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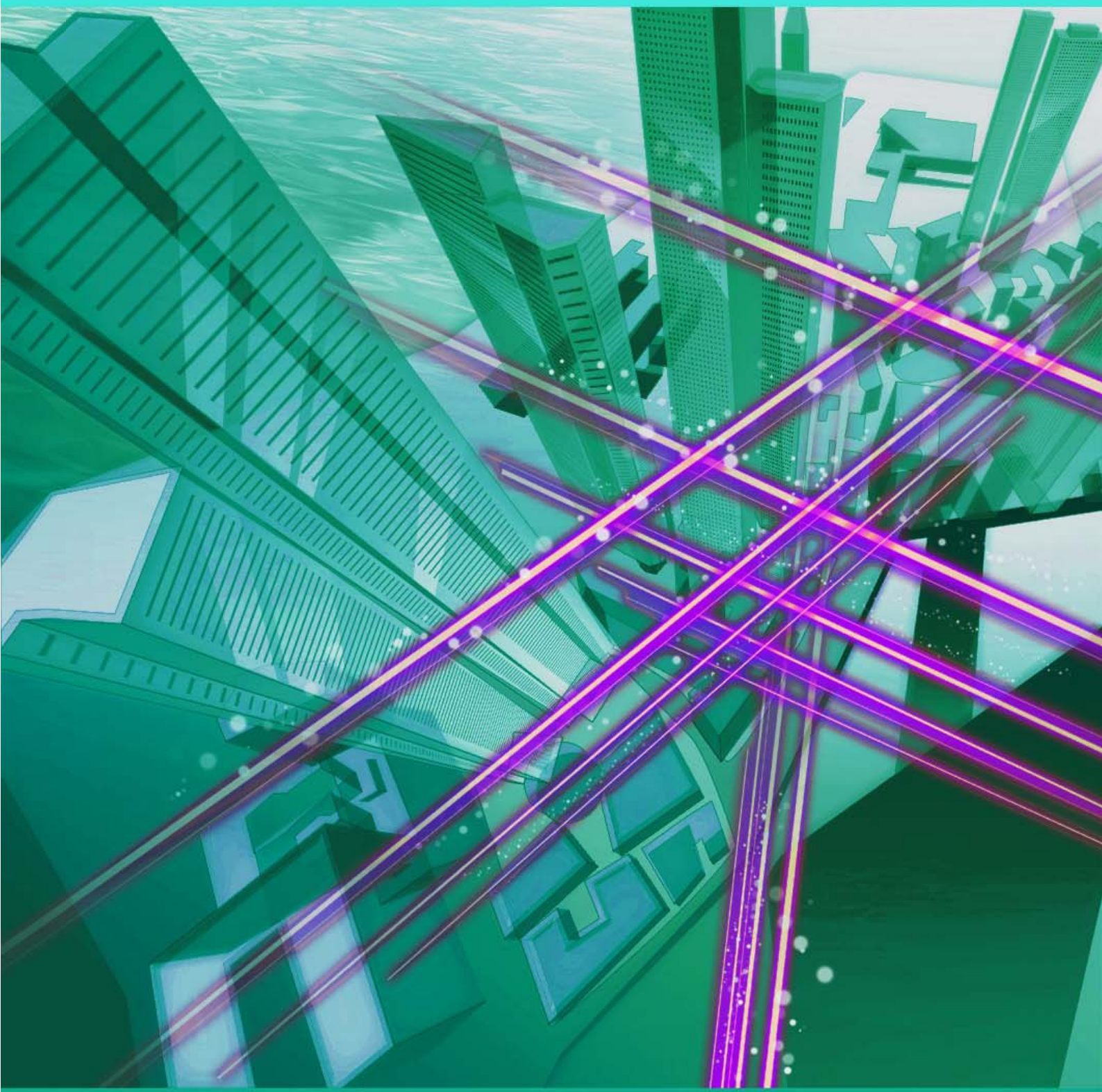

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Sharing Philosophies and Values with Employees and Contributing to the Digitalization of Society

Toshi Fujiwara
Senior Executive Vice President and Representative Director, NTT DATA

Overview

The spread of the novel coronavirus has brought about major changes in society. Now that *remote life* has become the norm, there is a growing need for supply chains that adapt to uncertain situations, safe and secure data linkage, and information technology infrastructure and security that support the changed business environment. The corporate philosophy of NTT DATA is to help contribute to a more affluent and harmonious society. We asked Toshi Fujiwara, senior executive vice president and representative director of NTT DATA, about the progress of the mid-term management plan and mindset of top management.

Keywords: digitalization, NTT DATA Technology Foresight, center of excellence

Profitable global growth should be emphasized

—This year is the final fiscal year of the current mid-term management plan. Can you outline the progress of the plan thus far?

NTT DATA has been strengthening its global expansion for about 15 years. Starting in Europe and the United States and now operating in 53 countries and regions, we have gradually gained experience and executed large-scale mergers and acquisitions. Our consolidated sales were approximately ¥2.27T in fiscal 2019 (April 1, 2019–March 31, 2020), and of our 133,000 employees, approximately two-thirds are non-Japanese nationals, among which the largest number are Indian.

Our current mid-term management plan (fiscal years 2019–2021) [1] covers the critical three years for achieving the Global 3rd Stage by around 2025. By pursuing profitable global growth with consistent belief and courage to change, we are working on the four perspectives: *growth*, *earnings*, *transformation*, and *synergy*. While pursuing our global strategy and facing the prospect of accelerated digitization of society, we are concentrating our resources on increasing our strengths in new technological fields.

Our key phrase is “profitable global growth.” In other words, it is not only the amount of profit but also the profit margin that is important. As the volume of business increases, the amount of sales naturally increases. However, I think that the increase in profit margin is proof that we are highly evaluated by our clients. In other words, the increase in profit margin is achieved because our clients recognize the value of the services we provide. High evaluation by clients also increases our motivation, so we will continue to

increase client value through digital technology.

Fiscal year 2021 is the final year of our current mid-term management plan. In fiscal 2019, the plan was successfully implemented; however, as we all know, in fiscal 2020, the spread of the novel coronavirus (COVID-19) greatly affected the world. We have spent a lot of time with the top management of each of our global bases to grasp the actual situation and consider countermeasures. Overseas bases have been hit by the COVID-19 pandemic harder than Japan; for instance, in Europe and the United States, about 95% of our employees are still forced to work from home.

We usually report the previous fiscal year's results and plans for the current fiscal year around May; however, at the time of the announcement of our fiscal 2019 results in May last year, we were in the midst of a state of emergency in Japan, which made it extremely difficult for us to report our plans and forecasts. As a result, we announced our fiscal 2020 earnings target in August 2020. Considering the results as of the third quarter, we are expected to achieve the fiscal year 2020 target. This achievement was made possible thanks to the hard work of our employees. I also believe that we were able to achieve this target because, in a sense, we recognized the change in society caused by the pandemic as a tailwind.

—How has the COVID-19 pandemic changed or will change NTT DATA's business?

If the services we provide stopped, that stoppage would affect not only our clients but also society. When the state of emergency was first declared in early 2020, we were concerned about whether we could really continue our services under such circumstances; however, we just kept doing what we could.

At the beginning of the pandemic, we desperately tried to continue to provide services even if employees outside Japan handling our outsourcing business could not go to the office or visit our clients. Some had difficulty in ensuring remote-work environments because of the poor infrastructure in their countries. I can talk about it calmly now, but at that time, all the employees around the world worked frantically to create an environment and a system that would allow us to continue our business.

I believe that we have been able to continue our business without any major disruptions as a result of the understanding of our clients in Japan and around the world as well as the efforts of each and every employee in the field. Therefore, I'd like to express my sincere gratitude to our clients and employees.

As I mentioned, the COVID-19 pandemic has changed the way society works as a whole; as a result, the economic headwind tends to be the focus of attention, but the pandemic has also been a tailwind driving digitalization. This pandemic has forcibly accelerated the development of remote-work environments, and needs and issues have been clarified. I think that the areas in which our accumulated expertise and the capability of the entire NTT Group, i.e., technology, have expanded.

In particular, demand for digitalization is growing significantly compared with the situation a year ago, and we need to further strengthen this area of business. With the establishment of Japan's Digital Agency in September 2021, digitization of government offices and nationwide efforts toward the broader digitization of Japanese society are expected to gather pace. By leveraging our strengths, which include undertaking the digitization of many public offices and financial institutions as well as the development of infrastructure such as payment systems, I want us to actively work on the creation of mechanisms that connect all of society through digital technology.

Share our philosophy and values until they resonate with employees and go by the moto of "look at the big picture and start with small steps"

—Many employees from all over the world have come together to face an unprecedented situation.

To expand our business by uniting our 130,000 employees in 53 countries and regions, I have consistently communicated that it is important to share not only profit goals but also philosophies and values while emphasizing diversity. In particular, it is important to build long-term relationships with our clients. Generally, people might have the impression that the rapidly growing information technology industry is simply focused on selling technology in a short period, but we are different. We place great importance on building strong relationships with our clients for the long term. In the course of such a strong relationship, sometimes the client is struggling, and sometimes we are struggling; all the same, I believe that if we understand each other, we can overcome such difficult times.

The attitude that I described above underpins NTT DATA's group vision of being a Trusted Global Innovator, which was set forth on the occasion of the 30th anniversary of the company's founding. Long-term relationships are essential for building trustworthy relationships with clients. When we ask companies to join us through mergers and acquisitions, we confirm whether we can share these philosophies and values with them.

To achieve our group vision, the following three values are shared by all group employees and practiced by them on a daily basis. The first value is *clients first*. Our approach to system integration is to (i) understand the client's way of thinking and true objectives and (ii) propose the best solution for the client from a medium- to long-term perspective. For example, if we receive a request from a client that we deem will be unbeneficial to them in the future, we will clearly communicate that fact to them and propose an alternative solution.

The second value is *foresight*, namely, looking to the future of technology and society and proposing necessary technologies and services to society and clients. As an example, every year, we publish "NTT DATA Technology Foresight," forecasts based on research and analysis of advanced technologies and societal trends [2]. We want our clients to continue expecting us to propose ways to move forward.

The third value is *teamwork*. There is a limit to what we can do on our own, and especially in the case of large-scale projects, we need to work together with our clients, not just with people within the company, to achieve our goals. By overcoming difficulties together, we can build a strong relationship and recognize each other as brothers and sisters in arms. I still have strong bonds with clients from my time as a section manager, and even though my position has changed, I have kept those relationships for more

than 20 years. Those relationships are not only personal assets but also corporate assets.

—What are some of the important things that you do to make corporate philosophy a reality?

I think that top management must have a clear vision, disseminate that vision, and involve the people around them. On top of that, they must not only make sure that employees understand the vision but also keep communicating it until it resonates with them. That process continues until all employees can talk about the vision naturally.

Also, even if an idea is great, the reality may not go as planned. I want employees across the world to value the following three key phrases.

The first is "interactive communication." It is important to keep in mind that communication is the mutual exchange of information. Sometimes we communicate in a one-way manner by which we are not aware of the understanding of the other party and end up saying, "I told you that, didn't I?" or not listening to what we don't want to hear. We want to avoid such one-way communication and emphasize interactive communication.

The second is "mutual respect." Although there should be no hierarchical relationship between a client and a contractor, they sometimes misunderstand the relationship. If we take the initiative and say, "Let's respect each other as professionals," the other person may be willing to talk what they have to say.

The third is "passion and perseverance." I believe that it is important for leaders to show their readiness to team members because it will ensure their sense of security and motivation. To be honest, I used to feel a little nervous when presenting my plans. Even so, when I finished a project, I realized that it was the right thing to do. And when I received a message saying, "I was really impressed by your plan," I felt happy that I was able to share my thoughts with team members.

I have adopted the motto, "Look at the big picture, start with small steps." I am always looking at societal trends from a broad perspective and trying to find out as much as I can about what society and our clients expect from NTT DATA. I am in charge of technology strategy as well as management and personnel strategies. Accordingly, while pursuing social contribution through technological development, I am conscious of growing NTT DATA into a strong company by using our technological capability from a broad perspective. I always keep in mind NTT DATA's unique global management. At each layer of technological development ability and contact point with clients, I want to proceed with our business by using the common assets of the NTT DATA Group.

Establish a relationship of trust while sharing the responsibilities

—You joined NTT DATA in the first year of privatization of NTT, and you have been with NTT DATA through its development.

My induction ceremony in 1985 was also the unveiling of the "dynamic loop," which is NTT's logo, and I still remember looking at the loop on a large display. In 1988, I had an opportunity to study in the United States to obtain an MBA. At the time, the importance of management with a thorough understanding of technology was being discussed in the U.S., and Cornell University, where I studied for my MBA, was considering a joint program in engineering and business administration. That discussion probably led to the original concept of MOT (Management of Technology). International students from various countries, including myself, with a background in technical expertise were selected, and we had a challenging time completing a double degree of MBA and M.E. (Master of Engineering) in two years.

During the 35 years since I joined the company, I have been through many difficult times. I have been involved in developing many systems for financial institutions in Japan; for instance, I was in charge of a system that was so mission-critical that any failure would have had a fatal impact on the execution of business. When building a mission-critical system, the simple approach is to apply established means; however, we agreed with the client to build a system by looking 20 to 30 years into the future and made the bold decision to actively incorporate state-of-the art technology.

Since the system used the latest technology in each layer, technical issues piled up one after another. Seeing no clear future in sight, our employees were exhausted from the back-and-forth with international vendors as deadlines loomed. I declared that we intended to carry out the project through to the end and tried to coordinate with stakeholders, exploring the possibility of "sharing the responsibilities," so to speak. We built a relationship of trust, sometimes through heart-to-heart discussions, sometimes through a mixture of taking a hard line or a soft line. Consequently, we were able to align the targets of the entire project while confirming what we could and could not compromise. Thanks to this experience, I value a relationship of trust for moving forward while sharing the responsibilities. I also realized the importance of showing an attitude of persevering through to the end.

—Please give us a few words on future technological developments and for engineers.

We want to build on our strengths by aggregating technologies such as artificial intelligence (AI), blockchain, and software engineering in the technology layer. One of the measures in our mid-term management plan to achieve the expansion of global digital offerings is to enhance centers of excellence (CoEs). This measure is an initiative to contribute to digital transformation of our clients by leveraging the worldwide network of the NTT DATA Group to aggregate knowledge and provide training, technical support, and assets across the world. Up until now, we have been working in four areas: blockchain, digital design, Agile/DevOps, and AI. We have also established CoEs in Internet of Things, intelligent automation, and software engineering automation, which are indispensable for digitalization and in which we should differentiate ourselves. It is difficult to tackle all issues at the same time, so we "look at the big picture and start with small steps" and will narrow down where we need to start and work on it thoroughly.

To our engineers, technology is your strength as well as the common language of the world. While it is important to be interested in new technologies, it is also important to have your own core expertise and use it as a yardstick for your activities. I once heard an electrical engineer describe a dispute as, "We have a resistance circuit here," and I couldn't help but be impressed by that comment. I am sure that you all have your own special skills, so I want you to make the utmost effort to polish them and broaden them or add something new. I myself am not shy in asking younger employees to teach me what I don't know to update my knowledge. Indeed, lectures by younger employees are stimulating and fun. Although it takes time, we, engineers, have to constantly build up our skills.

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[1] NTT DATA Mid-term Management Plan, https://www.nttdata.com/global/en/about-us/mid-term-management-plan
[2] NTT DATA Technology Foresight, https://www.nttdata.com/global/en/foresight/trend-listing

Interviewee profile

■ Career highlights

Toshi Fujiwara joined NTT in 1985 and NTT DATA in 1988. In his career at NTT DATA, he became senior vice president and head of the Fourth Financial Sector in 2014, executive vice president and director in 2017, and senior executive vice president and representative director in 2018 in charge of the financial segment, Americas & Europe segment and global marketing. He became senior executive vice president and representative director, chief technology officer, chief knowledge officer, chief information security officer, chief financial officer, chief human resources officer and chief risk officer in June 2020.

Respond to Any Requests without Expecting Something in Return to Build a Trust Relationship with Others

Seishi Takamura
Senior Distinguished Researcher,
NTT Media Intelligence Laboratories

Overview

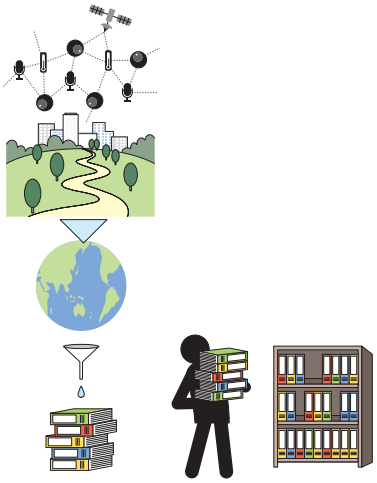
With the spread of the Internet, video data are becoming ubiquitous in our daily lives. Video-coding technology supports the stress-free situation in which we can send, receive, and use high-quality video via television broadcasting and the Internet. The amount of data is expected to increase to 40 YB (yottabytes) around 2040 due to the diffusion and sophistication of Internet-of-Things sensors, and technologies that support such huge amounts of data are attracting much attention worldwide. We interviewed Seishi Takamura, a senior distinguished researcher at NTT Media Intelligence Laboratories, about a coding technology for fully using a huge amount of data and his attitude as a researcher.

Keywords: video coding, multimodal data, omni-ambient data

Being at the forefront of video-coding technology by taking a different approach

—Please tell us about your current research.

I'm currently researching omni-ambient data-organizing technology (**Fig. 1**). This technology is a kind of ultra-high-compression coding for fully using the huge amount of globally generated data (i.e., omni-ambient data), which is said to increase to 40 YB (yottabytes; 1 YB = 10^{24} bytes) around 2040, without having to discard any. For storing and distributing such a huge amount of data, an approach based on information triage (i.e., selection of information)—which reduces the amount of data to fit into the available storage capacity and transmission capacity—is currently the mainstream. With this approach, low-priority data are discarded in accordance with the rules of triage, but valuable data may be included in the discarded data. In contrast, our omni-ambient data-organizing technology stores and distributes a huge amount of data without the need to discard any by enhancing noise removal and information compression. It enables compression by 100 to 1000 times while maintaining higher quality than the current technology. If we use this technology to change the focus of the data-distribution infrastructure from data volume to data quality, we believe that we can



A technology that (i) processes and organizes an enormous amount of information acquired from multimodal sensors distributed on a global scale and (ii) records that information in an easy-to-use state.

Fig. 1. Concept of omni-ambient data-organizing technology.

develop various applications and create new business. In particular, omni-ambient data-organizing technology focuses on video data, which account for more than 80% of the total amount of data. Since the amount of video data used is increasing annually, organizing such data is a major advantage of this technology.

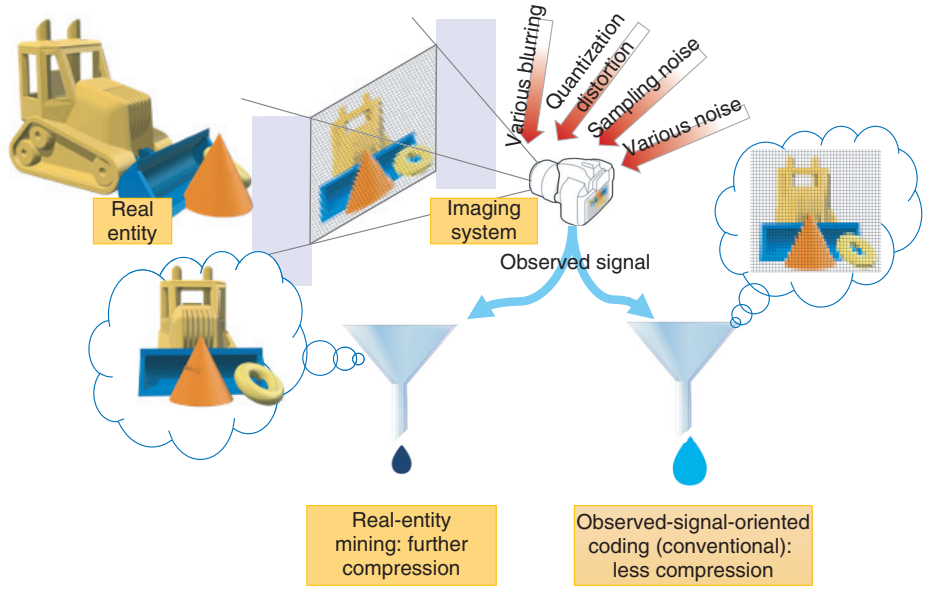
—It seems that this technology will make our lives more comfortable and enjoyable. Please tell us about the key components.

Omni-ambient data-organizing technology is composed of many technical elements, such as point-cloud processing and coding, ray-space processing and coding, error-control coding, 360° video processing and coding, and coding-oriented video generation. The key technology is real-entity mining (**Fig. 2**). Conventional coding technology encodes the captured video as is. However, real-entity mining removes disturbances such as noise, distortion, blurring, and flaws due to the lack of information from a captured video, infers the original image of the object, and encodes the inferred image. Since the state and information of materials and objects are extracted (i.e., inferred) as faithfully as possible to the original ones then encoded, the quality of decoded data exceeds that of the captured video, and an image that approaches the real object is reproduced. Of course, the video data can be further compressed compared with conventional coding.

Although real-entity mining has several applications, we developed water-bottom video coding, which reproduces an image of the real entity of an object seen through fluctuation of the water surface (**Fig. 3**). A scene containing water is an important element that gives the video a sense of presence, however, it is particularly difficult to encode such a scene by using conventional coding. Our water-bottom video coding is highly regarded, for example, we received an award at an international conference, and we have also been invited to submit a paper for a prestigious journal. To further evolve this technology and compare its performance with that of the latest version of international-standard reference software, we are conducting an extremely time-consuming simulation that takes four to five months for one frame[*1].

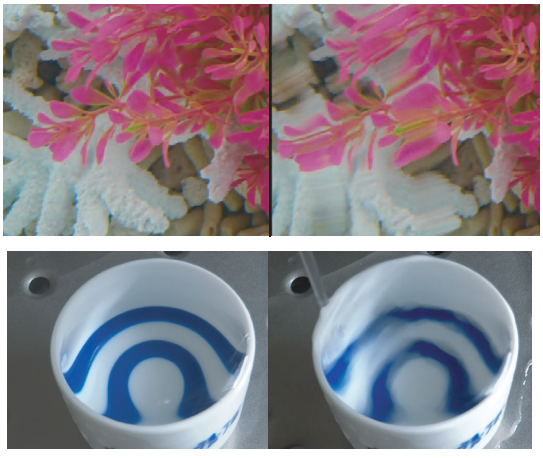
We are also working on point-cloud coding for video. Point clouds are a collection of points in a three-dimensional space that do not follow a grid pattern (i.e., the points exist at irregular positions), and they have a very high degree of freedom in terms of data-point dimension, color in accordance with view

*1 Frame: The unit (i.e., one image) that composes a video. For example, Japanese broadcast video consists of 30 frames per second, and general movies consist of 24 frames per second.



We aim for higher-quality coding through data processing that focuses on the existence of an original object (real entity), instead of conventional coding that is faithful to the observed signal.

Fig. 2. Real-entity mining.



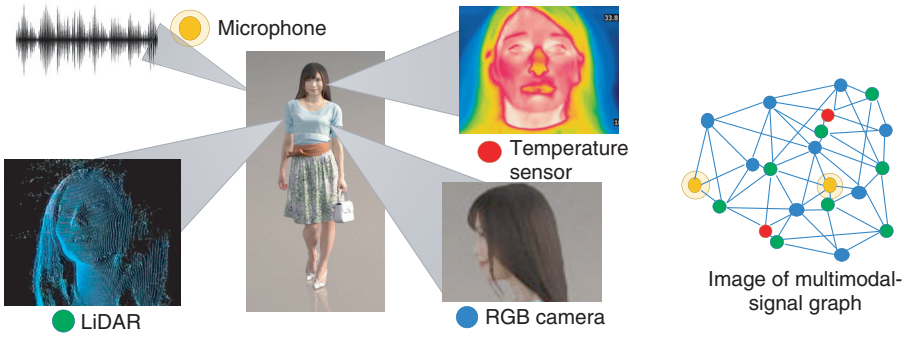
When water is still When water is moving

The shape of the bottom object changes drastically.

Fig. 3. Example images of water-bottom video.

angle, surface normal, etc., and represented by a large amount of data. Point-cloud coding is already an internationally standardized coding technology. However, taking a different approach, namely, lowering the degrees of freedom to increase compression rate and integrating information between multiple frames of video, I'm wondering if it is possible to achieve the contradictory goals of improving quality and increasing compression ratio at the same time.

I'm also investigating multi-modal data compression. The information carried by multimodal signals acquired from an object to be observed from various



Multimodal signals obtained by measuring the same object with various sensors are diverse and have different sampling times and positions but are fundamentally correlated by the laws of physics.

LiDAR: light detection and ranging
RGB: red, green, blue

Fig. 4. Graph signal processing.

locations with various sensors does not contain the temporal-sampling position or spatial-sampling position in a grid pattern, and the dimensions (temperature, coordinates, color, and sound pressure) also differ. Since there is only one real object to be observed, I think that there should be a correlation between these pieces of information, and finding it can be useful for reducing noise, predicting the future, and compressing the amount of data to make the data easier to use. However, a basic theory for handling such signals in an integrated manner is currently not available. Research on the framework called graph signal processing[*2] (**Fig. 4**) is being actively conducted for a single-modal signal. The challenge is to develop a framework for multimodal signals.

The sensor, which is the source of data generation, might have sensed too much data for the object to be observed. Speaking of image sensors, I should mention a technology called compressed sensing, which makes it possible to obtain a fairly accurate image signal by calculation processing in the subsequent process even if some pixels are thinned out. I believe that reducing the amount of data before processing will become more important to reduce power consumption as Internet-of-Things sensors become ubiquitous. The key is to restore the signal in the later calculation process, and the cleverer we are at doing this calculation, the more accurate the observation data will be.

I believe that there are two challenges: improving the accuracy of signal restoration on the basis of a new calculation principle and developing a cooperative restoration between different modal signals in a multimodal-sensor environment. We want to establish these technologies as international standards such as JPEG[*3] and MPEG[*4]. However, we have a long way to go and the hurdles are high, but that's why I find these challenges rewarding.

Besides great successes, there are medium and small success.

—Can you tell us the lessons you have learned while working as a researcher?

For several years after joining NTT, I repeated trial and error without worrying about time. That approach is a privilege for young people, and I think it should be taken if time permits. However, as I get older, I realize that time is not infinite. In 2006, a former NTT researcher, Professor Hiroshi Ishii of the Massachusetts

*2 Graph signal processing: Signal processing using graph, which is one of the methods for expressing the structure of information with nodes (points) and edges (lines or edges). It is a relatively new signal-processing technology used to analyze signals from social networks and sensor networks appropriately and efficiently.

*3 JPEG: Standards for still image coding developed by the Joint Photographic Experts Group, a working group of International Organization for Standardization/International Electrotechnical Commission (ISO/IEC).

*4 MPEG: Standards for audio and video coding data developed by the Moving Picture Experts Group, a working group of ISO/IEC.

Institute of Technology, visited our Yokosuka Research and Development Center and talked about his research strategy. Although Professor Ishii told us to plan our research by superposing our life span on a research timeline, I didn't immediately understand what he was saying. Now that I'm busy and have limited time for trial and error, I'm keenly aware that time is a finite resource. Since I have to carefully examine my research activities and act accordingly, I began to narrow my research themes. Fortunately, the direction of my selected themes did not deviate much from my research activities of the past; in fact, I think that lack of deviation is because I practiced trial and error when I was younger. The water-bottom video coding that I mentioned above is an example of how that approach worked. To investigate this technology, I had the rather twisted idea of "daring to increase the number of frames by one" to compress a given video. Then, after thinking from the standpoint of an encoder, I pondered the question of what kind of frame would be easier to encode, and I subsequently came up with the idea of letting the encoder generate (increase number of) frames and not stopping the generation of frames after one time, but repeating it many times.

It sounds easy to put it in words, but it took about 15 hours to generate a frame once, so it took a lot of patience and effort to repeatedly generate frames. Although this example is the story after narrowing down the theme, I think I wouldn't have come up with the idea without my experience of repeating trial and error.

I have hosted an international competition specializing in water-bottom video coding for two years, and our coding method surpassed the data produced by the winner of the competition. When I submitted a paper to an international conference, I had my first experience in which all three reviewers gave the highest evaluation and was commended as an "excellent paper" of the conference. I'm particularly honored that one of the authorities in this field, a respected Australian professor said, "It's an outstanding paper about a technology that can be used not only for the bottom of water but also for other purposes."

I think it is normal in the research world to have medium and small successes in addition to great successes. The wider the world you can see, the less attachments you will have, and the more challenges you can take on.

What I mean by "success" as a researcher is success when you obtain the results you originally intended or it may be success if you get unexpected by-products. On the contrary, I think that "failure" means that you cannot obtain results even if you spend a long time trying, the difficult situation continues, or you stop your research due to external pressure.

—Could you tell us what you have cherished as a researcher?

My idea of researching with an attitude of enhancing strengths rather than overcoming weaknesses that I talked about in my previous interview has not changed. Researchers aim to be "one of a kind," and if we are not prominent, we cannot survive, so this attitude is important.

In addition, I now feel the importance of give and give and not refusing requests as much as possible. When planning projects or events, you must make a request to various related parties. It is necessary to build relationships on a regular basis so that people will listen to your requests. For that reason, I try to respond to requests in a sincere manner. You will be able to understand the feelings of the person being asked and be less likely to make unreasonable requests. When building such relationships based on trust, I think it is very important not to think about getting something in return. If I receive a request when I am busy, even though it will take up my time, I try to respond to the request with an open mind.

On top of what I said above, I think that connecting with others is everything. I have undertaken quite a lot of external positions, including at academic societies, such as IEEE (Institute of Electrical and Electronics Engineers), and have developed relationships through those positions. Working as the secretary of an academic society led me to be invited by a professor whom I invited to the conference as a visiting researcher at his university.

Also, when talking to people outside the company, I am often surprised to hear that people become unexpectedly connected. Once I found out that the influential figure who was grateful to me at an academic society and a younger person in the company who was helpful to me at work were father and son, and the relationship with that younger person became closer. Having said that, I am not perfect, so there are some people who I don't get on with very well; however, I can learn by observing them. Many senior researchers are still working even as they approach 70, and I want to be like them. At the same time, I become inspired by communicating with people younger than me.

The world is always looking toward "What to do next?"

—You are nurturing not only research activities but also connections that transcend generations.

I think personal connections are a truly precious asset. I also think it is important to covet achievements from research activities. In other words, "Only those who run after two hares will catch both hares." For example, if the deadline for a paper overlaps the schedule of an event such as a get-together, most people would prioritize the paper, but I think it is better to start the paper after attending the event. You will never catch two hares if you act like as the proverb actually goes "If you run after two hares you will catch neither." Perhaps I came up with this idea because I am surrounded by many talented people, and I realize that their achievements cannot be measured on the scale for ordinary people.

Any achievement will be a thing of the past from the moment you achieve it. Making great inventions, writing groundbreaking papers, and winning prestigious awards are achievements to be proud of. However, people are always looking at what you will do next. Therefore, I always keep in mind that achievements are things of the past to aim for the next target.

—Please say a few words to our junior researchers.

You can choose a role model or a person you admire and emulate them as you move forward; however, since each person is different, it is quite natural if you don't end up like them. Although I was also aiming to emulate a certain person, when I look at my own footsteps, I see that I'm taking a different approach and producing different results from those of that person.

I think it's OK to modify your goals from time to time in a variety of situations and after different experiences; in fact, you may obtain better results if you don't stick to them. However, I feel that if you keep thinking about what you really want to achieve or want to be, it will come true unexpectedly, so I think it's important to continue. You may be delighted when that happens, but it's important to think that it's a waypoint, not a goal. They say fortune is unpredictable and changeable, right?

I also think that many young people these days are too serious. In the past, there were more off-the-wall people in the laboratory. Being too serious seems to go against the present trend towards increasing diversity. Even though you may cower when you get caught up in the results and evaluations, I think it is necessary to be a bit "off the wall" to overcome the difficult situations that you will one day encounter in your long research life. Research won't necessarily go better even if you think about it logically. If you are looking for a "hit" among various possibilities, it might be better to do research while thinking as flexibly as possible. I want you to take it easy while making sure to keep your attitude sincere.

■ **Interviewee profile**
Seishi Takamura
Senior Distinguished Researcher, Signal Modeling Technology Group, Universe Data Handling Laboratory, NTT Media Intelligence Laboratories.

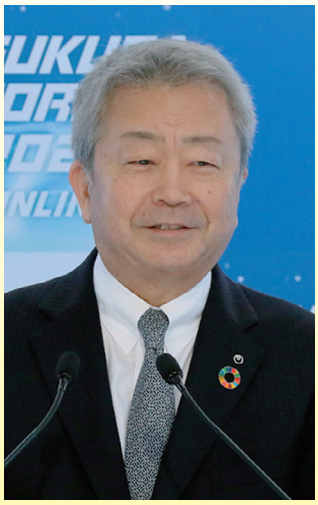
He received a B.E., M.E., and Ph.D. from the Department of Electronic Engineering, Faculty of Engineering, the University of Tokyo, in 1991, 1993, and 1996. His current research interests include efficient video coding and ultrahigh-quality video processing. He has fulfilled various duties in the research and academic community in current and prior roles, including serving as associate editor of IEEE Transactions on Circuits and Systems for Video Technology (2006–2014), editor-in-chief of the Institute of Image Information and Television Engineers (ITE), executive committee member of the IEEE Region 10 and Japan Council, and director-general of ITE affairs. He has also served as chair of ISO/IEC Joint Technical Committee (JTC) 1/Subcommittee (SC) 29 Japan National Body, Japan head of delegation of ISO/IEC JTC 1/SC 29, and as an international steering committee member of the Picture Coding Symposium. From 2005 to 2006, he was a visiting scientist at Stanford University, CA, USA.

He has received 57 academic awards including ITE Niwa-Takayanagi Awards (Best Paper in 2002, Achievement in 2017), the Information Processing Society of Japan (IPSJ) Nagao Special Researcher Award in 2006, Picture Coding Symposium of Japan (PCSJ) Frontier Awards in 2004, 2008, 2015, and 2018, the ITE Fujio Frontier Award in 2014, and the Telecommunications Advancement Foundation (TAF) Telecom System Technology Awards in 2004, 2008, and in 2015 with highest honors, the Institute of Electronics,

Information and Communication Engineers (IEICE) 100-Year Memorial Best Paper Award in 2017, the Kenjiro Takayanagi Achievement Award in 2019, and Industrial Standardization Merit Award from Ministry of Economy, Trade and Industry of Japan in 2019 (as an individual) and in 2020 (as NTT team).

He is an IEEE Fellow, IEICE Fellow, senior member of IPSJ, and member of Japan Mensa, the Society for Information Display, the Asia-Pacific Signal and Information Processing Association, and ITE.

NTT Group's Initiatives for a Post-COVID-19 Society



Jun Sawada

Abstract

This article introduces NTT Group's initiatives for a Post-COVID-19 society. The content of this article is based on a keynote speech presented by Jun Sawada, president and chief executive officer of NTT, at the Tsukuba Forum 2020 ONLINE held October 29–30, 2020.

Keywords: IOWN, All-Photonics Network, remote world

1. My involvement with Tsukuba R&D Center

To begin with, I would like to talk about the special place I have in my heart for Tsukuba R&D Center. I first entered the company in 1978 (then, the Nippon Telegraph and Telephone Public Corporation) as an engineer assigned to the telephone line division (now the access division). In my first assignment, I made many visits to what is now the Joso City area near the Tsukuba R&D Center. Then, in my third year, I was assigned to what was then the technology section and put in charge of structures. It was at this time that I undertook the research and development of construction technology at the Technology Construction Center (now, NTT Access Network Service Systems Laboratories). At this research laboratory, the soil experimental building had facilities for driving a trailer with a 20-ton load at speeds of up to 60 km/h that could be used to conduct experiments on road loads and measuring their effects on manholes, conduits, and cables. Actually, this research had already been completed, but the last person to drive that trailer was me. As the person in charge of structures, I also experienced first-hand the hard work performed by those involved in disaster recovery.

This photo that I carry around with me relates to experiments conducted at that time on freeze-proof polyethylene (PE) pipes with which problems had been occurring during cable laying (**Photo 1**). It shows how we would pull transparent PE pipes on land to emulate pulling within a conduit. These experiments examined the correlation between strain and the behavior of cables and PE pipe, tensile strength, number of cables, etc. I came to understand that conducting a series of such practical experiments enables us to operate our telecommunication facilities in a stable manner within a severe natural environment from several tens of degrees below to

Photo 1. My involvement with Tsukuba R&D Center.

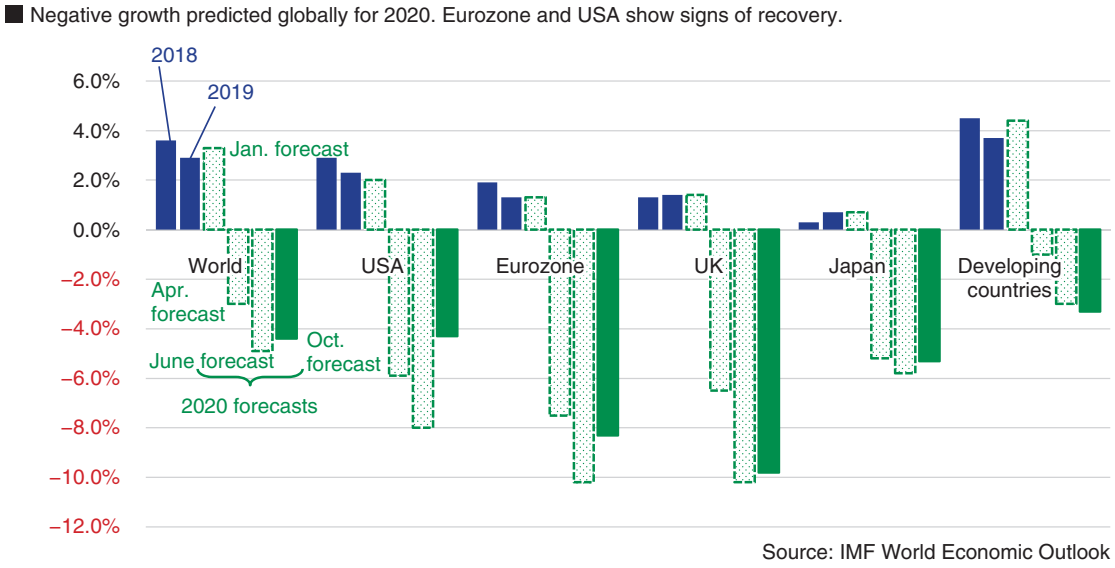


Fig. 1. Impact on global economy—GDP forecasts.

several tens of degrees above freezing. In the second half of this article, I will talk about the Innovative Optical and Wireless Network (IOWN), but let me say that even amazing technologies will not be accepted by society without such steady and dedicated research.

2. Global spread of COVID-19

The novel coronavirus (COVID-19) continues to spread. While people are still practicing social distancing and signs of a slight economic recovery are appearing, the number of infected individuals is growing again. In Japan, COVID-19 is classified as a designated infectious disease, so an individual that tests positive is basically quarantined in a hospital, which increases the load on the medical care system. While the results of analysis have shown that an infected individual is most likely to spread the virus during the first week or so after the onset of symptoms, even an asymptomatic person can infect others. The number of new infections in Japan is lower than that in the United States and major European countries by about two orders of magnitude. While this reason is not yet fully understood, further research into explaining this state of affairs may uncover elements other than a vaccine or method of treatment that can change the effects of such an infectious disease. The NTT Group is not involved in this research, but I feel that steady research efforts must be made in making changes in society.

The total number of infected individuals in the NTT Group is about 2400 as of October 29, 2020, which breaks down to about 400 in Japan and 2000 abroad. Unfortunately, 13 individuals have passed away, 2 in Japan and 11 abroad. I feel that we must be concerned about COVID-19 while dealing with it in an appropriate manner.

Amid this increasing number of infected individuals due to COVID-19, what sort of impact is this pandemic having on the global economy? The gross domestic product (GDP) forecasts by country announced by the International Monetary Fund (IMF) show a somewhat slow recovery in the UK and Japan and signs of a recovery in the Eurozone and the United States with only China showing positive growth. The world on the whole shows signs of a recovery from negative growth (**Fig. 1**). At the same time, the purchasing managers' index (PMI) shows that economic conditions in Japan fell during the country's state of emergency (in early 2020) with a similar drop in other countries, and that developed countries other than Japan have moved into the positive side as of September 2020. These indices indicate that only Japan has yet to make an economic recovery, which may reflect the cautious traits of Japanese people (**Fig. 2**).

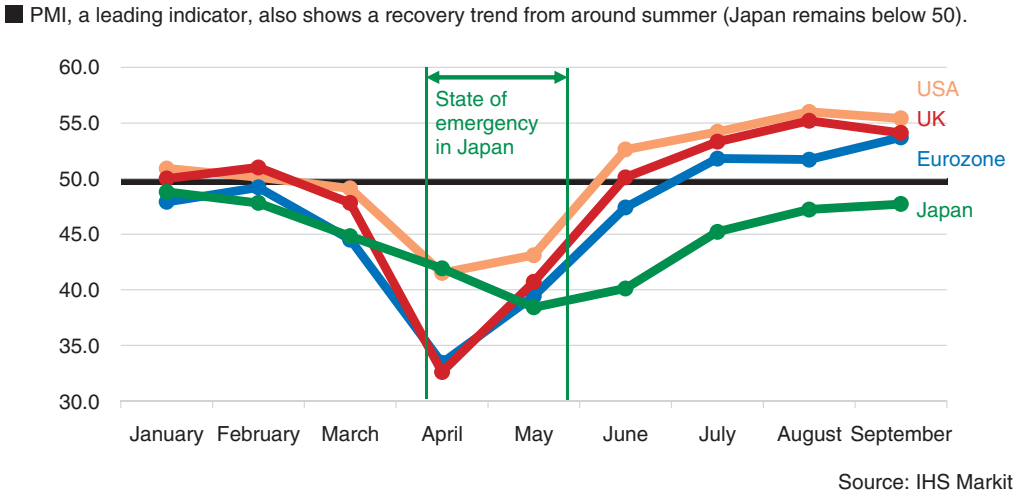


Fig. 2. Impact on global economy—PMI.

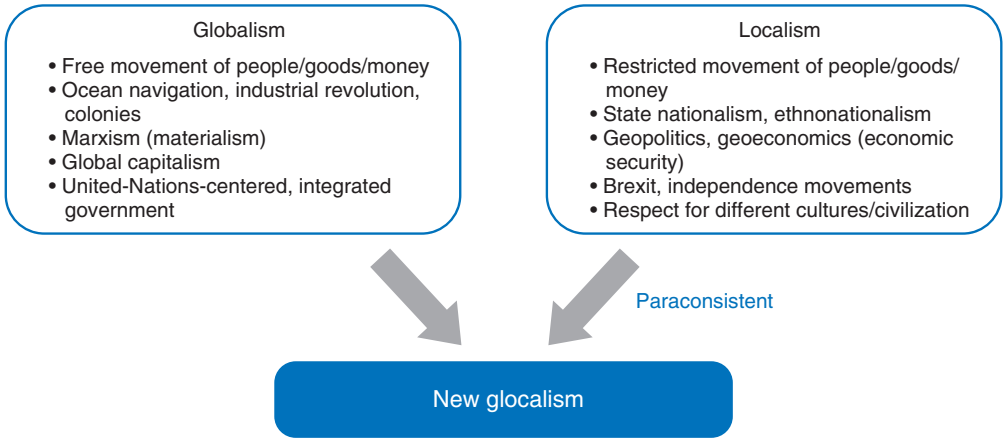


Fig. 3. Rise of new glocalism.

3. Creating a remote world

Next, I would like to take a look at trends for a post-COVID-19 society. One trend involves revitalizing the economy while achieving social distancing. I believe that achieving both simultaneously in a *paraconsistent* manner will lead to the creation of a remote world (dispersed society). In such an environment, could not the NTT Group offer some help from the perspective of information and communications technology (ICT)? This is one issue that we are now taking up.

4. Rise of new glocalism

Up to now, we have come to consider the global free movement of people, goods, and money as natural. However, the situation is now changing. People can no longer move about freely, and we cannot move goods freely. This signals a strong emergence of localism (**Fig. 3**). Culture has been locally rooted, so it's a concept contradictory to globalism. From here on, though, I think that both localism and globalism will be simultaneously achieved to create a world of "new glocalism." Even in Japan, the expression "economic security" is beginning to be used, and such a trend will have a significant impact on the world of

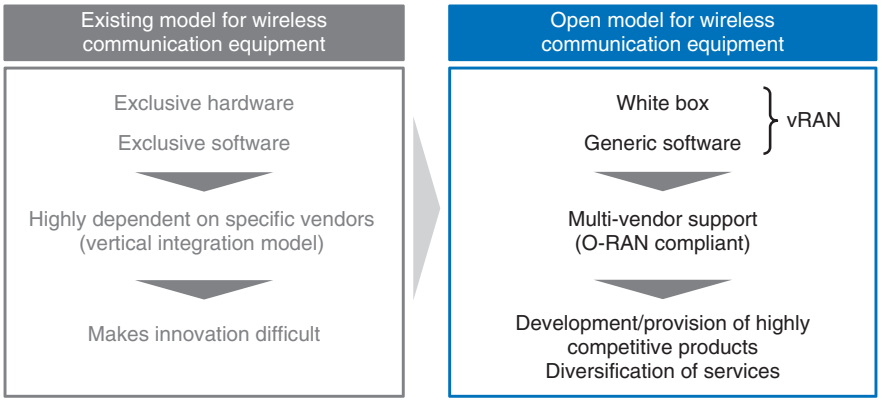


Fig. 4. Development/provision of O-RAN + vRAN.

ICT.

5. Changes in the environment surrounding the telecommunications market

I have mentioned that *creating a remote world* and *rise of new glocalism* are two key trends for a post-COVID-19 society, but I would also like to point out two important changes that are now taking place in the telecommunications market against the background of those trends.

One is the launching of fifth-generation mobile communications system (5G) services and technological development toward the sixth-generation mobile communications system (6G). With 6G, I believe that the barrier between fixed and mobile communications will become smaller or disappear altogether, so it will be necessary to provide integrated and seamless services.

The other change is the coming of severe market competition beyond the telecommunications layer, that is, a change in competing players. For example, over-the-top providers will cover vertically integrated services from the application layer to the infrastructure layer, and terminal manufacturers will provide communication services using an embedded subscriber identity module (eSIM)* as a trigger. With this change in structure, borderless market competition will become all the more severe.

6. Road to IOWN (future directions)

In 2019, we announced the concept of IOWN as a new information and communication infrastructure. The road to IOWN will be driven along four key directions: development/provision of new services that consider the remote world, concentration of resources and promotion of digital transformation (DX), implementation of research and development on a global scale, and enhancement of new businesses. In this article, I would like to discuss these future directions.

6.1 Development and provision of O-RAN + vRAN

In the *development/provision of new services that consider the remote world*, we announced a business and investment tie-up with NEC Corporation in June 2020 for joint research and development. I will introduce the directions that we envision this tie-up will take.

The first direction is the acceleration of the Open Radio Access Network (O-RAN). This is a model advocated by NTT DOCOMO to accelerate multi-vendor interoperability in partnership with NEC. It promotes a transition from the existing vertical integration model that is highly dependent on specific vendors to an O-RAN/vRAN (virtualized RAN) model to support white-box equipment and generic software in a multi-vendor environment. Therefore, both NTT and NEC plan to drive the spread of open architecture (**Fig. 4**). The next direction is collaboration on manufacturing devices and equipment. Our goal is joint development of a digital signal processor having both the world's highest level of performance and low power consumption as well as information-communication equipment that will embed the processor. In the long run, we would like to connect these

* eSIM: An SIM card integrated in a mobile terminal.

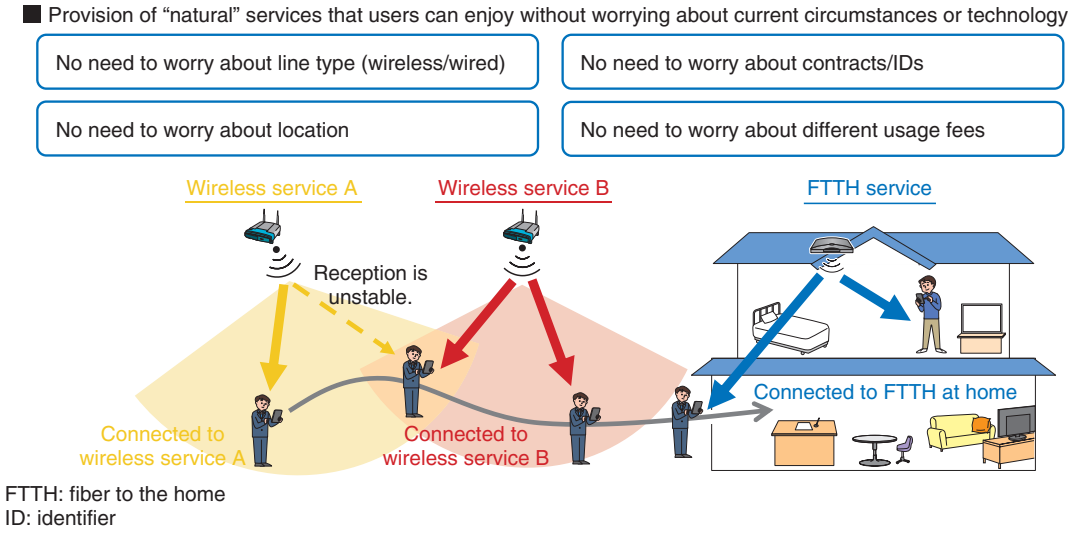


Fig. 5. Development of mobile/fixed seamless services.

initiatives to our efforts in making IOWN a reality.

6.2 Development of mobile/fixed seamless services

Beyond our promotion and development of the O-RAN/vRAN model, we would like to achieve cognitive communication that manages user presence (**Fig. 5**). From the user’s point of view, this means the ability to connect in a seamless manner using the most optimal communication environment regardless of location without having to worry about line type (wireless/wired), separate contracts, usage location, or different fees. In short, our goal is to achieve “natural” services.

6.3 Objective of converting NTT DOCOMO into a wholly owned subsidiary

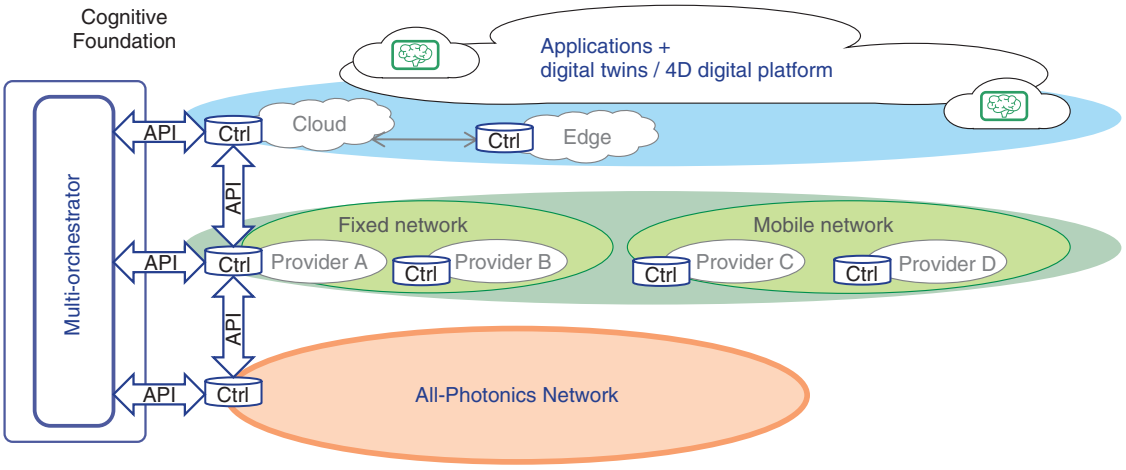
Next, as part of the second key direction of *concentration of resources and promotion of DX*, we announced the conversion of NTT DOCOMO into a wholly owned subsidiary of NTT. The objective of this move is to enhance the competitiveness and growth of NTT DOCOMO and promote the growth of the entire NTT Group. By leveraging the power of NTT Communications and NTT Comware, we aim to promote new services and solutions and a 6G-oriented communications infrastructure in the form of mobile/fixed seamless services as I just described and to drive the further evolution of NTT DOCOMO into a comprehensive ICT enterprise that extends as far as upper-layer businesses.

6.4 IOWN

IOWN can be expressed as a three-layer model (**Fig. 6**). In the middle of this model lies the network layer, which is currently divided into the fixed and mobile networks. In the future, though, the configuring of services will be centered about this layer. Supposing that 6G will be able to handle a communication capacity of more than ten times that of current 5G, the performance and capacity of optical fiber, fixed network, etc. that lie behind the scenes will naturally have to be raised. On a chip level, however, problems related to heat and efficiency present a strong barrier to these enhancements. The coming of the All-Photonics Network featuring photonics-electronics convergence as a key technology will help solve these problems. However, it will be Digital Twin Computing on an upper layer where many services using big data will be born. The All-Photonics Network and Digital Twin Computing will take on a cooperative existence. In addition, considering that efficiency is poor in the case of distributed networks, they will have to be connected. This is why an element called Cognitive Foundation® will be needed. These three elements—All-Photonics Network, Digital Twin Computing, and Cognitive Foundation—will become the basic framework of IOWN.

I believe that the convergence of core networks will be a prime driver in this development effort. The idea is that core-network components must work together to achieve a seamless connection between the mobile and fixed networks. At present, however, there are

■Achieving IOWN comprised of the All-Photonics Network, Digital Twin Computing, and Cognitive Foundation®



API: application programming interface
Ctrl: controller

Fig. 6. IOWN concept.

many nodes, systems, and networks that are being discussed in terms of voice communications and data communications, whether they should be consumer-oriented or business-oriented, etc., and research is needed to determine to what extent and in what form these elements should be converged. For this reason, close collaboration between NTT laboratories and the research laboratories of NTT DOCOMO is indispensable. Furthermore, if large volumes of data come to be processed using an open model, it will be necessary to study whether software and computer systems can operate under a disaggregated model. This, in short, means a migration to a serverless format by incorporating photonics-electronics convergence technology on the computer side as well. I also see the need for white boxes to support ultra-large-capacity, high-speed processing on such a platform.

In the United States, we have established a company called NTT Research, Inc. composed of three research laboratories. The research conducted there includes topics in medical and health science, and going forward, I think there will be increasing interest in discussing how medical ICT can support everyone's healthcare in the form of digital twins. Such a development will involve questions on how to deal with various types of wearable and implantable devices, so I think that the aforementioned fields of medical ICT strategy, mobile/fixed convergent core, disaggregated computing/operating systems (OSes), O-RAN/vRAN, and devices will attract attention as next-generation research and development themes from within IOWN (**Fig. 7**).

6.5 All-Photonics-Network use cases

As an official partner of Major League Baseball (MLB), NTT has been working to provide Ultra Reality Viewing experiences using its Kirari! technology, but in 2020, the effects of the COVID-19 pandemic put this initiative on hold. Spectator-based events have recently been changing into digital events, so we expect to be able to hold such events based on a dispersed remote world. Specifically, we would like to create a unified experience for spectators dispersed inside/outside the stadium. This will require the transmission of stadium information without delay to home-viewing or public-viewing sites and the feeding back of the reactions of those spectators to the stadium, likewise without delay. This, in turn, will require the All-Photonics Network to have extremely low delay (**Fig. 8**). We can treat such an event as an All-Photonics-Network use case.

In addition, quantum cryptography and quantum communication are two fields that are increasingly being taken up, and the All-Photonics Network will expand the range in which quantum cryptography can be applied by approaching optical end-to-end

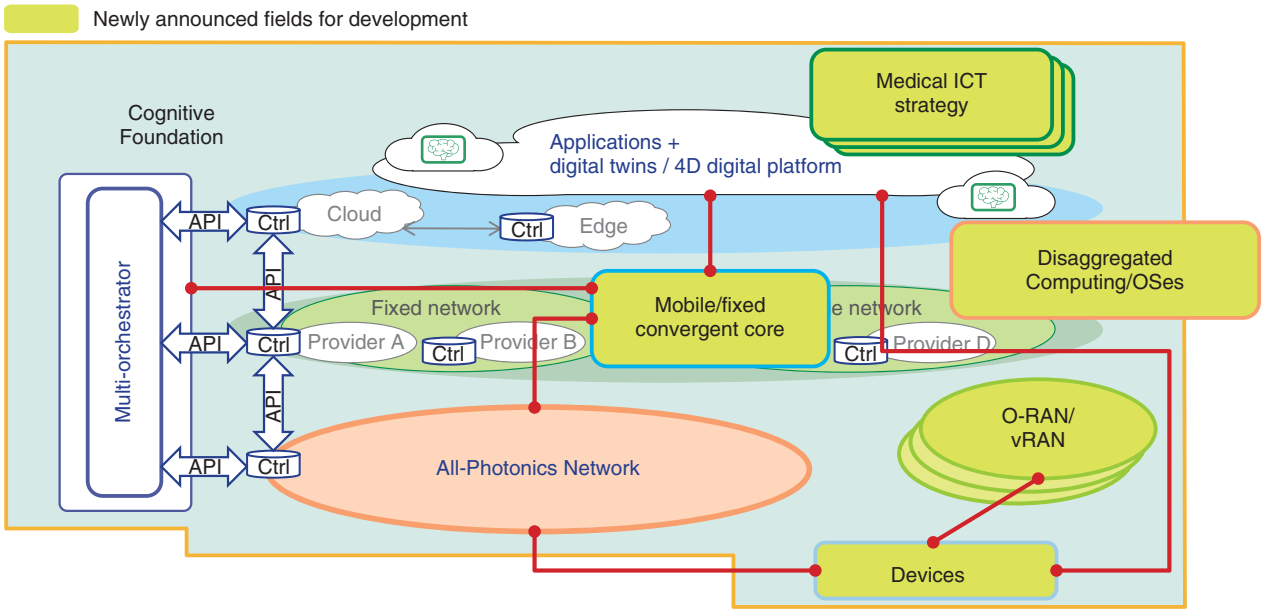


Fig. 7. Telecommunications structure of 2030 (envisioned).

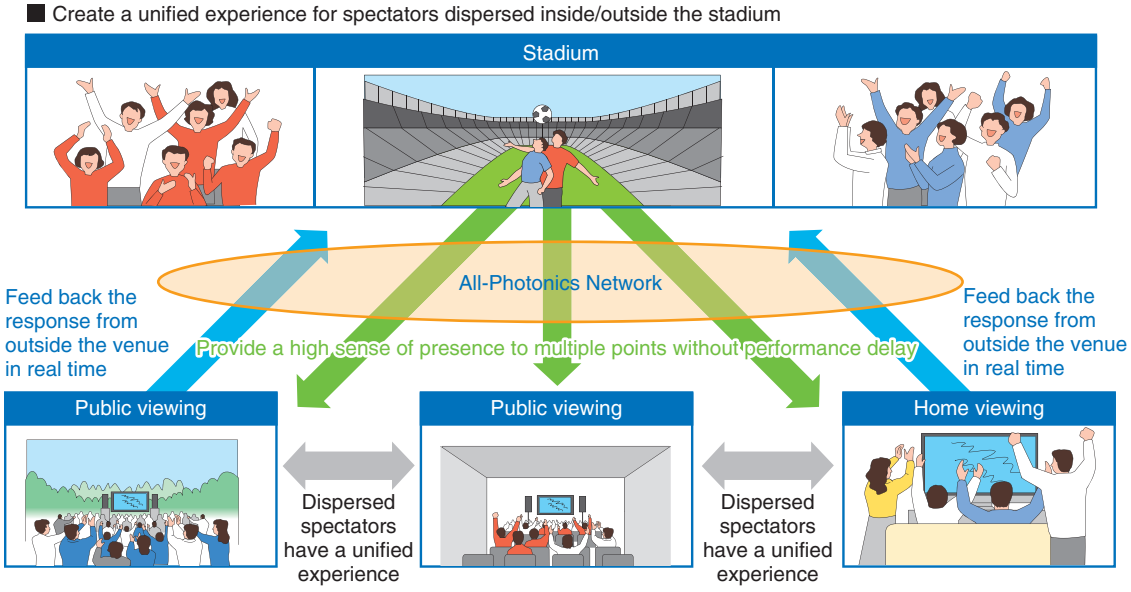


Fig. 8. All-Photonics-Network use case (Dispersed Ultra Reality Viewing).

communications. In fact, the development of the All-Photonics Network simultaneously takes into account support of quantum cryptography and quantum communication.

7. Access network on IOWN

I would like to see NTT Access Network Service Systems Laboratories enhance the access network toward IOWN. They have been researching and developing various elements and systems, but from

here on, I think it's necessary that they go beyond today's research and development stage and study means of dealing with demand that optical fiber in the field today would not be able to cover. For example, a decision must be made on whether to overlay or replace the present access network with a new system. Looking ahead ten years, I see an end to today's basic design model of fiber to the home (FTTH) in which optical fiber is allocated in single-wavelength format or fixed wiring intervals from the perspective of planned economics. I can imagine a hybrid access system that, depending on the demand, provides access by a base station's backhaul or fronthaul or by direct connection to a building, or that provides services in terms of wavelength or by conventional FTTH. A transition period and transition scheme must be studied to decide on how to absorb new infrastructure while having it coexist with existing equipment. The fixed access network, in particular, will continue to be provided to both individual and corporate customers.

I think the era is coming in which mobile communications or the customer's local 5G infrastructure system can be used for access. I would like to research and develop such technologies and promote research and development and business on a global scale so that we will be able to provide NTT Group systems throughout the world.

8. Concluding remarks

At the beginning of this article, I talked about the hardships we faced 40 years ago in development work. The research themes that I managed were often directly connected to work in the field, and I was often reprimanded for problems in the field when I went to regions throughout Japan. It would sometime happen that some procedure was done in a way different from the usual way causing, for example, stripped threading in equipment. Then, while thinking of how to develop a system or equipment technology that could reliably handle such irregular events, I would always be trying to overcome the thinking of "it must be done this way" or "this is the way it's always been done." I hope that we, the NTT Group, can work with our partners to overcome this thinking within us and create a world in which we can make new technologies.

Jun Sawada
President and Chief Executive Officer, NTT.
He joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1978. After serving as manager of communication lines and other network facilities, he became vice president of NTT America in 1998. In 2000, he moved to NTT Communications, and after serving as head of the Corporate Planning Department, executive manager of Consumer and Office Users Business Division, and general manager of the Kansai business office, he became senior vice president and executive manager of the Corporate Strategy Planning Department in 2008. He then became representative director, senior executive vice president of NTT in 2014, serving concurrently as chief executive officer of NTT Security from 2016. He assumed his present office in June 2018.

Toward the Realization of Smart Regional Societies, "To Be the Social ICT Pioneer"

Ichiro Uehara

Abstract

This article introduces case studies on the effort that NTT WEST Group is making as a social ICT (information and communication technology) pioneer to address the issues of local communities and strengthen the connections between people and society to promote smart regional societies. This article is based on a keynote speech given by Ichiro Uehara, senior executive vice president of NTT WEST, at the Tsukuba Forum 2020 ONLINE event held October 29–30, 2020.

Keywords: Society 5.0, digital transformation, community revitalization

1. What is a smart society?

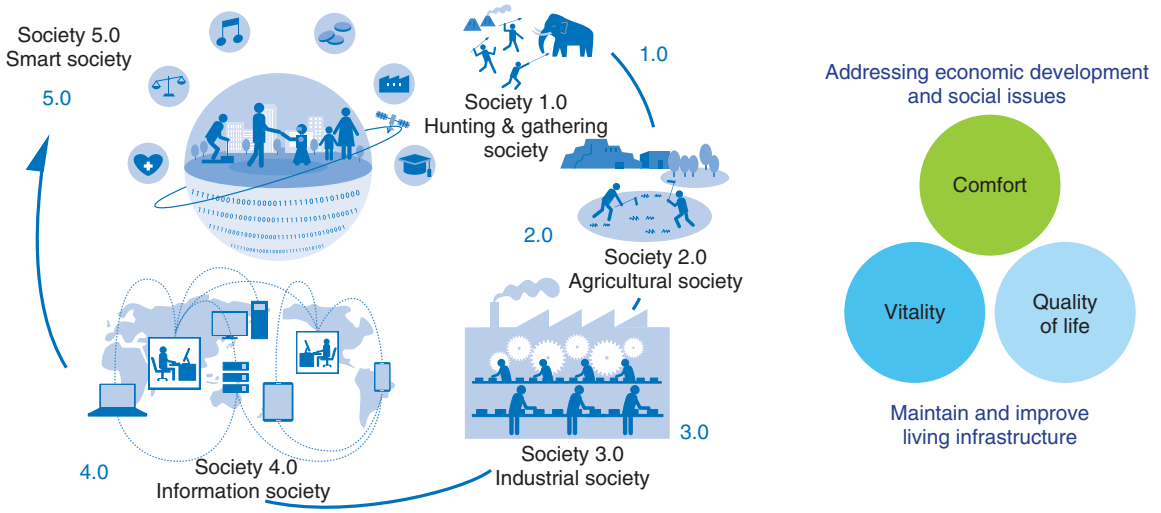
To promote smart societies according to Japan's "Society 5.0" initiative (**Fig. 1**), we need to focus more on a people-centered approach to achieving economic development and addressing social issues, rather than pursuing technology for its own sake. On the other hand, existing social systems have become outdated in terms of their sustainability and environmental considerations. Therefore, we should consider new social systems that focus on the happiness of each individual.

In the *World Happiness Report 2020*, which is a global survey of well-being published by the Sustainable Development Solutions Network, Japan ranked 62nd out of 156 countries. Although Japan's healthy life expectancy and GDP (growth domestic product) per capita are similar to those of other top countries, it ranked poorly in terms of generosity and perceptions of corruption. In another survey report, *Legatum Prosperity Index 2019* published by Legatum Research Institute, Japan earned low scores for social capital and for social relations and civic participation. A Harvard University report based on a survey of the lives of more than 700 people over a period of about 80 years found that building good relationships with other people is important for happiness and health. This suggests that in Japan, where people are less likely to establish connections with other people or with social communities, it might be possible to achieve higher levels of happiness by improving these connections.

2. Addressing local issues and strengthening connections by integrating digital space with the real space

In terms of consumption behavior, the evolution of human society can be broadly divided into the Society 1.0 and 2.0 eras when people consumed goods through hunting and farming, the Society 3.0 era of industrial society, and the Society 4.0 era in which information itself has become a commodity. In the next era, Society 5.0, the concept of digital spaces will be added, creating the important new perspective of time in both real and digital spaces as a commodity that people will seek to obtain as a path to their own fulfillment (**Fig. 2**).

It is also important to create new connections among people and between people and society by



Source: Cabinet Office, Government of Japan, "Society 5.0," https://www8.cao.go.jp/cstp/english/society5_0/index.html

Fig. 1. A smart society (Society 5.0).

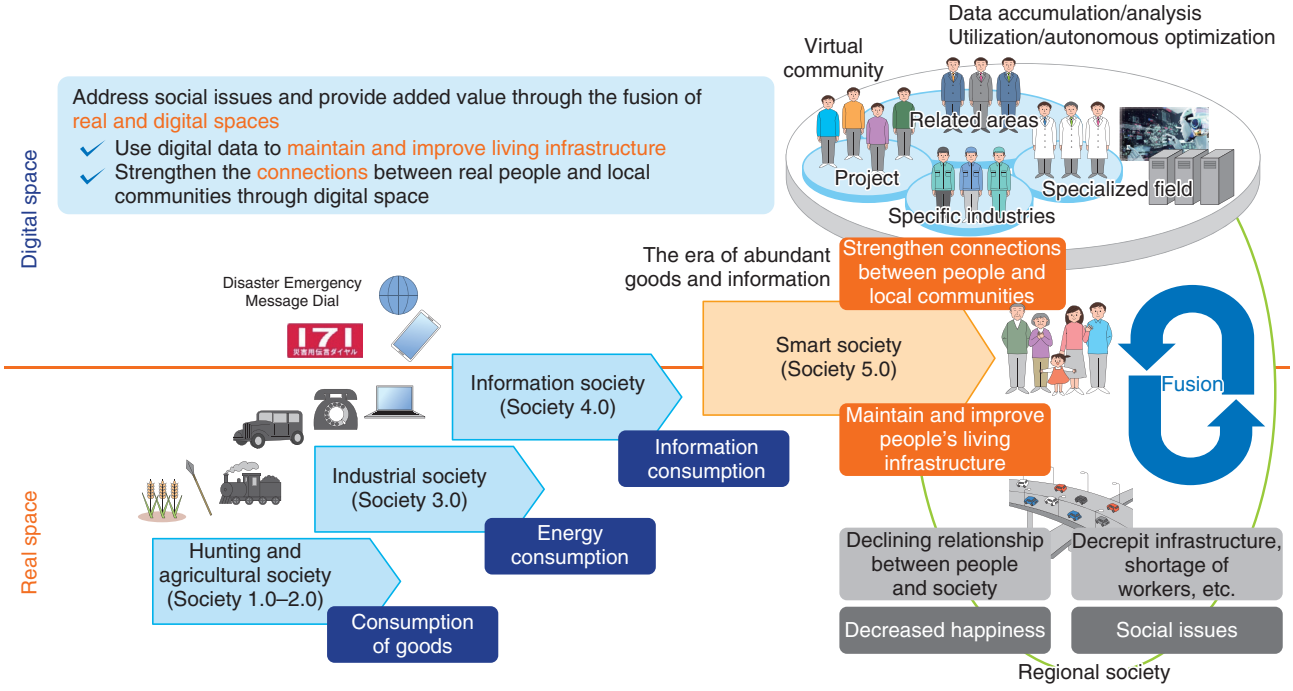


Fig. 2. Creating a smart society (fusion of real and digital spaces).

combining real and digital spaces to address social issues such as the aging of regional infrastructure, worker shortages, and the decline in relationships between people and society.

The high-level fusion of digital and real spaces is one of NTT's strengths. It is expected that this strength will lead to maintaining and improving the infrastructure of daily life in the use of digital data, strengthening the connections between people through digital space, and adding value.

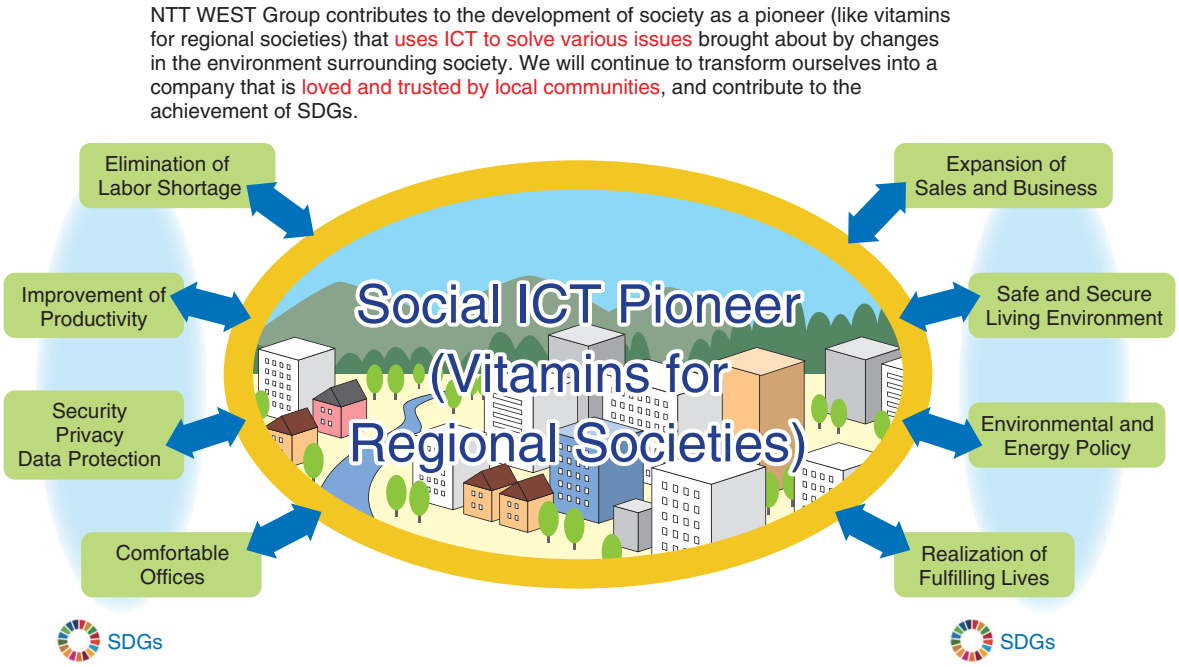


Fig. 3. Leading the way in social ICT.

3. Local communities and social ICT pioneers

Due in part to the coronavirus pandemic, the population of Tokyo has been decreasing. Provincial regions of Japan are also facing depopulation issues caused by a declining birthrate and aging population. As a result, employment positions are being left unfilled, and families are finding themselves without successors. If this problem continues, industries will decline, tax revenues will decrease, and it will become difficult to maintain and upgrade Japan's aging infrastructure, leading to a decline in the quality of government services and an even greater outflow of people. We must find a way to break this *negative spiral* and replace it with a *positive spiral*.

At NTT WEST Group, we aim to build on our role as a pioneer in the use of information and communication technology (ICT) to address social issues by playing the role of a regional *vitamin* to promote social development and achieve the United Nations' sustainable development goals (SDGs) (**Fig. 3**). The branch managers of 30 branches are currently serving as project leaders to address local issues in cooperation with local partners by combining NTT WEST's local expertise and resources with services in ten fields ("Smart10x"). Specific examples of such community revitalization projects are introduced below.

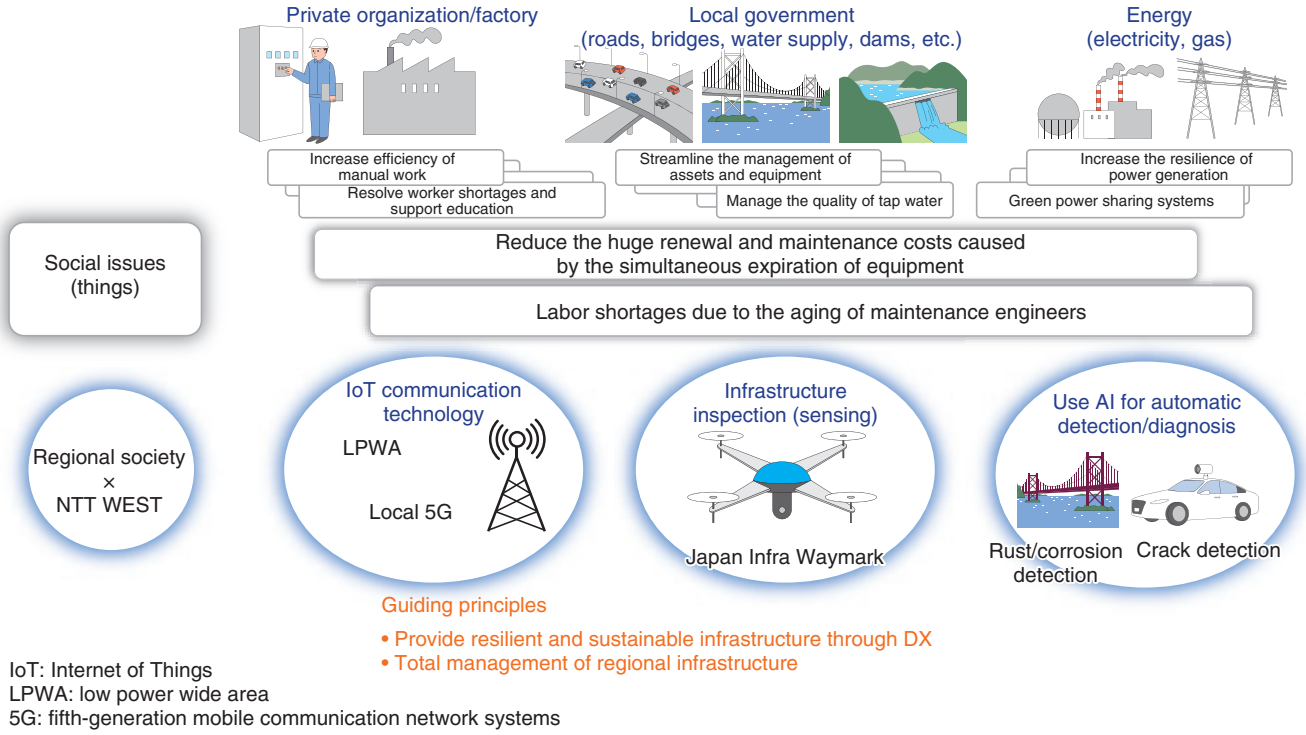
4. Examples of community revitalization projects with local partners using local features and connections

4.1 Sustainable social infrastructure

With regard to social infrastructure, we aim to provide resilient and sustainable infrastructure through our policy of digital transformation (DX) to address issues such as the increasing cost of renewing and/or maintaining ageing infrastructure and the decreasing number of engineers available to maintain this infrastructure (**Fig. 4**).

Inspection of infrastructure facilities with drones using the facility management expertise of the NTT WEST Group

In April 2019, we launched Japan Infrastructure Waymark, a company that uses drones to provide services including infrastructure inspection. It offers a one-stop service that includes inspection, reporting, and support services not only for telecommunication facilities but also for various other social infrastructures including electricity, gas, and solar power supply systems. It can identify the metal to be inspected, thus can identify rust and corrosion in this metal by learning from a large number of on-site images taken by drones as training data. We are currently able to detect rust and corrosion with an accuracy of 99.2%



IoT: Internet of Things
LPWA: low power wide area
5G: fifth-generation mobile communication network systems

Fig. 4. Maintenance and improvement of social infrastructure (smart infrastructure and energy).

and are using this technology to automate and improve the efficiency of rust and corrosion inspection on bridges and other structures. To promote the use of drones for indoor security as well as for infrastructure inspection, we are actively expanding the use of this technology, including participating in a demonstration experiment in which commercial facilities beyond the reach of GPS (the Global Positioning System) signals are automatically patrolled using drones and recognizing humans present in these facilities using artificial intelligence (AI).

4.2 Supporting lifelong learning in the era of high life expectancy and coronavirus pandemic

To address social issues in this era of declining birthrates, aging population, and hundred-year life spans, we are looking at ways of providing learning via a *remote world* and implementing customized life design and learning for each individual (**Fig. 5**).

Promoting computerized and recurrent education

We are currently working with Dai Nippon Printing to make all university teaching materials and textbooks available in electronic form. Although progress has been made with ordinary books, specialized books and teaching materials used at universities are lagging behind in this regard. In addition to teaching materials, we also hope to promote educational DX whereby learners can visualize their level of proficiency and combine it with attendance and grade data to obtain an individually tailored learning program.

In addition to developing a recurrent education environment that includes remote classes for joint use in collaboration with universities, monitoring of learning progress, and visualization of skills, we are also studying an AI-based counseling framework for recurrent students who wish to return to work. We hope to cooperate with regional banks and other regionally based partners to help match workers with companies.

We also offer a certificate-issuing service that enables people to have graduation certificates and certificates of achievement issued at convenience stores 24 hours a day, 365 days a year. This service is highly rated as it helps people to search for jobs and explore career changes without having to visit universities to perform the necessary processing. Thus far, about forty universities have signed up to this service.

In the future, as life expectancy increases and the demand for lifelong learning grows, we believe that it will become more important for people to be able to

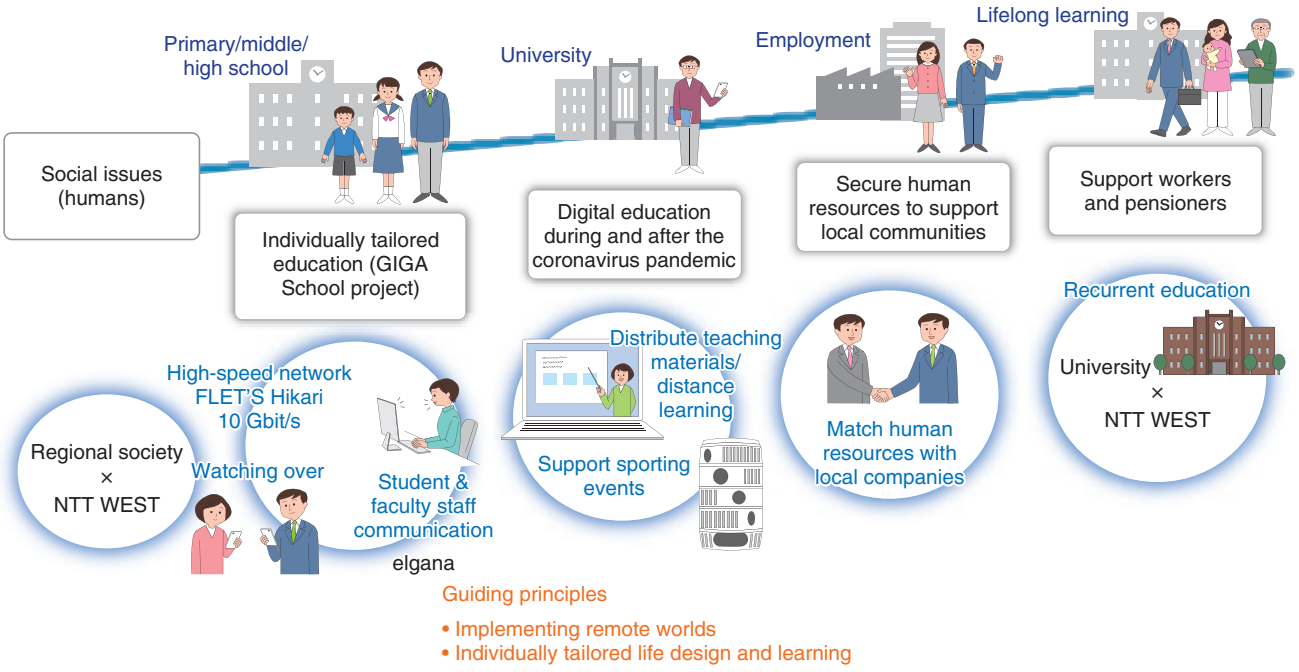


Fig. 5. Individually tailored lifelong learning & life design.

manage and record their learning activities with a consistent identifier (ID).

Using AI cameras to distribute video of amateur sports events during the coronavirus pandemic

As part of our effort to revitalize local communities, we established a company called NTTSportict on April 1, 2020, with the aim of promoting amateur sports. This company provides a service whereby unmanned cameras developed by Pixellot are used to capture video of sports events, and AI is used to automatically execute camera work and editing in accordance with the characteristics of the sport before distributing the video.

Pixellot provides an environment where people can watch amateur sports by making it easier to distribute video content than ever before. Even though the coronavirus pandemic has made it impossible for supporters to attend sports matches, we offered to distribute a hundred student sports games free of charge, and received over 700 applications.

4.3 Working closely with local communities to achieve DX of primary industries from a regional perspective

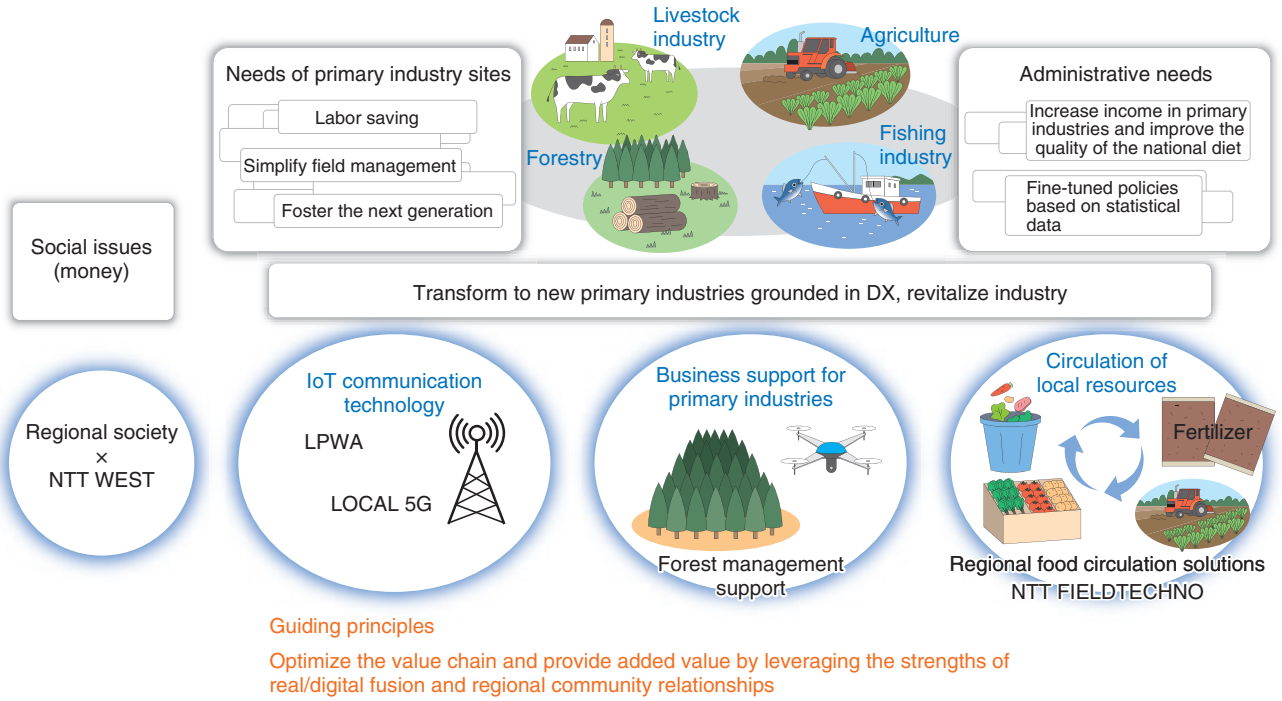
Smart Agri is an initiative for revitalizing primary industries, i.e., agriculture, forestry, and fisheries. By taking advantage of our close ties to local communities, we aim to optimize the value chain and provide added value while collaborating with people who are actually involved in local primary industries and integrating real and digital technologies (**Fig. 6**).

Applying ICT to forest management

Miyazaki Prefecture has abundant forest resources and has ranked first in Japan in the production of cedar for 29 years. Although forestry is the mainstay of the prefecture's economy, it faces challenges such as ensuring safety (there is a relatively high mortality rate among primary industries), complying with forest management requirements, and expanding the distribution of harvested timber. As a management model for forests, which are said to be upstream of the supply chain, we established a system that uses tools, such as drones, to efficiently count and measure the trees in a target area and store the data in the cloud. We are also working to revitalize distribution by establishing a downstream supply chain, including matching demand with lumber mills and house builders. At the same time, we are studying how biomass power generation can make effective use of thinned wood and branches that are ordinarily left unused on the forest floor.

Recycling of local waste materials as organic fertilizer

It has been reported that Japan generates about 28



*Smart Agri: A term that refers to the use of smart technology not only in agriculture but also in forestry, fisheries, etc.

Fig. 6. Revitalization of primary industries and circulation of local resources (Smart Agri).

million tons of food waste every year. In Shiga Prefecture, the cost of incinerating non-native fish, such as black bass, and water plants in Lake Biwa is also an issue. We are working at implementing a food cycle by providing waste-decomposition equipment so that waste can be converted into organic fertilizer and distributed to producers so they can produce organic vegetables for distribution and sale. By using AI to analyze organic fertilizers in terms of soil data, compost composition, and so on, we hope to match them to the most suitable vegetables and fruits so they can be circulated to where they are needed on the production side.

Using data to provide new tourism and mobility experiences and regional mobility as a service (MaaS)

We aim to promote sustainable local communities and cities by using data distribution related to transportation and tourism to help provide comfortable transportation and attractive tourism. As a first step, we are working on the use of data for driver safety education. To provide each individual with optimal educational support, we are also combining this with information about the weather and road conditions (including traffic jams or accidents), and the driver's habits (e.g., a tendency to perform sudden maneuvers or a history of traffic violations). As the next step, we hope to collect data on customers' needs, interests, and preferences so as to not only provide smooth transportation but also attract customers to nearby sightseeing spots and improve their purchasing motivation. Although the pandemic has caused a reduction in tourist numbers, we are also working to create a system that provides a variety of information in the pre-travel phase to stimulate interest and attract more visitors.

5. LINKSPARK co-creation labs to promote customer DX

A co-creation lab is a place where new community initiatives are encouraged. Ours are called LINKSPARK, where we support our customers' DX activities by using digital data and design thinking to address issues and create new value. Our first one opened in Osaka in August 2019, and the second opened in Nagoya in October 2020. In Nagoya, we have many customers in the manufacturing industry, so we are keen to support their DX efforts in production and manufacturing and help them create new

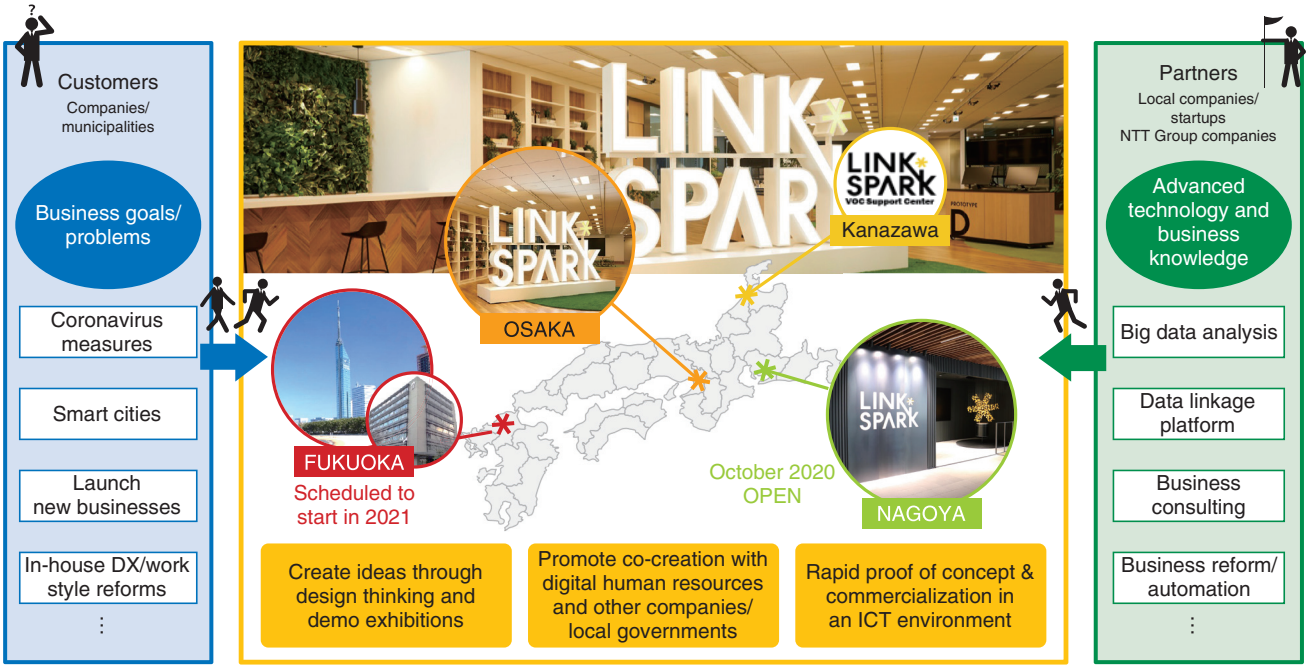


Fig. 7. Addressing social issues with LINKSPARK (co-creation lab).

products. In 2021, we plan to create our third co-creation lab in Fukuoka (**Fig. 7**).

6. The future of society

Preparations for the Osaka-Kansai World Expo 2025 have already started. In accordance with the theme of this event ("Designing Future Society for Our Lives"), we are promoting places for co-creation that will contribute to achieving the SDGs and enable the creation of Society 5.0. This would be a good time for us to think about the design of this future society while conducting various verification trials and to think about new ways of living and the creation of future society.

6.1 Half a century of change: 1970–2020

The last World Expo in Osaka took place in 1970, exactly 50 years ago. The theme then was "Human Progress and Harmony." At the time, Japan was experiencing a period of rapid economic growth, and "photochemical smog" was a major concern. Against this backdrop, the focus of the Osaka Expo in 1970 was economic development while pushing technology to the forefront. The theme of the Osaka-Kansai World Expo 2025 is "Designing Future Society for Our Lives." Since the winner of Japan's buzzwords award for 2019 was "One Team," it is important to consider how we can all connect, cooperate, and co-create. The mid-point of this half-century was 1995, during which Japan was hit by the Kobe earthquake. Since then, Japan has continued to suffer the effects of earthquakes and typhoons, and now we find ourselves facing a global pandemic. Although we have made progress in the development of technologies, we must think carefully about how to address issues resulting from these large-scale disasters since we are unable to control nature.

6.2 A natural world expo that transcends time and space

To prepare for the expo, the expo association is seriously discussing how to combine real and virtual venues and how to connect or integrate the two so that everyone can enjoy the event. In this sense, the expectations of the NTT Group are very high.

We will have to work hard to achieve a seamless, natural connection between the real and virtual worlds without any boundaries to obtain diverse data from the digital world, gather knowledge through Digital Twin Computing for the real world, and make effective use of this knowledge and data. At the NTT Group, we will work hard together on this project, and by taking on the role of an experimental site for

future society, I hope we will be able to test and propose specific services such as immersive systems and MaaS on the basis of future forecasting.

6.3 500 years of change (smart society then and now)

Earlier, I mentioned the World Expo that took place 50 years ago, but it is now over 500 years since the concept of utopia was discussed by the British philosopher Thomas More. In his book on the subject, there were 54 cities, all within a day's travel of each other. People worked fixed hours and spent the rest of the time studying whatever subjects they liked, such as art and science. They were also able to travel to all sorts of places without having to bring anything with them and lived a trouble-free existence. At the beginning of this article, I mentioned Society 5.0, and how the essential features of the ideal society that people seek include the close connection between people and cities and the ability of each individual to lead a fulfilling life. In this sense, although technology has transformed our lives beyond recognition over the last five centuries, the essence of what we all seek from life has remained the same all this time.

6.4 The IOWN concept

Finally, as set forth in IOWN (the Innovative Optical and Wireless Network), we will work to create a smart society of the future and make local communities smarter by using ICT to enhance natural connections and impart a sense of well-being.

Ichiro Uehara
Senior Executive Vice President, NTT WEST.
He joined NTT in 1988. He served as president and representative director of NTT Neomeit from 2013 to 2017. He has been the director of the Corporate Business Headquarters of NTT WEST and president and representative director of NTT Business Solutions since 2017 and became senior executive vice president of NTT WEST in July 2019.

Activities Centered Around the Smart Infrastructure Platform

Yoichiro Takaki

Abstract

The Smart Infrastructure (Smart Infra) Platform is a project NTT Infrastructure Network Corporation is advancing for improving the efficiency of infrastructure-facility work through digital transformation. We are developing digital twins that will provide high-accuracy position information (absolute position) of infrastructure facilities buried underground. By sharing digital information among infrastructure providers, we seek to implement a model in which tasks being done by workers to date are digitized and manpower is shared by unifying similar tasks. We are also aiming to add digital twins of aboveground facilities and expand the Smart Infra Platform to other fields such as disaster prevention/mitigation and smart cities. This article is based on a workshop lecture video-streamed on the Tsukuba Forum 2020 ONLINE website in October/November 2020.

Keywords: infrastructure facilities, digital transformation, 3D spatial information

1. Background of activities

Changing society structurally by making it "smart" has become necessary when it comes to infrastructure work. This is because in addition to the aging of infrastructure facilities and decline in the number of technical workers, we must also take into consideration how work will be carried out in the COVID-19/post-COVID-19 era.

Forty to sixty years have passed since the peak of infrastructure-facility construction by the NTT Group. The average age of workers has also increased, as can be seen from their age distribution (**Fig. 1**).

We believe that we can respond to these social challenges by advancing digital transformation (DX) of the infrastructure business, improving work efficiency by leveraging a wide range of digital data through data sharing. We are also pursuing sharing manpower and technologies to further improve efficiency.

2. Concept of Smart Infra

The Smart Infrastructure (Smart Infra) concept (**Fig. 2**), which NTT Infrastructure Network Corporation is advocating, involves developing a system that digitizes the locations/positions and conditions of infrastructure facilities by using high-accuracy position information that can be shared. By enabling the information to be visualized, skill-less work can be promoted and tasks for different types of infrastructure, such as telecommunications, power, and gas utility facilities, can be unified.

Looking toward the future, we want to make it possible to predict the conditions of underground facilities and take optimal actions.

Specifically, we are developing a system in which highly accurate three-dimensional (3D) positions based on high-accuracy 3D spatial information are assigned to facility data owned by infrastructure providers, enabling the information on facilities to be shared. We are also developing an environment that

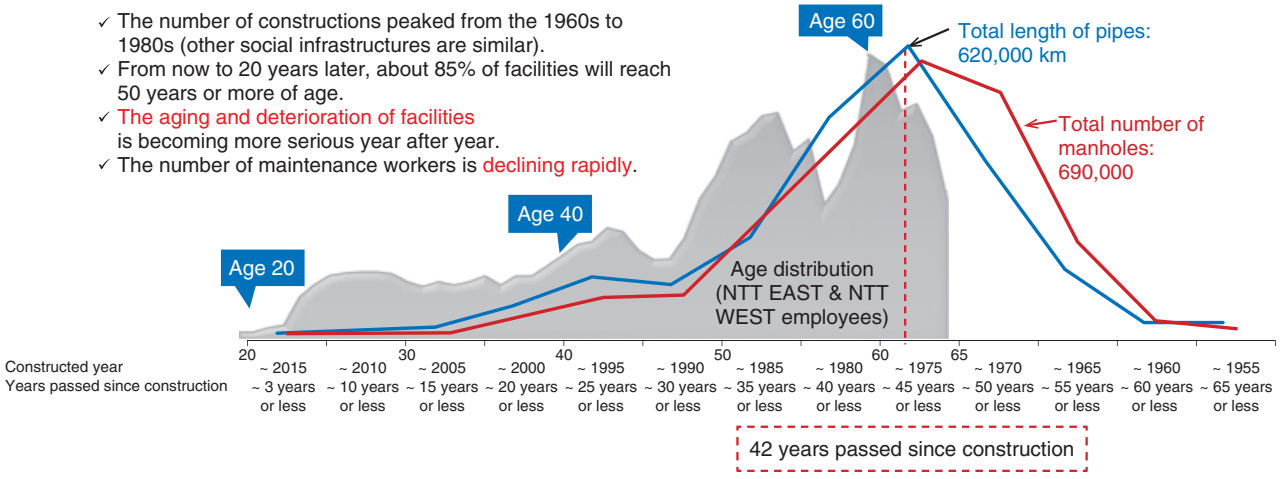
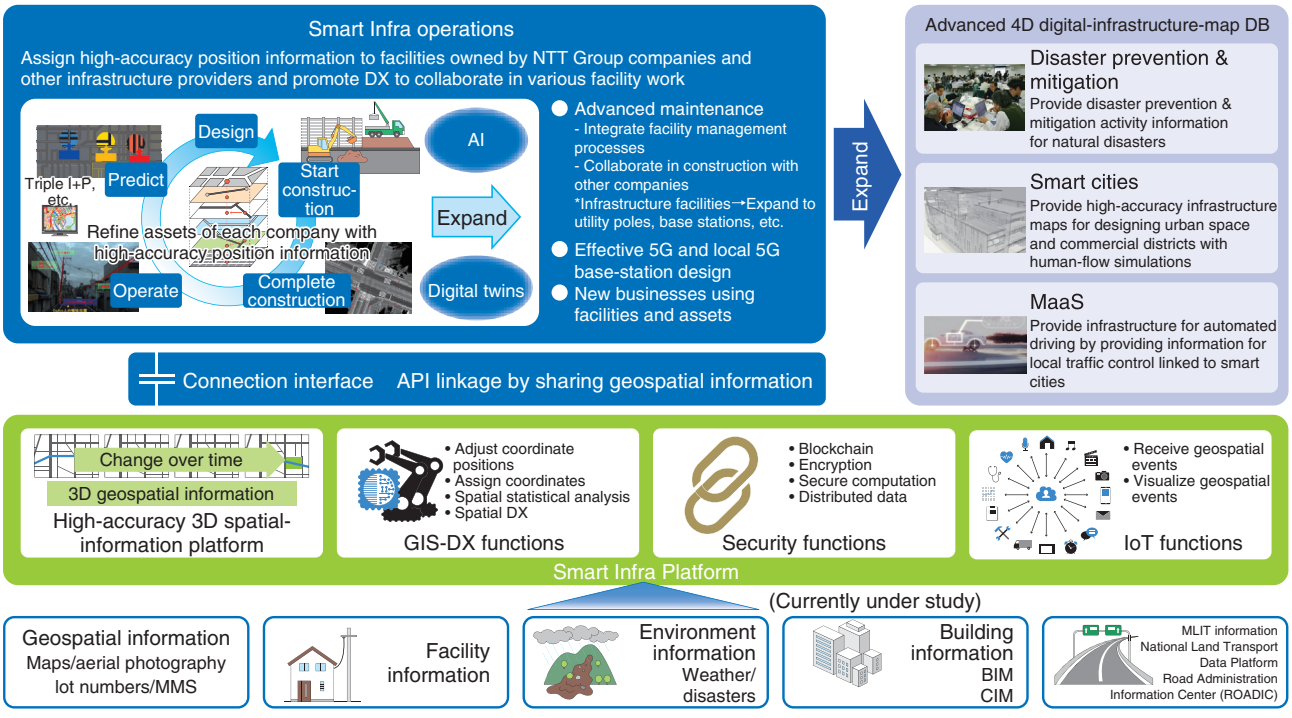


Fig. 1. Distribution of quantity of facilities by age and age distribution of employees.



AI: artificial intelligence
API: application programming interface
DB: database
5G: fifth-generation mobile communication system
GIS: geographic information system
IoT: Internet of Things
MMS: mobile mapping system
MLIT: Ministry of Land, Infrastructure and Transport and Tourism of Japan
Triple I+P: A GIS platform developed by NTT Infrastructure Network Corporation. Triple I+P is an abbreviation of Infrastructure, IT (information technology), Innovation Platform.

Fig. 2. Overview of Smart Infra Platform.

enables machine processing to render information pictured in a person's mind as 3D visualizations, allowing design, construction, and maintenance to be carried out efficiently. Sharing 3D facility information

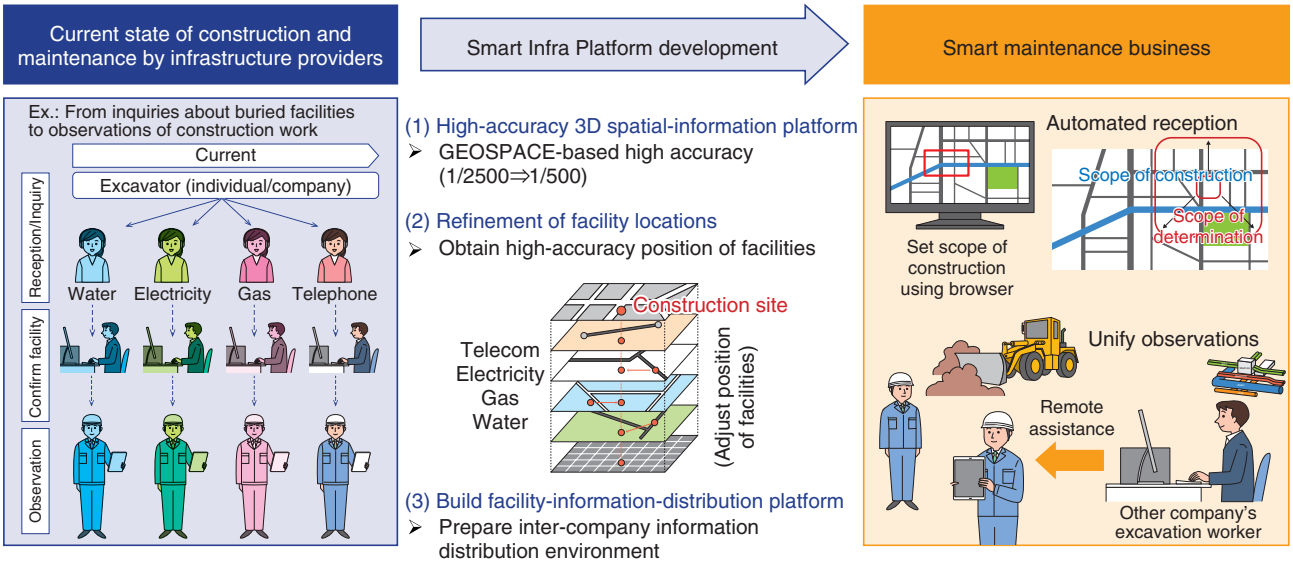


Fig. 3. Use cases (inquiries about buried facilities/onsite observations).

among infrastructure providers will also promote work sharing, thus improving efficiency. The Smart Infra Platform applies not only to underground infrastructure but can be expanded to existing aboveground infrastructure facilities.

We wish to contribute to growing the NTT Group's business by leveraging the Group's 4D digital platform™. This platform promotes linkages with external data, such as data in mobility fields such as mobility as a service (MaaS). It also links with smart-city and dynamic information, contributing to community-building and urban development through the distribution of building/construction information modeling, management (BIM/CIM) data.

3. Uses cases of the Smart Infra Platform

The Smart Infra Platform is currently being used in the following four themes as use cases for improving the efficiency of the infrastructure business.

- Centralized reception desk/first response for underground facility inquiries
- Visualization of facilities for onsite confirmation and observations
- Active proposals for joint construction
- Planned maintenance based on predictions of facility deterioration

3.1 Initial use cases

From inquiries about buried facilities to observations of construction work, each company currently handles cases in a disparate manner. Onsite observations are carried out as needed to confirm facility conditions and determine the impact of construction/excavation will have on nearby facilities. However, by using the Smart Infra Platform to assign high-accuracy position information and improve the accuracy of automatic estimations, it will be possible to identify on computers more cases that are determined as not impacting other facilities and services, thus reducing onsite observations. The labor required to confirm the impact on facilities by checking blueprints and other documents can also be reduced (**Fig. 3**).

When there is impact, we ask the company inquiring about a buried facility to visit us to have discussions about construction. In the future, it will be possible to carry out discussions remotely by using 3D virtual space (**Fig. 4**).

Regarding onsite observations, the Smart Infra Platform enables visualization of underground conditions. Even visualization of just NTT's facilities contributes to predicting dangers and improving decision-making. Furthermore, tasks can be unified by observing telecommunications, power, and gas utility facilities at the same time. We plan to enable observations and construction instructions to be carried out remotely in a manner similar to remote discussions about construction (**Fig. 5**).

Joint construction efforts are currently being carried

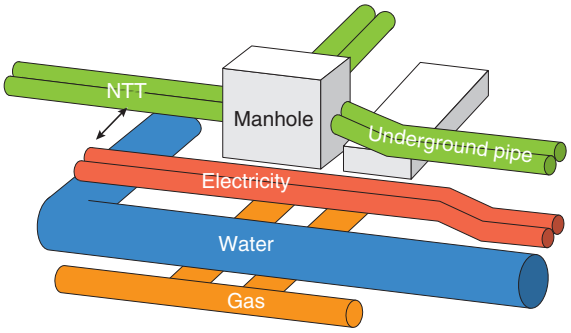


Fig. 4. Use case (construction discussion).

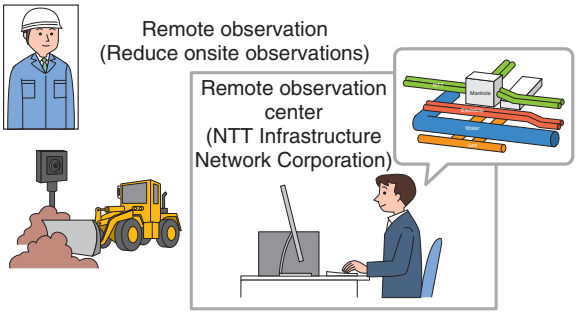


Fig. 5. Use case (remote observation).

out between NTT and other companies. However, there are still many cases in which each company carries out work separately, such as repeatedly excavating and filling in roads, which lengthens construction time. If conditions of underground space can be shared in advance, preparations for joint construction can also be made proactively. This leads to greater rates of joint construction and reduction in construction costs and shortened construction time since work, such as facility excavation and road filling, can be kept to a minimum.

Finally, a future plan is the prediction of facility deterioration. The conditions of facilities buried underground cannot be confirmed unless they are excavated. Therefore, there is no choice currently but to carry out maintenance only when a problem occurs. Preventive maintenance will be possible by predicting the future conditions of facilities based on soil and groundwater conditions. We plan to work on establishing efficient and effective maintenance plans based on predictions of facility deterioration.

3.2 High-accuracy 3D spatial information

Regarding 3D spatial information targeted for the infrastructure business, we are preparing data needed to align the locations and positions of infrastructure facilities. Specifically, we are preparing reference-position data on road boundaries (road edges, sidewalk edges—the boundary between a road and sidewalk, and median strips), utility holes (manholes and handholes), and underground entrances/exits to supplement a variety of data with position information and improve their accuracy.

To use the data being prepared as position references, high-accuracy position data are required. We are therefore preparing data based on map information level 500* accuracy (deviation of ±25 cm in position) (**Fig. 6**).

As a method of preparing data, we acquire information on the aforementioned road boundaries and utility holes by using high-resolution aerial photography with ground resolution of 5 cm. To prepare data on the 23 wards of central Tokyo, we manually convert aerial photos to stereo images and digitize them. We are also working on artificial intelligence (AI)-based automatic data acquisition by using the high-resolution 3D spatial information of the 23 wards we have prepared as training data.

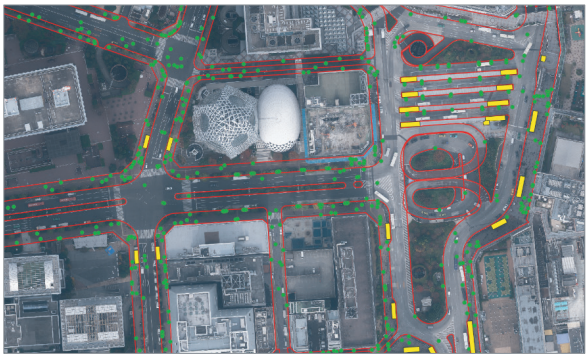
This is an initiative with significant hurdles. We are working with a variety of people, from venture companies to NTT Group companies and labs, to substantially reduce costs by automating tasks with AI.

3.3 Proof-of-concept demonstration with the Ministry of Land, Infrastructure, Transport and Tourism

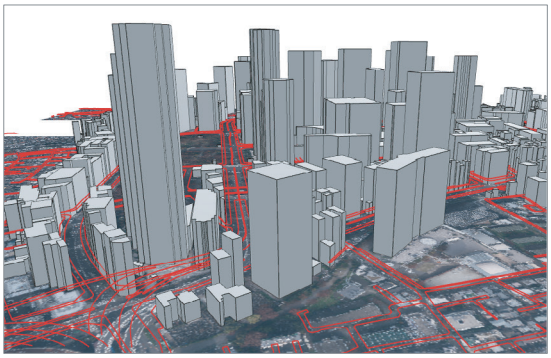
In fiscal year 2019, we consulted on a project with the Ministry of Land, Infrastructure, Transport and Tourism's Kanto Regional Development Bureau. For this task, 3D models of aboveground and underground facilities in the Minato Mirai-Kannai area in Yokohama City were created to see how they could contribute to improving work efficiency and safety (**Fig. 7**).

The Tokyo Electric Power Company, Tokyo Gas, and the Yokohama City Waterworks Bureau provided data on buried facilities, which we converted to 3D data to create data on underground space. Each organization separately manages its blueprints and the position information contained within. As a result,

* Mapping information level 500: The positional precision of topographic map data should have a standard deviation of 0.25 m or less for horizontal positions and 0.25 m or less for vertical positions.



Example of 2D presentation
Red lines: Road boundaries (although not displayed, presentation contains detailed information such as sidewalk boundaries and median strip boundaries)
Green points: Manholes, etc. (manhole-type objects and objects that can be recognized on the road surface)
Yellow boxes: Aboveground/underground entrances/exits



Example of 3D presentation
Red lines: Road boundaries (although not displayed, presentation contains detailed information such as sidewalk boundaries and median strip boundaries)
Buildings: GEOSPACE 3D (3D building objects created from aerial photos)

Fig. 6. High-accuracy 3D spatial information.

3D model of aboveground area

3D model of underground area

Fig. 7. Proof-of-concept demonstration with Ministry of Land, Infrastructure, Transport and Tourism (Kanto Regional Development Bureau).

there were cases in which integrating the data resulted in facilities overlapping positionally or being located in an impossible location in reality. These cases affirmed the importance of improving the accuracy of position information.

Improving 3D images of underground space with more accurate position information will clarify positional relationships between facilities and clarify the extent of the impact their excavation will have. Value is thus produced in the resulting safe and efficient construction.

4. Future plans

We began our DX service for underground communication facilities in December 2020. We provide services from responding to buried facility inquires to automatic determination of the impact construction will have and visualization of underground space to support onsite observations. In fiscal year 2021, we plan to expand the range of NTT's DX by expanding the preparation of high-accuracy 3D spatial information. We also plan to provide the functions we use for our DX to electric and gas utility companies for their DX.

Regarding high-accuracy 3D spatial data for the 23

wards of central Tokyo, we have not yet been able to obtain data on roads under elevated structures. This is because we are using aerial photography. For spots that cannot be seen from above, it is necessary to carry out high-accuracy measurements on the ground by using the mobile mapping system (MMS).

While aerial photography is effective in urban areas where roads are dense, data acquisition using MMS is more cost-effective in areas such as the suburbs, where roads are less dense. We are thus collaborating with NTT laboratories in conducting research and development of AI for MMS to gather and prepare data efficiently. We are also conducting research in MMS for switching to low-cost equipment while maintaining accuracy and quality.

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He graduated from Osaka Institute of Technology in 1986 and joined NTT in the same year. He moved to the NTT Research and Development Planning Department in 2008 and was in charge of business creation involving disaster-prevention-related technology then moved to NTT GEOSPACE in 2011 to engage in the map business. He is currently in charge of managing the Smart Infra Platform project.

R&D of Innovative Optical Transmission Line Technologies

Kazunori Katayama

Abstract

NTT Access Network Service Systems Laboratories is promoting research and development (R&D) on optical transmission line technologies necessary for the sustainable development of communications networks. In addition to R&D on such technologies for achieving efficient and sophisticated optical access networks, in 2019 we started R&D on innovative optical transmission line facilities toward implementation of the All-Photonics Network, which is one of the three key elements of the Innovative Optical and Wireless Network (IOWN) advocated by NTT. This article, which is based on a workshop lecture video-streamed on the Tsukuba Forum 2020 ONLINE website in October/November 2020, outlines the latest developments and future perspectives of optical transmission line technologies.

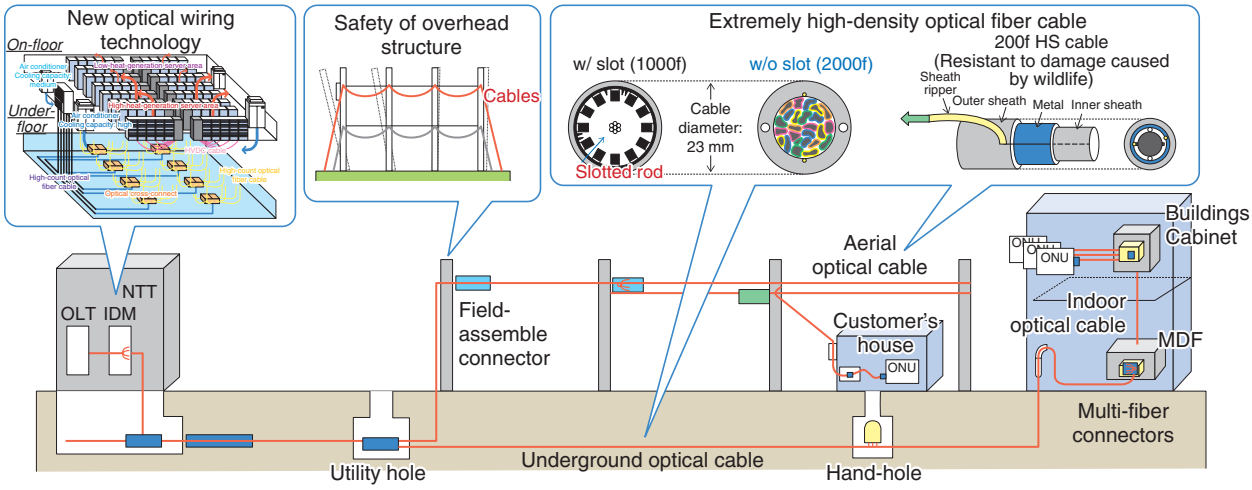
Keywords: optical transmission line, optical fibers and cables, IOWN

1. Promotion of efficient and sophisticated optical access networks

NTT Access Network Service Systems Laboratories has been leading the research and development (R&D) of optical transmission line technologies from fundamental research to practical application development toward sustainable development of telecommunication network services by economizing and upgrading optical access networks. **Figure 1** shows the technologies that make up an optical access network. An optical access network is composed of many products and technologies such as optical fiber cables, optical connectors, and overhead structures. We developed and installed various products and technologies to deploy efficient and sophisticated optical transmission line facilities, e.g., for simplified installation, and intelligent maintenance technologies. This article introduces our recent developments in optical transmission line technologies.

High-density and high-count optical fiber cables have been receiving increasing attention for installing a large number of optical fibers in a restricted space. NTT has proposed and developed an extremely high-density optical fiber cable by using the rollable ribbon and slot-less optical cable structure. By optimizing this cable structure, we developed the world's highest-density optical fiber cable, which is equipped with 2000 fibers with the same cable diameter as a conventional 1000-fiber cable. We have also developed a thin, high-density, high-strength (HS) optical fiber cable that is resistant to damage by wildlife. By applying and modifying the slot-less optical cable structure, we developed a smaller-diameter and lighter-weight cable structure with improved workability, which will become the mainstream for optical fiber cables in all network equipment.

The demand for optical fiber connection in datacenters has increased. Optical wiring conditions under raised floors is often unknown, which induces cable congestion and degrades air conditioning efficiency. NTT developed an estimation method of cable-stacking height by considering the cable type and number of laying cables and established an optical wiring



HVDC: high-voltage direct current
IDM: integrated distribution module
MDF: main distribution frame
OLT: optical line terminal
ONU: optical network unit

Fig. 1. Technologies and current trends in optical access networks.

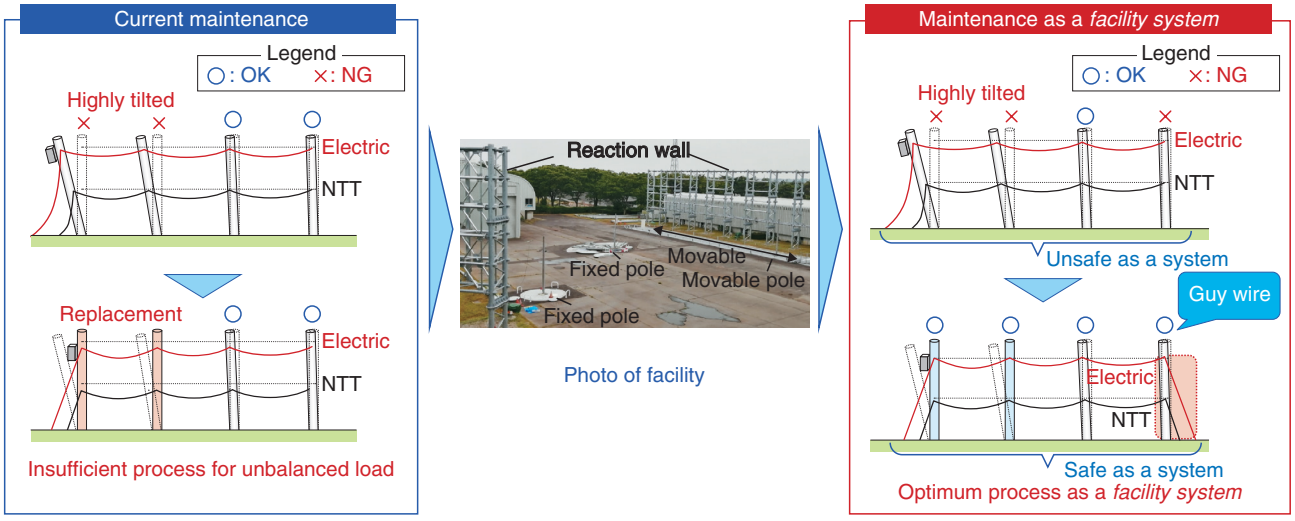
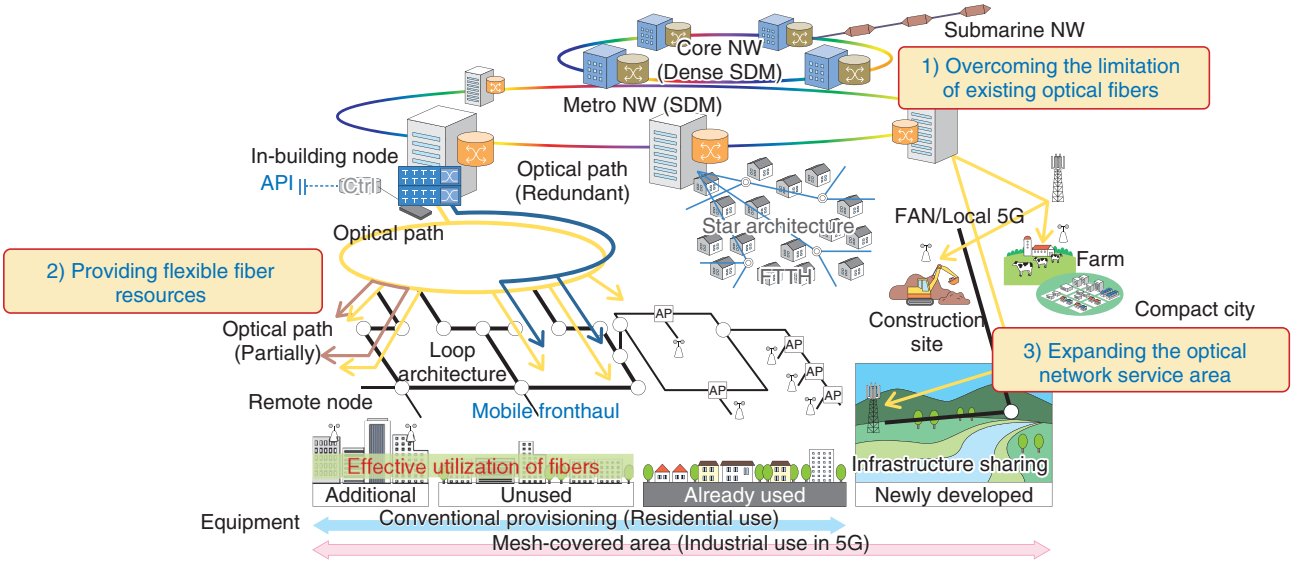


Fig. 2. Overhead Structure Comprehensive Verification Facility.

technology to improve air conditioning efficiency and reduce power consumption.

Next, we describe our efforts in maintenance technology for overhead structures. **Figure 2** shows the Overhead Structure Comprehensive Verification Facility. It has been clarified that unbalanced loads must be considered during the safety evaluation of utility poles, cables, and other components supporting overhead structures, which are considered to be one *facility system* of multiple utility poles connected by various cables. However, as shown on the left in Fig. 2, the conventional maintenance procedure of utility poles and other components do not provide a solution to this unbalanced load. NTT has constructed the Overhead Structure Comprehensive Verification Facility to verify the overhead structure as a facility system. At this facility, which simulates an actual environment, the fundamental cause of



AP: access point
API: application programming interface
FAN: factory automation network
FTTH: fiber to the home
NW: network

Fig. 3. Future optical transmission line facilities.

unbalanced loads are clarified and optimal measures are devised and implemented, as shown on the right of Fig. 2, achieving long-term safe use of the entire system. This approach is also very effective as a countermeasure against severe natural disasters.

The above are our latest developments in optical transmission line technologies for economization and upgrading optical access networks. NTT Access Network Service Systems Laboratories will continue to develop safe and secure optical transmission line technologies to support the sustainable development of telecommunication network services.

2. IOWN and future optical access networks

In 2019, NTT proposed the concept of the Innovative Optical and Wireless Network (IOWN) to overcome the processing limit and power-consumption increase in the smart society and the delay limit of the Internet. IOWN consists of the All-Photonics Network (APN), which uses photonics technology from networks to equipment to achieve large capacity, low latency, and low power consumption; Digital Twin Computing, which digitizes real space and creates new value in cyberspace; and the Cognitive Foundation, which optimally operates information and communication technology resources that comprise the above two components. NTT Access Network Service Systems Laboratories is conducting R&D to establish innovative optical transmission line technologies needed to implement the APN.

Figure 3 shows the future of the optical transmission line facilities we have proposed. Optical transmission line facilities are premised on long-term use, and it is necessary to ensure technical neutrality and openness for passive optical facilities. It is also necessary to respond to the diversification and advancement of services in a smart society and the development of high-speed wireless communications such as fifth/sixth generation mobile communications systems (5G/6G). To construct optical transmission line facilities that support such next-generation communications services, we established the following three directions and are promoting R&D on the basis of them: "Overcoming the limitations of existing optical fibers," "Providing flexible fiber resources without restriction of existing architecture," and "Expanding the optical service area to new destinations."

With regard to "Overcoming the limitations of existing optical fibers," there is concern that demand for transmission capacity will increase exponentially every year and that by the late 2020s the required transmission-system capacity will exceed the transmission-capacity limit of existing single-mode fibers

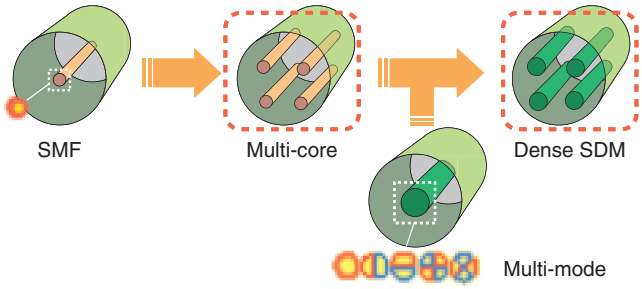


Fig. 4. SDM fibers.

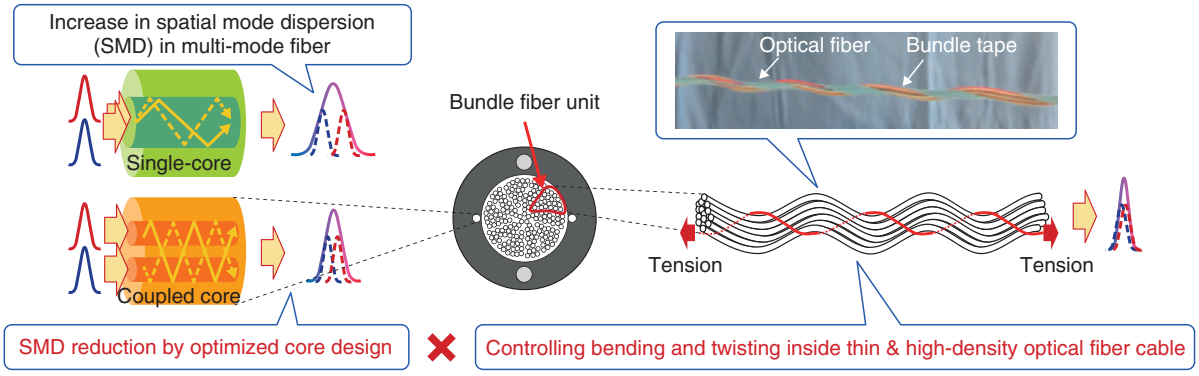


Fig. 5. Controllability of SDM fibers with cable structure.

(SMFs), which is considered as approximately 100 Tbit/s. Space division multiplexing (SDM) technology, which provides the space domain as a new multi-axis in addition to time and wavelength domains, has recently attracted interest worldwide. SDM transmission requires SDM fibers with multiple spatial channels in a fiber. An overview of SDM fibers is shown in **Fig. 4**. SDM fibers are roughly classified into multi-core with multiple core regions, multi-mode with multiple spatial channels in one core, and multi-mode multi-core, which achieves ultrahigh density SDM. NTT has recently proposed an SDM fiber cable that is compatible with existing optical fiber standards and optical equipment and is actively studying methods of accelerating the practical deployment of multi-core fiber lines. We are also conducting R&D on ultrahigh-density SDM optical fiber cable technology and its related technologies to further increase density and capacity.

Figure 5 shows an optical fiber cable with ultra-high-density SDM fibers. In such SDM fibers, optical signals are generally transmitted while being intermingled between spatial channels and demodulated by signal processing at the receivers. It is known that the transmission-delay difference between spatial channels deteriorates transmission characteristics. We have demonstrated for the first time that the transmission characteristics of an SDM fiber cable can be controlled by the simultaneous optimization of the optical fiber and optical cable structure by minimizing the transmission-delay difference through the structural design of SDM fibers and by controlling their bending and twisting in an optical cable.

With regard to "Providing flexible fiber resources without restriction of existing architecture," considering the future deployment of 5G/6G base stations, the conventional provision of fiber resources based on household distribution will not be sufficient, and a network configuration that can flexibly provide the necessary amount of fiber resources will be required. It is also important to ensure network reliability by assuming services that do not allow service interruption such as self-driving cars. We have started R&D on an access network design with concatenated loop

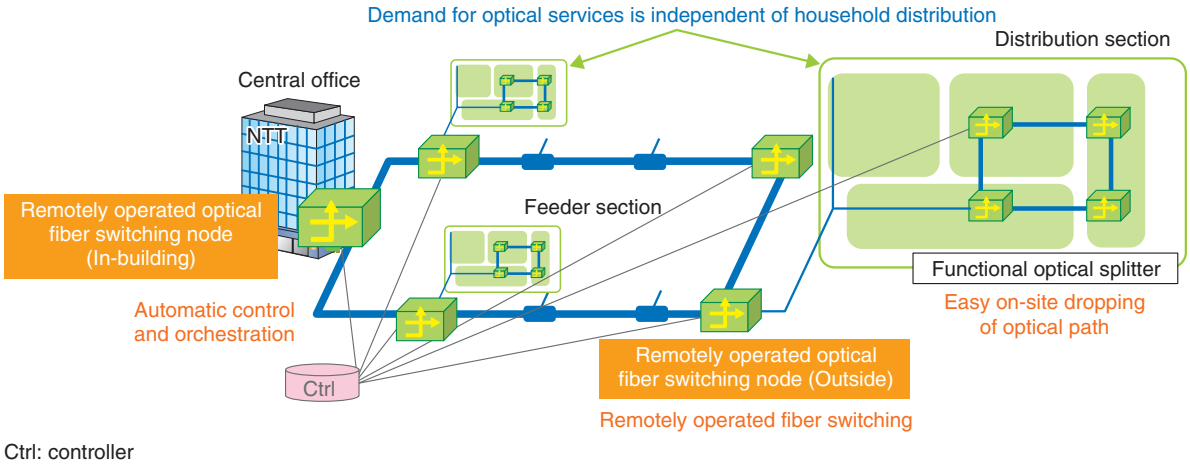


Fig. 6. Optical path switching in optical access network with concatenated loop topology.

topology (**Fig. 6**). This network configuration is equipped with a new remotely operated optical fiber switching node that can switch the optical path remotely at the fiber level. By overlaying this network configuration on the existing access network, it is possible to effectively use the fiber without services and to improve reliability by making the network redundant.

Regarding "Expanding the optical service area to new destinations," 5G base stations will be deployed not only in urban areas but also in rural areas with industrial potential. However, there are rural areas where optical equipment is not provided; thus, a method for economically and efficiently installing optical equipment will be essential. In urban and suburban areas, the expansion of base stations is expected to increase, and in non-residential areas, the demand for optical services is expected to expand. However, the cost burden of installing new optical equipment is particularly high in areas where optical equipment is not yet available. For this reason, we have started R&D on an economical and efficient method of installing optical fiber cables in areas that were not previously considered.

3. Future perspectives

NTT Access Network Service Systems Laboratories is committed to continuous R&D and establishment of safe and secure optical transmission line technologies to contribute to the sustainable development of the information and communications industry. In particular, it is necessary to consider natural disasters, which have become increasingly severe. To actualize IOWN, we are promoting innovative R&D of optical transmission line facilities that can be connected anytime and anywhere as well as smart-facility-operation technologies.

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Photonic Gateway and Related Optical Access Technologies to Achieve the All-Photonics Network

Tomoaki Yoshida

Abstract

We, members of Optical Access Systems Project of NTT Access Network Service Systems Laboratories, are engaging in the research and development of the Photonic Gateway to achieve low-latency optical access networks and the All-Photonics Network, an essential component of IOWN (the Innovative Optical and Wireless Network). This article, which is based on a workshop lecture video-streamed on the Tsukuba Forum 2020 ONLINE website in October/November 2020, introduces technologies that use the optical characteristics, such as wavelength management and optical path aggregation, required for high-bandwidth, low-latency networks.

Keywords: IOWN, APN, optical access systems

1. Background of optical access technologies

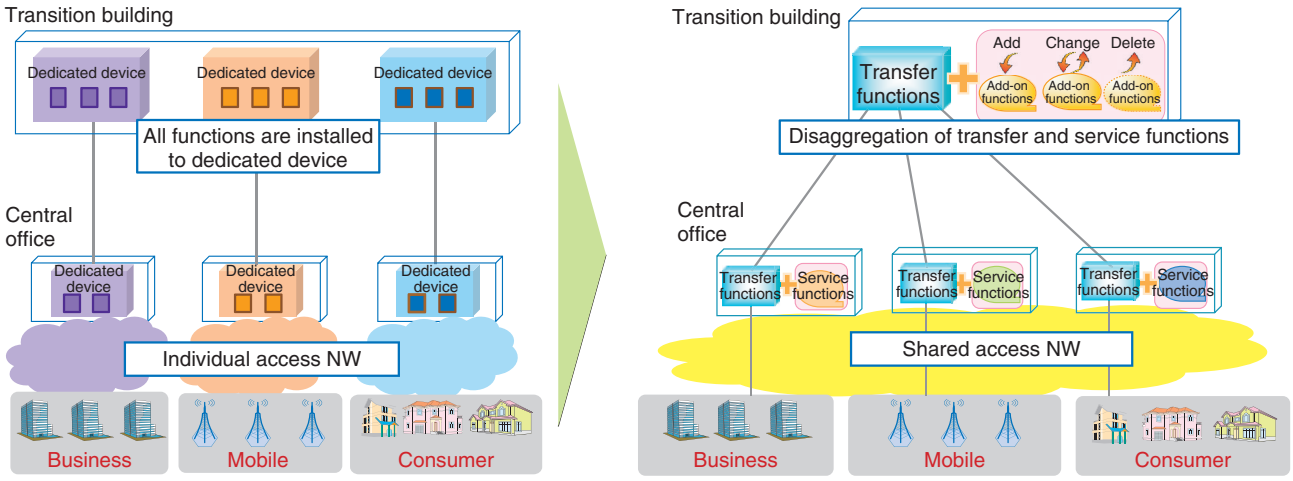
The communication services provided by optical access can accommodate the traffic created by the triple play of telephony, Internet access and video, and mobile access and Internet of Things. It can be said that these services are mainly intended to support human cognition. It is expected that the bit price will continue to decrease due to improvements in transmission speed, so it will be possible to transfer more information rapidly at low cost. Along with this, the near future is expected to see new communication applications such as cloud access, augmented reality/virtual reality, autonomous driving, and e-sports, which handle a large amount of information and rapid-service responses beyond human cognition. Therefore, optical access systems will be required to offer lower latency while accommodating diversified services more efficiently.

It has been pointed out that the labor population in Japan will continue to decline, with a 40% decrease expected by 2060 [1]. Access systems are distributed to cover a wide area, so reducing operation overheads including business trips and improving operation efficiency are important goals. Considering the impact of the COVID-19 pandemic, it has become critical to develop an optical access system that minimizes operation overheads.

2. Our vision of optical access systems

Current optical access systems were developed for different types of optical access networks, e.g., for business, mobile, and consumer use, and consist of dedicated devices that can efficiently provide specific communication services optimized for transmission speeds at the appropriate release time and area expansion for each use. However, we have to ensure not only adequate transmission speeds but also multiple attributes, such as low latency and efficient operation, to reduce operation overheads and improve flexibility.

To satisfy these requirements, it will be important for optical access systems to support the separation of the basic transmission/transfer functions from



NW: network

Fig. 1. Our vision of optical access systems.

additional functions. Our aim is to build an optical access system that standardizes and commonizes the basic transmission/transfer functions as much as possible (**Fig. 1**). This separation makes it possible to launch a service quickly with the minimum number of transmission/transfer functions; add or delete additional functions in accordance with various service requirements as they emerge. In addition, by reducing the number of system types, operation tasks can be standardized, and the maintenance process can be made easier and safer. Configuring the transmission/transfer functions in a simple manner makes it possible for services to share the optical access infrastructure, for example, optical fiber, and its devices. We are developing an optical access system for achieving high flexibility, low operation overheads, and infrastructure sharing.

3. The All-Photonics Network and Photonic Gateway for achieving large-capacity, low-latency networks

The Innovative Optical and Wireless Network (IOWN) announced by NTT in 2019 is aimed to promote a smart society with the three elements of the All-Photonics Network (APN), Digital Twin Computing (DTC), and Cognitive Foundation (CF) [2]. The APN targets 100 times greater power efficiency, 125 times greater transfer capacity, and 200 times lower end-to-end delay compared with the current network. Specifically, by using optical device technologies and wavelength division multiplexing, we aim to reduce the transfer delay to the limit by providing full-mesh connection of optical paths end-to-end. We also aim to create a large-capacity network that is protocol agnostic.

To provide end-to-end optical paths, the APN uses the Photonic Exchange (EX) and Photonic Gateway (GW), which together replace electrical-processing functions such as exchange, multiplexing, and switching with optical functions. The Photonic EX can cross-connect large-capacity paths of 1-Pbit/s class on the core in full-mesh manner. The Photonic GW offers the functions of controlling wavelength allocation to terminals and path aggregation on the local full mesh (**Fig. 2**). This makes the best use of the optical characteristics and enables low-latency transmission that is independent of specific protocols. We are researching and developing the Photonic GW.

4. Path aggregation and wavelength management by the Photonic GW

The Photonic GW consists of an optical node that has optical direct-aggregating and add-drop functions and a controller that performs automatic configuration. Specifically, the optical node hosts the following five functions, enabling low-latency path aggregation while minimizing the use of electrical processing (**Fig. 3**).

(1) Remote wavelength control: specifies and controls which wavelength the transceiver of a

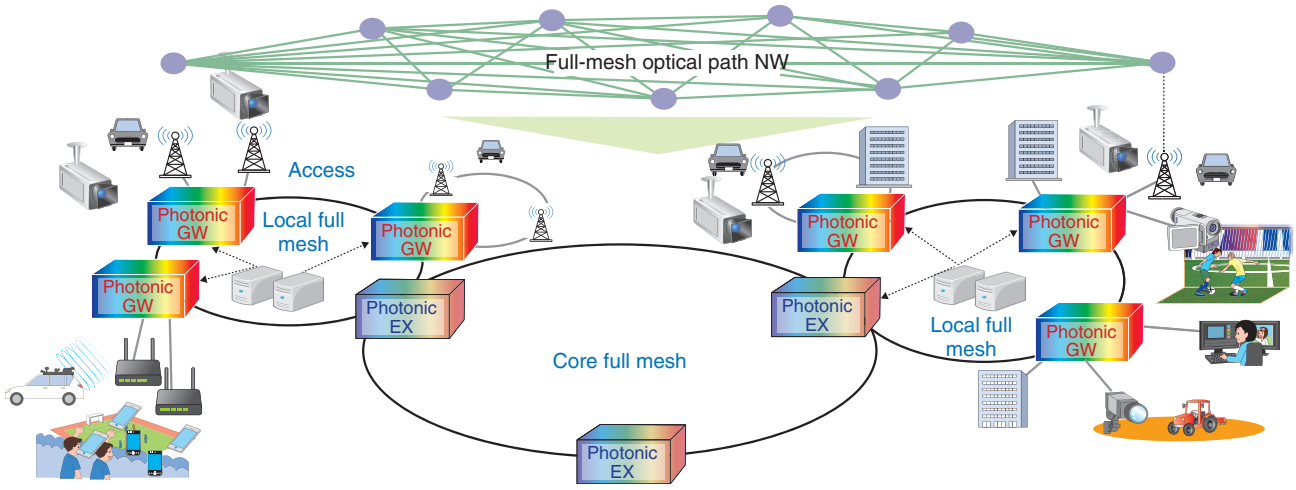


Fig. 2. APN transport and the Photonic GW.

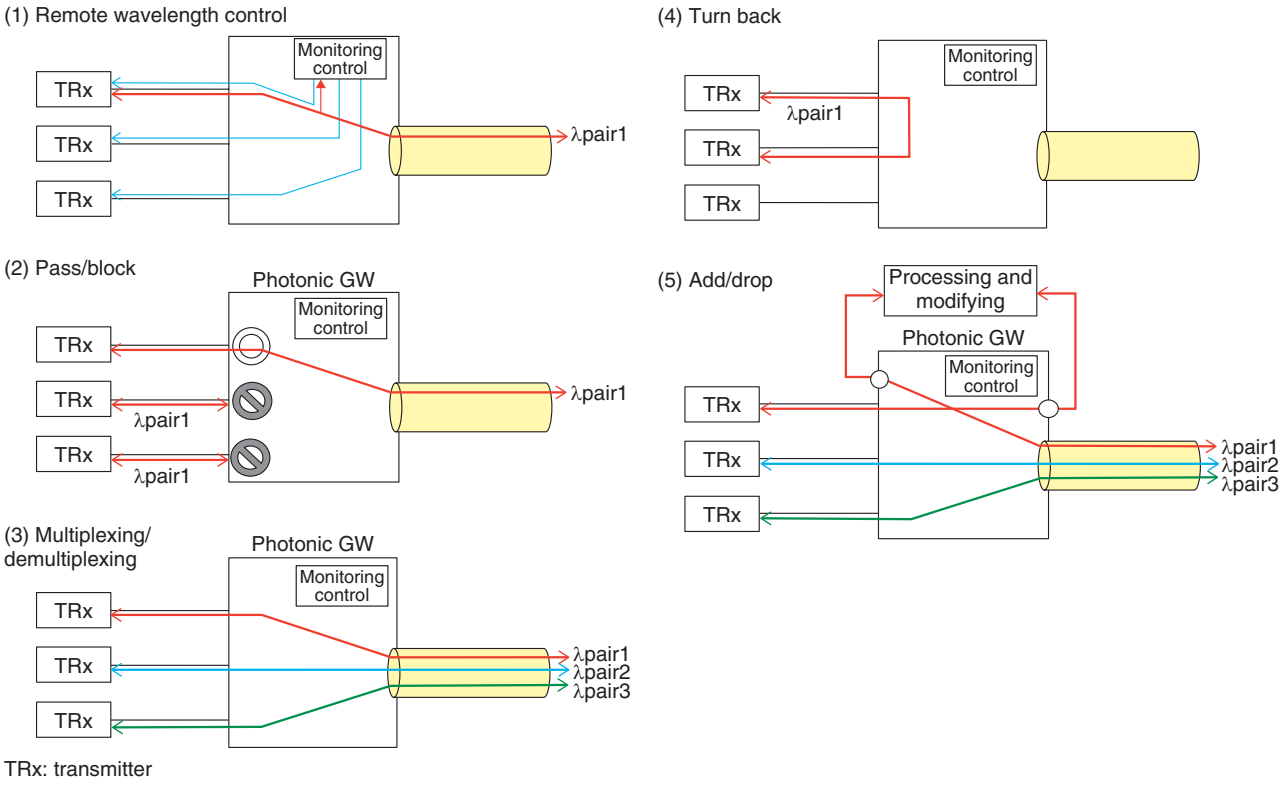


Fig. 3. Five functions in the Photonic GW.

user terminal uses and monitors the wavelength of the signal.

(2) Pass/block: passes signals when the path opens and stops unnecessary signals.

(3) Multiplexing/demultiplexing: aggregates the signals and transfers them to the core network in accordance with the wavelength and distributes the signals transferred from the core

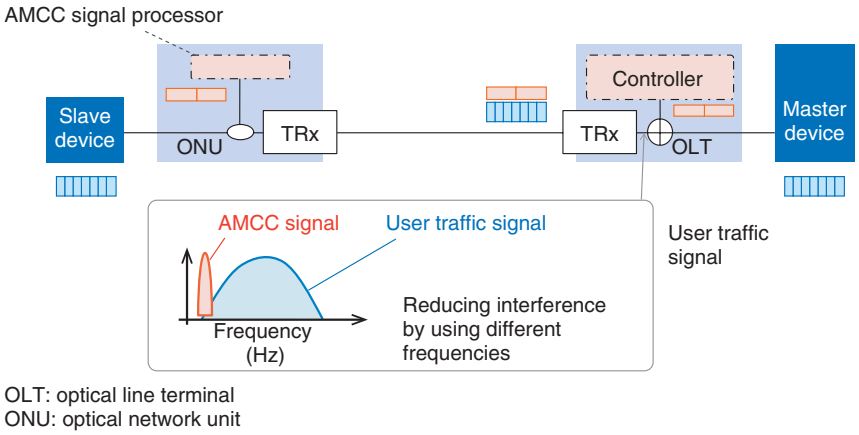


Fig. 4. AMCC mechanism.

network in accordance with wavelength.

(4) Turn back: enables turn back at the Photonic GW, rather than at the Photonic EX, for traffic that requires the shortest route.

(5) Add/drop: enables intermediate processing at the Photonic GW site for optical repeating, wavelength conversion, and electrical processing.

The remote wavelength control function uses the auxiliary management and control channel (AMCC), which is an in-channel control technology (**Fig. 4**). The AMCC is one of the main functions of the Photonic GW for wavelength management. It multiplexes the wavelength control signals with the user signal from the Photonic GW to the user terminal's transceiver. Because the frequency band of the control signal is low, it does not interfere with the user signal. In addition, wavelength control signal multiplexing is achieved with an additional simple circuit. By using the AMCC, it is possible to monitor and control wavelengths independently of the protocol of the user signal or the optical modulation format of the signal and to standardize and commonize the control functions.

5. Example of protocol-free network by the APN

The conventional approach to the transmission of radio frequency (RF) signals, such as television broadcasting service and fixed, mobile wireless services, requires the development and optimization of each transmission specification such as the transmitter, receiver, and relaying system for each licensed frequency. This duplicates the installation, operation, and renewal costs. As a result, the total cost has become excessive. At NTT Access Network Service Systems Laboratories, we put into practice the radio-over-fiber technology, which converts RF signals into optical frequency modulation (FM) signals and transmits them over long distances, as the FM conversion scheme [3]. Using a wideband FM conversion scheme for the APN composed of the Photonic GW makes protocol-free transmission possible in which analog RF signals in various bands are converted and transmitted over long distances. Since this transmission is transparent to the signal format and modulation method of the RF signals, we can provide a *protocol-free* transmission service that flexibly supports many formats such as digital signal formats, e.g., IP (Internet Protocol), Ethernet, or signal speed.

6. Separation of transmission/transfer functions from additional functions

We are also working on technology that allows separation of the transmission/transfer functions from additional functions. In particular, it is important that the transmission/transfer functions of a device are simply configured to make the additional functions easy to add, change, and delete as software and/or at a user terminal.

One of our activities to achieve separation is to promote the open development of access systems at the Open Networking Foundation. In cooperation with AT&T, Deutsche Telekom, and Turkish Telekom, we participated in the SEBA (SDN-Enabled Broadband Access – SDN: software-defined networking) project [4], formulated an optical line terminal function

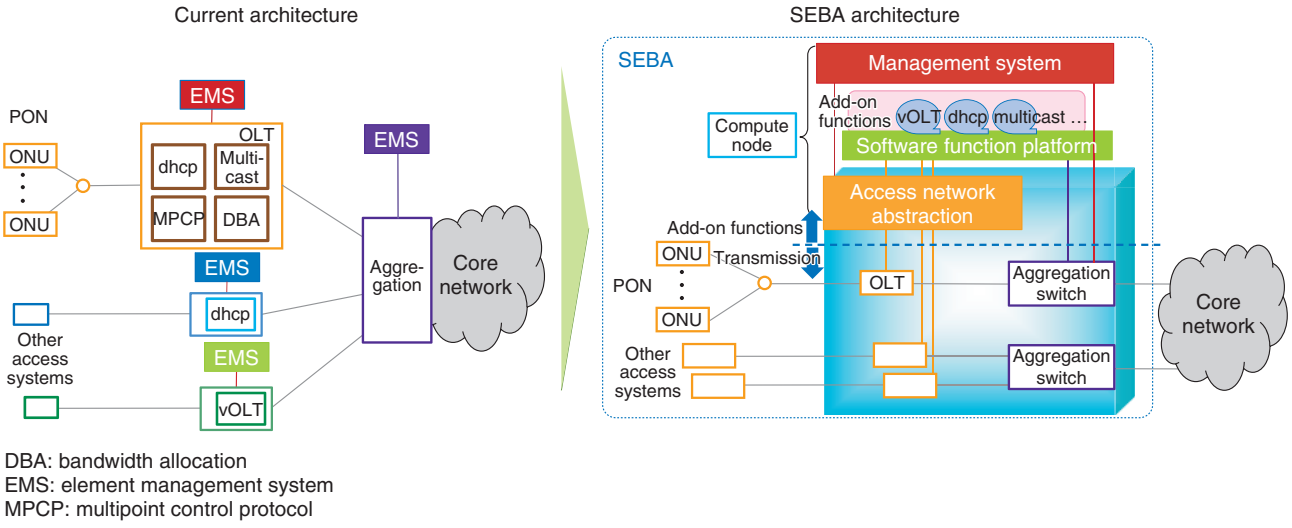


Fig. 5. OLT function disaggregation architecture.

disaggregation architecture, and developed it as open source (**Fig. 5**).

To provide optical access services through various methods, such as point-to-point and passive optical network (PON), dedicated hardware and an optimized element management system have to be used for each type of access system. However, SEBA makes it possible for access systems to implement functions and control schemes on a common software basis and to unify the management system. Since SEBA is open source, anyone can refer to it and freely implement and easily add or delete functions according to the operator's requirements.

As another example of separating the transfer functions from additional functions, we developed an additional function for hitless redundant switching at the edge device when a route failure occurs (**Fig. 6**). Conventionally, when a route failure occurs, a service experiences momentary interruption due to redundant switching, and some packets are discarded. With our technology for separating the transmission/transfer functions from additional functions, hitless redundant-switching devices are installed at both ends of the network, signals are transmitted along both routes, and the signal is selected on the receiving side. This makes it possible to switch routes without interruption. This technology has been in use for a long time, and the unique feature of this technology is that the simple L2 (layer 2) transfer function is used as a network service, and the function for achieving hitless redundant switching is located at the edge device, not the network. Therefore, it is possible to quickly provide hitless redundant switching to those users who need it. Users simply add the hitless redundant-switching device, and no change to the network is needed.

7. Future plans

We will continue our research and development activities on optical access system technology to achieve high bandwidth and low latency networks. We will also promote our technology for separating the basic transmission/transfer functions from additional functions to achieve high flexibility and low operation overheads. These technologies will be strongly leveraged in achieving IOWN and specifically the APN.

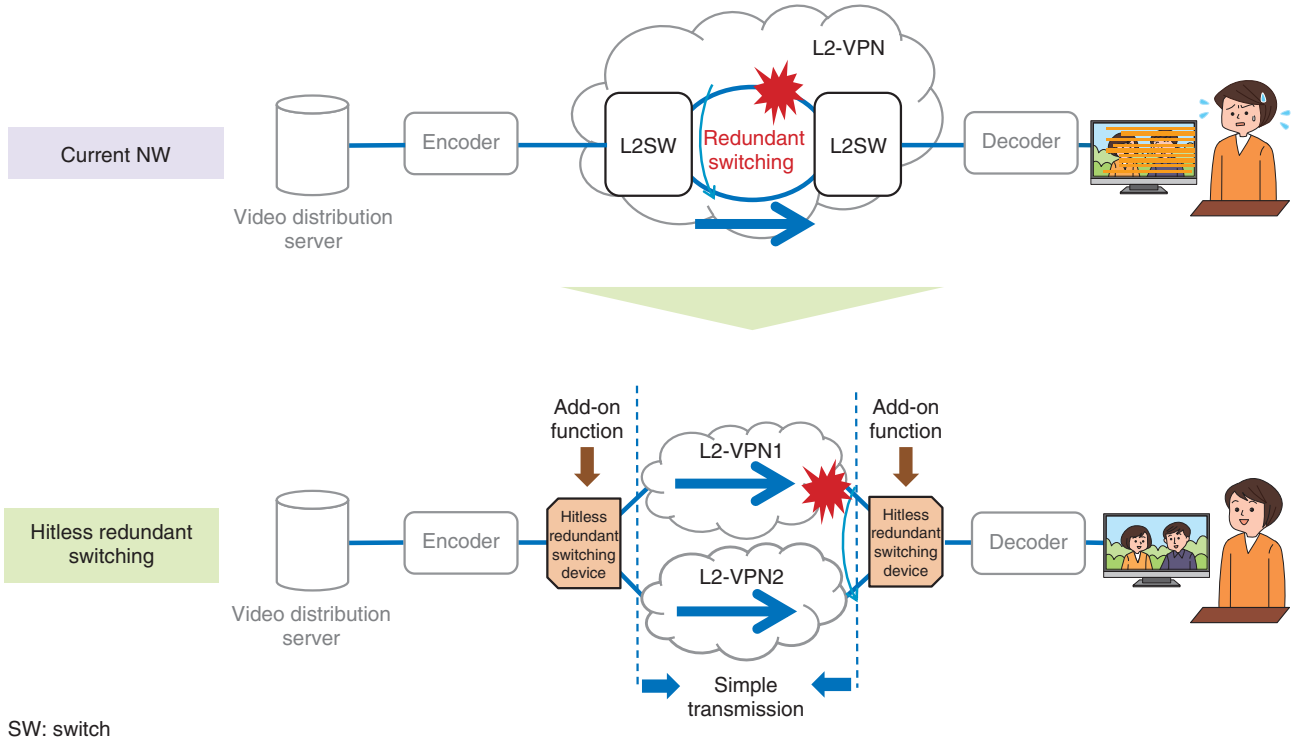


Fig. 6. Hitless redundant switching.

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Progress in Multi-wavelength Receiver Integration with Arrayed Waveguide Gratings

Yoshiyuki Doi, Toshihide Yoshimatsu, and Yasuhiko Nakanishi

Abstract

We describe the progress in integrated wavelength-division multiplexing (WDM) photoreceivers that feature low-loss arrayed waveguide gratings (AWGs) for high-speed throughput of up to 100 Gbit/s and beyond. The design and assembly of optical coupling between higher-order multimode beams and a photodiode are essential to obtain a flat-top spectral shape. We developed 10- and 40-Gbit/s WDM photoreceivers by using mechanical and visual alignment, respectively. We also fabricated a 100-Gbit/s photoreceiver by using high-accurate active alignment. The AWGs and assembly concepts of WDM integration enable scaling up to 400-Gbit/s and beyond and are key to achieving the multi-wavelength All-Photonics Network.

Keywords: arrayed waveguide grating, fiber optic communications, planar lightwave circuit

1. Introduction

In current photonics networks, wavelength-division multiplexing (WDM) is essential for large network capacity. Arrayed waveguide gratings (AWGs) have been globally applied for WDM as wavelength multiplexers and demultiplexers in line with the progress in silica-based planar lightwave circuits (PLCs) [1]. **Figure 1** illustrates the configuration of an AWG, which is compared with a conventional prism-type spectrometer. An AWG is composed of input waveguides, an input slab waveguide, arrayed waveguides, an output slab waveguide, and output waveguides. In comparison with a prism-type spectrometer, the arrayed waveguides correspond to a prism as a dispersive medium, and the input/output slabs correspond to collimating and focusing lenses.

Long-haul traffic has increased owing to the contribution of AWGs in dense-WDM line-side networks. The use of AWGs in shorter reaches is becoming more important because client-side interfaces have also progressed exponentially. Based on current technology trends, client-side networks, such as those used in datacenters and for mobile links with a reach of 100 km or less, will require more data for local wireless traffic with the advanced driver-assistance system, edge computing for artificial intelligence, and automation with Internet of Things. Toward achieving such networks, photonics technology will play a more important role in overcoming electronic limitations on operating frequency and power consumption. In particular, wavelength scalability and functionality through multi-wavelength optical devices will be key to promoting the spread of the innovative All-Photonics Network [2].

We now describe our research and development of WDM photoreceivers integrated with AWGs. Among the various advantages of an AWG, we focus on its low-loss and flat-top functions in a multimode-output AWG (MM-AWG). These photoreceivers are summarized in **Table 1**. They have different bit rates and are fabricated using several alignment techniques. The 10-Gbit/s photoreceiver was developed using mechanical alignment with eight-channel WDM with

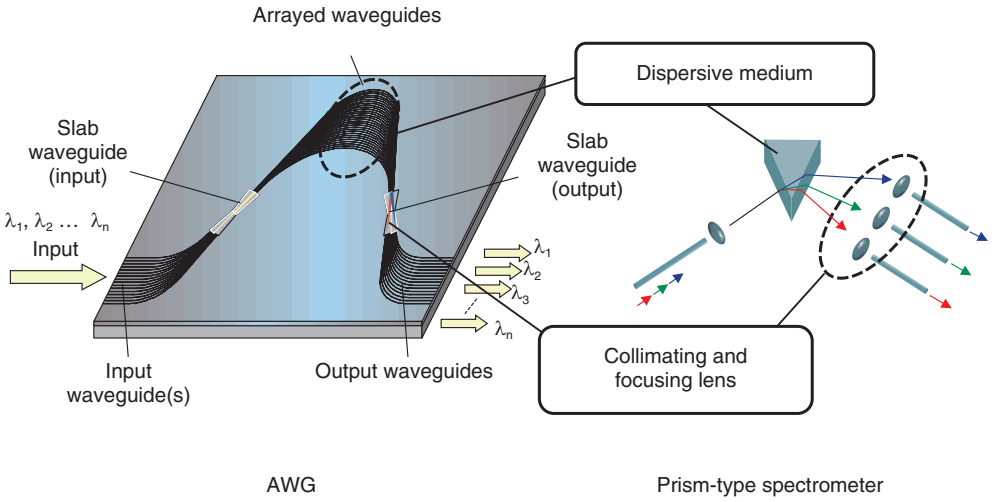


Fig. 1. Configuration of AWG compared with conventional prism-type spectrometer.

Table 1. Summary of photoreceivers with MM-AWGs.

	10-Gbit/s photoreceiver	40-Gbit/s photoreceiver	100-Gbit/s photoreceiver
Alignment technique	Mechanical	Visual	Active
Total bit rate (Gbit/s)	10	40	100
WDM (channels)	8	4	4
Baud rate (Gbaud)	1.25	10	25
Modulation format	NRZ		
Wavelength band (μm)	1.5 (C-band)	1.3 (O-band)	
Channel spacing (nm)	20 (CWDM)	24.5	4.5 (LAN-WDM)

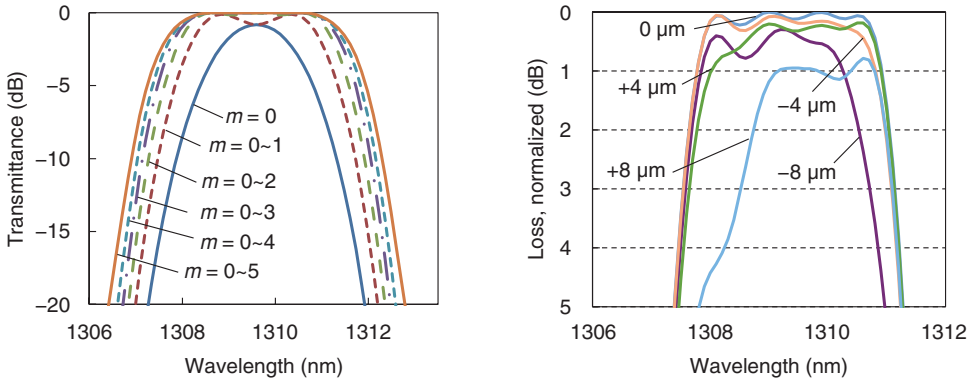
CWDM: coarse WDM
LAN: local area network
NRZ: non-return-to-zero

a baud rate of 1.25 Gbaud on a 20-nm wavelength grid in the 1.5-μm band. The 40-Gbit/s photoreceiver was fabricated using visual alignment with four-channel WDM with a baud rate of 10 Gbaud on a 24.5-nm wavelength grid in the 1.3-μm band. The 100-Gbit/s photoreceiver was fabricated using active alignment with a baud rate of 25 Gbaud on an 800-GHz or 4.5-nm spectral grid.

2. MM-AWG and optical coupling

Insertion loss and transmission bandwidth are essential parameters in AWG design. Although there are many proposals to improve these characteristics, both are apt to be in a trade-off relationship. We use a special AWG in which multimode waveguides are used at the output slab waveguide. In contrast to the conventional AWG with single-mode output waveguides, the MM-AWG provides a flat-top passband with low loss [3]. **Figure 2(a)** shows the calculated spectral shape of the MM-AWG. In waveguides, the more the width of the output waveguides is enlarged, the higher the modes are generated, improving spectral flatness together with a reduction in insertion loss. Parameter m is the mode order. In this case, a total of six modes exist including the fundamental one ($m = 0$).

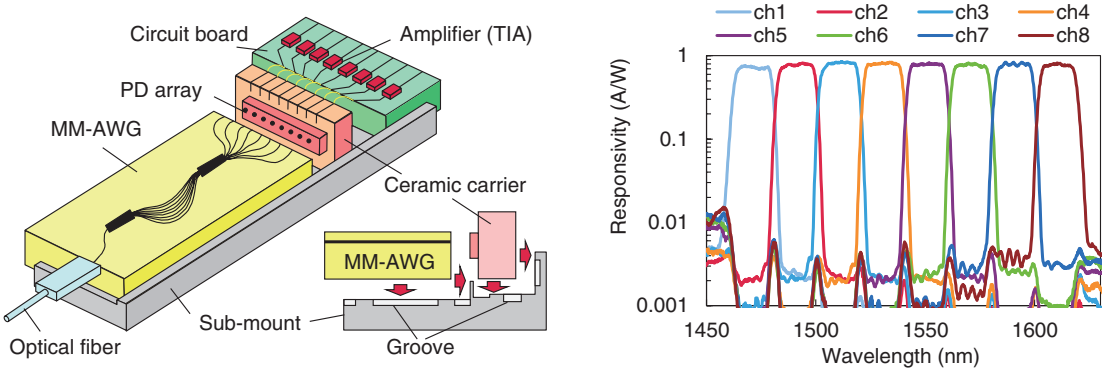
The demultiplexed multimode optical signal is not appropriate for retransmission through a single-mode optical fiber due to the loss of higher modes. Therefore, a photoreceiver in which the multimode signal is instantly converted into electric signal should be



(a) Calculated spectral shape of MM-AWG. Parameter *m* is the mode order.

(b) Example of measured spectrum shape dependent on center offset for 100-Gbit/s photoreceiver.

Fig. 2. Spectral shape of MM-AWG.



(a) Schematic configuration of photoreceiver

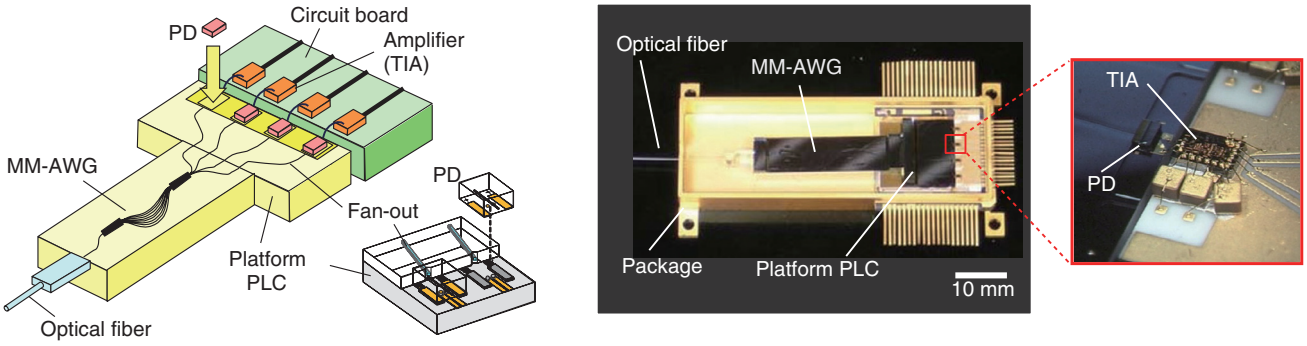
(b) Responsivity spectra of the photoreceiver

Fig. 3. 10-Gbit/s photoreceiver.

used. However, even if the spectral shape is flat at the output of the MM-AWG, poor coupling with a photodiode (PD) degrades the shape. **Figure 2(b)** shows an example of a measured spectrum dependent on center offset, which is the distance between receiving light axis of the PD and emitting light axis of the PLC. The optical parameters are based on our100-Gbit/s photoreceiver. They show that when the position of the MM-AWG and PD are aligned properly at the displacement of zero micrometers, the flatness of the spectrum is good enough. Therefore, it is important to design optical coupling and consider assembly tolerance to capture all multimode beams to be sufficiently received at the detection area of the PD.

3. Receiver integration using mechanical alignment

The WDM photoreceiver integrated using mechanical alignment is an eight-channel WDM photoreceiver with a total bit rate of 10 Gbit/s, in which coarse WDM with 20-nm channel spacing and a baud rate of 1.25 Gbaud is applied. A schematic of this photoreceiver is shown in **Fig. 3(a)**. It consists of an MM-AWG, PD array attached to a ceramic carrier, circuit board including transimpedance amplifiers (TIAs), sub-mount, and pigtail fiber, which is connected to the input edge of the MM-AWG. For hybrid integration with the MM-AWG and PD array, we used mechanical alignment. The sub-mount serves as



(a) Schematic of photoreceiver

(b) Photograph of photoreceiver

Fig. 4. 40-Gbit/s photoreceiver.

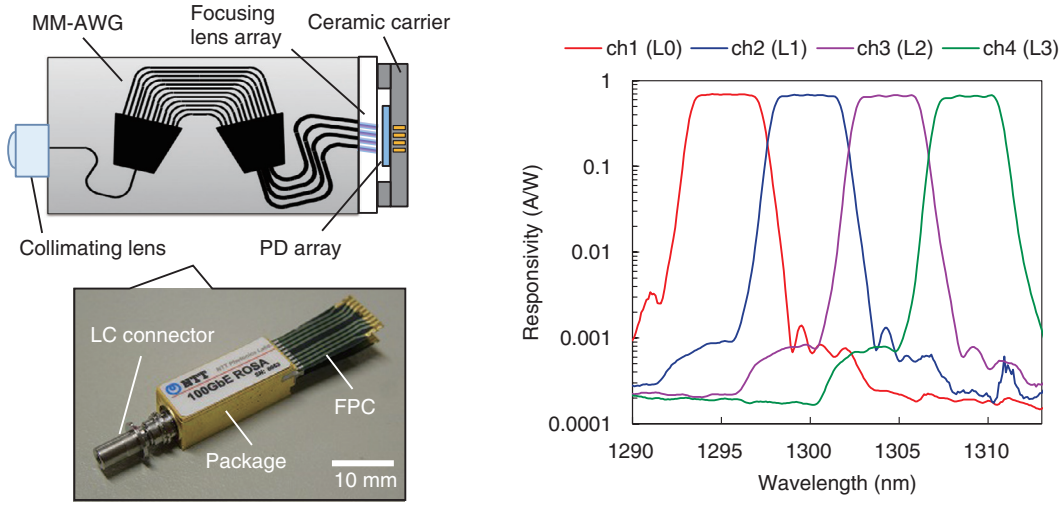
an alignment platform and is made with machining accuracy of better than 10 μm. On the sub-mount shown in the inset, several grooves are formed and filled with bonding adhesive during assembly. This provides high mounting accuracy for the MM-AWG and PD array of better than 5 μm because of the tensile strain induced by the adhesive spreading in the grooves while curing. Therefore, the total placement error in this mechanical alignment is less than 15 μm. The size of the package or sub-mount is 100 × 50 mm. The responsivity spectra of the photoreceiver shown in **Fig. 3(b)** indicate that a high, flat-top responsivity can be obtained for all channels. Within each passband of 13 nm, the responsivity ranges from 0.7 to 0.85 A/W with a crosstalk level of better than −22 dB. The polarization-dependent loss is 0.2 dB or less at the center wavelength of the grid, which is the same as that of the MM-AWG. We estimated coupling loss between the input fiber and PD as 1 dB, which is the same as in the fiber-coupled measurement; therefore, there is almost no degradation in optical coupling due to mechanical alignment.

4. Receiver integration using visual alignment

The second photoreceiver we developed operates at higher speeds and is more compact with 40-Gbit/s throughput. A schematic of this photoreceiver is shown in **Fig. 4(a)**. It is composed of an MM-AWG PLC, platform PLC that integrates fan-out waveguides and PDs, and electrical circuit including TIAs. The PLC of the MM-AWG and platform PLC are bonded in advance with adhesive with high optical transparency. Such a dual-PLC structure can ensure the quality of the two PLCs separately in terms of yield and size. On the platform PLC, edge-illuminated PDs are flip-chip bonded. Visual alignment is used for assembly with higher accuracy than that with the 10-Gbit/s photoreceiver. As shown in the inset illustrating the hybrid integration of the PDs on the platform PLC, alignment is carried out visually using markers on the PD and PLC. The assembly error is less than 1 μm. Designing the fan-out so that the channels are separated can suppress electrical interchannel crosstalk. According to our estimation from radio-frequency simulation, separation over 1.5 mm provides electrical isolation of more than 20 dB at a frequency of 10 GHz. **Figure 4(b)** shows photographs of this photoreceiver. The MM-AWG bonded with the platform PLC and circuit board are mounted in a package. The enlarged photograph shows the detecting area, where the PD is hybridly integrated on the platform PLC and connected to a TIA via electrical wire. As we estimated, the measured 3-dB-down bandwidth of the receiver is larger than 9 GHz with an adjacent crosstalk of better than 21 dB. The small and compact package is 64 × 25 mm.

5. Receiver integration using active alignment

This photoreceiver has a baud rate of 25 Gbaud with throughput of 100 Gbit/s by four-channel WDM. It meets the Institute of Electrical and Electronics Engineers (IEEE)'s standard of Ethernet 100 GbE for transmission reach of 10 and 40 km. A 4-channel WDM with a 25-Gbit/s non-return-to-zero (NRZ) signal and wavelength allocation, called local area network (LAN)-WDM with a grid spacing of 800 GHz [4], is applied. **Figure 5(a)** illustrates the core assembly of this photoreceiver, which is composed of



(a) Schematic and photograph of photoreceiver
FPC: flexible printed circuit

(b) Responsivity spectra of the photoreceiver

Fig. 5. 100-Gbit/s photoreceiver.

an MM-AWG, collimating lens, focusing lens array, and PD array, all bonded as a single assembly block. For all the optical connections in the core assembly, we used active alignment in which all the positions of optical components are aligned while monitoring the power of input light. This provides very high accuracy placement by means of inputting an optical signal into each component. A photograph of this photoreceiver is also shown in the figure. The photoreceiver consists of a metal hermetically sealed package, receptacle Lucent (LC) connector with another focusing lens, and flexible printed circuits. The size of the package is $7 \times 18 \times 6$ mm^3, which can be installed in compact Ethernet transceivers.

Figure 5(b) shows the responsivity spectrum of the photoreceiver. We observed a flat-top spectral shape of over 500 GHz and a maximum responsivity higher than 0.7 A/W for all channels. The total optical loss is about 1.5 dB, which includes 0.8-dB AWG loss, 0.3-dB coupling loss from the PLC to PD, and 0.3-dB loss from the PLC to receptacle. The crosstalk between adjacent channels is less than 25 dB in the 360-GHz passband. We also conducted reliability tests, such as temperature tracking from 5 to 80°C, high-temperature storage at 85°C, and mechanical vibration. In all tests, a loss change as low as less than 0.2 dB was confirmed, which reveals the high reliability of the photoreceiver owing to our stable assembly. For the bit-error-rate (BER) characteristics, we obtained a minimum receiver sensitivity of less than −10.9 dBm in optical modulation amplitude (OMA) at a BER = 10^{-12}. These results meet the specifications for 10-km 100 GbE links with a sensitivity margin of over 4 dB. By replacing the pin-PD with an avalanche PD, we confirmed further extended reach of 40 km [5].

6. Further studies

We have used the MM-AWGs and assembly concepts described in this article toward beyond-100-Gbit/s applications such as for ramping up to 200-Gbit/s throughput by adopting four-level pulse-amplitude modulation (PAM4) and 400-Gbit/s photoreceiver using an eight-channel WDM together with the PAM4 format [6–8]. These consecutive studies have clearly shown our receiver integration technology is promising for future client-side communications as well as the All-Photonics Network.

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Report of the 4th Meeting of the APT Preparatory Group for WTSA-20

Noriyuki Araki

Abstract

In preparation for the World Telecommunication Standardization Assembly (WTSA) of the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T), the 4th meeting of the Asia-Pacific Telecommunity (APT) Preparatory Group for WTSA-20 (APT WTSA20-4) was held in an online conference from November 16 to 20, 2020. This article reports the results of APT WTSA20-4 and the schedule for the WTSA.

Keywords: APT, WTSA-20, TSAG

1. Introduction

The Asia-Pacific Telecommunity (APT) is an international organization promoting developments in the information and communication technology (ICT) field in the Asia-Pacific region. It was established in 1979 and has 38 member countries in the region. The APT has been holding preparatory meetings to discuss the APT Common Proposal (ACP) for the World Telecommunication Standardization Assembly (WTSA) of the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T). Four meetings of the APT Preparatory Group were planned for WTSA-20, and the 1st meeting was held in June 2019 in Akihabara, Japan. Other meetings had been scheduled to be held in Thailand, China, and the Philippines. However, due to the COVID-19 pandemic, the plan was revised, and the second and subsequent meetings were all held online.

Participants registered for the 4th meeting of the APT Preparatory Group for WTSA-20 (APT WTSA20-4) held from November 16 to 20, 2020 were 235 members (16 countries) from APT member countries, 25 associate and supporting members, 22 representatives from other international standardization organizations, and 7 from the APT Secretariat, a total of 289 participants. An analysis by country shows that 59 participants, 1/4 of the total, were from China. The number of participants from emerging countries, such as Thailand, Malaysia, India, and Indonesia, is also increasing. From Japan, the Ministry of Internal Affairs and Communications, as the representative, participated with 14 representatives from private companies.

2. Management team of the APT Preparatory Group for WTSA-20

The list of officers at the APT Preparatory Group for WTSA-20 is shown in **Table 1**. As the chairmen and vice-chairmen of the three Working Groups (WGs), which promote detailed discussions on specific issues, three experts (Mr. Naganuma (NEC), Mr. Araki (NTT), the author of this article, Mr. Hondo (KDDI)) were selected from Japan. Accordingly, Japan serves as WG officers while maintaining cooperative relations with China, the Republic of Korea, and India.

3. Study items and work method

WTSA-20 is a general meeting of ITU-T that is held once every four years. It is an important meeting for organizing the ITU-T Study Groups (SGs) after 2021, selecting the positions of chairmen and vice-chairmen of SGs, and preparing Resolutions on standardization strategy such as on artificial intelligence (AI), Internet of Things (IoT), smart cities, Beyond

Table 1. APT Preparatory Group for WTSA-20 management structure.

APT WTSA-20	Chairman	Vice-Chairmen
Plenary	Mr. Yoichi Meda (Japan, TTC)	Dr. Hyoung Jun Kim (Korea) Ms. Li Fang (China) Mr. U. K. Srivastava (India)
Working Group (WG)	WG Chairman	WG Vice-Chairmen
WG1: ITU-T Working Methods	Dr. Kangchan Lee (Korea)	Ms. Miho Naganuma (Japan, NEC) Mr. Ashutosh Pandey (India) Mr. Tong Wu (China)
WG2: ITU-T Work Organization	Mr. Noriyuki Araki (Japan, NTT)	Mr. P. K. Singh (India) Mr. Nguyen Van Khoa (Vietnam) Mr. Kihun Kim (Korea) Ms. Wang Liang (China)
WG3: Regulatory/Policy and Standardization Related Issues	Dr. Cao Jiguang (China)	Ms. Eriko Hondo (Japan, KDDI) Ms. Arezu Orojlu (Iran) Mr. Premjit Lal (India) Ms. Nguyen Thi Khanh Thuan (Vietnam)

5G (fifth-generation mobile communications), and quantum communications, which are recent standardization topics in ITU-T.

In the APT Preparatory Group, three WGs share the task of drafting and examining relevant Resolution documents and draft Recommendations and discuss issues on the basis of the contributions from each country in accordance with the Terms of References of each WG.

Proposals that have reached consensus at the WG meeting will be considered as candidate proposals for approval at the plenary. The candidate proposals, which were approved at the closing plenary of the APT Preparatory Group meeting, became the Preliminary APT Common Proposal (PACP). The PACP, which was approved by the administrations of APT member countries, will then be the final ACP.

The approval of a PACP is based on the agreement reached at the plenary. However, if there is a disagreement, the approval of at least 25% of the countries attending the plenary is necessary. If the number of dissenting countries is not more than the number of countries supporting the approval, the PACP will be adopted.

The conditions for approval of an ACP are as follows: all APT member states (38 countries) are consulted on the approval of the ACP (endorsement); more than 25% of the APT member states (10 countries) approve the ACP; and more than 50% of the APT member states (19 countries) do not oppose the ACP. The approved proposal is submitted to the WTSA as an ACP.

4. Results of discussion

(1) WG1: ITU-T Working Methods

WG1 is considering modification (MOD) or suppression (SUP) of the WTSA Resolution on ITU-T working methods. Since the revision of the ITU-T A series Recommendations (e.g. Recommendations A.1, A.7) requires consideration at the Telecommunication Standardization Advisory Group (TSAG) meeting, WG1 prepared APT Views, which is a document type that enables submission of contributions to TSAG.

Regarding the deliverables from WG1, eight proposed PACPs were prepared and approved at the plenary. The proposed PACPs related to the MOD of Resolutions 22 (Resolution on the authorization of TSAG) and 32 (Resolution on electronic working method) and SUP of Resolutions 35 (Appointment and Term of ITU-T SG and TSAG Chairmen and Vice-Chairmen) and 45 (Resolution on coordination of standardization work across SGs) are based on the Japanese proposal, and Japan is in charge of editing the proposal documents.

(2) WG2: ITU-T Work Organization

WG2 is studying the structure of ITU-T SGs, including the work plans and Questions to be addressed by each SG. New standardization work items are also discussed in WG2 as they are closely related to the future SG structure.

New Resolutions were proposed regarding new work items by China and the Republic of Korea, including pandemic countermeasures including e-health for new coronavirus infections by using AI in ICT, promotion of studies on machine vision,

enhancement of studies on quantum information technology, and examination of future networks considering vertical applications. However, it was argued that it was too early to draw up a resolution, and some countries opposed the new Resolution since it is closely related to the work items in ITU-T SG11, SG13, and SG16, that each SG is currently studying these new work items, and that these new work items are being continuously examined by the Focus Group. At the closing plenary session, more than one country expressed their concern on the proposed Resolutions. Regarding the new Resolution, WG2 was able to agree only on the PACP of the Resolution "ITU-T's role in facilitating the use of ICTs to prevent the spread of global pandemics," which is an important issue related to new coronavirus infections. WG2 also agreed with a proposal on the MOD of the existing Resolution 78 on e-health.

Regarding the principle of SG restructuring, the APT View was agreed on the basis of a proposal from China, which was based on the seven high-level principles for SG structure* agreed upon at WTSA-16.

With respect to SG restructuring proposals, at the TSAG meeting, the TSB (Telecommunication Standardization Bureau) Director proposed a draft of the SG structure (Food for thought), and the proposal to drastically reduce the number of SGs from the current 11 is under consideration at other regional meetings such as the European Conference of Postal and Telecommunications Administrations (CEPT) in Europe. At the APT, there were opinions in favor of reducing the number of SGs, such as those from the Republic of Korea, Malaysia, and Indonesia. At this meeting, Japan proposed an SG structure. However, proposals to partially transfer SG20 IoT security issues (Question 6/SG20) to SG17 and SG2 are included, which would maintain the number of existing SGs. With the support of China and the consent of the Republic of Korea and Malaysia, the proposal was agreed as an ACP. Since discussions on SG restructuring are closely related to the election of the SG chair and vice-chair, it is necessary to understand the circumstances of each country and region and take further actions toward the conclusion of the WTSA.

(3) WG3: Regulatory/Policy and Standardization Related Issues

The number of PACPs agreed in the closing plenary of this meeting was 29 for revisions to existing Resolutions and 5 for APT View. The PACPs for the agreed revisions of Resolutions and Recommendations are listed in **Table 2**.

5. Future plans

In APT WTSA20-4, discussions on a substantial PACP were completed, but the WTSA was postponed until March 2022. Accordingly, it was proposed and approved to hold an additional meeting of the APT Preparatory Group for WTSA-20 in 2021. The schedule of future WTSA-related meetings is listed in **Table 3**. At the APT Preparatory Group meeting in 2021, APT policy for WTSA will be discussed. Discussions will be held on how to deal with the upcoming TSAG meeting, and common proposals from other regional standardization organizations to the WTSA will be analyzed.

* Seven high-level principles for SG structure: Optimized structure, clear mandates, enhanced coordination and cooperation, cost-effectiveness and attractiveness, efficient and productive working methods, timely identification of standardization needs, and support for bridging the standardization gap.

Table 2. List of proposed Resolutions and Recommendations of the APT.

1. APT WTSA-20 Resolutions

No.	Title	WG	Relevant document
1	Rules of procedure of the ITU Telecommunication Standardization Sector	1	OUT-07 (MOD)
2	ITU Telecommunication Standardization Sector study group responsibility and mandates	2	OUT-28 (MOD)
18	Principles and procedures for the allocation of work to, and strengthening coordination and cooperation among, the ITU Radiocommunication, ITU Telecommunication Standardization and ITU Telecommunication Development Sectors	1	OUT-08 /WTSA3 (MOD)
22	Authorization for the Telecommunication Standardization Advisory Group to act between world telecommunication standardization assemblies	1	OUT-05 /WTSA3 (MOD)
32	Strengthening electronic working methods for the work of the ITU Telecommunication Standardization Sector	1	OUT-06 /WTSA3 (MOD)
35	Appointment and maximum term of office for chairmen and vice-chairmen of study groups of the Telecommunication Standardization Sector and of the Telecommunication Standardization Advisory Group	1	OUT-05 (SUP)
45	Effective coordination of standardization work across study groups in the ITU Telecommunication Standardization Sector and the role of the ITU Telecommunication Standardization Advisory Group	1	OUT-07 /WTSA3 (SUP)
50	Cybersecurity	3	OUT-16 (MOD)
52	Countering and combating spam	3	OUT-14 (MOD)
55	Promoting gender equality in ITU Telecommunication Standardization Sector activities	1	OUT-04 (MOD)
58	Encouraging the creation of national computer incident response teams, particularly for developing countries	3	OUT-23 (MOD)
60	Responding to the challenges of the evolution of the identification/numbering system and its convergence with IP-based systems/networks	3	OUT-13 (MOD)
64	Internet protocol address allocation and facilitating the transition to and deployment of IPv6	3	OUT-11 (MOD)
67	Use in the ITU Telecommunication Standardization Sector of the languages of the Union on an equal footing	1	OUT-06 (MOD)
72	Measurement and assessment concerns related to human exposure to electromagnetic fields	3	OUT-20 (MOD)
73	Information and communication technologies, environment and climate change	3	OUT-19 (MOD)
76	Studies related to conformance and interoperability testing, assistance to developing countries, and a possible future ITU Mark programme	3	OUT-13/WTSA3 (MOD)
77	Enhancing the standardization work in the ITU Telecommunication Standardization Sector for software-defined networking	3	OUT-18 (MOD)
78	Information and communication technology applications and standards for improved access to e-health services	2	OUT-27 (MOD)
79	The role of telecommunications/information and communication technologies in handling and controlling e-waste from telecommunication and information technology equipment and methods of treating it	3	OUT-15/WTSA3 (MOD)
84	Studies concerning the protection of users of telecommunication/information and communication technology services	3	OUT-17 (MOD)
88	International mobile roaming	3	OUT-26 (MOD)
89	Promoting the use of information and communication technologies to bridge the financial inclusion gap	3	OUT-24 (MOD)
92	Enhancing the standardization activities in the ITU Telecommunication Standardization Sector related to non-radio aspects of international mobile telecommunications	3	OUT-12 (MOD)
95	ITU Telecommunication Standardization Sector initiatives to raise awareness on best practices and policies related to service quality	3	OUT-21 (MOD)
96	ITU Telecommunication Standardization Sector studies for combating counterfeit telecommunication/information and communication technology devices	3	OUT-22 (MOD)
97	Combating mobile telecommunication device theft	3	OUT-15 (MOD)
98	Enhancing the standardization of Internet of things and smart cities and communities for global development	3	OUT-25 (MOD)
New	ITU-T's role in facilitating the use of ICTs to prevent the spread of global pandemics	2	OUT-29 (ADD)

2. APT WTSA-20 A-series Recommendations

No.	Title	WG	Relevant document
A.1	Working methods for study groups of the ITU Telecommunication Standardization Sector	1	OUT-08 (MOD)
A.7	Focus groups: Establishment and working procedures	1	OUT-09 (MOD)
A.8	Alternative approval process for new and revised ITU-T Recommendations	1	OUT-10 (MOD)

Table 3. Future meeting plans.

Meeting	Date	Location/form of meeting
Additional APT Preparatory Group meeting	Q3 2021 (September, tentative)	Virtual meeting
TSAG	25–29 October 2021	Virtual meeting
TSAG	10–14 January 2022	Virtual meeting (tentative)
WTSA	1–9 March 2022	India (Hyderabad)

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Novel Tool for Finding a Defective Field-assembly Connector in the Field

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Abstract

This article introduces a novel tool for finding defective field-assembly connectors just after service personnel assembled them in the field. The tool uses multi-wavelength loss profiles to identify the defective connectors. This is the sixty-third article in a series on telecommunication technologies.

Keywords: field-assembly connector, FTTH, insertion loss

1. Introduction

Configuration of fiber-to-the-home (FTTH) service equipment is illustrated in **Fig. 1**. Field-assembly (FA) connectors are commonly used at each connection point in closures on utility poles and in customer's premises. In comparison with fusion-splice and mechanical splice connectors, FA connectors have the advantages of prompter opening of services and easier switching work. However, owing to incorrect procedures during assembly of the connectors or insufficient maintenance of tools, the quality of connection in an FA connector might deteriorate soon after installation.

The Technical Assistance and Support Center (TASC), NTT EAST, is continuously working to solve problems with various communication equipment. This article presents a novel maintenance tool using multi-wavelength loss profiles to find failures of FA connectors.

2. Reduce early failures of FA connectors

In accordance with previous investigations of failure cases and verifications based on reproductions of such failures, early failures of FA connectors have been found to occur due to incorrect procedures during connector-assembly work or insufficient maintenance of tools such as fiber cleavers [1]. The insertion-loss-generation mechanism [2] due to incorrect assembly of FA connectors is shown in **Fig. 2**. In the case of a correct connection, the insertion fiber and built-in fiber are butt-connected in the mechanical splice section without leaving any gaps. However, in the case of a defective connection, a minute gap forms at the butt joint due to incorrect fiber cleaving or incorrect cleaving length. In such a case, significant insertion loss due to the gap may not occur immediately after assembly because the gap is filled with a refractive-index-matching material. However, if air bubbles mixed in the material move, for example, due to temperature variations, and reach the point at which the communication light passes through the gap, large insertion loss will occur. As we described above, defective FA connectors may cause early failure.

As countermeasures against the above issues, we previously devised and developed tools that call attention to these issues during connector assembly. These tools include a fiber-cleaving checker, for checking the cleaved surface of the insertion fiber, and a pocket manual that lists key points during installation.

While these tools have helped decrease the number of failures of FA connectors, early failure has not been eradicated. Therefore, we developed an FA

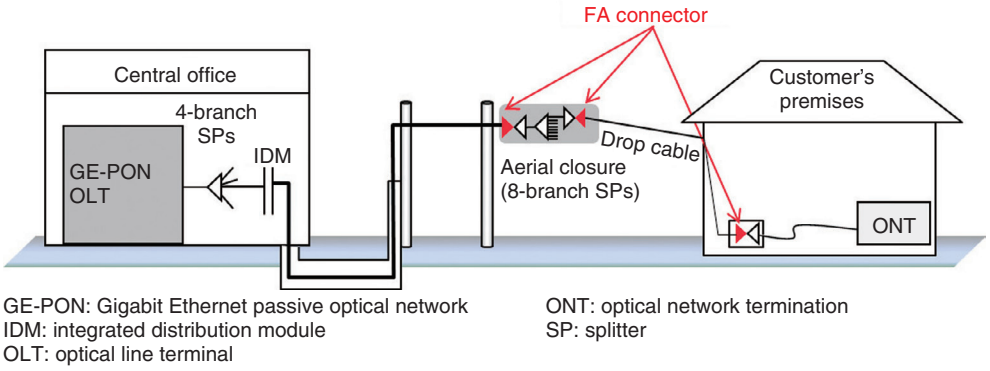

Fig. 1. Configuration of FTTH service equipment.

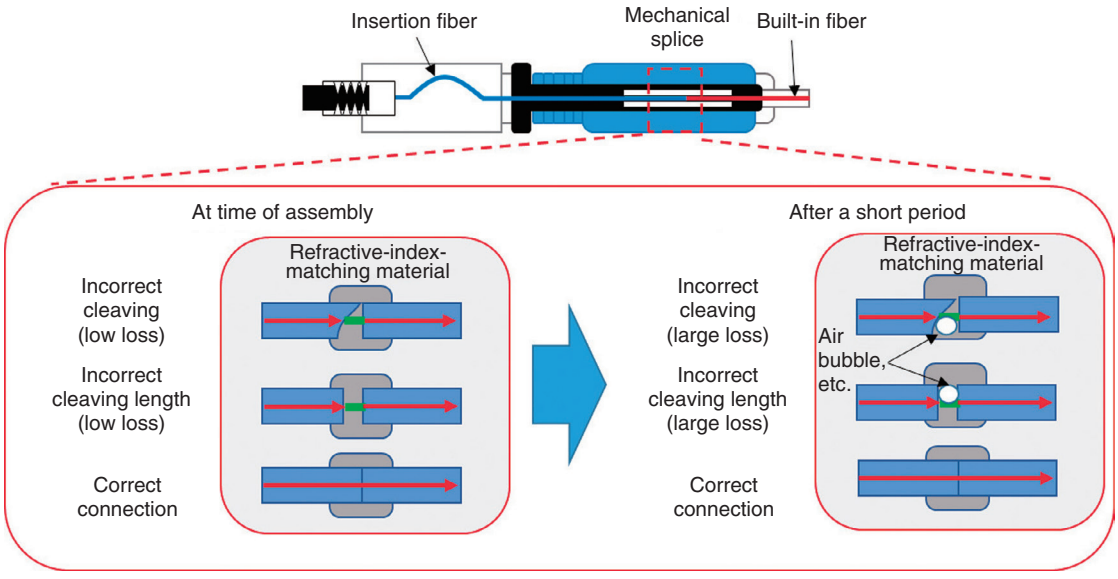

Fig. 2. Mechanical-splice section of FA connector.

connector checker that can easily determine defective connectors on the spot as a further countermeasure.

3. FA connector checker

3.1 Principle of the FA connector checker

The difference between a correct connector and defective connector is the presence or absence of a refractive-index-matching material on the path along which communication light passes. Accordingly, our FA connector checker finds a defective FA connector using the multiple wavelength characteristics on the refractive-index-matching material.

We investigated insertion losses of correct and defective connectors in regard to each wavelength. **Figure 3** shows the insertion losses of the refractive-index-matching material at each wavelength. We found that the insertion losses of the refractive-index-matching material depend on the wavelength of the light traveling through it. We also found that the insertion losses of the correct connector varied little, but those of the defective connector varied significantly in each wavelength. These findings indicate the FA connector checker can identify hidden defective connectors by comparing the insertion losses at multiple wavelengths.

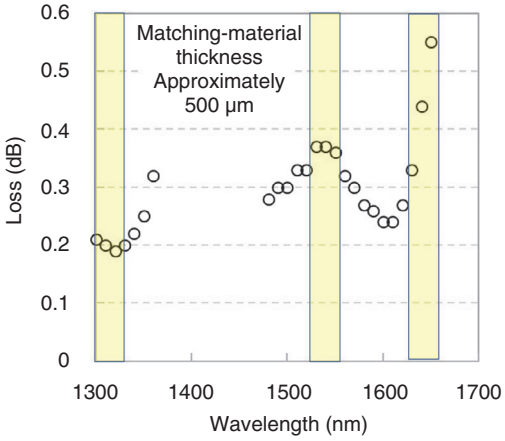

Fig. 3. Wavelength dependence of insertion loss of refractive-index-matching material.

Fig. 4. Photographs of FA connector checker (prototypes).

3.2 Investigation on installing the checker in a multi-wavelength optical-time-domain reflectometer

With an emphasis on portability and workability so that workers can easily determine defective connectors on site, we installed our FA connector checker in a multi-wavelength optical-time-domain reflectometer (OTDR). There are two types of compact OTDRs generally available: two wavelength (1310/1550 nm) and three wavelength (1310/1550/1625 nm). On selecting the type of OTDR under the assumption of actual field use, it is necessary to consider factors such as detection accuracy, operability, and price. Accordingly, we evaluated the accuracy of two- and three-wavelength prototypes of our FA connector checker in an experimental environment. One hundred FA connectors were fabricated, and connectors with variations in insertion losses immediately after fabrication and connectors with loss fluctuations of 3 dB or more during the temperature-cycling test were selected. From comparing the detection accuracies of the two- and three-wavelength checkers, we found that accuracy was 96% for the former and 100% for the latter. Although the accuracy of the three-wavelength checker was higher, both checkers were satisfactory.

3.3 Physical details of the prototypes

Photographs of the prototypes are shown in **Fig. 4**. These prototypes were respectively installed in two MT9090A OTDRs (two- and three-wavelength types) manufactured by Anritsu. Either of the two- or three-wavelength-type prototypes can be mounted in the MT9090A without changing its size. The difference in the two prototype checkers is that the two-wavelength one can measure two wavelengths via one port, but the three-wavelength one is divided into a 1310/1550-nm port and 1625-nm port.

3.4 Procedure for determining defective connector

The procedure for determining a defective connector using our checker is explained as follows. Our checker can be used on the spot where the FA connector

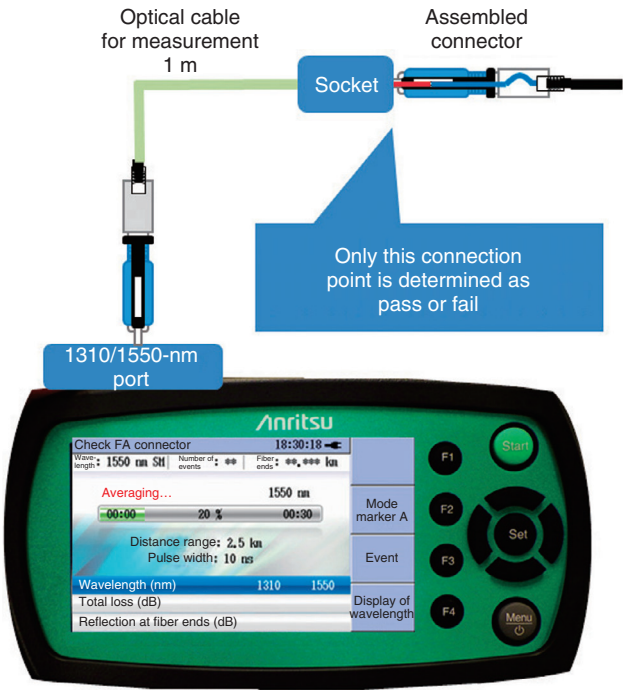

Fig. 5. Measurement screen of prototype two-wavelength-type checker.

is installed such as on utility poles or in customer's premises, as shown in Fig. 1. A defective connector can be identified simply by connecting the checker to the connector with an optical cable for measurement. Regarding the two-wavelength prototype checker, when the Start button is pressed, the insertion losses at two wavelengths (1310 and 1550 nm) are measured for 30 seconds each, then "pass" or "fail" is automatically displayed (**Fig. 5**). For the three-wavelength-type prototype checker, the user is given guidance prompting them to switch to the 1625-nm port after measurement at the two wavelengths (1310 and 1550 nm) have been completed (**Fig. 6**), and when the insertion loss at a wavelength of 1625 nm is measured, pass or fail is displayed (**Fig. 7**). These results indicate that the prototype checkers can automatically detect a defective connector without the need for the operator to analyze the measurements. Comparing their operation times, we clarified that the pass/fail result was displayed with the prototype two-wavelength-type checker in about one minute and with the prototype three-wavelength-type checker (including time to switch the ports) in about two minutes.

4. Summary and future work

We presented a novel FA connector checker for finding defective FA connectors and fabricated two prototypes of the checker, i.e., two- and three-wavelength. Although the two-wavelength-type checker has advantages in terms of workability (because it is not necessary to reconnect the measurement ports) and price expected from the configuration of its components, the three-wavelength-type checker has an advantage in terms of higher detection accuracy. In the future, we will investigate the advantages of both types through actual on-site trials aiming at their early commercialization.

5. Conclusion

We described our efforts in preventing early failures of FA connectors. Currently, measurements using OTDRs or power meters cannot identify a defective connector unless a significant insertion loss occurs. However, using our FA connector checker makes it possible to identify hidden defective connectors. We believe that this detection capability will greatly contribute to reducing early failures and improving the quality of service provided to our

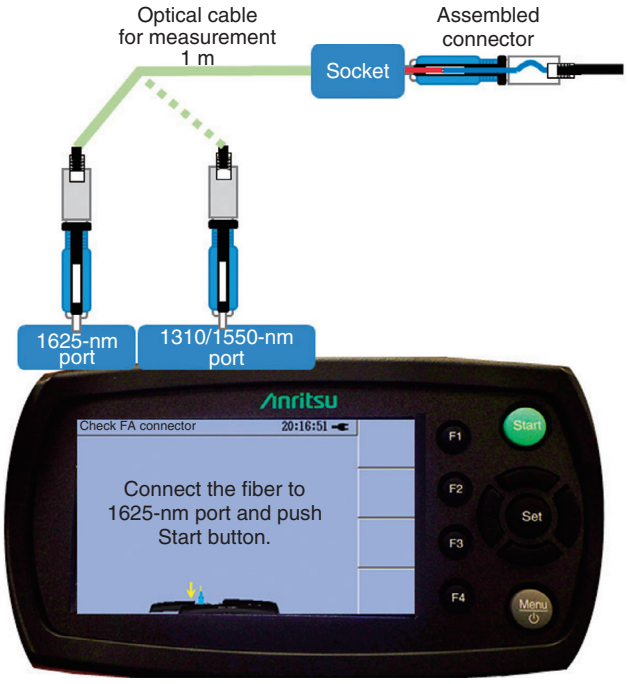

Fig. 6. Guidance given with prototype three-wavelength-type checker.

Fig. 7. Display of results (left: two-wavelength prototype; right: three-wavelength prototype).

customers.

At TASC, we will continue to improve the reliability of telecommunication equipment and reduce telecommunication failures on the basis of our accumulated knowledge and experience as well as new technologies.

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Event Report: Tsukuba Forum 2020 ONLINE

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Abstract

Tsukuba Forum 2020 ONLINE was held on October 29 and 30. To prevent the spread of COVID-19, the event was not held at the NTT Tsukuba R&D Center (Tsukuba City, Ibaraki Prefecture) as in previous years but online. The theme of the forum was "Supporting the smart world—Innovative technologies for the IOWN [Innovative Optical and Wireless Network] concept and advanced technologies for business growth." This article gives a brief overview of the speeches and exhibits presented at the forum.

Keywords: Tsukuba Forum, access networks, IOWN

1. Introduction

The theme of Tsukuba Forum 2020 ONLINE was "Supporting the smart world—Innovative technologies for the IOWN [Innovative Optical and Wireless Network] concept and advanced technologies for business growth." It was held with the intention of further developing access network technologies that support people and companies in response to changes in society, which has seen dramatic transformations of working styles and lifestyles. In addition to NTT Access Network Service Systems Laboratories (AS Labs), 85 organizations, including co-hosting organizations and NTT Group companies (**Table 1**), participated. They introduced and exhibited the latest research and development (R&D) and technological trends.

2. Overview of speeches

The two keynote speeches were streamed live on the first day.

2.1 Keynote speech 1

Jun Sawada, president, chief executive officer, and representative member of the Board of NTT, gave a speech titled "NTT Group's Initiatives for a Post-COVID-19 Society" (**Photo 1**). For details, see that article in this issue [1].

2.2 Keynote speech 2

Ichiro Uehara, senior executive vice president of NTT WEST, gave a speech titled "Toward the Realization of Smart Regional Societies, 'To Be the Social ICT Pioneer'" (**Photo 2**). For details, see that article in this issue [2].

The results from questionnaires revealed that 99% of audience members gave the comments that the speeches were "helpful" and "deepened my understanding of NTT's efforts." Because these speeches were streamed online, the venue and audience size were not restricted and were available on-demand for one month, four times as many people as in previous years viewed the speeches.

3. Workshops

Workshops were streamed on-demand beginning at 9 a.m. on the first day of Tsukuba Forum 2020 ONLINE and accessible for one month. An executive manager of NTT Infrastructure Network Corporation and two project managers from AS Labs conducted

Table 1. List of Tsukuba Forum 2020 ONLINE exhibiting companies.

■NTT Group companies
NIPPON TELEGRAPH AND TELEPHONE EAST CORPORATION
NTT EAST-MINAMIKANTO CORPORATION
NTT RENTAL ENGINEERING CO., LTD.
Nippon Telematique Inc. (NTI)
NIPPON TELEGRAPH AND TELEPHONE WEST CORPORATION
NTT FIELDTECHNO CORPORATION
NTT Communications Corporation
NTT WORLD ENGINEERING MARINE CORPORATION
NTT COMWARE CORPORATION
NTT Infrastructure Network Corporation
AIREC ENGINEERING CORPORATION
NTT Advanced Technology Corporation
NTT-AT Techno Communications Corporation
NTT TechnoCross Corporation
NIPPON CARSOLUTIONS CO., LTD.

■Information & Telecommunications Engineering Association of Japan (ITEA)
EXEO TECH CORPORATION
KYOWA EXEO CORPORATION
C-Cube Co., Ltd.
NIPPON DENTSU CO., LTD.
Seibu Electric Industry Co., Ltd.
DAIWA DENSETSU CORPORATION
Nippon COMSYS Corporation
TOSYS CORPORATION
NDS Co., Ltd.
Hokuriku Denwa Kouji Co., Ltd.
SYSKEN Corporation
TSUKEN CORPORATION
MIRAIT Corporation
MIRAIT Technologies Corporation
SOLCOM Co., Ltd.
Shikokutsuken Co., Ltd.
TTK Co., Ltd.

■Communication Line Products Association of Japan
Furukawa Electric, Co., Ltd.
SUMITOMO ELECTRIC INDUSTRIES, LTD.
Fujikura Ltd.
OKANO CABLE CO., LTD.
Sumitomo Electric Optifrontier Co., Ltd.
Fujikura Dia Cable Ltd.
OCC Corporation
NISHI NIPPON ELECTRIC WIRE&CABLE CO., LTD.
JAPAN RECOM Ltd.
SHODEN SEIWA CO., LTD.
Suzuki Giken Co., Ltd.
Nippon Tsushin Denzai Co., Ltd.
TOTSU–SOKEN CORPORATION
FUJIKURA HIGH OPT Co., Ltd.
Milliken Japan G.K.
Corning International K.K.
DAINICHI CONCRETE INDUSTRY CO., LTD.
NIPPON CONCRETE INDUSTRIES CO., LTD.
NIPPON CHIKO CO., LTD.
AICHI CORPORATION
TADANO LTD.
IWABUCHI CORPORATION
SUDA SEISAKUSHO CO., LTD.
ASABA MANUFACTURING CO., LTD.
KANDO Co., Ltd.
KABUSIKIGAISYA KAWANETSU

■Japan Telecommunications Equipment and Materials Manufacturers Cooperative Association (Zentsukyo)
MASARU INDUSTRIES, LTD.
MIYOKAWA manufacturing Co., Ltd.
Takacom Corporation
MSK Technologies Co., Ltd.
NISSHIN ELECTRIC CO., LTD.
Sankosha Corporation
TOMEI TSUSHIN KOGYO CO., LTD.
WATANABE CO., LTD.
Takachiho Sangyo Co., Ltd.
SANWA DENKI KOGYO CO., LTD.
NAGAMURA MANUFACTURING CO., LTD.
Taiei Seisakusho Co., Ltd.

■Other corporations
Anritsu Corporation
NEC Corporation
NEC Magnus Communications, Ltd.
Oi Electric Co., Ltd.
Hitachi, Ltd.
FUJITSU LIMITED
MARUBUN CORPORATION
Mitsubishi Electric Corporation
NTEC Co., Ltd.
SUNREC CO., LTD.
HARADA CORPORATION
MIKI Inc.
RIKEN KEIKI Co., Ltd.

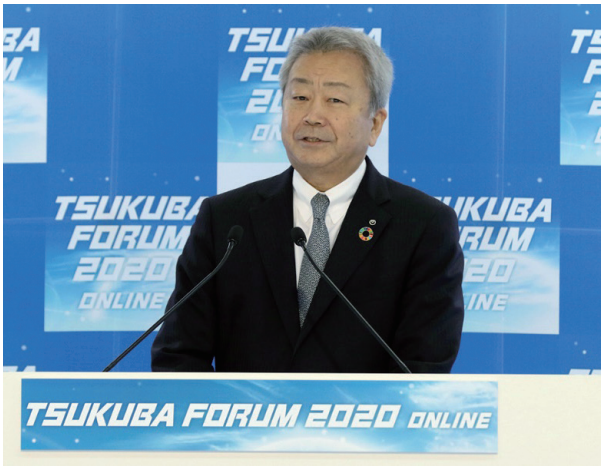

Photo 1. Keynote speech 1: Jun Sawada.

Photo 2. Keynote speech 2: Ichiro Uehara.

Photo 3. Workshops 1–3: (from left) Yoichiro Takaki, Kazunori Katayama, and Tomoaki Yoshida.

the workshops (**Photo 3**).

3.1 Workshop 1

Yoichiro Takaki, executive manager of the Smart Infra Promotion Department, NTT Infrastructure Network Corporation, gave a lecture titled "Activities Centered Around the Smart Infrastructure Platform." For details, see that article in this issue [3].

3.2 Workshop 2

Kazunori Katayama, project manager of the Access Network Media Project, AS Labs, gave a lecture titled "R&D of Innovative Optical Transmission Line Technologies." For details, see that article in this issue [4].

3.3 Workshop 3

Tomoaki Yoshida, project manager of the Optical Access Systems Project, AS Labs, gave a lecture titled "Photonic Gateway and Related Optical Access Technologies to Achieve the All-Photonics Network." For details, see that article in this issue [5].

4. Panel discussions

Co-hosting organizations, NTT Group companies, and the NTT laboratories united to introduce efforts and hold panel discussions on two themes: "Prospects for Space Satellite Utilization" and "Smart Access Technology." The panelists introduced examples from different companies. Their discussions were live-streamed.

4.1 Panel discussion 1

For the theme of "Prospects for Space Satellite Utilization," Fumihiro Yamashita, group leader of the Wireless Entrance Systems Project, AS Labs, served as facilitator. Members of the Japan Aerospace Exploration Agency (JAXA) and SKY Perfect JSAT Corporation joined the panel with members of the NTT Group and discussed the topic of "Expectations and challenges for space and satellite utilization in daily life." In the first part of the panel discussion, Mr. Yamashita introduced the current state of space satellite technology, and the panelists, all involved in the field of space satellites, expressed their views on why space satellite applications will increase going forward. In the second part, NTT DOCOMO, NTT EAST, and NTT Communications introduced examples of their current space satellite utilization efforts, challenges, and future expectations and exchanged views on issues when engaging in new space business. In the third part, JAXA and NTT laboratories introduced their space satellite R&D. They discussed the areas of R&D, national policy, and company measures needed for Japan to develop and lead the space satellite business and utilization by 2030 (**Photo 4**).

4.2 Panel discussion 2

For the theme of "Smart Access Technology," Takashi Ebine, project manager of the Access Network Management Project, AS Labs, served as facilitator. Members of NTT EAST and telecommunication construction companies took the stage and discussed the topic of "Smart access toward automated construction and remote control with robotics." In the first part of the panel discussion, Mr. Ebine introduced the background and direction of efforts in the area of smart access technology. Topics included

Photo 4. Panel discussion 1: Space satellite utilization.

Photo 5. Panel discussion 2: Smart access technology.

changes in the business environment of the telecommunication construction industry, trends in improving outside-plant work efficiency, technologies for smart outside-facility management, and future directions in the development of aerial structure construction. The panel members exchanged fresh viewpoints on the challenges of automated construction involving remotely controlled heavy machinery. They also discussed factors hindering efficiency such as how to deal with metal facilities going forward. In the second part of the session, the panelists discussed the need to review building materials and construction methods. They also presented a video that showed excavation using a power shovel controlled in virtual space as an example of efforts to automate construction. The panelists also discussed work using remote control in the IOWN era, which, together with major technological advances such as artificial intelligence (AI) and Internet of Things (IoT), will drastically transform conventional work methods. Finally, members from AS Labs voiced their desire to work closely with partners in the field and strongly support them into the future (**Photo 5**). During the livestreaming of the panel discussions, online audience members could send questions to panel members. Many participants gave the comment that they found this program meaningful.

Photo 6. Entrance to online site (lobby).

5. Overview of exhibits

In addition to exhibits from AS Labs, exhibits on the network access technologies by the co-hosting organizations and NTT Group companies were held (**Photo 6**). A total of about 150 exhibits were presented with videos and slides to introduce each organization's products and efforts. During the two days of the forum, staff members from the respective organizations virtually stood by their booths and responded to online visitors with direct chat, messages, and

Photo 7. Exhibits.

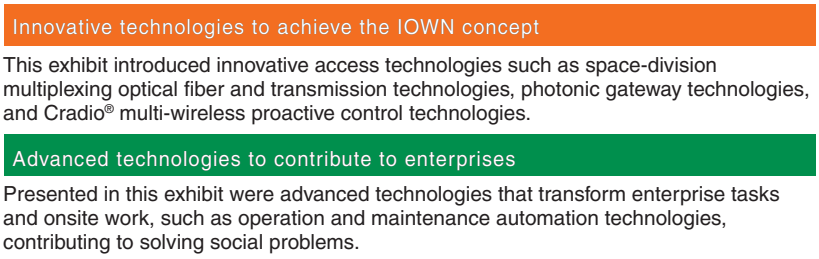

Fig. 1. Overview of NTT exhibits.

video conferencing.

5.1 Special exhibitions

Co-hosting organizations, NTT Group companies, and NTT laboratories united to introduce their efforts on the themes of "Contributing to disaster countermeasures" and "Contributing to the new normal." The results from questionnaires revealed that 96% of online visitors gave the comments that the exhibits were "helpful" or "very helpful." Visitors also commented that the exhibits on disaster countermeasures helped them understand how the organizations were leveraging past experiences to tackle challenges and that they found the materials extremely helpful. Concerning the theme of "Contributing to the new normal," visitors' comments included "I would like to try the technologies exhibited by NTT laboratories in my own company" (**Photo 7**).

5.2 NTT exhibits

In virtual exhibition halls, NTT presented its R&D achievements in the area of "Innovative technologies to achieve the IOWN concept" and "Advanced technologies to contribute to enterprises" (**Fig. 1**). These access network technologies promise to bring about a smart society. Visitors to the exhibits were able to directly converse with researchers via web conferencing (Webex), deepening their understanding (**Photo 8**).

(1) Innovative technologies to achieve the IOWN concept

The exhibition introduced innovative access network technologies such as space-division multiplexing optical fiber and transmission technologies, photonic gateway technologies, and Cradio® multi-wireless proactive control technologies. Visitors were able to talk directly with researchers using Webex at the following virtual exhibits: 1) Research and development toward future access networks for achieving IOWN, 2) Remote beamforming technology for analog RoF [radio-over-fiber] systems, 3) NW [network] resource management technology (NOIM [Network Operation Injected Model]) that unifies the management of various components of the IOWN APN [All-Photonics Network], 4) Optical fiber environmental monitoring technology using communication networks, 5) Multi-core optical fiber and cable technologies for supporting all-photonics networks, 6) Protocol-free management and control in All-Photonics Network, 7) Distributed antenna systems using higher frequency bands for ultra-high capacity and ultra-high

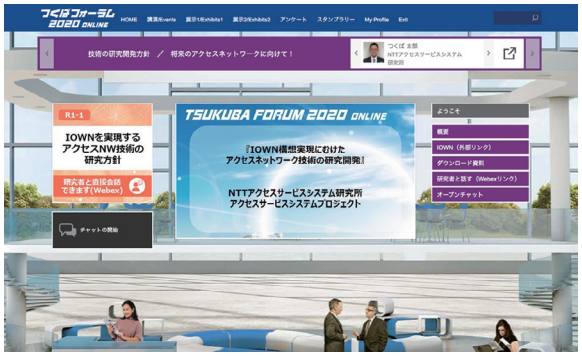

Photo 8. NTT exhibition booth.

speed in wireless access systems, 8) MIMO [multiple-input multiple-output] satellite systems and a global sensor network using LEO [low-Earth orbit] satellites, 9) FM [frequency modulation] conversion technology for protocol-free transmission, 10) Dynamic radio control—a component of Cradio® (multi-radio proactive control technology), 11) Intelligent radio-wave design, 12) Intelligent radio-wave design: virtual massive MIMO transmission, 13) Intelligent radio-wave design: radio-quality platform, 14) Intelligent radio-wave design: wireless sensing, 15) AI for wireless network design by estimating radio wave propagation, 16) Fast handover control technique by millimeter-wave positioning detection providing gigabit wireless transmission, 17) Single carrier MIMO technology for high speed toward super high frequency bands, 18) Centralized quality control independent of wireless networks, and 19) Connection pattern optimization between multi-networks and multi-terminals.

(2) Advanced technologies to contribute to enterprises

Presented in this exhibit were advanced technologies that transform enterprise tasks and onsite work, such as operation and maintenance automation technologies, contributing to solving social problems. Visitors could talk directly with researchers using Webex at the following virtual exhibits: 1) Management technique for stable operation of IEEE 802.11ah system, wireless LAN [local area networks] for IoT, 2) VHF [very-high- frequency] band digital radio subscriber system (TZ-68D), 3) Verification of bow-shaped guy wire for long-term safe use of outside facilities, 4) ICT [information and communication technology] conversion of Cable Tunnel Management System, 5) Inspection technology for deep underground manholes using automatic flying drones, 6) Work-allocation technology that can reproduce finest human judgment, and 7) Inter-system coordination using UI [user interface] augmentation technology.

5.3 Information & Telecommunications Engineering Association of Japan (ITEA)

This exhibition presented ITEA's efforts to develop secure, safe, and reliable information communication infrastructure facilities. These efforts include transmitting from one generation to the next the technologies and expertise that its member companies have developed, improving the quality and efficiency of these technologies and promptly restoring facilities in the event of a major disaster.

5.4 Communication Line Products Association of Japan

Exhibits ranging from those benefiting onsite workers to products related to IOWN were presented in three virtual halls: "Forefront of Communication Cables," "Latest Trends in Connection Technologies," and "Lineup of Aerial-related Technologies."

5.5 Japan Telecommunications Equipment and Materials Manufacturers Cooperative Association (Zentsukyo)

Under the slogan, "Zentsukyo, taking on the challenge of creating dependable technologies and products through DX [digital transformation]," the exhibits introduced efforts in the advancement of DX by developing products with each member company's outstanding technical capabilities and demonstrating collective strength through synergy that comes from uniting as one.

5.6 NTT Group

The exhibition introduced the NTT Group companies' latest technologies to further advance DX and contribute to solving social problems.

5.7 Other online functions

Over the two days of the online forum, an *interaction plaza* was provided as an open chat space where all registered participants could freely post comments. In addition, visitors used "vCard" functionality as virtual business cards on the Tsukuba Forum 2020 ONLINE website to communicate with one another and deepen exchanges. The digital stamp rally, which had been very well received in previous years, was held again. Participants received stamps

with points when they fulfilled conditions such as attending keynote speeches and visiting exhibit booths. Those who gained 3000 points or more were eligible for a drawing to receive novelty items.

6. Conclusion

This was the first time Tsukuba Forum was held online. About 9000 people registered, the most ever. While there were challenges such as not being able to view demonstration or touch exhibits and not being able to quickly obtain the responses of participants, and some participants expressed their desire for the forum to be held physically, the event was highly evaluated as it allowed participants to view exhibitions and listen to speeches at their own leisure without restrictions on location and capacity. Compared with previous years, four times as many visitors listened to the keynote speeches and three times as many people attended the panel discussions. The forum ended with high praise from numerous participants. 93% of the attendees replied that they could feel the urgency of the themes of Tsukuba Forum 2020 ONLINE, and many voiced the opinion that they found the IOWN exhibits useful and could feel hope for the future. Through the online exhibitions of innovative technologies to achieve IOWN and advanced technologies to solve social problems and contribute to business, Tsukuba Forum 2020 ONLINE became a more valuable place than ever before for sharing information.

Acknowledgments

We thank the Information & Telecommunications Engineering Association of Japan, the Communication Line Products Association of Japan, and the Japan Telecommunications Equipment and Materials Manufacturers Cooperative Association (Zentsukyo) for their support of Tsukuba Forum 2020 ONLINE.

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https://ntt-review.jp/archive/ntttechnical.php?contents=ntr202104fa5.html

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Effective Compression of Quantum Braided Circuits Aided by ZX-Calculus

1. Introduction

Researchers at the National Institute of Informatics (NII) and NTT proposed a compression method for reducing the resources associated with large-scale fault-tolerant quantum circuits that brings practical quantum computation one step closer to reality.

A major technical challenge for achieving practical quantum computation comes from the very need for a large number of physical qubits to prevent errors from accumulating during that computation. The consequence of this is that a fault-tolerant quantum circuit for a given computation requires a huge amount of resources, both in terms of qubits and computational time. In this work, published in Physical Review X on the 11th of November 2020 [1], they designed an efficient method of compressing such circuits with the purpose of decreasing their hardware demands. They used ZX-calculus as an intermediate language to reduce both the number of qubits and time required to execute such computation in many different circuits. With their method, they found an improvement of a 40% compression rate with respect to previous reductions, yielding compression rates higher than 70%. This method promises to open new venues of research in large-scale quantum computing and bring quantum computation closer to reality by relaxing its hardware demands.

2. Background

The fast-paced development of quantum technology has brought quantum computing into the era of noisy intermediate-scale quantum (NISQ) devices, which have served as the platform for early proof-of-principle experiments. However, they are still prone to errors, which significantly accumulate during their operation. To obtain a truly practical quantum advantage, the design of a fully operational large-scale quantum computer with high-error tolerance is required. Current cutting-edge technology allows us to engineer NISQ devices with approximately 100 qubits, while fault-tolerant computers are expected to require millions of physical qubits at least to encode the logical information with sufficiently low error rates. This difference in size is currently the main obstacle to the development of large-scale fault-tolerant quantum computers.

Progress in hardware technology is expected to bring scalability into quantum computer chip manufacturing and qubit controls. However, it is also possible for software to reduce the cost associated with fault-tolerant quantum computation implementations. Large-scale quantum computers will consist of many technological layers from the application level all the way down to the hardware, which will require various rounds of compilation and optimization. The resource cost will then come from the layers where quantum error correction codes are introduced to provide fault-tolerance for the implementation of the circuit. For most current quantum-computer architectures, topological error-correcting codes are preferred, in particular the surface code is expected to be used for superconducting-qubit-based quantum computers where lattice-surgery or braiding is chosen for logical gate operations, the latter being ideally suited to distributed quantum computation. A fault-tolerant implementation of quantum computational circuits not only makes the quantum computer larger but also the runtime longer. “These operations require a high level of external control over quite an extended time. In turn, this means the computation is more susceptible to errors,” says Michael Hanks from NII. Therefore, the possibility of compressing quantum circuits at the logical level not only implies a huge saving for the time and resources needed for quantum computation but also lower errors. “Once a quantum algorithm or computation is compiled into a fault-tolerant

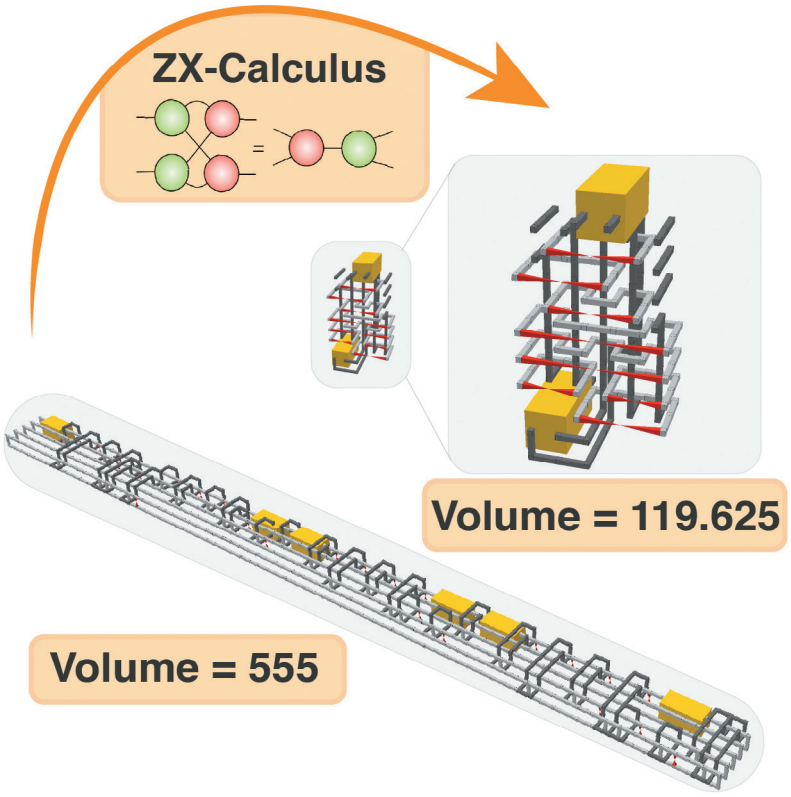

Fig. 1. Compression of a quantum circuit with a 77.4% reduction rate.

circuit, to reduce both the amount of time and space required is paramount to bring practical quantum computers closer to reality," says Marta Estarellas from NII. Thus far, there has been no established approach to tackle this problem, and effective methods to treat these logical gate circuits have not been formulated.

3. Research results

As mentioned above, their method is used for compressing braided fault-tolerant circuits on the three-dimensional (3D) topological code. Braided circuits are generally represented as 3D structures, a low-level close-to-hardware language whose main elements consist of tubes or pipes that represent the defects or logical qubits. A quantum gate circuit can be represented as interlacing pipes. By manipulating these pipes, the quantum gate circuit can be compressed. The main problem in braided circuit reduction is that there are few ad-hoc rules to manipulate these pipes. The first piece of this puzzle is to use ZX-calculus, a language that is equipped with a complete set of rules to manipulate logical gate circuits, to carry out this compression. However, we still need to solve another piece of the puzzle to harness ZX-calculus, and that is discovering the translation relations between ZX-calculus and the components of the braided circuit. The researchers have shown that these two representations of logical gate circuits can be mapped one to another by identifying a new interpretation hidden in ZX-calculus. After testing their compression method against a set of test circuits, they were able to reduce those circuit volumes by approximately 70% on average (**Fig. 1**).

Their method also allows unification of the two main operation models used in surface-code-based computation: lattice-surgery and braiding. "This unification promotes ZX-calculus from a representation of quantum logical circuits to a quantum computer language. We can now think about designing computer languages and compliers in the logical operation layer of the technological stack," says William J. Munro from NTT. Importantly, the unification of these two models also contributes directly to compression. Taking the hybrid compilation approach,

we can compress a circuit further, beyond what each individual method had achieved.

4. Methods

Previous methods for fault-tolerant quantum circuit compression have suffered from the complexity of trying to reduce circuits directly in the 3D representation. One of the key contributions of this new method is the inclusion of ZX-calculus as an intermediate language to minimize the circuit volume. This diagrammatic language can be used to represent quantum processes and circuits in the form of tensor networks with a limited set of elements or nodes. This language can then apply a set of transformation rules (axioms) to change the structure of the network without modifying its underlying mathematical meaning (hence its operation). These transformation rules can be carefully applied in such a way that the total number of nodes is reduced. As the set of transformations is complete, any minimal structure can be reached in principle. The compressed circuit in ZX-calculus is then mapped to the braided circuit by applying the newly identified relation between them.

5. Outlook

Global efforts are pushing quantum technology ahead rapidly with a steadily increasing number of qubits present in each next-generation chip. Nevertheless, in the race to achieve practical quantum computing, it is not enough to just improve the hardware. Software techniques can significantly reduce the requirement for quantum computer hardware, which can bring the development of fault-tolerant quantum computers forward by years. “The logical gate layer situates in the middle of the quantum computer technology stack, and our method can serve as a basis to further develop instruction set architectures and design quantum compliers,” adds Kae Nemoto from NII.

6. Funding

This research was made possible thanks to the support of the Japanese Ministry of Education, Culture, Sports, Science and Technology Quantum Leap Flagship Program (MEXT Q-LEAP) JPMXS0118069605.

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Researcher's comment

What is a Compiler for Error-tolerant Quantum Computers?

Kae Nemoto
Global Research Center for Quantum Information Science, Principles of Informatics Research Division, National Institute of Informatics

When processing information in a quantum computer, the information is stored in a collective quantum state formed on many qubits. Unfortunately, quantum states are fragile, meaning that the quantum information processes in a quantum computer are heavily affected by noise. Therefore, to increase the size of quantum computers and solve difficult problems over a long period, it is necessary to make them robust to such errors. Quantum computers that are robust to such errors are called fault-tolerant quantum computers (FTQCs). They are the long-term goal for the development of quantum computers, and it is currently an extremely active research field. In an FTQC, information processing is implemented by first creating logical qubits using a quantum error correction code, then implementing fault-tolerant logical quantum gates on those logical qubits. Generally, FTQCs require a great deal of physical resources to implement quantum gates in a fault-tolerant manner, as well as to encode the information on logical qubits. Naturally, an FTQC is a very big device, hence any saving in resources can have a profound effect in its development.

In collaboration with NTT Basic Research Laboratories, we have used ZX-calculus to design a method to compress quantum circuits. By using this new method for subroutine quantum circuits, we have made it possible to speed up fault-tolerant quantum computation and significantly reduce the resources it requires. This research not only accelerates the implementation of FTQCs but also proposes a new approach to quantum computer languages, which is at the core of compiler design. Our work will provide the foundation for the future development of quantum computer compiler design and quantum computer languages.

Researcher's comment

Quantum Circuit Compression of an Error-tolerant Quantum Computer

William John Munro
Theoretical Quantum Physics Research Group & Research Center for Theoretical Quantum Physics, Quantum Science and Technology Laboratory, NTT Basic Research Laboratories

The principles of quantum mechanics are expected to enable new forms of information and communication technology (ICT) and bring about revolutionary development in the current ICT. It is expected that the development of such quantum devices will be able to solve problems that are difficult or even impossible to achieve with current technologies. To date, NISQ devices with 50 to 100 qubits have been developed. The letter "N" in the word NISQ means noisy, so as the name implies it is a noisy quantum device. It has already been shown that these NISQ devices can create complexity that is extremely difficult to achieve on our traditional computers. However, the presence of noise also means that there is a significant limitation in the quantum computational tasks that can be performed; large and/or difficult problems requiring significant numbers of qubits cannot be solved. To avoid this limitation, it is necessary to develop an FTQC. The development of these FTQCs is believed to be the ultimate future computational goal where they will be able to solve unimaginably difficult problems. It however requires millions of times as many qubits as today's NISQ device. It is critical to bridge the large gap between today's NISQ devices and tomorrow's FTQCs. In November 2020, we proposed a quantum circuit compression method for FTQCs that dramatically reduces the number of logical qubits (thus physical qubits) required to execute a given quantum program. Lowering of these resources brings the development of FTQCs significantly forward, and the results were published in the American Physical Society journal Physical Review X. One of the advantages of our method is that it is easy to automate the quantum circuit compression with the resulting circuit naturally verified.

This work was a joint research project with Dr. Michael Hanks, Dr. Marta Estarellas, and Professor Kae Nemoto from the National Institute of Informatics. It was supported by the MEXT Quantum Leap Flagship Program. Researchers from a wide variety of disciplines, including physics, engineering, computer science, and chemistry, are participating in this research. I think that the method we have developed will stimulate the further development of quantum computer design.

For inquiries:
Public Relations, NTT Science and Core Technology Laboratory Group
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First Successful Measurement of Neutron Energy Dependence of Semiconductor Soft Errors

1. Introduction

NTT, Nagoya University, and Hokkaido University joined forces and successfully measured semiconductor soft error[*1] rates[*2] at continuously varying neutron energies from 1 to 800 MeV. The findings reveal, for the first time, the complete picture of the energy dependence of semiconductor soft errors.

Data on soft-error-rate dependence on neutron energy are critical when studying the impact of cosmic rays on semiconductors and investigating countermeasures because the number of soft errors is heavily dependent on the incoming neutron energy. However, it has been impossible to measure data that have a wide and continuous energy range. Therefore, the soft error rates measured to date have been limited to several discrete neutron energy levels.

We developed an ultrahigh-speed error-detection circuit that enables us to precisely measure flight times of neutrons arriving at the semiconductor even if the velocities are close to the speed of light. From the flight time, we can deduce the speed of the neutrons causing the soft errors. The circuit makes it possible to measure soft errors caused by neutrons across an extremely wide range of energies up to 800 MeV.

Soft error rates, which we measured successfully, are among the most basic and critical data to predict the number of soft errors caused by neutrons in various environments not only at ground level but also at high altitudes, in space, or even on another planet. The data will be useful in a variety of fields, e.g., evaluation of semiconductor reliability in space stations, study of soft-error prevention measures to be taken in semiconductor materials, soft-error tests using an accelerator, and simulation of the process in which soft errors occur.

The research results were published in IEEE Transactions on Nuclear Science on November 19, 2020 [1, 2].

2. Research results

In this research, we have developed a high-speed error-detection circuit that can detect soft errors within several nanoseconds (nanosecond = one billionth of a second) so that we can identify the energy of a neutron close to the speed of light using a time-of-flight method. With this method, measuring the traveling time of a neutron from a neutron-production target to a device, we can calculate the velocity of the neutron, hence its energy. Using the 800-MeV high-energy proton linear accelerator at Los Alamos National Laboratory, USA, we conducted experiments with three field programmable gate arrays (FPGAs) with different design rules: 28, 40, and 55 nm. We were able to measure soft error rates at continuous energies with very high-energy resolution, as shown in **Fig. 1**.

It was found that the energy dependence of soft error rates was more or less similar for the three FPGAs. The soft error rate increased rapidly from 3 to 20 MeV but was almost constant thereafter. Though upon closer examination, slight variations in the rate among the three FPGAs were found.

3. Key technical points

(1) Time-of-flight method

The (kinetic) energy E of a neutron can be determined by measuring the neutron speed, i.e., time it

*1 Soft error: Unlike hard errors, which cause permanent failures in a device, soft errors cause temporary failures, from which the device concerned can recover by rebooting itself or overwriting data.

*2 Soft error rate: The probability at which one neutron causes a soft error in a unit area. In more technical terms, it is defined as a single event upset (SEU) cross section or sometimes defined as the probability at which a soft error occurs within a unit time.

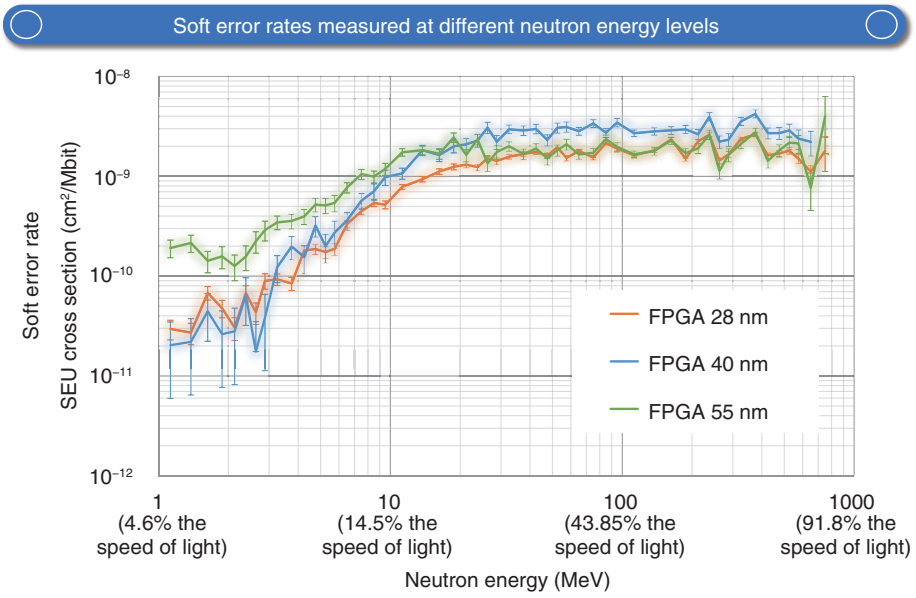

Fig. 1. Soft-error-rate measurement results.

takes for a neutron to travel a certain distance. It is expressed by Eq. (1) based on the special theory of relativity using the energy of the neutron having speed v and rest mass m_0, where c is the speed of light.

$$E = \frac{m_0 c^2}{\sqrt{1-\left(\frac{v}{c}\right)^2}} - m_0 c^2 \qquad \text{Eq. (1)}$$

In our experiments, neutrons were generated within an extremely short time of 125 picoseconds (picosecond = one trillionth of a second), and the time taken for them to fly about 20 meters was measured. This made it possible to measure the energy of a neutron traveling at a speed close to that of light.

(2) Ultrahigh-speed error-detection circuit (NTT, Nagoya University, and Hokkaido University)

Neutrons that cause soft errors travel at extremely high speed. To measure their energies, it is necessary to detect soft errors at nanosecond resolution. However, commonly used memories, such as static random access memory (SRAM), read data sequentially, thus take several milliseconds to scan the amount of data (megabit order) sufficient for soft-error detection. This means that the time-of-flight method cannot be used in such memory to determine the energy of high-energy neutrons. To solve this problem, we developed a circuit that can detect malfunctions caused by soft errors in logic circuits with extraordinary speed (**Fig. 2**). By using this circuit, we were able to detect a soft error that occurred in configuration random access memories (CRAMs). Each CRAM has a capacity of a few tens of megabits and is made up an FPGA circuit. Our circuit can detect a soft error at a speed equivalent to the operational speed of the FPGA, which is on the order of nanoseconds. By using this high-speed error-detection circuit, we can now identify the energy of neutrons that cause soft errors.

(3) The 800-MeV high-energy proton accelerator at Los Alamos National Laboratory

Using the high-energy accelerator at Los Alamos National Laboratory, we conducted experiments in which we measured soft error rates at continuous energies using our ultrahigh-speed error-detection circuit. The accelerator accelerates protons up to 800 MeV, which is about 90% the speed of light, and the protons hit the tungsten target and generate high-energy neutrons. The energy distribution of neutrons generated in this facility is similar to that in nature of up to 800 MeV. A neutron detector, called a fission chamber, has been used in this facility to measure the energy spectrum of neutrons up to 800 MeV.

4. Future prospects

The obtained data enable us to calculate the number

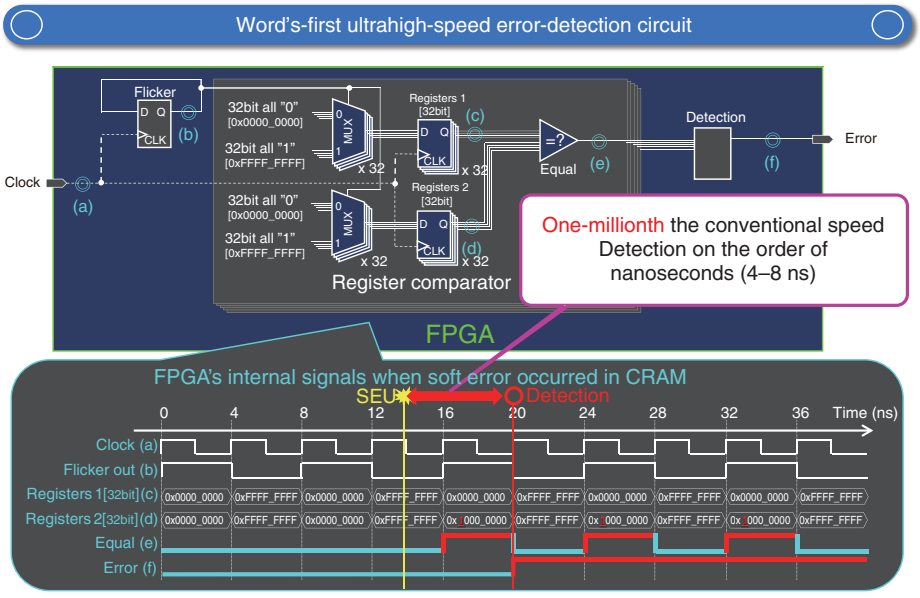

Fig. 2. Our ultrahigh-speed error-detection circuit.

of soft errors caused by neutrons in any environment, not only on earth but also at high altitudes, in space, or even on another planet. In addition, the data will be useful for selecting an optimal accelerator for soft-error tests, development of neutron sources for soft-error tests, studies of measures to prevent soft errors in semiconductor devices, and simulation of the process in which soft errors occur. The data have the potential to lead to dramatic advances in research and development in a variety of fields.

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NTT Information Network Laboratory Group
https://www.ntt.co.jp/news2020/2011e/201125a.html

External Awards

DICOMO 2020 Outstanding Paper Award
Winners: Arisa Yamauchi, Toshiki Onishi, Yuta Muto, Nihon University; Ryo Ishii, Yushi Aono, NTT Media Intelligence Laboratories; Akihiro Miyata, Nihon University
Date: October 7, 2020
Organization: Information Processing Society of Japan (IPSJ) and Multimedia, Distributed, Cooperative, and Mobile (DICOMO) 2020 Symposium

For "Study on a System for Rating Praising Behavior by Analysing Voice and Nonverbal Behavior."
Published as: A. Yamauchi, T. Onishi, Y. Muto, R. Ishii, Y. Aono, and A. Miyata, "Study on a System for Rating Praising Behavior by Analysing Voice and Nonverbal Behavior," Proc. of DICOMO 2020, Vol. 2020, pp. 98–106, June 2020.

Best Social Impact Paper Award
Winners: Hiromi Narimatsu, Hiroaki Sugiyama, Masahiro Mizukami, and Tsunehiro Arimoto, NTT Communication Science Laboratories
Date: January 8, 2021
Organization: The Sixth Linguistic and Cognitive Approaches to Dialog Agents (LaCATODA 2020)

For "Rationale for Using Chat-oriented Dialogue System's Experience to Convey Empathy."
Published as: H. Narimatsu, H. Sugiyama, M. Mizukami, and T. Arimoto, "Rationale for Using Chat-oriented Dialogue System's Experience to Convey Empathy," LaCATODA 2020, Jan. 2021.

IPSJ Journal Specially Selected Paper
Winners: Ryo Ishii, NTT Media Intelligence Laboratories; Kazuhiro Otsuka, Yokohama National University; Shiro Kumano and Ryuichiro Higashinaka, NTT Communication Science Laboratories; Yuji Aono, NTT Media Intelligence Laboratories
Date: January 15, 2021
Organization: IPSJ

For "Estimation of Personal Empathy Skill Level Using Dialogue Act and Eye-gaze during Turn-keeping/changing."
Published as: R. Ishii, K. Otsuka, S. Kumano, R. Higashinaka, and Y. Aono, "Estimation of Personal Empathy Skill Level Using Dialogue Act and Eye-gaze during Turn-keeping/changing," IPSJ Journal, Vol. 62, No. 1 pp. 100–114, Jan. 2021.

Kenjiro Takayanagi Achievement Award
Winner: Hiroshi Sawada, NTT Communication Science Laboratories
Date: January 20, 2021
Organization: Kenjiro Takayanagi Foundation

For his research on blind source separation of audio signals.

Certificate of Contributions
Winner: Seishi Takamura, NTT Media Intelligence Laboratories
Date: January 21, 2021
Organization: 13th International Conference on Knowledge and Smart Technology (KST 2021)

For his contribution to the quality of KST 2021 by delivering a keynote lecture entitled "The Latest Advances in Video Coding Technology for Next Generation Communications."

Promotion and Nurturing of Female Researchers Contribution Award
Winner: Makoto Takamura, NTT Basic Research Laboratories
Date: February 1, 2021
Organization: The Japan Society of Applied Physics

For her research on functional devices based on large-scale graphene.

Network Systems Research Award
Winners: Kotaro Matsuda, Hiroki Ikeuchi, Yousuke Takahashi, Tsuyoshi Toyono, NTT Network Technology Laboratories
Date: Mar. 4, 2021
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE) Technical Committee on Network Systems

For "People Flow Reconstruction Based on Anonymous Sensor Data toward Smart City Infrastructure for Estimating Infection Route."
Published as: K. Matsuda, H. Ikeuchi, Y. Takahashi, and T. Toyono, "People Flow Reconstruction Based on Anonymous Sensor Data toward Smart City Infrastructure for Estimating Infection Route," IEICE Tech. Rep., Vol. 120, No. 297, NS2020-103, pp. 85–90, Dec. 2020.

Information Networks Research Award
Winners: Kengo Tajiri, NTT Network Technology Laboratories; Ryoichi Kawahara, Toyo University
Date: Mar. 4, 2021
Organization: IEICE Technical Committee on Information Networks

For "Theoretical Evaluation of Processing Performance and Accuracy of Machine Learning with Edge Cloud Cooperation."
Published as: K. Tajiri and R. Kawahara, "Theoretical Evaluation of Processing Performance and Accuracy of Machine Learning with Edge Cloud Cooperation," IEICE Tech. Rep., Vol. 120, No. 163, IN2020-23, pp. 7–12, Sept. 2020.

Papers Published in Technical Journals and Conference Proceedings

Formant-altered Auditory Feedback on Non-native Vowel Production

S. Hiroya and T. Mochida

12th International Seminar on Speech Production (ISSP 2020), Online conference, December 2020.

In this study, we conducted a formant-altered auditory feedback experiment for native Japanese speakers, which converts the vowels of English syllable “had” or Japanese mora “ha” to English vowel sounds [æ]. Results showed that the formant frequencies significantly changed in “had,” but that no significant changes were observed in “ha.” Our results suggested that speaking a non-native language may be more affected by auditory feedback than native language.

Classically Simulating Quantum Circuits with Local Depolarizing Noise

Y. Takahashi, Y. Takeuchi, and S. Tani

24th Annual Conference on Quantum Information Processing (QIP 2021), Online conference, February 2021.

We study the effect of noise on the classical simulatability of quantum circuits defined by computationally tractable (CT) states and efficiently computable sparse (ECS) operations. Examples of such circuits, which we call CT-ECS circuits, are instantaneous quantum polynomial-time (IQP), Clifford Magic, and conjugated Clifford circuits. This means that there exist various CT-ECS circuits such that their output probability distributions are anti-concentrated and not classically simulatable in the noise-free setting (under plausible assumptions). First, we consider a noise model where a depolarizing channel with an arbitrarily small constant rate is applied to each qubit at the end of computation. We show that, under this noise model, if an approximate value of the noise rate is known, any CT-ECS circuit with an anti-concentrated output probability distribution is classically simulatable. This indicates that the presence of small noise drastically affects the classical simulatability of CT-ECS circuits. Then, we consider an extension of the noise model where the noise rate can vary with each qubit, and provide a similar suffcient condition for classically simulating CT-ECS circuits with anti-concentrated output probability distributions.
