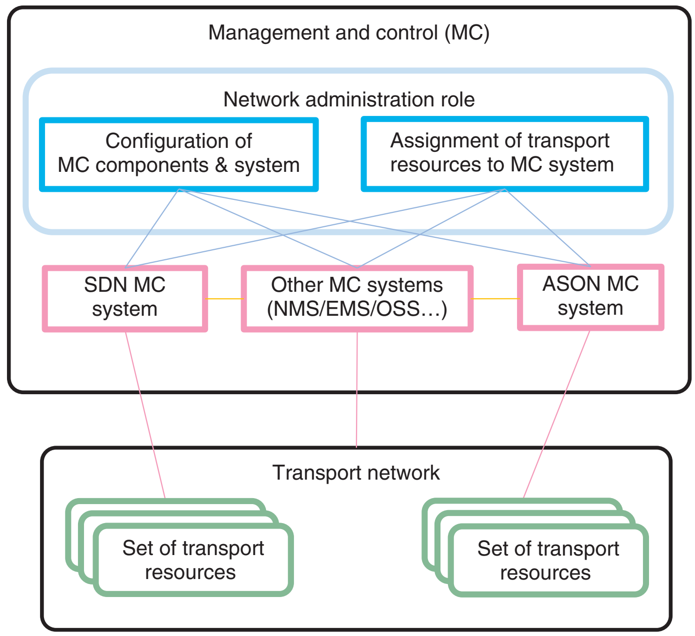


Fig. 6. Management and control architecture.

OTN Recommendations [4].

The MPLS-TP uses basic MPLS data-forwarding mechanisms but adds enhancements for high reliability and maintenance capability achieved in TDM-based systems while excluding functions in MPLS that may preclude carrier-grade network operation. The management of a connection-oriented path between the two end points is difficult with penultimate hop popping, equal-cost multipath, and label merging because of a lack of full traceability of the path; OAM packets must pass through the same path as the signal packets to accurately monitor the condition of the path. Another significant point is the separation between the control plane and data plane; a conventional MPLS network may disconnect user data traffic in the case of control-plane failure but this is not allowable in carrier-grade network operation. A series of Recommendations, G.811xx, have been standardized for MPLS-TP based packet networking [4].

Most basic standards for packet transport technology have been completed in ITU-T SG15, and current discussions mainly focus on equipment information and data models and text modifications in accordance with developments in IEEE discussions.

6. Architecture and management/control

The automatically switched optical network (ASON) was originally standardized as G.8080 before the emergence of software-defined networking (SDN). The structure of relevant standards was then reviewed and a concept of management control (MC) systems was introduced, which includes discrete management and control functions including an element management system (EMS), network management system (NMS), and operation support system (OSS) with SDN and ASON, as shown in **Fig. 6**. The "Configuration of MC components and system" function instantiates an MC system and its MC components, and the "Assignment of transport resources to MC system" function assigns transport resources. Other MC systems include transport-resource management functions and FCAPS (fault, configuration, accounting, performance and security). The transport resources are partitioned and assigned to a specific MC system to be configured by only the MC system. The Recommendations for transport SDN and ASON are rebuilt as G.7702 and G.7703, respectively, and common control aspects are described in G.7701.

The architecture for transport SDN is designed to provide multi-dimensional heterogeneity for optimizing the network and services in terms of infrastructure granularity, capacity-adjustment flexibility,

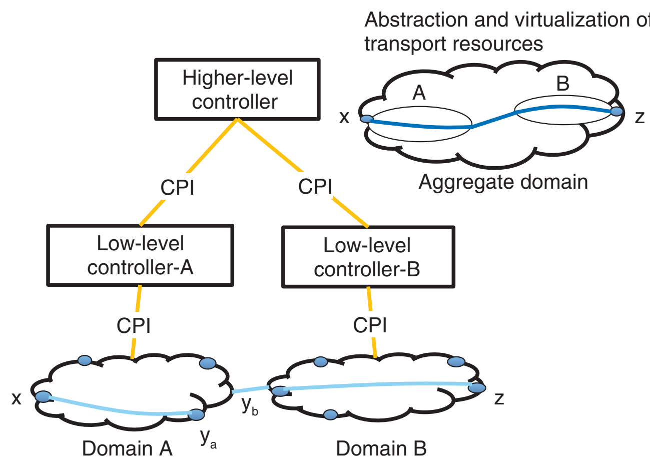


Fig. 7. Multilayer transport SDN.

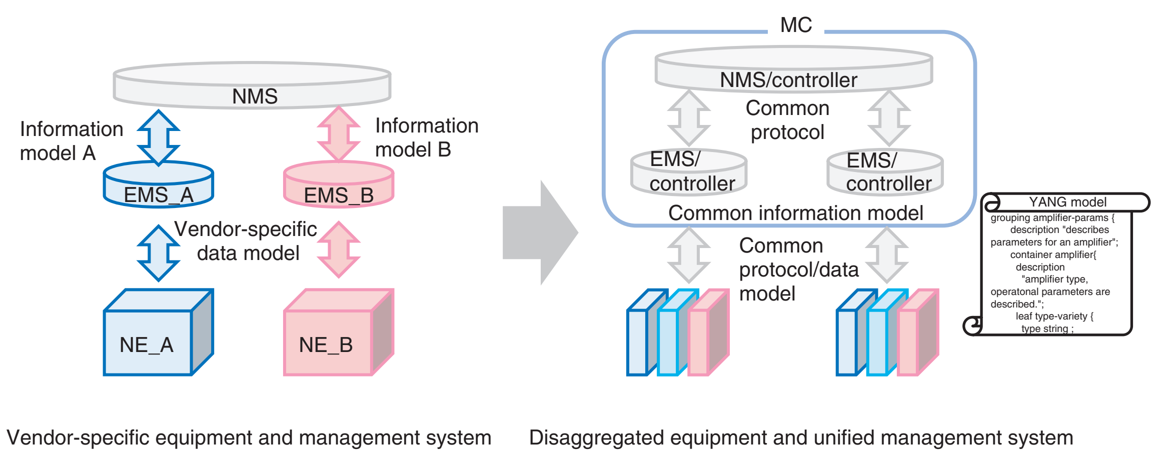


Fig. 8. Evolution of management and control model.

survivability, and infrastructure evolution. It has multiple hierarchical controllers that can be connected to each other through control plane interfaces (CPIs), as shown in **Fig. 7**, and an SDN controller supports one or more clients to establish a client/server relationship. An SDN controller has both local resources and resources provided by one or more server SDN controllers, including the transport resources and MC components, and transport resources are assigned to a virtual network in a client controller; the server SDN controller presents a virtualized view of the transport resources to the client SDN controller. Thus, the architecture enables centralized management and control of connections, network abstraction, and route optimization over different domains. New discussions have started to use artificial intelligence or machine leaning for advanced root cause analysis applicable for a complicated failure case; discussions will include MC architecture, interfaces, and the relationship with current MC components.

The structure of Recommendations for network management consists of generic standards that are independent of specific technology and protocols, and technology-specific standards addressed to the OTN, Ethernet, and MPLS-TP. **Figure 8** shows an evolution of network control and management and equipment configuration. While a traditional approach depends on the vendor-specific EMS and equipment, a future approach is expected that would consist of disaggregated equipment and unified control and management to avoid vendor lock-in and reduce procurement cost.

In the short term, an approach will be promising that uses a vendor-specific EMS/controller and unifies end-to-end paths by NMS. A common EMS/controller will then achieve unified control and management. To this end, standardization of common management information models and data models of equipment, network, and protocols are being discussed. Information models are generally conceptual, protocol independent, and abstracted from implementation and services, while data models are specific, protocol dependent, and abstracted from detailed equipment components.

ITU-T SG15 has standardized G.7711, a common information model that is independent of specific equipment, control, and protocol. Technology-specific information models have also been standardized as G.875, G.8052, and G.8152 for the OTN, Ethernet, and MPLS-TP, respectively. Further discussions include generation of a protocol-specific data model by using conversion tools. ONF discusses information models, interfaces, implementation, and interoperability on the basis of CORD (Central Office Re-architected as a Datacenter), ONOS (Open Network Operating System) controller, and OpenFlow protocols. IETF proceeds with internet drafts that specify conversion methods of information models developed in ITU-T and ONF to YANG models.

7. Conclusion

The significance of further development and standardization of ultra-high-capacity optical network technology is being emphasized because of rapidly increasing traffic and diversified services envisaged in the coming beyond 5G and big data era. Creating common specifications by international standardization is expected to essentially reduce cost and development time and stimulate the market. We will proactively contribute to developing optimum optical network technology standards toward the implementation of IOWN (the Innovative Optical and Wireless Network) [5] in view of international service requirements and leading-edge technology development.

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Makoto Murakami

Researcher, NTT Network Service Systems Laboratories.

He received a Ph.D. in electrical engineering from the University of Tokyo in 2009. He was engaged in the research and development (R&D) of long-haul transmission systems using optical amplifiers and coherent modulation/demodulation schemes at the emergence of those technologies in NTT laboratories. After developing and deploying a commercial optically amplified submarine system installed in Japan, he continued R&D of WDM systems to further increase the fiber-transmission capacity. From 2001 to 2003, he worked for NTT Communications, where he was involved in the construction and operation of international communication networks mainly in the Asia-Pacific region. Since 2003, he has been involved in R&D and standardization of large-capacity optical networks. He has actively participated in various standardization organizations including ITU-T SG15, where he has been the head of the delegation for Japan. He is currently the chairperson of the transport networks and EMC (Electro-Magnetic Compatibility) Working Group in the TTC of Japan. He received the accomplishment award from the ITU Association of Japan and the distinguished service award from TTC in 2015.

Salt Damage in RT-BOXes: Investigation and Countermeasures of Salt-damage Environments

Technical Assistance and Support Center, NTT EAST

Abstract

This article provides an overview of salt-damage maps, describes a case study of salt damage in remote-terminal boxes (RT-BOXes) installed in coastal regions, and introduces methods of implementing environmental investigations and countermeasures against salt damage in RT-BOXes. This is the seventieth article in a series on telecommunication technologies.

Keywords: salt damage, RT-BOX, salt-resistant filter

1. Introduction

NTT's telecommunication facilities are installed in various natural environments throughout Japan. The materials that constitute these facilities, such as metals and plastics, deteriorate due to ultraviolet rays and other effects of the surrounding environment. As shown in **Fig. 1**, salt damage, one of the causes of such deterioration, is a phenomenon by which strong winds blow sea-salt particles (salt) onto metal-containing equipment, where they adhere and accelerate corrosion. Sea-salt particles blowing from sea spray fall to the ground in coastal regions owing to the limited distance they can travel; consequently, the effects of salt damage are more pronounced in facilities closer to the coast, which suffer premature deterioration.

In response to requests from the field, the Technical Assistance and Support Center (TASC), NTT EAST, has been investigating the effects of salt damage to outdoor facilities and indoor equipment. At TASC, we have also devised ways to protect telecommunication facilities from salt damage by using salt-damage maps [1] and creating new inspection methods of determining the deterioration status of remote-terminal boxes (RT-BOXes) [2].

This article provides an overview of salt-damage maps, describes a case study of salt damage in RT-BOXes installed in coastal regions, and introduces methods of implementing environmental investigations and countermeasures against salt damage in RT-BOXes.

2. Salt-damage maps

The salt-damage maps were created by NTT's former Energy and Environment Systems Laboratories and the underlining technology was provided to NTT EAST in 2011. In 2018, TASC improved the maps by refining them with the latest weather data. As shown in **Fig. 2**, these maps display the corrosion rate of zinc with colors at any given point in Japan in a manner that makes it easy to determine the degree of salt damage by looking at differences in colors.

Hardware and other fixtures used in telecommunication facilities are galvanized on the surface (plated) to prevent corrosion of steel plates. Since the corrosion rate of zinc represents the rate at which this plating wears off, a high corrosion rate of zinc results in early loss of the zinc plating and direct exposure of

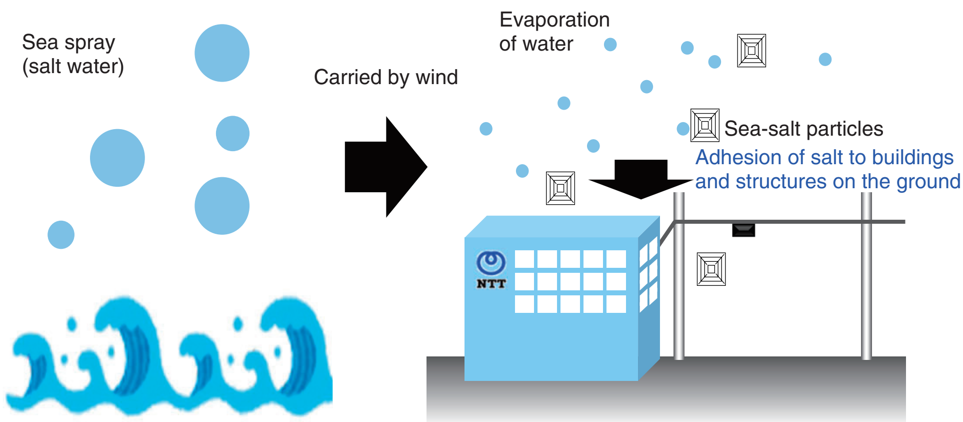
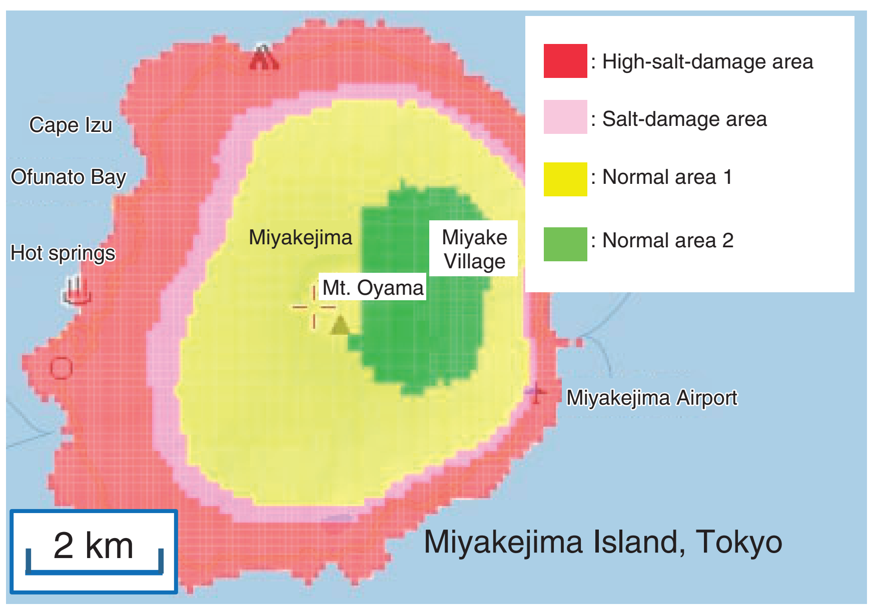


Fig. 1. Mechanism of salt damage.

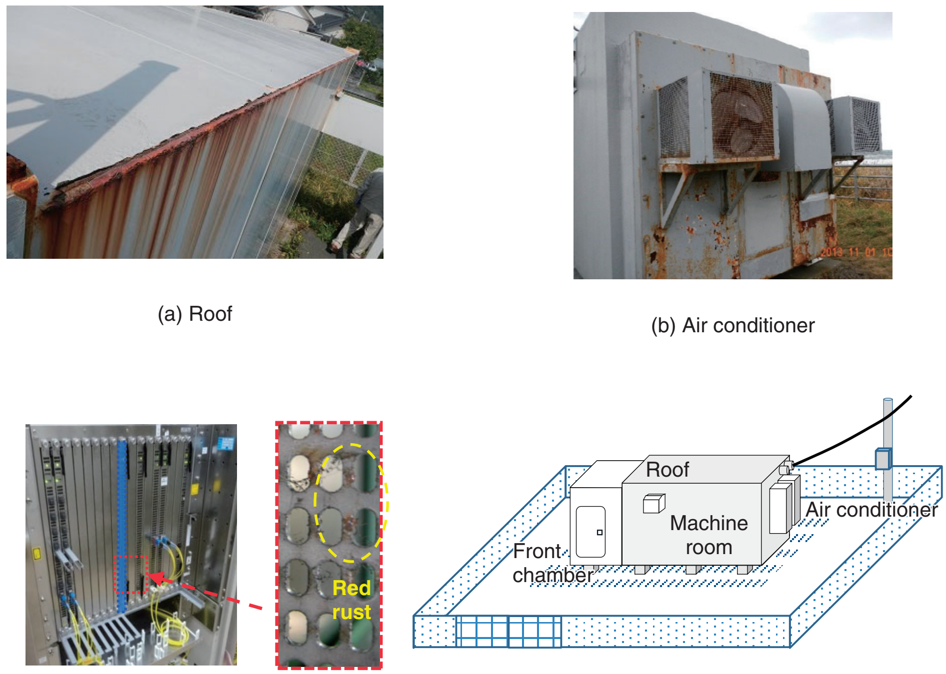


Map data © NTT InfraNet

Fig. 2. Salt-damage map.

the underlying steel plates to the environment. As a result, corrosion of the steel plates progresses at an accelerated rate, causing thinning of the plates that leads to problems in terms of strength and other safety aspects of the facility.

Under such circumstances, a salt-damage map can be used to determine where to implement measures to deter early deterioration of facilities. Such measures include applying a heavy-duty anti-corrosion coating (with higher salt-damage resistance) to outdoor facilities in areas with severe salt damage. For indoor facilities, salt must be prevented from entering the facilities. The following section introduces an example of such a salt-resistance measure used for RT-BOXes.



(a) Roof

(b) Air conditioner

(c) Equipment packages (in machine room)

Fig. 3. Examples of corrosion deterioration inside and outside an RT-BOX.

3. Investigation of the salt-damage environment of RT-BOXes and related countermeasures

3.1 Examples of outdoor and indoor corrosion in an RT-BOX

The occurrence of red rust on the exterior surface and interior of an RT-BOX installed in a coastal region is shown in **Fig. 3**. Outside the RT-BOX, rust occurs at the edges of structures where the paint tends to thin out and in areas where the structure is complex and moisture tends to accumulate. An example of such an area is where the outdoor unit of an air conditioner is installed.

Indoors, rusting was observed inside the communication-equipment packages and on bolts inside the machine room, suggesting that salt was somehow entering the room.

3.2 Method of investigating the salt-damage environment

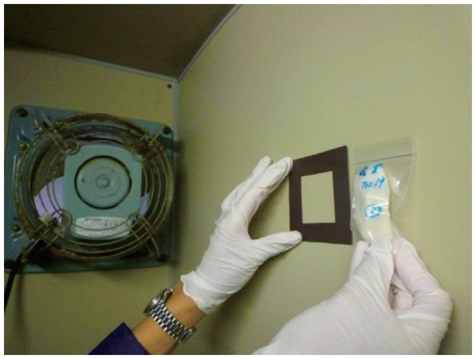
Whether the environment in which the telecommunication facility is located is significantly affected by salt damage can be evaluated by directly measuring the amount of salt present in the environment using the measurement methods. These measurements can also be taken indoors to determine if salt is entering the facility. The two measurement methods used for the interior of an RT-BOX are described as follows.

Method I: Measuring the amount of adhered salt by conducting a wipe test (Fig. 4(a)).

This method is used to measure the amount of salt remaining inside an RT-BOX. The surface of areas presumed to be less affected by access from workers thus more prone to salt accumulation, such as under equipment racks, is wiped with a non-woven cloth containing ion-exchange water to collect deposits. The amount of chloride ions (Cl^-) contained in the deposits is measured using ion chromatography then converted into sodium chloride (NaCl) to determine the amount of adhered salt.

Method II: Measuring the amount of airborne salt by conducting a dry-gauze test (Fig. 4(b)).

This method is used to measure the amount of airborne salt that infiltrates an RT-BOX from outdoors. In accordance with JIS Z2382 (the Japanese industrial standard for measuring environmental-pollution factors to evaluate the corrosivity of atmospheres), a dry-gauze plate (i.e., a plastic plate with a dry gauze attached) is used to collect airborne salt. The plate is exposed to the atmosphere inside the RT-BOX, and



(a) Wipe test

(b) Dry-gauze test

Fig. 4. Methods of measuring amount of adhered salt and airborne salt.

Table 1. Results of investigation of the amount of adhered and airborne salt in RT-BOXes in coastal regions.

Location	Distance from coast [m]	Presence or absence of salt-resistant filter	I. Amount of adhered salt [mg/m^2]		II. Maximum amount of airborne salt indoors [mg/(dm^2 · 30 days)]	Salt-damage environment inside the RT-BOX
			Outdoor	Indoor		
Town A	90	None	17–103	13–371	0.49	Salt damage
Town B	100	None	12–100	8–77	0.00	Salt damage
Town C	80	None	39–307	10–64	0.01	Salt damage

salt suspended in the air adheres to the gauze. Specifically, several dry-gauze plates are placed on open-air inflow points inside the RT-BOX (such as near ventilation fans), and the dry gauzes are retrieved after approximately 30 days to collect the airborne salt. The amount of airborne salt is then measured using ion chromatography in the same manner as with Method I.

3.3 Investigation of salt-damage environment in RT-BOXes in coastal regions

The results of the investigation of the amount of adhered and airborne salt in RT-BOXes in coastal regions are listed in **Table 1**.

The maximum amount of adhered salt measured at ten locations inside an RT-BOX exceeded the standard for salt-affected areas (i.e., 50 mg/m^2) in all RT-BOXes [3]. The amount of airborne salt measured at four indoor locations was particularly high in the RT-BOX in town A. These results confirm that for all RT-BOXes, salt infiltration into an RT-BOX occurs due to the coastal location of such facilities.

3.4 Countermeasures against salt infiltration by using salt-resistant filters

The salt detected inside RT-BOXes is considered to have entered through (i) gaps in the wall surface caused by aging or (ii) the outdoor unit of the air conditioner installed outside RT-BOXes. Accordingly, to curtail salt adhesion inside an RT-BOX, a commercially available salt-resistant filter was fitted to the outdoor unit of the air conditioner, as shown in **Fig. 5**. The amount of adhered salt at seven locations in the RT-BOX before and after fitting the filter are compared in **Fig. 6**.

It was observed that the amount of adhered salt in all locations decreased after the filter was fitted. It can thus be concluded that the filter effectively prevents salt from entering the RT-BOX. Note that two locations still gave values close to 50 mg/m^2 (the standard for salt-affected areas) after the filter was fitted, but those values may be due to salt accumulated inside the RT-BOX prior to the filter fitting. It is thus necessary to remove that salt by carefully cleaning without dispersing salt particles during cleaning.

These measures to prevent salt from infiltrating an RT-BOX are thought to contribute to preventing the

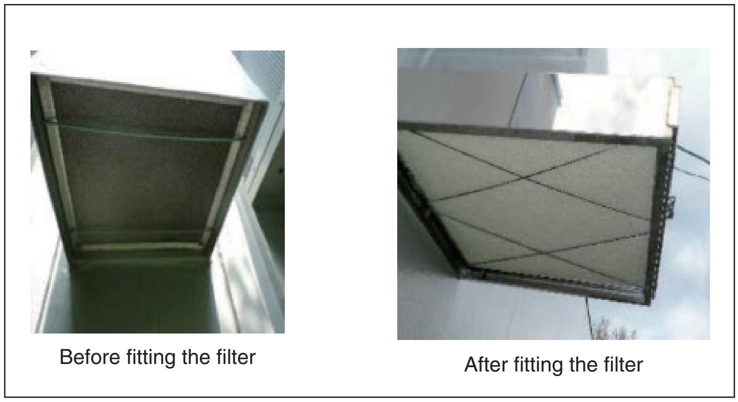


Fig. 5. Appearance of fitted salt-resistant filter.

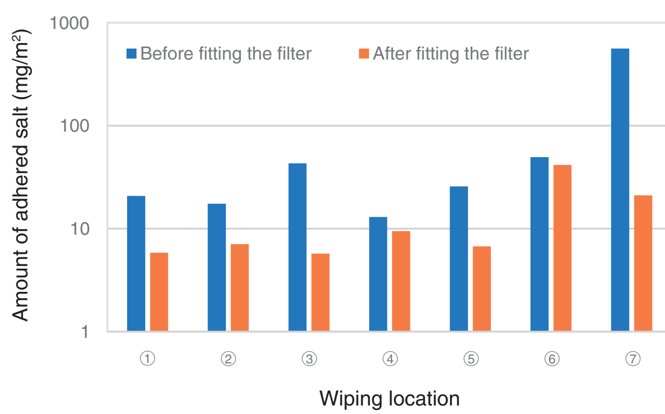


Fig. 6. The amount of adhered salt before and after fitting a salt-resistant filter.

corrosion of steel walls inside the facility as well as equipment failure and other malfunctions.

4. Conclusion

To protect telecommunication facilities from corrosion damage caused by salt, it is necessary to (i) apply appropriate heavy-duty anti-corrosion coatings to facilities outdoors where direct contact between steel plates and salt occurs and (ii) implement countermeasures such as fitting filters to prevent salt from entering from outside and accumulating inside the facilities. The application of these countermeasures will prolong the service life of facilities, especially in salt-affected areas along the coast. TASC will continue to promote technical cooperation to solve problems in the field, such as problems related to equipment deterioration due to corrosion from salt damage, and contribute to improving the quality and reliability of telecommunication services.

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External Awards

Professional Group of Spintronics English Presentation Award
Winner: Shingo Kaneta-Takada, NTT Basic Research Laboratories
Date: December 20, 2021
Organization: The Japan Society of Applied Physics (JSAP) Professional Group of Spintronics

For "Quantum Limit Transport and Two-dimensional Weyl Fermions in Epitaxial Ferromagnetic Oxide $SrRuO_3$ Thin Films."
Published as: S. Kaneta, Y. K. Wakabayashi, Y. Krockenberger, T. Nomura, Y. Kohama, H. Irie, K. Takiguchi, S. Ohya, M. Tanaka, Y. Taniyasu, and H. Yamamoto, "Quantum Limit Transport and Two-dimensional Weyl Fermions in Epitaxial Ferromagnetic Oxide $SrRuO_3$ Thin Films," The 82nd JSAP Autumn Meeting, 13p-S302-10, Sept. 2021.

Young Researcher's Award
Winner: Takeo Sasai, NTT Network Innovation Laboratories
Date: March 17, 2022
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE)

For "Learning Nonlinear Schrödinger Equation: Loss Profile and Passband Narrowing Estimation."
Published as: T. Sasai, M. Nakamura, S. Yamamoto, E. Yamazaki, H. Nishizawa, and Y. Kisaka, "Learning Nonlinear Schrödinger Equation: Loss Profile and Passband Narrowing Estimation," Proc. of the 2021 IEICE General Conference, B-10-11, Mar. 2021.

Young Researcher's Award
Winner: Takuma Tsurugaya, NTT Device Technology Laboratories
Date: March 17, 2022
Organization: IEICE

For "Reservoir Computing Using Semiconductor Optical Amplifiers on Si."
Published as: T. Tsurugaya, T. Hiraki, M. Nakajima, T. Aihara, N. Diamantopoulos, T. Fujii, T. Segawa, and S. Matsuo, "Reservoir Computing Using Semiconductor Optical Amplifiers on Si," Proc. of the 2021 IEICE Society Conference, C-3/4-23, Sept. 2021.

Young Scientist Presentation Award
Winner: Shingo Kaneta-Takada, NTT Basic Research Laboratories
Date: March 22, 2022
Organization: JSAP

For "Quantum Limit Transport and Two-dimensional Weyl Fermions in Epitaxial Ferromagnetic Oxide $SrRuO_3$ Thin Films."
Published as: S. Kaneta, Y. K. Wakabayashi, Y. Krockenberger, T. Nomura, Y. Kohama, H. Irie, K. Takiguchi, S. Ohya, M. Tanaka, Y. Taniyasu, and H. Yamamoto, "Quantum Limit Transport and Two-dimensional Weyl Fermions in Epitaxial Ferromagnetic Oxide $SrRuO_3$ Thin Films," The 82nd JSAP Autumn Meeting, 13p-S302-10, Sept. 2021.

Papers Published in Technical Journals and Conference Proceedings

"Remote High Five" Achieved by Vibrotactile Transmission: Case Studies for Family Communication of Athletes and Sports Viewing with Hearing-impaired Person

K. Komazaki and J. Watanabe

Transactions of the Virtual Reality Society of Japan, Vol. 27, No. 1, pp. 2–5, Mar. 2022.

High-five is a physical communication in which two people tap their palms together at face level. Particularly in sports, high-five can share greetings, praise, and congratulations. However, recently physical contact, including high-five, has been limited due to COVID-19 pandemic. In this paper, we explore a possibility of "remote high-five" communication system using vibrotactile transmission. This system can measure and present vibration in addition to audiovisual information, allowing users to remotely share their emotions by sending and receiving tapping vibration like giving a high five. We also discussed cases where this system was actually used in sports scenes: family communication of athletes and sports viewing with hearing-impaired person.