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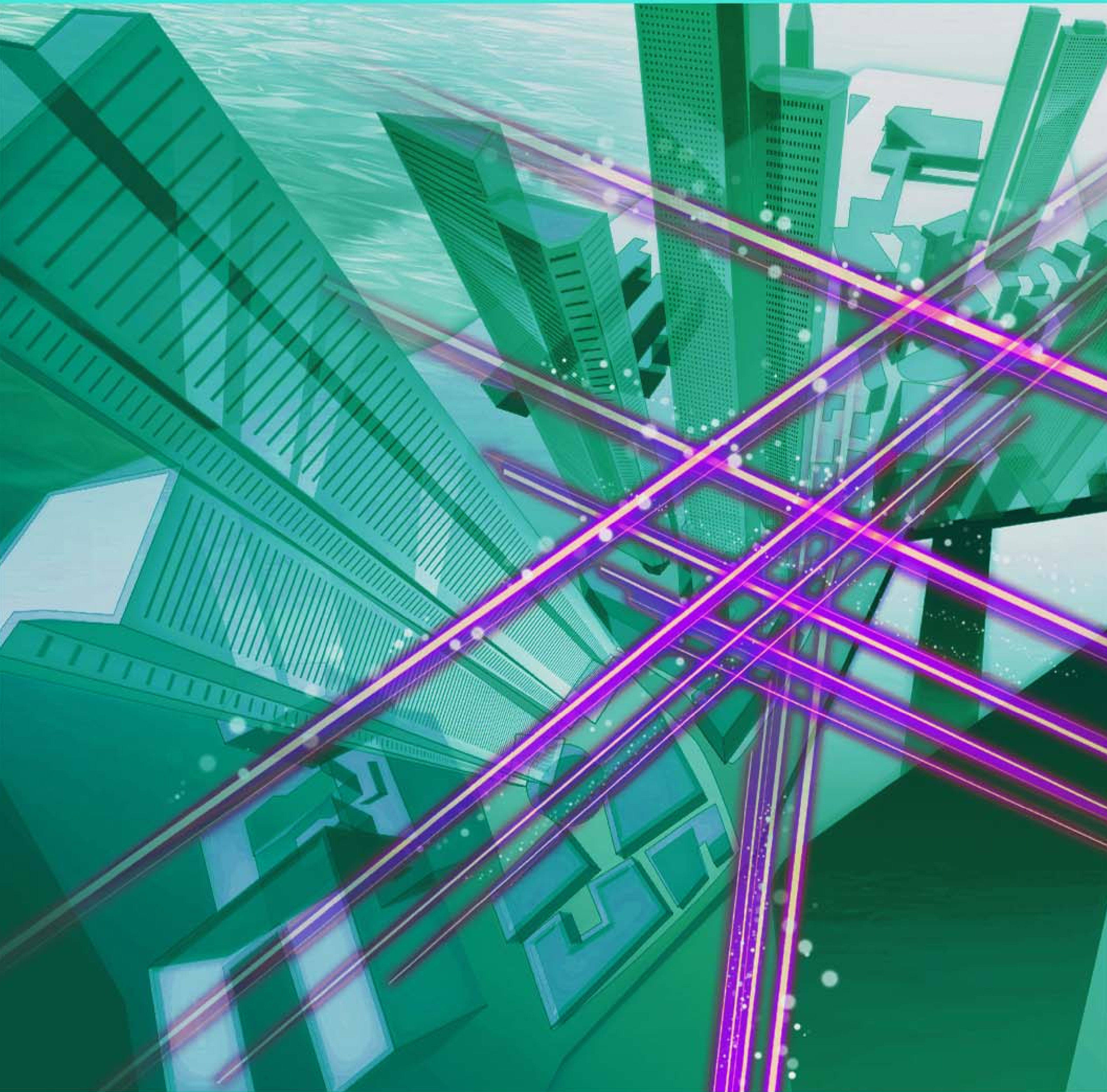

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Short Reports

- NTT, Ruhr-Universität Bochum, and Kobe University Develop a New Cryptanalytic Technique to Improve the Design of Lightweight Ciphers for Internet of Things

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Generating New Value with xICT —Advancing B2B2X Business—

Hiroo Unoura
President and Chief Executive Officer, NTT

Overview

This article introduces NTT Group initiatives to promote the B2B2X (business-to-business-to-X) business model. The content of this article is based on a lecture presented by Hiroo Unoura, NTT President and Chief Executive Officer, at NTT R&D Forum 2017 held in February 2017.

Keywords: ICT, B2B2X, big data

1. Changes in the business environment

Information and communication technology (ICT) has evolved considerably over time as reflected by the adoption of Internet protocol, expansion of broadband and mobile networks, development of compact terminals, and advances in processing speed. The use of cloud computing has also progressed. In contrast to the past model of centralized computer processing on mainframes, devices and servers now interact with each other to perform complex forms of processing.

Against this background, NTT business is undergoing a major transformation. Unlike the telephone era in which device and network services were provided in an all-in-one manner, customers today use a variety of services in combination. Here, the participation of diverse players has greatly broadened the choices available to service users (**Fig. 1**).

In this type of era, what does it mean to be competitive? This is an era in which diverse ICT-based services are provided by not only the communications industry but also other industries or business areas, and users are able to freely select which services they would like to use. It is also easy for users to switch to other services, which means that service providers must make an effort not just to be selected once but also to be continuously selected. This ability to be continuously selected as a service provider is what I believe to be the meaning of competitiveness from here on.

How can a service provider be continuously selected? In this era, it is extremely difficult for a single company to meet the wide variety of user needs, so collaborative ability, ability to initiate collaboration, and ability to accept collaboration are important for being continuously selected.

2. Basic concept of medium-term management strategy

In our medium-term management strategy announced in May 2015, I stated that NTT would

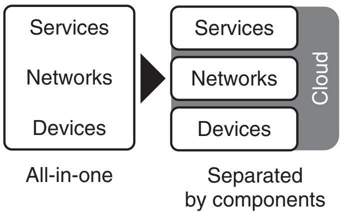


Fig. 1. Changes in the business environment.

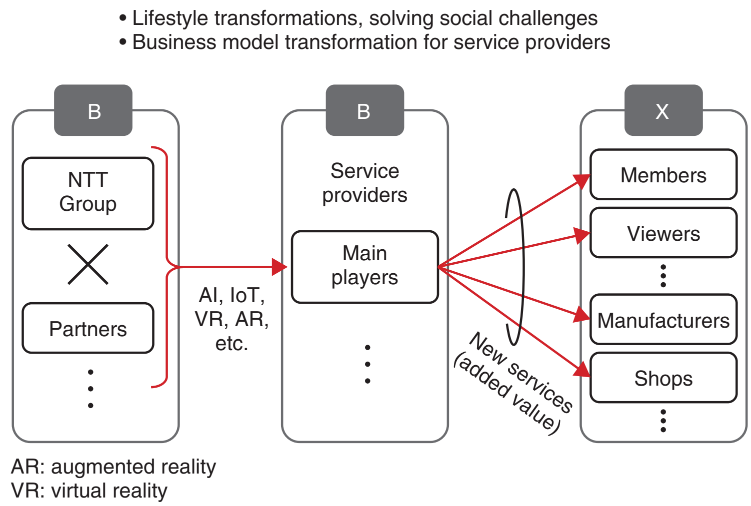


Fig. 2. Direction of initiatives for B2B2X model.

promote the business-to-business-to-X (B2B2X) business model. Various predecessors of mine came to create visions foreseeing the digital society of today, such as the Information Network System (INS), Visual, Intelligent, and Personal (VI&P), Multimedia Vision, and Resonant Vision. In the past, when the plain old telephone service played a leading role, telecom companies were the main players in providing services to customers directly. We have now entered an era in which networks are selected not as a single service but in combination with applications and services as a package. In this business environment, telecom companies are no longer the main players but simply one option among many; that is, we have become "one of them." I declared, however, that we would be viewed as "one of them" with value.

With this in mind, we assigned the three letters making up "NTT" to three key expressions: we let the first letter 'N' stand for Next Value Partner, the second letter 'T' for Transformation, and the last letter 'T' for Trusted Solution. A major pillar of this medium-term management strategy was our own self-transformation to promote this new B2B2X model as a value partner that can help transform the business models and lifestyles of a wide range of users.

3. Direction of initiatives for B2B2X model

I would like to see the creation of many kinds of value for society through the B2B2X model. Moreover, I would like to see the creation of a new ecosystem based on collaboration with diverse partners. To create new services and added value toward lifestyle transformations and resolving social issues, the NTT Group will support service providers—the second 'B' in B2B2X—in transforming their business models. Here, the value that NTT can provide service providers can take various forms, such as artificial intelligence (AI), Internet of Things (IoT), and other advanced ICT technologies, user interface technologies, and security tools. I believe we can support the creation of new value in this way.

The B2B2X model represents our transformation from one type of business model to another. In the traditional model, the NTT Group provided services directly to either individual or corporate consumers to increase revenue. In the B2B2X model, we collaborate with diverse partners to deliver added value to consumers through a wide range of service providers (**Fig. 2**).

4. Progress of B2B2X initiatives

In this section, I would like to introduce several initiatives that represent our progress in promoting the B2B2X model. In April and September of 2015, we concluded respective comprehensive partnership agreements with Fukuoka City and Sapporo City to help find solutions to key social issues enveloping each of these cities. One example of the contributions we have so far made to these cities is the use of Wi-Fi* and other techniques to analyze the routes taken by

* Wi-Fi is a registered trademark of Wi-Fi Alliance.

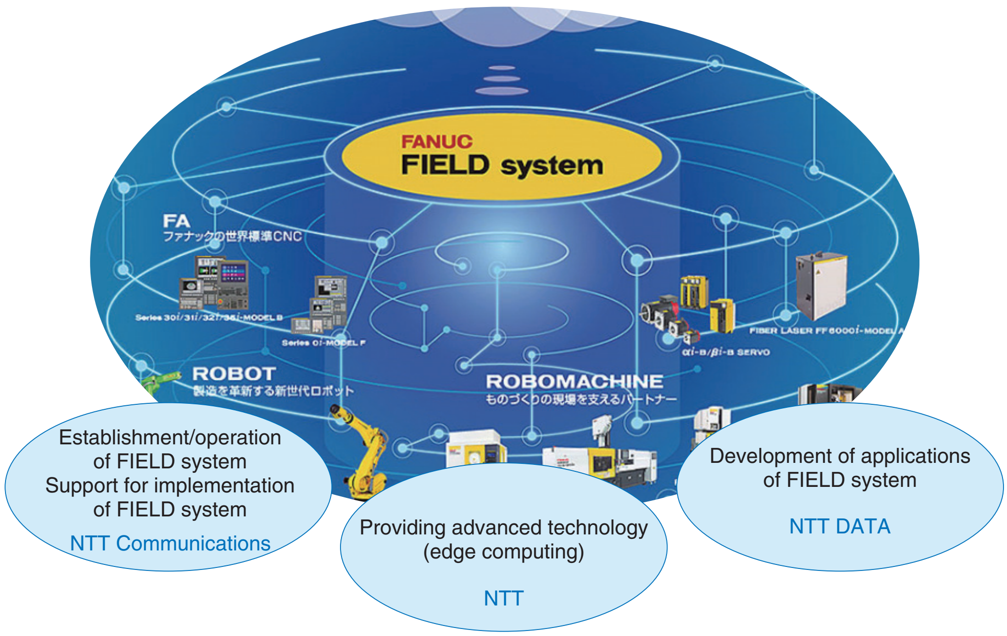


Fig. 3. Example 1 of B2B2X model.

inbound tourists, the places they go for sightseeing, and what types of items they tend to purchase.

Moreover, since April 2016, we have been pursuing collaborations with service providers and main players representing the second 'B' in B2B2X, such as SHOCHIKU Co., Ltd., Kubota Corporation, and the J.League (Japan's professional soccer league). In this article, I would like to describe, in particular, our collaborative efforts with FANUC CORPORATION, SHOCHIKU, and Le Tour de France.

4.1 FANUC

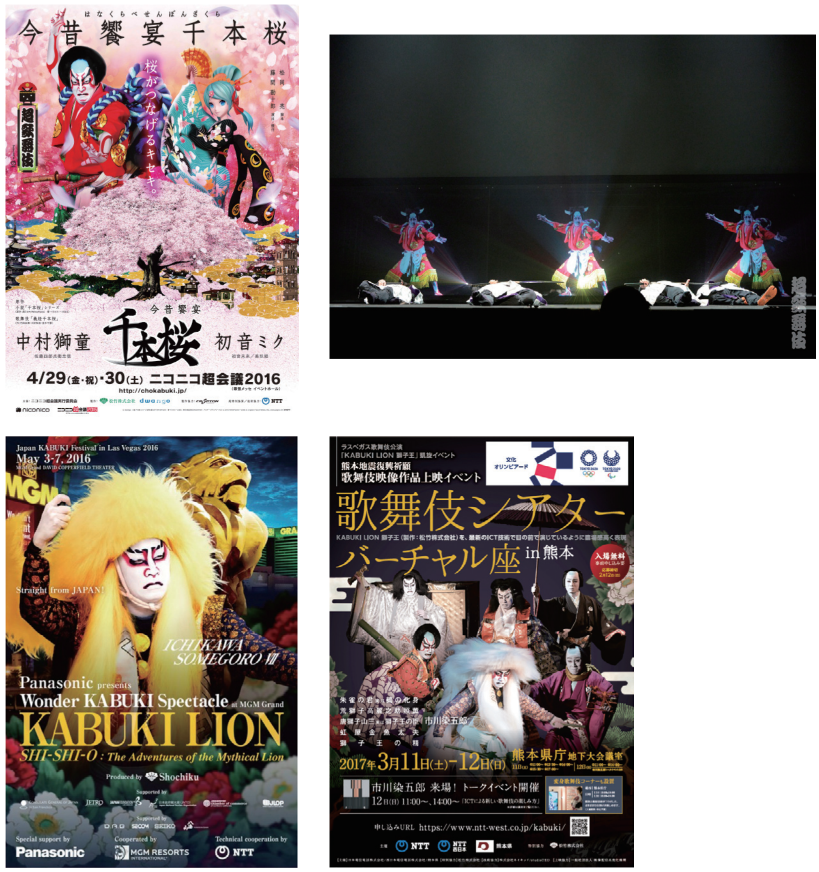
FANUC is a global supplier of factory automation and robot services. It aims to provide novel and smart manufacturing sites by connecting various types of machine tools and devices used on manufacturing floors to the network and by using the big data created by such connections in creative ways. This is achieved by the FANUC Intelligent Edge Link and Drive (FIELD) system.

Through collaborations with Preferred Networks, Inc. and other partners, the NTT Group has supported FANUC to develop and commercialize the FIELD system by providing AI and edge computing technologies. In this effort, the NTT laboratories have been in charge of edge computing technologies, while NTT Communications and NTT DATA have respectively been handling system construction/operation and application development (**Fig. 3**). Combining AI and edge computing technologies in this way enables distributed machine learning, while performing real-time processing of the data collected from machines at the edge (locations near machine tools) enables these machines to cooperate with each other in a flexible, immediate, and intelligent manner. The goal here is to achieve advanced manufacturing at a level not yet seen and to make them into a de facto standard.

4.2 SHOCHIKU

I would like to introduce here our efforts in achieving a new way of enjoying kabuki performances through collaboration with SHOCHIKU. In April 2016, the Niconico Chokaigi (super conference) sponsored by Dwango Co., Ltd. included a public performance of "Cho Kabuki." Through the use of the immersive telepresence technology "Kirari!®" developed by NTT laboratories, the kabuki actor Shido Nakamura appeared together with the vocaloid Hatsune Miku and also performed alongside duplicates of himself (doppelgangers) on stage (**Fig. 4**).

Niconico Chokaigi is a major event attended by many young people. SHOCHIKU has said that it would again like to present kabuki in new ways at Niconico Chokaigi in 2017. It expects to attract new fans to kabuki and young people in particular by



Clockwise from top left: Poster of Cho Kabuki, performance of Cho Kabuki, poster of kabuki in Las Vegas, and poster of Kabuki Virtual Theater

Fig. 4. Example 2 of B2B2X model.

adding a modern touch to traditional kabuki with new forms of ICT. I believe that an initiative of this type can become a powerful weapon in expanding consumption, a key element of the Japanese economy.

In addition, in May 2016, stage greetings from the kabuki actor Somegoro Ichikawa, then in Las Vegas as part of a kabuki performance, were transmitted in real time to a remote showing at Haneda Airport. This event included a question and answer session with reporters just as if he were actually there standing in front of them. At the same time, some people at the event were asked to put on a head-mounted display as part of a virtual reality experiment that gave them the sensation of being inside the Las Vegas theater.

Furthermore, for two days on March 11 and 12, 2017, the Kumamoto prefectural government held a “Kabuki Virtual Theater” free to the public as part of a “prayer for recovery” in the wake of the Kumamoto earthquakes of 2016. Though a virtual performance, I believed it enabled many people to enjoy a work filled with a high sense of presence just as if Somegoro Ichikawa and other kabuki actors were performing right before their very eyes.

4.3 Le Tour de France

Dimension Data, a member of the NTT Group, has formed a technology partnership with Le Tour de France, the greatest cycling race in the world. It provides a mechanism that identifies the speed and location of each rider by placing a sensor under the saddle of each bicycle and transmitting positional information to Dimension Data’s Big Data Truck (**Fig. 5**). This information is used to create video that can be delivered to televisions, smartphones, and other devices in real time. Spectators can then see for themselves how the riders are lining up in a completely new and enjoyable way.

This mechanism not only represents an evolution in

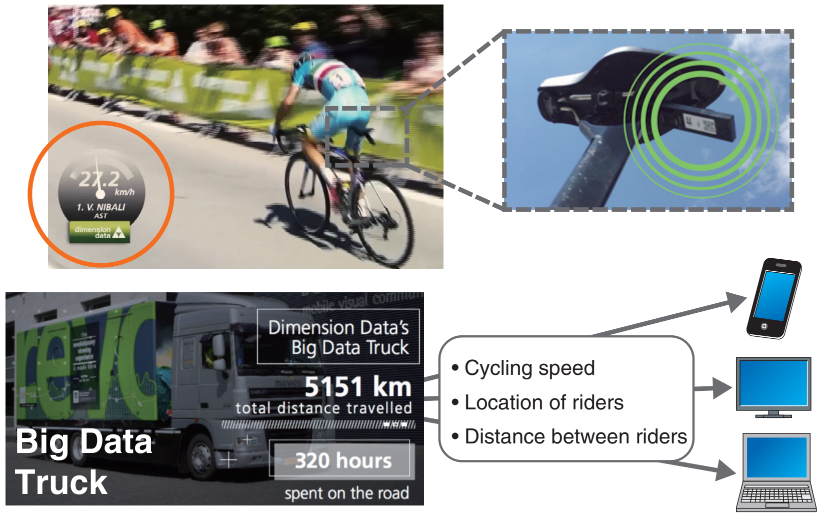


Fig. 5. Example 3 of B2B2X model.

the way that spectators enjoy Le Tour de France but also an evolution in the way that team coaches and riders compete. In July 2016, I myself was in France for Le Tour de France and heard a team coach comment that "I'm totally exhausted from all the data that are now available for rider support!" In fact, it will eventually become possible to deliver the vital signs of each rider by combining this mechanism with other types of devices. I think that the addition of such information should enable the coach of a competing team to make more strategic decisions and to even change training methods if necessary.

What I think all of us at NTT have in common is a desire to support service providers and other players representing the second 'B' in B2B2X in growing a successful business. To promote consumption and economic growth, it is essential that the business ventures of main players, that is, service providers, are successful. Providing support in this way should lead to our growth as well.

5. Further promotion of B2B2X model

I will now describe some important points for promoting the B2B2X model even further. Most important of all is coming up with a clear definition of 'X' in B2B2X, that is, the service end users. Doing so should bring into view a system of collaboration between NTT and service providers and partners as well as best business models, customer touch points, etc.

Let me give some examples of this approach in the field of self-driving cars. What kind of interfaces would be needed to enable the elderly and people with mobility problems or disabilities to use self-driving cars? No doubt, voice input and other types of interfaces would be needed. Moreover, in the case of voice input, some type of technology would be needed to ensure that the person's voice was clearly understood in a noisy environment, and in Japan, there would also be a need for technology that could identify different dialects. Here, instead of preparing special interfaces for each and every car, a better approach would be to develop cars that could support the circumstances of individual users from the cloud based on common specifications.

However, a self-driving car equipped with such interfaces and various types of safety equipment is apt to be expensive. Plus, considering the frequency of usage, the business model itself would not likely be a self-ownership type but rather a shared type. What kind of players would then be best for providing such a service based on a shared type of business model? I believe that local municipalities might make a positive contribution in this regard, and that local taxi companies and public transportation systems might team up as second B players.

Here, it would not do for automobile manufacturers or NTT to play the role of service provider. I think that supporting the provision of a new business model or service as the first 'B' in B2B2X would be more effective for speeding up the development of self-driving technology.

In this way, instead of a product-out approach based

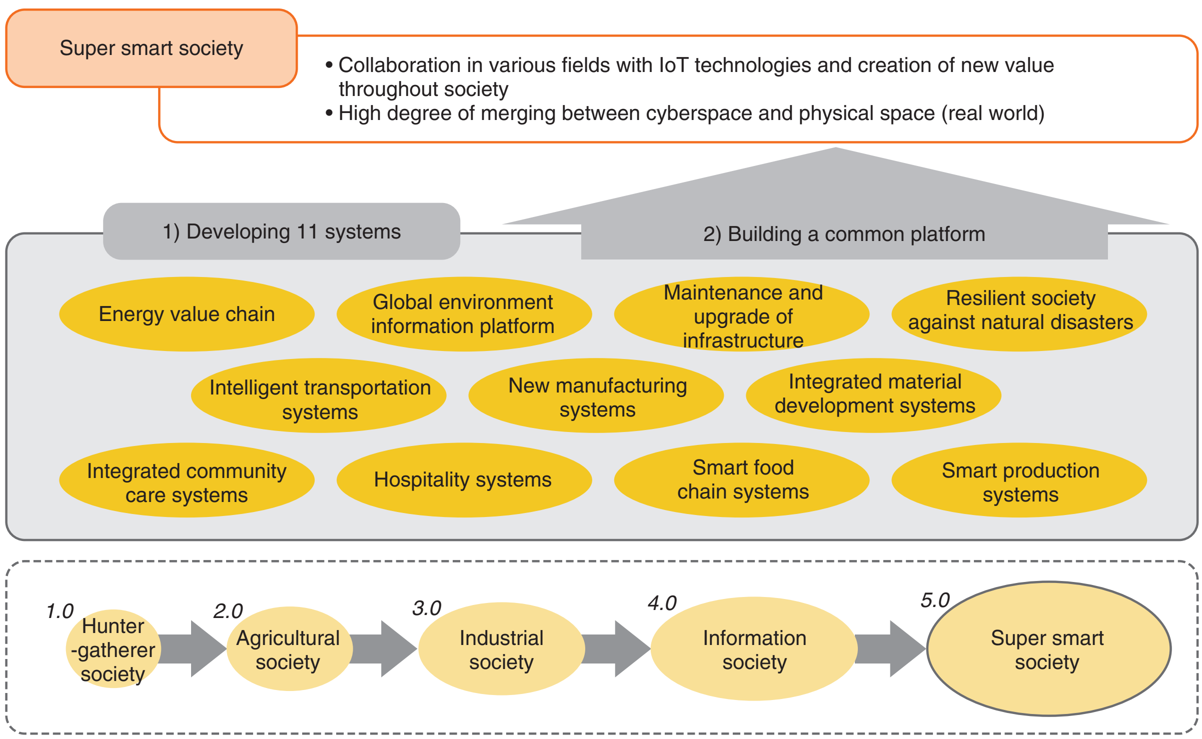


Fig. 6. Society 5.0 (The 5th Science and Technology Basic Plan).

only on technology, I believe, as I stated above, that finding a clear definition of 'X' in B2B2X, or in other words, defining what are new values or new sensations, will lead to new partners and new business models.

6. Japan revitalization by Society 5.0

The Cabinet Office of the Government of Japan is promoting the creation of a "super smart society" (Society 5.0) under the theme "New Initiatives toward Japanese Industry of the Future and Social Transformation" as The 5th Science and Technology Basic Plan (**Fig. 6**).

The keyword "Society 5.0" signifies how society has become progressively smarter through its transformation from a hunter-gatherer society to an agricultural society, industrial society, and information society, and the coming super smart society. As a broad theme that includes Industry 4.0 (Fourth Industrial Revolution), I acknowledge that Society 5.0 is precisely the next big concept that Japan should adopt in future policy making.

In response to this Cabinet Office policy, the Japan Business Federation (Keidanren) has begun its implementation by drafting an action plan based on key subthemes underlying Society 5.0 [1].

Specifically, a future society as envisioned by Keidanren can be broken down into five subthemes: a smart society undaunted by the decrease in population; a society in which every individual, including elderly people and women, can actively participate; a safe and secure society in both cyber and physical spaces; a society that connects cities and outlying regions, making for a comfortable and pleasant life anywhere; and an environmentally and economically sustainable society. In addition, cities, regions, objects/things/services, infrastructure, and cyberspace have been designated as specific study areas.

In this way, the government and Keidanren, that is, the public and private sectors, are promoting Society 5.0 with the aim of building the society of the future. Here, AI, big data, and IoT will play important roles in making Society 5.0 a reality. IoT will enable a wide variety of real-world data to be stored as big data, and AI will enable that data to be analyzed, so we can expect a wide range of social and global issues to be solved in this way. However, such social issues cannot be solved if companies and local municipalities keep their data to themselves. It is essential that all

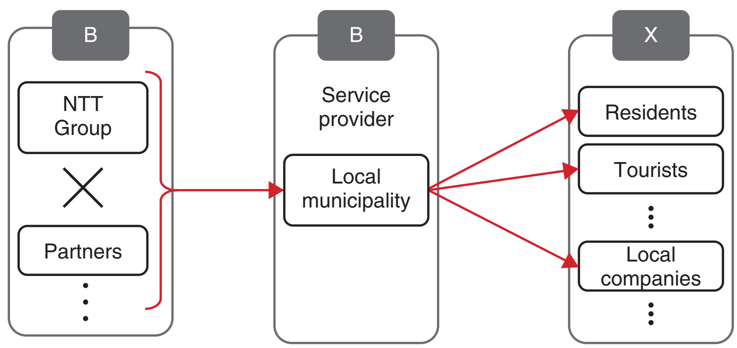


Fig. 7. Data sharing with local municipality as hub.

data in society be shared across industries and fields.

7. Concerns in data usage

A key issue in the use of data throughout society is the handling of personal data. Who does personal data belong to? Do you, the individual, own it? Or does it belong to the companies that gather the data?

The EU approved the right to data portability in April 2016. In Europe, legislation is moving forward to enable individuals to retrieve their personal data—for example, a purchasing history gathered by Google or Apple—and to transfer that data to other business operators if so desired. In Japan as well, the handling of personal data is a very sensitive issue, and I think there is a need here to proceed carefully.

Rather than obsessing about the ownership of personal data, I have proposed to various parties the concept of treating various types of data as belonging to society and citizens.

With an eye to appropriate handling of such sensitive information, the NTT laboratories have been developing secret-sharing and secure multi-party computation technology. This technology securely stores personal data through encryption and distributed storage, and at the time of data analysis, enables only the results of analysis to be obtained without data analysts having to touch the raw data. We are using this technology in initiatives that aim to advance the use of big data throughout Japan.

There are also other issues in addition to the handling of personal data that must be resolved to achieve data sharing and data usage throughout society. First, there is a need for widespread gathering of good-quality data. I believe that the biggest risk in the AI and big data society of today is that smart AI will routinely process malicious or intentionally erroneous data. For example, traffic signals may behave in an abnormal manner on the basis of erroneous data, and control equipment in a power plant may automatically stop if it detects something it considers to be dangerous. The widespread gathering of good-quality data will require security technology that can remove such erroneous data. It will also be necessary to ensure fair usage in data gathering. What exactly is "fair usage?" As I explained earlier, data gathering to improve community services and solve social problems is a fair objective. Of course, there is a need for encryption to protect personal data and a check system to prevent abuse. I also think that the standardization of data formats and ciphers is necessary.

8. Data sharing with local municipality as hub

I believe that one method of resolving these data sharing and usage issues is to promote the gathering and use of big data with local municipalities serving as hubs. Considering the need for combining and handling a wide variety of data to solve social issues, I think there would be a problem allowing a single company to gather and use such information.

In particular, I believe that opening up the data held by a local municipality, such as demographics, maps, disaster prevention measures, and sightseeing information, and providing the big data held by companies to industry as public property can expand possibilities in the integrated use of all kinds of data and revitalize local business.

The concept of a local municipality serving as a service provider to improve community services is shown in **Fig. 7**.

The NTT Group, working with partners such as

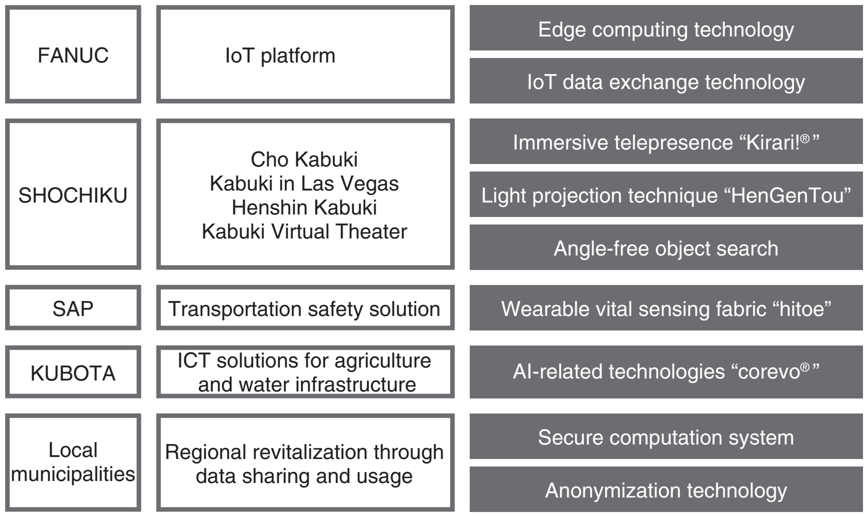


Fig. 8. Technologies underlying B2B2X model.

Panasonic Corporation and Hitachi, Ltd., would like to provide local municipalities with support tools. We would like to see local municipalities take on a leadership role in data sharing and data usage within their communities with the aim of improving community services and expanding local business, as I just mentioned. Although we are talking about local municipalities here, we know that undertaking this initiative simultaneously throughout the country would be quite difficult from an operations point of view. We have so far concluded agreements with Sapporo City and Fukuoka City to get this initiative started.

I would like to see this initiative with local municipalities evolve so that they shift to the first ‘B’ in B2B2X while local industries and companies act as the second ‘B.’ In this way, I would like local municipalities, NTT, and other players to become partners in supporting local industries and contributing to the expansion of local economies. I see this type of activity as another major theme in Japan that can lead to regional revitalization.

9. Technologies underlying B2B2X model

Finally, examples of technologies that NTT laboratories and NTT Group companies are providing to service providers and other players making up the second ‘B’ in B2B2X are shown in **Fig. 8**.

Going forward, the NTT Group will continue to pursue collaboration with diverse partners to generate new value and new sensations, help grow the Japanese economy, and help find solutions to a wide variety of social issues.

Reference

[1] Keidanren, “Toward Realization of the New Economy and Society - Reform of the Economy and Society by the Deepening of ‘Society 5.0’-,” 2016.
https://www.keidanren.or.jp/en/policy/2016/029_outline.pdf

NTT Research and Development—Leading the Way to B2B2X

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Overview

This article introduces NTT's research and development (R&D) activities for creating new value through collaboration with various partners to promote the B2B2X (business-to-business-to-X) business model under the NTT Group's medium-term management strategy, *Towards the Next Stage 2.0*. It is based on a lecture presented by Hiromichi Shinohara, NTT Senior Executive Vice President and Head of the Research and Development Strategy Department, at NTT R&D Forum 2017, which was held in February 2017.

Keywords: B2B2X, artificial intelligence, Internet of Things

1. Expansion of B2B2X model and roles of R&D

We believe that research and development (R&D) serves as an engine for driving the business-to-business-to-X (B2B2X) business model. This is because propelling innovation is the foundation of our ability to provide new value to service providers (the second B in B2B2X) and consumers and enterprises (X). On the basis of this understanding, the NTT R&D laboratories (hereinafter, NTT R&D) is pursuing co-innovation with various partners. This effort, over the last two years, has shown us that collaboration, especially with partners in unrelated industries, can generate hitherto unimagined concepts, so we are currently focusing on that type of collaboration (**Fig. 1**). While network, security, and cloud technologies are naturally important for driving B2B2X, this article focuses on artificial intelligence (AI), the Internet of Things (IoT), and media technology.

2. NTT Group's AI technology: corevo®

AI can be approached in two different ways. One is to simulate human intelligence and thinking. The other is to supplement and draw forth human ability. NTT R&D is working on the latter, namely, AI that creates new value through coexistence and co-creation with humans.

In the spring of 2016, the NTT Group unified the group's AI-related activities under the brand name corevo®. It signifies our wish to bring about new, revolutionary developments in collaboration with a variety of players (*co-revolution*) by integrating different types of AI technology. Specifically, our R&D is focused on four categories of AI (**Fig. 2**).

Agent-AI is closest to the AI that is presently making news. It supports humans by interpreting the information that they generate. For example, Agent-AI makes it possible for a robot to conduct an intelligent conversation with humans. Ambient-AI interprets humans, objects, and the environment, and instantly forecasts and controls the immediate future. In this sense, it embraces the concept of IoT. Heart-Touching-AI interprets human emotions and physical conditions and understands our deep psyche, intellect, and instinct so that it can see things from a

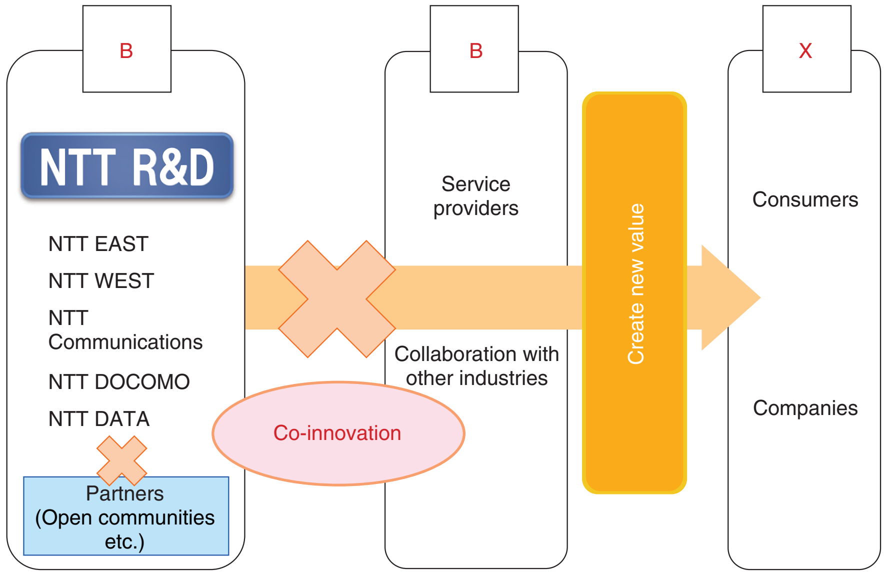


Fig. 1.   Expansion of B2B2X model and roles of R&D.

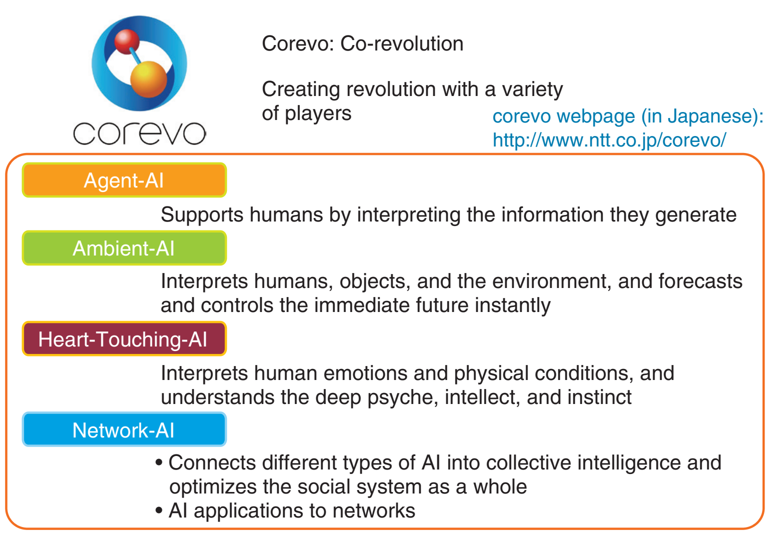


Fig. 2.   NTT Group's AI Technology: corevo®.

human perspective. Network-AI embraces two concepts. One is to connect different types of AI into collective intelligence and optimize the social system as a whole. The other is to apply AI to networks in order to enhance their reliability, efficiency, and other qualities.

2.1 Agent-AI technologies

Agent-AI is founded on three types of technology: auditory technologies; speaking technologies, which include the capacity to understand speech; and viewing technologies. Representative technologies are presented below.

(1) Auditory technologies

One auditory technology is noise suppression. This makes it possible to hear a human voice clearly, even in an environment filled with noise and cheering to a level of more than 100 dB. Speaker diarization

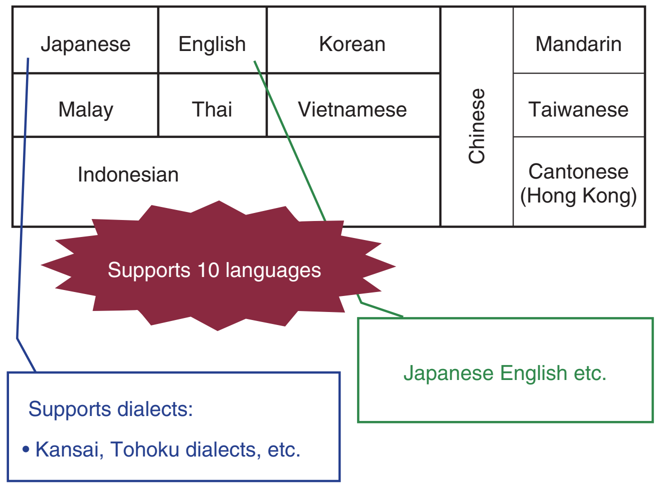


Fig. 3. Language-identified speech recognition.

technology allows the user to identify a speaker from among many people speaking simultaneously. Currently, one speaker can be identified from among up to six people talking at the same time. If this technology is used inside a vehicle, for example, the user can listen to the voice of just the driver.

In the CHiME-3 (the 3rd CHiME Speech Separation and Recognition Challenge), an international technical evaluation contest in which participating organizations competed in speech recognition in a variety of noisy environments, NTT's distortionless speech enhancement and deep-learning speech recognition technology achieved a speech recognition rate of 94.2%, the highest in the contest. Language-identified speech recognition has been developed based on this technology. Currently, it identifies and recognizes speech in ten different languages (**Fig. 3**). It can even recognize the type of English typically spoken by Japanese people, and its coverage of representative Japanese dialects is being expanded.

Frequently asked question (FAQ) search is often employed when AI is used to answer questions. One challenge is that different people ask the same question using different expressions. AI must accurately understand which question in the FAQ list the questioner is referring to. NTT R&D's utterance comprehension technology understands questions accurately, thanks to its machine learning that utilizes a text corpus containing extremely diverse expressions and a large-scale semantic dictionary that has been enriched over a long period.

We are also working on emotion recognition technology. This determines, for example, if a person is angry, satisfied, or worried from the way he or she speaks. In addition to *hot* anger characterized by shouting, this technology can identify the more subtle *cold* anger, which is characterized by the speaker sounding calm but being angry inside, an attitude said to be very common in Japanese people.

(2) Speaking technologies

We are studying technology that automatically constructs intonation information of a speech using deep learning (**Fig. 4**). AI needs to differentiate words that have the same sounds but different accents and meaning, such as "haSHI" (bridge) and "HAshi" (chopsticks) in Japanese, or the noun "object" (ɑ́bdʒikt) and the verb "object" (əbdʒékt) in English. The aim of this technology is similar to that of the emotion recognition technology mentioned above. It is intended to help the user to communicate in a manner that is appropriate for the occasion, for example, speaking to someone in trouble in a sympathetic manner or speaking to an angry person in a soothing manner. This technology can efficiently construct prosodic information.

Free dialog technology is aimed at enabling AI not only to answer questions but also to conduct a free conversation. In March 2016, at SXSW (South by Southwest), a major business and content event held in Austin, Texas, an android built by Professor Hiroshi Ishiguro of Osaka University called "Geminoid" had a conversation with a woman, a total stranger to the android. This was made possible by incorporating our speech and dialog-related technologies into the

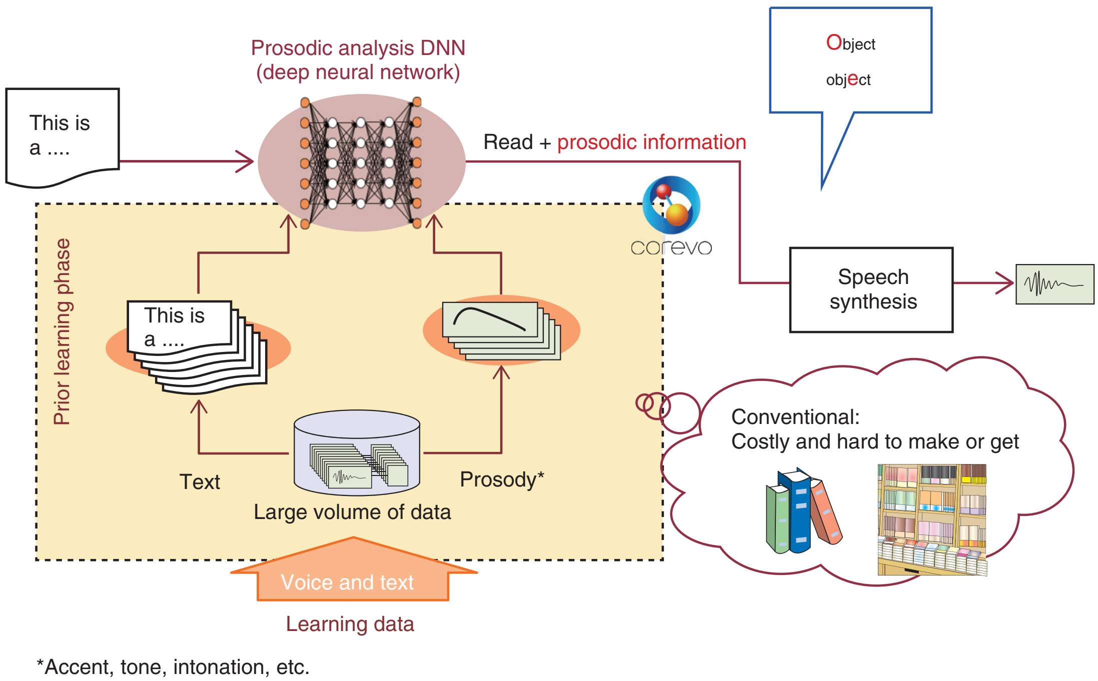


Fig.4. Automatic acquisition of prosodic information using deep learning.

android. We will seek to enable robots to perform something more challenging, such as carrying out a debate or improvising amusing dialog.

(3) Viewing technologies

We humans recognize an object by comparing what we see with what we have in our memory. Angle-free object search technology does just that. It searches images previously registered in a cloud for the object captured by a smartphone camera. Its forte is that it can recognize an object even if only one or two photos are pre-registered and even if the object is captured from an oblique angle or in close-up, or part of the object is obscured by someone standing in front of it.

We are studying video event detection technology, which searches for a video showing a scene of eating or a scene of driving a car, for example. At TRECVID 2016, a worldwide workshop hosted by the U.S. National Institute of Standards and Technology, NTT R&D won first to third places in several categories with this technology.

2.2 Application examples of Agent-AI

Using Agent-AI technologies, NTT Communications has initiated a commercial service using Communication Engine COTOHA™. This service understands natural language and answers questions from users. If the question is vague, the engine attempts to understand what the user wants by asking specific questions for clarification. If it determines that it still cannot understand the question, it transfers the question to a human operator and learns from the way in which the operator interacts with the user.

In addition to introducing individual technologies, we are holding concept exhibits such as corevo for drivers and corevo for service desks so that people can get some idea of specific situations in which corevo technologies can be used.

2.3 Support for robots and sensors

A variety of services can be created by combining a group of some of the AI technologies mentioned above with robots and sensors. With a view to enabling customers to create their own services using our AI technologies, rather than leaving service creation to professionals, we have developed R-env®, a cloud-based human-machine interaction control. It provides a mechanism whereby the user can quickly construct a program using a web browser. NTT EAST, NTT WEST, NTT Communications, and NTT DOCOMO are conducting joint field trials on potential applications for medical care or invigoration of local economies. The trials have already yielded some practical services.

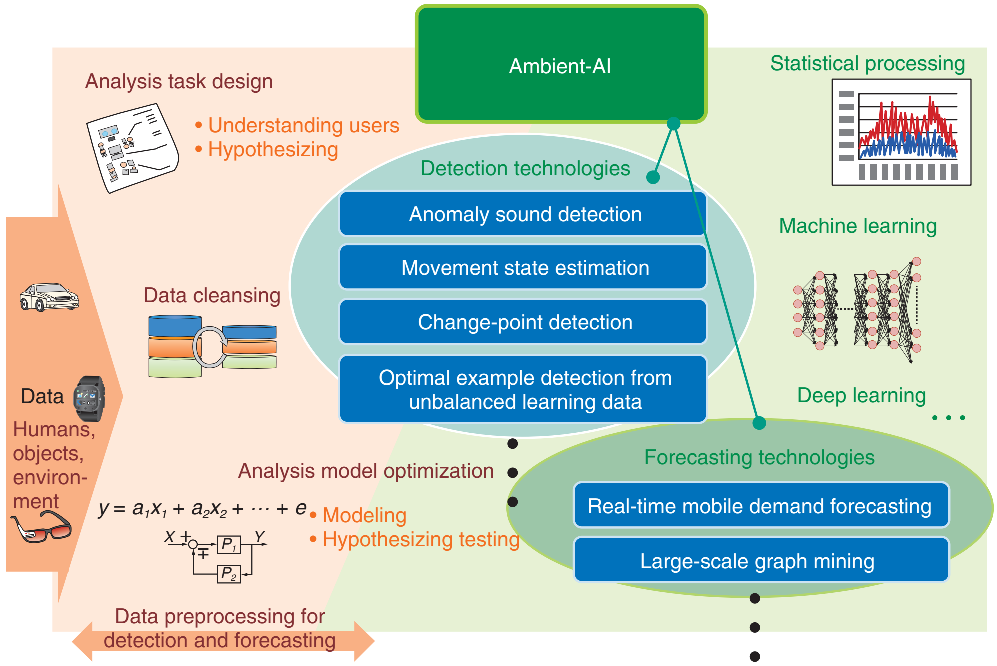


Fig. 5. Ambient-AI.

2.4 Ambient-AI technologies

Some of the Ambient-AI technologies being developed by NTT R&D are described below. These days, we frequently hear terms such as machine learning and deep learning. These are also utilized in Agent-AI. The most important factor in using machine learning, deep learning, or statistical processing tools is to optimize the analysis model used. How good or bad your analysis model is determines the value of your data. For instance, it has a significant impact on detection or forecasting performance. Thus, we are optimizing analysis models used by detection and forecasting technologies (**Fig. 5**).

We are developing technology that can quickly detect significant differences between two satellites or aerial photos of the same area taken at different times. It does so by measuring the difference in information quantity, called *entropy*, at each pixel after the photos are compressed using the video encoding applied to 4K and 8K. Currently, the rate of successful detection of change-points is about 90%, indicating that there is still room for improvement. We will conduct a field trial during this fiscal year with NTT GEOSPACE.

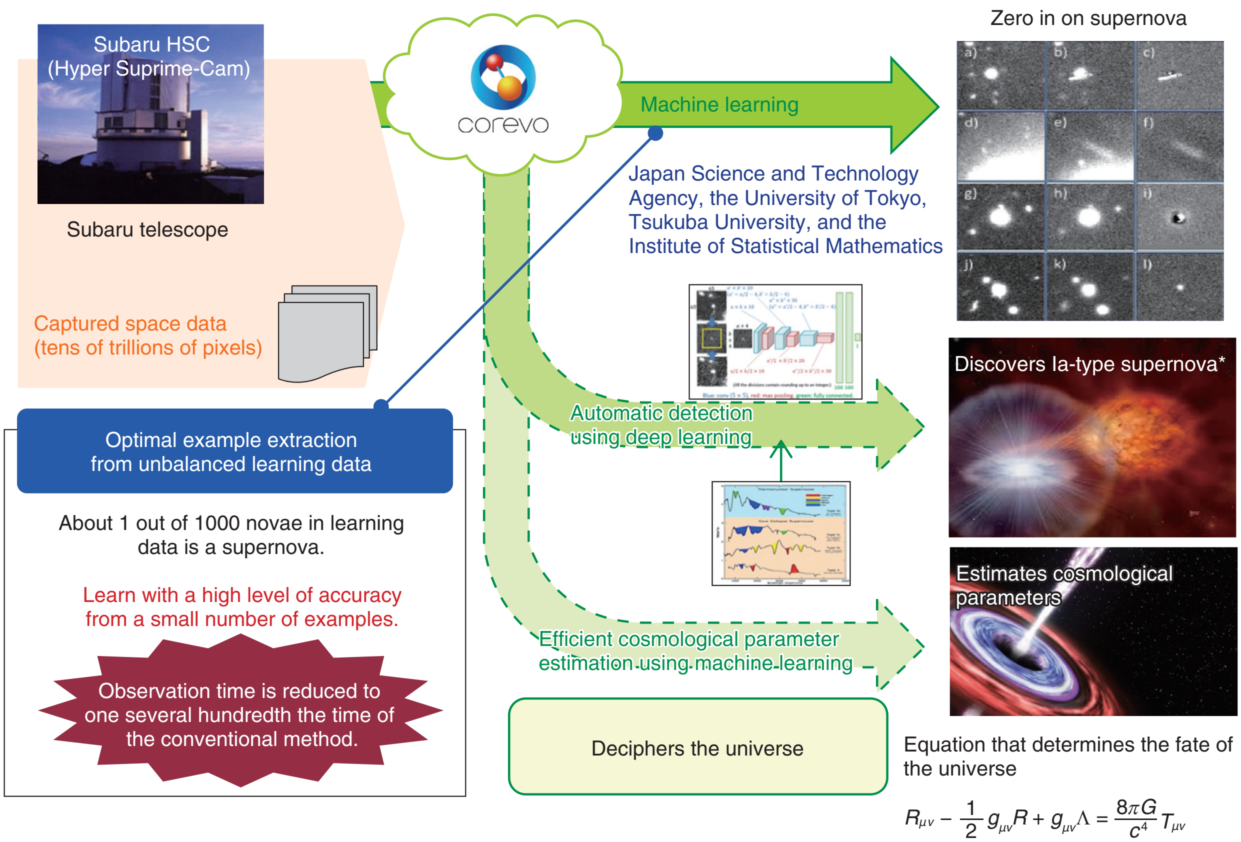
We are studying technology for learning with a high degree of accuracy just the relevant data from among a group of data of which only an extremely small fraction is relevant (**Fig. 6**). In collaboration with the Japan Science and Technology Agency, the University of Tokyo, Tsukuba University, and the Institute of Statistical Mathematics, we are using this technology to zero in on supernovae from among a huge collection of space photos taken with the Subaru telescope. The number of pixels comprising these photos is on the order of several tens of trillions. Although only 1 in 1000 novae in the learning data is a supernova, this technology has reduced the observation time required to detect supernovae by a factor of several hundred compared to that of the conventional method. We next tried to discover Ia-type supernovae and found the first one at the end of 2016. Ultimately, we will try to use machine learning to estimate the parameters of the equation that determines the fate of the universe. Our aim is not exactly to decipher the universe but, rather, to refine our technologies through these activities.

2.5 Application examples of Ambient-AI

Some commercial applications of Ambient-AI technologies are described below.

(1) Detection of advance signs of machine failures

A technology that NTT DATA has jointly developed with Hitachi Zosen Corporation focuses on machine operation sounds in order to support stable operation of factories. It detects glitches and advance



*One of the subcategories of supernovae and cataclysmic variable stars

Fig. 6. Detection technology.

signs of failures using intelligent microphone technology, which picks up target sounds clearly even in noisy environments, and technology that distinguishes between normal and abnormal sounds.

(2) Detection of dangerous driving behavior

This technology detects dangerous driving of a car by analyzing multimodal information in video data stored in a drive recorder, and sensor data such as speed and acceleration information. In a trial jointly conducted by NTT Communications and Nippon Car Solutions Co., Ltd., dangerous driving was detected with about 85% accuracy. The information gained will be used for educating drivers and formulating measures to reduce accidents.

(3) Congestion forecasting

NTT DATA is seeking to help reduce traffic congestion by visualizing congested conditions and predicting imminent jams. This is achieved by applying large-scale graph mining to data from beacons and traffic information in text form. Field trials are being carried out in China, and another is planned for the UK.

(4) Taxi demand forecasting

We are also using AI to combine and analyze a variety of information ranging from taxi operation data through demographic data, weather data, and event data, in an attempt to forecast areas that will see large taxi demand 30 minutes ahead. Allocating taxis based on such forecasting could boost taxi company sales and reduce waiting times for taxi users. NTT DOCOMO is conducting joint field trials with the Tokyo Musen Cooperative Association and Tsubame Taxi Group in Nagoya (**Fig. 7**).

2.6 Network-AI technologies

One category of Network-AI is application of AI to networks. We are working on technologies for detecting faulty parts in a network with a high degree of accuracy, for forecasting communication traffic by area, such as urban areas and residential areas, and for routing traffic to avoid faulty or congested points, if any. The other category of Network-AI is connecting

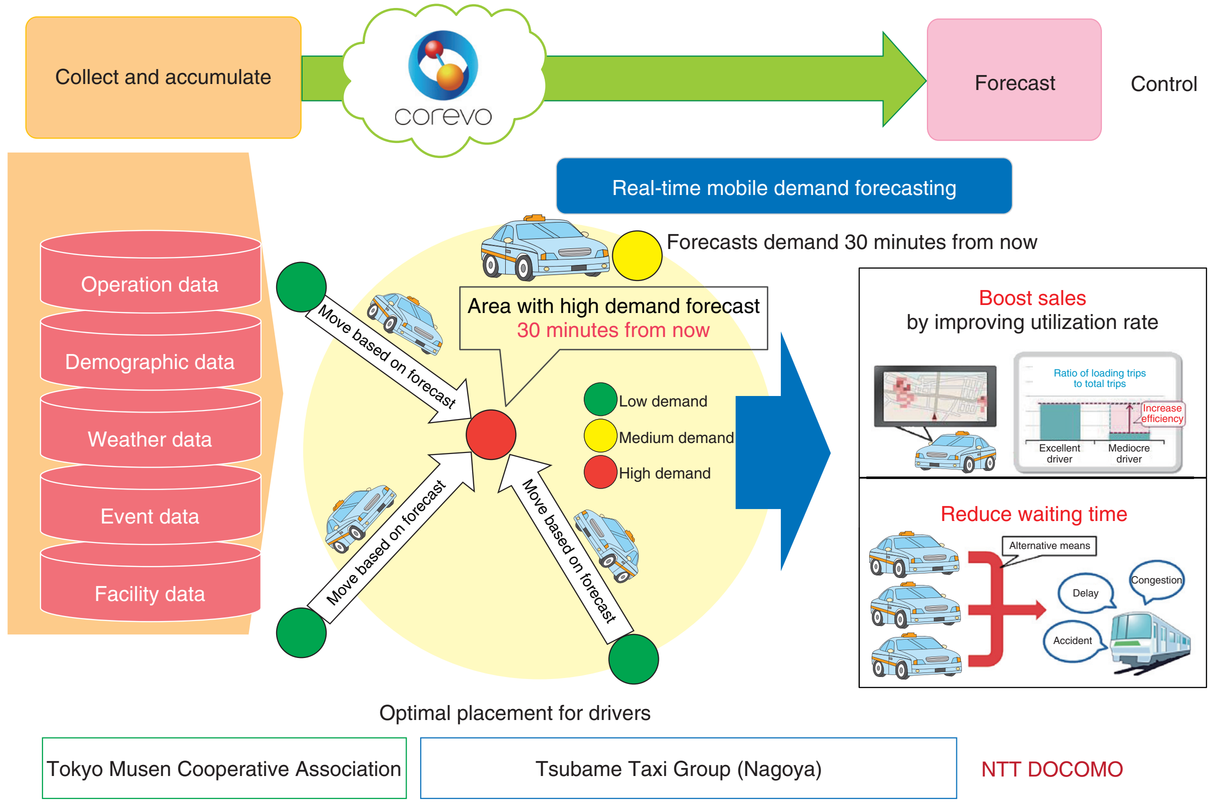


Fig. 7. Taxi demand forecasting.

different types of AI in order to achieve global optimization of a system. In collaboration with the Japan Agency for Marine-Earth Science and Technology, we are developing technology for combining wide-area simulation with local area-specific processing in order to improve the accuracy of weather forecasting.

2.7 Heart-Touching-AI technologies

We have recently initiated new activities in the field of sports brain science. According to specialists, physical performance is affected not only by physical conditions but also by the brain. The objectives of our activities are to elucidate brain mechanisms and to create effective training methodologies that can be used in the field.

3. IoT targeted by NTT R&D

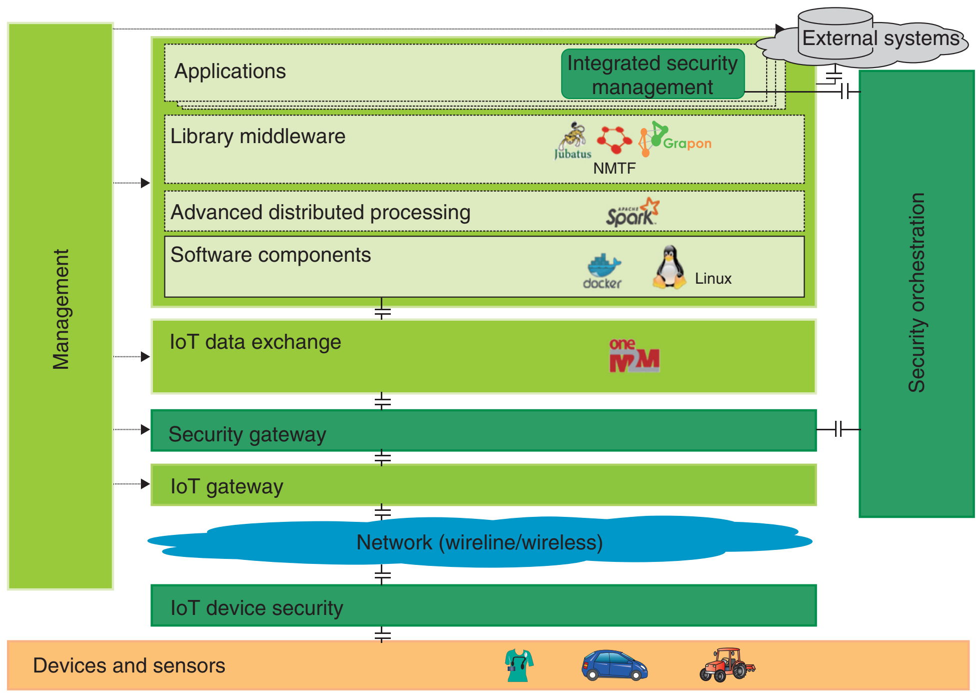
The IoT world is aimed at creating new value by collecting data from various things in society, visualizing them, and analyzing them using AI technologies. NTT R&D is focusing on the following four IoT requirements.

First, for data collection, sensors need to permeate humans and objects *naturally*. Second, while some data processing, such as that for paddy field management in agriculture, has no time constraints, data processing for operation of machinery in factories must be carried out in real time in order to minimize delay. Third, for value creation, a mashup of diverse types of data is important. Lastly, a common requirement is secure handling of data.

3.1 IoT basic architecture

In line with these requirements, NTT R&D uses the following IoT basic architecture (**Fig. 8**).

If we are to promote circulation of information, the architecture needs to embrace the following parts: 1) an IoT gateway that unifies, at the entrance, communications standards that vary from industry to industry; 2) IoT data exchange that standardizes data formats and distributes data to different analysis functions; 3) software components and high-speed distributed processing needed to optimize data analysis performance; 4) library middleware and applications for turning data into value; and 5) management of the



NMTF: Non-negative Multiple Tensor Factorization

Fig. 8. IoT basic architecture.

entire operation. Furthermore, the following security measures should be added to the architecture: 6) IoT device security for protecting information at the communication layer; 7) a security gateway for detecting and blocking malicious data at the receiving points; and 8) integrated security management and security orchestration for detecting abnormalities in a system as a whole and immediately applying blocking rules.

We are developing functional units that implement NTT R&D technologies in the IoT basic architecture. We are also studying which of these functional units should be used in combination for a specific application area or usage, and how to allocate these functional units among clouds, edges near devices, and gateways if we wish to reduce delay or achieve compact packaging.

3.2 Sensing

In collaboration with Toray Industries, Inc., we have developed "hitoe," a sensing fabric that can measure cardiograms and electromyograms. In addition to using the fabric to simply collect data, we have begun to study how to identify fatigue, heat stroke, and the user's mental state from a cardiogram, and how to determine muscle fatigue and lactate threshold from an electromyogram. For example, "hitoe" is used to estimate the fatigue level of long-distance bus drivers and to determine if outdoor workers are suffering from heat stroke. NTT WEST is employing "hitoe" to visualize the mental states of golfers.

Formerly, we were able to claim only that "hitoe" could measure heart rate. Since registering "hitoe" as a general medical device in August 2016 (**Fig. 9**), we have been permitted to state that the fabric can measure a cardiogram. Today, it is used in many hospitals. We are conducting a joint field trial with Fujita Health University to study how "hitoe" can be used to reduce the duration of hospitalization for patients undergoing rehabilitation.

We are also applying the fabric in professional sports. In the Indy 500 in the United States, NTT DATA uses "hitoe" to monitor the physical loads on racecar drivers in the extremely demanding environment. In bicycle races, "hitoe" is used to visualize not only road racers' heart rates, speeds, and rotations but also their reserves of physical strength.

3.3 Application examples of IoT

Examples of the use of NTT R&D's IoT technologies are presented below.

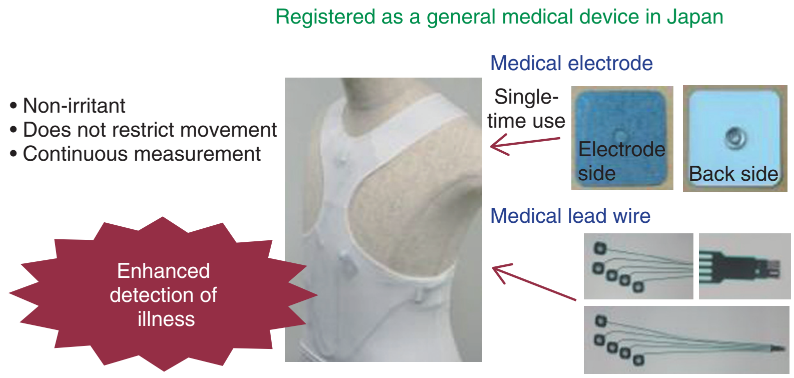


Fig. 9. Applications of “hitoe.”

(1) Support for vehicle operation

IoT technologies can support vehicle operation by estimating the fatigue levels of bus or truck drivers and recommending rest when a certain level of fatigue is suspected. In a field trial on a highway, conducted jointly with Keifuku Bus, data on the driver’s fatigue level were visualized. The data showed that after the start of the drive, the fatigue level increases gradually and that after resting at a service area, the driver recovers from the fatigue. Following this field trial, NTT Communications launched a service that supports vehicle operation. In addition to “hitoe” being used to obtain bioelectrical data, NTT R&D’s high-speed distributed processing plays a critical role in processing streaming data such as heart rate data in real time.

(2) Optimization of manufacturing/production in a factory

With a view to innovating manufacturing, we are seeking to raise production efficiency by getting various machine tools in a factory to work in coordination and by processing the data involved in real time (**Fig. 10**). A key to achieving this real-time processing is edge computing, in which the necessary processing functions are allocated at edges near the machine tools rather than in clouds. We have combined edge computing with an IoT data exchange function, which circulates information handled by various types of machine tools in the form of common data, and with a software component management function, which flexibly selects application programs according to the particular usage of machine tools in a factory. We are working with FANUC CORPORATION toward its planned launch of a service in autumn this year.

(3) Improvement of farming productivity

The NTT Group is collaborating with Kubota Corporation to improve productivity and competitiveness in agriculture by combining NTT R&D’s technologies with NTT GEOSPACE’s map data, which are NTT assets, Halex’s weather data, and JSOL’s yield forecast data.

3.4 Security

An important consideration in promoting IoT is security. The IoT environment is characterized by an inability to execute complex processing due to limited processor power.

Our next-generation passwordless authentication technology does not require servers to manage information needed for authentication (**Fig. 11**). The user can securely authenticate an IoT device with only two items of information: a device identification and an item of secret information held in the IoT device. The server does not hold authentication information for each device. This technology has been developed and released as open source software. As a future application, we are studying the possibility of using this technology to prevent spoofing of IoT devices. For example, when a genuine home delivery drone and a fake home delivery drone arrive, it will be possible to authenticate only the real one.

We are researching technology for lightweight encryption, which is secure and does not impose a heavy processing load. It is important to confirm that the encrypted information will not be broken. We do so by creating encryption analysis methods ourselves and checking resistance to new attacks. We recently developed a new encryption analysis method called a nonlinear invariant attack and proved that some existing lightweight encryption systems are vulnerable.

We are also studying how to strengthen the security

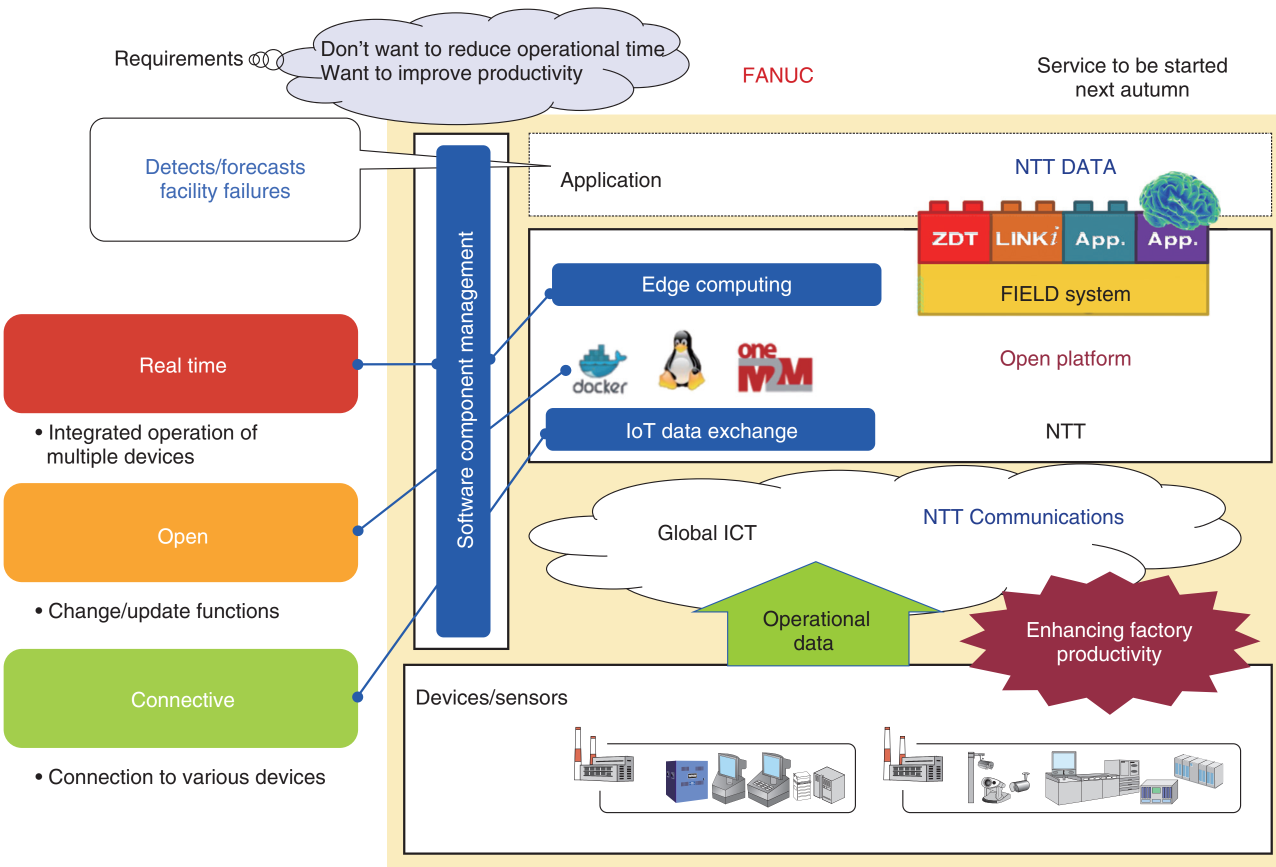


Fig. 10. Optimization of manufacturing/production in a factory.

of a system as a whole, especially critical infrastructure, in addition to the security of individual IoT devices. Cyber-attacks aimed at disrupting critical infrastructure can produce serious consequences. With Mitsubishi Heavy Industries, Ltd., we are jointly developing a system that determines the operating mode of a certain infrastructure from data collected from sensors, detects abnormalities, and restores the infrastructure. We are studying a way to minimize damage from novel cyber-attacks by combining security gateways, analysis applications, and security orchestration.

4. Visualizing the near future and beyond

Looking to 2020 and the creation of lasting assets, we believe that NTT should play three roles: providing stable high-quality network services, implementing reliable network security measures, and providing hospitality, deep positive impressions, and new experiences to visitors. This article focuses on our activities in respect to the third role.

4.1 Hospitality

We have initiated a number of trials aimed at providing services for international tourists, who continue to increase in number. In field trials underway at a Tokyo Metro subway station and at Nissan Stadium, angle-free object search technology, mentioned above, and 2.5-dimensional (2.5D) map representation technology are used to provide intuitive navigation (**Fig. 12**). When a tourist points a smartphone at an information sticker pasted in a Tokyo Metro station, his/her current location is detected without any need for beacons. When the user inputs his/her destination information, a 2.5D map, which is a 2D map with height information added, is displayed on his/her smartphone so that he/she can easily find the way to the destination. In the field trial at Nissan Stadium, navigation using an accessibility map is also provided.

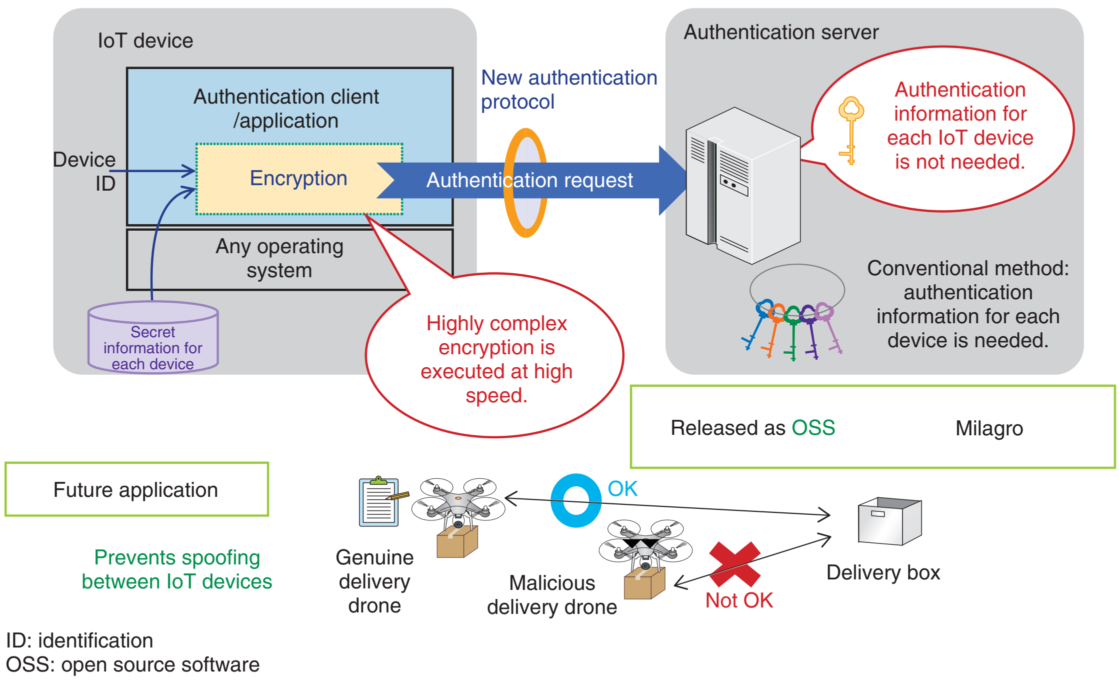


Fig. 11. Next-generation passwordless authentication.

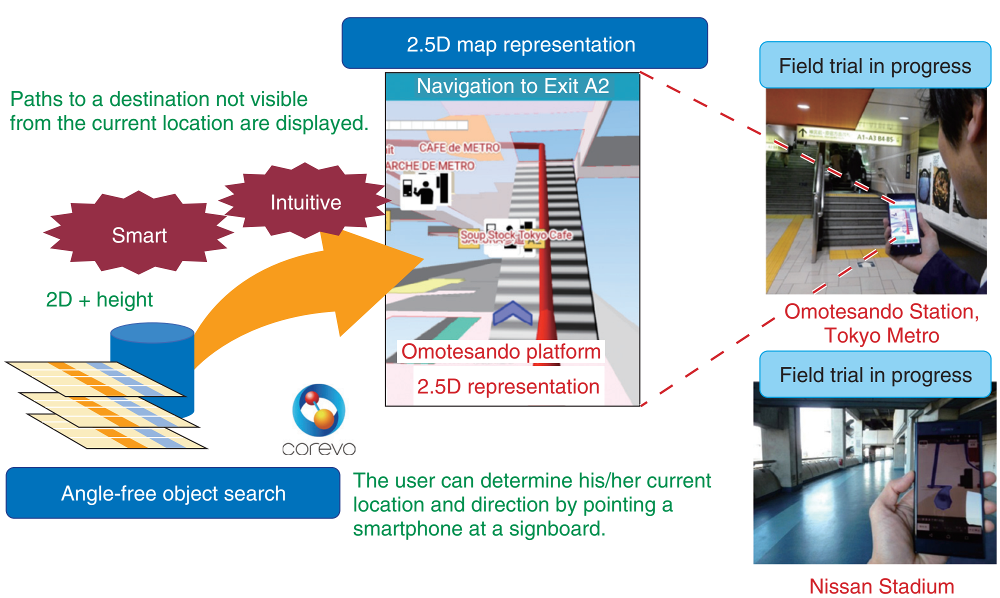


Fig. 12. Navigation for international tourists.

For example, when the system learns that a person is in a wheelchair, it provides navigation specifically designed for wheelchair-bound persons.

In the field trial at the Tokyo Metro subway station, angle-free object search technology is used to direct passers-by using advertisements on walls. For example, when a person points a smartphone at an advertisement on a wall, he/she receives a coupon for a

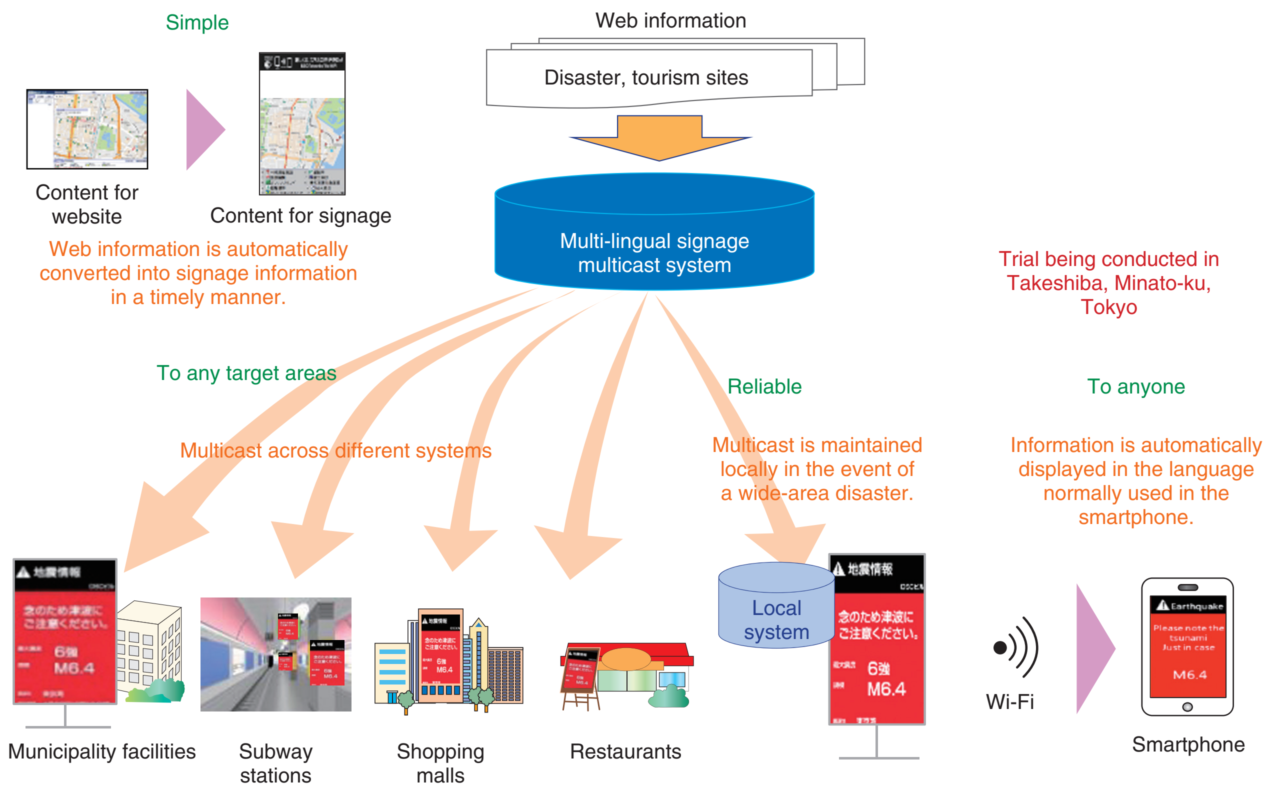


Fig. 13. Multicast of multi-lingual information on signage.

special offer as well as information on how to navigate to the shop concerned. This will be especially convenient for overseas visitors.

In a field trial conducted in Takeshiba, Minato-ku, in Tokyo, emergency information is multicast to various signage systems in the event of a disaster (**Fig. 13**). It is vital to ensure that information that has been multicast to signage units dispersed through a town is definitely displayed, irrespective of the sign owners or the types of signage units. We have developed a multi-lingual multicast system that multicasts information to different signage systems and directs those systems to send information to the smartphones of passers-by in such a way that the information is automatically displayed in the language used in the smartphone. The objective is to enable overseas visitors to promptly receive emergency information in the event of a disaster.

In the retail and distribution fields, NTT and Seven & i Holdings Co., Ltd. are carrying out a joint field trial in which overseas visitors can easily get product information using smartphones. For example, when a person points a smartphone at a rice ball, he/she can immediately get information on the ingredients and allergic substances contained in the rice ball—currently, in any of 15 languages.

With a view to providing ease of use, we have developed a see-through device in collaboration with Panasonic Corporation (**Fig. 14**). Since the device is not as powerful as a smartphone, its operation is assisted by edge computing technology. When it is pointed at an object, it displays information about that object. It uses the latest transparent color display from Japan Display Inc. Widespread use of these technologies will expand the industry in Japan.

Since last year, we have been holding R&D Forum Showcase to enable visitors to the forum to have hands-on experience with our R&D technologies. In this event, visitors can try our official app. It recommends a route to an individual user based on his/her interests and the current distribution of people on the floor, and answers questions about recommended exhibits using AI. When the user points a smartphone at an exhibited panel, the “point and get information” function of the app displays information relating to that exhibit. Information is shown in English if the

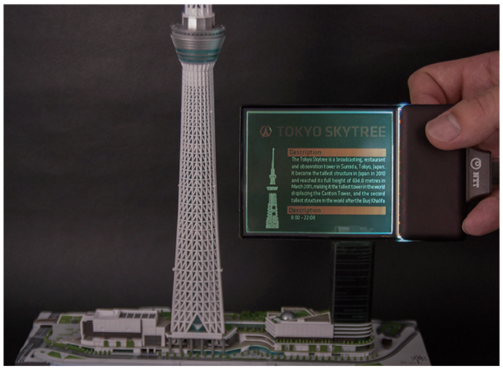


Fig. 14. See-through device.

user is from overseas.

4.2 Deep positive impressions and new experiences

The immersive telepresence technology called “Kirari!®” has been exhibited at NTT R&D Forum since 2015, when images of people were extracted from a recorded video and displayed in quasi-3D. In 2016, images of people were extracted from a video in real time for the first time during my keynote address. In 2017, we attempted a more challenging undertaking of extracting images of people from a wider area in a higher-definition video.

We have been experimenting with convergence of information and communication technology (ICT) and kabuki, a Japanese traditional performing art. At the Niconico Chokaigi (super conference) held in April 2016, “Cho Kabuki” was presented. This was followed by a performance of “KABUKI LION SHI-SHI-O” produced by SHOCHIKU Co., Ltd. in Las Vegas, in May. In March 2017, “Virtual Kabuki Theater” was staged in Kumamoto. The latest object extraction technology has been used to display the “swinging of head hair” by a kabuki actor. Details of his whirling hair were extracted and displayed clearly and naturally.

We will continue to improve Kirari!. Next year, we will develop technology for projecting a 3D image in such a way that it can be viewed from an arena-shaped spectator area. In other words, the image will be viewed not just from one direction but from all directions.

4.3 Convergence of sports and ICT

We are using ICT to assist the training of athletes and to captivate fans by giving them deep, positive experiences of sports events.

Our efforts to help train athletes target both endurance-type sports such as swimming and cycling, and instantaneous and interpersonal sports such as baseball and badminton. For the latter, we are elucidating brain functions of athletes by collecting data from former professional baseball players and members of university baseball teams. For the former, we are studying analysis of heart rates and myoelectric information on swimmers because it has become technically possible to use the sensing fabric “hitoe” for underwater monitoring.

We are studying the use of virtual reality to offer new experiences in watching sports events. We have developed athlete first-person vision synthesis technology. This was initially targeted at baseball. It synthesizes a real baseball park video and a CG (computer graphics)-reproduced baseball so precisely that the user can view the ball and the park from any viewpoint, for example, from the position in the right batter’s box or from the position of the catcher. Our objective was to enable children to experience fast balls pitched by top players. However, systems that implement this technology are now also used by professional baseball teams for training.

We have expanded the application of this technology to other types of sports. For example, the user can experience a free kick by a soccer player or a drop shot serve by Kei Nishikori, a Japanese tennis player with whom we have concluded a sponsorship contract. Conveying the amazing skills of top athletes to children—the next generation of players—will help to expand sports-related business.

5. Conclusion

Although I have mainly introduced applied technologies in this article, we are also committed to basic research, knowing that the various AI technologies in our hands today have been built on the results of our past basic R&D spanning several decades. The lesson is that we should not confine ourselves to R&D of technologies that are useful today. We must also pursue basic R&D that may become applicable five or ten years from now.

Let me introduce two types of basic research. We have developed a new quantum computing principle that uses light to rapidly solve difficult mathematical problems that cannot be cracked using today’s super computers. This was published in *Science*, a U.S. scientific journal. In the quantum world, there is a realism problem whereby the state cannot be determined before the time of observation. There has been intensive argument as to whether this is true only in the quantum world or also holds in the real world or in the macroscopic world. We have proven that breaking of realism occurs even in the macroscopic world. This was released in *Nature Communications*, a UK scientific journal.

We are convinced that if we want to promote B2B2X, we must garner abilities that enable us to continue to be selected by our partners. If we are to succeed in collaboration, we must have the ability to integrate the strengths of all those involved in any such collaboration, and NTT R&D must consistently produce cutting-edge research results. We will not emphasize one or the other of the above but will commit ourselves to garnering the ability to collaborate and pursuing basic and fundamental research.

Research and Development Activities toward Smart and Flexible Future Network: NetroSphere Concept

Kimihide Matsumoto

Abstract

The NTT laboratories announced the NetroSphere concept in March 2015 with the aim of creating future networks that support the Hikari Collaboration Model (business model to wholesale fiber access). This article introduces our recent efforts concerning NetroSphere and explains the importance of creating future smart and flexible networks based on the NetroSphere concept in order to accommodate the digitization of various industries and the rapid growth of multiple Internet of Things services. These Feature Articles are based on lectures given during workshops at the Tsukuba Forum 2016 held on October 26, 2016.

Keywords: NetroSphere, future network, smart and flexible

1. Introduction

The progress made in information and communication technology (ICT) in recent years has led a multitude of industries that had not previously embraced ICT to incorporate ICT into their businesses and reform their operations through digitization. At the same time, the Internet of Things (IoT)—which connects various devices through wireless transmissions—has been rapidly expanding. Moreover, devices such as smartphones are improving in performance and functionality, and video services are improving in image resolution, and as a result, the amount of communication traffic is steadily increasing.

A diverse range of industries utilizes communication networks, and consequently, there are diverse requirements for different communication networks. To handle these requirements and the continuing increase in communication traffic, it is necessary to not only create future networks economically but also to make them flexible so they can handle additions and changes to requirements.

From a historical standpoint, services provided by communication networks have long been centered on telephony. However, the introduction of Internet connection services, video delivery services, and other recent changes has resulted in the triple play of Internet access, telephone, and video distribution becoming available in the era of next-generation networks (NGNs).

In addition, with the progress of digitization and the IoT, it is necessary to understand that communication networks no longer provide all services, but rather, they support some of the diverse end-to-end services provided by service providers in various industries. It is thus considered difficult to sufficiently handle these circumstances by utilizing demand-forecasting techniques and network-design techniques that have been fostered on public switched telephone networks and NGNs.

With these circumstances in mind, we consider that future networks will have the features outlined below.

- An architecture that can flexibly handle changes resulting from fluctuations in demand and differing requirements

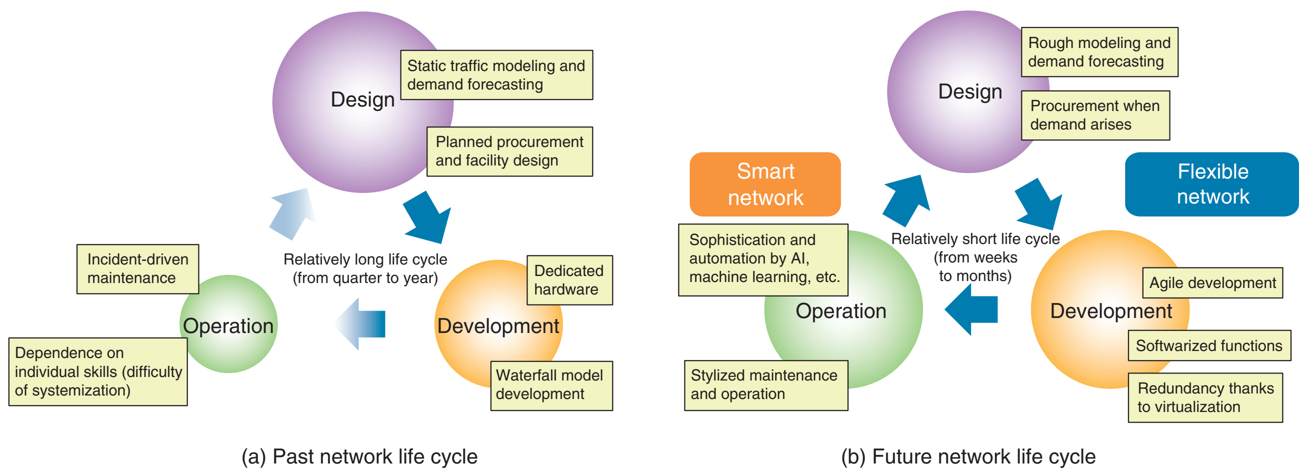


Fig. 1. Network life cycle.

- *Intelligent* operation that can handle events that are difficult to forecast
- A structure that efficiently achieves the above-stated features without incurring high costs

2. Life cycle of future networks

The life cycle of networks can be split into three phases: design, construction, and operation. That is, a communication network is designed in accordance with given requirements and demands, constructed on the basis of that design, and then operated. The knowledge gained during operation is fed back to the design phase as required. However, with the progress of digitization and the expansion of IoT, it has become necessary to change the way this life cycle is understood.

When services are directly provided by a communications carrier in the manner of conventional telephone networks and NGNs, the upstream of the life cycle has tended to receive the most attention. In other words, the approach taken has been to firmly forecast demand in the design phase, optimize the network design on the basis of the forecast demand, and procure hardware according to plan. In the development phase, requirements are specified, and the network is developed in an orderly manner according to the waterfall model. By doing so, operations are optimized in the operation phase (**Fig. 1(a)**).

If the requirements concerning a communication network are simple, and if fluctuations in demand are comparatively easy to forecast, the above-described approach is sufficient. However, the situation must be reviewed if the communication network has numerous requirements or if the fluctuations in demand for future networks are expected to vary considerably. That is, since requirements and demand are indeterminable beforehand, the network design will proceed in a rough manner, and hardware must be procured according to each demand.

We aim to implement agile development in order to flexibly accommodate changes in requirements. To handle events that are difficult to predict, new technologies such as artificial intelligence (AI) are being applied in the operation phase to improve functionality and performance. To efficiently create such a future network, we are simultaneously *softwarizing* network functions by utilizing software instead of hardware in the conventional manner, establishing network flexibility and redundancy (reliability) through virtualization of resources, and reducing operational costs through automation and *stylization* of maintenance (i.e., establishing a certain form for network maintenance and making it routine) (**Fig. 1(b)**). In creating a future network, we consider it important to establish a flexible network via the upstream processes (design and construction) and a smart network via the downstream process (operation).

Our approach for the NetroSphere concept announced in 2015 [1] involves efficiently creating a flexible network based on separation of resources and equipment, separation of functions and equipment, and separation of optical and electrical components, and a smart network for intelligent operation and maintenance (**Fig. 2**).

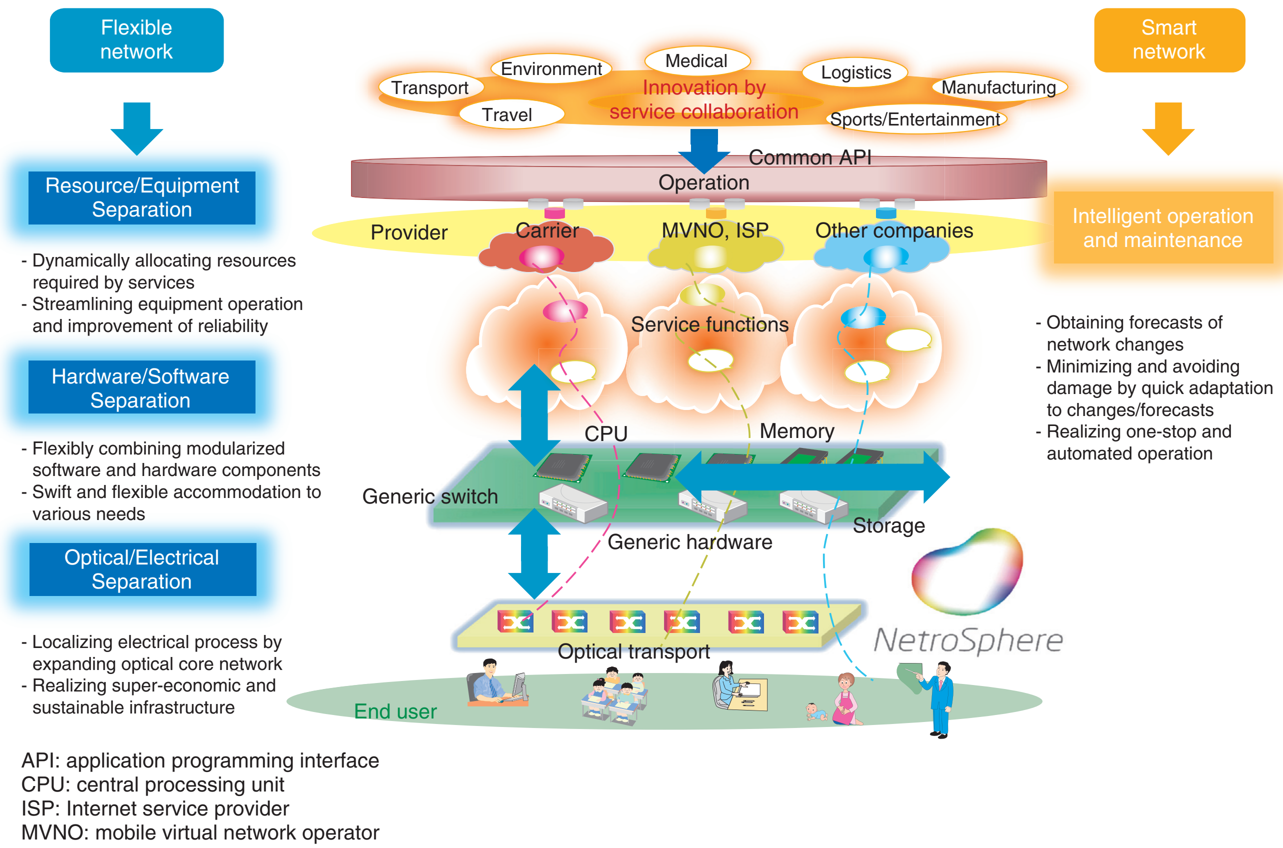


Fig. 2. Key elements of NetroSphere concept.

3. Activities aimed at realizing the NetroSphere concept

At NTT laboratories, we are developing technology in five areas in order to realize the NetroSphere concept (**Fig. 3**): (1) high-speed and highly reliable server architecture technology for speeding up application development (MAGONIA), (2) transport network configuration technology for achieving both scalability and economy (Multi-Service Fabric: MSF), (3) network equipment modularization technology for enabling flexible and low-cost access networks (Flexible Access System Architecture: FASA), (4) enhancement of operational technology by applying AI, and (5) verification of the NetroSphere concept (NetroSpherePIT). The current status of these activities are explained below.

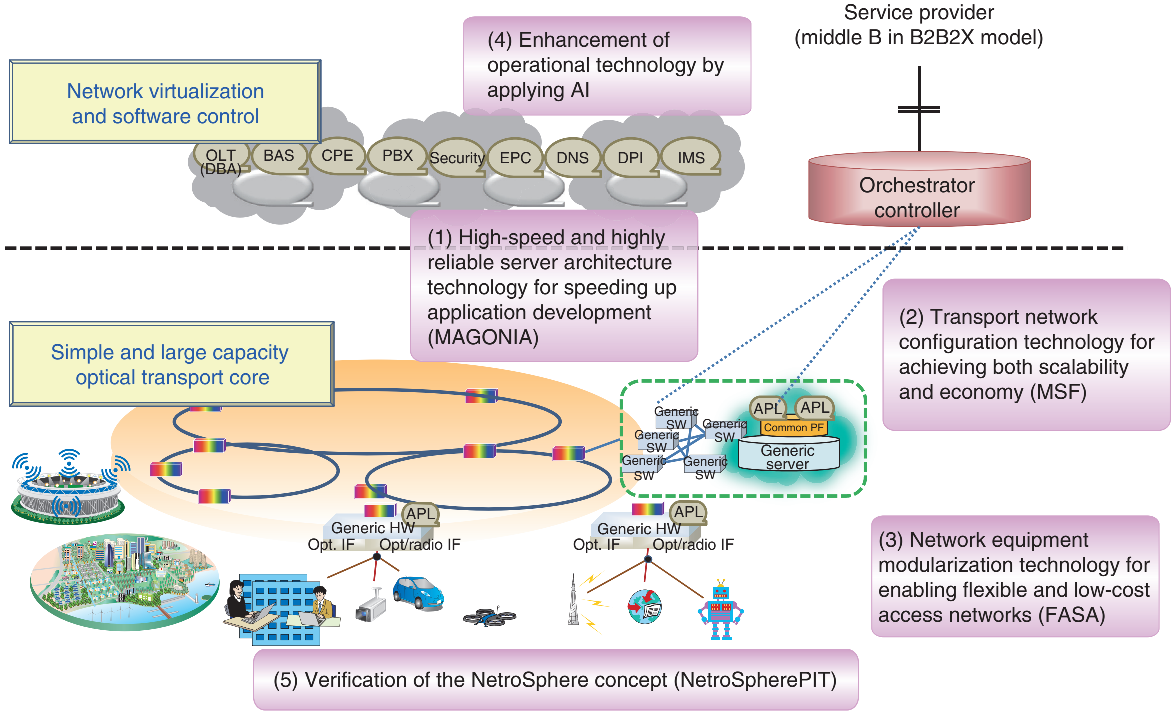
(1) High-speed and highly reliable server architecture technology for speeding up application development (MAGONIA)

This technology utilizes virtualization technology to implement on a shared platform network functions that in the past were implemented on exclusive-use appliances with separate functional capabilities, and network functions that were created with high-performance hardware. We confirmed that when this technology is applied to traffic simulation in ITS (intelligent transport systems), it enables congestion forecasting and signal control with high availability and scalability [2].

(2) Transport network configuration technology for achieving both scalability and economy (MSF)

This is a technology for configuring clusters by flexibly and optimally combining and controlling general-purpose switches. Since no exclusive-use equipment is needed, installation and operation costs can be reduced, and various services can be provided in a prompt and flexible manner. We published the architecture of this technology in August 2016 [3], and we are continuing to collaborate with various partners.

(3) Network equipment modularization technology for enabling flexible and low-cost access networks (FASA)



APL: application
BAS: business application service
B2B2X: business-to-business-to-X
CPE: customer premises equipment
DBA: dynamic bandwidth allocation
DNS: domain name system
DPI: deep packet inspection
EPC: evolved packet core
HW: hardware
IF: interface
IMS: Internet protocol multimedia subsystem
OLT: optical line terminal
PBX: private branch exchange
PF: platform
SW: switch

Fig. 3. NTT research and development activities for the NetroSphere concept.

The modularization of access system functions and the use of softwarization technology (access equipment modularization) in FASA enable it to share equipment. They also simplify maintenance and operations and achieve flexible and prompt handling of services. In May 2016, we released a FASA white paper, including FASA APIs (application programming interfaces) (proposal), and we are presently seeking partners to participate in technical discussions concerning the development of technical specifications [4].

(4) Enhancement of operational technology by applying AI

We are working on enhancing operational technologies that utilize big data analysis, AI/machine learning, and other techniques to handle various kinds of large-capacity data (network equipment, server information, traffic information, etc.) acquired from communication networks and the cloud. We have recently been working on anomaly detection technology and workflow visualization technology using syslog (system-log analysis).

(5) Verification of the NetroSphere concept (NetroSpherePIT)

We have established a verification environment called NetroSpherePIT as a venue for specifying and sharing common thoughts with various partners regarding technology created based on the NetroSphere concept [5]. The name NetroSpherePIT is analogous to a pit at a racing circuit, namely, a place where experts from various fields (car bodies, engines, tires, etc.) come together and think as one as they assemble racing cars and discharge them onto the circuit. It is a venue for not only verifying technology but also promoting collaboration with our partners. Moreover, we think that by incorporating networks utilized for daily work at our labs in NetroSpherePIT, we can operate NetroSpherePIT as a venue for accumulating our own operational technologies.

4. Future development

At NTT laboratories, we are striving to create a smart and flexible future network that can handle the upcoming era of seismic change. By jointly creating a wealth of value through collaboration with various partners, we aim to promote research and development that is more open than ever.

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He received a B.E. and M.E. from Nagoya Institute of Technology, Aichi, in 1988 and 1990. He joined NTT in 1990 and engaged in research on traffic engineering and quality management in telecommunications networks. From 1999 to 2005, he developed systems for IP-based services at NTT EAST. He is currently working on developing the architecture of future telecommunications networks.

Flexible Access System Architecture: FASA

Akihiro Otaka

Abstract

The NTT laboratories announced FASA: Flexible Access System Architecture, the new architecture based on the NetroSphere concept, in February 2016. This article provides an overview of FASA, which is designed to achieve flexibility in future access systems, and introduces its application to optical access systems accommodating mobile base stations.

Keywords: access systems, virtualization, FASA

1. Introduction

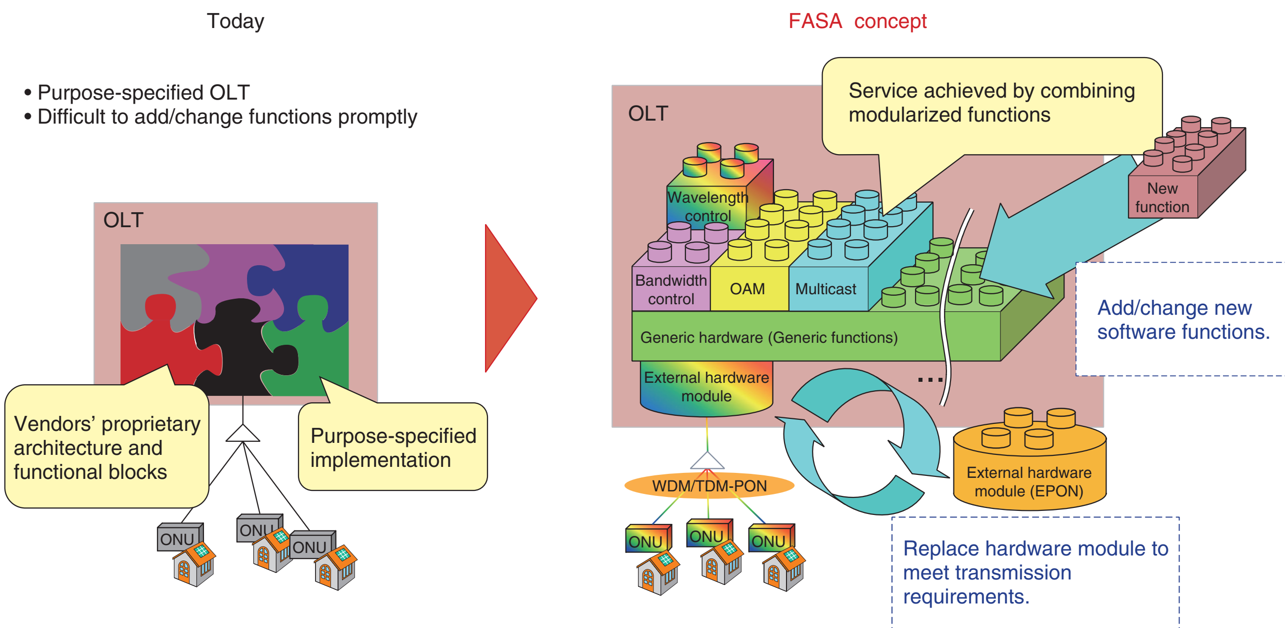
The NTT laboratories announced in February 2015 the NetroSphere concept, which is designed to enable rapid creation and provision of various new services through collaboration with business partners [1]. The concept is based on the Hikari Collaboration Model (wholesaling of fiber access services) and aims to disaggregate network functions to small modules as much as possible and enable the network to flexibly achieve required functions and capacity by combining various modules. The research and development of access networks will need to be synchronized with the NetroSphere concept in order to achieve flexible network configuration.

Current access networks have evolved under the situation where individual systems have been developed for each provisioned service, so the configuration of network functions in the network equipment depends on the service or the system vendor, and any subsequent upgrading or addition of network functions is not flexible. In core networks, Ethernet communication is used in the generic server or router, so it is not difficult to disaggregate the optical transmission function and the electrical frame processing function. In access networks on the other hand, various frame formats such as EPON (Ethernet passive optical network), GEM (generic encapsulation method), and DSL (digital subscriber line) are used depending on the transmission length, transmission media, and geographical subscriber density. Thus, the generic network function area of access networks is different from that of core networks.

The NTT laboratories announced FASA (Flexible Access System Architecture) in February 2016 [2] as a specific NetroSphere concept for access networks. FASA can also disaggregate access network functions to small modules and combine them flexibly, as shown in **Fig. 1**. A feature of FASA is that it uses the software module (FASA application) or the external hardware module according to the network function. For example, in the software module, it modularizes and operates the bandwidth control function, network maintenance function (OAM: operations, administration, and maintenance), and multicast process function. In the external hardware module, optical transceivers and network functions for error correction, encryption, and framing, all of which require high-speed processing at wire speed, are modularized, and the required modules are flexibly added according to each transmission system. We can achieve the following objectives of the NetroSphere concept by combining each software module and external hardware module for required functions.

(1) Quick provision of services

The addition of required network functions as



OAM: operations, administration, and maintenance
OLT: optical line terminal
ONU: optical network unit
WDM/TDM-PON: wavelength division multiplexing/time division multiplexing - passive optical network

Fig. 1. FASA concept.

FASA applications into the system will enable quick provision of services.

(2) Operating expenses (OPEX) reduction

Commonalization of maintenance and inventory will reduce OPEX.

(3) Capital expenditure (CAPEX) reduction

The system configured using commonalized generic hardware will reduce CAPEX.

(4) Service continuity

Achieving the upgrading and replacement of generic hardware independent of network functions will enable the continuous provision of services.

These activities require collaborative technology development between telecom carriers, who set requirements for network functions, and vendors, who provide the technology to implement the system and equipment. Therefore, the NTT laboratories simultaneously called for collaboration with vendors when it announced the FASA concept.

2. Key technologies of FASA

FASA is based on three key technologies as follows. It is presumed that FASA will produce the expected effect incrementally by realizing these technologies.

2.1 Common interface achieving function modularization and combination of function modules

We are now investigating the FASA common application programming interface (API) that defines the functions to be modularized and enables function modules to be freely combined (**Fig. 2**). This API requires technology to dynamically combine function modules and to flexibly set and change the sequential order of each function. Our ultimate goal is to enable the operation of function modules on a generic server. The immediate goal, however, is to design a configuration to implement the FASA common API with vendors' dedicated equipment and to operate software function modules by using this API. One advantage of these software modules is that they can be used even if the dedicated equipment is replaced with generic servers in the future. Therefore, the developed software modules are available sustainably. However, at this time, the softwarization of network functions requiring high-speed processing at the wire speed on the physical layer is difficult, so it is

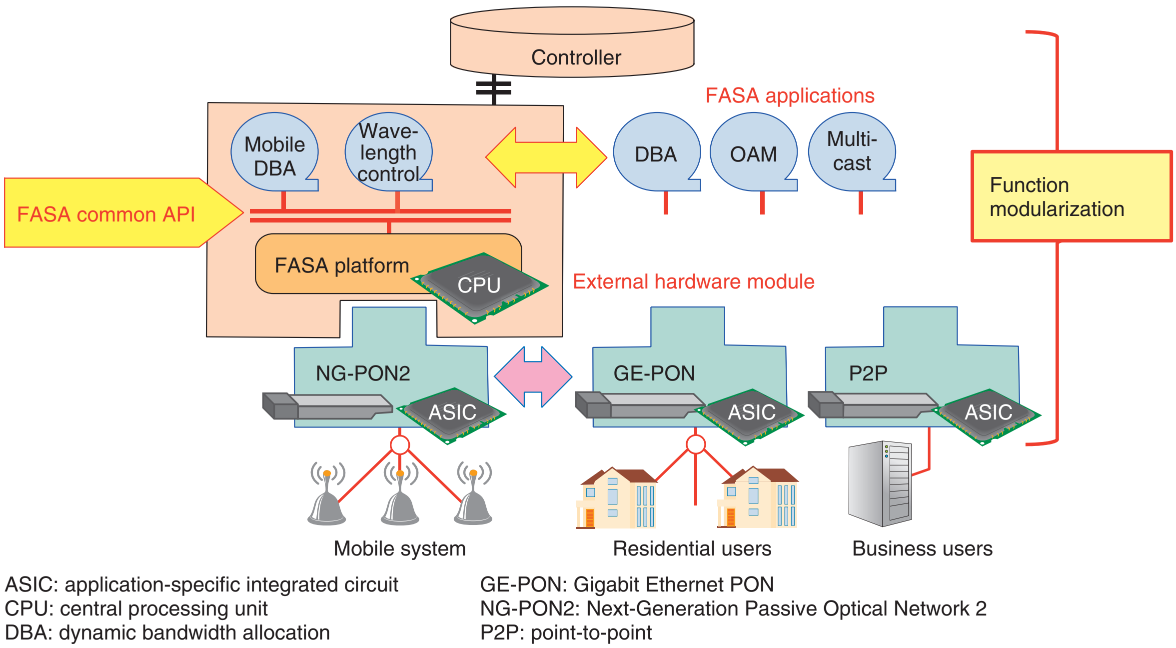


Fig. 2. FASA common API.

achieved using the hardware module, which can be replaced externally. The NTT laboratories published a white paper explaining FASA and proposed some ideas about the FASA common API.

2.2 Softwarization of function module

We are now investigating the implementation of the passive optical network (PON) OLT (optical line terminal) in the server, as shown in **Fig. 3**. We achieved the network function required in access networks as an application on the operating system by using high-speed processing technology with software. We have achieved the high-speed processing function in the physical layer by using the external hardware module, and we are currently investigating whether the generic GPGPU (general-purpose graphics processing unit) can process the error correction function and the encryption function in the physical layer by using software in order to flexibly enhance the upgradable area.

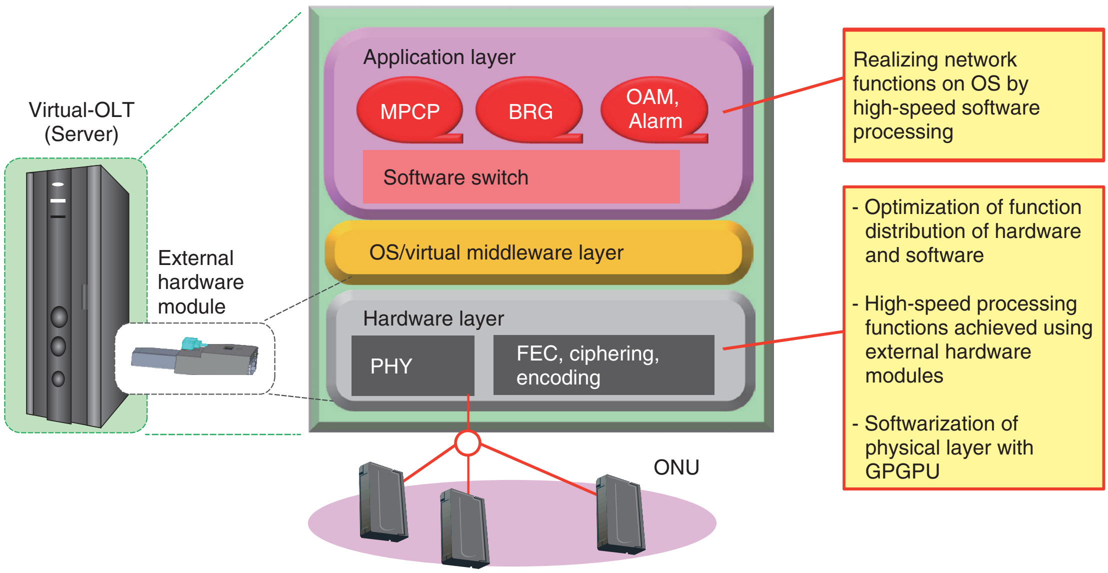
2.3 Function module cloud

We are targeting an effective system that centralizes function modules that are not processed frequently and that require low-speed processing, as shown in **Fig. 4**. Some projects are currently underway such as Cloud CO (Central Office) in the Broadband Forum (BBF) and R-CORD (Residential Central Office Re-architected as a Datacenter) in the Open Networking Lab (ON.LAB). These projects involve investigating and standardizing the operation of access systems by the controller on the software-defined network concept. The aims are to be able to flexibly control, set, and maintain functions of access systems. In contrast, the aim with FASA is to flexibly add and change the functions themselves, including the high-speed processing functions. Therefore, FASA complements the above activities. The NTT laboratories proposed starting the FASA project in the BBF, and standardization of FASA has begun.

3. Application of FASA: mobile access systems in 5G era

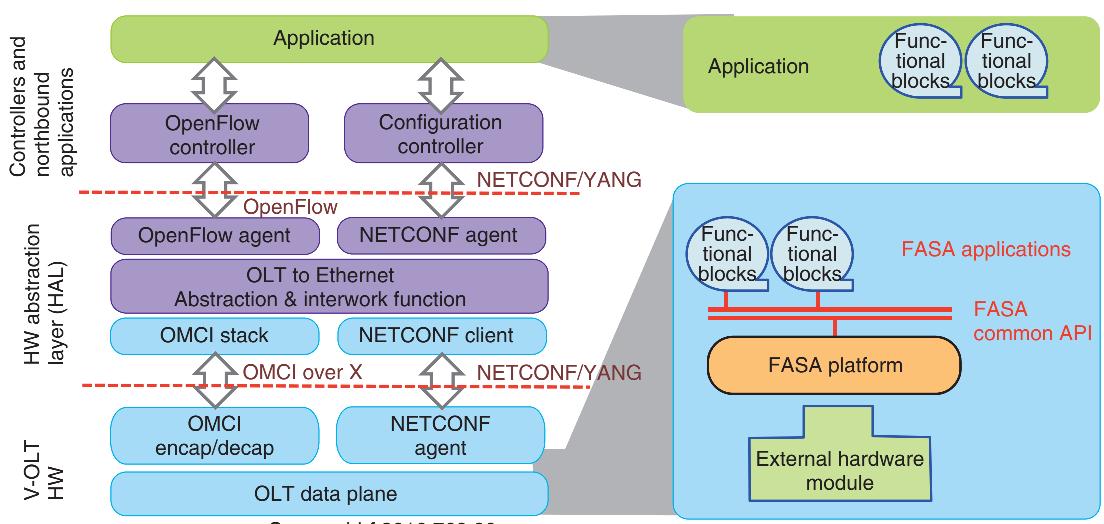
FASA consists of technology for configuring access systems, as mentioned in the previous section. Therefore, the application of FASA—that is, how NTT laboratories will realize flexible access systems by using this technology—is explained in this section.

In fifth-generation (5G) mobile systems, many small cells are assumed to be located densely. PON is the promising solution to accommodate densely located base stations, as shown in **Fig. 5**. The application of PON to the 5G mobile access system utilizes the existing fibers more efficiently than the current



BRG: bridge block
FEC: forward error correction
GPGPU: general-purpose graphics processing unit
MPCP: multipoint control protocol
OS: operating system
PHY: physical layer

Fig. 3. Modularization of software function virtual-OLT.



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Cloud CO: Cloud Central Office
Encap/decap: encapsulation and decapsulation
HW: hardware
NETCONF: Network Configuration Protocol defined by IETF (Internet Engineering Task Force)
OMCI: ONU management and control interface
R-CORD: Residential Central Office Re-architected as a Datacenter
YANG: A data modeling language for NETCONF. YANG is an acronym for Yet Another Next Generation.

Fig. 4. FASA and Cloud CO and R-CORD projects.

point-to-point system and drastically reduces the number of interfaces in the equipment in the central office. Consequently, it helps to reduce the site space and the power consumption.

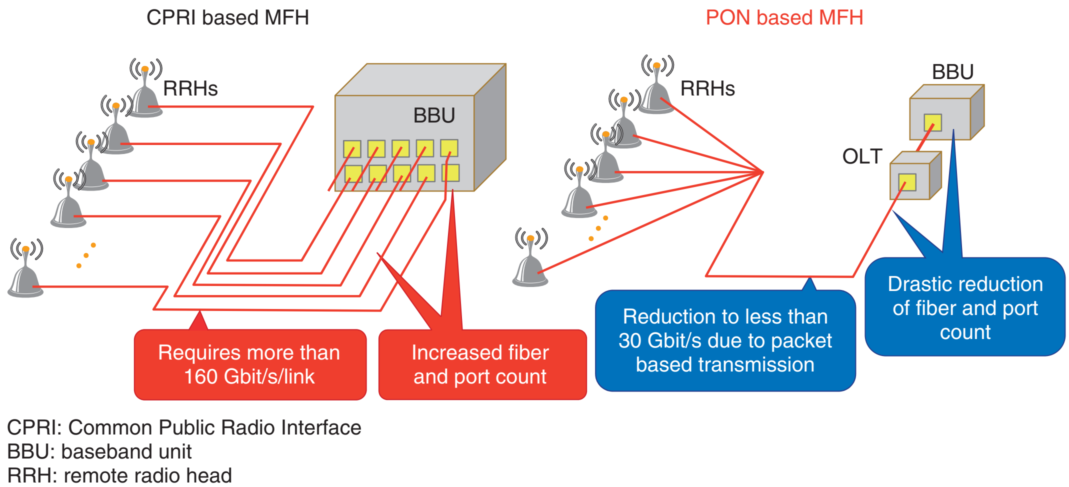

Fig. 5. PON based mobile fronthaul (MFH).

The NTT laboratories are investigating the following approaches in order to apply PON to mobile fronthaul (MFH):

(1) Redefinition of the functional splitting point between base band unit (BBU) and remote radio head (RRH) to reduce the bandwidth of MFH with packet based interface

(2) Cooperation between the mobile and optical schedulers to achieve low latency in upstream communication

These approaches enable packet multiplexing for effective traffic aggregation in MFH and a change of the connecting condition between the BBU and the RRH in their future virtualization. However, these are ongoing investigations, so network functions have to be revised quickly and implemented in the system in line with technological trends and the standardization progress. Therefore, it is preferable to realize these revisions through FASA configurations that smoothly change and modularize network functions.

3.1 Redefinition of functional splitting point

The current Common Public Radio Interface (CPRI) based MFH configuration requires 16 times the optical transmission capacity of the radio frequency (RF) capacity because the base station is divided into RF processing and baseband processing. For example, a 5G system requires 160-Gbit/s transmission in the optical access link for the 10-Gbit/s RF capacity in this configuration, which makes it too expensive. Optimal redefinition of the functional splitting point between BBU and RRH will make it possible to reduce the optical transmission capacity to less than one-fifth that of the current configuration without degrading the CoMP (coordinated multipoint transmission) performance of several RRHs. Moreover, the current CPRI always transmits optical signals at a fixed bitrate regardless of the user traffic. In contrast, this technology transmits packets only when the user traffic is transmitted, so it enables packet multiplexing. The standardization of this interface in MFH is being discussed in the 3rd Generation Partnership Project (3GPP).

3.2 Cooperative technology between mobile systems and PON

The principle of the cooperative technology between a mobile system and PON is shown in **Fig. 6**. PON shares the bandwidth with several optical network units (ONUs) and uses dynamic bandwidth allocation (DBA) for the upstream signal control. DBA can improve the bandwidth utilization efficiency, but the bandwidth allocation calculation causes high latency. Although this latency is not a major issue in normal Internet access, it becomes a major issue in the 5G mobile access system, which requires low latency. We are working to solve this issue by investigating technology to reduce the latency by achieving cooperation between the schedulers of the mobile system and PON. The mobile system controls each sending time of the upstream signal to each piece of user equipment by scheduling them without RF interference. The PON can schedule the sending time of each ONU in advance by transferring the

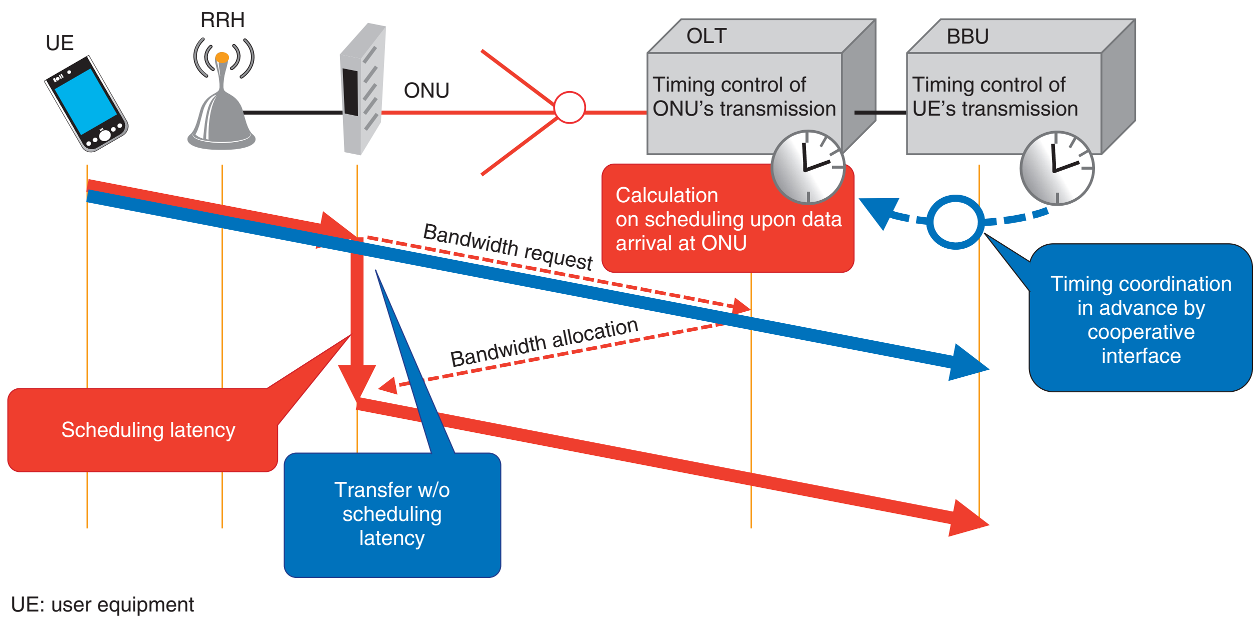

Fig. 6. Cooperative technology between mobile system and PON.

above information and can transmit upstream signals without the high latency caused by the DBA.

We are proposing the standardization of this technology to ITU-T (International Telecommunication Union, Telecommunication Standardization Sector) and are also going to propose it to 3GPP, the organization responsible for mobile system standardization. In the next-generation MFH, the optical transmission capacity depends on the total traffic from all user equipment, so the optical access system accommodating mobile traffic requires flexible bandwidth allocation. Therefore, we are investigating a way to achieve large-capacity transmission of 40 Gbit/s by NG-PON2 (Next-Generation Passive Optical Network 2), which combines time division multiplexing and wavelength division multiplexing, as well as a way to achieve optimal time slot and wavelength allocation to the RRH based on the user traffic.

4. Next step

The NTT laboratories will continue working to improve the technologies of FASA and to expand its use by many operators and vendors. Efforts will also continue on standardizing FASA in order to realize a flexible, cost effective, and sustainable access system.

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■ **Author profile**

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He received a B.S. and M.S. in physics from the University of Tokyo in 1989 and 1991. He joined NTT in 1991 and developed optical lithography technologies for LSI (large-scale integrated circuit) fabrication. In 1998, he began working on the development and standardization of optical access systems such as Gigabit and 10 Gigabit EPON. From 2010 to 2014, he was with NTT EAST R&D Center, where he worked on optical access, wireless access, and wireless home networks. He has been with NTT Access Network Service Systems Laboratories since 2014. He is a member of the Institute of Electronics, Information and Communication Engineers and the Japan Society of Applied Physics.

Research and Development of Innovative Operation Technology for Access Network Infrastructure

Kiyoharu Sasaki

Abstract

The Optical Access Network Project underway at NTT Access Network Service Systems Laboratories involves research and development on access network technology. This article is based on a lecture given at the NTT Tsukuba Forum held in October 2016; it introduces the research and development designed to innovate access network operation and the areas of development planned for the future.

Keywords: innovation of operation, equipment/facility inspection, Tsukuba Forum

1. Introduction

The NTT Group has built and operates huge numbers of telecommunications facilities in Japan, and this is continuing with the spread of telephone networks and optical broadband services nationwide. In order to continuously provide safe and secure social infrastructure services, a lot of effort and resources are required for operation and maintenance, and thus, the cost of maintaining and operating these facilities is extremely high. NTT Access Network Service Systems Laboratories (hereinafter referred to as AS Labs) has undertaken initiatives to reform the operation of these huge numbers of telecommunications facilities. We aim to streamline the process of inspecting equipment and facilities through innovation.

AS Labs has been studying the equipment inspection techniques in cooperation with NTT EAST and NTT WEST in order to improve efficiency. Inspection work in the future, however, will require technical innovation. This will involve checking and evaluating equipment structures quantitatively and in a planar manner with centimeter-order precision by maximizing the use of robotic technology such as mobile mapping systems (MMS). An MMS is a tool for acquiring point cloud data and images that is installed on measuring vehicles equipped with a high-density laser, camera, and GPS (Global Positioning System). This technology is already being used in the civil engineering construction industry and in the mapping industry. The reflection of a laser beam emitted at 1 million points per second from a high-density laser onto the measuring equipment in the measuring vehicle produces white trace data called point cloud. Each point in a point cloud has coordinates, so accurate position information can be acquired, thus enabling spatial data of equipment to be acquired together with image data obtained by the camera (**Fig. 1**).

In addition, AS Labs has been developing technology to model the point cloud data measured by MMS and automatically detect the condition of a piece of equipment. For example, in the case of a utility pole, modeling is achieved by extracting aggregates of circles from point cloud data and then removing noise (**Fig. 2**). Once the modeling is done, it is possible to detect the presence/absence of abnormalities such as inclinations and deflections, and to determine what the extent of the abnormality is. For example, in the field photograph on the far left in Fig. 2, the telephone pole appears to be leaning. When modeling is done using the above-mentioned technique, we see that it

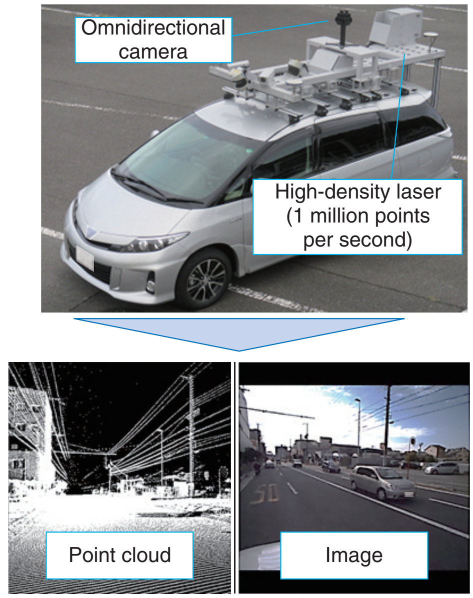

Fig. 1. MMS measuring vehicle and acquired data.

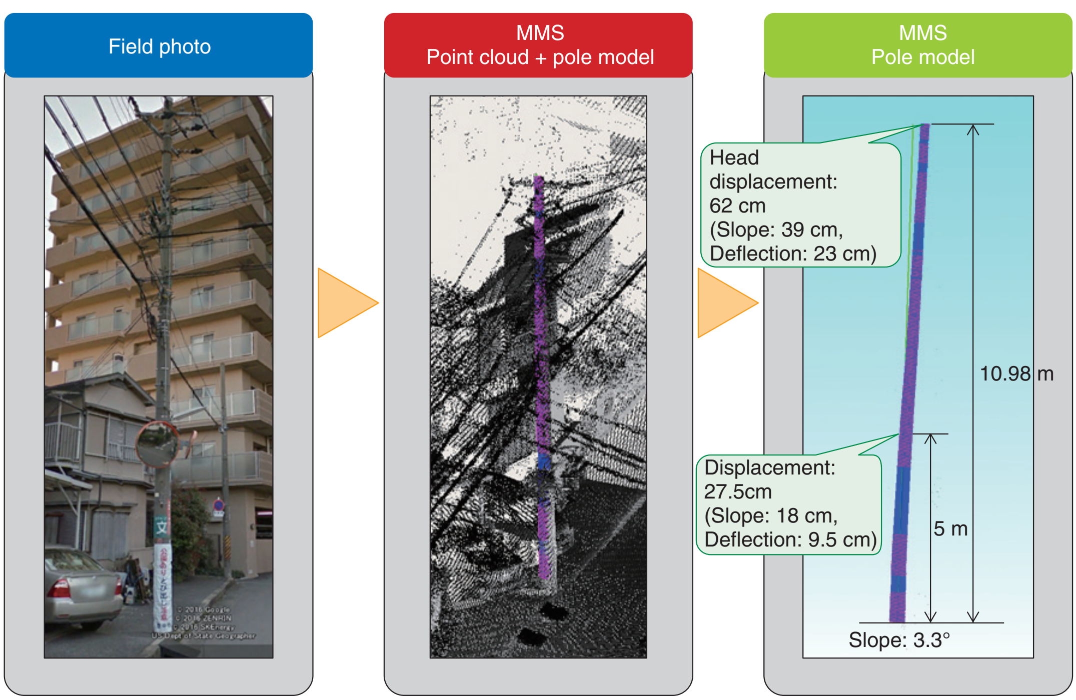

Fig. 2. Automatic detection of poles and three-dimensional modeling.

has shifted to the right from the center position by 62 cm at the head of the utility pole and 27.5 cm at the aerial position of the cable. Furthermore, we can determine that the deviation of 62 cm at the head of the utility pole is caused by a 39-cm inclination of the utility pole and a 23-cm deflection of the utility pole itself. As with the case of the utility pole, the MMS can measure the distance to the ground from the cable

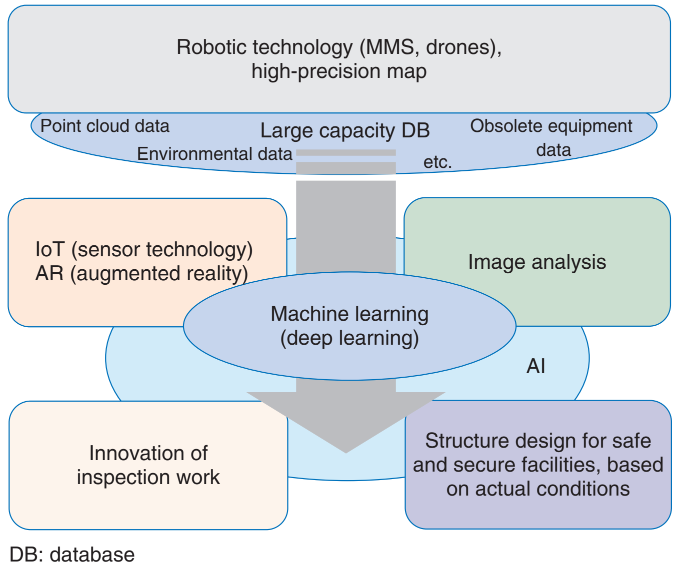

Fig. 3. Technology category related to inspection innovation.

attached to the utility pole. Therefore, the shortage of the distance to the ground from the cable, which is one of the problems in facility operation, will be possible to grasp, and concrete measures to rectify it can be implemented.

We experimentally measured and analyzed facilities using an MMS in the Koiwa area of Tokyo in March 2016. The Koiwa area has about 10,000 telephone poles. In MMS measurement, safety is an important factor, so the range of safe traveling (in terms of speed and time) of the measuring vehicle is taken into consideration. Thus, we were able to safely measure 2000 poles per day. The measurement results indicated that most utility poles were found to have a deflection of 5 cm or less. A deflection of 20 cm will likely lead to cracking, and cracks will enable water to penetrate the pole, resulting in possible deterioration of the rebar. None of the utility poles in this measurement area had deflections as large as 20 cm, so they were in relatively good shape.

To utilize data acquired by MMS, we first need to develop a high-precision map. The map currently being used has a scale of 1:2500, with a reported error of about 2 m. Utilizing the data acquired with MMS makes it possible to generate a highly accurate map with a scale of 1:500. A map at this scale has an error of about 30 cm, so the equipment position can be grasped very accurately. Moreover, in addition to facility inspection, we believe that with such a map we can improve services such as selecting equipment with greater precision when providing NTT services.

This article thus far has focused on robotic technology using MMS, which is a method of inspecting objects from the ground. However, we are also considering using drones to obtain an aerial viewpoint, and we are planning to utilize the high-precision map based on the coordinate positions obtained by drones.

2. Inspection innovation for a safer society

Five technological fields are considered to be key areas in designing safe and secure telecommunications facilities that reflect the innovation and the actual conditions of inspection work. These fields are the Internet of Things (IoT), augmented reality (AR), image analysis, machine learning, and artificial intelligence (AI). These are very trendy terms; however, since a wide range of operational services are provided in business, we would like to realize a society in which telecommunications facilities are continuously monitored (watched over) by promoting innovation through the use of the technologies in these fields (**Fig. 3**).

2.1 IoT and fiber sensing

After the MMS is used to grasp the equipment condition, it will be necessary to immediately repair or replace any equipment determined to be in poor condition. Equipment with progressing deterioration but not at a stage requiring immediate renewal will be

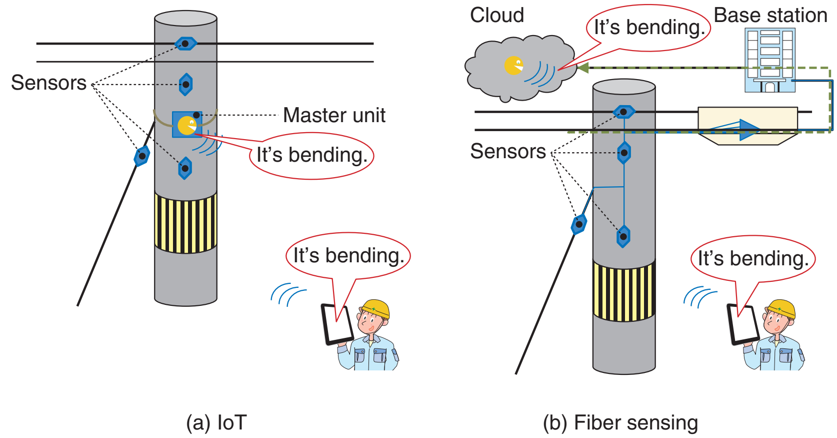

Fig. 4. IoT and fiber sensing technology.

recorded as needing a follow-up observation. It is currently only possible to increase the frequency of manual inspections by workers. However, installing a sensor (IoT technology) on equipment that needs such follow-up observations will enable the equipment state to be sent automatically any time someone approaches the equipment. In addition, fiber sensing is expected to be used for equipment in poor condition, with notification of the equipment condition being automatically sent to the appropriate department. Such remote monitoring will make it possible to detect dangerous conditions and their signs at an early stage (**Fig. 4**).

2.2 AR

The year 2016 saw everyone talking about Pokémon GO, a virtual monster-like character that appears on a map with AR technology. We can represent the equipment information obtained using robotic technology and IoT on a map by applying AR technology with a smartphone application. In this way, we aim to provide a fun way for experts and other members of society to be able to watch over society and to create a system that can accumulate useful data. In terms of watching over society, we can imagine using the system to keep an eye on elderly people who may have a tendency to wander, but we would like to use the system to monitor NTT facilities (i.e., equipment and buildings), which are also aging in our aging society.

2.3 Image analysis

The image analysis feature involves using the photos taken by MMS of corroded branching hardware, rusting equipment, lateral cracks of utility poles, and other such defects in order to assess the degree of damage and to plan for repairs. As camera technology advances, we will need to adapt how we proceed with maintenance work. The current use of this technology to detect wear in manholes is steadily progressing at AS Labs.

2.4 Machine learning

It is also important to be able to apply machine learning (deep learning) of images. For example, NTT Media Intelligence Laboratories is advancing machine learning of images, and even if an object is placed at an angle that is different from the registered image, it can be identified and detected. We aim to utilize this technology to determine the appropriate time to replace equipment such as closures, branching hardware, and lead-in lines installed in outdoor facilities (**Fig. 5**).

We will continue to innovate inspection work by combining the technologies introduced so far. The next task is to examine what the entire structure is like (**Fig. 6**). When measuring structures using MMS, we can see the routes of communication cable lines and suspension wires. It is also possible to determine whether or not a branch line or support pillar is necessary depending on the wire route situation. In this way, monitoring the entire facility situation such as the arrangement and state of the utility pole, the communication cable lines, the wire route, the branch line, and the support pillar as one system, and by seeing the balance of the whole system, it will likely be possible to analyze and predict any imbalance or distortion of such facilities. There is no problem when the balance of the entire system is sound. However,

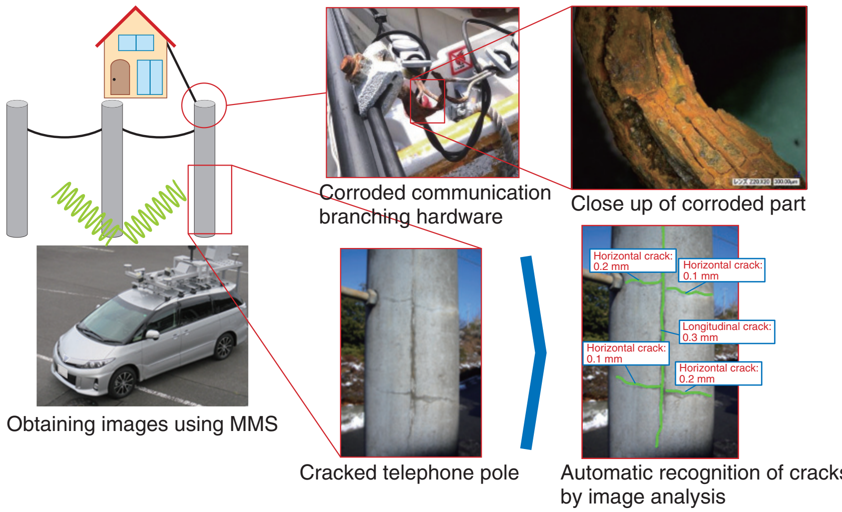

Fig. 5. Image analysis technology.

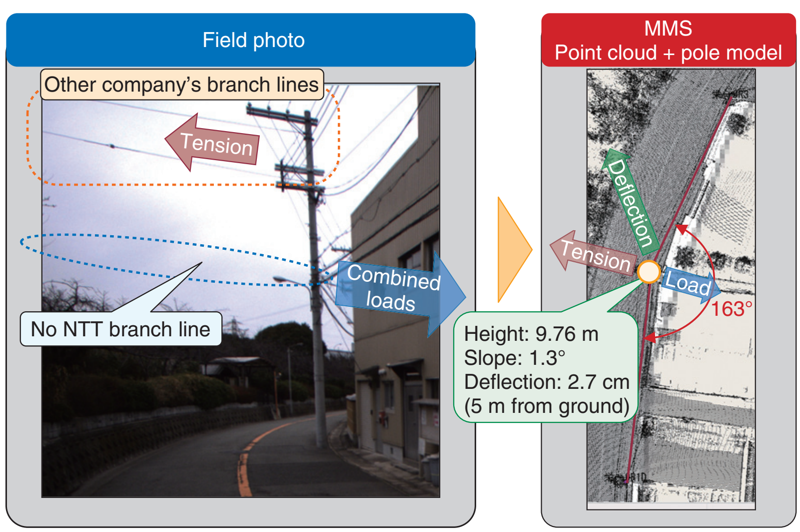

Fig. 6. Evaluation image of structure.

most of the existing facilities are 30 to 40 years old, so some of them are structurally unbalanced. Consequently, it is preferable to confirm the safety and security of such facilities according to the structural design reflecting the actual situation.

2.5 AI

Until now, we have investigated the new approach based on information on the structure and material of equipment, but further innovation of inspection work will not reach a sufficient level unless external information (external factors) is also taken into consideration. External factors include environmental indicators such as information on other companies' equipment, temperature, humidity, and other environmental data. It is important to combine these indicators to determine when to replace NTT equipment so as to avoid unnecessary capital investment by using equipment for as long as possible. AI technology can comprehensively support experts in deciding how to utilize the acquired data when updating or maintaining equipment. Therefore, we intend to further develop

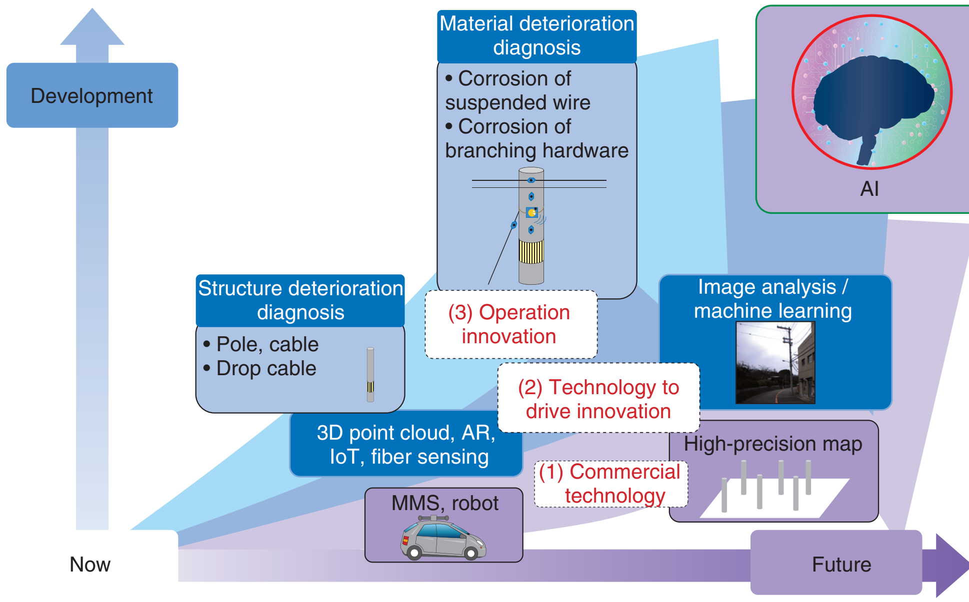

Fig. 7. Three pillars of inspection innovation.

AI technology in collaboration with partners both inside and outside the NTT Group.

We can summarize the above inspection work as being the three pillars of inspection innovation (**Fig. 7**).The base involves using general-purpose technologies such as MMS, robots, and high-precision maps ((1) in Fig. 7). The end goal is to improve the accuracy of technology applied for diagnosing the deterioration of structures and materials and to improve the efficiency of operations ((3) in Fig. 7). The element connecting these is to combine the 3D (three-dimensional) point cloud we are now researching and developing and the technology described here ((2) in Fig. 7). Our goal is to continue to expand these three pillars of inspection innovation from now on. We have manufacturing know-how that we have acquired at AS Labs for this effort, but our future efforts will not be realized unless we create new operation methods and techniques by collaborating with others in this field. The capability of field personnel is NTT's valuable asset. My aim is to improve the efficiency of NTT's business operations by successfully combining the element that improves efficiency through technology development with the element that increases the professional ability of field personnel.

3. Future deployment of services

In the environment surrounding ICT (information and communication technology), the demand for optical communication, which was always the center of equipment construction, is showing a tendency of saturation. As we pursue the Hikari Collaboration Model (wholesale fiber access service), various uses such as IoT, cloud formation, and the fusion of wired and wireless services are progressing, and the deployment of new services is expected. The NTT Group must operate facilities and services with the optimal number of personnel, while maintaining the quality of the equipment in order to take advantage of new business opportunities.

To achieve innovation of equipment/facility inspection, it is necessary to change not only the operation technology but also the current network to some extent. The optical network that NTT has built and expanded in Japan is another valuable asset of the NTT Group and ultimately of Japan, and it is therefore necessary to improve it so that it is more efficient and economical.

There are two necessary elements for updating access networks. One is our new access system architecture called FASA (Flexible Access System Architecture), which enables us to modularize and combine the functions of the access network equipment so that we can provide various services flexibly and promptly.

Another is the need for a new ground design for the optical fiber network. One example is to simplify the access network (e.g., aggregation of function points). We are currently placing splitters in optical networks and placing optical line terminals in public switched telephone networks in small buildings and considering how we can aggregate some of them. We would like to expand the scope of remote maintenance and increase the efficiency of operations by reducing the amount of maintenance done on site. This is referred to as equipment renovation at AS Labs. We plan to research the innovation of operation and equipment renovation and the way the network should improve in the future.

In our vision of the future access network infrastructure that expands optical network services to every person, thing, and business and continues to support society as a safe infrastructure beyond the age *anywhere*, *any business*, *any period*, we aim to deepen our cooperation with those we are collaborating with and strive to realize the results of research and development in a timely manner.

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He joined NTT in 1989. During 2002–2005, he was with NTT Access Network Service Systems Laboratories as a Senior Research Engineer, where he worked on the development of the optical access system. During 2007–2014, he was a General Manager at NTT EAST, where he helped develop the operation system for the optical access network.

Wireless Access Technologies to Enable a Variety of Services

Masato Mizoguchi

Abstract

In the wireless access project at NTT Access Network Service Systems Laboratories, we are researching and developing wireless access technologies centered around wireless local area network (LAN) technology. This article describes the issues that have arisen due to the growing use of wireless LANs and introduces our research and development efforts aimed at solving these issues and expanding the use cases of wireless LANs.

Keywords: cooperative wireless LAN, unlicensed radio, fifth-generation mobile

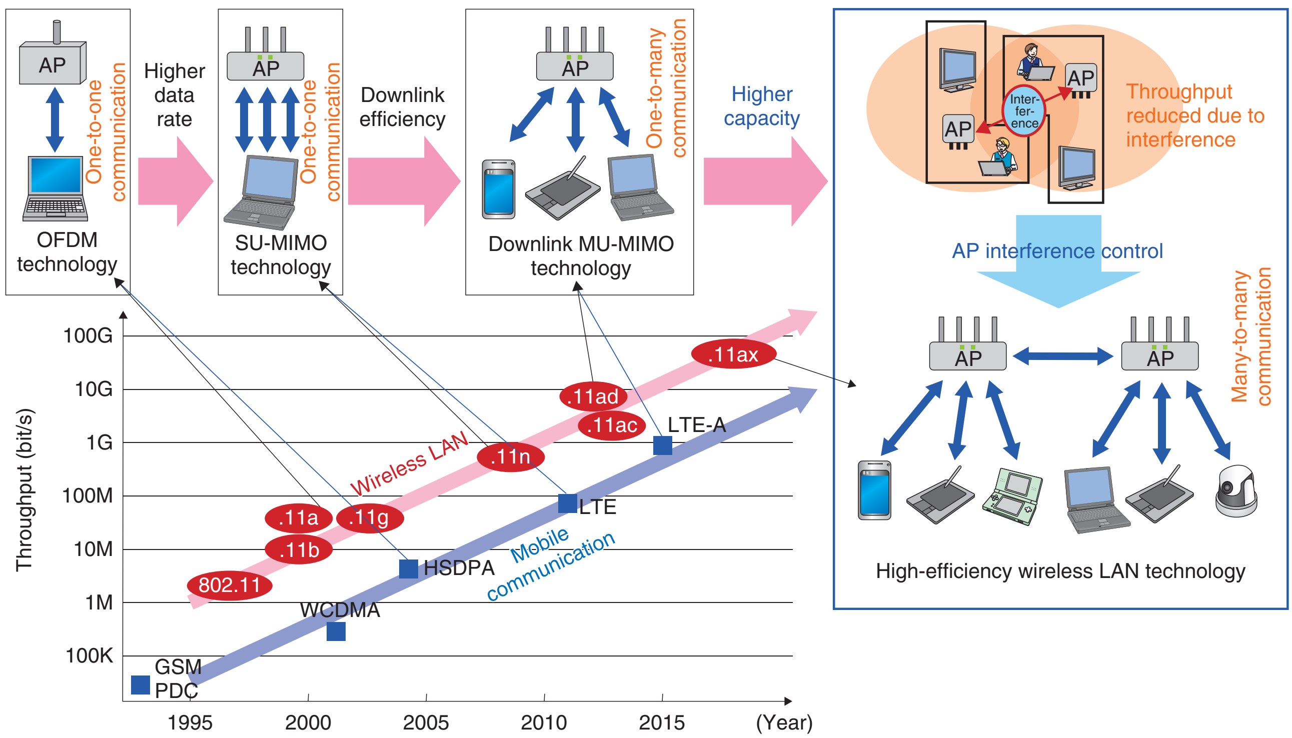
1. Introduction

Wireless local area networks (LANs), or Wi-Fi*1 networks, are gaining much attention due to the rapid growth in the number of user devices including smartphones and tablets being used in homes and offices. It was reported that in 2016, over 50 million user devices equipped with wireless LAN functions were sold in Japan [1]. Access points (APs) are also being installed to handle the increasing traffic in mobile networks, and the number of users of public wireless LAN services is increasing.

One of the factors behind the spread of wireless LANs is that they operate on the unlicensed frequency band, which has made it possible for users to install their own equipment for as little as $100 or so. To provide this feature, the wireless LAN standard IEEE*2 802.11 was established in 1997 as the first to use wireless access control methods with autonomous distributed control, which is called carrier sense multiple access with collision avoidance (CSMA/CA). The maximum transmission speed of this initial standard was 2 Mbit/s, but that has risen 1000-fold in just under 20 years, where the products compliant with the latest IEEE 802.11ac standard have a maximum speed of 1.7 Gbit/s (**Fig. 1**). Throughout this time, CSMA/CA has remained the basic wireless access control method, allowing for backward compatibility with earlier wireless LAN equipment.

CSMA/CA is a mechanism that allows multiple wireless devices to share the same frequency channel [2]. Instead of having a centralized controller to control the access of each device as in the mobile phone system, in CSMA/CA the wireless APs and user devices perform autonomous distributed channel access before their radio emissions so as not to interfere with those of other devices. Specifically, this method carries out transmission after ensuring there are no radio waves from other terminals (carrier sense) and pausing for a prescribed random interval. It thus avoids interference with the radio transmissions of other terminals (collision avoidance), enabling multiple devices to share the same frequency channel (multiple access). Centralized access control methods are effective in systems where each licensed operator occupies and uses a different set of frequencies, but with unlicensed wireless access, autonomous distributed control is necessary in order for radio waves to be shared by the devices of different owners.

*1 Wi-Fi is a registered trademark of Wi-Fi Alliance.
*2 IEEE: The Institute of Electrical and Electronics Engineers



GSM: global system for mobile communications
HSDPA: high-speed downlink packet access
LTE: Long Term Evolution
LTE-A: LTE-Advanced
MU-MIMO: multi-user multiple input multiple output
OFDM: orthogonal frequency division multiplexing
PDC: personal digital cellular
SU-MIMO: single-user MIMO
WCDMA: wideband code division multiple access

Fig. 1. Evolution of wireless LAN standard technology.

2. Issues of wireless LAN technology

Despite the popularity and convenience of wireless LANs, there has been an increase in the problems caused by excessive numbers of users. In an environment where many wireless LANs are used in close proximity to one another, it is harder to secure transmission opportunities in the CSMA/CA protocol, resulting in a higher incidence of packet errors due to collisions. Problems are also caused by congestion of wireless channels caused by the exchange of management signals such as beacon signals that are periodically transmitted by wireless APs, and probe signals that are used by terminals searching for a wireless AP to connect to. This can make it impossible to make proper use of wireless LANs in busy places such as train stations where many people would like to use them.

As Japan prepares for the major events in 2020, there are growing expectations for the provision of entertainment services using wireless LANs in stadiums. However, with the current wireless LAN technology, a stadium is an even more difficult environment than a train station. When providing high-bandwidth content such as videos to large numbers of spectators in a stadium, it is possible to increase the traffic capacity to some extent by installing wireless APs more densely, but the traffic capacity does not rise in proportion to the number of installed APs. In a stadium, the line of sight between the spectator seats is particularly good, and it is usually possible for radio waves from a wireless LAN installed in the back stands to be received in the main stands. In this sort of environment, many wireless APs have to contend for the same frequency channel, resulting in lower traffic capacity per wireless AP.

Development of the fifth-generation mobile communications system (5G) is underway worldwide as part of efforts to exploit the expected commercial opportunities that will arise in 2020. Mobile traffic is continuing to grow due to the increasing use of smartphones and advances in mobile applications. Although the rate of increase has eased lately, it is still growing by a factor of 1.4 every year according to a recent report [3], and it is expected that the amount of traffic in 2020 could be about a thousand times greater than in 2010. To accommodate this traffic, 5G technologies that use a combination of diverse wireless access techniques, including the use of new frequency bands, are being researched and developed, and it is expected that wireless LANs and other unlicensed wireless technologies will also be used as a way of supporting 5G traffic [4].

At the Radio Policy Vision Council that met in December 2014, the Ministry of Internal Affairs and Communications resolved to secure a frequency bandwidth in the 2700-MHz range for mobile communication systems by 2020, with the assumption that mobile frequencies will be integrated with the frequencies used for wireless LANs [5]. However, as mentioned above, wireless LANs using unlicensed frequencies suffer from poor throughput in congested radio environments. Consequently, improving the characteristics in congested environments is a major challenge in order to accommodate mobile traffic in unlicensed bands.

3. Development of wireless LAN technology at NTT

In order to implement 5G services in time for the big events of 2020, further evolution of wireless LAN is expected. To respond to these needs, we must ensure that service quality is maintained even in environments where wireless APs and terminals are packed closely together. One way of minimizing the deterioration of wireless LAN quality in high density environments without damaging the ease of access to ordinary users to wireless LAN services is to continue using the CSMA/CA distributed access control method while optimizing wireless resources such as the transmission power and the number and bandwidth of wireless channels.

The current wireless APs generally choose wireless channels in which there are few interfering APs after observing wireless AP signals in the vicinity, but in environments with high wireless LAN density, APs that are liable to cause interference are themselves subject to interference from other APs. As a result, the wireless environment can become extremely congested. In such circumstances, a complete overhaul of the radio environment is warranted. At NTT laboratories, we are researching and developing an architecture called cooperative wireless LAN, whereby information about the wireless environment is collected from multiple APs, and the parameters of each wireless AP are set appropriately based on this information. Wireless access control is still performed by CSMA/CA autonomous distributed control, while some of the wireless AP parameters are optimized by centralized control in order to improve the overall bandwidth usage efficiency.

In May 2014, the IEEE 802.11 Working Group embarked on the standardization of high-efficiency wireless LAN (11ax) as the next generation standard. The technical requirements set by this standard include the provision of an operating mode where the average throughput is at least four times that of a conventional terminal in high-density environments, and work is under way with the aim of implementing this standard by the end of 2018. Although compatibility with high-density environments is thus being promoted for standard technology, the range of parameters that can be set according to diverse needs in the 11ax standard is becoming broader, and we believe that wireless AP control would work more effectively in a cooperative wireless LAN. NTT is actively participating in the 11ax standardization process by promoting the implementation of standards that are suitable for cooperative wireless LAN configurations, and leading in the development of 11ax-compatible radio resource control techniques.

4. Efforts aimed at implementing a cooperative wireless LAN platform

It is thought that a cooperative wireless LAN architecture, where some of the wireless AP parameters are controlled centrally from the cloud, could be developed to provide diverse services in addition to wireless resource control functions (**Fig. 2**). This section introduces a number of techniques that we are working on with the aim of providing a platform with diverse functions obtained by controlling wireless APs.

4.1 Cooperative wireless LAN channel setup technique

The configurable wireless resources of an ordinary wireless AP include the wireless channel and channel

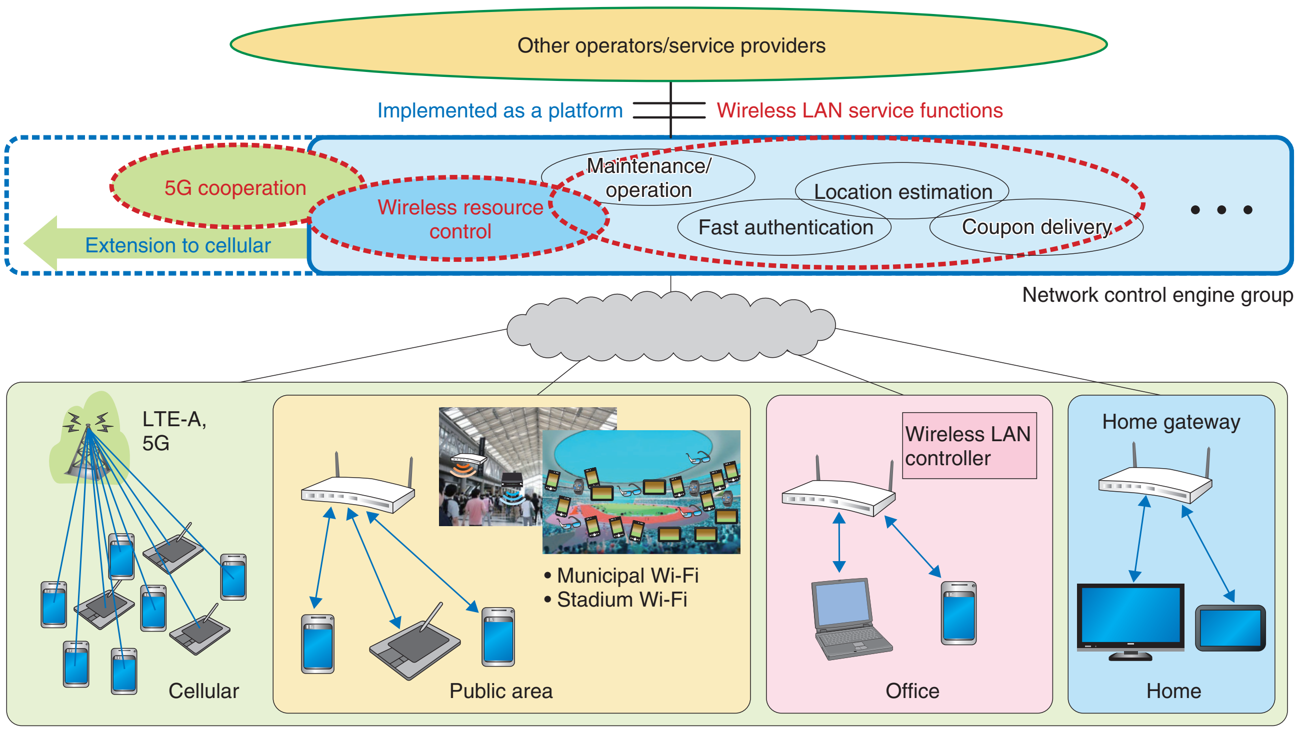


Fig. 2. Platform for deployment of diverse wireless services.

bandwidth. In 2015, we developed prototype channel configuration software that optimally configures these wireless resources based on wireless environment information collected from multiple wireless APs. This technology uses the collected wireless environment information to construct a virtual wireless LAN environment on a server, and repeatedly tries out different resource settings in this virtual environment in order to converge settings that maximize the predicted throughput performance [6]. We used this technique to perform optimal wireless channel configuration in a free Wi-Fi service at the Tsukuba Forum 2016 event. We also constructed a premium area where specific wireless APs were configured for high-speed communication, enabling us to validate this technique (**Fig. 3**).

4.2 Cooperative wireless LAN with distributed smart antennas

In environments such as stadiums where wireless LANs are subject to very high-density use, it is not sufficient to simply optimize the wireless channel configuration. Instead, technology is needed to suppress interference more fundamentally. We are therefore developing a cooperative wireless LAN system with distributed smart antennas arranged so that multiple wireless AP antennas are placed close to the user terminals. Since this technique allows communication to take place without scattering radio waves around any more than necessary, it allows frequency channels to be recycled over shorter distances, thereby maximizing the area throughput [7] (**Fig. 4**). Although distributed smart antenna technology has already started to be introduced into mobile systems, its application to CSMA/CA systems has up until now been considered difficult. The application of distributed smart antennas should make it possible to achieve at least double the overall throughput of a conventional system.

4.3 Wireless LAN service function: radio wave environment visualization

By making use of the wireless environment information collected by terminals as well as wireless APs, it is possible to perform wireless control that is better suited to the user's environment. In the future, by analyzing the collective intelligence obtained as wireless environment information from devices that are in regular use, it should be possible to ascertain the status of wireless environments at many different

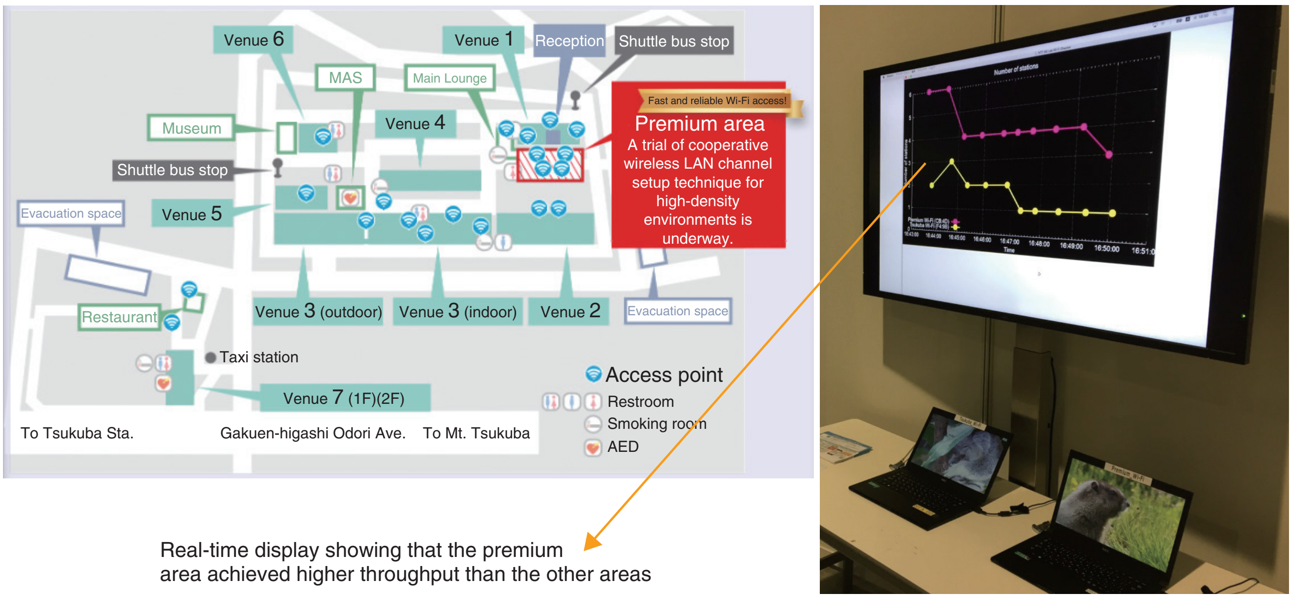


Fig. 3. Conducting trials at the Tsukuba Forum venue.

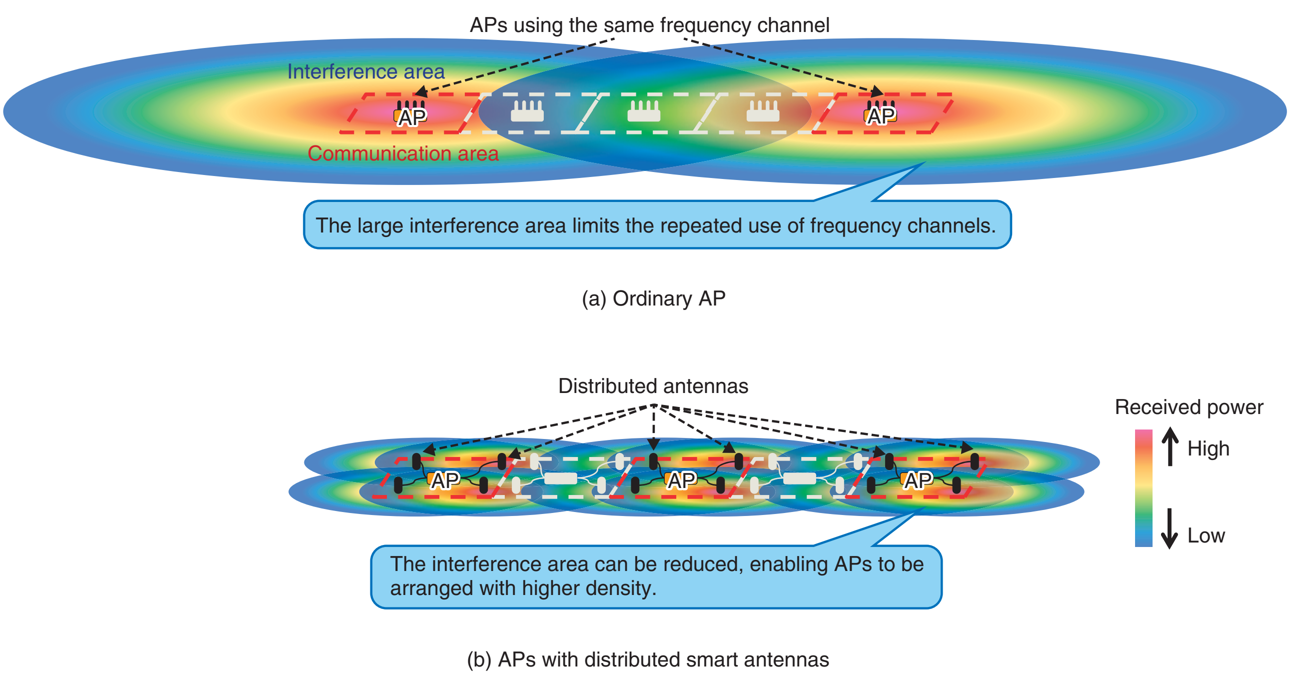
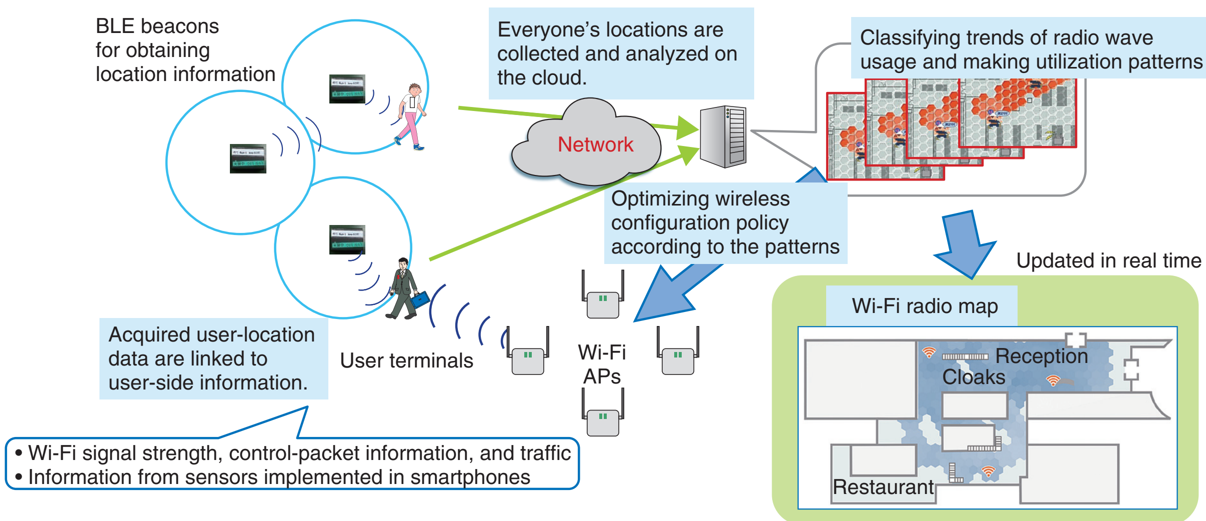


Fig. 4. Application of cooperative wireless LAN technology to distributed smart antennas.

locations in real time, and to promote the efficient use of radio waves. At the NTT R&D Forum held in February 2016, we tested a service based on a reduced set of features from the technology discussed here that created and provided free Wi-Fi signal strength maps using a terminal application provided to visitors. As a result, we confirmed that it was possible to visualize the wireless environment in almost real time [8]



BLE: Bluetooth Low Energy. Bluetooth is a registered trademark of Bluetooth SIG Inc.

Fig. 5. Wireless LAN service function: radio wave environment visualization.

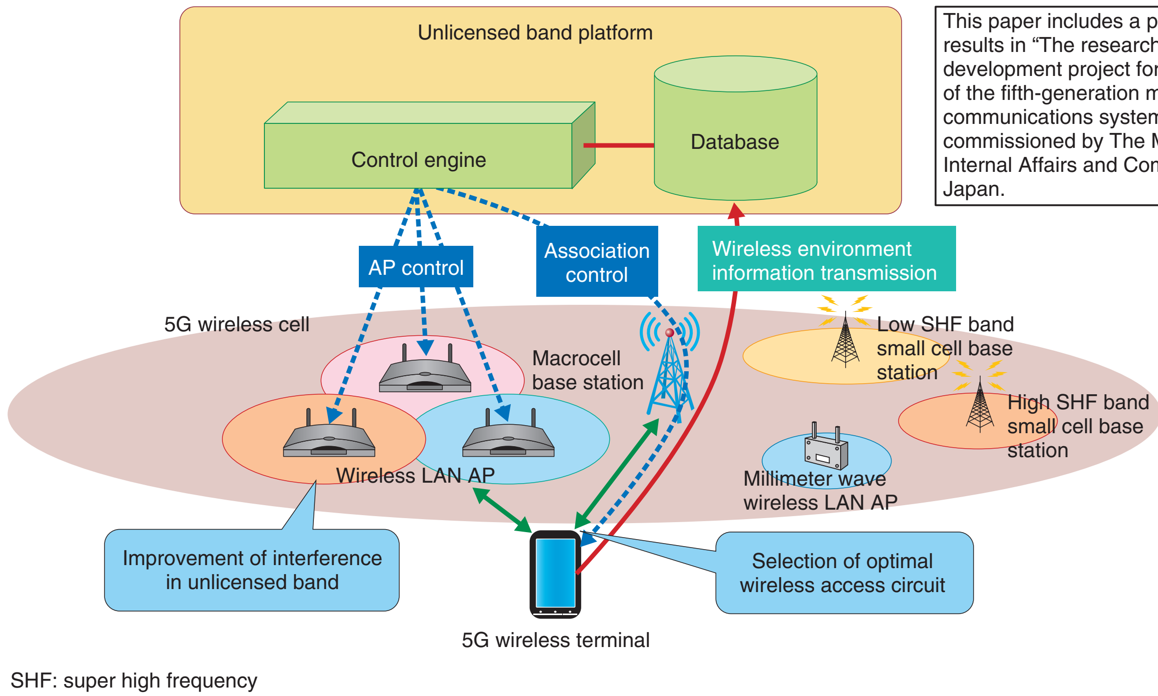
(**Fig. 5**).

4.4 Cooperation between 5G and wireless LANs

In 5G, it is expected that devices will not only be able to switch between wireless LAN connections and mobile circuits as they have been able to do so far, but will also be able to use unlicensed wireless services in close cooperation with mobile networks as a heterogeneous network [5]. The key technologies needed to achieve this are thought to include technologies for ascertaining the quality of unlicensed wireless circuits and controlling wireless resources to reduce interference. Even in unlicensed wireless services where the quality tends to become unstable during high-density use, it will still be possible to select and use services of favorable quality if the service quality can be estimated with high precision [9]. Also, when using wireless resource control to improve the quality of unlicensed wireless services, mobile circuits can be used as control circuits for unlicensed wireless services to perform control using wireless environment information collected from the terminals. This should make it possible to improve the service quality even further [10] (**Fig. 6**). This paper includes a part of the results in "The research and development project for realization of the fifth-generation mobile communications system" commissioned by The Ministry of Internal Affairs and Communications, Japan [11].

5. Future prospects

With the growing popularity of inexpensive yet highly convenient commercial products based on IEEE standard technology, wireless LANs have become essential as a means of connecting mobile terminals to networks. However, a growing number of use cases cannot be accommodated with standard technology alone. To meet growing demand with limited radio resources while providing exciting new services, we think that there will be many more situations in the future where our technology will be required. At NTT Access Network Service Systems Laboratories, we will continue developing wireless LAN solutions for ultra-high density environments, and contributing to the realization of reasonably priced 5G services that cooperate with wireless LAN services.



This paper includes a part of the results in "The research and development project for realization of the fifth-generation mobile communications system" commissioned by The Ministry of Internal Affairs and Communications, Japan.

Fig. 6. 5G mobile/wireless LAN cooperation.

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Low Latency Dynamic Bandwidth Allocation Method with High Bandwidth Efficiency for TDM-PON

Saki Hatta, Nobuyuki Tanaka, and Takeshi Sakamoto

Abstract

This article describes a low latency dynamic bandwidth allocation (DBA) method with high bandwidth efficiency that is intended for use in campus area networks and mobile fronthaul based on TDM-PON (time division multiplexing passive optical network). These network systems require low latency of under 100 µs and high bandwidth efficiency. Our method involves only three steps for allocation and employs an adaptive DBA cycle depending on the traffic load. The DBA cycle length, which is proportional to the latency, can be minimized because the simple allocation steps are appropriate for hardware implementation. Our DBA method automatically optimizes the cycle length to reduce the latency and improve bandwidth efficiency. We implemented it on a 10-gigabit Ethernet passive optical network (10G-EPON) media access control system-on-a-chip and evaluated the allocation results and the latency on the 10G-EPON system. Our DBA achieved a minimum latency of 60 µs with priority control and high bandwidth efficiency, depending on traffic.

Keywords: TDM-PON, DBA, low latency

1. Introduction

Time division multiplexing passive optical network (TDM-PON) systems, such as gigabit passive optical networks (GPON) [1] and Ethernet passive optical networks (EPON) [2], have been widely deployed for fiber-to-the-home (FTTH) services because of their cost advantage over point-to-point systems. Point-to-point systems such as large campus area networks (campus-LANs) and mobile fronthaul (MFH) for the fifth-generation mobile communications network (5G) are still potential markets for TDM-PON [3, 4].

However, there are two problems with employing TDM-PON for MHF and campus-LANs. The first is the large upstream latency. In TDM-PON, dynamic bandwidth allocation (DBA) must be implemented in an optical line terminal (OLT) to avoid upstream data collisions. DBA increases the latency. The second problem is bandwidth efficiency. In general, the bandwidth efficiency decreases in proportion to the reduction in latency, as shown in **Fig. 1**.

Reducing the grant processing time (GPT), which is the time taken to process the DBA in the OLT, is important to reduce the latency. The handshaking between the OLT and optical network units (ONUs) derived using the status reporting (SR) method is

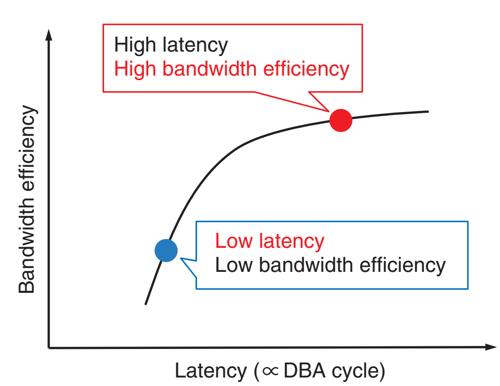


Fig. 1. Latency vs. bandwidth efficiency.

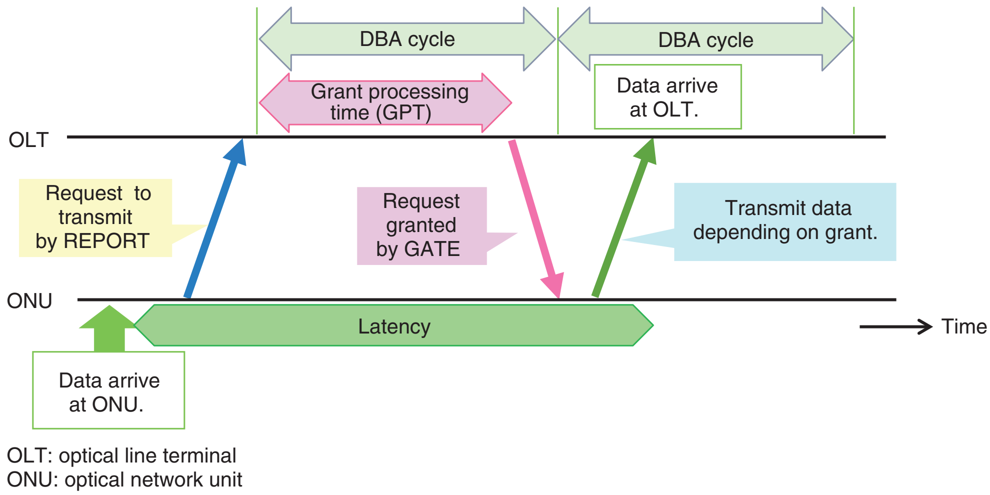


Fig. 2. Message exchange between ONU and OLT in SR-DBA.

shown in **Fig. 2**. When the OLT receives all of the ONU's REPORTs (a type of control message), it begins to calculate the transmission time and start timing for upstream data using a grant processor. The transmission time is a time slot of a DBA cycle, which is proportional to the latency. After the calculation, the OLT informs ONUs of these results by using GATEs (another type of control message) to grant each ONU's data transmission. The length of the GPT depends on the DBA method, and a complex method increases it. The latency due to DBA for FTTH services is now on the order of milliseconds [5] because of its advanced software processing designed to achieve strict fairness.

To solve the two problems specific to TDM-PON, we devised a low latency DBA method with greater bandwidth efficiency. In addition, our DBA is equipped with a priority-control function. This is because in campus-LANs, the layer-two switch has to support priority control among its ports. Thus, priority control among ONUs is an important requirement for TDM-PON-based campus-LANs.

2. Low latency DBA method to improve bandwidth efficiency

We propose a new DBA algorithm consisting of three simple steps that is appropriate for hardware (HW) implementation. HW implementation makes it possible to reduce the GPT and the latency. In addition, we adopt an adaptive DBA cycle to improve bandwidth efficiency. The adaptive cycle length can optimize both latency and bandwidth efficiency depending on the traffic load from ONUs.

Our DBA algorithm is shown in **Fig. 3**. It consists of three simple steps. First, the grant processor allocates a shorter time that is equivalent to the requested bandwidth (RB_n, where n represents the identification number of ONU) or a guaranteed bandwidth (GB_n) for each ONU. Next, it allocates the unallocated bandwidth (ΔUB_I) for ONUs, requesting more bandwidth in descending order of priority. After the second allocation, in the high-traffic-load case, high bandwidth efficiency is achieved and the latency is determined as the maximum latency that has been set as an initial configuration. Last, when excess bandwidth (ΔEB) is generated, that is, in the low-traffic-load case, our DBA reduces the length of the DBA cycle to achieve low latency because high bandwidth efficiency is not demanded. The details of the three-step DBA method are explained as follows.

The DBA cycle, T_{DBA}, is expressed as

$$T_{DBA} = T_{rep} + T_{data}, \quad (1)$$

where T_{rep} and T_{data} represent the time for sending REPORTs and the time for sending user data, respectively. T_{rep} depends on the number of linked ONUs, N ($N = 1,2, \ldots$). It is expressed as

$$T_{rep} = BOH \times N, \quad (2)$$

where BOH represents the burst overhead time, which is determined by the optical transceiver ON/

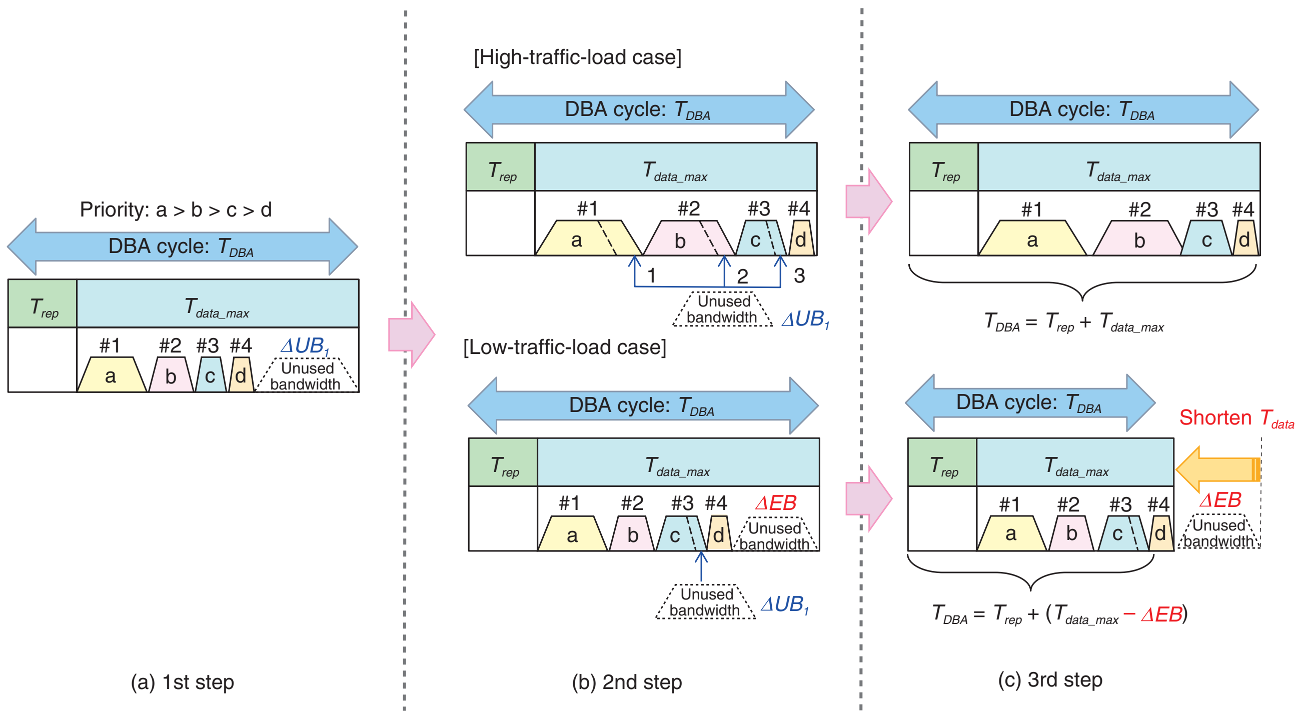


Fig. 3. Proposed DBA.

OFF time and the sync time. It is fixed.

In the initial configuration of our DBA, T_{data_max}, four kinds of priority (a > b > c > d), and the GB_n for each ONU are set. Here, T_{data_max} represents the maximum length of T_{data}. We can set an arbitrary length of T_{data_max} according to the system requirements. After the configuration has been set, when REPORTs including accumulated data in ONUs come to the OLT, the grant processor starts to allocate a time slot for each ONU in T_{data} as shown in Fig. 3. First, as shown in Fig. 3(a), the grant processor calculates RB_n using the accumulated data and allocates a shorter time that is equivalent to the GB_n or RB_n for each ONU. The allocated time, namely, the grant length for each ONU ($GL1_n$) is expressed as

$$RB_n < GB_n \;\; GL1_n = (T_{data} - BOH \times N) \times \left(\frac{RB_n}{R_{max}}\right) \quad (3)$$

$$GB_n < RB_n \;\; GL1_n = (T_{data} - BOH \times N) \times \left(\frac{GB_n}{R_{max}}\right), \quad (4)$$

where R_{max} represents the effective maximum throughput between the OLT and ONUs, excluding the overhead of line coding. The above allocation enables each ONU to always acquire the guaranteed bandwidth or more in one period of the DBA cycle.

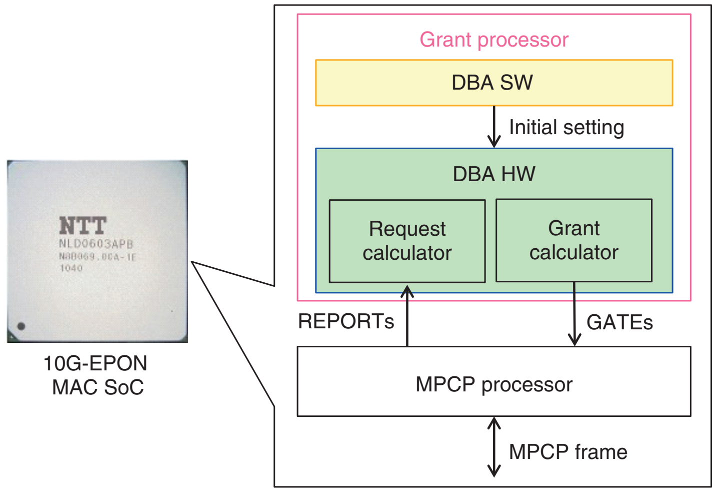
When the sum of RB_n for each ONU is larger than the sum of GB_n, the allocation is finished and the GB_n is allocated for each ONU. In contrast, when the sum of RB_n for each ONU is smaller than the sum of GB_n, unallocated bandwidth (ΔUB_m, $m = 1,2, \ldots$, where m represents the number of iterations until $\Delta UB_m = 0$) is derived from the delta between the sum of RB_n and GB_n. Then, the second allocation starts in Fig. 3(b). The grant processor allocates the ΔUB_m for each ONU requesting more bandwidth, in descending order of priority. This achieves priority control among ONUs. The second grant length for each ONU ($GL2_n$) is expressed as

$$\Delta UB_m > GL2_n \;\; GL2_n = (T_{data} - BOH \times N) \times \left(\frac{(RB_n - GB_n)}{R_{max}}\right) \quad (5)$$

$$\Delta UB_m < GL2_n \;\; GL2_n = \Delta UB_m \quad (6)$$

$$\Delta UB_{m+1} = \Delta UB_m - GL2_n. \quad (7)$$

When the grant processor finishes allocating all unallocated bandwidth, the second allocation ends, which is for high-traffic-load cases. The grant length eventually conveyed to ONUs by GATEs is expressed as



MPCP: Multi-Point Control Protocol
SW: software
HW: hardware

Fig. 4. Implementation of grant processor with our DBA.

$$GL_n = GL1_n + GL2_n. \quad (8)$$

T_{DBA} in the high-traffic-load case is expressed as

$$T_{DBA} = T_{rep} + T_{data\_max}. \quad (9)$$

The latency is determined as the maximum latency that has been set as an initial configuration. In contrast, in the low-traffic-load case, excess bandwidth (ΔEB) is generated after all ΔUB_m allocations. ΔEB is expressed as

$$\Delta EB = \Delta UB_1 - \sum GL2_n. \quad (10)$$

Then the third step starts. The grant processor subtracts the time equivalent to ΔEB from T_{data_max}. As a result, T_{DBA} in the low-traffic-load case is expressed as

$$T_{DBA} = T_{rep} + (T_{data\_max} - \Delta EB). \quad (11)$$

The proposed DBA algorithm is appropriate for implementation in HW because the simple calculations for three-step bandwidth allocation from Eqs. (1) to (11) are repeatedly executed in each DBA cycle. Therefore, it can greatly shorten the T_{data_max} length after the second step of allocation.

3. Experimental evaluation

We conducted an experiment in order to evaluate our DBA technique. We describe here the experiment and results.

3.1 Implementation and experimental setup

To evaluate the allocation results and latency, we implemented our DBA function in the grant processor on a 10-gigabit Ethernet passive optical network (10G-EPON) media access control (MAC) system-on-a-chip (SoC) [6] for the OLT as illustrated in **Fig. 4**. A schematic of the experimental setup is shown in **Fig. 5**. We utilized a 10G-EPON system with one OLT and five ONUs (ONUs#1–5). The local area network (LAN) analyzer was connected to the OLT-SNI (server node interface) and the ONU-UNI (user network interface) to measure throughput and generate RB_n from the ONUs. In this system, ONUs#1–4 were set to measure throughput and the DBA cycle. ONU#5 was set to adjust ΔUB_1, which can be generated by adjusting RB_5 of ONU#5.

In the experiment, as priorities, "a" was set to ONU#1, "b" to ONU#2, "c" to ONU#3, and "d" to ONU#4 and ONU#5. We set GB_n (n = 1–4) at 500 Mbit/s. A burst overhead time was set to 3280 ns. Upstream Ethernet-frame data of 1518 bytes were transmitted from the LAN analyzer at 1000 Mbit/s, which is equivalent to RB_n (n = 1–4). We adjusted

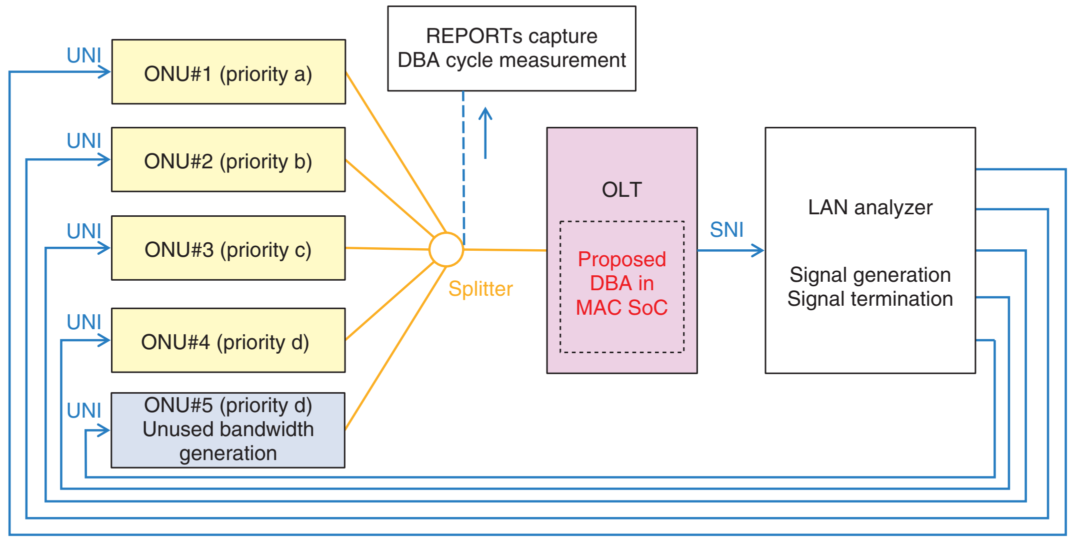


Fig. 5. Experimental setup.

ΔUB_1 using ONU#5. To measure the DBA cycle, we captured REPORTs from ONU#1 and investigated the received interval, which is equivalent to the DBA cycle.

First, to confirm the minimum latency utilizing the proposed DBA, we calculated the maximum latency from the measured DBA cycle in the high-traffic-load case when T_{data_max} was set to 21, 216, 416, 816, or 1016 µs. The latency in the TDM-PON system is theoretically nearly equal to 1.5 DBA cycles [7]. Next, we confirmed the priority control by adjusting the unallocated bandwidth using ONU#5 and measuring throughput for ONUs#1–4 after DBA allocation. Finally, we confirmed the automatically adjusted function by investigating the change in DBA cycle length when ΔUB_1 was adjusted. T_{data_max} was set to 1000 µs so that the initial bandwidth efficiency would be more than 95%.

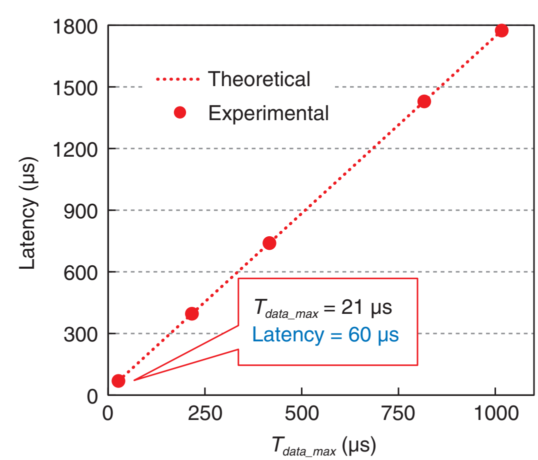


Fig. 6. Maximum latency.

3.2 Measured results

The maximum latency calculated from the DBA cycle measurement is shown in **Fig. 6**. The result of the DBA cycle measurement matches the theoretical value. One can see that when the minimum setting of T_{data_max} was 21 µs, the minimum latency of 60 µs was achieved. This is because most of the processing of our DBA is handled by HW.

The results of measuring throughput and DBA cycle are plotted in **Fig. 7** and **Fig. 8**. The throughput results match the theoretical values. When $\Delta UB_1 = 0$, in other words, when the sum of RB_n (n = 1–5) was larger than the sum of GB_n (n = 1–5), all ONUs were allocated the guaranteed bandwidth of 500 Mbit/s. When $\Delta UB_1 > 0$ but $\Delta EB = 0$, that is, in the high-traffic-load case, ΔUB_1 was allocated to ONU#1 first, because its priority was the highest among the ONUs, and its throughput reached 1000 Mbit/s of RB_1. After that, ΔUB_1 was allocated in descending order of priority. The length of the DBA cycle stayed constant.

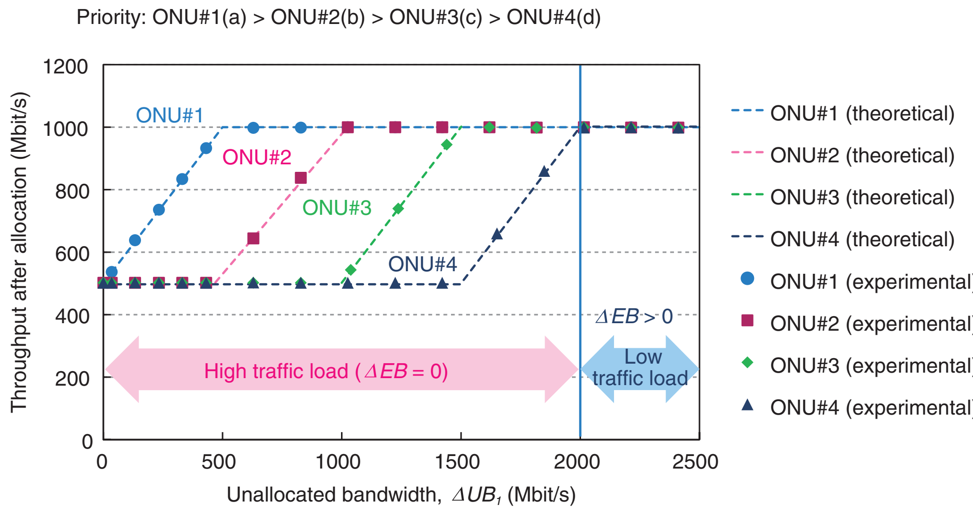


Fig. 7. Throughput measurement result after allocation.

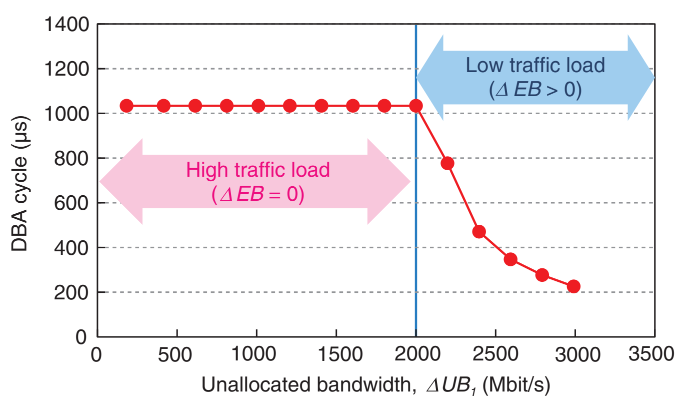


Fig. 8. DBA cycle length depending on traffic load.

On the other hand, when $\Delta EB > 0$, that is, in the low-traffic-load case, the throughput stayed constant at 1000 Mbit/s. The length of the DBA cycle automatically decreased as ΔEB increased. These results indicate that our method can automatically adjust the DBA cycle length depending on the traffic load. When the initial T_{data_max} was set to 21 µs in the low-traffic-load case, our DBA achieved low latency with high bandwidth efficiency.

4. Conclusion

We proposed a DBA method with an adaptive DBA cycle depending on traffic load for a TDM-PON that accommodates future campus-LANs or 5G MFH. The results of experiments showed that the minimum latency was 60 µs or less owing to simple three-step allocation and cooperation with HW on a 10G-EPON MAC SoC. Moreover, they demonstrated that our method automatically adjusts the DBA cycle length and the bandwidth efficiency depending on traffic load. These results show that our DBA can be used in various networks employing TDM-PON, such as future campus-LANs and 5G MFH.

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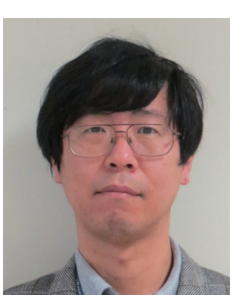

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Report on ITU Telecom World 2016 and ITU Kaleidoscope 2016

Hideyuki Iwata, Kazuhide Nakajima, and Noriyuki Araki

Abstract

ITU Telecom World 2016 and the eighth ITU Kaleidoscope academic conference, both of which are organized by the International Telecommunication Union (ITU), took place November 14–17, 2016, at the IMPACT Exhibition and Convention Center, Bangkok, Thailand. With the demise of His Majesty King Bhumibol Adulyadej of Thailand in October, ITU Telecom World was formally opened in a solemn atmosphere by Her Royal Highness Princess Maha Chakri Sirindhorn, second daughter of the late king. This article gives an overview of the exhibits and discussions at the ITU Telecom World and the accompanying Kaleidoscope academic conference.

Keywords: ITU Telecom World, ITU Kaleidoscope, ICT

1. Overview of ITU Telecom World 2016

ITU Telecom World 2016 was a four-day event organized by the International Telecommunication Union (ITU) and attended by some 8800 participants. It brought together some 250 exhibitors from 37 nations and 173 speakers from 56 nations. Over 330 information and communication technology (ICT) leaders from 90 countries, representing both the public and private sectors, took part in the discussions.

1.1 Overview of roundtables and other main meetings

Following the opening address by Her Royal Highness Princess Maha Chakri Sirindhorn, ITU Secretary-General Houlin Zhao, the Prime Ministers of Luxembourg and Vanuatu, the Crown Prince of Tonga, the Deputy Prime Minister of Thailand, and others gave speeches. In the morning of Day 2, an Economic and Industry Roundtable was held with senior executives of telecommunications operators, vendors, and financial organizations in attendance.

In the afternoon of Day 2, a Ministerial Roundtable took place with participation by Thailand, Vanuatu, Bahamas, Bangladesh, Belarus, Cambodia, Côte d'Ivoire, Samoa, Hungary, Iran, Japan, Nigeria, and Switzerland. The meeting was chaired by the Deputy Prime Minister and Acting Minister of Digital Economy and Society of Thailand. Representing Japan was Vice-Minister for Policy Coordination Shigeki Suzuki. He stressed the importance of strengthening access networks (including making overseas investments), pursuing innovation using Internet of Things (IoT) and big data, and ensuring the security and free flow of information.

1.2 Overview of exhibition

There were 14 country pavilions—7 from Africa (Kenya, Ghana, Rwanda, Nigeria, Madagascar, Zimbabwe, and Senegal), 6 from Asia, the host region (Iran, Japan, China, South Korea, Malaysia, and Thailand), and Azerbaijan. Exhibitors in the Japan Pavilion were NTT Communications, Internet Initiative Japan, Japan Battery Regeneration, National Institute of Information and Communication Technology (NICT), and Nextech. Japanese exhibitors in the ITU Telecommunication Standardization Sector (ITU-T) booth were NEC, OKI, NICT, and the Telecommunication Technology Committee. In the NTT Communications booth, NTT Communications Thailand, the company's local subsidiary, exhibited information on its datacenters. That booth also incorporated exhibits by NTT Security and NTT DATA (**Photo 1**). Nextech, a Hokkaido-based company,

Photo 1. NTT Communications exhibit at Japan Pavilion.

Photo 2. Greeting by Chaesub Lee, the director of TSB.

which exhibited a Wi-Fi[*1] access point system with a solar panel attached, received an SME[*2] award. Occupying 30% of the exhibition floor area, the Thailand pavilion exhibited the ICT policies of its ministries, agencies, and research institutes, including the National Broadcasting and Telecommunications Commission, Thailand Post, the Ministry of Science and Technology, the Ministry of Digital Economy and Society, and the Defense Technology Institute. Also on show were smart solutions developed by telecommunications operators including AIS, CAT, dtac, TOT, and True. In addition, there were exhibits by a number of local SMEs, indicating the steady proliferation of ICT-related enterprises in Thailand.

1.3 Next event

ITU Telecom World 2017 will be held September 25–28, 2017, in Busan, South Korea.

2. Overview of ITU Kaleidoscope 2016

In conjunction with ITU Telecom World 2016, the ITU Kaleidoscope academic conference was held November 14–16, 2016. The objective of the conference was to understand and discover standardization technologies and needs that ITU should consider in coming years by examining research on information and telecommunication technology from different perspectives from an early stage. The main theme of this eighth conference was "ICTs for a Sustainable World." It was attended by some 100 persons from 21 countries. There were 25 presentations: 19 lectures and 6 poster presentations.

2.1 Opening ceremony and keynotes

In the opening ceremony, welcoming speeches were given by speakers from the host country: Virasak Kittivat, Principal Advisor for Foreign Affairs, Ministry of Digital Economy and Society, and Supot Tiarawut, Advisor to the President of Chulalongkorn University. Mr. Tiarawut spoke on behalf of Bundhit Eua-arporn, President of Chulalongkorn University and also the ITU Kaleidoscope 2016 General Chairman. These speeches were followed by a greeting remark by Chaesub Lee, Director of ITU's Telecommunication Standardization Bureau (TSB), the organizer of ITU Telecom World (**Photo 2**).

There were three keynote addresses. Prof. Dr.-Ing[*3] Thomas Wiegand of the Fraunhofer Heinrich Hertz Institute, Germany, reported on research and development (R&D) trends in machine learning. He spoke about concerns regarding the increase in video transmission traffic, the use of video coding compression technology to reduce the volume of data transfers, and the research activities aimed at reducing power consumption in communications. He also touched on future technical trends and went on to discuss different fields to which machine learning can be applied, including the application of IMT-2020 (5G) to driverless vehicles, reduction of delay time through automation of mobile base station switching, and the application of machine learning to big data.

Mr. Hossein Moiin, Executive Vice President and Chief Technology Officer for Nokia Mobile Networks, noted that Nokia has defined environmental

*1 Wi-Fi is a registered trademark of Wi-Fi Alliance.
*2 Small- and medium-sized enterprises, startup enterprises, and venture capital enterprises.
*3 Dr.-Ing: Doctor of Engineering

indicators for its entire production cycle. He also introduced the future goals and direction of the environmental aspect of his company's R&D, which he said was founded on three guiding principles: to enhance quality of life, protect the environment, and respect humanity through further use of IoT. The BBC screened a video on its activities addressing environmental issues such as global warming and the need to reduce carbon dioxide emissions. The video explained the trade-off between the number of viewers of broadcast communications and the environmental impact, and addressed the issue of the environmental impact of travel for program production.

2.2 General sessions

There were six general sessions with six distinct themes: the role of ICT in environmental conservation, standardization of services and quality, efficient frequency utilization, network innovation, service development, and sustainability.

The use of wireless links in coastal fishing in India was introduced in the session on the role of ICT in environmental conservation. Varying usage fees according to the quality of the communications service was proposed in the session on standardization of services and quality. The session on efficient frequency utilization focused on methods of frequency resource assignment for device-to-device systems that use wireless links. In the session on network innovation, it was proposed to execute delay management and to place a caching function in all network elements. The need for remote medical care and remote rehabilitation in aging societies was advocated in the session on service development. The need for standards in relation to privacy and the importance of wireless communication standards for drones were reported in the session on sustainability.

Kazuhide Nakajima (co-author of this article) of NTT Access Network Service Systems Laboratories presented a paper entitled "Space Division Multiplexing Technology: Next-generation Optical Communication" [1]. He introduced a multi-core fiber, consisting of a relatively small number of cores, that is compatible with a conventional G.652 single-mode fiber and stated that the development of this optical fiber was already at an advanced stage where it is possible to hold concrete discussions on standardization and commercial development.

Photo 3. Kazuhide Nakajima (center) receiving a Best Paper Award.

2.3 Best Paper Award

The Best Paper Award review committee for this academic conference evaluated the content and presentation of each paper and selected three papers to receive awards. One went to the above-mentioned paper on space division multiplexing technology (**Photo 3**).

2.4 Looking ahead

With its membership exceeding 100 universities and other institutions, ITU Academia sees its activities expanding. The restrictions on confining the scope of its activities to ITU-T, ITU-R (ITU Radiocommunication Sector), and ITU-D (ITU Telecommunication Development Sector) was lifted in 2015. Today, academia members can participate in any ITU meetings without restriction. This was a boon to the members because it enables them to obtain information and enables their junior personnel to gain experience in international activities. That is why membership has been growing steadily. At WTSA-16 (World Telecommunication Standardization Assembly 2016), held in November 2016, a resolution encouraging academia activities was adopted. It is expected that Kaleidoscope will continue to play a liaison role between ITU and academia.

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Senior Research Engineer, Supervisor, Research and Development Planning Department, NTT.

He received a Ph.D. in electrical engineering from Yamagata University in 2011. From 1993 to 2000, he conducted research on high-density and aerial optical fiber cables at NTT Access Network Service Systems Laboratories. Since 2000, he has been responsible for standardization strategy planning for NTT research and development. He has been a delegate of International Electrotechnical Commission (IEC) Subcommittee 86A (optical fiber and cable) since 1998 and of the ITU-T Telecommunication Standardization Advisory Group since 2003. He is a vice-chair of the Expert Group on Bridging the Standardization Gap in the Asia-Pacific Telecommunity Standardization Program Forum. In 2004, he received an award from the IEC Activities Promotion Committee of Japan for his contributions to standardization work in the IEC.

Kazuhide Nakajima

Senior Research Engineer, Supervisor (Senior Distinguished Researcher) and Group Leader of NTT Access Network Service Systems Laboratories.

He received an M.S. and Ph.D. in electrical engineering from Nihon University, Chiba, in 1994 and 2005. In 1994, he joined NTT Access Network Service Systems Laboratories, where he engaged in research on optical fiber design and related measurement techniques. He is also acting as the rapporteur of Question 5 in ITU-T Study Group (SG) 15. Dr. Nakajima is a member of the Institute of Electronics, Information and Communication Engineers (IEICE), the Institute of Electrical and Electronics Engineers (IEEE), and the Optical Society of America.

Noriyuki Araki

Senior Research Engineer, Access Media Project, NTT Access Network Service Systems Laboratories.

He received his B.E. and M.E. in electrical and electronic engineering from Sophia University, Tokyo, in 1993 and 1995. He joined NTT Access Network Service Systems Laboratories in 1995, where he researched and developed operation and maintenance systems for optical fiber cable networks. He has been contributing to standardization efforts in ITU-T SG6 since 2006. He was the rapporteur of Question 6 in ITU-T SG6 from 2006 to 2008 and the rapporteur of Question 17 in ITU-T SG15 from 2008 to 2012. He also served as the chairman of the ITU-T Focus Group on Disaster Relief Systems and Network Resilience and Recovery. He has been a vice-chair of ITU-T SG15 since 2013. He also contributes to the activities of IEC TC86 (Technical Committee 86: Fibre optics). He received the ITU-AJ award from the ITU Association of Japan in 2012. He is a member of IEICE.

Case Study of Bolt Corrosion in Remote Subscriber Module-Feeder Point

Abstract

This article describes causes of and countermeasures to corrosion in bolts used for securing RSBM-F (remote subscriber module-feeder point) equipment. This is the thirty-ninth article in a series on telecommunication technologies. This contribution is from the Materials Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: RSBM-F, bolt corrosion, countermeasures to corrosion

1. Introduction

Today's information and communication services are supported by various facilities including radio towers, utility poles, conduits, manholes, and tunnels. Among these, the remote terminal box (RT-BOX) and remote subscriber module (RSBM) play important roles in accommodating and multiplexing public and leased circuits and connecting them using optical fiber to NTT buildings. In particular, the remote subscriber module-feeder point (RSBM-F) has been installed at wiring points with the aim of converting metal cables to optical fiber. This equipment is installed outdoors and is therefore continuously exposed to a variety of environmental conditions such as wind, rain, and airborne salt. This makes periodic inspection of such facilities all the more important.

The RSBM-F is subject to inspections just as with other NTT facilities, and the facility inspection manual includes checks for abnormal operation of the RSBM-F main unit as well as other inspection items such as equipment doors and covers. However, no particular inspection method is specified for the steel bolts used to secure the RSBM-F equipment to the ground, and since these bolts are situated in locations that cannot be viewed from outside the equipment, they can be overlooked at the time of an inspection. These steel bolts are made of iron and therefore naturally generate concerns about corrosion-related deterioration due to the effects of the surrounding environment. Bolts that are deteriorating because of corrosion lose their ability to safely secure the equipment, so countermeasures are necessary to maintain their strength.

The Materials Engineering Group of the Technical Assistance and Support Center has investigated past occurrences of bolt corrosion in RSBM-F equipment. In this report, we introduce a case study of bolt corrosion in RSBM-F and describe its causes and countermeasures.

2. RSBM-F configuration

An RSBM-F consists of a main unit, pedestal, and base (**Fig. 1**). The main unit has upper and lower sections. The upper unit contains communication wiring, whereas the lower unit does not. The pedestal is a steel component used for securing the main unit to the concrete base.

There are two doors for maintenance purposes on the side of the RSBM-F (indicated by the colored rectangles on the left side of **Fig. 2**). The door to the upper section of the main unit that houses communication wiring includes packing that hinders the inflow

Fig. 1. External view of RSBM-F.

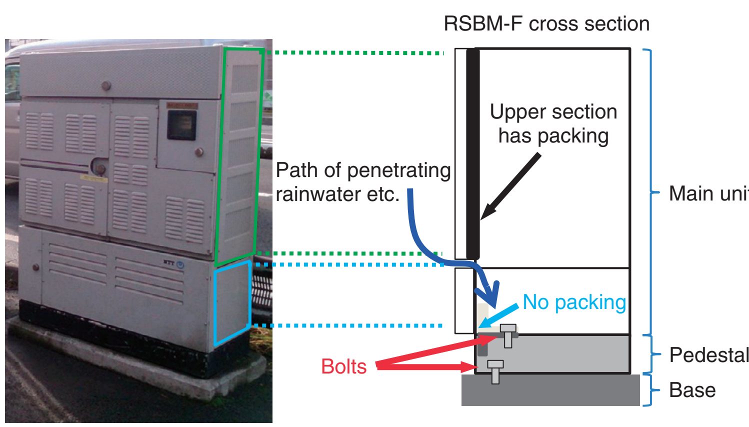

Fig. 2. RSBM-F configuration diagram.

of moisture such as rainwater or snowmelt from the outside. In contrast, the door to the lower section of the main unit, which houses no communication wiring, does not include packing. Opening the lower door brings a bolt into view (Fig. 2, right; **Fig. 3**). This bolt secures the main unit to the pedestal and is positioned in an easy-to-reach location. There is also a bolt beneath the above bolt for securing the pedestal to the concrete base (Fig. 2, right). This bolt, however, is situated in a recessed location, making its maintenance quite difficult.

3. Causes of bolt corrosion

Although inexpensive and high-strength material known as carbon steel is now commonly used for steel bolts, it is more susceptible to corrosion compared with the stainless steel used for the RSBM-F enclosure.

Because the door to the lower section of the main unit does not include packing, moisture such as rainwater or snowmelt can penetrate the main unit from that section (right side of Fig. 2). Moreover, because this door is normally closed, any moisture that penetrates this section cannot easily evaporate due to poor ventilation and shaded conditions. Thus, if such

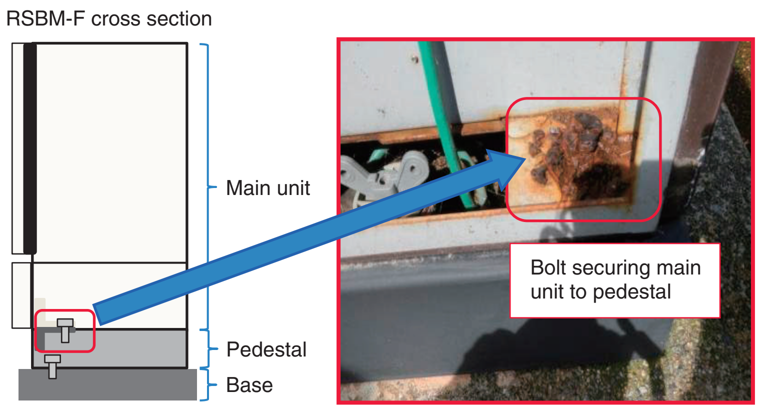

Fig. 3. Example of RSBM-F bolt corrosion.

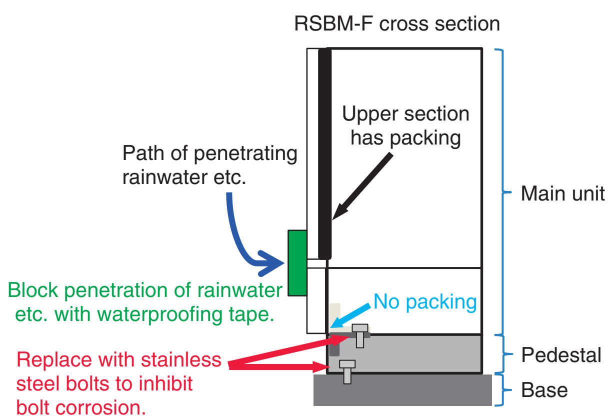

Fig. 4. Countermeasures to bolt corrosion.

moisture from the outside gets into the area surrounding the bolt, it will tend to accumulate, thereby hastening bolt corrosion. In addition, RSBM-F equipment installed in coastal regions may suffer from the penetration of saline matter from the ocean, while those installed along highways in regions with heavy snowfall may be affected by the penetration of chloride from snow-melting agents. Chemical solutions containing chloride are highly conductive, promoting the ionization of steel and accelerating corrosion. In particular, if corrosion of the bolt head progresses to a point of layered rusting, the bolt may expand and crack and then start to crumble as it loses its strength, making it difficult to remove (Fig. 3).

4. Countermeasures to bolt corrosion

If bolt corrosion progresses to the extent that the fixing ability of the bolt begins to deteriorate, the equipment runs the risk of shifting from its original position, and in the worst case, collapsing. Countermeasures to corrosion are therefore needed. We consider here two corrosion countermeasures, one on the equipment side and one on the bolt side (**Fig. 4**).

The countermeasure on the equipment side is to stop the moisture from penetrating the equipment. This can be accomplished, for example, by affixing waterproofing tape to the gaps surrounding the lower door to block the path of moisture.

The countermeasure on the bolt side, meanwhile, is to replace the bolt material with something that is more corrosion-resistant. This could be stainless steel (SUS430, SUS304, etc.), which would inhibit bolt corrosion.

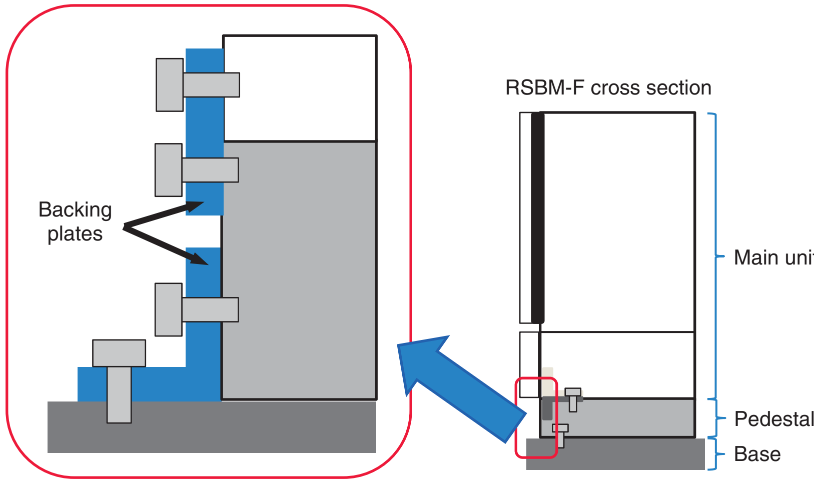

Fig. 5. Proposed technique of using backing plates to provide screw holes for securing bolts.

5. Future bolt corrosion countermeasures

Presently, no specific methods for inspecting RSBM-F steel bolts are described in facility inspection manuals, but it is nevertheless important that they be inspected together with other equipment inspection work. That is, when carrying out an RSBM-F inspection, the maintenance door on the side of the main unit should be opened and the state of the bolts visually checked. If corrosion is observed on a bolt, that bolt should then be replaced with a new one. Additionally, the use of stainless-steel bolts is recommended in order to suppress bolt deterioration by corrosion. However, if bolt corrosion at the time of a visual inspection has progressed as far as that shown in Fig. 3, it will be difficult to remove that bolt using an ordinary wrench. In such cases, a commercially available rusted-bolt removal tool can be used, or a method of destroying the bolt itself with a hammer or other tool to extract it can be considered.

There are cases, however, in which a corroded bolt cannot be replaced by the above methods or in which the bolt connecting the pedestal and concrete base cannot be replaced because of its difficult-to-reach location. A technique that can be considered for such situations is to use backing plates applied to the outside of the RSBM-F enclosure to provide new screw holes for securing bolts. We plan to conduct trials to study the effectiveness of this approach (**Fig. 5**).

6. Conclusion

In this report, we described causes of and countermeasures to corrosion in bolts used for securing RSBM-F equipment. Since bolt corrosion progresses as a result of moisture penetrating the equipment from the outside, it is necessary to either replace the bolts themselves with corrosion-resistant stainless steel bolts or to block the path of penetrating moisture. In future studies, we plan to examine methods for removing substantially corroded and deformed bolts and a method for providing new bolt-fixing locations by using backing plates applied to the outside of the RSBM-F enclosure.

Event Report: Tsukuba Forum 2016

Wataru Yamada, Keiji Okamoto, and Koji Ieda

Abstract

Tsukuba Forum 2016 was held on October 25 and 26. The theme of the forum was "Future Social Infrastructure: Co-creating a Better Life with Valued Partners ~ Innovative Access Network to Actualize the NetroSphere Concept." This article gives a brief overview of the speeches and exhibits presented at the forum.

Keywords: Tsukuba Forum, access network, NetroSphere

1. Introduction

The focus of Tsukuba Forum 2016 was transforming the access network of the future from a connecting network into a service platform that adds value to daily life. The main forum theme was "Future Social Infrastructure: Co-creating a Better Life with Valued Partners ~ Innovative Access Network to Actualize the NetroSphere Concept." In addition to NTT Access Network Service Systems Laboratories (AS Labs), 111 organizations (**Table 1**) participated and presented the latest research and development (R&D) and technology trends. The organizations included many from the NTT Group as well as member companies from the co-host organizations: the Information & Telecommunications Engineering Association of Japan, the Communication Line Products Association of Japan, and the Communications and Information Network Association of Japan.

2. Overview of speeches

The keynote speech and special speech were given at the Tsukuba International Congress Center on the first day. They were relayed from the main convention hall of the International Congress Center, which was the main venue, to a venue at the NTT Tsukuba Research and Development Center, with many audience members in attendance.

2.1 Keynote speech

Mr. Motoyuki Ii, Senior Executive Vice President, Senior Executive Manager of Corporate Sales Promotion Headquarters from NTT EAST, gave a keynote speech entitled "NTT EAST Group Activities Targeting Business Markets" (**Photo 1**).

First, he informed the audience of market trends, including that the number of subscribers to the FLET'S HIKARI optical broadband service is slowing down, that NTT EAST will shift its main target of business to the business user market rather than the consumer market, that the churn rate is low, the unit price is high, and that there is room for market expansion. He specifically discussed the idea of promoting the adaptation of information and communication technology (ICT) for small and medium enterprises, which form 99% of the business market in Japan, by combining various services utilizing an optical platform. He then stated that NTT EAST is now focusing on expanding the lineup of services for business markets, mainly to security, cloud, and support services. Moreover, NTT EAST is wholesaling optical services to various service providers as a new value creation with the Hikari Collaboration Model, and he gave examples of new services in which the services of those companies are combined with optical services. Mr. Ii also explained efforts to support the Hikari Collaboration collaborators by preparing various service menus for a charge.

Next, he explained that the introduction of ICT to small and medium enterprises has been lagging

Table 1. List of exhibitors.

■NTT Group companies
- NTT EAST CORPORATION
- NTT EAST-MINAMIKANTO CORPORATION
- NTT Infrastructure Network Corporation
- AIREC ENGINEERING CORPORATION
- NTT RENTAL ENGINEERING CO., LTD.
- NTT Broadband Platform, Inc.
- NTT GEOSPACE CORPORATION
- NTT WEST CORPORATION
- NTT FIELDTECHNO CORPORATION
- NTT Communications Corporation
- NTT Electronics Corporation
- NTT Advanced Technology Corporation
- NIPPON CAR SOLUTIONS CO., LTD.
- NTT History Center of Technologies

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

■Communication Line Products Association of Japan
- AICHI CORPORATION
- ASABA MANUFACTURING CO., LTD.
- OCC Corporation
- Okano Cable Co., Ltd.
- Kando Co., Ltd.
- KYOEI HIGH OPT Co., Ltd.
- JFE Metal Products & Engineering Inc.
- JAPAN RECOM Ltd.
- SHODENSHA CO., LTD.
- SWCC SHOWA CABLE SYSTEMS CO., LTD.
- Suzuki Giken Co., Ltd.
- SUDA SEISAKUSYO CO., LTD.
- Sumiden Opcom, Ltd.
- 3M Japan Limited
- Sumitomo Electric Industries, Ltd.
- SEIWA GIKEN INC.
- SENSHU ELECTRIC CO., LTD.
- DYDEN CORPORATION
- DAITO DENZAI CO., LTD.
- TADANO LTD.
- Tsushin Kogyo Electric Wire & Cable Co., Ltd.
- TOSHIN ELECTRIC CO., LTD.
- TOTSU-SOKEN CORPORATION
- SEI Optifrontier Co., Ltd.
- NISHI NIPPON ELECTRIC WIRE & CABLE CO., LTD.
- NIPPON CONCRETE INDUSTRIES CO., LTD.
- Nippon Seisen Cable, Ltd.
- Nippon Tsushin Denzai Co., Ltd.
- Hakusan Mfg. Co., Ltd.
- Fujikura Ltd.
- Furukawa Electric Co., Ltd.
- Masaru Industries, Ltd.
- Milliken Japan G.K.
- Dainichi Co. Ltd.
- Hitachi Metals, Ltd.

■Communications and Information Network Association of Japan (CIAJ)
- Anritsu Corporation
- NEC Corporation
- NEC Networks & System Integration Corporation
- NEC Magnus Communications, Ltd.
- Oi Electric Co., Ltd.
- OSAKI ELECTRIC CO., LTD.
- Oki Electric Industry Co., Ltd.
- Seiko Solutions Inc.
- NAKAYO, INC.
- Hitachi, Ltd.
- Viavi Solutions Inc.
- FUJITSU LIMITED
- Fluke Networks
- HellermannTyton Co., Ltd.
- MARUBUN CORPORATION
- Mitsubishi Electric Corporation
- Yokogawa Meters & Instruments Corporation
- ASAKURA FACTORY Co. Ltd.
- IWABUCHI CORPORATION
- Kawaguchi Electric Works Co., Ltd.
- Kiya Corporation
- SANKOSHA CORPORATION
- SANRITZ ELECTRONICS CO., LTD.
- SANWA DENKI KOGYO CO., LTD.
- TAIEI Manufacturing Co. Ltd.
- Takacom Corporation
- TAKACHIHO SANGYO CO., LTD.
- TOKAI COMMUNICATION INDUSTRY CO., LTD.
- TOMEI TSUSHIN KOGYO CO., LTD.
- NAGAMURA MANUFACTURING CO., LTD.
- NISSHIN ELECTRIC CO., LTD.
- HACHIKO ELECTRIC CO., LTD.
- Fukuoka Tsushin Kozai Seisakusho Co., Ltd.
- MIYOKAWA Manufacturing Co. Ltd.
- WATANABE CO., LTD.
- Japan Telecommunications Equipment and Materials Manufacturers Cooperative Association

■Other companies
- FXC Inc.
- NTEC
- SUNREC CO., LTD.
- HARADA CORPORATION
- MIKI Inc.

behind large enterprises due to a lack of information technology talent, and he introduced an actual cloud services implementation as a case study to show how it can contribute to pursuing the asset-light business model as part of the effort to revitalize small businesses.

Mr. Ii also explained how NTT EAST supports problem solving in order to address priority issues in Japan such as invigorating local economies. He then introduced in an easy-to-understand manner several examples of the introduction of ICT in various fields, including a minutes support system for local governments, a support system for disaster victims, improvements to the education environment with ICT, the science information network SINET 5, robot services for long-term care facilities in the field of medical care and nursing care, big data analysis of personal data to understand the preferences of international visitors, and smart agriculture, which uses ICT in the primary industry field.

He also explained the latest network technology to support these solutions: high-speed, broadband metro access connecting all 47 prefectures in Japan in a 100G full-mesh network. This technology is capable of reducing the amount of electricity and space required by switching routes via remote control operation and switching without optical/electric conversion, and it was operational even when a 300-optical-fiber cable was cut during the Kumamoto earthquake in April 2016. In addition, the use of drones for rapid restoration in isolated areas and inspection of facilities where visual checking is difficult was

Photo 1. Keynote speech (Mr. Ii, NTT EAST Senior Executive Vice President).

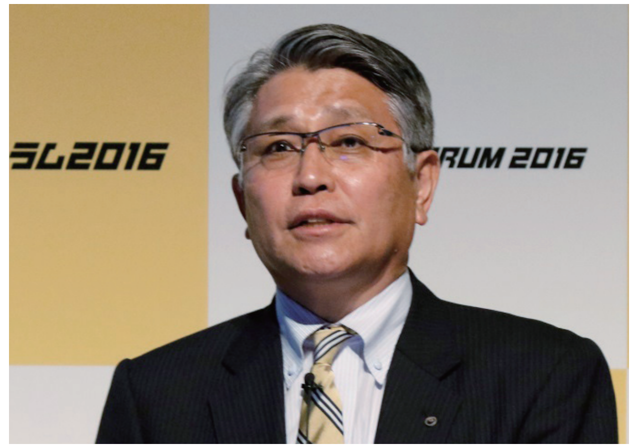

Photo 2. Special speech (Mr. Inose, President & CEO of NTT GEOSPACE).

introduced, and further expansion of this effort was indicated as a future plan.

Finally, the case of a stadium solution in the works for 2020 was introduced. Building a Wi-Fi* environment and enhancing the stadium application will contribute not only to the inside of the stadium but also to the shopping area in the vicinity. It was an enthusiastic keynote speech that expressed an eagerness to come up with solutions in various fields.

2.2 Special speech

Mr. Takashi Inose, President and Chief Executive Officer (CEO) of NTT GEOSPACE CORPORATION, gave a special speech entitled "Trends in Open Innovation and the GEOSPACE 2.0 Initiative" (**Photo 2**).

Mr. Inose first introduced the geospace map that NTT GEOSPACE currently provides. The map initially provided just two items of content—an electronic map and aerial photographs—but more content has been launched in the five years since the map's establishment, most recently the cloud service and satellite images distributed over the Internet. Mr. Inose described an environment that will make the map easier to use by applying an application programming interface, and he also explained the data composition and past efforts relating to the electronic map.

Next, he envisioned technological innovation trends. Since the emergence of various technologies in 2010, it has been expected that a very large paradigm shift relating to development will occur after 2020, as evidenced by the advent of self-driving cars, automatic agricultural maneuvering, and the introduction of Pokémon GO. While describing the relationship between technology development and the underlying technology, Mr. Inose stated that various innovations will arise from open innovation such as cooperation with automobiles and home appliances. He stated that NTT GEOSPACE too has to self-reform to "GEOSPACE 2.0," change its way of making maps, provide various types of content according to the requirements of various partners, and develop novel services through open innovation.

Drawing on the domestic trends surrounding self-driving cars, he explained the development of three-dimensional (3D) spatial information infrastructure using NTT GEOSPACE's two-dimensional electronic map overlaid with road and lane networks. Overseas, HERE Corp. is leading the map adjustment technology, and NTT GEOSPACE would like to consider joint developments with HERE in order to advance into Asian markets in the future. He also spoke about i-Construction, which the Ministry of Land, Infrastructure, Transport and Tourism is working on to promote construction work using ICT, and trends related to products and services for mass users.

Among those trends, he mentioned that the motivation of NTT GEOSPACE related to the social issues facing Japan is to overcome such problems through technical innovation and the development of a 3D spatial information platform. Then, as an initiative of GEOSPACE 2.0, he presented the ideas of distributing content on the B2B2X (business-to-business-to-X)

* Wi-Fi is a registered trademark of Wi-Fi Alliance.

model in cooperation with partners to ensure that accuracy is maintained in line with market demand, securing appropriate updates, and offering a user-friendly database. Examples of GEOSPACE 2.0 efforts related to data know-how logic and data measurement processing technology and its usage scenarios were introduced, namely: 1) map/address data + lot number registration change information to support the management of communication facilities, 2) 3D spatial information + meteorological and geological information to support facility disaster-prevention planning, 3) a foreign visitor tourism service, 4) utilization of mobile mapping system (MMS) data for infrastructure management, and 5) indoor positioning and indoor/outdoor seamless navigation. He also presented three new technical development cases related to new elemental technologies, namely: 1) automatic DSM (digital surface model) generation from aerial photographs, 2) automatic change detection (small satellite imaging), and 3) automatic detection of topology from satellite/aerial photography.

Finally, Mr. Inose stated that the town he had dreamed of 40 years ago will be realized if various systems underground, on land, and in the air merge with open data, artificial intelligence (AI), big data, and the cloud, and that information on the experience of the ecosystem that is being developed through open innovation could be dispatched to Asia and all over the world. This was an ardent speech that demonstrated strong feelings about attaining an ultra-smart society.

2.3 Global session

On the afternoon of the first day, a global session was held at the NTT Tsukuba Research and Development Center. Two lectures were given on the trends of overseas fiber to the home (FTTH) by Mr. Peter Macaulay, President of the FTTH Council Asia-Pacific (Malaysia) and by Mr. Ivan Felipe Toledo Medina, a representative of ETB (Colombia). It was a valuable opportunity to learn more about the FTTH deployment status throughout the world (**Photo 3**).

Photo 3. Global session (Mr. Macaulay, President of FTTH Council Asia-Pacific (left) and Mr. Felipe Toledo Medina, ETB (right)).

2.4 Workshops

A series of workshops was held on the second day, and these included lectures given by four project managers from NTT Network Technology Laboratories and AS Labs (**Photo 4**).

(1) Workshop 1

Mr. Kimihide Matsumoto, Vice President, Executive Manager of the Network Architecture Innovation Project from NTT Network Technology Laboratories, gave a lecture entitled "NTT R&D Activities toward Smart and Flexible Network (the NetroSphere Concept)." First, he analyzed the direction of R&D for a future network on the basis of changes surrounding the current communication network. The future network is expected to be a smart and flexible network able to respond flexibly and economically to various demands from different business partners and to unpredictable demands such as those arising from the Internet of Things (IoT). The future network is also expected to support the Hikari Collaboration Model. Mr. Matsumoto also explained NetroSphere, NTT's network concept for responding to the challenges of diversity and prediction difficulties. NTT laboratories' efforts to realize the NetroSphere concept include: 1) high-speed and highly reliable server architecture (MAGONIA), 2) Multi-Service Fabric (MSF) transport network configuration technology that achieves both scalability and economy, 3) Flexible Access System Architecture (FASA) that enables modularization of network equipment, 4) advanced operation technology utilizing AI, and 5) verification of the NetroSphere concept (NetroSpherePIT).

(2) Workshop 2

Mr. Akihiro Otaka, Vice President, Executive Manager of the Optical Access Systems Project from AS Labs, gave a lecture entitled "R&D Activities of FASA: Flexible Access System Architecture." He first discussed the realization of the NetroSphere concept for the access network, which is the FASA concept announced in February 2016, and introduced a

Photo 4. Workshop leaders (From left to right: Mr. Matsumoto, a project manager of NTT Network Technology Laboratories, Mr. Otaka, Mr. Sasaki, and Mr. Mizoguchi, project managers of AS Labs).

white paper published in May the same year on the FASA website [1]. FASA is a concept to achieve service provision by combining functionalized blocks and to realize an access network in the virtualization era. The cooperation between various organizations to achieve global diffusion was also addressed. In addition, the important points of this technology, which include modularization of functions, interfaces connecting the functions, the realization of functions using software, and the accommodation of functions on cloud services, were discussed. Finally, Mr. Otaka explained that AS Labs is conducting R&D on FASA focusing on a passive optical network (PON) system that accommodates a fifth-generation (5G) mobile base station as the initial target.

(3) Workshop 3

Mr. Kiyoharu Sasaki, Senior Manager of the Optical Access Network Project from AS Labs, gave a lecture entitled "Research and Development of Innovative Operation Technology for Access Network Infrastructure." First, he explained the concept of *If infrastructure could speak* in an easy-to-understand manner by presenting a performance involving a person wearing a telephone pole costume (known as "Mr. Paul," **Photo 5**). This idea is centered on the utilization of MMS and cars to acquire point cloud data and image data. The telephone pole of the NTT-owned infrastructure is then converted into a 3D model in order to automatically detect abnormalities of the pole such as a tilt or insufficient ground clearance of the cable. He also spoke of how in the future it will be important to review operation tasks by combining various technologies such as IoT, augmented reality, image analysis, AI, and machine learning. He also briefly discussed the importance of developing the capabilities of field personnel and issued a call for NTT—as a company that provides social infrastructure services—to contribute to the maintenance of a safe and secure social infrastructure. Finally, he emphasized the need to renovate the access network with FASA and the new ground design of the optical fiber infrastructure as part of efforts to improve the operability and flexibility of access facilities while maximizing the utilization of existing facilities.

Photo 5. Performance with telephone pole character "Mr. Paul."

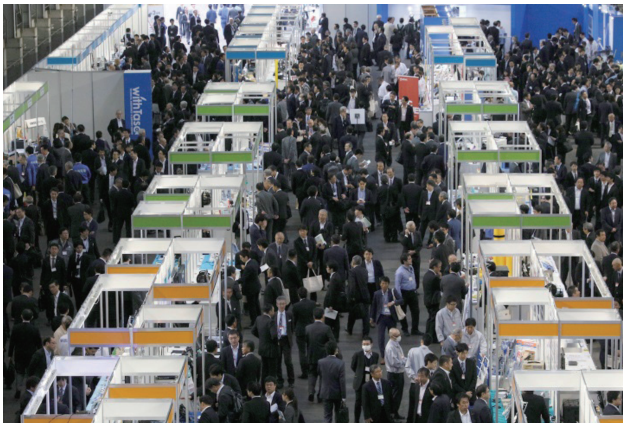

Photo 6. Main venue.

Photo 7. Outdoor exhibition zone.

(4) Workshop 4

Mr. Masato Mizoguchi, Senior Manager of the Wireless Access Systems Project from AS Labs, gave a lecture entitled "Wireless Access Technologies to Enable a Variety of Services." First, he explained the problem with the current wireless local area network (LAN), which is that sufficient communication quality cannot be achieved in an environment where wireless LAN devices are densely located. Then he discussed the technology that will be used to solve this problem and to further expand the wireless service—cooperative wireless LAN technology that improves throughput and stabilizes traffic to enhance the quality of user experience and that is aimed at utilizing wireless LAN for 5G mobile access. In the future, cooperative wireless LAN architecture will continue to be developed in order to manage wireless LAN from the network side and to build a wireless LAN service platform capable of providing various wireless services. The elemental technologies necessary for this realization were explained, and the schedule was clarified.

3. Overview of exhibits

Exhibits from AS Labs and exhibits on the latest technologies by co-sponsored organizations and NTT Group companies were also held (**Photos 6** and **7**).

3.1 AS Labs

The exhibition area was divided into four zones in which a wide range of R&D results of AS Labs were exhibited (**Fig. 1**). Information on recommended exhibits was displayed to visitors in an easy-to-understand manner (**Photo 8**). The four zones consisted of a special exhibition zone (divided into two areas) as well as regular zones I, II, and III. The exhibits held in the four zones are described below.

(1) Special exhibition zone

Special exhibition zone I: Flexible Access Network Technology focused on access network configuration technology for quickly responding to various services; it has been a major topic of study recently and is designed to realize the NetroSphere concept. Recommended exhibits in this zone were those on FASA, which is intended to meet the various requirements of service providers, and a PON system for the 5G mobile network.

Special exhibition zone II: Innovative Facility Inspection Technology featured inspection technology to innovate outdoor facility operations. The innovative technology included aerial facility inspection technology using MMS that was demonstrated as a recommended exhibition (**Photo 9**).

(2) Zone I

On the theme of "Creation Technology," we exhibited technologies that will contribute to the creation of new services in the future and to the creation of a prosperous life. Network technologies and optical and wireless technologies that transmit diverse traffic were the focus in this zone. In particular, we introduced multi-core optical fiber technology that is evolving to achieve the extreme level of space utilization as a recommended exhibition.

(3) Zone II

The theme in this zone was "Protection and Support Technology," and the exhibits featured current services and operations designed to achieve this. Infrastructure technology, maintenance and operation, and

Special exhibition zone **I: Flexible Access Network Technology**
II: Innovative Facility Inspection Technology

This zone introduces *flexible access network technology* to provide various services immediately and *innovative facility inspection technology* to operate outdoor facilities effectively. We are developing these technologies steadily and surely to realize the NetroSphere concept.

Zone I **Creation Technology**

This zone introduces *creation technology* that contributes to the establishment of new services for a more affluent lifestyle in the future. It is focused on network technologies to accommodate multiple services and optical wireless convergence technologies.

Zone II **Protection and Support Technology**

This zone introduces *protection and support technology* that supports provisioning and current service operations, focusing on infrastructure technology, fundamentals, maintenance, operation, and disaster recovery.

Zone III **Display of a model network**

This zone visually introduces an overall picture of access network technologies (those already deployed) in a physical sequence from an NTT building to a customer's premises.

Fig. 1. Summary of NTT exhibition.

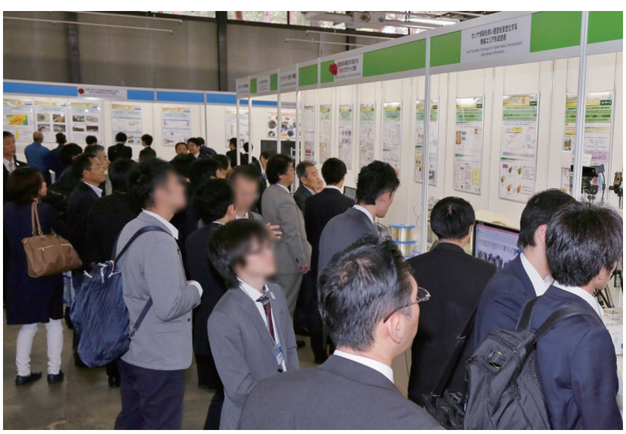

Photo 8. NTT exhibition zone.

Photo 9. NTT demonstration.

disaster countermeasure technologies were the focus in this zone. In particular, technology to improve network reliability by predicting pipe conduit damage from earthquakes with high accuracy and annotation technology to add know-how information on user terminal screens were introduced as recommended exhibitions.

(4) Zone III

An overall picture of the access network technologies was displayed as a model network from inside an NTT building to a customer's premises in an easy-to-understand way with actual equipment.

3.2 Information & Telecommunications Engineering Association of Japan (ITEA)

Exhibitors affiliated with ITEA introduced their efforts to improve quality and efficiency, and to achieve rapid equipment restoration in the event of large-scale disasters to realize a safe, secure, and reliable communications infrastructure. The exhibits featured their acquired technologies, know-how inheritance, and construction and maintenance of optical access facilities.

3.3 Communication Line Products Association of Japan

Exhibitors belonging to the Communication Line Products Association of Japan introduced their latest efforts, focusing on technologies and products related to outdoor equipment, including optical and metal cables and related equipment.

3.4 Communications and Information Network Association of Japan (CIAJ)

Together with the Japan Industrial Association for Telecommunications Equipment and Materials (Zentsukyo), exhibitors belonging to CIAJ presented various products and solutions related to communication networks to realize a safe, secure, and prosperous society.

3.5 NTT Group companies

To provide the best and most trusted services as a *value partner*, NTT Group companies displayed the latest technologies to contribute to the realization of a safe, secure, and prosperous society where people, society, and the earth are connected through *communication*.

3.6 Events

Demonstrations and technical seminars by exhibitors were held at the AS Labs main venue and at an outdoor venue, with many participants in attendance (**Photo 10**).

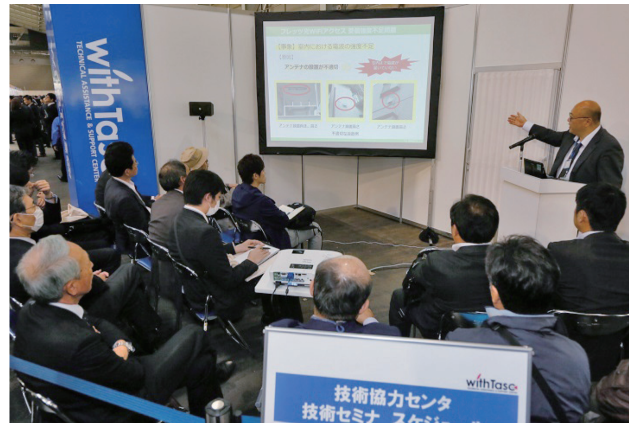

Photo 10. Technical seminar held by an exhibitor.

3.7 Free Wi-Fi trial

We collaborated with NTT Broadband Platform, Inc. to conduct a free Wi-Fi trial within the main venue of AS Labs. In the free Wi-Fi area, all of the speeches were delivered by live streaming. The speeches were also recorded on video, and when the speeches were finished, the video was distributed. At the Rest Station, a premium Wi-Fi service using cooperative wireless LAN technology was deployed. Visitors were able to experience wireless LAN technology under high-density conditions without having to worry about congestion.

4. Conclusion

Although there was light rain on the first afternoon of the event, the second day was blessed with fine weather. About 9400 people including many customers from abroad participated in this forum; thus, Tsukuba Forum 2016 was a resounding success. Various exhibits on the latest R&D and future trends of AS Labs were received with high interest. A visitors' questionnaire was administered after the exhibition, and the responses indicated that 98% of participants were satisfied with their experience. Overall, it was a rewarding event that offered a place to share knowledge with the participating companies, including the co-host organizations, on the transformation of the access network that supports a high quality of life brought on by the realization of the NetroSphere concept.

Acknowledgments

We thank the Information & Telecommunications Engineering Association of Japan, the Communication Line Products Association of Japan, and the Communications and Information Network Association of Japan for their support of Tsukuba Forum 2016.

Reference

[1] Website of FASA, http://www.ansl.ntt.co.jp/e/global/FASA/index.html

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He received a B.E., M.E., and Ph.D. from Hokkaido University in Japan in 2000, 2002, and 2010. Since joining NTT in 2002, he has been researching propagation characteristics of wide band access systems. From 2013 to 2014, he was a visiting research associate at the Centre for Telecommunications Research at King's College London, UK. He received the Young Researcher's Award, the Communications Society Best Paper Award, and the Best Paper Award from the Institute of Electronics, Information and Communication Engineers (IEICE) in 2006, 2011, and 2014. He is a member of IEICE and IEEE (Institute of Electrical and Electronics Engineers).

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He received a B.S. and M.S. from Tohoku University in 2003 and 2005. In 2005, he joined NTT Access Network Service Systems Laboratories, where he has been engaged in research on optical signal measurement. He is a member of IEICE.

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Senior Research Engineer, Planning Section, NTT Access Network Service Systems Laboratories.

He received a B.E. and M.E. in electronic engineering from Nagoya University, Aichi, in 1994 and 1996. In 1996, he joined NTT Access Network Service Systems Laboratories, where he has been conducting research on optical customer networks. Mr. Ieda is a member of IEICE.

NTT, Ruhr-Universität Bochum, and Kobe University Develop a New Cryptanalytic Technique to Improve the Design of Lightweight Ciphers for Internet of Things

1. Research result

NTT, jointly with Ruhr-Universität Bochum and with Kobe University, has developed a new cryptanalytic technique (the nonlinear invariant attack) that helps improve the design and security of lightweight symmetric-key ciphers, which are considered to play an active part in the IoT (Internet of Things) era.

Most of the previous cryptanalysis techniques assume unrealistic scenarios where adversaries have opportunities to obtain encrypted data of plaintext they deliberately choose, in terabytes. In contrast, the new cryptanalytic technique, when applied to several existing (lightweight) ciphers, recovers part of the plaintext from encrypted data in amounts smaller than one kilobyte, under the condition that either the plaintext contains repetition or the same plaintext gets encrypted multiple times. The new technique can be used to greatly improve the design of lightweight ciphers and to re-evaluate the security of other existing symmetric-key ciphers.

The paper reporting this research result [1] received the distinction of being "Invited to the Journal of Cryptology," meaning that it was one of the top three papers accepted at Asiacrypt 2016 (held in Hanoi, Vietnam, December 4–8), a prestigious conference organized by the International Association of Cryptologic Research.

2. Key facts

Linear cryptanalysis was published in 1993 and applied to the Data Encryption Standard (DES), which was essentially the world standard at that time, demonstrating the first cracking of DES by a computer. Linear cryptanalysis was applied to numerous cryptographic primitives as a generic cryptanalytic technique, and cryptographic primitives newly developed after the publication of linear cryptanalysis were required to provide evidence of resistance to linear cryptanalysis. Linear cryptanalysis, as the name suggests, linearly approximates nonlinear behavior of cryptographic primitives. It has been a long-standing open problem whether it is possible to devise a similar type of cryptanalysis using nonlinear (quadratic or higher) approximation rather than linear approximation. A previous attempt in 1995 used nonlinear approximation to analyze input and output parts of a cryptographic primitive, but no previous attempts succeeded in cryptanalyzing an entire cryptographic primitive. Our new cryptanalytic technique, the nonlinear invariant attack, provides an answer to the open problem for the first time.

The previously mentioned paper describes how the nonlinear invariant attack is applied to SCREAM, iSCREAM, and Midori64. SCREAM and iSCREAM are symmetric-key schemes submitted to CAESAR, a competition to evaluate authenticated encryption (symmetric-key ciphers equipped with an integrity check). Midori64 is a symmetric-key cipher published at Asiacrypt 2015. The key idea of the attack is to identify a quadratic (hence, nonlinear) invariant quantity associated with the nonlinear component of the cipher called sbox and then to observe that the sum of the quadratic function (nonlinear approximation) applied to each sbox output also remains unchanged through the linear part of the cipher where a binary orthogonal matrix is used. When the attack is applied to SCREAM and iSCREAM, 32 bits of plaintext are instantly recovered from 33 blocks (one block is 128 bits) of encrypted data, under the condition that the secret key is one of the 2^{96} special keys (called "weak keys") out of the entire 2^{128} key space. When applied to Midori64 in most modes of operations used in practice, for example in the CTR (counter) mode, 32 bits of plaintext are instantly recovered from 33 blocks (one block is 64 bits) of encrypted data for 2^{64} special keys out of the entire 2^{128} key space.

3. Future plans

NTT Secure Platform Laboratories is continuing to re-evaluate the security of other existing ciphers by applying the nonlinear invariant attack and is also pursuing cryptanalytic techniques for developing secure cryptographic algorithms.

Reference

[1] Y. Todo, G. Leander, and Y. Sasaki, "Nonlinear Invariant Attack—Practical Attack on Full SCREAM, iSCREAM, and Midori64," Proc. of Asiacrypt 2016, Part II, pp. 3–33, Hanoi, Vietnam, Dec. 2016.

For Inquiries

NTT Service Innovation Laboratory Group
http://www.ntt.co.jp/news2016/1612e/161201a.html

External Awards

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

Winner: Ryuichiro Higashinaka, NTT Media Intelligence Laboratories; Minoru Etoh, Yoshinori Isoda, and Takeshi Yoshimura, NTT DOCOMO
Date: April 20, 2016
Organization: Ministry of Education, Culture, Sports, Science and Technology

For their development of a voice agent service.

Best Paper Award

Winner: Go Irie and Hiroyuki Arai, NTT Media Intelligence Laboratories; Yukinobu Taniguchi, Tokyo University of Science
Date: June 2, 2016
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE)

For "Hashing with Locally Linear Projections."
Published as: G. Irie, H. Arai, and Y. Taniguchi, "Hashing with Locally Linear Projections," IEICE Trans. Information and Systems (Japanese Edition), Vol. J97-D, No. 12, pp. 1785–1796, Dec. 2014.

Excellent Paper Award

Winner: Harumi Kawamura, Salesian Polytechnic; Yasuhiro Yao, Dimension Data; Shunichi Yonemura, Shibaura Institute of Technology; Jun Ohya, Waseda University; Akira Kojima, NTT Media Intelligence Laboratories
Date: June 18, 2016
Organization: The Institute of Image Electronics Engineers of Japan

For "Estimating Scene Illuminant Colors from the Color Images Acquired by a Fixed Camera under Different Illuminations."
Published as: H. Kawamura, Y. Yao, S. Yonemura, J. Ohya, and A. Kojima, "Estimating Scene Illuminant Colors from the Color Images Acquired by a Fixed Camera under Different Illuminations," The Journal of the Institute of Image Electronics Engineers of Japan, Vol. 43, No. 2, pp. 164–174, Nov. 2014.

IEICE ISS Young Researcher's Award in Speech Field

Winner: Yusuke Ijima, NTT Media Intelligence Laboratories
Date: August 25, 2016
Organization: IEICE Information and Systems Society (ISS)

For "Objective Evaluation of Synthetic Speech Using Association between Dimensions within Spectral Features."
Published as: Y. Ijima, T. Asami, and H. Mizuno, "Objective Evaluation of Synthetic Speech Using Association between Dimensions within Spectral Features," IEICE Tech. Rep., Vol. 115, No. 392, SP2015-90, pp. 27–32, Jan. 2016.

IEICE ISS Young Researcher's Award in Speech Field

Winner: Taichi Asami, NTT Media Intelligence Laboratories
Date: August 25, 2016
Organization: IEICE ISS

For "Training Data Selection for Acoustic Modeling Based on Submodular Optimization of Joint KL Divergence."
Published as: T. Asami, R. Masumura, H. Masataki, M. Okamoto, and S. Sakauchi, "Training Data Selection for Acoustic Modeling Based on Submodular Optimization of Joint KL Divergence," IEICE Tech. Rep., Vol. 115, No. 184, SP2015-58, pp. 45–50, Aug. 2015.

FIT2016 Funai Best Paper Award

Winner: Yukihiro Bandoh, Seishi Takamura, and Atsushi Shimizu, NTT Media Intelligence Laboratories
Date: September 8, 2016
Organization: The 15th Forum on Information Technology (FIT2016)

For "Encoding-oriented Video Generation Algorithm Based on Control with High Temporal Resolution."
Published as: Y. Bandoh, S. Takamura, and A. Shimizu, "Encoding-oriented Video Generation Algorithm Based on Control with High Temporal Resolution," Proc. of FIT2016, RI-002, Toyama, Japan, Sept. 2016.

FIT2016 Paper Award

Winner: Yuichi Sayama, Yukihiro Bandoh, Seishi Takamura, and Atsushi Shimizu, NTT Media Intelligence Laboratories
Date: September 8, 2016
Organization: FIT2016

For "Optimal Design of Adaptive Intra Predictors Based on Sparsity Constraint."
Published as: Y. Sayama, Y. Bandoh, S. Takamura, and A. Shimizu, "Optimal Design of Adaptive Intra Predictors Based on Sparsity Constraint," Proc. of FIT2016, RI-003, Toyama, Japan, Sept. 2016.

Technical Committee Prize Paper Award

Winner: Hiroyuki Manabe, NTT DOCOMO; Munekazu Date and Hideaki Takada, NTT Media Intelligence Laboratories; Hiroshi Inamura, NTT DOCOMO
Date: October 3, 2016
Organization: The Industrial Lighting and Displays Committee, Institute of Electrical and Electronics Engineers (IEEE) Industrial and Applications Society (IAS)

For "Low Power Driving Techniques for 1-pixel Displays."
Published as: H. Manabe, M. Date, H. Takada, and H. Inamura, "Low Power Driving Techniques for 1-pixel Displays," Proc. of the IEEE IAS Annual Meeting 2015, Dallas, TX, USA, Oct. 2015.

Best Poster Award

Winner: Seishi Takamura, NTT Media Intelligence Laboratories
Date: December 1, 2016
Organization: The 31st Picture Coding Symposium of Japan and 21st Image Media Processing Symposium (PCSJ/IMPS 2016)

For "Efficient Video Coding Based on Object Tracking."
Published as: S. Takamura, "Efficient Video Coding Based on Object Tracking," PCSJ/IMPS 2016, P-2-16, Shizuoka, Japan, Nov. 2016.

Best Poster Award

Winner: Takayuki Sasaki, NTT Media Intelligence Laboratories
Date: December 1, 2016
Organization: PCSJ/IMPS 2016

For "Accelerated Optimization of Nuclear Norm in Region Coding."
Published as: T. Sasaki, "Accelerated Optimization of Nuclear Norm in Region Coding," PCSJ/IMPS 2016, P-3-20, Shizuoka, Japan, Nov. 2016.

Best Paper Award

Winner: Takahiro Suzuki, Sang-Yuep Kim, Jun-ichi Kani, Ken-Ichi Suzuki, and Akihiro Otaka, NTT Access Network Service Systems Laboratories
Date: December 7, 2016
Organization: Transmission, Access, and Optical Systems (TAOS) Technical Committee, IEEE Communications Society

For "Real-time Demonstration of PHY Processing on CPU for Programmable Optical Access Systems."
Published as: T. Suzuki, S. Kim, J. Kani, K. Suzuki, and A. Otaka, "Real-time Demonstration of PHY Processing on CPU for Programmable Optical Access Systems," 2016 IEEE Global Communications Conference, Washington, DC, USA, Dec. 2016.

Outstanding Reviewer Award 2016

Winner: William J. Munro, NTT Basic Research Laboratories
Date: February 3, 2017
Organization: IOP Publishing

This award is given to reviewers for their expertise and outstanding contribution to *New Journal of Physics*.

IDW/AD'16 Demonstration Award

Winner: Shin'ya Nishida, Takahiro Kawabe, Taiki Fukiage, and Masataka Sawayama, NTT Communication Science Laboratories
Date: February 10, 2017
Organization: The Institute of Image Information and Television Engineers and the Society for Information Display

For "Animating Static Objects by Illusion-based Projection Mapping."
Published as: S. Nishida, T. Kawabe, T. Fukiage, and M. Sawayama, "Animating Static Objects by Illusion-based Projection Mapping," IDW/AD'16 (The 23rd International Display Workshops in conjunction with Asia Display 2016), Sendai, Japan, Dec. 2016.

RSA Conference Award (Excellence in the Field of Mathematics)

Winner: Tatsuaki Okamoto, NTT Secure Platform Laboratories
Date: February 14, 2017
Organization: RSA Conference

For the last 30 years, he has been actively working in many areas of cryptography and has become a world leader in the field based on his numerous fundamental solutions and other central contributions.

Papers Published in Technical Journals and Conference Proceedings

Differential Contributions of GABA Concentration in Frontal and Parietal Regions to Individual Differences in Attentional Blink

K. Kihara, H. M. Kondo, and J. Kawahara

The Journal of Neuroscience, Vol. 36, No. 34, pp. 8895–8901, August 2016.

Selective attention plays an important role in identifying transient objects in a complex visual scene. Attentional control ability varies with observers. However, it is unclear what neural mechanisms are responsible for individual differences in attentional control ability. The present study used the following attentional blink paradigm: when two targets are to be identified in rapid serial visual presentation, the processing of the first target interrupts the identification of the second one appearing within 500 ms after the first-target onset. It has been assumed that the reduction of the second-target accuracy is mainly due to a transient inhibition of attentional reorienting from the first to the second target, which is modulated by the g-aminobutyric acid (GABA) system. Using magnetic resonance spectroscopy, we investigated whether individual variation of attentional blink magnitude is associated with GABA concentrations in the left prefrontal cortex (PFC), right posterior-parietal cortex (PPC), and visual cortex (VC) of humans. GABA concentrations in the PFC were related negatively to attentional blink magnitude and positively to the first-target accuracy. GABA concentrations in the PPC were positively correlated with attentional blink magnitude. However, GABA concentrations in the VC did not contribute to attentional blink magnitude and first-target accuracy. Our results suggest that frontoparietal inhibitory mechanisms are closely linked with individual differences in attentional processing and that functional roles of the GABAergic system in selective attention differ between the PFC and PPC.

Auditory and Visual Scene Analysis: an Overview

H. M. Kondo, A. M. van Loon, J. Kawahara, and B. C. J. Moore

Philosophical Transactions of the Royal Society B, Vol. 372, 20160099, January 2017.

We perceive the world as stable and composed of discrete objects even though auditory and visual inputs are often ambiguous owing to spatial and temporal occluders and changes in the conditions of observation. This raises important questions regarding where and how ‘scene analysis’ is performed in the brain. Recent advances from both auditory and visual research suggest that the brain does not simply process the incoming scene properties. Rather, top-down processes such as attention, expectations and prior knowledge facilitate scene perception. Thus, scene analysis is linked not only with the extraction of stimulus features and formation and selection of perceptual objects, but also with selective attention, perceptual binding and awareness. This special issue covers novel advances in scene-analysis research obtained using a combination of psychophysics, computational modelling, neuroimaging and neurophysiology, and presents new empirical and theoretical approaches. For integrative understanding of scene analysis beyond and across sensory modalities, we provide a collection of 15 articles that enable comparison and integration of recent findings in auditory and visual scene analysis.

Auditory Multistability and Neurotransmitter Concentrations in the Human Brain

H. M. Kondo, D. Farkas, S. L. Denham, T. Asai, and I. Winkler

Philosophical Transactions of the Royal Society B, Vol. 372, 20160110, January 2017.

Multistability in perception is a powerful tool for investigating sensory–perceptual transformations, because it produces dissociations between sensory inputs and subjective experience. Spontaneous switching between different perceptual objects occurs during prolonged listening to a sound sequence of tone triplets or repeated words (termed auditory streaming and verbal transformations, respectively). We used these examples of auditory multistability to examine to what extent neurochemical and cognitive factors influence the observed idiosyncratic patterns of switching between perceptual objects. The concentrations of glutamate-glutamine (Glx) and g-aminobutyric acid (GABA) in brain regions were measured by magnetic resonance spectroscopy, while personality traits and executive functions were assessed using questionnaires and response inhibition tasks. Idiosyncratic patterns of perceptual switching in the two multistable stimulus configurations were identified using a multidimensional scaling (MDS) analysis. Intriguingly, although switching patterns within each individual differed between auditory streaming and verbal transformations, similar MDS dimensions were extracted separately from the two datasets. Individual switching patterns were significantly correlated with Glx and GABA concentrations in the auditory cortex and inferior frontal cortex but not with the personality traits and executive functions. Our results suggest that auditory perceptual organization depends on the balance between neural excitation and inhibition in different brain regions.

Individual Differences in Visual Motion Perception and Neurotransmitter Concentrations in the Human Brain

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Recent studies have shown that interindividual variability can be a rich source of information regarding the mechanism of human visual perception. In this study, we examined the mechanisms underlying interindividual variability in the perception of visual motion, one of the fundamental components of visual scene analysis, by measuring neurotransmitter concentrations using magnetic resonance spectroscopy. First, by psychophysically examining two types of motion phenomena—motion assimilation and contrast—we found that, following the presentation of the same stimulus, some participants perceived motion assimilation, while others perceived motion contrast. Furthermore, we found that the concentration of the excitatory neurotransmitter glutamate-glutamine (Glx) in the dorsolateral prefrontal cortex (Brodmann area 46) was positively correlated with the participant’s tendency to motion assimilation over motion contrast; however, this effect was not observed in the visual areas. The concentration of the inhibitory neurotransmitter g-aminobutyric acid had only a weak effect compared with that of Glx. We conclude that excitatory process in the suprasensory area is important for an individual’s tendency to determine antagonistically perceived visual motion phenomena.
