I Want to Think from a Broader Perspective to Achieve My Ultimate Goal

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Abstract

In Japan, against the backdrop of the spread of high-definition video-streaming services and network applications such as cloud storage and work applications, the provision of high-speed communication services is gaining pace, and the research and development of optical access networks to support these services is under high expectations. Jun-ichi Kani, a senior distinguished researcher at NTT Access Network Service Systems Laboratories is playing a leading role in researching and developing new optical access networks for the beyond fifth-generation mobile communication system (5G)/6G era. We interviewed him about the progress of his research activities and his approach to research.

Keywords: optical access network, digital coherent access, All-Photonics Network

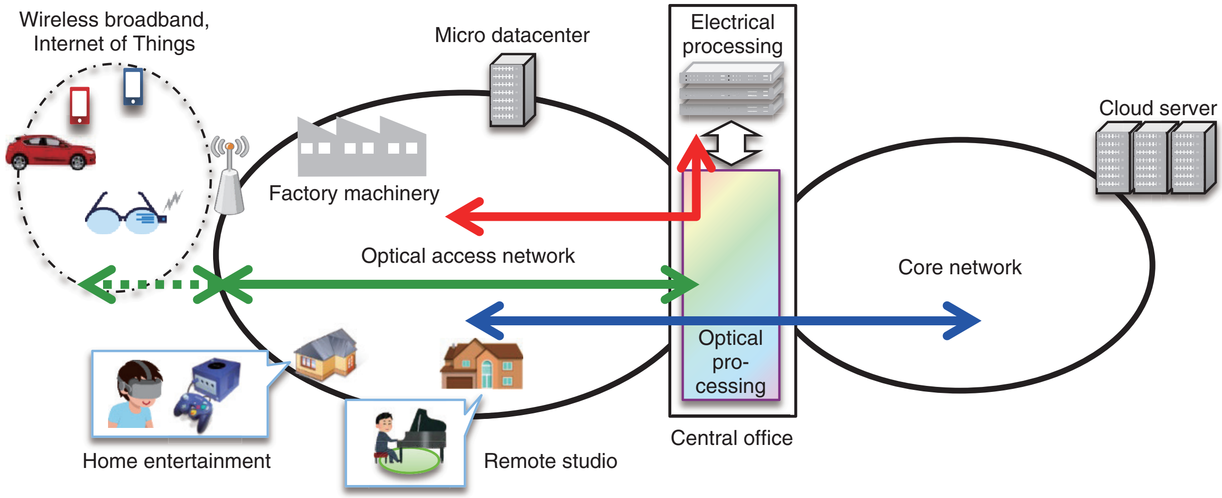
Pursuing a new optical access network that accelerates the evolution of information and communication services

—It has been two years since our last interview. Could you first give us an overview of the research you are currently conducting?

I am continuously pursuing the development of new optical access networks that will accelerate the evolution of information and communication services. In addition to researching, along with my team members, elemental technologies and architectures that will dramatically improve system performance and flexibility of optical access networks, I am also involved in global collaborative activities to implement and popularize new optical access networks.

A current optical access network transfers traffic to a core network at a central office. An analogy of this is a bus passenger transferring to a train at a train station. This transfer involves converting an optical signal into an electrical signal, processing the electrical signal for transfer, and converting the electrical signal back into an optical signal after the transfer. We aim to integrate the access and core networks to create a network that can transmit optical signals to designated locations without signal conversion (**Fig. 1**).

Optical-access-network technology has supported the development of a broadband service called fiber to the home (FTTH), which provides optical services to every home. Today, high-speed mobile Internet is



- Separation of optical and electrical processing makes it possible for optical signals to access designated locations without signal conversion. (Just like being able to travel anywhere by car instead of having to transfer from bus to train.)
- As much of the electrical processing is handled by commodity servers possible. (Just like it is now possible to do various things using personal computers and smartphones by simply adding or changing software; in contrast, dedicated devices, such as word processors, calculators, and portable music players, were conventionally used.)

Fig. 1. Future optical access network.

becoming more widespread, and equipment in central offices and antennas for 5G (5th-generation mobile communication systems) and next-generation wireless local area networks are all connected by fiber optic networks.

Under the assumption that everything from factory machinery and various sensors to transportation systems and electric-power systems will be connected via a network, the requirements for bandwidth and latency will become more complicated. Therefore, I believe that optical access networks will evolve from the foundation of FTTH to a common access platform for supporting diverse services and systems. Accordingly, we are researching and developing optical access networks with an eye on evolving them into that future common access platform.

—I hear that you have achieved high-profile research results. Would you tell us about them?

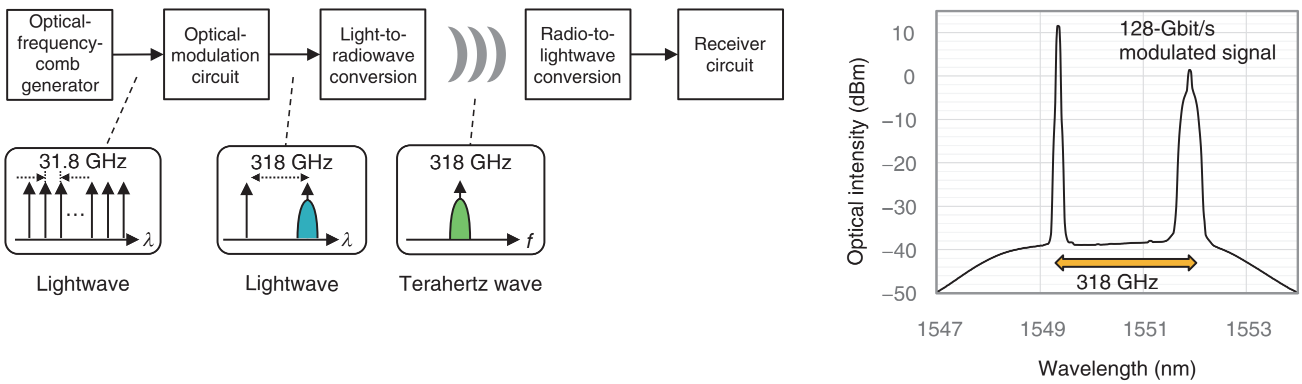
I'll explain two research results on elemental technology of optical access networks: (i) significant improvement in transmission performance and (ii) improvement in flexibility of network systems through softwarization of transmission functions.

Optical access systems called passive optical networks (PONs) are currently being deployed in Japan and other countries to roll out FTTH services. Current PON systems transmit binary intensity-modulated signals and receive only the optical intensity, and access networks with a transmission rate of 1 to 10 Gbit/s, splitting ratio of 1:32, and transmission distance of about 20 km are in widespread use.

To drastically improve the transmission performance of current PON systems, we have been conducting pioneering research on a method called *digital coherent access*. As we reported in Optics Express in 2021 [1], we experimentally verified the real-time feasibility of this method on a PON system with both uplink and downlink transmission rates of 10 Gbit/s and achieved a transmission distance of 40 km and power budget of more than 50 dB, which is a significant milestone.

The published results represent a twofold improvement in transmission distance and a 20-dB (100 times) improvement in power budget for the current 10G-PON. In the U.S., CableLabs, which sets cable television-related standards, has begun standardizing digital coherent access, and we are proud to have contributed to this technological trend.

Regarding improving the flexibility of network systems through softwarization of transmission functions, we have been striving to reduce latency, which had been a challenge, and achieved a processing



(a) Configuration used in the experiment

(b) Output spectrum of optical-modulation circuit

Fig. 2. Terahertz-wave communication technology using optical frequency comb.

speed of less than 1 ms for a 10G-PON by using software on a commodity server without the use of dedicated large-scale integrated circuits (LSIs). Our paper reporting this result has been published by IEEE Network [2].

We also accomplished signal processing using software on a commodity server without using dedicated LSIs in digital-coherent reception, which is essential for long-distance transmission, and demonstrated a transmission speed of 10 Gbit/s. Our paper reporting these accomplishments was presented at the European Conference on Optical Communication (ECOC) 2021 [3].

Publications in top optics-related journals and continuous achievement of world-class research results

—You have attracted attention for your research activities, which are highly regarded both academically and socially.

I received the ITU Association of Japan Accomplishment Award in 2021 for contributing to the development of high-speed and sophisticated optical access networks by leading standardization activities of optical access systems as an associate rapporteur at the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group 15. My contributions to accelerating the formulation of recommendations on optical access systems at ITU-T by facilitating technical discussions and promoting the formulation of technology roadmaps at the Full Service Access Network (FSAN) initiative was also recognized.

I am also researching ultrahigh-speed wireless communication using terahertz waves, a new domain of radio waves, in collaboration with Professor Tadao Nagatsuma of Osaka University, who is a leading expert in terahertz communication. By using a multi-wavelength light source called an *optical frequency comb*, it is possible to generate precise terahertz waves with a system that is compatible with fiber optic networks. We experimentally demonstrated a 128-Gbit/s transmission, which is the world's fastest data rate for terahertz-wave communication when using an optical-frequency-comb-based transmitter and intradyne receiver (**Fig. 2**). This result was reported at the Opto-Electronics and Communications Conference (OECC) in 2022 [4].

Regarding research on architecture, my team discussed and devised a new configuration of the optical-processing functions at a central office and called it Photonic Gateway, as it is considered an entry point for the future All-Photonics Network (APN), and implemented it as a combination of components. The results were reported at the Optical Fiber Communication Conference and Exposition (OFC) in 2021 and 2022.

These achievements will contribute to actualizing Japan's vision of the future called Society 5.0 in which cyberspace and physical space are highly integrated to balance economic development and solving social issues. Artificial intelligence and virtual reality are attracting attention for achieving this vision; however, it is crucial for information to be transmitted stably and smoothly by optical communication on the infrastructure that supports these technologies.

The optical communication that I pursue is behind the scenes in the sense that it is a technology that supports the foundation of information and communication services; even so, it is an important technology that accelerates the evolution of information and communication services and is useful to society. I hope to continue to play a leading role in developing advanced optical access technology.

—You are also focusing on IOWN, right?

In 2019, NTT announced the Innovative Optical and Wireless Network (IOWN) as a future vision of an innovative optical-based network and information-processing infrastructure. Although still limited to specific applications and areas, we will start providing IOWN services at the beginning of 2023, as we gradually improve its performance and expand its usage.

IOWN consists of three key components: (i) the APN, which introduces photonics-based technology to everything from networks to terminals, (ii) Digital Twin Computing, which enables highly accurate predictions by combining the real and digital worlds, and (iii) Cognitive Foundation, which connects and controls information and communication technology (ICT) resources in multiple domains and multiple layers. I am focusing on the access architecture and transmission technology needed to build the APN.

I am also participating in the IOWN Global Forum (IGF), which aims to promote global implementation of IOWN, to discuss the architecture of the APN. To achieve step-by-step deployment of the APN, it will be important to deliver short-term solutions as well, so I am shifting gears slightly from research. I am pleased that the research I have been pursuing for many years can contribute to making IOWN a reality. I want to continue to take on the challenge of creating new technology and architecture for networks to build a new ICT environment. IGF has provided me with more opportunities to have discussions with various experts in Japan and abroad, and I am grateful for the stimuli I have received from these discussions. Since the foundation of IGF as a U.S. corporation in 2020, meetings have been held online due to the COVID-19 pandemic, but in 2022, an in-person meeting was held for the first time since the pandemic began.

I have been a researcher for 20 years. Just predicting the evolution of technology is interesting

—What do you value in your research activities?

I value having discussions with people in various fields. As I mentioned earlier, I have been involved in international-standardization activities for a long time and have been a researcher for more than 20 years. In 2021, I was honored to serve as general chair of OFC, at which it has been my goal to present a paper ever since I was a young researcher. As I have been witnessing and excited about the evolution of the optical communication industry, it was very stimulating to be involved in the management and planning of OFC, which covers the entire industry. I will continue to cooperate with many researchers and engineers in global forums such as academic societies and standardization committees and will take on challenges toward the year 2030.

Discussions in these forums help me understand the differences in perspectives on certain issues. I am reminded that if I am to pursue global standards in my field, namely, communication networks, I need to think from a broader perspective to achieve my ultimate goal of making the results of my research useful to as many people as possible.

To achieve this goal, I'd like to look at the evolution of technology from a long-term perspective, as I mentioned in my previous interview. This is because if you set short-term goals of two, three, or five years, your research will inevitably become too limited in scope. As we discussed last time in regard to Amara's law, the impact of a new technology is overestimated in the short term and underestimated in the long term. While we have hope for various technologies in the short term as technology trends, we tend to avoid making bold predictions concerning the long term. However, in reality, over the span of the last 10 or 20 years, many things have changed more drastically than we had expected.

—What are your thoughts when you are competing as a world-class researcher? What would you like to say to future generations of researchers?

I find it interesting simply to predict the evolution of technology. The hit or miss of the prediction is also exciting. For example, during your research activities, just when you think that no more progress can be made in a certain field, a new theme will pop up, and you will be betrayed by your thoughts—in a good way. I believe that being a researcher is an interesting job that enables you to pursue your field of expertise unceasingly.

Therefore, I don't feel a sense of "defeat" when other researchers publish their results ahead of us. There were a few times when other researchers published similar ideas of mine and I thought I should have taken a little more time to pursue them. Even so, I am happy that the technology I am involved in is progressing with other researcher's help, so I will strive to do better next time. Rather than focusing on themes that are already apparent, I want to focus on capturing potential needs that could lead to long-term changes in Amara's law.

What I am realizing at my age is that one can continue doing what they like and that "continuity is the father of success." I think one will be good at what they like after keeping on doing it; no one starts off being excellent.

As a senior distinguished researcher, I am also responsible for supporting the younger generation of researchers in taking on new challenges. I want to support them as a way of repaying the debt of gratitude for all the support I received during my research career.

As an active researcher, I want to keep the spirit of challenge in mind. Momofuku Ando, the founder of Nissin Foods, invented instant noodles at the age of 51, and he continued developing new products into his 90s. I am now in my 50s, and I too want to keep doing the best I can. I want to continue to approach my research from a fresh perspective, the same as that of the younger generation, while keeping in mind the balance between intellectual curiosity and usefulness to the world.

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■ Interviewee profile

Jun-ichi Kani received a B.E., M.E., and Ph.D. in applied physics from Waseda University, Tokyo, in 1994, 1996, and 2005. He joined NTT Optical Network Systems Laboratories in 1996, where he researched optical multiplexing and transmission technologies. He has been with NTT Access Network Service Systems Laboratories since 2003, where he is engaged in research and development of optical communications systems for metropolitan and access network applications and currently heads the Access Systems Technology Group. He has been participating in ITU-T and the FSAN initiative since 2003.