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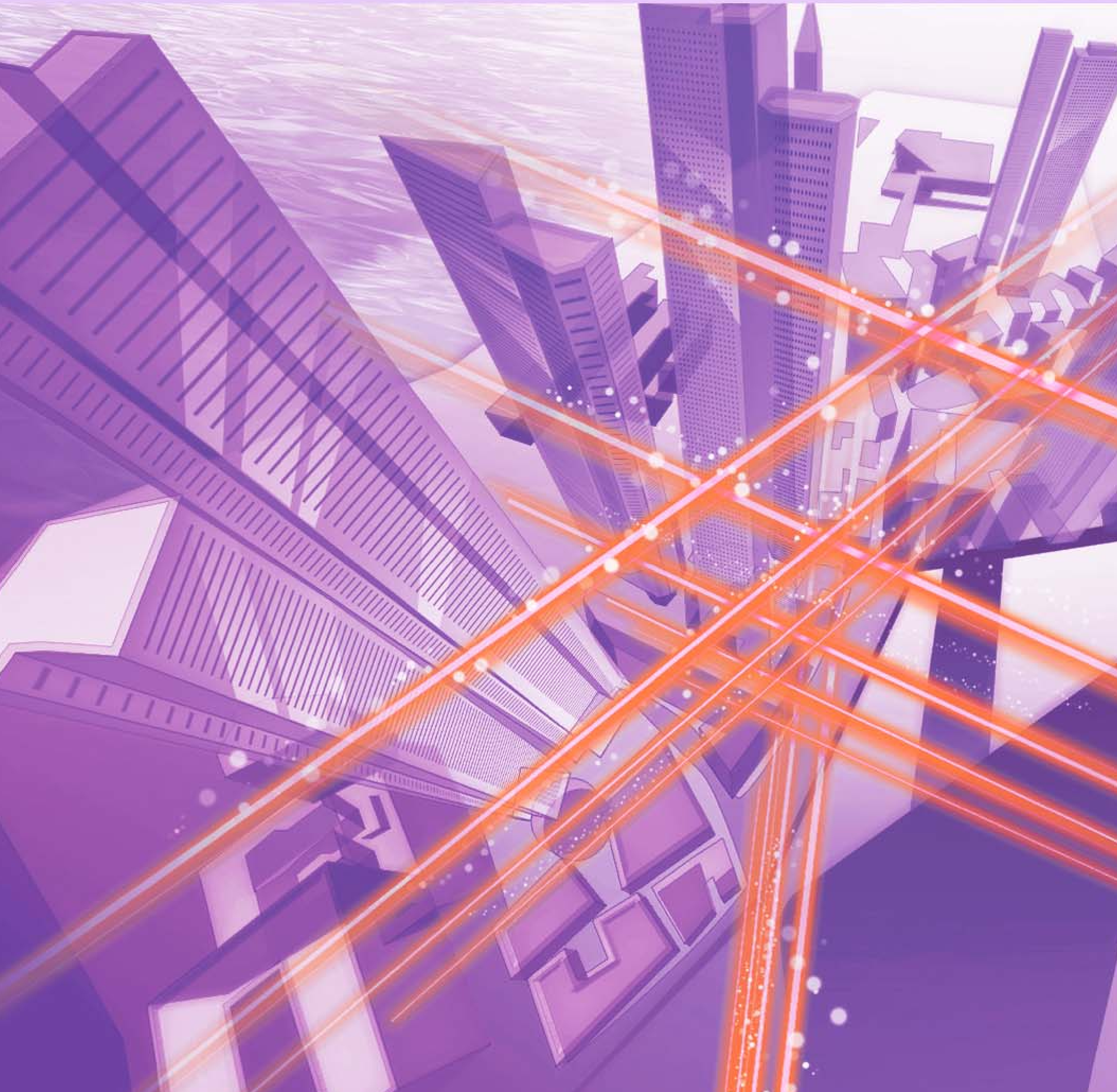

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If You Are Determined, You Can Achieve Anything—Take on New Challenges While Strengthening Existing Businesses

Akira Shirahase
Senior Vice President, Executive Manager of Technology and Innovation Department, NTT WEST

Abstract

NTT WEST continues to take on challenges together with its stakeholders to create an exciting future by using information and communication technology. The company has redefined the "NTT WEST Spirit" and designated the company purpose in pursuit of a future in which all people are happy and prosperous. We interviewed Akira Shirahase, senior vice president and executive manager of the Technology and Innovation Department, NTT WEST, about his technology strategy and his mindset as a top executive.

Keywords: open innovation, purpose, QUINTBRIDGE

Re-defining "NTT WEST Spirit" at a major inflection point

—Could you tell us the status of NTT WEST's business?

Amid declining revenue mainly due to the decrease in the number of fixed-telephone subscribers, NTT WEST is going through a period of transformation to shift its revenue structure to that focused on businesses in growth areas. To remain a useful partner with regional communities and transform ourselves into a company that can grow even more, we are accelerating our transformation into a leaner organization capable of responding quickly to changes in the environment by reviewing our working practices while boosting our business in growth areas to more than 50% of our revenue by 2025.

In 2021, we set a new purpose, "'Connecting' then 'opening' the door to the new world. As a member of regional communities, we will continue to pursue a vision of a future in which all people are happy and prosperous. To that end, we will refine our technology and wisdom and take on the challenge of co-creating new value." To achieve this purpose, all employees are taking ownership of their work.

—It is important to take ownership over everything. What are you doing to achieve the company's purpose?

In addition to encouraging employees to link their

purpose to that of the company's, we have set up dialogue meetings in each department to exchange opinions and provide opportunities to talk with top management. I also participate in such meetings and listen to the discussions. I receive reports from managers on a daily basis, so I find the time I spend meeting face-to-face with non-managerial employees, talking with them at length, and listening to them very enjoyable and fulfilling. Naturally, some of the opinions expressed in those meetings have been harsh, but such candid exchanges have given me valuable insights. Today is said to be the age of VUCA (volatility, uncertainty, complexity, and ambiguity), in which we are faced with complex and diverse social issues. In this age of diversity, it is important to learn about each other's different values and ways of thinking through such direct communication, and as a venue for this learning, these dialogue meetings are very meaningful. I believe that proactive action based on a mutual understanding of different values is truly taking ownership of work.

In the process of achieving our purpose, we will primarily focus on local regions, but, at the same time, we see the potential to expand our business not only locally but also globally. Specifically, we are expanding new businesses that have been successful in Japan to overseas markets. For example, "Comic C'moA," a manga and e-book distribution service provided by NTT Solmare, an NTT WEST Group company, has 35 million monthly users. Recognizing that Japanese manga culture has taken root overseas, we launched "Manga Plaza," an e-book distribution service for North America in March 2022 and are strengthening our international business. I believe that other businesses originating from Japan, such as local food-waste recycling solutions that invigorate local economy, robots for labor saving, and artificial-intelligence solutions, have great potential. Conversely, we want to actively collaborate with overseas ventures in providing competitive services in Japan.

In addition to technology, it is important to anticipate the market

—So you are conducting business not only on a regional basis but also with a view to global expansion. As a chief technology officer, can you tell us about the technology strategy and vision that is key to achieving the purpose?

In the field of information and communication technology (ICT), we are focused on multi-cloud, network-integrated ICT infrastructure, and managed services. Regarding problem solving, we are focused on municipal digital transformation, education, and healthcare. Regarding creating the future, we intend to create services in areas of lifestyle, health, economy, and the environment to build a future society of well-being. In consideration of these areas, our technology strategy and vision has two axes: (i) transforming ourselves into an innovative company for solving social problems and (ii) providing telecommunications services as a critical infrastructure that supports the digital society.

Specifically, we will create new businesses that have a positive impact on society through open innovation and the early use of Innovative Optical and Wireless Network (IOWN) technologies to create and expand services in priority growth areas and develop technologies for the stable operation, high efficiency, and advancement of network infrastructure as a social infrastructure. For example, we are considering a service that provides customers with prompt and easy-to-understand information on service quality and infrastructure status by visualizing such pieces of information so that customers can use telecommunications services with peace of mind and we can respond more quickly when problems occur. Toward the era of IOWN, we will also promote the migration to the next network. Current network systems, which have been adapted to change over time, are inherently complex and inefficient partly because they have responded to each milestone of change step by step. I therefore believe that next-generation network operation systems and architectures must be investigated. With an eye on Web 3.0 and other digital technologies, we must also investigate a new network architecture that uses IOWN-related technologies. We hope to introduce some of those technologies and architectures at Expo 2025 Osaka, Kansai, Japan.

Incidentally, QUINTBRIDGE, the venue for this interview, is an open innovation facility established in March 2022 as a place to solve social problems and create a future society together with partners such as companies, including start-ups, local governments, and universities. People of various nationalities, genders, and ages from all walks of life have visited the facility where many discussions and events have been held. NTT WEST's open innovation takes place right here. We will also actively use our relationships with global partners to achieve open and network-related innovation.

—The spacious open spaces and private rooms are very modern in design and almost make you feel like being in a café. And discussions are going on even at the coffee stand, which stimulates creativity just by looking at it.

In today's complex, diverse, and changing environment, the ability to anticipate the market is important in addition to technological capability. I believe the key to how to anticipate the market is open innovation. After all, social and technological trends cannot be noticed by the activities of a single company. We cannot anticipate the market without understanding such trends in a timely manner through meetings, conversations, and discussions with people from various walks of life about the trends in society and technology. I believe it is critical to make new discoveries through these endeavors.

QUINTBRIDGE has been used by a total of 92,000 people since it opened. It has hosted over 470 events in one year and three months. I consider the open innovation approach at QUINTBRIDGE to be an innovation in itself. Normally, open-innovation facilities operated by operating companies attract people who want to work with those companies; in contrast, at QUINTBRIDGE, which does not solely focus on matching people with NTT WEST, each member first brings their questions and challenges as well as assets that can be provided to the venue, which will lead to the opportunity of opening the door for co-creation activities for solving social problems with other members, including NTT WEST.

Therefore, QUINTBRIDGE has brought together more partners than anticipated and created many lively activities as we see today.

I feel it difficult for many Japanese companies, especially large ones, to push the envelope on their own. Therefore, I want to create a process that allows companies to push themselves beyond their limits. By providing this process, I believe that NTT WEST can become a next-generation social enterprise by expanding and supporting each company. One mechanism to achieve this is QUINTBRIDGE. I can feel the expectations its participants have toward us from the daily activities at QUINTBRIDGE. Since the establishment of QUINTBRIDGE more than one year ago, we have established the foundation for open innovation; however, we need to further clarify what we need to do to create new business and fully use QUINTBRIDGE as a training ground to maximize our achievements. In addition, I feel that member companies, including start-ups, are hoping to collaborate with the NTT Group as a whole. We therefore intend to serve as a hub for collaboration between member companies and NTT Group companies and create business that has a positive impact on society by leveraging the NTT Group's combined capabilities as well as take on challenges that can demonstrate the strength of NTT WEST.

Top management are the ones who change things and decide matters, but we must not be self-righteous

—Can you share with us some of the lessons you have learned since joining NTT?

I joined NTT in 1992 and engaged in corporate sales, two years after which I was transferred to the Los Angeles office of NTT America. While working to support the global expansion of our corporate customers based in western Japan, I witnessed the rapid commercialization of the Internet in the U.S. I suggested to executives that "The Internet could be good business." and became involved in Internet connection services with the support of NTT's research laboratory there. Through this experience, I reaffirmed that NTT is a company that takes suggestions positively and has a treasure trove of human resources including its laboratories.

It was my experience at the APEC Osaka Conference (1995)—where I was assigned to a project to promote Internet-related businesses after returning to Japan—which made me realize how important human relationships are. To support Internet connection for the conference, manufacturers, broadcasters, advertising agencies, and other companies and universities were assembled. Together with these organizations, we then launched "Cyber Kansai," a joint industry-government-academia consortium that promotes the development and demonstration of advanced Internet technologies. Led by members of Cyber Kansai, new companies, such as NTT SmartConnect, and new services, such as radiko—a service that enables users to listen to the radio via smartphone, were established.

I feel how rewarding these experiences are and how they could contribute to society. I want to create a new legacy at the Expo 2025. Perhaps the lesson drawn from these experiences is that diversity is important. It takes “awareness” to actively embrace diversity because people can only see what they want to see.

I also learned the importance of balancing between new and existing businesses. In corporate activities, we tend to be drawn to deepening/strengthening existing businesses rather than exploring new businesses. Sometimes we cannot afford to create a new business because we focus too much on operating an existing business. However, random attempts to search for a new business will not work. I value this balance and rebalancing in decision-making on the basis of market needs and knowledge.

—What do you do to improve the quality of your decision-making?

To improve the quality of my decision-making, I value interacting with people from various positions inside and outside the company. Until recently, due to the COVID-19 pandemic, it was not possible to interact directly with people, and that situation made me realize the value of such interaction.

I believe that if you are determined, you can achieve anything. Through my past experiences, I have come to realize that making a choice first is a powerful tool for achieving something, no matter how long it takes. I also believe that top management are “the people who decide and make changes.” The final decision is the responsibility of top management, but it is not a self-righteous decision. I make decisions by listening to understand different situations and positions, considering outlooks, and making sure that I’m guiding employees in the right direction. It is difficult for people to change, especially stop, the direction in which they are moving in what they believe to be the best way. That is why top management have the responsibility of making decisions.

It is also difficult for companies to initiate change on their own. That is where open innovation—which I mentioned earlier—becomes important. Because change can be created through co-creation with a variety of people.

—Finally, what is your message to us all?

First, to all our researchers, NTT Group’s strength is its ongoing commitment to research and development, including basic research. I want you to take on the challenge of creating new technologies, but do so with an assumption of how the technology might be valuable. It is OK if the technology you developed turns out to be used in areas that differ from your original purpose. I urge you to create new value with confidence.

Next, to our engineers and technicians, to transform into an innovative company solving social problems while protecting the telecommunications infrastructure, we must simultaneously work on both deepening/strengthening existing businesses and exploring new businesses. We need both people who do new things and people who maintain things; therefore, I want us to foster a culture of mutual respect and mutual help. I also want to create a community that connects the group’s human resources horizontally while using QUINTBRIDGE, so I urge you to join or plan to create such communities.

Last but not least, to our customers and partners, we would like to create and share various business ideas with you by hosting events at QUINTBRIDGE and the upcoming 2025 Expo as platforms. Let us create new ideas and services to build a better society.

Interviewee profile

■ Career highlights

Akira Shirahase joined NTT in 1992. He became a member of the board, NTT SmartConnect, in 2014, president and representative member of the board, NTT SmartConnect, in 2016, and member of the board and executive manager of the Business Design Department, NTT WEST, in 2020. He has been in his current position since June 2021.

Aiming to Become a Visible Researcher by Taking Up Challenges without Fear of Failure

Yoshitaka Taniyasu
Senior Distinguished Researcher, NTT Basic Research Laboratories

Abstract

Green innovation involves creating new solutions to environmental problems and sustainable development, and research and development of innovative technologies in the fields of the environment, resources, and energy is being conducted worldwide to create a low-carbon and circular society. We interviewed Yoshitaka Taniyasu, a senior distinguished researcher at NTT Basic Research Laboratories, who has produced world-class research results concerning functional materials for green innovation, about his achievements and attitude as a researcher.

Keywords: materials research, green innovation, aluminum nitride

Pursuing functional materials for green innovation and solving social problems

—Could you tell us about the research you are currently conducting?

I'm currently researching functional materials for green innovation. When I was appointed as a senior distinguished researcher, I chose green innovation as a research theme that I would pursue for the long term.

As you know, reducing carbon dioxide is a global challenge. Addressing growing demands for efficient use of energy, effective utilization of limited resources, and creation of a sustainable society, researchers like me are taking up the challenge through approaches such as developing methods to generate energy and use energy efficiently. As a researcher specializing in materials research, I'm researching and developing technologies for synthesizing and controlling the properties of next-generation materials to fabricate new functional devices that contribute to the creation of a sustainable society. My specific objectives are to (i) elucidate the physical properties of materials, (ii) make devices more efficient with lower loss on the basis of scientific principles, and (iii) demonstrate the principles of device operation by establishing technologies for synthesizing new materials and fabricating devices using those materials.

The discovery and synthesis of new materials and innovations in device technology can significantly change society, and this potential is what makes materials research so interesting. In 2002, my colleagues and I were the first in the world to demonstrate the use of aluminum nitride (AlN), which had been used as an insulator since its synthesis more than a century ago, as a semiconductor. That breakthrough opened up the possibility of applying AlN to semiconductor devices. In this interview, I will talk about our impactful research results concerning AlN that will contribute to green innovation.

—Research results that will contribute to solving social problems and have an impact on the world sound very exciting.

In 2006, for the first time in the world, we succeeded in operating a light-emitting diode (LED) based on AlN, which is theoretically predicted to emit light with the shortest wavelength among all semiconductors. We observed light in the deep ultraviolet (UV) region (210-nm wavelength) from the AlN LED. AlN is a direct-bandgap semiconductor and has the same crystal structure as gallium nitride (GaN), which is widely used in blue LEDs and semiconductor lasers for high-density digital versatile discs. AlN has the largest bandgap energy (i.e., the energy required for an immobile electron to become a free electron) among semiconductors, i.e., 6 eV. Accordingly, it is theoretically predicted that if AlN LEDs could be fabricated, they would emit light at a wavelength of 210 nm, which is the shortest among all semiconductors.

In the UV spectrum, light with wavelength in the range of 300 to 400 nm is called "near UV," and light with wavelength in the range of 200 to 300 nm is called "deep UV." In addition, UV light with a wavelength of 200 nm or less, known as "vacuum UV," is absorbed by the atmosphere and can only be used in a special environment such as a vacuum.

Widely used deep-UV light sources are gas-light sources such as mercury lamps and gas lasers. However, mercury lamps use hazardous substances, and gas lasers have practical problems such as the need to supply the gas regularly, large size, and low efficiency. If these gas-light sources could be converted into semiconductor devices, they would be not only harmless from an environmental standpoint but also highly reliable, compact, highly efficient, long lasting, and portable, thus creating new industries as well as replacing existing gas-light sources.

AlN LEDs have not been fabricated because n-type and p-type doping[*1], which are essential for fabricating semiconductor devices, have not been possible with AlN. Under these circumstances, we found that we could not dope AlN because of problems with crystal growth such as crystal defects and the contamination of many impurities, which lowered the purity of AlN.

To produce high-purity AlN, we developed a technique for suppressing unfavorable secondary reactions between Al and nitrogen gas sources by increasing the velocity of supplying them and improved the AlN fabrication system so that it can withstand crystal growth at a high temperature of 1200°C. Therefore, we can reduce crystal defects and the impurity density in AlN to less than one-tenth the conventional level, successfully establishing crystal-growth technology and attaining the world's highest quality. This technology enabled us to fabricate AlN LEDs, which were theoretically predicted to emit light at the shortest possible wavelength, thereby opening up the potential of semiconductor light-emitting devices for deep-UV light applications.

Staying at the forefront of materials research

—Could you tell us about your achievement in 2022, which has been widely reported in the mass media?

In 2022, to further reduce power losses of power devices, which are an essential component for using clean energy, we demonstrated—the world's first—operation of a transistor using AlN (**Fig. 1**). Silicon (Si) is the main material used in semiconductor power devices, which are widely used in home electronics, personal computers, smartphones, server equipment, and electric vehicles. Using a wide-bandgap semiconductor with a high breakdown voltage[*2] makes it possible to reduce the loss and increase the breakdown voltage of power devices. Accordingly, power devices using wide-bandgap semiconductors, such as silicon carbide (SiC) and gallium nitride (GaN), are being developed.

The use of ultrawide-bandgap semiconductors, which have higher breakdown voltages than wide-bandgap semiconductors, is expected to further improve the performance of power devices. Ultrawide-bandgap semiconductors include AlN, diamond, and gallium oxide (Ga_2O_3). If power devices using AlN, which has the highest breakdown voltage of any semiconductor, could be fabricated, it is theoretically expected that power loss could be reduced to less than 5% that of Si-based devices, 35% of SiC-based devices, and 50% of GaN-based devices.

*1 Doping: Addition of impurities to high-purity semiconductor crystals to enable free movement of electrons and holes in the semiconductor.

*2 Breakdown voltage: The voltage at which current begins to flow when insulation is lost.

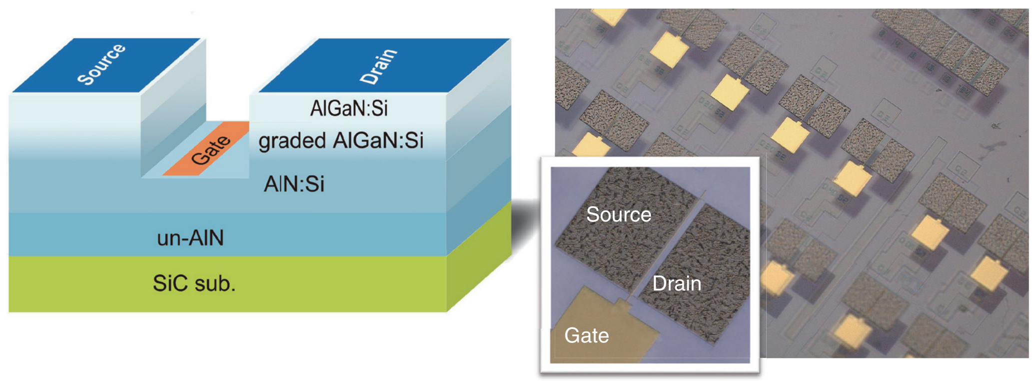

Fig. 1.   Schematic diagram and micrograph of an AlN transistor.

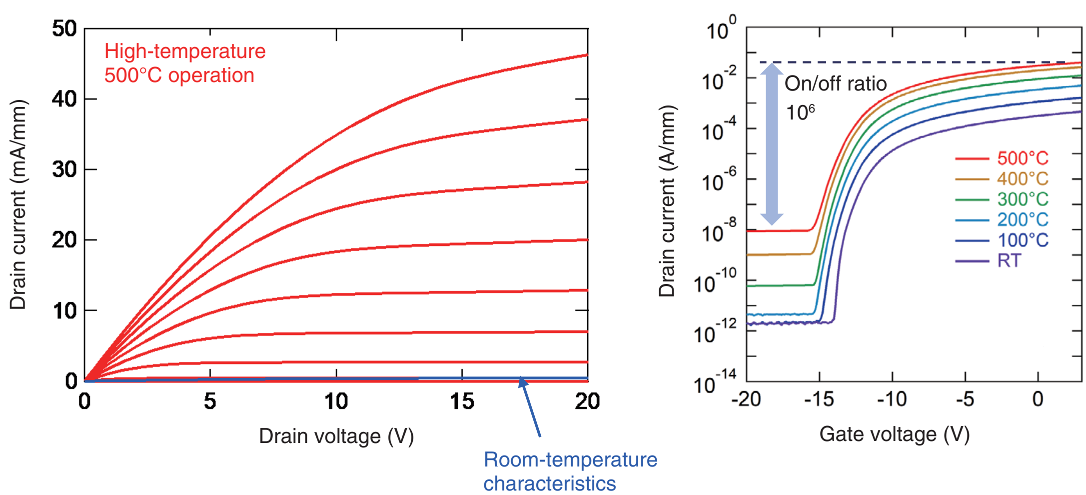

Fig. 2.   High-temperature (500°C) operation of AlN transistors.

Among ultrawide-bandgap semiconductors, AlN is advantageous in that (i) devices can be fabricated on large wafers, which are necessary for industrial applications, and (ii) various device structures can be fabricated by forming a heterojunction between AlN and GaN. However, AlN power devices have rarely been reported, and the characteristics of the devices that have been developed have not been outstanding.

By combining technologies that we have accumulated over the past 20 years, we developed a metal-organic chemical-vapor-deposition (MOCVD) system for fabricating high-quality AlN and succeeded for the first time in the operation of AlN transistors with good characteristics.

The current-voltage characteristics of our AlN transistor showed a linear increase in current due to its good ohmic characteristics and an extremely small leakage current[*3]. Its breakdown voltage, which is an important factor in the performance of power devices, was as large as 1.7 kV.

We also confirmed that our AlN transistor, unlike conventional semiconductor materials, can operate stably at high temperatures. Specifically, its performance improved at high temperature; namely, the drain current increased about 100 times at 500°C than at room temperature. Even at 500°C, the leakage current was kept extremely small at 10^{-8} A/mm. As a result, the on/off ratio of our AlN transistor was very high, over 10^6, even at 500°C (**Fig. 2**).

*3 Leakage current: An electric current that flows from insulating regions or on paths on which it should not flow in the electronic circuit.

—You are highly regarded both in Japan and abroad for your advanced research and technological capabilities.

Thankfully, our research results have been globally recognized. In 2011, at the age of 37, I received the Young Scientists' Prize, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology. The prize is awarded to young researchers under the age of 40 who have achieved outstanding results from their research—such as exploratory research and research from an original viewpoint—that demonstrates a high level of research and development capability. In the same year, I also received the Young Scientist Award at the International Symposium on Compound Semiconductors (ISCS), the top international conference on compound semiconductors, which is a gateway to success as a researcher in this field. It is an award for achievements in the field of compound semiconductors by scientists under the age of 40. In 2012, I received the Best Paper Award at the International Workshop on Nitride Semiconductors (IWN), an international conference with more than 1000 participants, and in 2019, I received the Japan Society for the Promotion of Science (JSPS) Prize for pioneering research on wide-bandgap semiconductor UV LEDs.

Quantity creates quality

—Would you tell us what you value as a researcher?

I try not to take for granted what is considered common sense or established theory or what is written in textbooks. I say that because things written in the textbooks are the solutions found by the means available at the time of writing. Therefore, I explore other possibilities while referring to textbooks and work with both my head and hands, that is, I think and experiment a lot.

I ponder a problem over and over to find a solution. Sometimes I'm driven by my intuition in a way that I'm not even aware of, and say to myself, "This might work." At such times, by intently conducting experiments with a "Let's try it!" attitude, you can sometimes get good results. I respect the Nobel Prize laureate Dr. Hiroshi Amano, who invented the world's first technology for creating high-quality GaN crystals necessary for blue LEDs. He overturned the established theory in the field that "blue LEDs cannot be made from GaN." He believed in the potential of a material that no one else would pay attention to according to conventional theory and continued to conduct more than 1500 experiments with GaN. This perseverance led to great success. I think it must have been quite stressful for him until he got successful results. However, research activities are an act of attempting to solve problems that no one has yet answered, so it is not surprising that they often don't succeed quickly.

Nowadays, everyone talks about efficiency in regard to everything; however, materials research involves low-key efforts, and some things can only be revealed by doing a lot of work. Although it is said that "quality" is important in research, I believe that only when you pursue research through quantitatively large amount of effort, your sense is refined, and you can accumulate experience and knowledge, you will be able to understand what determines the quality of the research.

In that sense, it is very important for researchers to work in an environment in which their long-term commitment is appreciated. NTT Basic Research Laboratories provides such an environment, for which I am grateful.

—What are the responsibilities and joys of a researcher?

It is a joy for a researcher to be able to stand at the forefront and take on the challenges that people say "cannot be done," it is "just a dream," "difficult," "unintelligible" or "impossible." It is the responsibility of researchers to propose and explore new possibilities through such challenges.

Having curiosity and peers is crucial for conducting such research activities. When I was younger, I wanted to handle the entire research process by myself. However, I have learned through experience that by cooperating with many people, we can accomplish great things. In basic research, it is highly likely that new things will be created through multiple approaches of various experts using their techniques and ideas. The ideas of young people can be especially invigorating.

I want to be an "eternally young researcher" who continues to take up challenges without fear of failure; at the same time, I want to be a "visible researcher." That is, I want to be a researcher who learns from the achievements of my predecessors and, while passing those achievements on, builds up my own originality and strengths as a researcher so that people will recognize me as "Yoshitaka Taniyasu is the one for this research."

To all young researchers, let's pursue our research activities with conviction and determination while keeping with interest and curiosity as our driving force.

■ **Interviewee profile**

Yoshitaka Taniyasu received a B.E., M.S., and Dr. Eng. in electrical engineering from Chiba University in 1996, 1998, and 2001. He joined NTT Basic Research Laboratories in 2001, where he has been engaged in wide-bandgap semiconductor research. He received the Young Scientist Award at the 2007 Semiconducting and Insulating Materials Conference, the Young Scientist Award of the ISCS 2011, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology of Japan (the Young Scientists' Prize) in 2011, and the JSPS Prize in 2019.

Applying Optical Oscillator Networks to Diverse Problems as the First Step to Information Processing Systems of the Future

Takahiro Inagaki
Distinguished Researcher,
NTT Basic Research Laboratories

Abstract

In the field of computer science requiring advanced information processing, an algorithm called simulated annealing is widely used to derive optimal solutions from a combination of numerous options in a network. However, in an era in which increasingly complex networks are coming to be constructed, any approach based on conventional methods is reaching its limits. To break down this wall, information processing techniques that can be applied to a variety of physical systems are being proposed. In this interview, we talked with NTT Distinguished Researcher Takahiro Inagaki about his research on new computing systems using optical technologies.

Keywords: coherent Ising machine, optical oscillator, spiking neural network

Solving combinatorial optimization problems with coherent Ising machine technology using light

—Dr. Inagaki, please explain the nature of combinatorial optimization problems that have become a key issue in computing today.

A combinatorial optimization problem searches for a solution applicable to the current objective from a combination of multiple options. For example, "Should I turn left or right?" is a simple problem having only two options. However, the number of combinations increases exponentially as the number of options increases, resulting in a massively large number of combinations. As a result, deriving the best answer from among all combinations is extremely difficult even with today's digital computers. To solve such a difficult problem, algorithms such as simulated annealing that derive approximate solutions at high speed using heuristic techniques have come to be used. Simulated annealing is a very powerful algorithm, but as the network structure of options in a combinatorial optimization problem becomes increasingly large and complex, the computing time and energy consumption needed for obtaining approximate solutions with good results have become issues of concern.

In recent years, the Ising model has been attracting attention as a technique for solving such combinatorial

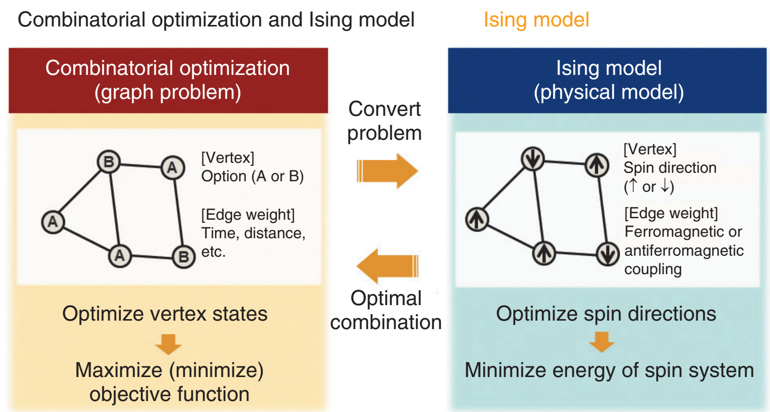

Fig. 1. Overview of combinatorial optimization problem and Ising model.

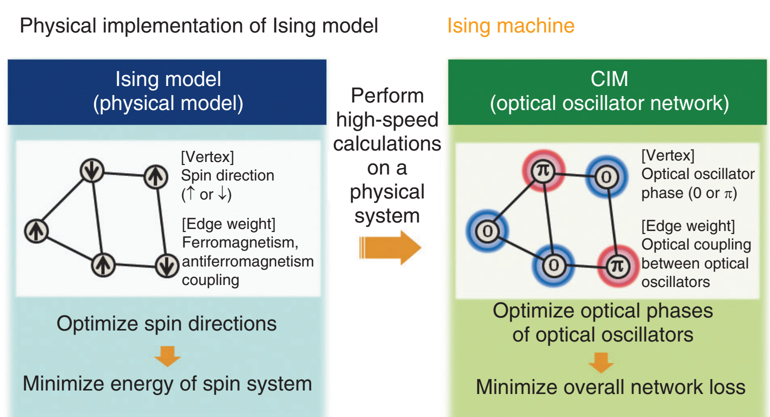

Fig. 2. Overview of CIM using the Ising model.

optimization problems at high speed with high accuracy. The Ising model is a network model featuring two types of states (spins), one in the upward direction and the other in the downward direction, similar to the S-pole and N-pole of a magnet. This model makes it possible to solve a combinatorial optimization problem by replacing two options in the problem with upward spin and downward spin and determining the optimal relationship among options through spin interaction (**Fig. 1**). Techniques for solving combinatorial optimization problems on a physical system based on this Ising model have been proposed such as a quantum annealing machine based on a network of superconducting qubits.

—What is a physical system that actually uses the Ising model?

We have developed an information processing system based on a new mechanism called a coherent Ising machine (CIM) by representing the Ising model using a network of optical oscillators. This computer divides output light into two states—0 phase and π phase—by using a special optical oscillator called a degenerate optical parametric oscillator (DOPO). Replacing these two states with spin directions achieves the Ising model using optical oscillators (**Fig. 2**).

This is a computer based on a new principle different from the simulated annealing or quantum annealing. A key feature of the CIM is that a network of same-phase or opposite-phase optical coupling can

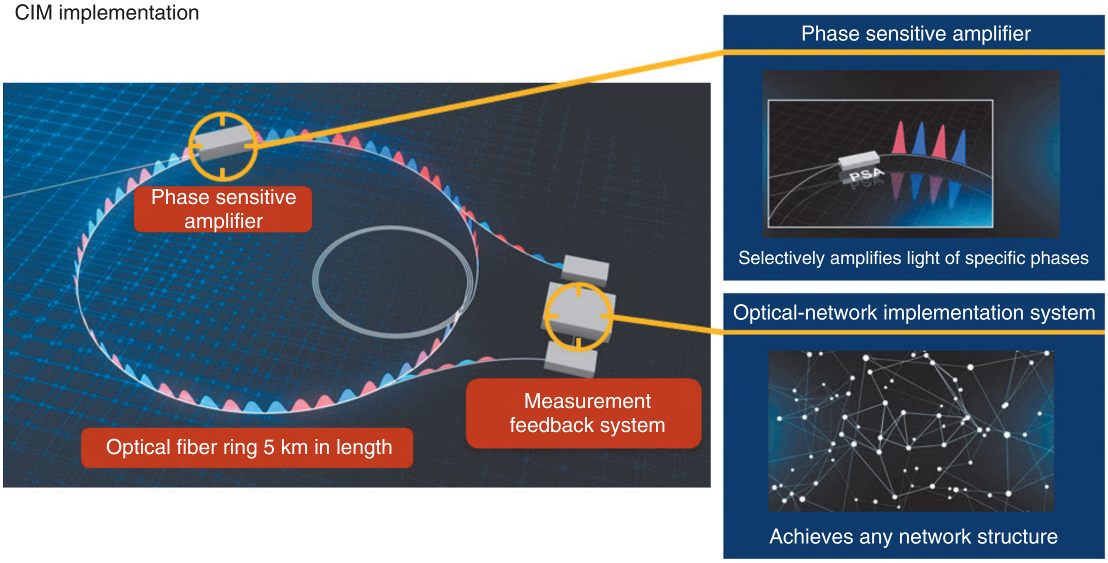

Fig. 3. System implementing a CIM.

be set up among all optical oscillators. Light has the property by which "energy is increased when same-phase light couples and decreased when opposite-phase light couples." The CIM naturally selects the 0-phase and π-phase states of all optical oscillators so that the energy loss arising from optical coupling in the entire network is small, which means, in terms of the Ising model, that spin directions change into states in which overall energy is low. By replacing this with combinatorial optimization problems, we can derive combinations of options producing excellent results.

There has already been much research on solving combinatorial optimization problems using physical systems and many proposals have been made, but a major issue here is how to prepare many uniform physical elements and implement a complex network among those elements. For example, in quantum annealing technology, a network is created by wiring together an arrangement of superconducting qubits, but variation in the quality of each element and spatial constraints in wiring have been problems in implementing a complex network structure. NTT's CIM, on the other hand, solves those problems in generating a network of many uniform optical oscillators by using time-domain multiplexing in a single optical circuit. In this way, running time-shifted optical pulses in a ring of optical fiber much like running trains on the Yamanote loop line in Tokyo makes it possible to create multiple optical oscillators and implement many uniform optical oscillators. Multiplexing in the time domain also makes individual measurements unnecessary since a single detector can be used to measure different optical oscillators in each time slot. A complex network can therefore be created based on the measurement results of a detector and feedback system. Using this technology, we have implemented a large-scale system having a maximum of 100,000 optical oscillators within an optical fiber ring having a total length of 5 km (**Fig. 3**). At present, we are searching for solutions of combinatorial optimization problems using this technology, which we expect will find use in a variety of fields such as drug discovery and radio frequency allocation.

—What is your current line of research?

Now, using the large-scale optical oscillator network that we have achieved in our CIM research as a foundation to work from, I am actively engaged in the research of spiking neural networks (SNNs) based on artificial optical neurons. From the beginning, I have been deeply interested in biological academic fields seeking to answer the question "What is the mechanism of the human brain?" Consequently, in many discussions with my fellow researchers, I and my collaborators wondered whether the spiking of nerve cells in the brain (firing phenomenon) could be simulated by applying DOPO characteristics using our

CIM. Inspired by this idea, I began my research.

One advantage of using DOPOs in this research is that the firing mode of artificial optical neurons can be freely selected by changing the pump intensity of the optical oscillators. In addition to the two types of nerve-cell firing modes called Class-I and Class-II that I am focused on in my present research, a variety of firing modes exist in the nerve cells of living organisms, and I believe that those modes could interact to perform advanced information processing. If we can use DOPOs to reproduce the firing modes of complex nerve cells in the brain and construct a network of diverse artificial optical neurons, we should expect to have a major advantage in understanding the mechanism of information processing in the brain.

We have so far conducted network experiments using a maximum of 256 artificial optical neurons. In these experiments, we began by observing basic artificial-neuron firing dynamics and then moved on to observing spontaneous synchronized phenomena in the network and synchronous/asynchronous coexisting states called chimera states, for example.

—What is your future outlook for optical SNN research?

As the next step in our research, we are expanding the scale of our optical SNN by constructing experimental equipment for 10,000 artificial optical neurons. To conduct tests with general machine-learning applications in mind, using 256 artificial optical neurons is still insufficient, so we are aiming for a 10,000-neuron network as our next target. In recent years, there has been much research on applying image recognition based on artificial NNs and information processing such as time-series prediction to SNN models, so I would like to implement applications like these in physical systems using our network of artificial optical neurons.

To completely imitate the human brain, I believe that the ultimate target is to achieve a large-scale neural network of from 10 billion to 100 billion neurons. But first of all, I would like to clarify the role that diversity in the neuron-firing model in our research plays in neural information processing. From here on, to achieve information processing that is even closer to the human brain, I will take up the challenge of incorporating knowledge of various firing modes including Class-I and Class-II modes in an optical SNN to clarify the information processing model of our brains.

To researchers who take a leap into the unknown and break new ground

—What is your impression of NTT Basic Research Laboratories where you currently work?

I think the image that "a corporate research laboratory conducts research and development along designated themes" is widely fixed in people's minds. However, NTT Basic Research Laboratories that I belong to, despite being a corporate research laboratory, enables researchers to choose research themes with a very high degree of autonomy. At our laboratories, we are conducting a wide range of research such as quantum information technology, on-chip optical circuits, and sensing-ware using bioelectrodes. I feel that this support for research diversity reflects, in the end, the autonomy given to researchers in their selection of research themes. Although each research group has a direction to some extent, I believe that NTT Basic Research Laboratories is a place where a researcher who can clearly explain his or her reasons for wanting to pursue a new research theme will receive full backing in launching that research. Research can provide much satisfaction once you have achieved your goal, but most of the work along the way can be hard and painful. This is why I think that the answer to the question "Are the research goals in line with the researcher's own motivation?" can greatly affect the quality of the final research results. In this regard, I consider that NTT Basic Research Laboratories, which undertakes basic research while respecting autonomy in research themes, has a rare approach to research in relation to other corporate research laboratories.

I also feel that the presence of many theorists in our laboratories is a great advantage. While many experiments are needed to connect technology from basic research to development, it is not unusual in our research for a single idea from a distinguished theorist to bring about a dramatic breakthrough and solve difficult problems in our experiments. In my group, persons working on theory sit with those conducting experiments in the same office, which enables us to discuss the data that we have obtained and exchange feedback on that very day thereby speeding up our experiments. Here, a theorist can predict more appropriate parameters from experimental results and an experimenter can reflect that prediction in the next experiment. This type of feedback loop is very encouraging. I think of it as a lighthouse whose beacon illuminates the path that we should be taking, and I feel that it is simply the greatest strength of NTT Basic Research Laboratories.

—Dr. Inagaki, please leave us with a message for researchers, students, and business partners.

For me, the real pleasure of research is the moment that I become the first to set foot in an area that no one knows about. When moving forward with my research, I feel as if a line is drawn out in front of me, and I love the fear and elation that I feel when venturing into pitch-black territory unexplored by mankind on the other end of that line. Ninety percent of the time, there is a cliff ahead that I fall off of, but on the other hand, there have been any number of times that I have entered into new ground. The key to success here is to be resolute in researching what you yourself think is interesting even if you should fail. This kind of trial-and-error environment is sufficiently rooted at NTT laboratories, and I feel very fortunate to be able to conduct my research in such an environment every day. Making preparations thinking that it's OK to fail and taking a step forward if it's pitch black ahead, or in other words, repeating a cycle of falling and getting up again is something that I would like to continue as a researcher while I'm still alive.

Additionally, there have been many cases in recent years of new research themes rising up at the boundaries of different research fields. For example, research of optical SNNs that I am now working on spans a broad range of research fields such as optics, brain science, and computer science, so I feel that it's research that cannot be handled by only one person. Under these conditions, I feel that being able to say "Could you help me?" to someone with the expertise that you need is absolutely essential to breaking through barriers. At present, I receive the cooperation of many individuals not only inside the company but outside the company too. The diversity of specialized fields in a researcher's network can be a great source of strength, so going forward, I would like to continue to be engaged in research that even researchers in other research fields find interesting. I would be glad to hear from anyone reading this article having interest in our research, and I look forward to taking on the challenges of new research fields together.

■ Interviewee profile

Takahiro Inagaki received his Ph.D. in engineering science from the Graduate School of Engineering, Tohoku University in 2012 and entered NTT in the same year. He has been a distinguished researcher since 2019. He is a member of the Physical Society of Japan (JPS) and the Japan Society of Applied Physics (JSAP). He received the Young Scientist Presentation Award from the JSAP in 2015, the Invention Award from the President of NTT in 2016, NTT Science and Core Technology Laboratory Group Director Award (Best Press Release) in 2018, and NTT Basic Research Laboratories Director Award (Achievement Award) in 2022. He is currently engaged in the research of information processing using quantum optics and quantum electronics.

Underwater Acoustic Communication Technology for Wireless Remotely Operated Vehicles

Ryota Okumura, Hiroyuki Fukumoto, Yosuke Fujino, Seiji Ohmori, and Yuya Ito

Abstract

Toward the 6th-generation mobile communication system, extreme coverage extension is expected to provide wireless communication services in the sky, at sea, and in space, which are regions not serviced by mobile communication systems. To achieve extreme coverage extension to the sea, NTT Network Innovation Laboratories is investigating higher-speed, longer-distance, and more stable underwater acoustic communications. In this article, we introduce our underwater acoustic communication technology and the feasibility demonstration of the world's first fully wireless remotely operated vehicle applying this technology.

Keywords: extreme coverage extension, underwater acoustic communication, remotely operated vehicle (ROV)

1. Demand for underwater wireless communications to achieve extreme coverage extension

Research and development (R&D) of the 6th-generation mobile communication system (6G) is in progress toward its implementation in the 2030s. 6G is expected to provide communication services for everywhere including the sky, at sea, and in space, which are regions not serviced by mobile communication systems, as well as enhance terrestrial wireless communication systems [1]. We call this concept of expanding communication coverage *extreme coverage extension*. The undersea region has been a region where wireless communications have not been widely used, although the utilization of wireless communications has been desired for enhancing operational efficiency in industrial sectors such as subsea resource development and port construction.

Radio waves are widely used in terrestrial wireless communication systems, however, they cannot be used similarly underwater because of high attenuation. Low-frequency electromagnetic communications have been put to practical use, but their transmission distance and speed are extremely limited. Therefore, using sound waves or visible light is effective for underwater wireless communications. Acoustic communications that use sound waves can use a higher frequency range and achieve longer transmission distance compared with electromagnetic communications. However, the frequency range is still much narrower than that of terrestrial wireless communication systems. The data rate of practical acoustic communications is less than 100 kbit/s, which can be used only for transferring sensor data. Optical communications that use visible light can use a wider frequency range than acoustic communications, so they are suitable for high-speed communication. However, the transmission distance for high-speed communication is limited because the turbidity of seawater attenuates visible light.

Because it is difficult to use flexible wireless communications underwater, unmanned exploration vehicles for resource exploration and underwater equipment for port construction are often connected to support vessels by wired cables for remote control. However, there are problems with equipment costs and personnel for handling the cable as well as with cables being swept away by the ocean currents. Small underwater drones, i.e., general-purpose remotely operated vehicles (ROVs), have appeared on the market, and many trials are being conducted to replace the tasks previously performed by divers, such as inspection of port facilities and fishing equipment, with ROVs. In such attempts, cable handling interferes with operations.

In summary, the market for underwater equipment, such as ROVs, is expanding, but wired communications at sea interfere with the flexible operation of underwater equipment. Therefore, there is a strong demand for Mbit/s-class wireless communication technology that can transfer detailed video in real time without cables. NTT Network Innovation Laboratories is conducting R&D on higher-speed, longer-distance, and more stable underwater acoustic communications toward achieving extreme coverage extension undersea [2].

2. Underwater acoustic communication technology

In underwater acoustic communications, it is difficult to achieve high-speed and stable communications due to the unique underwater environment and the characteristics of sound waves. A factor hindering high-speed transmission is delayed waves, which are caused by sound waves reflecting off the sea surface, seabed, or quays. A sound wave transmitted underwater arrives at the receiver not only as a direct wave but also as delayed waves through various paths, and the combination of these waves at the receiver results in distorted waves. To demodulate such received signals to achieve successful communication, the received signal should be compensated by inverse characteristics derived from estimated wave distortion. In underwater acoustic communications, the propagation speed of sound waves is around 1500 m/s, which is 200,000 times slower than that of terrestrial radio, so it causes larger and different propagation delays for each path. Each path is also affected by different Doppler shifts*1 due to fluctuations in the sea surface and vessels equipped with communication devices, resulting in drastic and complex fluctuations in the propagation path. Therefore, the distortion-compensation techniques used in terrestrial wireless communication systems cannot overcome this propagation-path variation.

Environmental noise, such as noise from marine life, is one of the factors that impairs the stability of acoustic communications. Snapping shrimp, which live in shallow waters around the world, are sources of environmental noise because they make snapping sounds with their claws when intimidating prey. This snapping is very loud, disrupting the stability of underwater acoustic communications.

In response to these problems, NTT Network Innovation Laboratories proposed the spatio-temporal equalization technique to achieve higher-speed communications and environmental-noise-resistance-improvement technique to achieve stable communications [3–6]. The use of the two techniques in underwater acoustic communication technology is shown in **Fig. 1**. The spatio-temporal equalization technique suppresses the effect of delayed waves caused by sea-surface reflections and extracts only the direct wave. This technique enhances the duration the propagation path is stable by removing the effect of delayed waves and improves compensation performance, thus contributing to increasing the data rate. Delayed waves are suppressed spatially and temporally by processing signals received at multiple antennas, i.e., forming the null of receiving directivity for the arrival directions of delayed waves. The environmental-noise-resistance-improvement technique controls the equalizer and error correction based on the assumption that loud environmental noise, such as snapping, temporarily contaminates the received signal. By suppressing the effect of environmental noise, this technique contributes to achieving stable transmission even in noisy environments.

We confirmed the effectiveness of each technique in achieving Mbit/s-class underwater acoustic communications through on-site experiments at sea. By the combined use of the spatio-temporal equalization technique and multi-input multi-output (MIMO)*2 transmission technique, high-speed transmission of 5 Mbit/s at a transmission distance of 18 m was achieved [4]. By integrating the environmental-noise-resistance-improvement technique and multi-carrier bandwidth-division transmission technique*3, we also confirmed the achievability of a data rate of

*1 Doppler shift: A phenomenon in which a frequency different from the actual frequency is observed when there is a relative speed difference between the observer and source of the wave (e.g., sound or light).

*2 MIMO: A technique that uses multiple elements for both transmission and reception to expand the capacity of wireless communications and improve the spectral efficiency.

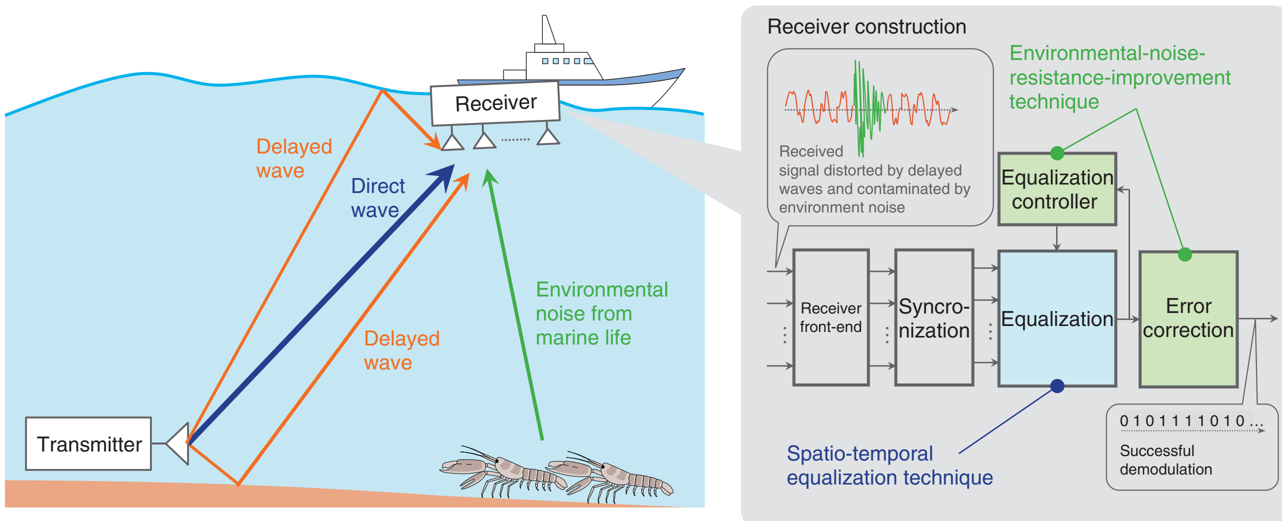

Fig. 1. Spatio-temporal equalization technique and environmental-noise-resistance-improvement technique for underwater acoustic communications.

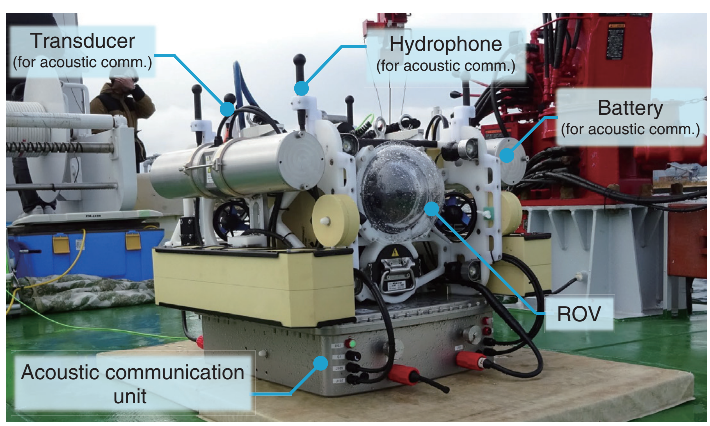

Fig. 2. Wireless ROV.

more than 1 Mbit/s at a distance of 300 m [3]. With Mbit/s-class data-rate communication performance, the acoustic communication technology can handle streaming traffic of standard definition quality (i.e., 640 × 480 px) video. Compared with conventional underwater acoustic communication technologies, our Mbit/s-class underwater acoustic communication technology can expand use cases including the transfer of detailed underwater video.

3. Wireless ROV

We consider a use case of Mbit/s-class high-speed acoustic communication technology involving a wireless ROV. NTT Network Innovation Laboratories developed the world's first wireless ROV by using our underwater acoustic communication technology [3, 7]. **Figure 2** shows the developed wireless ROV. The acoustic communication unit where the acoustic communication device and amplifiers are enclosed is located at the bottom of the ROV. At the

*3 Multi-carrier bandwidth-division transmission technique: A technique for transmitting a signal over a wide band by using multiple transducers with different resonant frequencies. It enables highly efficient transmission by parallel transmission (i.e., multi-carrier transmission) for each transducer.

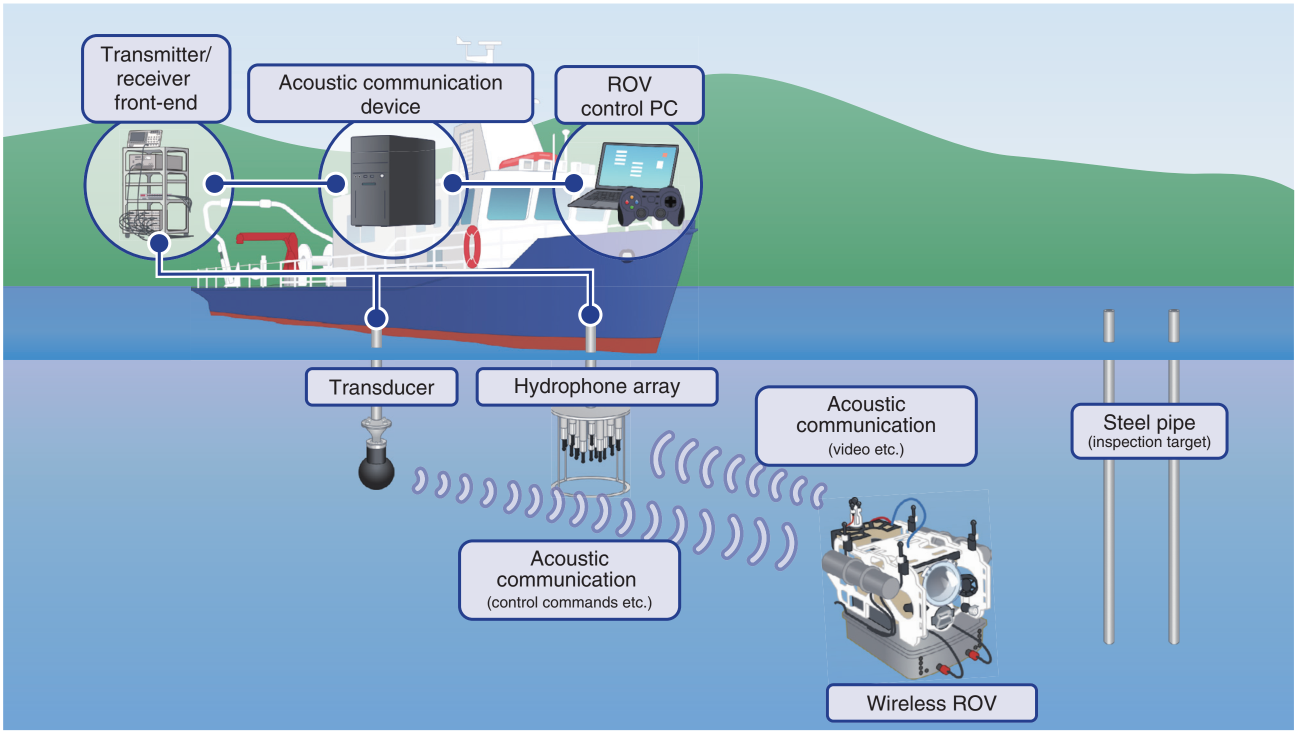

Fig. 3. Configuration of wireless ROV field demonstration.

top of the ROV, there are four transducers and four hydrophones that are used for transmitting and receiving acoustic signals, respectively. Batteries for the acoustic communication unit and buoyancy materials are attached on the sides of the ROV. The ROV can be wirelessly controlled and video can be wirelessly transferred for more than 2 hours.

4. Field demonstration of wireless ROV

To confirm the feasibility of the wireless ROV in a practical port environment, we conducted a demonstration experiment at Shimizu Port, Shizuoka City, Shizuoka Prefecture [7]. **Figures 3** and **4** show the system configuration, and photos of the demonstration site, respectively. A control center with equipment for wirelessly controlling the ROV was located on a ship moored at sea. Steel pipes were installed around the ship as the equipment-inspection target for the wireless ROV. We verified that the operator in the control center can control the wireless ROV by watching the transferred video, taking advantage of the wireless functionality of the ROV.

Bi-directional acoustic communications enable the remote control of the wireless ROV. The parameters for acoustic communications are summarized in **Table 1**. The data rates in the media access control (MAC) layer are 164 kbit/s and 13.2 kbit/s for uplink and downlink communications, respectively. In the uplink communications from the wireless ROV to the control center, video data and the wireless ROV's attitudes were transferred. At the control personal computer (PC) in the control center, a video of 640 × 420 px, 10 fps was displayed, a clip of which is shown in **Fig. 5**. **Figure 6** shows example results of the demodulation and estimated signal-to-noise ratio (SNR) of uplink communications measured during the demonstration. Except for the duration of sound waves blocked by air bubbles emitted by the diver pulling up the wireless ROV, all frames were demodulated successfully, and stable uplink communications were achieved. In the downlink communications from the control center to the wireless ROV, control commands were transferred. The operator manipulated the controller by referring to the video, and commands were successfully transferred to the wireless ROV via downlink communications. In addition to basic operations, such as observing each target steel pipe while watching transferred video, we conducted operations that are difficult for conventional

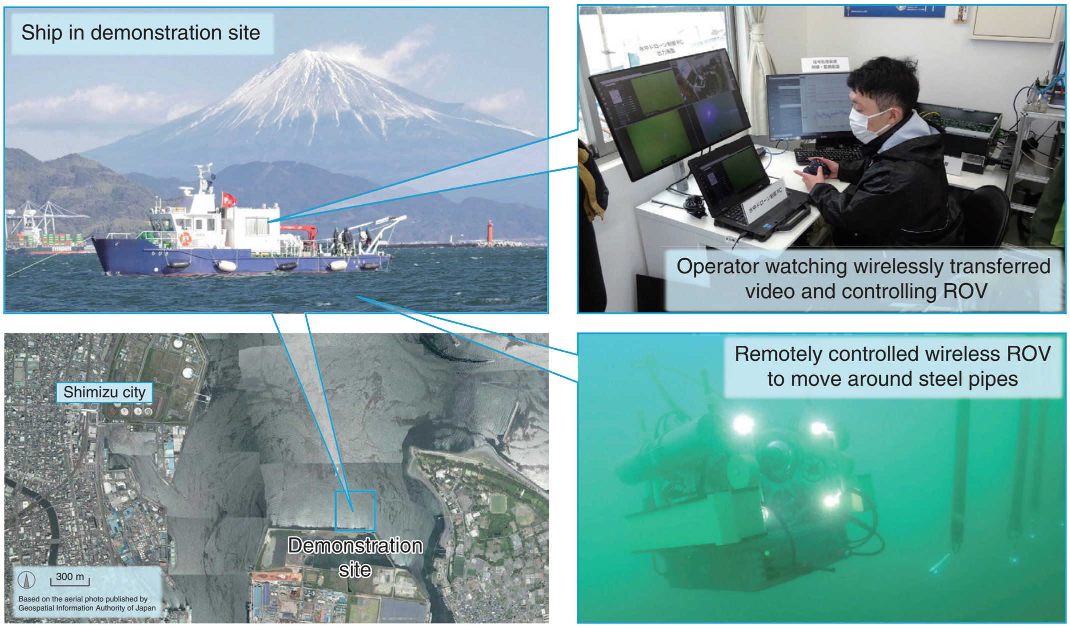

Fig. 4. Scenes from demonstration experiment of wireless ROV.

Table 1. Bi-directional communication parameters in wireless ROV demonstration.

	Uplink (ROV → control center)	Downlink (control center → ROV)
Number of transducers	4 (Changing active number depending on transmission distance)	1
Number of hydrophones	8	4
Center frequency	110 kHz	12.5 kHz
Bandwidth	120 kHz	10 kHz
Modulation	Single carrier, QPSK	Single carrier, QPSK
Coding	DVB-S2-compliant concatenated code	DVB-S2-compliant concatenated code
Acoustic frame length	153 ms	1831 ms
Throughput performance (in MAC layer)	164 kbit/s	13.2 kbit/s

QPSK: quadrature phase shift keying
DVB-S2: Digital Video Broadcasting - Satellite - Second Generation

wired ROVs, such as moving the ROV while dodging steel pipes and passing under the ship. The demonstration confirmed the flexibility of the wireless ROV.

Note that there may be restrictions on the size and weight of the wireless ROV equipment for underwater acoustic communications because the application of the target (i.e., the ROV) used in the demonstration was small. Also, the required data rate for transferring video is around 150 kbit/s; therefore, the equipment of the wireless ROV has limited performance, and the wireless ROV was operated with parameters that prioritize higher stability than a higher data rate.

5. Conclusion

This article described the R&D activities on underwater acoustic communications, including the feasibility

Fig. 5. Clip of video transferred from wireless ROV by using underwater acoustic communication technology (640 × 420 px, 10 fps).

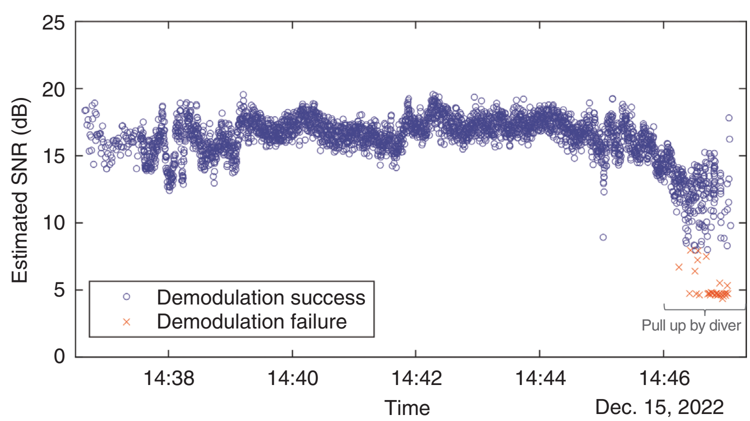

Fig. 6. Results of demodulation and estimated SNR characteristics in uplink communications measured at demonstration site.

demonstration of a wireless ROV. Toward achieving extreme coverage extension that enables underwater wireless communication services for various use cases, we will continue R&D of our underwater acoustic communication technology to achieve higher-speed, longer-distance, and more stable communications. We will also attempt to implement our underwater acoustic communication technology with NTT Group and partner companies.

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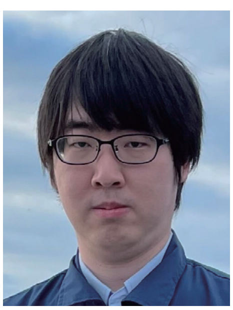

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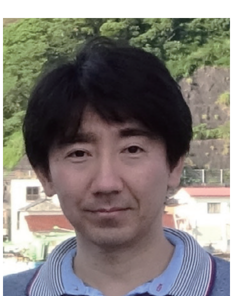

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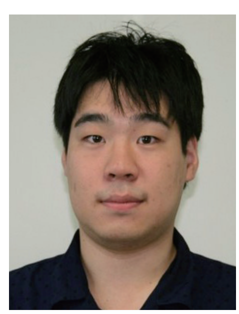

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Multi-layer Non-terrestrial Network for Beyond 5G/6G Mobile Communications

Fumihiro Yamashita, Munehiro Matsui, Hisayoshi Kano, and Junichi Abe

Abstract

NTT is currently investigating the Space Integrated Computing Network, which is a novel infrastructure that will integrate multiple orbits consisting of the ground to high-altitude platform stations, low Earth orbit satellites, and geostationary orbit satellites. This article introduces the concept of this network and the current research and development status at NTT Access Network Service Systems Laboratories, especially on non-terrestrial network technologies.

Keywords: satellite communications, HAPS, NTN

1. Introduction

NTT has announced the concept of the Space Integrated Computing Network as an element of the Innovative Optical and Wireless Network (IOWN) [1]. This concept assumes the use of geostationary orbit (GEO) satellites, low Earth orbit (LEO) satellites, and high-altitude platform stations (HAPSs) for achieving space sensing, space datacenter, and the space radio access network (Space RAN).

Space sensing is an internet-of-things (IoT) sensor-data collection and processing platform that will use LEO satellites to collect many low power wide area (LPWA) sensor signals on Earth, including oceans and rural areas. The collected sensor data will be sent to base stations on Earth and demodulated. Space datacenter will be part of the computing platform and data storage on GEO satellites to cleanse satellite observation data, e.g., photos and leader data. Space RAN is a non-terrestrial network (NTN) consisting of GEO/LEO satellites and HAPSs. This network will enable extreme cellular coverage extension in the Beyond fifth-generation mobile communication network (5G)/6G era [2]. Therefore, actualizing Space RAN is key to implementing the IOWN Space Integrated Computing Network.

Figure 1 shows the concept of Space RAN. It is currently common to use GEO satellite communications where terrestrial mobile cellular services are not provided. The networks for satellite communications are independent of that for terrestrial mobile cellular services. Toward Beyond 5G/6G, an NTN will consist of multi-layer networks comprising GEO satellites, LEO satellites, and HAPSs (multi-layer NTN). These satellites and HAPSs will be connected to each other by inter-satellite links. Since Space RAN will build a mutually complementary network with satellites and HAPSs, availability will increase compared with stand-alone networks (only GEO/LEO/HAPS networks) and a wide coverage area will be established. Therefore, Space RAN is expected to enable multiple use cases such as Internet connection services in airborne/vessels, wide area IoT services, and disaster relief.

2. Multi-layer NTN

2.1 Concept

Since the communication protocol for satellite communications is independent of that for cellular-phone

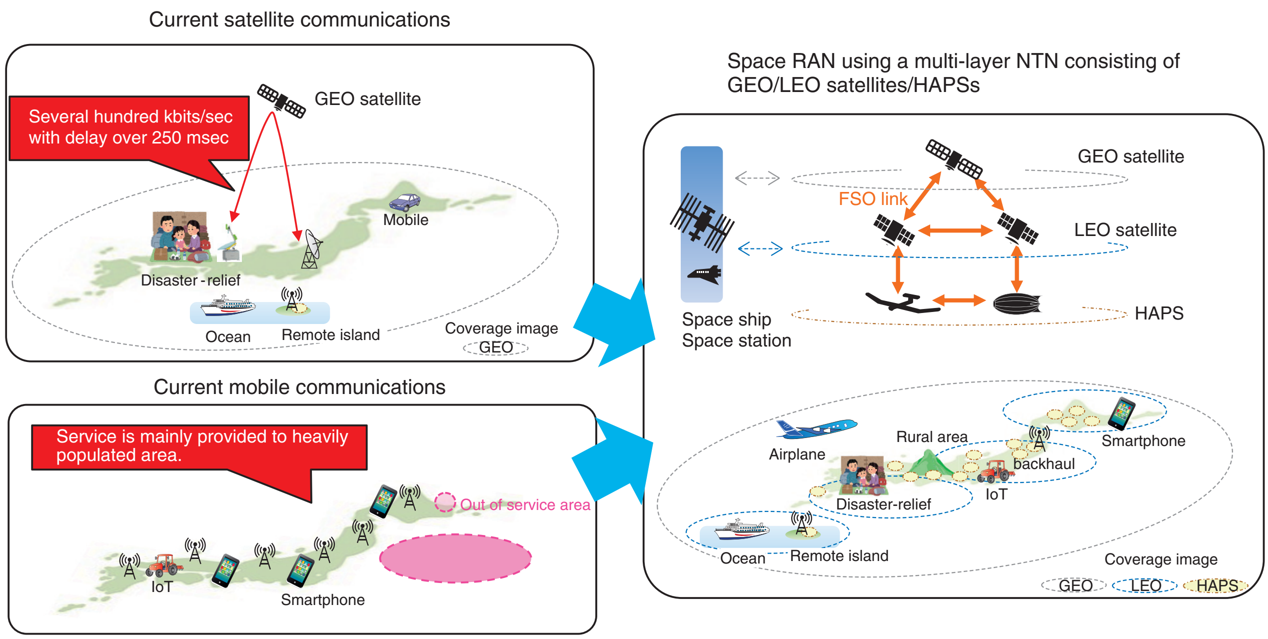

Fig. 1. Space RAN for Beyond 5G/6G mobile communication services.

services, the network for satellite communication services is also independent of that for cellular-phone services. The cellular-phone service area is currently limited to heavily populated areas, so such service is unavailable in rural areas or oceans. In the Beyond 5G/6G era, the goal is to provide extreme-coverage cellular-phone/smartphone services in new areas including space, sky, and oceans. It is highly expected that cellular phones/smartphones will be connected seamlessly to the core network via a GEO/LEO satellite or HAPS where the terrestrial network does not cover. For this purpose, a communication chip customized for using LEO satellites was developed and commercial services connecting smartphones and LEO satellites have begun. The current service is mainly message/text service for disaster-relief, but, the communication speed will increase in the near future for other services.

In the Beyond 5G/6G era, GEO/LEO satellites and HAPSs will have advantages and disadvantages in terms of service coverage, cost, delay, technical heritage, and so on. For example, the service coverage and delay time of GEO satellites are the largest. However, the delay time of LEO satellites is much smaller. To provide real-time communication services, hundreds or thousands of LEO satellites are needed. A HAPS flies much nearer the Earth compared with other satellites, so is expected to enable high throughput with small delay. However, its technologies are not yet matured and it takes longer to provide stable commercial services all year round. Therefore, Beyond 5G/6G communication services will be able to be provided by combining an NTN consisting of GEO/LEO satellites/HAPSs with a terrestrial network.

Figure 2 shows the research and development (R&D) milestones for achieving a multi-layer NTN. As we described above, to enlarge the service coverage using smartphones, HAPSs are the most promising NTN solution because it is possible to accommodate signals from smartphones at higher power compared with using satellites. For Milestone 1, service will start being provided in limited areas using a single HAPS.

However, since HAPS technologies are not yet matured, it is not practical to procure hundreds of HAPSs to cover the exclusive economic zone of Japan. Thus, it is reasonable to enlarge the service area of a HAPS using backhaul via satellite and provide services to limited areas. This configuration is considered Milestone 2 and will connect a HAPS with a GEO satellite as backhaul. Finally, a multi-layer NTN will be completed by including a broadband LEO network. This configuration is Milestone 3. In this milestone, GEO/LEO satellites will be vertically connected with HAPSs via free space optics

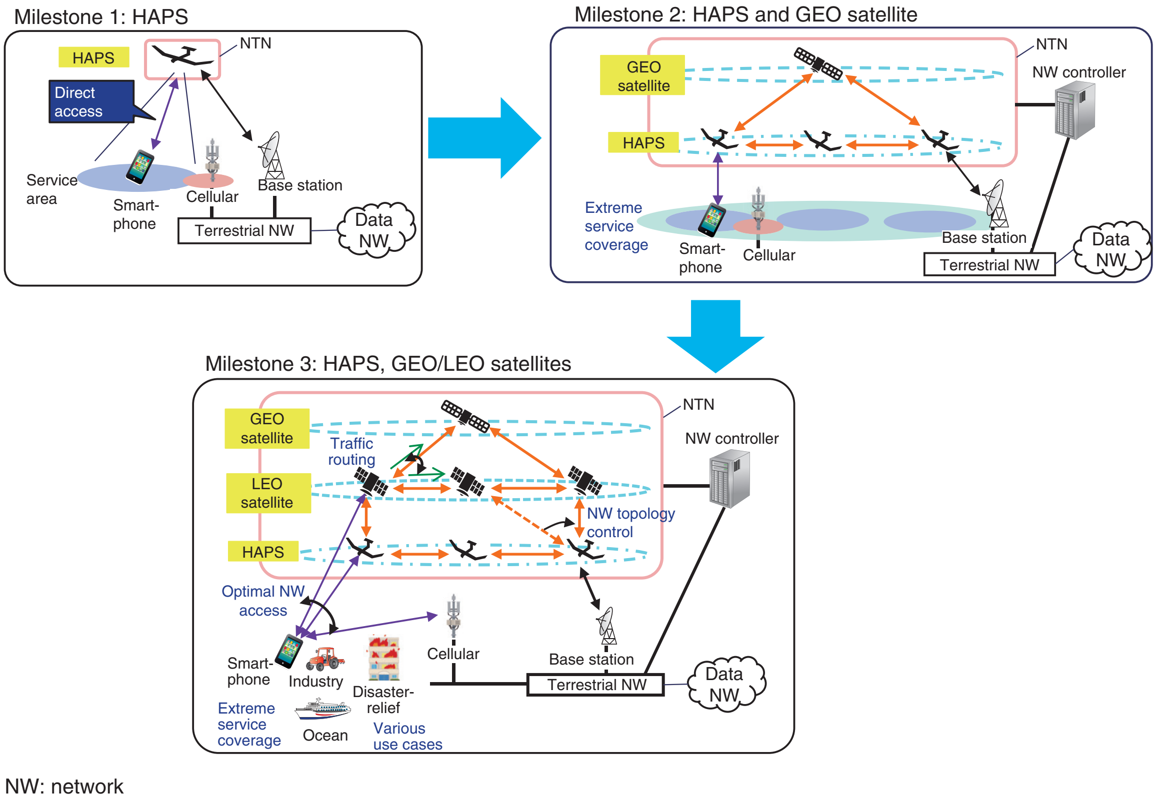

Fig. 2. R&D milestones for achieving a multi-layer NTN.

(FSO). The smartphone traffic will be flexibly transferred via a multi-layer network on the basis of network congestion and application required quality.

2.2 NTN study items

GEO/LEO satellites and HAPSs are expected to be used to greatly enhance mobile-service coverage. This will contribute to the convenience and value of mobile communications. For example, a highly reliable messaging service and ultra-wide-area service coverage will be possible.

Figure 3 shows the joint R&D project for B5G (Beyond 5G)-NTNs funded by the National Institute of Information and Communications Technology (NICT) [3]. This project was promoted by SKY Perfect JSAT Corporation, NTT Corporation, NTT DOCOMO, INC., and Panasonic Corporation. This project consists of five study items.

(1) Research on NTN technologies:
- (1-a) Network-architecture design of B5G-NTNs
- (1-b) Network-control algorithm among multi-layered NTN nodes
- (1-c) Optical link for HAPS-HAPS connection

(2) Development of an NTN service:
- (2-a) Safety management system of small ships via the HAPS platform
- (2-b) In-flight communications by dual connectivity of a satellite and HAPS

2.2.1 Network-control algorithm among NTN nodes

NTT Access Network Service Systems Laboratories is mainly investigating item (1-b) in collaboration with other companies. For network control among NTN nodes, since the frequency band of the feeder link for a HAPS is the Q band, problems occur when the feeder-link communications are interrupted due to rain attenuation. In this case, traffic is concentrated on a specific link. When the traffic flows exceed the network capacity of a link, packet loss or transfer delay occurs due to traffic congestion. To overcome this problem, we proposed a traffic-control algorithm suitable for NTNs [4].

Our algorithm is shown in **Fig. 4**. For transferring traffic over the sea, two approaches are assumed, transferring traffic by hopping adjacent HAPSs and

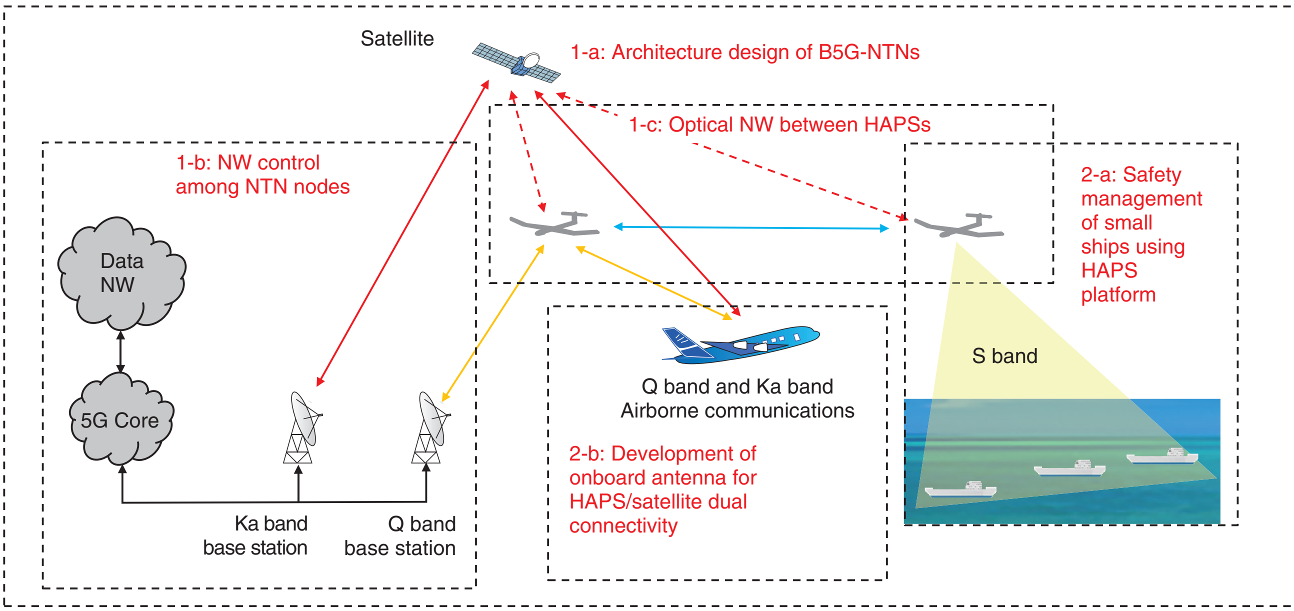

Fig. 3. NICT R&D project for B5G-NTNs.

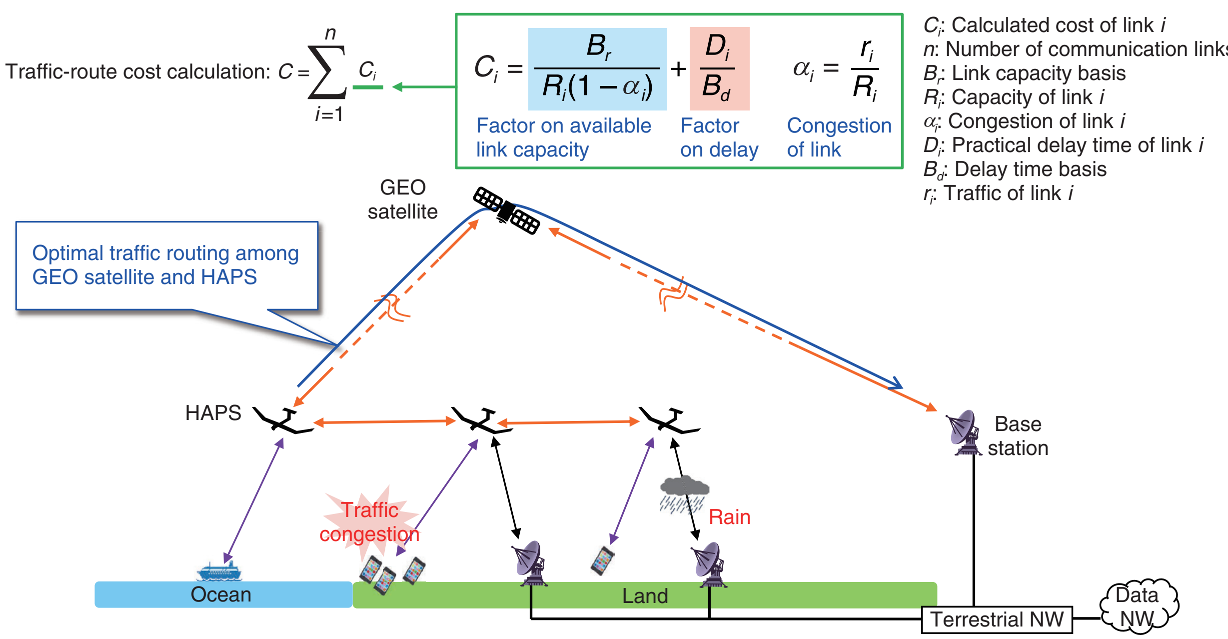

Fig. 4. An example of traffic control by using multi-layer NTN consisting of a GEO satellite and HAPSs.

transferring traffic by hopping satellites as well as HAPSs. Our algorithm calculates the network cost C on the basis of congestion and/or delay route by route then selects the optimal route that minimizes C. The simulation results indicate that the algorithm distributes traffic and avoids traffic concentration on a specific link even under rainy conditions [4].

2.2.2 HAPS technologies

The weight and power budget for onboard equipment of HAPS is so limited that it is difficult to carry out onboard signal processing such as in terrestrial base stations of cellular phones. HAPS technology needs to evolve to tackle this problem. For example, to enlarge the service area, multi-hop connection among HAPSs or satellites is needed. FSO is the key technology to connect adjacent HAPSs and is currently being investigated.

2.2.3 Communications using 30/40 GHz

To ensure high-speed communications in service links between a HAPS and smartphones, the communication capacity of feeder links between HAPSs and base stations needs to be increased. Thus, the frequency band around 30/40 GHz (Q band) was newly allocated for a HAPS in World Radiocommunication Conference 2019. It is advantageous to use a wider bandwidth at a higher frequency such as the Q band. However, millimeter waves are heavily attenuated by rain. To overcome this problem, a compensation method for rain attenuation is needed. We are currently researching a new proactive base-switching technique and traffic routing as well as conventional diversity techniques to avoid rain attenuation.

3. Summary

This article introduced study items focusing on NTNs, which NTT Access Network Service Systems Laboratories is currently investigating. NTT is currently promoting R&D for building the Space Integrated Computing Network by collaborating with other space research institutions and businesses.

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Position-control Technologies of Oceanographic Equipment for Ultra-wide-area Ocean-atmosphere Observation Technology

Yuka Shinozaki and Masaki Hisada

Abstract

NTT Space Environment and Energy Laboratories is investigating global environmental futures forecasting technology, which reproduces Earth's past and present in cyberspace and forecasts the future, with the aim of regenerating the global environment and environmental adaptation through global observations. In this article, we introduce *ultra-wide-area ocean-atmosphere observation technology*, which enables continuous, real-time, wide-area, high-density direct observation of the ocean on a global scale by using Internet-of-Things sensors, and discuss its main components, i.e., position-control technologies for observation equipment.

Keywords: ultra-wide-area ocean-atmosphere observation technology, global environmental futures forecasting technology, typhoon observation

1. Initiatives for global environmental futures forecasting technology

NTT Space Environment and Energy Laboratories is investigating global environment futures forecasting technology [1], which reproduces Earth's past and present in cyberspace and forecasts the future, with the aim of regenerating the global environment and environmental adaptation through global observations. The ocean, which covers 70% of the Earth's surface area, involves extreme weather events, such as typhoons and linear precipitation zones, and greatly impacts our lives. It is important to enhance the direct observation data in the sea area for elucidating the mechanism and modeling of phenomena occurring in the ocean. However, due to various oceanic challenges related to power consumption, data communication, weather resistance, and position control, not enough observations have been conducted. In this article, we introduce *ultra-wide-area ocean-atmosphere observation technology* [2], which enables continuous, real-time, wide-area, high-density direct observation of the ocean on a global scale by using Internet-of-Things (IoT) sensors, and its main components, i.e., position-control technologies for observation equipment.

2. Ultra-wide-area ocean-atmosphere observation technology

Ultra-wide-area ocean-atmosphere observation technology (**Fig. 1**) is an observation technology for achieving ultra-low power consumption and enabling low-cost observation by placing IoT sensors in all areas of the ocean, including unexplored areas where direct observation has been difficult. In collaboration with NTT's Space Integrated Computing Network [3], observation data will be collected in real time from low-power wide-area radio waves emitted by IoT sensors via low-Earth orbit satellites and high-altitude platform stations. This technology will elucidate the mechanisms of meteorological phenomena,

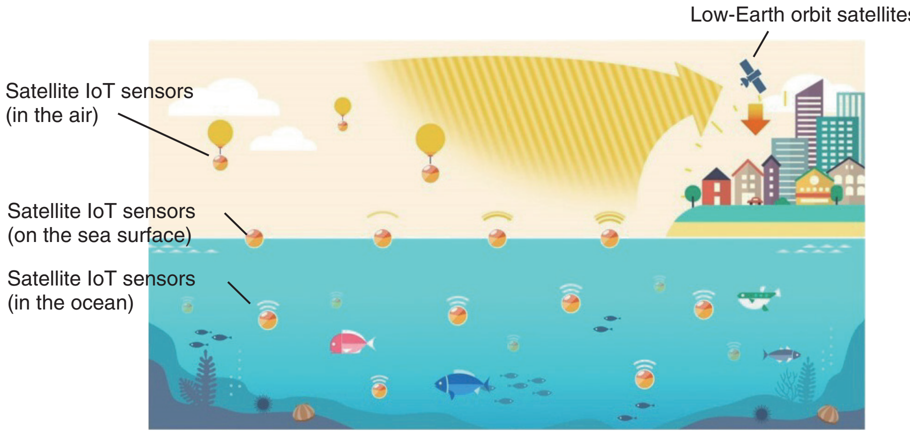


Fig. 1.   Ultra-wide-area ocean-atmosphere observation technology.

such as typhoons and linear precipitation zones, and marine ecosystems, such as microbes and nutrients, as well as acquiring oceanographic observation data that contribute to modeling the global environment in cyberspace. Remote sensing, which is mainly used for oceanographic observations, does not produce sufficient data both qualitatively and quantitatively, and several challenges unique to the ocean need to be addressed to enable continuous, real-time, wide-area, and high-density direct observation in the ocean.

The four main challenges with observation equipment are: reducing power consumption, ensuring communication with land, improving weather resistance, and controlling position.

2.1 Reducing the power consumption

For long-term oceanographic observations, it is essential to reduce the power consumption of observation equipment. Current oceanographic observations rely on batteries and photovoltaics for power, but battery replacement during the observation period is more difficult than on land, and solar photovoltaics are not able to provide power during rough weather. To enable long-term observations in the ocean, it is important to reduce the power consumption of onboard sensors and propulsion equipment. Longer observation periods reduce the frequency of equipment replacement, leading to lower observation costs.

2.2 Ensuring communication with land

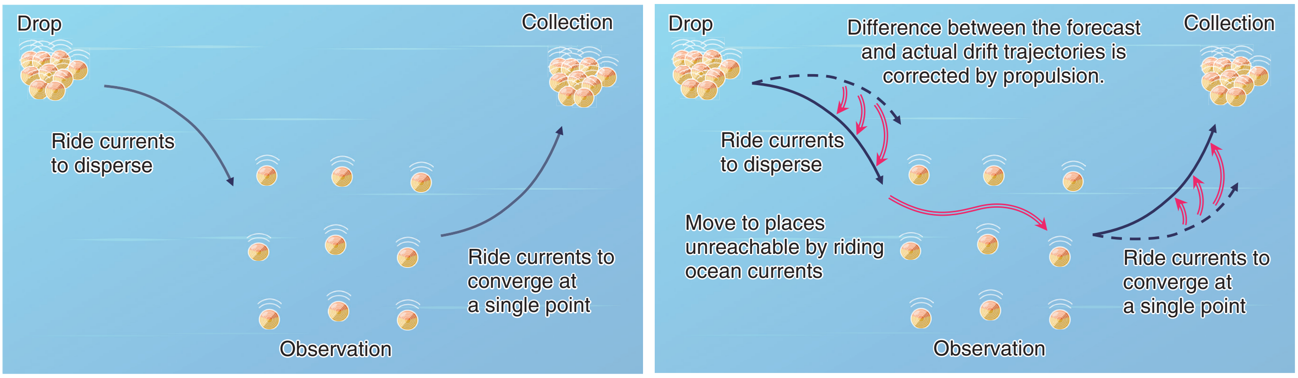
To collect observation data in real time from equipment located anywhere on Earth, it is essential to be able to communicate with base stations in a wide area and in large quantities. It is currently possible to collect observation data in the ocean far from land, mainly by using satellite communication, but there are problems such as the limited amount of data that can be transmitted at one time and the high cost of communication. It is also necessary to stabilize the transmission and reception of data even in ocean environments where waves exist around the observation equipment.

2.3 Improving weather resistance

To achieve stable oceanographic observations even in stormy weather such as typhoons, it is essential to improve the weather resistance of observation equipment so that observation can be conducted even in harsh environments. It is necessary to prevent electronic components of observation equipment used at sea from being damaged by submersion or salinity. It is also important to develop observation equipment to survive the harsh marine environment, e.g., constant swaying due to waves and wind, and strong winds and high waves such as during typhoons can cause fatal damage.

2.4 Controlling position

To achieve wide-area and high-density observations in areas affected by currents and winds, it is essential to control the position of observation equipment. There is a method of mooring observation equipment to the seabed with cables to fix their positions, but it is difficult and expensive to install in deep-water areas. Positions can be controlled with a propulsion device such as a screw propeller or water jet, but observation periods will need to be shorter



(a) (b)

Fig. 2. (a) Ideal oceanographic observations and (b) position control of observation equipment.

due to the large amount of power required to operate such a device.

We introduce two position-control technologies of oceanographic equipment for ultra-wide-area ocean-atmosphere observation technology to mitigate the above problems.

3. Position-control technologies of oceanographic equipment for ultra-wide-area ocean-atmosphere observation technology

In oceanographic observation using ultra-wide-area ocean-atmosphere observation technology, we aim to collect observation data by installing a large number of satellite IoT sensors evenly over a wide area. However, we need to collect these sensors for maintenance and replacement. Therefore, as shown in **Fig. 2(a)**, if satellite IoT sensors are placed in one general area, it will be possible to observe that area by automatically moving the sensors so that their positions are in a grid. This is ideal to efficiently collect sensors when necessary. However, when using observation equipment that does not have a propulsion device, such as buoys, the observation density will be biased due to the equipment being carried on ocean currents and wind. Because it is also very expensive to recover a large number of observation equipment scattered in the ocean, they are currently abandoned instead of being recovered. Certain observation equipment uses a propulsion device powered by electric power to control movement, but it is not suitable for long-term oceanographic observations that require lower power consumption. To overcome these challenges and enable effective and efficient observation, it is necessary to develop and implement position-control technologies for placing satellite IoT sensors by using external forces such as ocean currents, waves, and wind.

Therefore, we are researching and developing two position-control technologies to enable observation equipment to use ocean currents and winds for position control. One technology is based on drift-trajectory-prediction information [4]. Observation equipment in the sea is affected by currents and winds and drift on the sea surface, so this position-control technology uses the movement from this drift. The other technology is based on wave and wind propulsion technology. This technology uses waves and wind to add propulsion to observation equipment to control its position (**Fig. 2(b)**). We aim to enable oceanographic observation with position control without requiring electric power by combining these technologies.

3.1 Position-control technology with drift-trajectory-prediction information

Drift-trajectory prediction is a prediction of how a floating structure at a certain point will drift under the effect of currents and wind. Drift-trajectory prediction uses a model that shows how much the drift trajectory is affected by the shape of the floating structure and predicts the direction and amount of movement of the floating structure on the basis of the forecast data of ocean currents and wind by the Japan Meteorological Agency. The positions of satellite IoT sensors are controlled by predicting how they will move in the ocean and adjusting the location and time to install them. Current drift-trajectory prediction is not accurate enough; thus, it is essential to improve this accuracy. However, there is little observational data to compare forecasts with actual results. We aim to improve the accuracy of drift-trajectory prediction by continuously conducting such prediction during observations and accumulating observation data on the basis of predictions and actual results.

In March 2023, drifting observations were conducted off the coast of Miyako Island, Okinawa, Japan, using a drifting buoy (**Fig. 3**) equipped with a water-temperature gauge and the Global Positioning System to verify the accuracy of drift-trajectory prediction. We modeled the effects of ocean currents and winds on drifting buoys to make drifting-trajectory predictions and conducted actual drifting observations to verify such predictions. By analyzing the causes of the discrepancy between drift-trajectory predictions and actual drift trajectories, we are developing prediction models and gathering necessary input data to improve prediction accuracy.

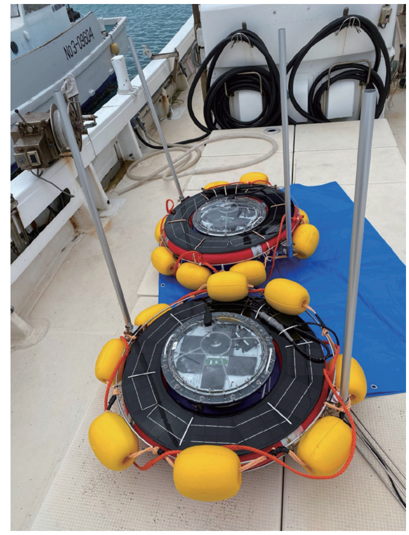


Fig. 3. Drifting buoy.

3.2 Wave and wind propulsion technology

It is also important to add propulsion to observation equipment to modify the position of satellite IoT sensors when controlling their position at sea. We aim to develop a propulsion system that converts waves and wind directly into propulsion, which can be supplied infinitely from the surrounding environment. By using both wave and wind power as the power source, we are developing a technology that can flexibly provide propulsion in accordance with changes in the weather. We set a goal to produce small observation equipment (total length: 1 m, total weight: about 25 kg) that can be easily loaded onto ships during installation and recovery even if a very large amount of equipment is in operation. We are currently designing propulsion systems using wave and wind power and using simulators for virtual verification. Using the verification results as a basis, we will build a prototype of the equipment that uses propulsion-control technology to improve the oceanographic observations.

4. Future prospects

We introduced ultra-wide-area ocean-atmosphere observation technology related to the position control of observation equipment. To enable long-term oceanographic observations, position-control technologies that do not depend on electric power is a major issue. With ultra-wide-area ocean-atmosphere observation technology, satellite IoT sensors are placed in the oceans on the basis of drift-trajectory prediction; thus, observations will be possible while controlling the equipment position using our wave and wind propulsion technology. By enriching observation data in ocean areas, it will be possible to accurately model physical phenomena such as ocean currents. We will also be able to gather a wide variety of data useful for the study of typhoons, linear precipitation zones, and ecosystems, as well as for various fields. In the summer of 2023, we will place drifting buoys in the path of typhoons using the drifting-trajectory prediction introduced in this article to monitor changes in sea temperatures before and after the passage of typhoons.

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Recent Activities of ITU-T SG13 on Future Networks

Yoshinori Goto

Abstract

This article introduces the recent activities of the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group 13 (SG13), which is responsible for the study on *future networks*. The study area covers, but not limited to, mobile networks, cloud computing, and quantum key distribution. Standardization organizations and groups are working toward implementing future networks in 2030. SG13 is expected to define the concept of future networks in this global standardization community.

Keywords: future networks, IMT, quantum key distribution

1. Introduction

As International Mobile Telecommunications-2020 (IMT-2020), which is also known as the 5th generation mobile communication system (5G), becomes mature, the global standardization community is moving toward *future networks*, which is sometime referred to as 6G and expected to be implemented in 2030. The International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group 13 (SG13) is responsible for defining the concept of future networks. A wide range of subjects, such as virtualization, artificial intelligence and machine learning (AI/ML), computing and network convergence, and quantum information technology, are being discussed. Different from the fora and consortia in which experts are mostly from developed countries, SG13 attracts many experts from developing countries who have different motivations and unique ideas. This article introduces the activities of SG13 focusing on future-network technologies that will be applied in next-generation mobile networks.

2. Overview of SG13

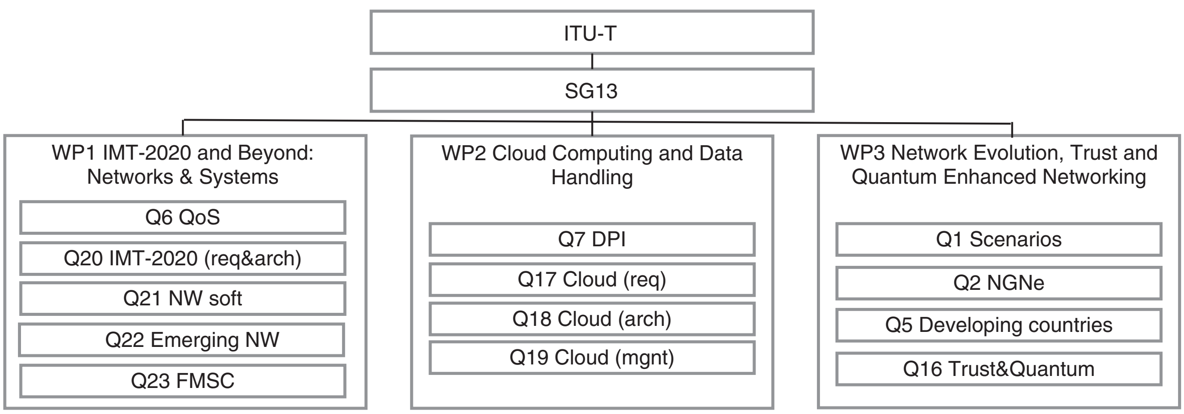
The major objective of SG13 is to define the concept of future networks. While other SGs are working on detailed technical specifications to be used in the implementation of technologies, the deliverables of SG13 are published as requirement and architecture documents showing abstractive views of the targeted systems and technologies. With high-level architecture, the targeted systems and technologies will be developed in various implementations optimized for real situations.

As the entrance of new ideas in ITU-T, SG13 welcomes new technical concepts that will drive the future information and communication technology (ICT) industry. Many proposals asking for new studies are submitted in SG13. Some of these proposals are more relevant for discussion in Focus Groups (FGs) in which the work methods are more friendly to academic experts as defined in ITU-T Recommendation A.7. FGs work intensively on specific subjects with limited lifetime in a flexible working environment.

In the more competitive environment of global standardization, where standard developing organizations (SDOs) are pursuing similar subjects with slightly different focuses, collaboration among SDOs to strengthen the value of standards is becoming important. SG13 uses the mechanism of Joint Coordination Activity (JCA) as defined in ITU-T Recommendation A.1. Although JCA does not produce any technical deliverable, it contributes to the global standardization community by providing a platform

Table 1. List of groups associated with SG13.

Group	Note
FG-AN	This FG is conducting pre-standardization work on autonomous networks since its establishment in 2020.
JCA-ML	This group coordinates the standardization work on machine learning among the SDOs and groups.
JCA-IMT2020	This group coordinates the standardization work on IMT-2020, which is equivalent to 5G, among the SDOs and groups.
JCA-QKDN	This group coordinates the standardization work on quantum key distribution networks coordination among the SDOs and groups.
SG13 RG-EECAT	This group promotes SG13 related activities in the region of Eastern Europe, Central Asia, and Transcaucasia.
SG13 RG-AFR	This group promotes SG13 related activities in the African region.



DPI: deep packet inspection
FMSC: fixed, mobile and satellite convergence
NGNe: Next Generation Network evolution
NW: network
QoS: quality of service

Fig. 1. Structure of SG13.

of information exchange among different groups within ITU-T as well as SDOs. The FGs and JCAs under the responsibility of SG13 or associated with SG13 are listed in **Table 1**.

The actual technical discussion of SG in ITU-T is carried out at Questions, which are small groups responsible for specific study subjects. There are 13 Questions grouped in 3 Working Parties (WPs), as shown in **Fig. 1**.

The SG13 meeting is held every 9 months. To accelerate the discussion, Joint Rapporteur Meetings consisting of all Questions and WP Plenary are held between SG meetings. This means SG13 has three chances of having intensive discussion across the entire SG and launching the approval process of its deliverables. SG13 attracts about 200 contributions and several hundred experts around the world. This fact shows that SG13 is not only one of the largest SGs in ITU-T but also its importance is critical to the standardization work of ITU-T.

3. Technical subjects

3.1 Mobile networks including IMT-2020

Mobile networks including IMT-2020 is one of the major study subjects of SG13. A mobile network consists of the wired section, which is under the responsibility of ITU-T, and the wireless section, which is under the responsibility of ITU Radiocommunication Sector (ITU-R). Therefore, the study scope of mobile networks in SG13 does not include the wireless section.

In the standardization work for IMT-2020 predating the work of FG-IMT2020, SG13 focused on the

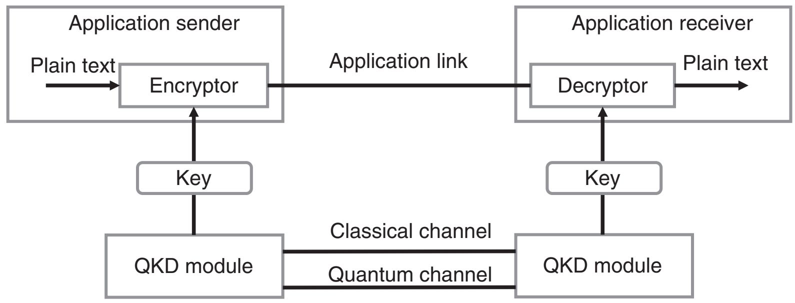


Fig. 2. Configuration of QKD networks.

concept of network resource virtualization, including the management of virtual networks called network slice. This study evolved to the application of AI/ML technologies for network management, which are conducted in FG-ML5G (Focus Group on Machine Learning for Future Networks including 5G) and FG-AN (Focus Group on Autonomous Networks). The standardization work in this field has progressed in collaboration with other SDOs such as ETSI (European Telecommunications Standards Institute) ISG ZSM (Industry Specification Group Zero Touch Network and Service Management).

3.2 Cloud computing

The cloud-computing study in ITU-T was launched from Focus Group on Cloud Computing (FG-Cloud) established in 2010. After conclusion of FG-Cloud in 2012, the work on cloud computing was transferred to the Questions of SG13 WP2, which was established to advance the work toward ITU-T recommendations. The computing industry has established its own ecosystem of standardization. Thus, it is important to consider the focus area of SG13 to avoid unnecessary duplication of this work. SG13 identified the inter-cloud, which is a use case of cloud computing connecting multiple datacenters via a wide area network, as relevant. The concept of inter-cloud is produced as ITU-T Recommendation Y.3511.

As the importance of data is being recognized by industry experts, the focus area of SG13 in the work on cloud computing has moved to data-related technologies. Particularly, cloud computing as the platform for big data is gaining momentum. A series of ITU-T recommendations for data providers, data brokerage, and data consumption have been produced.

3.3 Quantum key distribution

Quantum key distribution (QKD) (see **Fig. 2**) is a mechanism to share encryption keys between distant locations based on quantum physics. The safety of QKD does not rely on mathematical difficulties. Therefore, the safety of QKD is maintained regardless of the advancement of computing technologies, which will undermine the traditional key exchange technologies. The technology of QKD is becoming mature; thus, several implementations are being conducted in the field.

The study on QKD in SG13 was launched in 2018. It is well known that the transmission distance of QKD is limited within several 10 km. This makes the construction of a QKD network covering the whole nation difficult. Therefore, a wide area QKD network needs to deploy a number of intermediate nodes located every 10–20 km. A series of ITU-T recommendations, such as Y.3800 (general overview), Y.3801 (requirements), and Y.3802 (architecture), was produced on the basis of this idea. As shown in **Fig. 3**, further studies, such as key management, management systems, software-defined QKD, and secure storage, are progressing. The study on QKD is progressing mainly in Question 16, while its quality of service (QoS) aspect is being discussed in Question 6. The study items are also being coordinated with SG17, which is the lead study group on security.

3.4 Other subjects

Question 7 is conducting a study on deep packet inspection (DPI), which is a technical idea of using analysis of information contained in packets for network security and QoS. This technical idea is gaining the attention from national governments imposing the obligation of confidentiality of communications to their telecommunication carries. ITU-T recommendations on DPI contain text mentioning the compliance

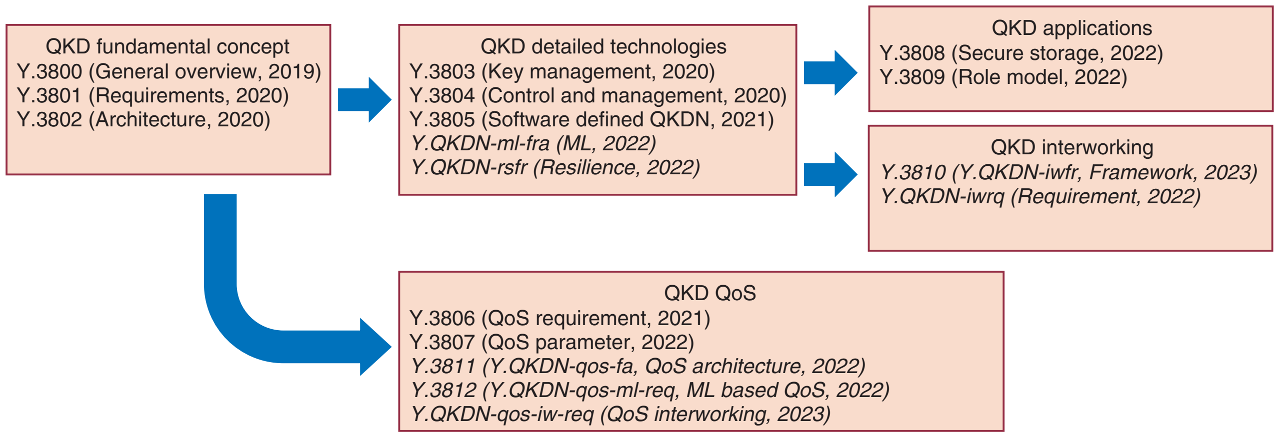


Fig. 3. ITU-T recommendations on QKD networks.

with national laws and regulations. Even with this notification, SG13 is continuing the debate on the use of DPI technology in networks.

The standardization discussions are being conducted mostly by experts from advanced countries. However, the majority of the Member States of ITU-T are categorized as developing countries and their opinions are still not well considered in the standardization discussion. SG13 has Question 5, a Question addressing the issues of developing countries. The participants of Question 5 are mostly from the African region and discuss the issues of, for example, the development of telecommunication infrastructure such as mobile networks and cloud computing. Their motivation is high. They submit contributions about the telecommunication infrastructure and economic development in the ICT industry and contain interesting information of the reality of developing countries that the participants from the advanced countries do not know. SG13 also established 2 regional groups, SG13 RG-AFR (Regional Group for Africa) and SG13 RG-EECAT (Regional Group for Eastern Europe, Central Asia and Transcaucasia), to encourage participation from these regionals.

4. Future activities of SG13

SG13 as an entrance of new technologies of standardization focuses on the concept of future networks. Currently, SDOs are working toward the vision of future networks targeting 2030, and ITU-R is working on the concept of future mobile networks. SG13 will accelerate the work on the wired section of future mobile networks.

In the study of IMT-2020, SG13 established FG-IMT2020 in 2015 and produced new concepts such as network slicing and network softwarization. Similar activities are expected for future mobile networks. Expected subjects are network management using AI/ML and computing/network convergence for supporting AI/ML, which are being discussed as beyond IMT-2020. Computing/network convergence is a relevant subject for SG13, which has been working in the area of cloud computing. The study on emerging technologies needs new participants with new ideas and culture. FG is the best platform to accommodate these new participants and promote the discussion of future network technologies.

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Field Trial of Preventive Measures for Insulation Faults in Aerial Electrical Cables

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Abstract

This article presents two preventive measures for insulation faults in aerial electrical cables verified in an actual facility environment. This is the seventy-seventh article in a series on telecommunication technologies.

Keywords: aerial cable, insulation faults, humidity control

1. Introduction

The insulation of electrical wires in aerial communication cables can fail when the insulating coating of the wire deteriorates and the inner copper core is exposed to the outside air through changes in the amount of rainfall or humidity. Addressing telecommunication failures associated with such insulation faults in aerial electrical cables requires a large number of work hours to search for and repair a faulty point; therefore, in terms of not only maintaining quality of telecommunication services but also reducing work hours, it is important to implement preventive measures against the cables being affected by changes in the amount of rainfall and humidity. This article presents two preventive measures for insulation faults in aerial electrical cables verified in an actual facility environment.

2. Mechanism of insulation faults

The mechanism of insulation faults in aerial electrical cables involves the following steps:

(1) The insulating coating of an electrical wire deteriorates through oxidation by oxygen in the air.
(2) This deterioration is accelerated by factors such as heat, ultraviolet light, and sea salt.
(3) Continuous cracks develop in the coating of the wire.
(4) Moisture (condensation or rainwater) deposits on the exposed copper core.
(5) Insulation resistance of the wire decreases, and the insulation fails.

The coating of an electrical wire inside a closure mainly deteriorates due to oxygen, heat, etc. and exposes the copper core inside the wire (**Fig. 1**). Moisture adheres to the exposed copper core and forms a water film, which lowers the insulation resistance between the wires (**Fig. 2**). If the insulation resistance falls below a certain threshold, i.e., insulation fault occurs, the quality of telecommunications degrades.

3. Overview of preventive measures

Humidity-control packs and coating gels are currently used by NTT EAST and NTT WEST as preventive measures against moisture (e.g., condensation) in closures caused by rainfall and humidity (**Fig. 3**).

The humidity-control pack is composed of highly

Fig. 1. Deterioration of insulating coating of electrical wires.

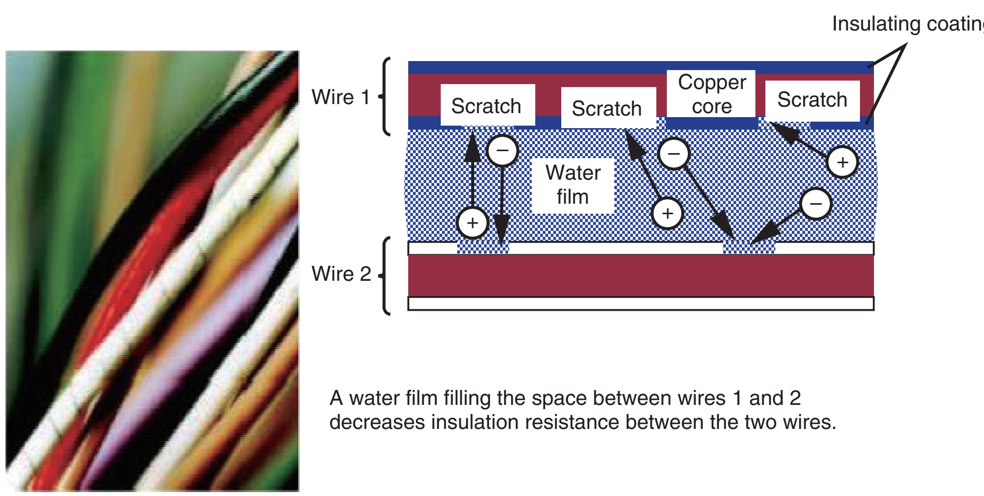

Fig. 2. Mechanism of decreasing insulation resistance.

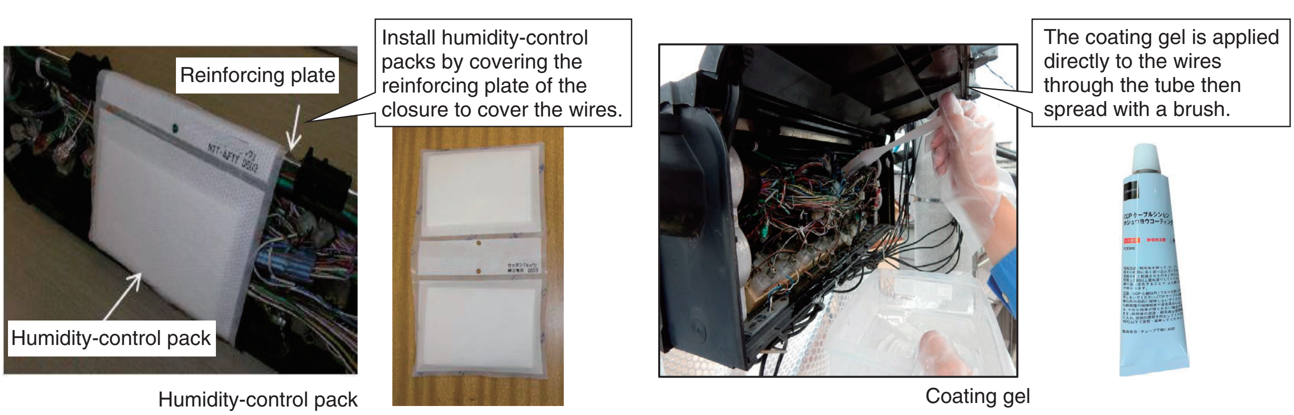

Fig. 3. Methods of implementing preventive measures.

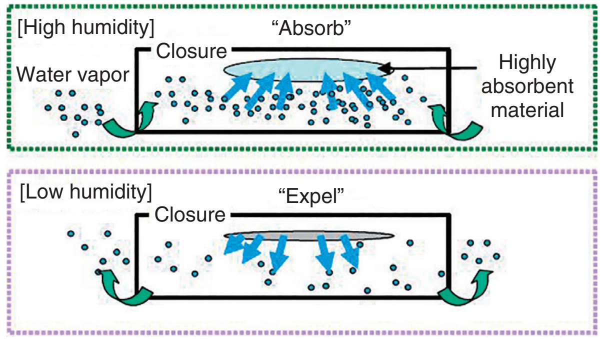

Fig. 4. Schematic diagram of humidity control.

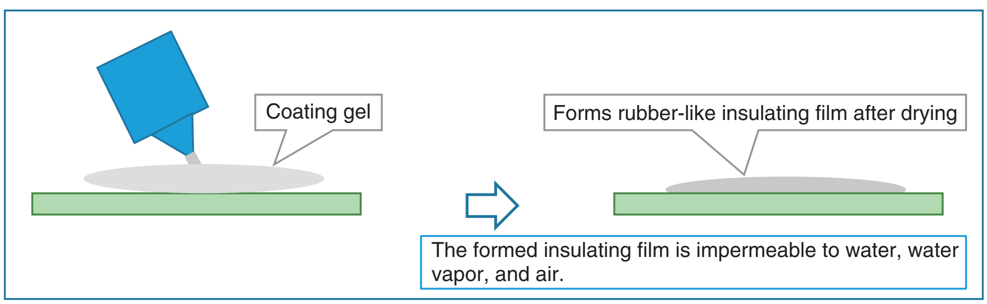

Fig. 5. Schematic diagram of insulating film formation.

absorbent polymer particles that can absorb moisture in a high-humidity environment and expel it in a low-humidity environment, keeping the humidity constant and prevent condensation by absorbing and expelling the moisture inside the semi-sealed closure (**Fig. 4**).

The coating gel is a coating material with excellent water resistance and electrical insulation. When applied to wires, the gel forms a rubber-like film after drying, which is expected to prevent exposed copper cores from coming into contact with adherent moisture and neighboring wires (**Fig. 5**).

4. Details of field trial

4.1 Trial area

We sampled areas with high failure rates of aerial electrical cables throughout the year and a significant increase in failure rates from July to September (a period of high humidity and rainfall in Japan) and selected three areas from those samples.

4.2 Configuration

To compare the effects of the preventive measures (humidity-control packs and coating gel) under the same environment in each of the three areas, we prepared three configurations, i.e., installation of humidity-control packs, application of coating gel, and no countermeasures implemented, for units*1 connected to the same central office in each area (**Fig. 6**). We selected two central offices per area and three units per central office (18 units in total) with relatively high failure rate and assigned the unit to each of the above three configurations at each central office (**Fig. 7**).

The two preventive measures were applied to all the closures connected to each unit to confirm their effectiveness of these measures.

4.3 Analysis method

Insulation-resistance tests of all the verification wires in the 18 units were first conducted in February,

*1 Unit: A set of electrical wires connected to and housed in cable cabinets installed in central offices. Each unit consists of 100 wires.

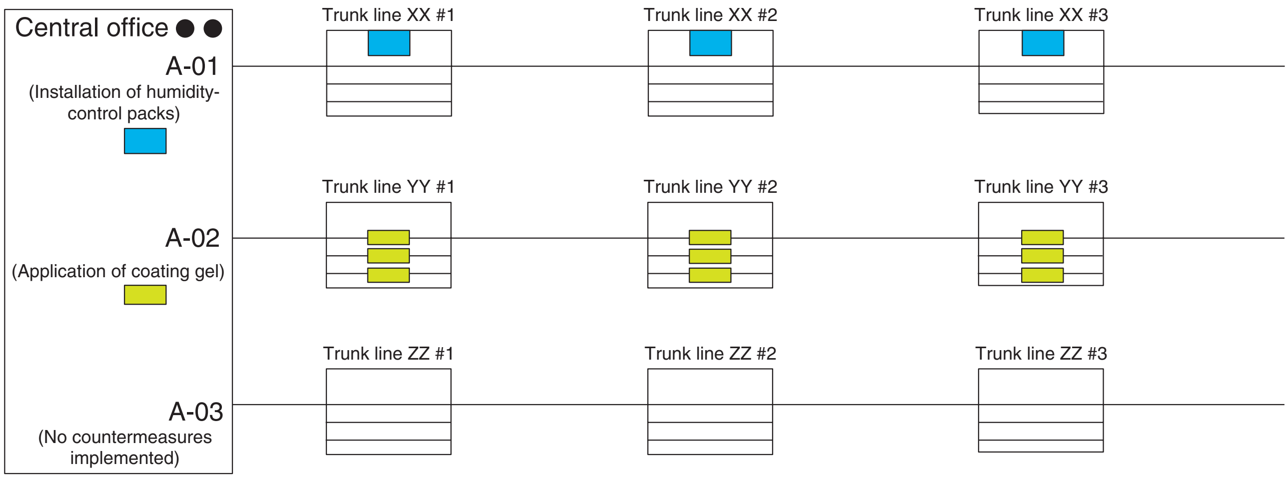

Fig. 6. Configuration of field trial.

Area	Area; Central office; Unit	Conditions
I	I : ● ● : A-01	Humidity-control packs
I	I : ● ● : A-02	Coating gel
I	I : ● ● : A-03	No countermeasures
I	I : ○ ○ : B-01	Humidity-control packs
I	I : ○ ○ : B-02	Coating gel
I	I : ○ ○ : B-03	No countermeasures
II	II : ▲ ▲ : A-01	Humidity-control packs
II	II : ▲ ▲ : A-02	Coating gel
II	II : ▲ ▲ : A-03	No countermeasures
II	II : △ △ : B-01	Humidity-control packs
II	II : △ △ : B-02	Coating gel
II	II : △ △ : B-03	No countermeasures
III	III : ■ ■ : A-01	Humidity-control packs
III	III : ■ ■ : A-02	Coating gel
III	III : ■ ■ : A-03	No countermeasures
III	III : □ □ : B-01	Humidity-control packs
III	III : □ □ : B-02	Coating gel
III	III : □ □ : B-03	No countermeasures

Fig. 7. Selected verification units.

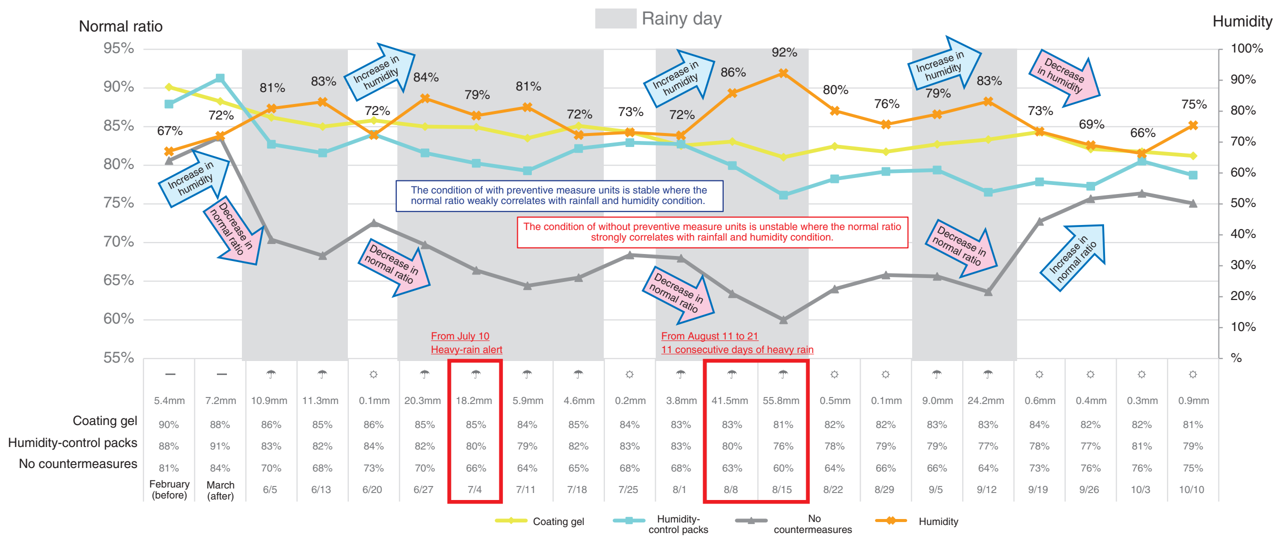

Fig. 8. Test results of verification units (weekly average: June 5–October 16).

before the implementation of the two preventive measures (referred to as February (before)), and in March, after the preventive measures (referred to as March (after)), when rainfall is sparse. To observe fluctuations in insulation resistance, the insulation resistance tests were then conducted daily at certain times during a five-month period (June 5 to October 16) when rainfall was plentiful. We focused on the ratio of the number of normal wires to the total number of verification wires (referred to as normal ratio) and investigated two points: (i) whether the normal ratio correlated with changes in the amount of rainfall and humidity and (ii) whether the preventive measures could mitigate the impact of changes in the amount of rainfall and humidity on the normal ratio.

4.4 Trial results

In all three areas, the normal ratio of the units without preventive measures being implemented (without preventive measure units) was unstable and decreased significantly during increases in rainfall and humidity. For units with implemented preventive measures (with preventive measure units), however, the decrease in the normal ratio was small and stable (**Fig. 8**).

Note that after September 19, for without preventive measure units, the normal ratio recovered to almost the same level as those from the February (before) and March (after) tests (Fig. 8).

5. Discussion

Since the normal ratio of both with and without preventive measure units decreases during heavy rainfall and high humidity, and that of without preventive measure units recovered as the amount of rainfall and humidity decreased after September 19, we consider that there is a correlation between the normal ratio and amount of rainfall and humidity.

From a viewpoint of the effectiveness of these preventive measures for mitigating the impact of changes in the amount of rainfall and humidity, we confirmed the normal ratio of with preventive measure units remained stable throughout the trial period (June 5 to October 16) (**Fig. 9**). This finding suggests that telecommunication failure caused by insulation faults due to condensation under high-humidity conditions can be suppressed by implementing these preventive measures.

6. Conclusion

The effectiveness of two preventive measures against insulation faults in aerial electrical cables was verified in an actual facility environment. The insulation resistance of without preventive measure units varies greatly during periods of high humidity and heavy rainfall and other periods; in contrast, that of with preventive measure units stayed fairly stable throughout the year.

Since aerial electrical cables are deployed with

	Normal ratio (mean value)			Variance*
	February (before)	March (after)	June to October	
Coating gel	90%	88%	84%	10.4
Humidity-control packs	88%	91%	80%	17.8
No countermeasures	81%	84%	69%	80.1

* A measure of how far the data are spread out from their mean value. Smaller value means a large amount of data are concentrated close to their mean value, corresponding to a stable condition.

Fig. 9. Normal ratio for each preventive measure (mean and variance).

multiple wire connections*2, installing humidity-control packs and applying coating gel to only some of the closures may not prevent insulation faults occurring in the unit. As confirmed from the results of this field trial, these preventive measures should be applied to all closures in the target units to increase the effectiveness of the measures.

The Access Network Engineering Group of Technical Assistance and Support Center, NTT EAST provides technical support to resolve difficult-to-solve failures of access network equipment and facilities that occur throughout Japan. We will continue to contribute to resolving problems in the field and develop tools for improving technical capabilities and efficiency by using the expertise gained through technical support and knowledge gained through the investigation of the causes of failures.

*2 Multiple wire connections: Wiring configuration in which a main wire and branch wires are connected in a closure, flexibly meeting customer demand at a wide range of locations.

External Awards

Best Paper (Outstanding User Modeling)

Winners: Takeshi Kurashima, NTT Human Informatics Laboratories; Tomoharu Iwata, NTT Communication Science Laboratories; Tomu Tominaga, NTT Human Informatics Laboratories; Shuhei Yamamoto, NTT Human Informatics Laboratories; Hiroyuki Toda, NTT Human Informatics Laboratories; Kazuhisa Takemura, Department of Psychology, Waseda University

Date: June 8, 2023

Organization: The International AAAI Conference on Web and Social Media

For "Personal History Affects Reference Points: A Case Study of Codeforces."

Published as: T. Kurashima, T. Iwata, T. Tominaga, S. Yamamoto, H. Toda, and K. Takemura, "Personal History Affects Reference Points: A Case Study of Codeforces," Proc. of the International AAAI Conference on Web and Social Media, Vol. 17, No. 1, pp. 507–518, Limassol, Cyprus, June 2023. https://doi.org/10.1609/icwsm.v17i1.22164

Papers Published in Technical Journals and Conference Proceedings

Simplest Fidelity-estimation Method for Graph States with Depolarizing Noise

T. Tanizawa, Y. Takeuchi, S. Yamashika, R. Yoshii, and S. Tsuchiya

arXiv:2304.10952, April 2023.

Graph states are entangled states useful for several quantum information processing tasks such as measurement-based quantum computation and quantum metrology. As the size of graph states realized in experiments increases, it becomes more essential to devise efficient methods estimating the fidelity between the ideal graph state and an experimentally-realized actual state. Any efficient fidelity-estimation method, in general, must use multiple experimental settings, i.e., needs to switch between at least two measurements. Recently, it has been shown that a single measurement is sufficient if the noise can be modeled as the phase-flip error. Since the bit-flip error should also occur in several experiments, it is desired to extend this simplest method to noise models that include phase and bit-flip errors. However, it seems to be nontrivial because their result strongly depends on properties of the phase-flip error. In this paper, by analyzing effects of the bit-flip error on stabilizer operators of graph states, we achieve the extension to the depolarizing noise, which is a major noise model including phase and bit-flip errors. We also numerically evaluate our simplest method for noise models interpolating between the phase-flip and depolarizing noises.

Anonymous Estimation of Intensity Distribution of Magnetic Fields with Quantum Sensing Network

H. Kasai, Y. Takeuchi, Y. Matsuzaki, and Y. Tokura

arXiv:2305.14119, May 2023.

A quantum sensing network is used to simultaneously detect and measure physical quantities, such as magnetic fields, at different locations. However, there is a risk that the measurement data is leaked to the third party during the communication. Many theoretical and experimental efforts have been made to realize a secure quantum sensing network where a high level of security is guaranteed. In this paper, we propose a protocol to estimate statistical quantities of the target fields at different places without knowing individual value of the target fields. We generate an enanglement between L quantum sensors, let the quantum sensor interact with local fields, and perform specific measurements on them. By calculating the quantum Fisher information to estimate the individual value of the magnetic fields, we show that we cannot obtain any information of the value of the individual fields in the limit of large L. On the other hand, in our protocol, we can estimate theoretically any moment of the field distribution by measuring a specific observable and evaluated relative uncertainty of k-th (k = 1, 2, 3, 4) order moment. Our results are a significant step towards using a quantum sensing network with security inbuilt.