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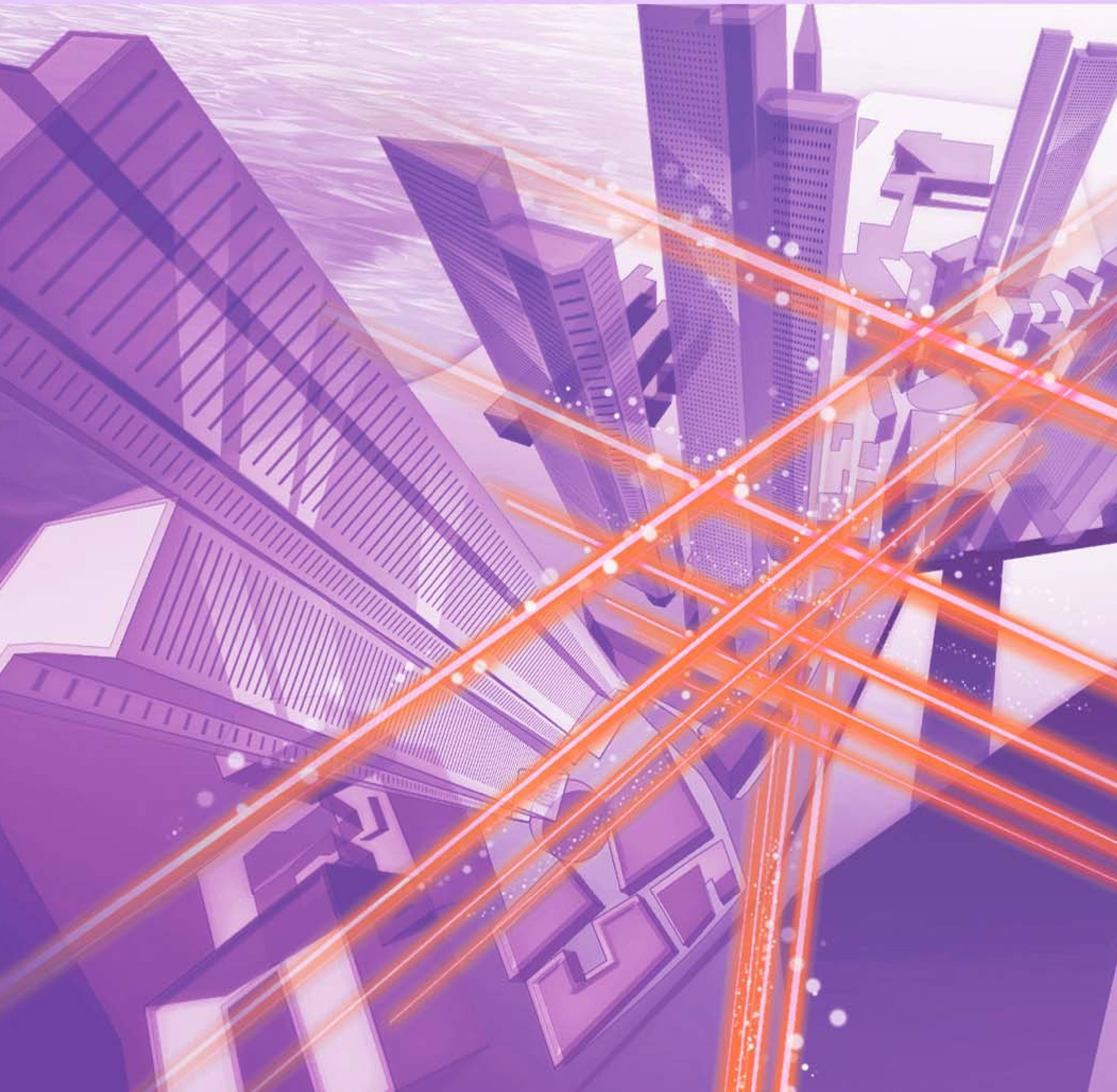

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Pursuing the Essence of Technology Thoroughly. Passion Is Something You Can Only Pour into What You Love

Seizo Onoe
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Abstract

Seizo Onoe, former chief standardization strategy officer of NTT and current director of the Telecommunication Standardization Bureau, International Telecommunication Union (ITU), has been awarded the 2025 IEEE Jagadish Chandra Bose Medal in Wireless Communications by the Institute of Electrical and Electronics Engineers (IEEE). As one of 21 IEEE Medals awarded in different fields, this award was established in 2025 as the award second only to the highest award, the IEEE Medal of Honor. To commemorate this award, we spoke with Mr. Onoe, who proposed the concept of Long-Term Evolution (LTE)—a key technology for 4G (4th generation of mobile communication systems)—and considered "the father of LTE," about his thoughts on receiving the award and evolution and standardization of mobile communication systems.

Keywords: standardization, mobile communications, LTE

The "father of LTE" receives a new award recognizing his contributions to wireless communication technology with a global impact

—Congratulations on receiving the 2025 IEEE Jagadish Chandra Bose Medal in Wireless Communications. What was the award ceremony held in Tokyo like?

Thank you. The award ceremony was held as part of a gala dinner attended by distinguished guests, and awards not only to me but also to other IEEE Awards winners were presented. When the awards were being presented, a short video introducing the winners was played in the venue, and on seeing the video for the first time, I was impressed with how well the photos and other materials that I had submitted were collated, and when I mentioned that impression in my speech, as well as the fact that I had just seen the video for the first time, the audience laughed.

The official notification of winning the award from the Institute of Electrical and Electronics Engineers (IEEE) was by email, which I missed. At the end of 2024, my secretary asked me if I had heard anything from the IEEE, so I checked my email and found that the email informing me of the official announcement of the award in the trash folder. Although I had been informed about the award prior to the email through another source, I was once again reminded that I had actually received the award.

In my career thus far, I have received the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology (Award for Science and Technology in the Development Category) in 2014, and the Medal with Purple Ribbon in 2018. Although it is always a pleasure to receive such awards, this latest award comes from the IEEE, so I am especially pleased to be recognized globally.

—This commemorative award is given by the IEEE Awards Program, the world's premier peer-recognition program, to outstanding leaders and visionaries who have made important contributions to the advancement of wireless communication technology that has significantly impacted the world. You are the first recipient of this award. Could you tell us again about the IEEE and this award and why you are the first to receive it?

As a public-interest organization dedicated to advancing technology for humanity, the IEEE is the world's largest technical professional organization. The IEEE is the trusted voice in a wide range of fields—from aerospace systems, computers, and telecommunications to biomedical engineering, electric power, and consumer electronics—and earns its reputation through its publications, conferences, technology standards, and professional and educational activities.

For over a century, the IEEE Awards Program has been honoring individuals who have contributed to the advancement of science, technology, and engineering in 21 areas of the technical field that the IEEE is interested in. As a newly established award (in 2025), the Jagadish Chandra Bose Medal in Wireless Communications will be awarded to individuals who have made a significant contribution to wireless communication technology. It recognizes outstanding technical contributions in wireless communications, implementation, standardization, or commercialization of new technologies, impact on the profession and/or society, leadership in achieving goals, previous honors, and other achievements such as publications, patents, or other materials. As the first recipient of this award, I have been recognized for my global leadership in research, development, and international standardization of 3rd generation of mobile communication systems (3G) and 4G and for my contributions to adoption of these standards globally.

Focusing on 3G and 4G, the award highlights my technical contributions, such as the development of cell-search algorithms; however, making me most fortunate and proud is the fact that I have been involved in all generations of mobile communications, from 1G to 5G and am currently working on 6G. I mentioned this fact in my acceptance speech, and I truly believe it. I feel that it was extremely fortunate that the award focused on the mobile communication generations that were at the most critical time in terms of standardization: 3G, which aimed to become a globally unified standard, and 4G, which achieved that aim.

For me, standardization has been a part of system development. It is just a tool, but it is an extremely important and powerful one that I have tried to make the most of. I believe the importance of standardization is not just discussing how to incorporate technology into standard specifications; instead, it is ultimately to spread the technology being standardized widely and to make it useful to society. I think this award is in recognition of understanding these beliefs and activities.

Being highly praised for contributions during the most important period of standardization: the 3G and 4G eras

—The award is being given to research and development concerning 3G and 4G. What are the characteristics of each generation of mobile communication system technology?

On joining Nippon Telegraph and Telephone Public Corporation in 1982, which was three years after the launch of the world's first car-phone service in Japan, I was assigned to a research laboratory. Although the number of subscribers to that service was not particularly large at the time, the development of a high-capacity system was a major theme. The 1G era was the dawn of analog mobile communications with many different standards in different countries. Starting with car phones, it evolved into mobile phone systems as terminals became smaller. In the 2G era, the number of standards decreased due to Europe unifying its standards; however, 2G systems in Japan, the US, and Europe were different. Japan and the US had made some efforts toward harmonization of 2G standards, and although they shared a common 3-channel time-division multiple access (TDMA) architecture, their 2G systems were incompatible. The Japanese 2G system was called personal digital cellular (PDC), in which voice is also digitally multiplexed. It enabled data and facsimile communications at 2400 kbit/s. The release of the "i-mode" mobile Internet service ushered in a period of explosive growth. Globally, the Global System for Mobile Communications (GSM) standard, which originated in Europe, spread across regions and around the world.

The concept of 3G was to develop globally unified radio interfaces, and discussions at the International Telecommunication Union - Radiocommunication Sector (ITU-R) led to the creation of the IMT Vision—Framework and overall objectives of the future development of International Mobile Telecommunications (IMT) for 2020 and beyond (Recommendation ITU-R M.2083), which included the goal of enabling 2-Mbit/s communications. Proposals were made from various countries and regions. In Japan, the wideband code division multiple access (W-CDMA) system promoted by NTT DOCOMO was selected at an early stage, which was ultimately adopted as part of IMT-2000. W-CDMA later evolved into HSPA (high-speed packet access), which enabled packet communication rate exceeding 2 Mbit/s up to 14.4 Mbit/s.

When 3G was officially launched onto the market, NTT DOCOMO was steadily progressing with research on 4G, and around 2002–2003, it achieved a data rate of 100 Mbit/s, and even 1 Gbit/s, at the research level. While research was progressing, however, the number of 3G subscribers was not growing as expected, and in this disappointing situation, it seemed extremely difficult to bring the results of 4G research to the market. The lesson learned from that period is that a smooth evolutionary path between generations is important. Therefore, we proposed the "Super 3G Concept." This concept was to first develop 3G—as so-called "Super 3G"—then build 4G on top of it. This plan was purely conceptual, and, in fact, our aim was to adopt orthogonal frequency-division multiplexing (OFDM) developed for 4G.

Standardization of Super 3G resulted in the Long-Term Evolution (LTE) standard. LTE uses MIMO (multiple input multiple output), a technology that increases communication speed by simultaneously transmitting and receiving data via multiple antennas. Voice over LTE, which digitizes voice signals and transmits them via packet communications, was also adopted, making it possible to adopt new audio codec for clear sound quality.

—Would you share any memorable episodes concerning the difficulties that you faced in the arena of international standardization, where the aims of various countries and regions intersect?

For 3G, the aim was to create a globally unified standard, and fierce debate ensued as players from each country tried to make their technology the international standard. The debate became heated as each country and region selected their technology until, finally, each technology was integrated into the global standard.

At that time, five candidates, one of which was W-CDMA, were being considered for the standard system in Europe. Within the European Telecommunications Standards Institute (ETSI), a fierce debate regarding the choice between W-CDMA and time-division (TD)-CDMA continued for about a year. Japan had already decided to adopt W-CDMA, which was promoted by NTT DOCOMO. Although this discussion took place in Europe, NTT DOCOMO was also deeply involved, and as its staff member, I made business trips to Europe frequently during that time. At one such meeting with a European operator, it was agreed to use W-CDMA for wireless access with GSM as the core network protocol. Finally, at a meeting held in January 1998, it was decided that the European standard would be based on W-CDMA and partly incorporate TD-CDMA. During this process, I had a separate technical debate with an engineer from a vendor who was promoting TD-CDMA, but later, I co-authored an article with that engineer, and the article was published in the IEEE Communications Magazine.

In the United States, major players were promoting a different standard from W-CDMA, namely, CDMA2000. Although it may be seen as a battle between Japan and Europe versus the United States, strictly speaking it was not a battle between countries and regions but a debate between promoters of W-CDMA and CDMA2000 and a discussion between individual vendors and operators. This period was the final stage in our quest for a globally unified standard. It was not just a technical debate; it was also a debate over how to handle intellectual property rights (IPR) such as patents, which are, in a sense, inextricably linked to standardization. This situation put the progress of standardization in jeopardy to the point that, at the time, it seemed as if an international standard for 3G would never be established. Numerous attempts were made to technically harmonize W-CDMA and CDMA2000, but they were met with successive failures. In the end, the harmonization proposal discussed by the Operator Harmonization Group (OHG) was agreed upon. Although some parameters were changed to increase commonality, the proposal was to recognize both methods and define extensions for interoperability; in other words, it was not a truly globally unified standard. The IPR issue was also resolved by agreement between vendors, and standardization was to proceed in accordance with the OHG harmonization proposal. NTT DOCOMO was proceeding with system development in preparation for the commercial launch of 3G in 2001; however, changes to key parameters at the final stage and delays in standardization had a major impact on commercial-system development, which was a challenge.

In regard to 4G, the lesson learned from 3G—ensuring a smooth evolutionary path to the next generation—was important. I mentioned earlier that NTT DOCOMO's 3G business was not growing as expected, in fact, other operators, including those in Europe, were hesitant to invest in the next generation after making huge investments in 3G, and they were reluctant to standardize 4G. Therefore, standardization of 4G began with the creation of a group of people who wanted to start the standardization. We started with individual meetings with vendors with a strong influence on standardization, and we gradually increased the momentum for standardization through multilateral meetings including operators. These vendors included those who had been our opponents in the CDMA2000 debate, and we recognized that many of them were technically advanced and had respectable engineers. We moved forward in a cooperative relationship, just as in the phrase "yesterday's enemy is today's friend."

I remember that an agreement was reached to begin discussions at a meeting of the 3rd Generation Partnership Project (3GPP) in December 2004, and the content of an interview I gave with reporters there were reported on the front page of the Nikkei newspaper's morning edition on New Year's Eve as "Super Third Generation." As discussions at 3GPP progressed, the abbreviation for the work item, "LTE," which stood for "Long-Term Evolution," became well known.

Standardization of CDMA2000 as its evolved form, ultra mobile broadband (UMB), was also moving ahead. Since CDMA2000 was easy to upgrade from cdmaOne, which was considered the second generation, it quickly took off; however, W-CDMA was based on the GSM core network, and operators who used GSM, which had become widely used for 2G worldwide, naturally adopted it, so it became clear that the number of W-CDMA subscribers would surpass that of CDMA2000 many years after standardization of W-CDMA. In this situation, the major CDMA2000 operators announced that they would introduce LTE instead of its evolved form, UMB, and it became clear that LTE would become the only globally unified standard. I later had the opportunity to meet the chief technical officer of the CDMA2000 operator who is said to have made this decision and expressed my gratitude. Standards are not always decided in standardization forums; that is, they can be determined by the market. Ten years later, the importance of reading market trends and the correctness of the decision to ride on the success of GSM have been proven.

Promoting standardization to disseminate technology standards while making technology more affordable and spreading it further to create a world in which people can benefit from it

—Looking at standardization and research and development as a former developer of each generation of mobile communication systems and as your current position as director of the ITU's Telecommunication Standardization Bureau, what are your thoughts on the future development of Beyond 5G/6G technologies?

As exemplified by discovering the "law of great success for even-numbered generations of mobile communications only," I enjoy predicting future trends through analysis. I am always conscious of and analyze the trends in technology and development through wondering why they occur as they do. My intention is to grab people's attention with an unexpected message while conveying an important message.

When I looked at the technological developments in mobile communications from that perspective, I realized that this law of even-numbered generations' success would no longer hold in the future. I realized this when a reporter from the economics department asked me a simple question in a recent interview: "Why do mobile communication systems undergo a generational change?" Until now, a new generation has appeared about every 10 years. If that has happened three or four times, it is natural to think it will continue to be the case that a new generation will appear every 10 years.

Up until 4G, new wireless access technologies emerged with each generation change, from analog FM (frequency modulation) to digital TDMA, W-CDMA, and OFDMA. However, from 5G onwards, technologies can be said to be an extension of current technologies rather than ones based on new concepts. I called this way of extending current technologies, such as increasing the number of antennas, "brute-force technology." In terms of technological evolution, the situation is thus changing from 5G onwards. Furthermore, from the perspective of standardization, the situations up to 4G, which led to a globally unified standard, and the situation concerning 5G are different. In light of these changes, I have recently come to think that the application of the previous "law of mobile communication generations" to 5G and beyond may be in jeopardy.

In the case of 5G, while there is the positive side of attracting attention from other industries, which leads to collaboration between industries, I think there is also the negative side of 5G being used excessively as a marketing tool, causing confusion in the market.

It is important to identify the true nature of technology without being distracted by marketing and branding and consider carefully when and which technologies should be popularized in the next decade and the next generation. From my current position at the ITU, I must also pay attention to the fact that one-third of the world's population is still not connected to the Internet, and many countries still rely on 2G. A generational change that is faster than necessary risks widening the gap with these regions. It is necessary to pursue generational evolution that optimizes the ecosystem of the entire world for developing countries as well as technologically advanced countries.

—Finally, what are your future aspirations? And what is your message to the next generation of researchers and engineers, both inside and outside NTT?

When I first joined NTT, I conducted research and development out of curiosity, but in the end, the results of that research and development were not adopted, and I think now that the laboratory made the right decision that they were not truly useful. Even with those experiences, I have always worked on my job with a passion for technology. At the time, I was absorbed in research and development, and I never would have imagined receiving this award or being in the position I am in today. I was always striving to advance technology and improve performance. Generally speaking, technological advances lead to happiness in people's lives and society, but technology for the sake of excessive marketing, or advances that are not rooted in the essence of technology, have a negative impact on the world as a whole. Looking back from my current position, I need to examine whether my past attitudes and achievements had a positive effect on the global ecosystem, but I believe that technological advances have contributed to making society better.

Regarding my message to researchers and engineers, it is best for you to focus on developing technologies that interest and inspire you; however, it is important to remember that your work should be useful to people worldwide. Many different people populate the world, and they live with different cultural and economic backgrounds. Being useful to all those people means that technologies must be usable anywhere in the world; international standards make that possible. Therefore, I urge you to proceed with technological development with an awareness of the value of international standardization, and to progress in that manner, I also urge you to cherish your passion.

The current position of director of the ITU's Telecommunication Standardization Bureau is elected, and I am currently working hard to meet the commitment I made on being elected to spread technical standards worldwide. I believe that international standardization has value only when standards are not only developed but also widely adopted. I will continue to work diligently on international standardization to promote the spread of technology standards, thereby making services more affordable, spreading technology further, and working to create a world in which people and society can benefit.

Moving Ising Machines Forward While Taking a Step towards Quantum Networks by Multi-photon Entangled States Based on Time-bin Qubits

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Abstract

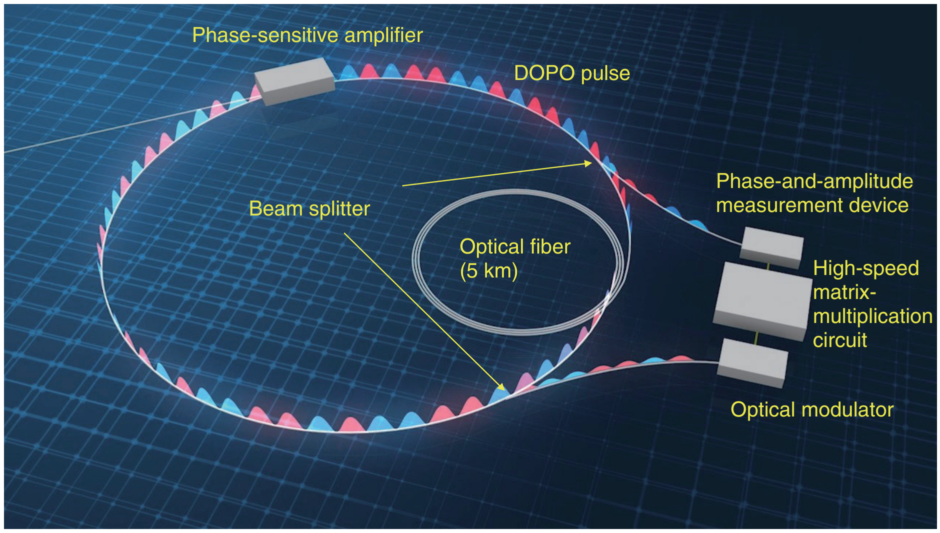
Solving a combinatorial optimization problem involves finding an optimal combination among a large number of options, and when the number of options becomes large, it becomes difficult to solve even with modern digital computers. We spoke with Hiroki Takesue, a senior distinguished researcher at NTT Basic Research Laboratories, who is exploring the "coherent Ising machine," a photonic computer that uses a network of optical oscillators to solve a combinatorial optimization problem. He is also studying the "quantum internet" by creating the world's first three-photon entangled state based on time-bin qubits. We asked him about his current efforts and thoughts on his research approach of working hard on site and getting outside once in a while.

Keywords: coherent Ising machine, multi-photon entanglement, time-bin qubit

Evaluating the performance of the coherent Ising machine in regard to solving problems directly related to applications while simulating the phase transition of a two-dimensional Ising model to understand the essence of a coherent Ising machine

—Would you tell us about the research you are currently working on?

My research is focused on two themes: the coherent Ising machine (CIM) and quantum communication using multi-photon entanglement. An Ising machine can be thought of as a physical simulator that simulates the Ising model. The Ising model is a theoretical model that describes the behavior of interacting spins. A spin is the angular momentum of a particle, which is a quantity that takes one of two values. It is known that many combinatorial optimization problems can be converted into problems to find the combination of spin values that minimizes energy in the Ising model. Accordingly, with physical experiments



DOPO: degenerate optical parametric oscillator

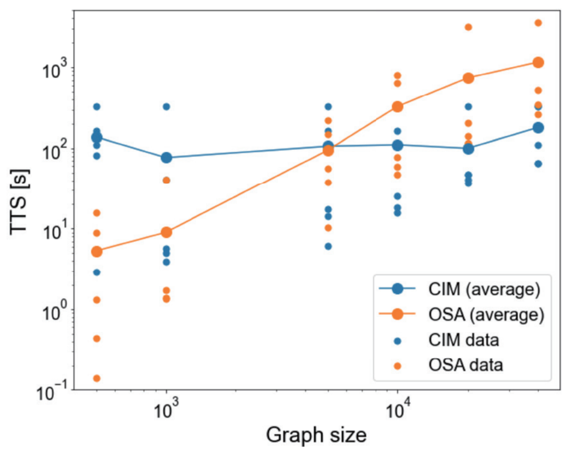
Fig. 1. Conceptual diagram of a CIM.

using an Ising machine, we can find the spin configuration that minimizes the energy; thus, we can obtain a solution to the target combinatorial optimization problem efficiently.

In 2016, in collaboration with various research institutes participating in the Impulsing Paradigm Change Through Disruptive Technologies Program (ImPACT) of the Cabinet Office, we developed two CIMs that can execute stable and high-speed calculations of the Ising model by using the phase (0, π) of a special laser (called an optical parametric oscillator) to represent a spin (**Fig. 1**). In 2021, we reported that we had increased the number of spins of these CIMs from 2000 to 100,000 in Science Advances [1]. These achievements generated a significant response and were cited in many papers. They have led to various new Ising machines being proposed by many institutions around the world. I have been invited to give talks at many international conferences and have also been increasingly asked to serve as a committee member for international conferences and overseas journals. I hope that Ising machines will continue to be developed and become established as a new field. As pioneers in the field of Ising machines, we are pursuing research to evolve CIMs, and that research has recently produced two significant results.

One result concerns searching for solutions to problems involving the magnetic-field term. Although an increasing number of institutions are researching physical Ising machines, such as a CIM, the majority of physical Ising machines only solve problems without the magnetic-field term. The magnetic-field term is a term in the Ising model Hamiltonian that corresponds to an external magnetic field, which forces the orientation of each spin either to positive or negative. A problem without the magnetic-field term is a basic optimization problem that only involves the term representing interaction between spins.

Since our team solved this basic problem in our first CIM experiments, many physical Ising machines of other research institutes have been evaluated using problems without the magnetic-field term. However, most real-world optimization problems are problems with the magnetic-field term, so for practical applications of CIMs, it is important to evaluate the performance of a CIM by using these problems. We proposed a method for implementing the magnetic-field term in a CIM by using some spins as auxiliary spins. We then used this method to search for a solution to the maximum-independent-set problem, one of the representative problems with a magnetic-field term, by using the CIM and optimized simulated annealing (OSA) implemented on a conventional digital computer. We generated graphs with numbers of nodes ranging from 500 to 40,000 and compared the average times to reach the target solution (TTS) by using OSA and the CIM (**Fig. 2**). According to the results in the figure, when the problem size was small, OSA was faster to obtain the target solution (shorter TTS); however, when the number of nodes was around



TTS is the average time to reach the target solution with 99% probability. Graphs of five different instances are created for each size, and the small dots represent the TTS of each instance, while the large dots represent the average TTS of the five instances. The target solution is set to the size of the largest independent set obtained using a CIM.

Fig. 2. Dependency of graph size on TTS.

5000, the performances of OSA and the CIM were about the same. It is shown in the figure that for larger problem (graph) sizes, the CIM obtained the target solution faster than OSA, and the difference in TTS widened as problem (graph) size increased. These results were published in Science Advances (a sister journal of Science) in February 2025 [2]. I believe that by solving the problem with a magnetic-field term by using a CIM (namely a physical Ising machine), we have made a step forward in the entire research field of Ising machines.

My other research result concerns understanding the essence of a CIM. Immediately after we announced our CIMs in 2016, which couple optical parametric oscillators through measurement and feedback, a question was raised as to whether measurement and feedback is equivalent to mean-field approximation, which is an approximation method well known in statistical physics.

The mean-field approximation reduces many-body problems, which take into account the interactions between many particles, to a one-body problem. In detail, the interactions of each particle with all other particles are considered an average effect, and instead of considering the interactions between individual particles (which are ignored), it is assumed that each particle behaves in an average "field." While the mean-field approximation can simplify calculations for many-body problems, it generally reduces the accuracy of the calculations.

While pondering ways to clarify the question "Isn't a CIM a mean-field-approximation solver?", I realized that all we needed to do was to simulate the phase transition of a two-dimensional Ising model on a CIM. As an important theoretical model, the exact solution of which was derived by Nobel Prize laureate Lars Onsager, the two-dimensional square-lattice Ising model is known to exhibit clear phase transitions. Interestingly, a mean-field-approximation solution of a two-dimensional Ising model is also well known, and the phase-transition temperature of the solution is clearly different from that of the exact solution. The results of an experiment using a CIM to reproduce the phase transition of the two-dimensional Ising model, as shown in **Fig. 3**, did not completely match the theory; however, we confirmed that the CIM clearly behaves closer to the exact solution rather than the mean-field approximation. I believe this result (shown in Fig. 3) strongly suggests that the CIM is not a mean-field-approximation solver but a physical simulator that simulates multi-body systems. These results were published in Physical Review Applied in March 2023 [3], and I believe we may have answered the question that had been posed to us.

Generating three-photon entangled states on the basis of time-bin quantum bits and contributing to the actualization of the quantum internet

—"Quantum communication using multi-photon entanglement" is your new theme, correct?

Since 2003, I have been researching quantum entanglement, which is a quantum state in which correlations exist between two or more particles that cannot be explained classically. Its existence was first discussed in a paper (which described the Einstein–Podolsky–Rosen paradox) by Einstein et al. in 1935, and quantum correlations have been researched extensively since then. In 2022, the Nobel Prize was awarded to Dr. Alain Aspect from France, Dr. John Clauser from the United States, and Dr. Anton Zeilinger from Austria for their experimental research on quantum entanglement.

In 2004, under the guidance of my then supervisor, Professor Kyo Inoue (currently Professor Emeritus at Osaka University), I generated quantum entanglement of photons in the 1.5-µm wavelength band in an optical fiber [4]. This experiment was the world's first to generate quantum entanglement in an optical

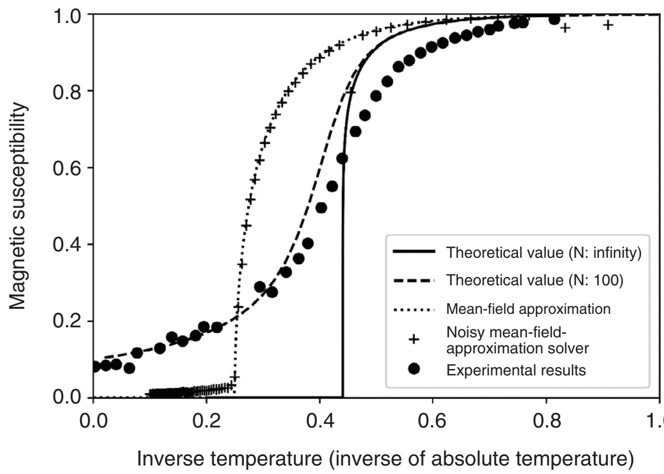


Fig. 3. Results of experimental simulation (using CIM) of the phase transition of a two-dimensional Ising model (● in the figure).

fiber, which rivaled that of the Prem Kumar group at Northwestern University, marking the starting point of my research on quantum entanglement. Although my experiment involved quantum entanglement of two photons, Professor Zeilinger's group, mentioned above, and others have advanced research into quantum entanglement of multiple photons, so it is now possible to generate quantum-entangled photon states of three or more photons. Most of these groups generated quantum-entanglement states related to the polarization state of photons.

While polarization-based qubits are easy to control in free space, they are subject to disturbances caused by fluctuations in the refractive index of optical fibers and polarization-mode dispersion during transmission in optical fibers. Aiming for applications to quantum communication using optical fibers, we have been researching—and were the first in the world to achieve—three-photon entanglement based on time-bin qubits, which are stable quantum bits that use a superposition state with respect to the temporal position of photons (February 2023) [5]. For a multi-photon time-bin quantum-entanglement generator (**Fig. 4**), one of two quantum-entangled photons from an entangled photon source and a single photon are input into an optical switch to entangle the photons in a manner that generates a quantum-entangled state between three photons, which include the remaining entangled photon from the entangled photon source. The three photons generated in this way have the property that, although the results of measuring each photon are completely random, the measurement results of these photons exhibit a clear correlation. On the basis of this three-photon entanglement, for example, quantum cryptography—a type of absolutely secure encrypted communication based on the principles of quantum mechanics—between three parties (Alice, Bob, and Charlie) will be possible.

Starting in FY2023, we have been participating in the Ministry of Internal Affairs and Communications' national project "Research and Development of Key Technologies for the Realization of a Quantum Internet," and we will be pursuing research with the National Institute of Information and Communications Technology (NICT), Osaka University, Yokohama National University, Gakushuin University, and Tohoku University. The project will run until FY2027, and we hope to be able to demonstrate—as one of the project's outcomes—a prototype of quantum communication using the above-described time-bin multi-photon entanglement.

Memories of Dr. Sae Woo Nam

—What do you keep in mind as a researcher?

On a personal note, in January 2024, my friend and a former collaborator, Dr. Sae Woo Nam of the National Institute of Standards and Technology (NIST), passed away due to illness. Dr. Nam was a colleague with whom I conducted experiments on quantum cryptography when I was a visiting researcher in the laboratory of Professor Yoshihisa Yamamoto at Stanford University in the US (currently

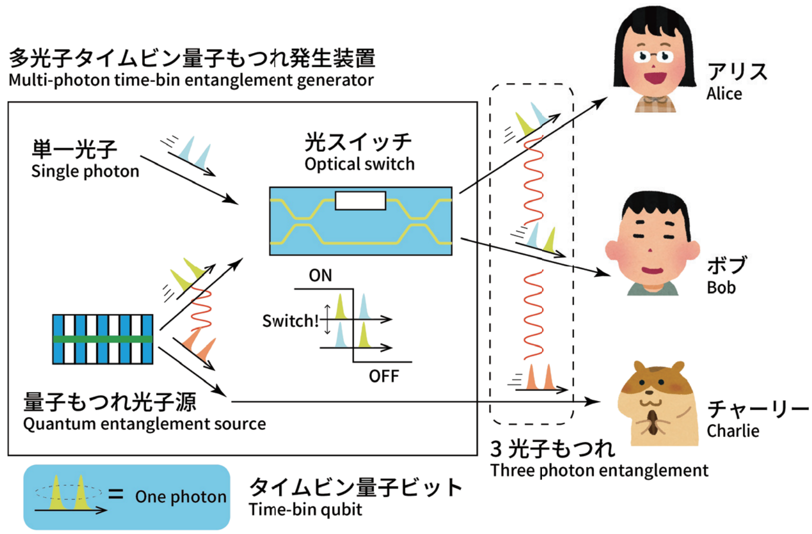


Fig. 4. Generation of three-photon entangled states on the basis of time-bin qubits.

director of Physics & Informatics Laboratories at NTT Research, Inc.). He was the same generation as me (one year older), and although we sometimes had heated discussions (some might say arguments) in the lab late at night about how to conduct experiments, we produced several outstanding experimental results together, and we were able to publish them in Nature Photonics. A few years later, I became a visiting researcher at NIST and stayed in Boulder, USA, where we conducted experiments on quantum teleportation over the world's longest optical fiber. After establishing the field of superconducting photon detectors, he went on to become one of the world's leading researchers conducting quantum-information experiments of our generation. As well as giving me much knowledge and know-how about superconducting photon detectors, he also greatly influenced me in terms of his research style.

First and foremost, Dr. Nam was a hard worker. He was a brilliant man who graduated from the Massachusetts Institute of Technology (MIT) and earned his doctorate from Stanford University, but he was also an engineer who was patient and proactive in doing tedious work like wiring superconducting devices inside refrigerators. Although he was already a group leader at NIST at the time I worked with him, he would not just leave it to his subordinates to carry out experiments; instead, he would take the initiative in conducting experiments himself in a manner that would guide his subordinates.

Above all, he was consistent in his approach of actively interacting with collaborators from various backgrounds (as he did when he came to Stanford University for collaborative research) and making friends and conducting research with them in a way that strengthened himself as well as his team. I think he not only made his team but also his collaborators, myself included, stronger. He packed the superconducting photon detector that he had created into his car and visited many universities around the US, with whom he conducted collaborative research. Later, when he came to Japan, he brought the superconducting photon detector in his carry-on luggage! He was truly a researcher who got out there.

I was greatly influenced by these styles of Dr. Sae Woo Nam. While I am a hard worker just like him, I was mostly experimenting alone. Watching him work, I became aware that sometimes getting outside and doing research can lead to achieving more-outstanding results and experiencing a wider world than ever before.

Get outside once in a while

—What is your message to younger researchers?

I have been influenced by the research approaches of many researchers other than Dr. Sae Woo Nam, and each person's research methods are truly different, so even if you can take inspiration from many people, in the end, you have no choice but to create your own way of doing things. However, if I could send just one message, it would be "Get outside once in a while." By "outside," I mean overseas, other groups and research institutions, other fields, or outside of your own existing framework. I have "gone outside" a number of times; for example, in 2003, I moved from NTT Access Network Service Systems Laboratories to NTT Basic Research Laboratories through an internal job posting and plunged into the world of quantum mechanics; in 2004, I stayed at Stanford University to conduct collaborative research with the Professor Yamamoto's lab; and in 2015, I participated in the above-described CIM project. Each time, I plunged into new fields, met new people, and learned new things.

Of course, I often feel confused in a new field, but I also often feel that my knowledge and skills are useful in a different field; above all, I feel like I have gained a new direction as a researcher. In a word, I urge you to work hard on site and get outside every once in a while. I hope this advice is helpful to everyone.

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■ Interviewee profile

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

Using Neural Networks to Enable Computers to Listen to Voices Selectively as Humans Do

Marc Delcroix
Distinguished Researcher, NTT Communication Science Laboratories

Abstract

We live our lives surrounded by many sounds. People are capable of "selective listening," which allows them to distinguish specific voices or sounds even when multiple people are speaking simultaneously; however, computers find selective listening difficult. If a computer could extract only desired voices or sounds, it would be possible to eliminate noise and enable the listener to hear, for example, only the sound of a doorbell or phone through headphones. This would help people working from home and those who need visual or hearing support. On this issue, we spoke with Marc Delcroix, a distinguished researcher at NTT Communication Science Laboratories, who has successfully developed technologies for extracting the voice of a desired speaker from voices of multiple speakers.

Keywords: selective listening, SpeakerBeam, SoundBeam, neural network

Technology for extracting only a specific person's voice from a conversation involving multiple people

—Would you tell us about the type of research you are conducting?

One of my major research themes is computational selective hearing, namely, extracting only specific sounds from multiple sounds. We humans gather information from sounds in various situations. We also sometimes speak to personal computers, smartphones, or voice recorders, record our speech, then transcribe it. My research group aims to develop technology that enables computers to understand and support human communication in natural conversations in a manner that goes beyond simply understanding what a single user is saying.

We are frequently immersed in various sounds. Some of these sounds we want to hear, some we don't need to hear, but all reach our ears. During an online meeting, for example, we may hear unnecessary sounds that we do not need to hear at that time, such as phones ringing, sirens sounding outside, dogs barking, and the sounds of family life. Normally we just want to hear the meeting audio. Even in these situations, we humans are basically able to focus on the people and sounds we want to hear and ignore the sounds that we do not need to hear. This ability is called "selective listening," and I want to give computers

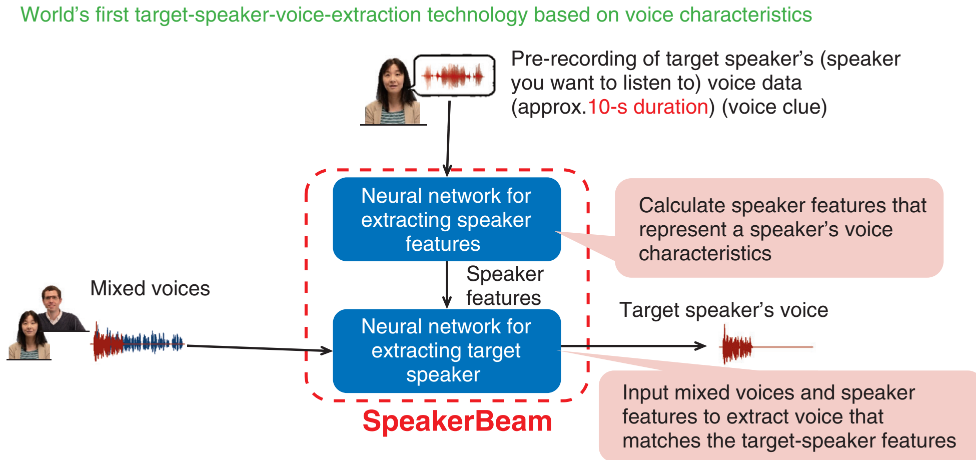

Fig. 1. SpeakerBeam: Extracting a specific speaker on the basis of voice clues.

this ability, so I am developing technology that can extract only the voice of a specific speaker when multiple people are talking.

This technology can be combined with other technologies and applied to various use cases. For example, by combining it with speech-recognition technology, it becomes possible to extract only one person’s voice from among multiple speakers’ voices and transcribe only the words spoken by that person. For other use cases, we upgraded this technology to extract only the sounds one wants to hear, such as telephones ringing and dogs barking, in addition to human voices, from among many other sounds.

We have been researching selective listening since around 2017 and succeeded in developing technologies for extracting the voice of a specific speaker from voices of multiple people on the basis of the speaker’s voice characteristics. For example, when extracting the voice of a specific speaker from audio data of two people talking, we first record the voice of the speaker to be heard (the target speaker) in advance and use a neural network to analyze and learn the target speaker’s voice features. A second neural network is then used to extract voices that match the voice features of the target speaker from data that contain a mixture of multiple voices.

This technology is called “SpeakerBeam” (**Fig. 1**). It can be applied even when it is unclear how many people are speaking. In other words, even if three or more speakers, rather than just two, are speaking, it is possible to extract the voice of a specific person from the mixed voices.

While SpeakerBeam can extract any type of voice with high accuracy on average, we found that its performance drops when the voices are similar; for example, when two women or two men are speaking together. It has evolved since we initially developed it, so its performance has improved to a certain extent in such cases. However, when the voices are similar it still has difficulty distinguishing them. For a solution to this problem, we proposed a multi-modal version that uses not only recorded audio data but also captured video showing lip movements as a clue to who is speaking. These improvements enable the technology to reliably extract the voice of the desired speaker even when similar voices are mixed.

—What are the unique strengths of your research?

My original research was on speech recognition, which involved adapting a speech-recognition system to the voice of a specific speaker to improve the performance of speech-to-text transcription. My research group consists of a speech-recognition team and speech-enhancement team (working on themes such as noise reduction and sound-source separation). I started new research with the idea that I might be able to extract the voice of a specific person by combining the speaker-adaptation technology I previously mentioned with neural-network technology for sound-source separation, and that combination led to the development of SpeakerBeam. I believe that it was only because people from different research fields joined forces to work in the same group that we were able to create this world’s first technology.

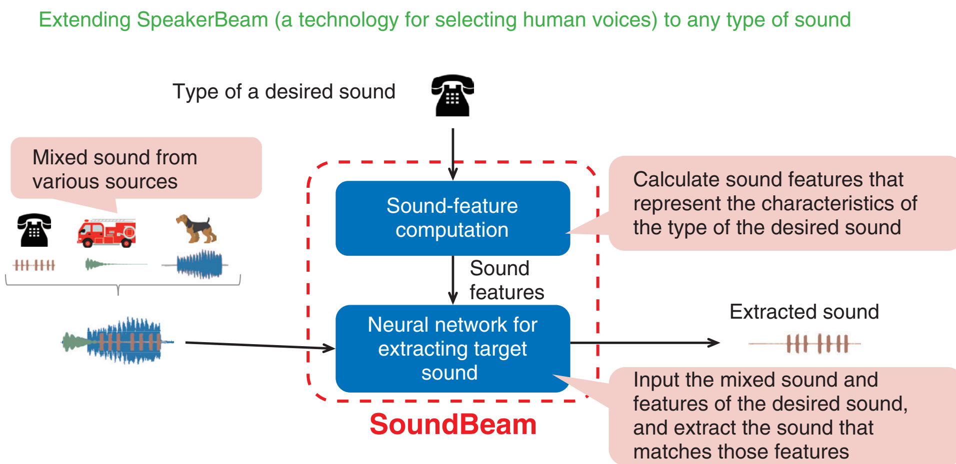

Fig. 2. Selective listening to any sound via SoundBeam.

SpeakerBeam is a versatile technology, and one of its strengths is that it can be used to extract not only a specific voice but also specific (non-speech) sounds. Using this strength, we also proposed a technology called "SoundBeam." For example, if you are working from home and a siren is going off outside, the sound will become noise. On the contrary, when you are driving a car, sirens are an important sound that you must be able to hear. To achieve this optimal selective listening suited to the situation, we are teaching SoundBeam many sounds and expanding the types of sounds that it can handle; as a result, by simply inputting the command "I want to hear [a certain sound] in [a certain situation.]" into the computer, the desired sound will be rendered audible and other sounds will be muted (**Fig. 2**). I believe that if this technology can be implemented, it will have many applications such as customizing the noise-canceling functions of hearing devices, e.g., earphones, headphones, and hearing aids. It will also be possible to set car-audio systems so that the sounds of car horns and sirens are emphasized while music is playing in the car. The technology could also be used for sound post-production, e.g., to extract sounds to be emphasized during editing of the sound track of videos, etc. so that they become easier to hear.

Generally, SoundBeam can extract sounds with high accuracy as long as it can identify the type of sound; however, it can only extract the types of sounds that it has been trained with ("seen" during training). For example, if SoundBeam is trained with the sounds of dogs and cats, it can extract those sounds from audio data, but it cannot extract the roar of a lion, which it has not been trained with ("unseen"). In response to this limitation, we proposed a technology that enables SoundBeam to handle unseen-sound types, as well as the seen-sound types. This is a relatively new research field, and this technology has been under development for less than five years. I believe it still has room for improvement, so we are developing it further.

SpeakerBeam and SoundBeam for comfortable listening in noisy environments

—Would you tell us about the future prospects of this research?

I hope this research will be useful in people's daily lives. My goal is to make it possible to select important sounds from among a mixture of different sounds and clearly recognize the information expressed by those sounds. For example, the ability to hear a baby crying without the sound of the television or the ability to make one's own voice heard more clearly on the phone or during video conferences can help eliminate people's burden and make life more comfortable. Even in situations outside of everyday life, for example when talking to journalists, I often hear them say, "I wish that when recording various conversations or lectures with a voice recorder, I could precisely extract only the voices of the people I want to hear."

Many artificial-intelligence technologies, such as automatic speech recognition or machine translation, have been developed and are improving day by day; however, when they are used in a noisy environment, their translation accuracy inevitably decreases. Naturally, the performance of each technology is improving, but while it is easy to distinguish between noise and human voices, the characteristics of multiple voices differ from those of background noise, so it is not always easy for current speech-recognition or machine-translation technologies to distinguish the sound of the target speaker from multiple voices. However, I believe that if the technologies we are researching can be used effectively, they could be applied in a variety of ways, such as making it possible to hear clearly and translate the target party's voice correctly (even when using machine translation in a noisy place) or to distinguish who said what in a meeting accurately and create minutes of the meeting. We are striving to improve the accuracy of voice extraction while considering how to make voice-extraction technology useful to a wide range of people in the many situations in which they hear sounds.

—What are the challenges and key points in your research? What issues remain to be solved?

When I began researching this technology, it was important to establish the basic theory first. We then demonstrated our voice-extraction technology at the NTT Communication Science Laboratories Open House in 2018. We thus demonstrated that the technology works not only in theory but also in a real environment with many visitors and much noise.

However, several issues remain, and as I explained earlier, it will be necessary to increase the types of sounds that can be handled in the future. We already know that it is possible to satisfy that necessity to a certain extent, but I believe that to improve accuracy and performance of the technology, it must be possible to learn many more types of sounds, and that attaining that possibility is one of our future challenges.

Another issue is the recording environment. It is necessary to anticipate dynamic changes in the environment such as a quiet place, very noisy place, or place where unusual sounds are produced. Unless the technology works properly in a variety of recording environments, not just in experimental environments, it cannot be put to practical use. For that reason, I am pursuing research with the consideration of the need to change processing automatically according to the recording environment. For example, certain sounds can be expected to be heard at home, while different sounds can be expected to be heard in the office; accordingly, to handle both situations, we need to develop technology that can specify the type of sound environment in addition to the type of sound to be heard. We are not yet satisfied with the quality of voice extraction and are aiming to extract higher quality, more realistic voices.

We envision earphones and hearing aids as devices using voice extraction; however, when our technology is implemented in small devices that are worn in the ear, reducing the size of the neural network becomes essential. Although the performance of neural networks has improved, the computing power of small devices is limited, so we need to improve the technology so that it can maintain high accuracy even on small devices.

—Finally, what is your message to young researchers and students?

Research has various phases, from theoretical considerations to verification with a real system. For SpeakerBeam and SoundBeam, I was involved in both creating the theory and developing the demonstration systems. I was happy to have created a theory for voice extraction, but I was especially pleased to see that it worked as predicted in a real environment. Research thus enables you to contribute to the world in many different ways, from theory to practice, and you can experience a sense of accomplishment in either.

I have also had the opportunity to conduct research with many people, including colleagues and interns at NTT laboratories, and joint research with multiple universities. For example, SpeakerBeam was developed in collaboration with Brno University of Technology, Czech Republic. I am currently conducting joint research with universities in Germany, the United States, and other countries. In addition to cooperating with overseas universities, NTT has a

variety of research laboratories, and several deal with speech and audio processing research, so we work closely together with them on several projects. NTT laboratories have high implementation capabilities, and the support of the laboratories made it possible to handle the above-mentioned Open House demonstration. I feel that I am in a very fortunate environment in which I can conduct research with highly capable researchers who excel in both research and development.

Another feature of NTT is that it enables you to pursue your research in a global environment, even within Japan. Our group conducts research activities globally, host many outstanding interns from overseas, and have several internationally renowned and gifted researchers on our staff. I think these circumstances are amazing.

Many people think that researchers conduct their research alone. This can be true depending on the person, but others succeed by talking to many people and coming up with good ideas as they pursue their research. I encourage young researchers and students to talk to as many people as possible when they have a problem instead of keeping it to themselves and to enjoy their research.

■ **Interviewee profile**

Marc Delcroix received an M.Eng. from the Free University of Brussels, Belgium, and the Ecole Centrale Paris, France, in 2003 and Ph.D. from the Graduate School of Information Science and Technology, Hokkaido University in 2007. After joining NTT in 2010, he has been researching speech and acoustic signal processing, including speech enhancement, speech recognition, and target-speech extraction. He is a member of the Institute of Electrical and Electronics Engineers (IEEE) and the Acoustical Society of Japan.

Latest Standardization in OpenROADM MSA

Yoshiaki Sone, Mitsuteru Yoshida, Jun-ichi Kani, and Koichi Takasugi

Abstract

The OpenROADM Multi-Source Agreement (MSA) is promoting the specification of optical interface standards at the physical layer and control APIs (application programming interfaces) for equipment controllers to enable multi-vendor interoperable reconfigurable optical add/drop multiplexer (ROADM) networks in the domain of metro and long-haul wavelength-division multiplexing optical transport networks. This article introduces an overview of the standards defined by the OpenROADM MSA and its latest activities.

Keywords: OpenROADM MSA, open interface, multi-vendor interoperability

1. Background

With the proliferation of smartphones and the rapid advancement of artificial intelligence services, communication networks have become indispensable. For service providers, it is essential to maintain the scalability and cost efficiency of optical transport networks that support the ever-increasing communication traffic. To achieve sustainable scalability over the long term, it is also necessary to consider network architecture and ecosystem aspects [1].

Traditionally, transmission equipment and its management systems have been provided as vertically integrated solutions by a single vendor. Therefore, it was difficult to incorporate systems from other vendors once deployed, raising concerns about limited flexibility and delays in adopting new technologies. To overcome these challenges and foster a competitive and rational market environment, it is crucial to have an open architecture that supports multi-vendor interoperability.

On the basis of the background above, the importance of open standardization enabling multi-vendor optical networks has been increasing. Multiple standardization bodies and forums, such as the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) [2], IOWN Global Forum (IOWN GF) [3], and Telecom Infra Project (TIP) [4], are leading related initiatives. The OpenROADM Multi-Source Agreement (MSA) [5] is one of the key forums in the optical communications field, offering open and interoperable specifications for metro dense wavelength-division multiplexing (DWDM) optical transport networks.

2. Standard specifications of OpenROADM MSA

The OpenROADM MSA formulates interoperable interface specifications for open and flexible reconfigurable optical add/drop multiplexer (ROADM) networks and aims to build an open optical networking ecosystem. Since its launch in 2016, the MSA has 32 member organizations as of April 2025, including 15 operators and 17 optical-communication-equipment vendors.

The goal of the OpenROADM MSA is to define open standard interfaces that avoid vendor lock-in caused by vertically integrated systems—an issue with traditional carrier networks—and achieve open and flexible networks. **Figure 1** illustrates the ROADM network configuration and interface definitions envisioned by the OpenROADM MSA.

The interoperability specifications defined by the

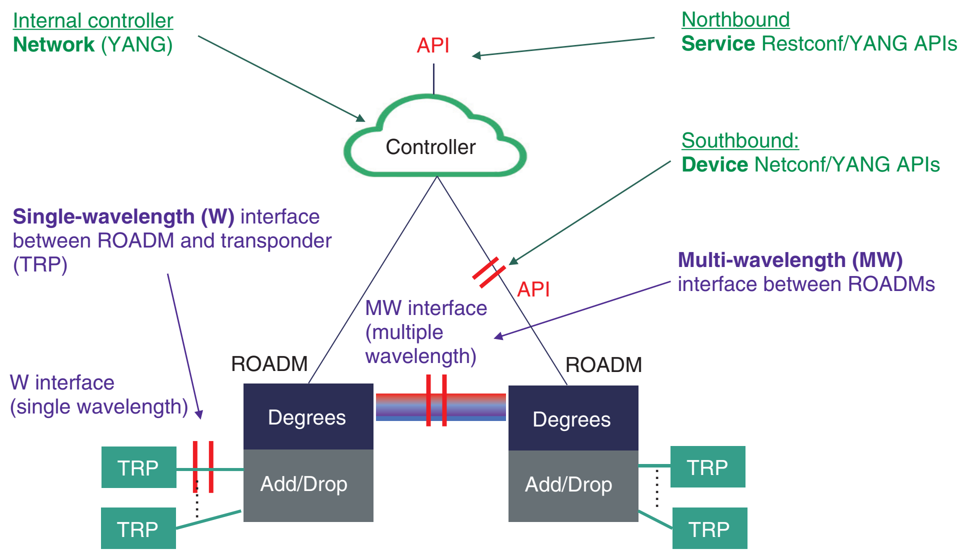

Fig. 1. Interoperable specifications defined in OpenROADM MSA.

Table 1. Optical interface specifications defined by OpenROADM MSA (100–400 Gbit/s).

Specifications	Modulation format	Baud rate [Gbaud]	FEC	rOSNR [dB]
100G	QPSK	28.0	SC-FEC	17
100G	QPSK	31.6	oFEC	12
200G	16QAM	31.6	oFEC	20.5
200G	QPSK	63.1	oFEC	17
300G	8QAM	63.1	oFEC	21
400G	16QAM	63.1	oFEC	24

QAM: quadrature amplitude modulation
QPSK: quadrature phase-shift keying
rOSNR: required optical signal-to-noise ratio. A performance measure for optical receivers.
SC-FEC: Hard-decision FEC defined in ITU-T G.709

MSA include optical transmission interfaces for the physical layer and application programming interfaces (APIs) for equipment controllers. These specifications are published by the MSA. Optical interface specifications are available in spreadsheet format on the OpenROADM website. API definitions are provided on the OpenROADM GitHub repository [6] using the Yet Another Next Generation (YANG) model*1. A white paper outlining implementation guidelines for the API model is also available on the website.

3. Optical interface specifications

The physical layer specifications define several functional blocks and their interfaces, including a ROADM, Xponder (transponder, multiplexer-ponder, and switch-ponder), and in-line amplifier (ILA). The optical WDM transmission signal between a ROADM and ILA is defined as the multi-wavelength (MW) interface. The single-wavelength optical interface between an Xponder and the ROADM add/drop function is referred to as the wavelength (W) interface.

Table 1 presents the W interface specification released in 2022 (Optical Interface Specification Ver.

*1 YANG model: A data modeling language used for network configurations and states, commonly used with control protocols such as NETCONF.

Table 2. Beyond 400-Gbit/s optical specifications (400–800 Gbit/s) currently under discussion in OpenROADM MSA.

Specifications	Modulation format	Baud rate [GBaud]	FEC	Framer	rOSNR [dB]
400G	DP-QPSK	118.2	oFEC	FlexO-4e-DO	20 (TBD)
400G	DP-QPSK	124.1	oFEC	FlexO-4-DO	20 (TBD)
600G	PCS DP-16QAM	118.7	oFEC	FlexO-6e-DPO	TBD
600G	PCS DP-16QAM	124.7	oFEC	FlexO-6-DPO	TBD
800G	DP-16QAM	118.2	oFEC	FlexO-8e-DO	27 (TBD)
800G	DP-16QAM	124.1	oFEC	FlexO-8-DO	27.2 (TBD)
800G	PCS DP-16QAM	131.3	oFEC	FlexO-8e-DPO	25 (TBD)
800G	PCS DP-16QAM	131.3	oFEC	FlexO-8-DPO	26 (TBD)

DP: dual polarization
TBD: to be determined

5.1). The OpenROADM MSA developed these specifications using a standardized soft-decision forward error correction (FEC) scheme called open FEC (oFEC)*2 for metro DWDM applications, Ver. 5.1 of which includes 30 Gbaud for 100- and 200-Gbit/s transmission and 63.1 Gbaud for 200-, 300-, and 400-Gbit/s transmission. These interface specifications use various modulation formats to achieve multiple rates and reach options suitable for metro optical WDM transmission.

The OpenROADM MSA is currently working on specifications for beyond 400-Gbit/s systems, with a provisional version published as Optical Interface Specification Ver. 8.0. **Table 2** summarizes the content.

In the beyond 400-Gbit/s specifications, the OpenROADM MSA became the first in the industry to standardize the interoperable probabilistic constellation shaping (PCS) scheme, released as W-Port Digital Specification Ver. 6.0. PCS is applied to 600- and 800-Gbit/s specifications. In addition to the standard Optical Transport Network (OTN) framer, the beyond 400-Gbit/s specification introduces the Ethernet-optimized framer.

As shown in Table 2, FlexO-n-e refers to the Ethernet-optimized framer, while FlexO-n refers to the standard OTN framer. The Ethernet-optimized framer operates at a slightly lower baud rate than OTN framers, reduces frame overhead by minimizing management features, thus achieving higher transmission performance and lower power consumption. These specifications have been shared via liaisons with other standardization bodies such as ITU-T and expected to be widely adopted.

4. API specifications for equipment controllers

For equipment controller specifications, the OpenROADM MSA defines three categories of YANG models for its controller APIs: service, network, and device.

(1) Service model

Defines the northbound interface for responding to service requests from higher-level operation systems. It specifies the set of parameters required to provide services.

(2) Network model

Abstracts physical-layer equipment information and manages it as topology information. This enables minimized impact on higher layers during equipment replacement. It expresses inter-device connectivity, resource availability, and functional constraints that are referenced when determining the wavelength service paths across a ROADM network.

(3) Device model

A template for managing device parameters, supporting plug-and-play functionality. It allows for flexible management of multiple line cards and pluggable modules such as CFP2-DCO (C form-factor pluggable digital coherent optics) inserted into equipment chassis.

YANG model Ver. 7.1 is a commercially deployable specification that supports 400G systems and has been implemented in multi-vendor commercial systems. While this version supports functionalities for commercial operation, the YANG model continues to be enhanced to address new use cases and emerging physical layer specifications. As of April

*2 oFEC: A soft-decision FEC scheme standardized by the OpenROADM MSA.

2025, the latest release is Ver. 17.0.

One example of newly added flexible control features is the ability to manage "bookend connections," which is an interworking with non-OpenROADM-compliant transponders.

Work is also underway on YANG model specifications to manage systems that use both the C-band*3 and L-band*4, beyond the traditionally assumed C-band-only configurations.

5. Collaboration with other standardization bodies

The OpenROADM MSA actively collaborates with other standardization and open forums. One notable example is its cooperation with IOWN GF, with which a liaison relationship has been established.

IOWN GF has adopted OpenROADM MSA specifications as part of its Open All-Photonics Network (Open APN) functional architecture [7]. It has also identified additional functions that OpenROADM MSA should expand to meet Open APN requirements. On the basis of this, the OpenROADM MSA worked with IOWN GF members to extend its specifications to support optical wavelength connections between user premises, which is a core requirement of Open APN [8]. Specifically, it defined a remote transponder control architecture that enables an Xponder located at a user site to be controlled via an optical supervisory control channel that shares the same fiber as the main signal. A new single-wavelength optical interface specification (W' interface) was also introduced, and Optical Specification Ver. 7.0 reflecting this was published in April 2024.

Previously, optical wavelength connections between Xponders under the same ROADM device were not permitted. To permit this, the MSA added a "turn-back" function to the controller API specification and published Device Model Ver. 13.0 in March 2023.

The OpenROADM system has been widely implemented in commercial products, and numerous multi-vendor interoperability demonstrations have been conducted by OpenLab@UT Dallas, which maintains close ties with the OpenROADM MSA [9]. Joint demonstrations with IOWN GF have also been showcased at the Optical Fiber Communication Conference and Exhibition (OFC) 2024 and are planned for OFC 2025, involving multiple companies [10].

The collaboration between IOWN GF and OpenROADM MSA specifications is accelerating the evolution of Open APN architectures sought by operators.

6. Conclusion

The OpenROADM MSA is an open forum that defines interoperable specifications for metro and long-haul DWDM optical networks. It specifies both physical-layer optical interface standards from 100G to 800G and YANG models for equipment controller APIs. These specifications are being implemented by multiple vendors and have demonstrated interoperability through industry exhibitions.

The OpenROADM MSA is expected to continue contributing to the establishment of an open ecosystem in the optical networking domain through collaboration with other open forums.

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*3 C-band: Optical wavelength range from 1528.77 to 1566.77 nm used in WDM transmission.

*4 L-band: Optical wavelength range from 1570.42 to 1610.49 nm used in WDM transmission.

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He received an M.E. in electronics engineering from Tohoku University, Miyagi, in 2003. Since joining NTT the same year, he has been involved in research and technological development of optical transport systems and associated network engineering and standardizations. His primary focus is on the development of open optical transport systems as well as related standardization activities including the OpenROADM MSA. He is a member of the Institute of Electrical and Electronics Engineers (IEEE) and the Institute of Electronics, Information and Communication Engineers (IEICE).

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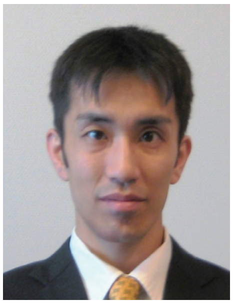

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Investigations on Traffic Vibration around Telecommunication Facilities: Maintenance Holes as an Example

Technical Assistance and Support Center, NTT EAST

Abstract

Technical Assistance and Support Center, NTT EAST is investigating vibrations due to traffic around NTT EAST's telecommunication facilities to evaluate their impact on the surrounding area. This article presents results of investigations of traffic vibrations around a maintenance hole.

Keywords: traffic vibration, maintenance hole, resonance frequency

1. Introduction

NTT EAST's facilities are spread throughout Japan in various forms so that they can deliver telecommunication services to all parts of the country. For example, utility poles and maintenance holes are installed in residential areas, so it is necessary to harmonize with the local community and ensure that they do not disturb the living environment of residents.

As part of efforts to ensure that telecommunication facilities do not disrupt the lives of local residents, the Materials Engineering Group at Technical Assistance and Support Center (TASC), NTT EAST is investigating vibrations due to traffic around NTT EAST's facilities to evaluate their impact on the surrounding area. This article introduces the results of investigations targeting a maintenance hole.

2. Overview of investigations

When heavy vehicles, such as trucks, are travelling along roads, their vibrations are transmitted into the ground, and that transmission causes the road to vibrate. The magnitude of the vibration depends on the condition of the road surface and strength of the ground. If large vibrations propagate through the ground and reach houses adjacent to the road, people inside those houses may feel the vibrations. NTT's maintenance holes are buried underground along roads, so they may affect those vibrations by resonance. TASC therefore conducted the following two investigations around a target maintenance hole.

1. Investigate the vibration state around the maintenance hole by measuring vibration levels.
2. Investigate the presence or absence of resonance with the maintenance hole by measuring the frequency of traffic vibration.

2.1 Investigation 1: Vibration levels

(1) Overview of investigation

The spaces in which people live are subject to numerous vibrations such as those caused by factory machinery, by civil engineering and construction work, and by trains and large vehicles.

To protect the living environment of local residents, the Vibration Regulation Act [1] was enacted in 1976 to set limits on the vibration level (i.e., an index, measured in decibels, expressing the magnitude of vibration). Since then, the government has taken vibration-prevention measures such as providing guidelines to businesses and repairing road surfaces. The required

Table 1. Standard values of vibration levels stipulated by the Vibration Regulation Act.

Area classification	Time-of-day classification	
	Daytime	Nighttime
Class-1 area	65 dB	60 dB
Class-2 area	70 dB	65 dB

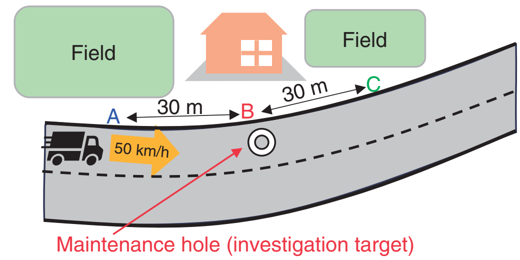

Fig. 1. Location of measurement points in vibration investigation.

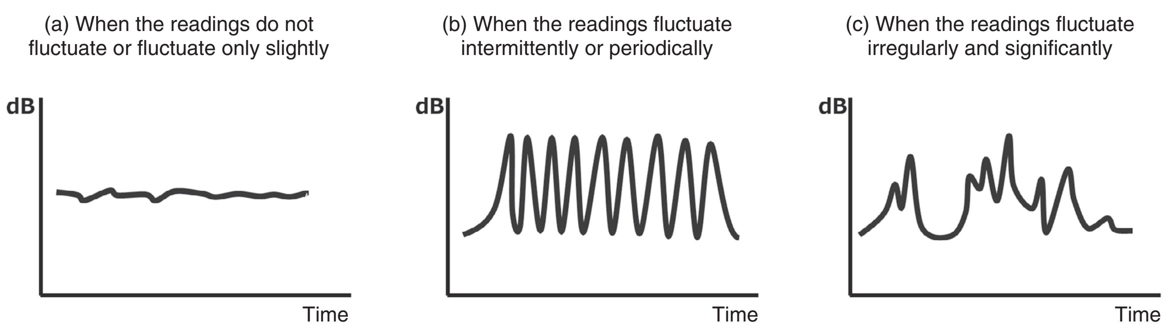

Fig. 2. General patterns of vibration waveforms.

limits on vibration levels are set by the enforcement regulations of the Vibration Regulation Act as listed (as standard values) in **Table 1**. The vibration level for each class of vibration is measured and evaluated on the basis of whether it exceeds the standard values stipulated in Table 1. In investigation 1, the vibration level around a target maintenance hole installed in a road passing through a residential area was measured.

(2) Method of investigation

Vibration levels were measured using the measurement equipment specified in JIS (Japanese Industrial Standards) C 1510. As shown in **Fig. 1**, the measurement points were near the target maintenance hole in a road (point B) and at two nearby (30 m from B) locations where maintenance holes are not buried in the road (points A and C). To ensure measurement reproducibility, a bucket truck (weight approximately 6 t) was driven past points A, B, and C multiple times (at speed of 50 km/h), and the vibrations generated by the moving truck were measured at each point. The vibration direction measured was taken as vertical in accordance with JIS Z 8735.

The three general patterns of the measured vibration waveforms are shown in **Fig. 2**. According to the guidelines of the Ministry of the Environment [2], it is recommended that the method of measuring the vibration level be changed according to the vibration pattern being measured. For example, when the vibration-level meter readings do not fluctuate or fluctuate slightly (Fig. 2(a)), each reading can be used as the measured level as is; in contrast, when the readings fluctuate intermittently or periodically (Fig. 2(b)), the average of the maximum measured values for each fluctuation is taken as the measured level. Traffic vibration, which occurs only when vehicles are passing, corresponds to the pattern shown in Fig. 2(c); namely, the vibration-level meter reading fluctuates irregularly and significantly. In this case, the upper limit of the 80% range is taken as the measured vibration level and its magnitude is evaluated.

The 80% range refers to the remaining 80% of multiple measured vibration levels arranged in order of magnitude, after the maximum 10% and minimum 10% have been excluded, as shown in **Fig. 3**. The maximum vibration level within the 80% range is taken as the upper limit of the 80% range (Lv_{10}).

(3) Results of investigation

The measured vibration levels (Lv_{10}) are listed in

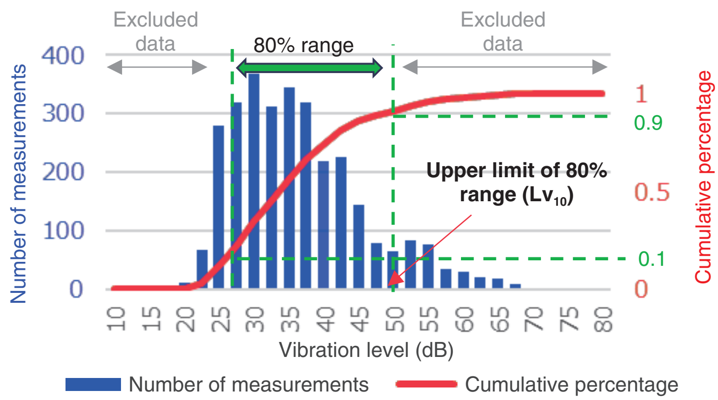

Fig. 3. Example of 80% range and its upper limit.

Table 2. Upper limit of 80% range of vibration level at each point.

Measurement point	Position relative to maintenance hole	Upper limit of 80% range of vibration level (dB)
A	30 m west of maintenance hole	53 dB
B	Near maintenance hole	53 dB
C	30 m east of maintenance hole	51 dB
Reference	Standard value of Vibration Regulation Act for class-1 area	65 dB (daytime) 60 dB (nighttime)

Table 2. According to these investigation results, none of the vibration levels measured at the three measurement points exceeded the standard values stipulated in the Vibration Regulation Act. Also, Lv_{10} values measured near the maintenance hole (point B) and at the other two points (A and C) did not significantly differ, indicating no particularly large (or small) vibrations occurred near the maintenance hole. It can be concluded from these results that when the vehicle passed the target maintenance hole, no vibrations that exceeded the legal standard values were generated, and regardless of whether a maintenance hole was buried nearby, no significant differences in the vibration levels at each measurement point were observed.

2.2 Investigation 2: Vibration frequency

(1) Overview of investigation

We investigated vibration frequency to ascertain any effect of the maintenance hole on traffic vibration. It is thought that the effect of a maintenance hole (buried underground) on traffic vibration is one of resonance between the traffic vibrations and the maintenance hole that amplifies the vibrations. We therefore verified whether the maintenance hole resonated by comparing the frequency of vibrations observed on site with the resonance frequency of the maintenance-hole casing.

(2) Method of investigation

First, we created a three-dimensional (3D) model (see **Fig. 4**) from a drawing of a maintenance-hole casing and calculated the resonance frequency by displacing the 3D model by simulation with the finite element method.

Resonance frequency is unique to the object in question, and when vibrations with that frequency are applied externally to the object, resonance occurs and the vibrations are amplified. According to the results of the simulation, the natural (resonance) frequency of the target maintenance hole was estimated to be in the range of 228.1 to 359.6 Hz.

The vibration frequency on site was obtained by measuring vibration acceleration by using acceleration sensors installed at the site, and the obtained acceleration data were converted to frequency by using a Fourier transform. The acquisition interval for the acceleration data was set to 0.1 ms, and the measurement points were the three points used in

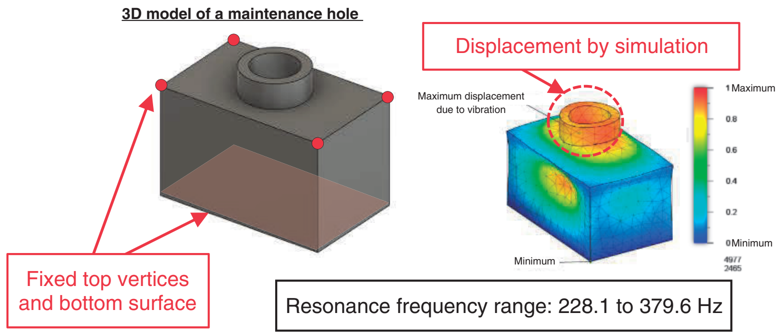

Fig. 4. 3D model of maintenance hole and example of simulation related to resonance frequency.

investigation 1, as shown in Fig. 1.

(3) Results of investigation

Vibration frequency measured on site when the truck passed by is plotted against vibration acceleration in **Fig. 5**. According to this plot, vibration frequency is prominent at around 20 Hz at all measurement points (A to C), and almost no vibration was detected in the maintenance hole's resonance-frequency range (shown in orange in the figure). These measurement results are consistent with the results of similar investigations conducted by TASC as well as with other published results [3, 4].

The above results of investigation 2 suggest that the target maintenance hole does not resonate with traffic vibrations; in other words, it does not affect (amplify) traffic vibrations.

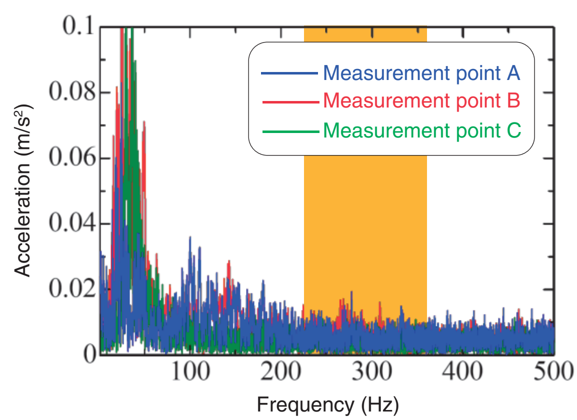

Fig. 5. Vibration frequencies measured at each measurement point.

3. Conclusion

The results of investigations on traffic vibration around a maintenance hole were presented. According to these investigations, vibrations exceeding the standards set by the Vibration Regulation Act were not detected near the maintenance hole or at the two nearby locations, and the vibration levels measured at the three locations did not significantly differ. It is also inferred that since the vibration frequency measured at the three measurement points did not match the natural vibration frequency of the maintenance hole, the maintenance hole did not resonate and affect (amplify) traffic vibration. It was thus confirmed that the target maintenance hole is not related to traffic vibrations and does not disrupt the lives of local residents.

TASC will continue contributing to solving on-site problems through technical support for those involved in the maintenance and operation of telecommunication facilities.

References

[1] Act No. 64 of 1976, Vibration Regulation Act, https://www.env.go.jp/en/laws/air/vibration/index.html

[2] Ministry of the Environment, "Guide for Local Government Officials to Vibration Countermeasures for Construction Work," 2012 (in Japanese). https://www.env.go.jp/air/sindo/const_guide/lg.html

[3] T. Igarashi and H. Hatakeyama, "Predominant Frequencies of Vibrations Produced by Traffic on Overhead Roads," Annual Report of the OYO Geological Survey Office, No. 3, pp. 75–82, 1981.

[4] T. Matsuoka, "Relation between Ground Properties and Vibrations Caused by Traffic," The Journal of the INCE of Japan, Vol. 3, No. 2, pp. 20–23, 1979.

External Awards

The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, Award for Science and Technology (Development Category)

Winners: Junichi Koga, NTT Network Innovation Center; Akihiko Tsuno, NTT Network Innovation Center; Tsuyoshi Joucha, NTT Advanced Technology Corporation; Takaho Shibata, NTT-AT SYSTEMS Corporation; Hiroaki Matsumura, NTT TechnoCross Corporation
Date: April 15, 2025
Organization: The Ministry of Education, Culture, Sports, Science and Technology

For the system development of PSTN (public switched telephone network) migration and IP interconnection.

Young Scientist Presentation Award

Winner: Ikue Hiraoka, NTT Device Technology Laboratories
Date: May 14, 2025
Organization: The Japan Society of Applied Physics (JSAP)

For "InP Metasurfaces for Optical Circuits Operating at Telecom Wavelengths."
Published as: I. Hiraoka, M. Miyata, Y. Yamada, T. Hashimoto, and F. Nakajima, "InP Metasurfaces for Optical Circuits Operating at Telecom Wavelengths," The 72nd JSAP Spring Meeting 2025, Chiba, Japan, Mar. 2025.

ITU-AJ Encouragement Award

Winner: Takashi Matsui, NTT Access Network Service Systems Laboratories
Date: May 16, 2025
Organization: The ITU Association of Japan

Lab on a Chip Outstanding Research Award

Winners: Riku Takahashi, NTT Basic Research Laboratories; Shogo Himori, NTT Basic Research Laboratories; Aya Tanaka, NTT Basic Research Laboratories
Date: May 17, 2025
Organization: The Royal Society of Chemistry, The Society for Chemistry and Micro-Nano Systems (CHEMINAS)

For "Biomorphic On-chip Hydrogel Device Capable of Actuation in Cell Culture Conditions."
Published as: R. Takahashi, S. Himori, and A. Tanaka, "Biomorphic On-chip Hydrogel Device Capable of Actuation in Cell Culture Conditions," CHEMINAS 51, 3P04, Osaka, Japan, May 2025.

Wiley Prize 2025 (Most downloaded)

Winners: Moyu Hasegawa, Osaka University; Kenji Miki, Osaka University; Takuji Kawamura, Osaka University; Ikue Takei-Sasozaki, Osaka University; Yuki Higashiyama, Osaka University; Masaru Tsuchida, NTT Communication Science Laboratories; Kunio Kashino, NTT Communication Science Laboratories; Masaki Taira, Osaka University; Emiko Ito, Osaka University; Maki Takeda, Osaka University; Hidekazu Ishida, Osaka University; Shuichiro Higo, Osaka University; Yasushi Sakata, Osaka University; Shigeru Miyagawa, Osaka University
Date: March 29, 2025
Organization: Wiley, Japanese Society of Developmental Biologists

For "Gene Correction and Overexpression of $TNNI_3$ Improve Impaired Relaxation in Engineered Heart Tissue Model of Pediatric Restrictive Cardiomyopathy."
Published as: M. Hasegawa, K. Miki, T. Kawamura, I. Takei-Sasozaki, Y. Higashiyama, M. Tsuchida, K. Kashino, M. Taira, E. Ito, M. Takeda, Hi. Ishida, S. Higo, Y. Sakata, and S. Miyagawa, "Gene Correction and Overexpression of $TNNI_3$ Improve Impaired Relaxation in Engineered Heart Tissue Model of Pediatric Restrictive Cardiomyopathy," Development, Growth & Differentiation, Vol. 66, No. 2, pp. 119–132, 2024.

Springer Nature Editorial Contribution Award 2025

Winner: Takahiro Kawabe, NTT Communication Science Laboratories
Date: May 29, 2025
Organization: Springer Nature

Achievement Award

Winners: Sachio Suda, NTT Network Innovation Center; Kiyofumi Kikuchi, NTT Innovative Devices Corporation; Seiji Okamoto, NTT Network Innovation Laboratories
Date: June 5, 2025
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE)

For the development of a compact/power-saving optical open line system.

Best Paper Award

Winners: Josuke Ozaki, NTT Device Innovation Center; Yoshihiro Ogiso, NTT Device Innovation Center; Hiroshi Yamazaki, NTT Device Technology Laboratories; Yasuaki Hashizume, NTT Device Innovation Center; Kazuya Nagashima, Furukawa Electric Co., Ltd.; Mitsuteru Ishikawa, NTT Device Innovation Center; Nobuhiro Nunoya, NTT Device Innovation Center
Date: June 5, 2025
Organization: IEICE

For "InP-based Ultra-high-bandwidth Coherent Driver Modulator for over 160-Gbaud-class Operation."
Published as: J. Ozaki, Y. Ogiso, H. Yamazaki, Y. Hashizume, K. Nagashima, M. Ishikawa, and N. Nunoya, "InP-based Ultra-high-bandwidth Coherent Driver Modulator for over 160-Gbaud-class Operation," IEICE Trans. Electronics (Japanese Edition), Vol. J107-C, No. 6, pp. 242–249, 2024.

KDD 2025 Excellent Reviewer

Winner: Yasuhiro Fujiwara, NTT Communication Science Laboratories
Date: June 11, 2025
Organization: The 31st ACM SIGKDD Conference on Knowledge Discovery and Data Mining (KDD 2025)

CVPR 2025 Outstanding Reviewer

Winner: Akisato Kimura, NTT Communication Science Laboratories
Date: June 11, 2025
Organization: The IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) 2025

Papers Published in Technical Journals and Conference Proceedings

Real2Sim2Real for Point Cloud-based mmWave Link Quality Prediction: An Empirical Study

S. Ohta, T. Nishio, R. Kudo, K. Takahashi, and H. Nagata

IEEE Transactions on Vehicular Technology, Vol. 74, No. 3, pp. 5270–5275, March 2025.

This paper demonstrates the feasibility of the real-to-sim-to-real (Real2Sim2Real) scheme for point cloud-based proactive millimeter-wave (mmWave) link quality prediction. To alleviate the mmWave line-of-sight blockage problem, proactive wireless network management based on predicted future link quality values leveraging computer vision-aided deep learning (DL) is an effective solution. However, a large dataset is required to train the high-accuracy DL-based prediction model. In this paper, we configure a Real2Sim2Real pipeline, which aims to automatically generate a realistic synthetic dataset, close to that obtained from real sensors, for pre-training by analyzing a small real-world dataset and computer simulation. Experimental results reveal that our method can reduce prediction errors even with a small sample of real-world datasets for fine-tuning compared with previous pre-training methods using manually created 3D simulation models.

Experimental Evaluation of an SDN Controller for Open Optical-circuit-switched Networks

K. Anazawa, T. Inoue, T. Mano, H. Ou, H. Ujikawa, D. Briantcev, S. B. Ali, D. Dass, H. Nishizawa, Y. Sone, E. Kenny, M. Ruffini, D. Kilper, E. Oki, and K. Takasugi

Journal of Optical Communications and Networking, Vol. 17, No. 6, pp. 498–513, May 2025.

Open optical networks have been considered to be important for cost-effectively building and operating networks. Recently, optical-circuit-switches (OCSes) have attracted industry and academia because of their cost efficiency and higher capacity than traditional electrical packet switches and reconfigurable optical add-drop multiplexers (ROADMs). Though the open interfaces and control planes for traditional ROADMs and transponders have been defined by several standard-defining organizations, those of OCSes have not. Considering that several OCSes have already been installed in production datacenter networks and several OCS products are on the market, bringing openness and interoperability into OCS-based networks has become important. Motivated by this fact, this paper investigates a software-defined networking controller for open optical-circuit-switched networks. To this end, we identified the use cases of OCSes and derived the controller requirements for supporting them.We then proposed a multi-vendor (MV) OCS controller framework that satisfies the derived requirements; it was designed to quickly and consistently operate fiber paths upon receiving the operation requests. We validated our controller by implementing it and evaluating its performance on actual MV-OCS networks. It satisfied all the requirements, and fiber paths could be configured within 1.0 s by using our controller.

Low-noise Forward Pumping with Optimized Longitudinal Modes for Distributed Raman Amplifier in S+C+L-band Transmission

H. Kawakami, F. Hamaoka, K. Kimura, M. Nakamura, T. Sasai, T. Kobayashi, Y. Miyamoto, and E. Yamazaki

The 30th OptoElectronics and Communications Conference/International Conference on Photonics in Switching and Computing (OECC/PSC 2025), TuB2-4, Sapporo, Hokkaido, Japan, June/July 2025.

We show the improvement of signal quality in S+C+L-band transmission using a low-beat-noise forward pumping. After 1200-km transmission, the measured signal-to-noise ratios were improved by more than 0.7 dB compared to using a conventional technique.
