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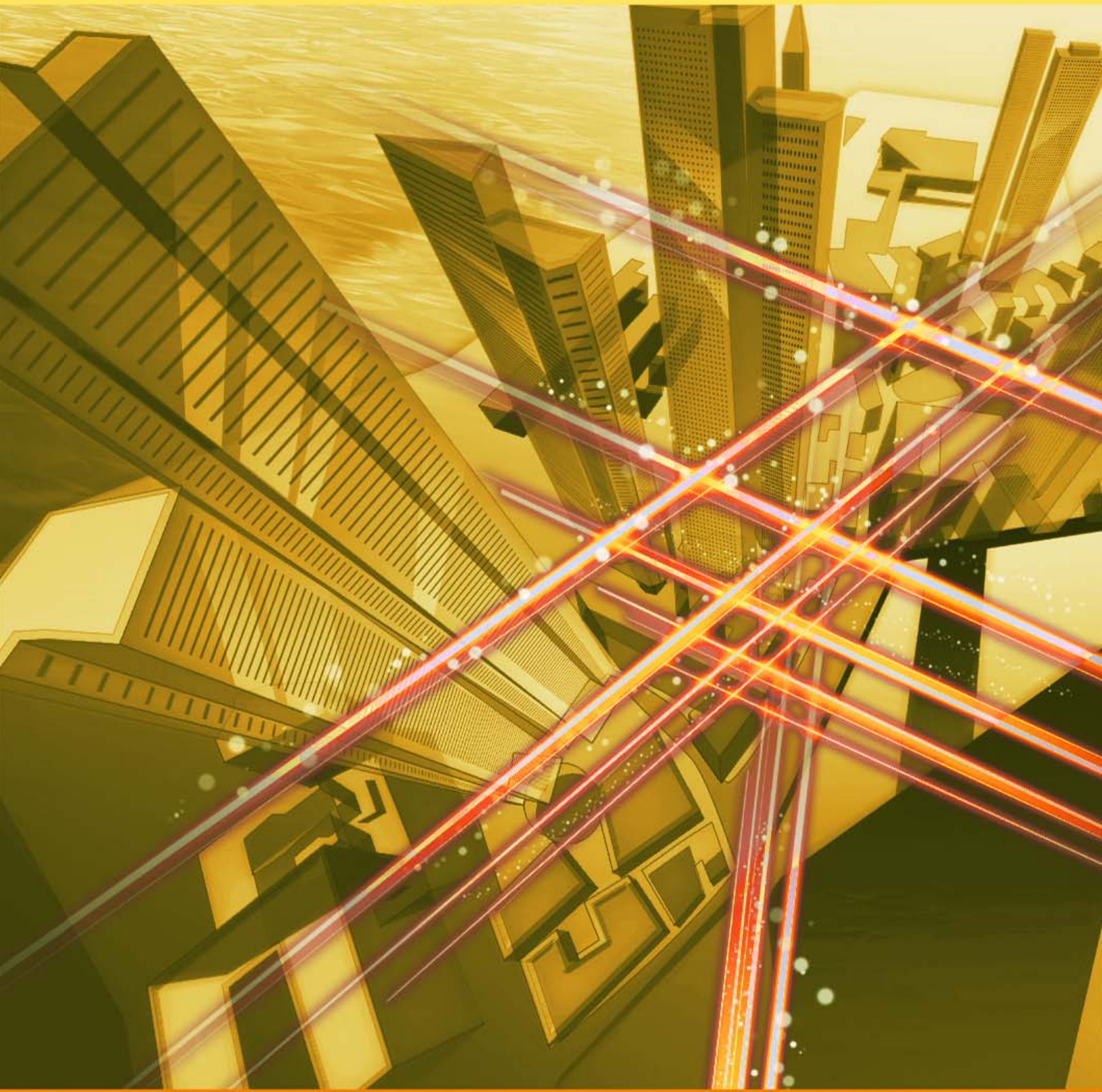

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Creating a Rock-solid Foundation of Shared Values Based on "Connect, Trust, and Integrity"

Jun Sawada
President and Chief Executive Officer, NTT

Overview

Ranking 20th in this year's "Brand Finance Global 500," NTT has built up a global corporate brand and firmly established its position in the world. Jun Sawada, NTT President and Chief Executive Officer, states that a further transformation is needed to ensure growth in both the domestic and international markets. We asked him about his beliefs and management principles in light of this statement.

Keywords: digital transformation, globalization, management principles

Supporting customers, collaborating with partners, and striving for self-transformation are basic to the NTT Group

—Mr. Sawada, how have you been approaching your duties since assuming this office?

I have yet to settle down in my new position, but recognizing the importance of integrity in my work, I make an effort to graciously meet with those that come to offer explanations and hold discussions. As far as activities are concerned, I try to be proactive in my work. For example, immediately after my appointment was decided, I established a monthly meeting with the presidents of major NTT Group companies (presidents' meeting) and began to create a mechanism to promote smooth communication.

—Please tell us about your beliefs and management principles going forward.

To begin with, let me point out that our previous president, Mr. Hiroo Unoura, implemented a variety of business reforms and raised operating revenues and operating income to record levels in fiscal year 2017. All in all, we are in very good shape at present. However, we are in a rapidly changing business environment, and to do even better, I believe it is necessary for us to undergo further reforms (digital transformation) to respond effectively to market changes and outdo the competition. In this endeavor, globalization is an important keyword. If we take up these challenges, I would like to incorporate the global market that is in the growth phase. Revenues in the markets outside of Japan currently account for 20% of our overall revenues, but I would like to expand even more. At the same time, we are encountering changing times in the Japanese market too. This is an era in which the number of subscribers to fixed (landline) telephones is declining every year while the number of mobile-phone subscribers is increasing. In this regard, we plan to switch over from this fixed telephone network to an IP (Internet protocol) network in a migration from the public switched telephone network (PSTN) scheduled for 2024, so it is imperative that we foresee and determine what services will be our core business in Japan going forward and promote a self-transformation.

The purpose of management is to increase corporate value, so an effort must be made to raise profits. Basic principles can be summed up as supporting customers in their own transformation, collaborating with partners, and working toward our own transformation. Corporate contributions to society are referred to as CSR (corporate social responsibility), which I believe to be our main line of business. In short, our corporate activities are closely associated with social contributions. However, pursuing a self-transformation while making social contributions with integrity may appear to be contradictory at first glance. Nevertheless, by placing the three principles of "connect, trust, and integrity" at the root of our business activities and creating a rock-solid foundation of shared values based on these principles, I believe that we can expand our corporate activities with a good balance between self-transformation and social contributions and with a sense of unity among the roughly 300,000 employees of the NTT Group.

—What do you think is important for supporting well-balanced corporate activities?

Of primary importance in corporate activities is "people." At NTT, there are about 180,000 employees in Japan and about 120,000 in other countries throughout the world of different nationalities and cultures. Getting 300,000 people of different backgrounds to move in the same direction is not easy. However, I believe that doing our work while recognizing the diversity within the company will enable us to connect our efforts to both business and social contributions. I therefore felt the need for a mechanism that could facilitate communication among 300,000 people, so I set out to reform the communication structure that up to now had developed on a company-by-company basis. To begin with, I released a video letter in English to the entire NTT world at the time of my appointment as president. At this time, I greeted everyone with our head office in Otemachi, Tokyo, in the background, which generated many comments from employees around the world such as "Ah, this is the head office!" and "This is much more realistic than paper-based greetings!" My greetings in Japanese were delivered on paper, but some employees mentioned that they would have also enjoyed seeing a video letter oriented to employees in Japan. In this way, a new communication method was able to elicit a positive response.

From here on, I intend to deliver a video letter to all employees at each event or milestone to help everyone grasp the state of the entire NTT Group. I have also established meetings for face-to-face discussions with executives of the global operating companies to promote communication. At the same time, I am encouraging the presidents of NTT Group companies to create opportunities for facilitating communication such as through discussions and meetings with employees and exchanges with all sorts of people. The idea here is to establish a communication platform with which to personally convey information and plans not only to the top management of each company but to employees also.

I have also decided to have the top management of each major Group company participate in the formulation of NTT Group medium-term management strategies that have so far been drawn up by the holding company so that the strategy of individual companies can be reflected. The plan is to have NTT EAST, NTT WEST, NTT Communications, NTT DOCOMO, NTT DATA, and NTT Urban Development participate in the formulation of the next medium-term management strategy. However, while we are presently holding a presidents' meeting twice a year for major Group companies, we have not as yet held a global presidents' meeting. Looking to the future, I would like to make use of ICT (information and communication technology) to expand the presidents' meeting globally while establishing a mechanism for occasional face-to-face exchanges. Meetings using telephones and video are fruitful, but I feel that holding face-to-face meetings at our head office here in Japan is meaningful in an entirely different way.

Introducing worldwide evaluation standards; delegating authority and sharing basic principles in policy-making in an 8-to-2 ratio

—Unifying the management team of a 300,000-employee corporation seems to be no easy matter.

That's right. It's not that simple. Two years ago, we launched a company called NTT Security, bringing together five NTT Group companies and 1500 employees from 15 different countries. At that time, it was felt that it would be impossible for all of these employees to move in the same direction on receiving an order from the head office. It was therefore decided that 80% of policy making would be entrusted to the various regions with the remaining 20% left to the head office. A process of trial and error ensued until settling into this ratio, but in the end, we came to respect this 80% portion of policy-making that was working based on the actual state of affairs in each region. Principles, system decisions, etc., should fall broadly in line with the plans of the head office, but authority should be delegated for everything else. Japanese corporations are not very good at delegating authority. Sometimes, when people intend to delegate, it simply becomes impossible to do so, or while they claim to delegate, there is actually no delegation in the true sense of the word due to the reports that are being requested all the time. Evaluating the results of delegation based on clearly stipulated standards is now a worldwide trend.

In terms of a worldwide standard of evaluation systems, a poor evaluation typically results in asking for the resignation of the person in charge while a good result means granting a bonus. In Japan, however, comprehensive and relative evaluations have been the norm, with the result that people have not been asked to resign. I would like to bring this situation in line with the global standard, which is already being practiced by our global companies. Leaving aside this extreme talk of having to resign from one's position or company, I would like to gradually introduce this idea and mechanism of delegating authority in our Japanese companies. However, culture cannot be changed overnight. It took our previous president, Hiroo Unoura, five or six years of steering the company before achieving record levels of profit and higher stock prices. Surely about the same amount of time would be needed to implement some other kind of major reform. I believe that the PSTN migration scheduled for 2024 will provide us with a big opportunity to transform our business within Japan.

In addition, I would like to make it so that each and every employee can work in a proactive manner. In the past, whether I was in charge of sales or of the customer premises section (a maintenance department concerned with communication cables and terminals), I would analyze the data and make it visual (visualization) before presenting it to my subordinates. In the case of sales, I would convert the number of orders, for example, to a per-person value and arrange the data in a time series. In this way, employees could see trends and factors for themselves and establish appropriate work strategies on their own. As a result, sales doubled over a period of two and a half years. The time that I was in charge of maintenance was exactly the time that maintenance cost data was released. On working out the national average, for example, I found out that actual results (costs) ranked low regardless of whatever pride we could take in our technical abilities. On showing these results to highly skilled employees who had originally thought differently, the poor results roused them to action, and they voluntarily took steps in their work to remedy the situation. In the end, actual results improved by three times. On hearing about these improved results, branch offices would ask us, "How in the world did you do that!"

These experiences reflect the importance of visualizing actual results and raising awareness. Many NTT employees are known for their excellence and integrity in their work. Given the appearance of some kind of problem, these employees confront the problem on their own in the manner of "We must do something!" and perform whatever work needs to be done systematically. Conversely, what I personally am capable of doing depends perhaps on how I can make people aware through visualization. However, if a trustworthy

relationship has not been developed, visualization may not have much of an effect. Simply presenting results in a graphical manner is no guarantee that people will pay attention. I believe that creating an easy-to-work environment for employees is the job of top management. Although it can't be helped in a large organization, a problem in the workplace may be watered down as it makes its way up the chain of command, preventing the true nature of the problem from being understood. To solve this, I would like to delegate more authority so that on-site employees are committed to results in their work. I think this is a sound approach to work.

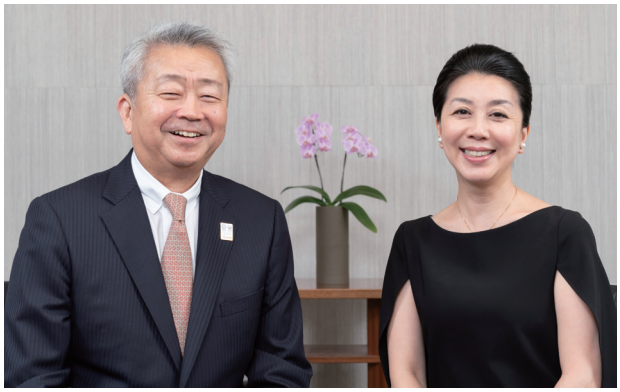
Let's work to make people happy

—Technology is a keyword alongside people as a pillar for promoting reform. What thoughts or ideas do you have on this?

All things considered, I understand that technology provides an opportunity for changing the world. The relationship between technology and people and society can be thought of as that between innovation and markets. These two processes work together, but in the end, no reform will occur without innovation coming first. In this sense, there are great expectations of our research laboratories.

In recent years, technical innovation has been expanding as has marketing technology. The barriers between them have been disappearing, and as part of this flow, "incubation" has come to be done, leading to the creation of new products and services. Information communications is a tool, and providing value to people and society through this tool is important. We would like the tools that we provide to be used in medical care, healthcare, transport, and many other fields, and we therefore must develop technologies that are indispensable to partners in various fields.

What supports this activity is research and development (R&D). While it is common to simply say "R&D," there can be no 'D' (development) without 'R' (research). My goal is to become the world's best in both 'R' and 'D' by discerning technology trends and formulating and developing an R&D strategy with the growth of both 'R' and 'D' in mind. To this end, I will hold discussions with the Research and Development Planning Department and announce our direction at the next NTT R&D Forum.



—What fields in NTT R&D do you think require urgent attention?

One would be robotics—I think there is a real need for useful robots. Whether they are shaped as a camera, a desk, or whatever, any robot having elements that can make people happy is good. And for that matter, any work that can provide something that people can take great pleasure in is worthwhile.

In addition to the field of robotics, there are many others, including artificial intelligence, genomics, advanced self-driving cars, drone navigation management, flexible Internet of Things sensing, brain-machine interfaces, and micro-robots. I have so many ideas on each of these fields that it's difficult to put them into words.

However, if I were to talk about one, it would be a software platform that I would call a "cognitive foundation." This platform would have the role of connecting a variety of things and processing and storing the data obtained. In simple terms, processing would be handled on the cloud and stored in storage equipment, and the linking of the two, that is, the connected portion, would constitute a network. In other words, all sorts of things are connected via the network portion and analyzed as big data. However, this network portion (the linked portion) is achieved by software, but no robust software platform exists as yet. This level of connection can be achieved by the fifth-generation mobile communications system (5G), but 5G is still only part of the public network. Generally speaking, there are local area networks, factory systems, and other things outside the public network, but without end-to-end connections, they are meaningless, becoming much like the boa constrictor in the famous novella *The Little Prince* ("What is essential is invisible to the eye").

For example, if each company involved in the field of self-driving cars creates its own system, how to connect these systems becomes an issue. The word "cognitive" refers to the ability to perceive and make connections even for things different in nature. This cannot be done without software. In other words, there is a need here for a multi-orchestration capability.

On another matter, I can imagine a business that converts electric power to direct current (DC) and makes an NTT exchange (central office) into an energy storage station for charging electric vehicles or for supplying local businesses with power. Batteries and solar power generators all use DC, and many motors such as those of electric vehicles likewise run on DC, so converting real-world equipment to DC would make for more efficient operations. Furthermore, since natural energy is becoming easier to use, such a business plan could help ease global warming. Such an initiative has yet to be launched on a global basis, but I think it could be done in Japan to provide something very useful for people and society throughout the world.

—An opportunity for Japan to contribute to the world seems to be taking shape. Is there anything that touches a chord with you on becoming president?

My job is to reply to a variety of requests coming from all around me and to resolve any problems that come up. The scale and global impact of NTT is large, so I'm always asking myself whether my knowledge and experience are commensurate with my position as president and always thinking that I need to continuously improve my skills. In addition, I strive to make decisions as quickly as possible in all sorts of scenarios and to convey them clearly. In the case of a difficult subject, I tell them whether or not we should conduct a study, and once a mutual understanding is reached as to do or not to do that, I want to get the matter settled. Moreover, if someone should come up with a good idea along the way, I want to incorporate that idea without hesitation and quickly adopt what is considered to be correct regardless of what may have been said before. I believe that this approach reflects a sense of integrity in the end.

—Mr. Sawada, can you leave us with a message for all employees of the NTT Group?

I believe that we are in a very good state at present, but technical innovation and social trends are rapidly changing beyond our expectations. Please confront these changes head-on through your own transformation from your own position. In actuality, it's a continuous process of improvisation no matter how much you try to prepare. But if you understand that, you will be unbothered by even a major problem. In addition, it's better to enjoy whatever you're doing. Being enthusiastic and energetic about your work will create a virtuous cycle. Let's join hands in creating a more enjoyable society!

Interviewee profile

■ Career highlights

Jun Sawada joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1978. After serving as manager of communication lines and other network facilities, he became NTT America Vice President in 1998. In 2000, he moved to NTT Communications, and after serving as Head of the Corporate Planning Department, Executive Manager of Consumer and Office Users Business Division, and General Manager of the Kansai business office, he became Senior Vice President and Executive Manager of the Corporate Strategy Planning Department in 2008. He then became Representative Director, Senior Executive Vice President of NTT in 2014, serving concurrently as Chief Executive Officer of NTT Security from 2016. He assumed his present office in June 2018.

NTT Research and Development Efforts Supporting Global Business Expansion

Ryuichi Sumi and Kei Karasawa

Abstract

Global business is one of the pillars of growth of the NTT Group, and it has been expanding a great deal due to factors such as mergers and acquisitions. Research and development (R&D) efforts to support that growth are also expanding in various forms. The Feature Articles in this issue introduce examples of the R&D efforts underway at operating companies of the NTT Group in various regions around the world.

Keywords: digital transformation, strategic innovation, global R&D

1. NTT's global business

Under its medium-term management strategy announced in 2015, the NTT Group has made global business one of the pillars of growth, and in fiscal year 2017, the group's non-domestic sales increased to $19.5 billion, which includes profits of $1.0 billion. As a result of proactive mergers and acquisitions by the NTT Group, approximately 116,000 people—about 40% of the group's employees—are currently working outside Japan, and the importance of the group's global business is increasing.

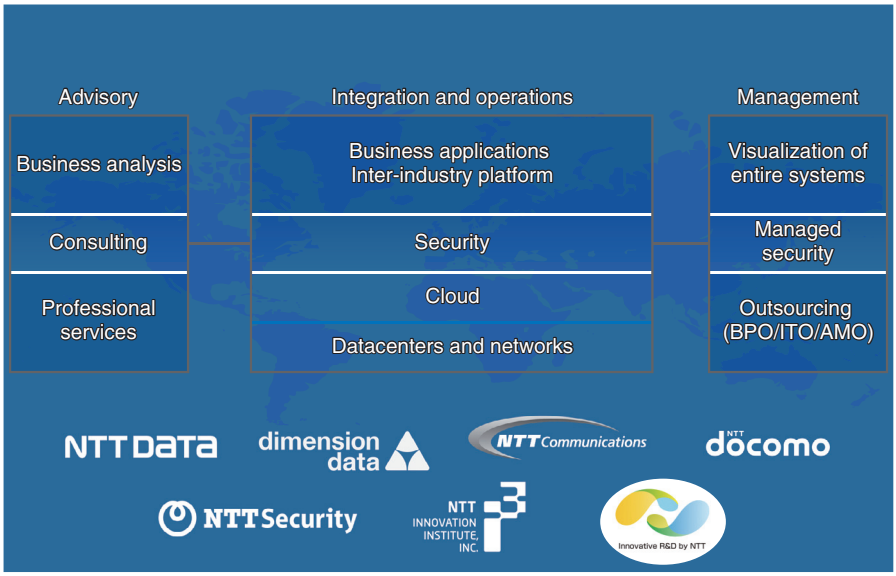
The NTT Group's customer base has been expanding in various regions since the acquisitions of Dimension Data by NTT in 2010 and everis by NTT DATA in 2014. Moreover, in 2013, NTT Innovation Institute, Inc. (NTT i^3), which conducts research and development (R&D) in North America in the cloud and security fields, was inaugurated, and it took up the challenge to develop various services from scratch.

It has become our strength that by fusing these activities, NTT Group companies are cooperating globally and supporting customers by offering full-stack services ranging from information technology (IT) infrastructure such as networks and datacenters to business applications through their full lifecycle from the advisory phase to the management phase (**Fig. 1**).

2. System structure to support digital transformation

In the NTT Group, in addition to our existing IT infrastructure business, it is becoming more important to help customers make a digital transformation in a full-stack manner, such as by offering managed services and applications, and to provide new value to them by utilizing innovative digital technologies created through R&D. Accordingly, we are seeking to utilize digital technology to strengthen our advisory and proposal capabilities in order to respond to the business challenges set by our customers. We thus consider it necessary to strengthen our software-defined, flexible cloud services, our security services responding to sophisticated cyber-attacks, and our business applications that perform advanced analysis and prediction from diverse data. We also consider it important to establish strong relationships with customers that lead to provision of new services by operating services and operation processes in an end-to-end manner and by maintaining our customers' security.

Until now, by repeating studies and examinations



AMO: application management outsourcing
BPO: business process outsourcing
ITO: information technology outsourcing

Fig. 1. Overview of global business areas.

with various customers such as universities, customers working on digital transformation (in the fields of sports viewing and nature conservation, for example), and customers with complex systems (such as the financial industry), and by creating new value after each study, we have accumulated trust as a partner supporting digital transformation.

In Japan, we are collaborating with partners on the basis of the B2B2X (business-to-business-to-X) model, which is aimed at creating new value utilizing technologies developed through NTT Group's R&D, including that of the NTT laboratories. When providing that value to global customers, it is a challenge to build a local support system. We are therefore fostering human resources within our global operating companies, particularly presales staff (who can explain technologies) and sales engineers (who can perform multiple duties including maintenance) to build a system to support our customers' digital transformation on-site (**Fig. 2**).

In the future, to further accelerate the global rollout of technologies developed through the NTT Group's R&D, we believe that cycles that create new differentiated technologies based on customer needs and obtained from companies operating globally will become even more important.

3. Steps toward driving innovation

The NTT Group's R&D needs to achieve innovation, and in terms of future changes, it is important to substantiate value in cooperation with customers. Given that importance, it is necessary to predict future changes by investigating technology trends, to create ideas to convert those changes into value tailored to the customer, to create services that substantiate ideas by experts, and to construct an ecosystem in which services continue to be provided globally (**Fig. 3**).

These Feature Articles introduce efforts to promote innovation through R&D by our core global businesses, namely, the NTT Communications Group, NTT DATA Group, Dimension Data Group, and NTT i^3.

In particular, we introduce digital transformation efforts by the NTT Communications Group that utilize NTT's artificial intelligence (AI) technology called corevo® cultivated in Japan for customers in Asia [1]. We also explain the work being done in the Dimension Data Group involving technologies such as AI, Internet of Things (IoT), and blockchain. Then, endeavors towards new digital transformation such as those concerning North American professional sports and animal protection in Africa, as well as new efforts

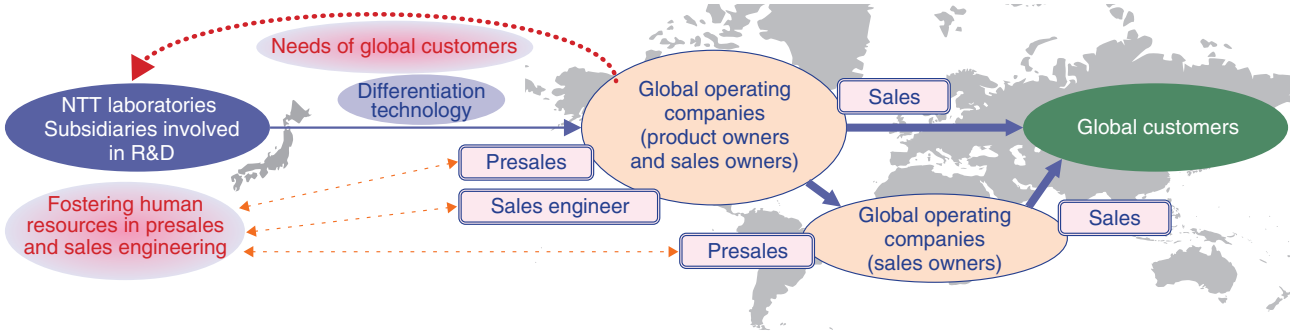
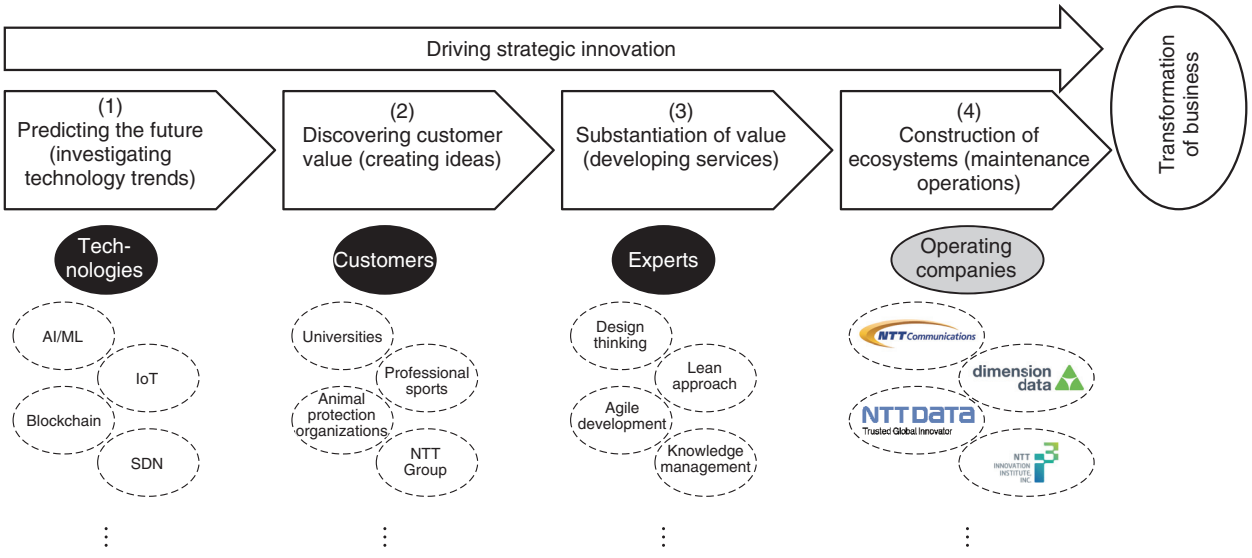


Fig. 2. System for global roll-out of NTT R&D technologies.



AI: artificial intelligence
IoT: Internet of Things
ML: machine learning
SDN: software-defined networking

Fig. 3. Steps toward driving innovation.

in collaboration with NTT Group companies are introduced [2]. Efforts of the NTT DATA Group include work being done to develop mechanisms for strategic innovation, efforts concerning design-thinking development for customers such as European universities, and an example of ecosystem construction are introduced [3, 4]. NTT i^3's efforts concerning the new CLOUDWAN service launched in 2017—which integrates software-defined networking and network functions virtualization—and its development in the IoT field are also introduced [5].

Through the above-described efforts, the NTT Group is pursuing further growth through global business development centered on digital technology cultivated both in Japan and the rest of the world.

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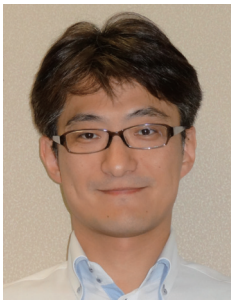
Ryuichi Sumi
Vice President, General Manager, Research and Development Planning Department, NTT.

He received a B.E. in administration engineering from Keio University, Kanagawa, in 1988 and joined NTT Software Laboratories the same year. He studied software development support environment for CHILL (CCITT High Level Language for telephone switching systems) using a UNIX workstation and the Internet during 1988–1994. He moved to NTT Multimedia Business Department, where he developed a video-on-demand system over an optical fiber network with Microsoft. He also worked at NTT WEST and was actively involved in developing a local area information-sharing portal and a video conference system over Internet protocol (IP) networks. After that, he was with NTT Resonant, where he established a live entertainment ticket information service company with ticket sellers. When he returned to NTT, he led open source projects and joined the InfoQ, Java and JBoss communities and fostered committers. He also managed the development of network technology at the Information Network Laboratory Group. He has been in his current position since 2016, where he oversees the promotion of the Laboratory Group's technical achievements.



Kei Karasawa
Senior Manager, Research and Development Planning Department, NTT.

He received a B.E., M.E., and Ph.D. from the Department of Information Systems Engineering, Faculty of Engineering, Osaka University in 1994, 1996, and 1999. Since joining NTT in 1999, he has been engaged in research on IPv6 networking, network security, and cloud computing. From 2005 to 2006, he was a visiting scholar in the Applied Cryptography Group at Stanford University, California, USA. He is a member of the Institute of Electronics, Information and Communication Engineers and the Information Processing Society of Japan.

Initiative Concerning Global Service Development by NTT Communications

Yukinori Kishimoto, Akira Taji, and Jumpei Maruyama

Abstract

NTT Communications has established bases in over 120 cities in more than 40 countries and regions, where it provides information and communication technology services on a global scale. The network services it provides cover an area exceeding 190 countries and regions. At the company's Technology Development department, we have set *service development of new technologies* as one of our missions and are developing state-of-the-art technologies while verifying developed technologies and evaluating their performance. In this article, we introduce an example of global service development by NTT Communications.

Keywords: AI, global, service development

1. Introduction

To develop new services and deploy them globally, it is important to consider and reflect not only the advanced nature and future prospects of the technology to be adopted but also various factors such as the market, infrastructure, and the regional characteristics of the area in which services are provided. Therefore, NTT Communications (hereafter, NTT Com) dispatched two of our engineers from the Technology Development department to its subsidiary, NTT Com Thailand, where they worked on service development tailored to match the circumstances in Thailand for about a year starting in September 2016. The main reason we chose Thailand as the dispatch destination is that the economic growth in Southeast Asia has been remarkable in recent years, and Thailand is a major economic country in that promising market. Moreover, its citizens in general are positive about accepting new things. Thus, it is easy to obtain the cooperation of users in demonstration experiments using state-of-the-art technology such as artificial intelligence (AI). This article introduces our initiative concerning the AI Concierge service.

2. AI Concierge

In this section, we present an overview of AI Concierge and explain the background that led to its development, as well as its architecture and functions.

2.1 Overview

AI Concierge was developed with the aim of converting operations for concierge and reception services into AI and thereby improving operational efficiency. It uses the COTOHA™*1 communication engine provided by NTT Com. By using voice or text input to AI Concierge, the user can search for phone numbers, communicate by phone with persons in charge of visits, be guided to meeting rooms, toilets, or other areas, and receive information about recommended lunch spots. In addition to Japanese and English, AI Concierge supports 17 other languages, including French, Spanish, Thai, and Indonesian.

*1 COTOHA™: A communication engine that handles business processes such as answering inquiries, problem solving, order entry, and invoicing while analyzing and understanding people's spoken and written language with high accuracy and communicating with customers (end users).

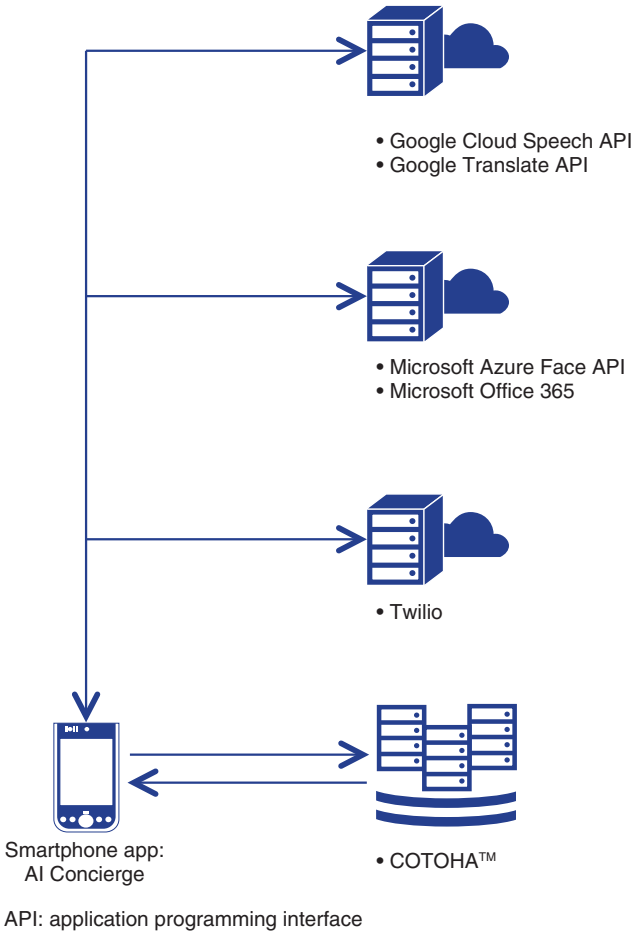


Fig. 1. Architecture of AI Concierge.

2.2 Background to development

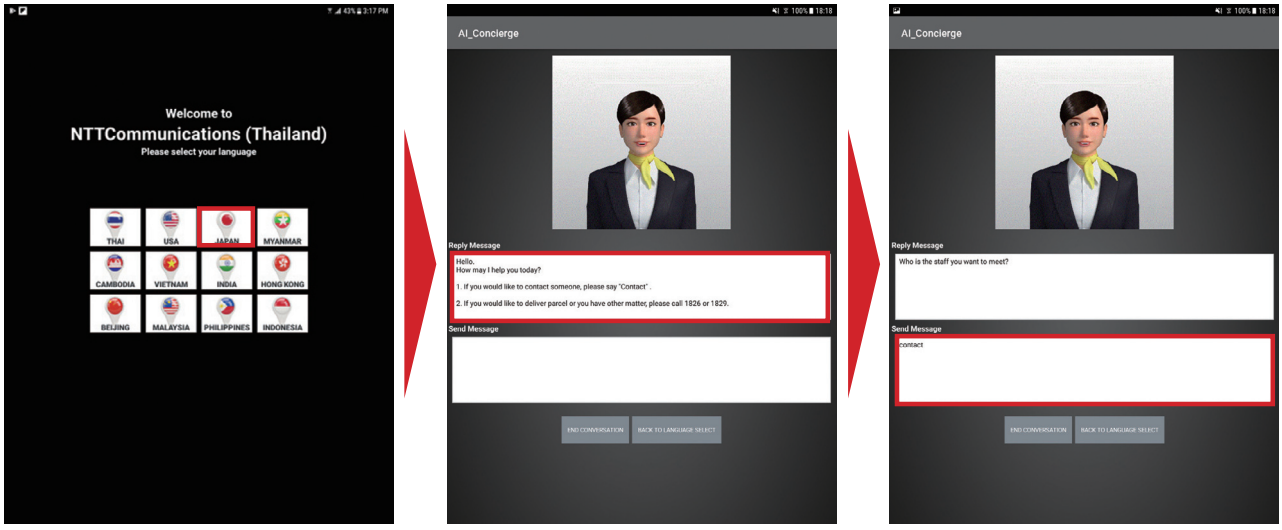
In Thailand, there is much interest in the latest ICT (information and communication technology) such as the IoT (Internet of Things) and AI. Accordingly, in collaboration with NTT Com Thailand, we focused our efforts on developing services using AI. One problem at NTT Com Thailand was that they did not have staff dedicated to the company's reception desk, and at times no staff members were present at reception. Additionally, the English proficiency of the staff dealing with customers was not very high, so they could not respond appropriately to some customers. Consequently, by developing a reception service utilizing multilingual AI, we aimed to solve the problem at NTT Com Thailand and also promote the development of new services utilizing AI.

2.3 Architecture and functions

AI Concierge is being developed under the assumption that its functions will be used at company reception desks. The architecture of AI Concierge (as of May 2018) is shown in **Fig. 1**.

AI Concierge incorporates several AI engines on the cloud—namely, COTOHA, the Google Translate API (application programming interface), Google Cloud Speech API, Microsoft Azure Face API, Microsoft Office 365, and Twilio—as components. The six components incorporated in AI Concierge are summarized below.

- Communication engine COTOHA (conversation scenario processing function)
- Google Translate API (translation function)
- Google Cloud Speech API (voice-to-text/text-to-voice conversion function)
- Microsoft Azure Face API (face-analysis function)
- Microsoft Office 365 (groupware function)
- Twilio (outbound calling function)



The visitor selects a language.

A conversation in the selected language begins. The words that AI Concierge utters are displayed in text in the Reply Message box in the center of the screen.

The content of the speech uttered by the visitor is displayed in text in the Send Message box at the bottom of the screen, translated, and sent to COTOHA.

Fig. 2. Transition of AI Concierge's screen.

When the application is launched, AI Concierge first displays a language-selection screen, and the visitor begins a conversation in the designated language by selecting the language of choice. When the visitor responds to the question from the application, the words uttered by the speaker are converted into text by the voice-to-text conversion function of the Google Cloud Speech API, the text is translated by the Google Translate API, and the translated text (English text) is sent to COTOHA. COTOHA stores a group of scenarios written in English and returns the appropriate answer taken from those scenarios based on the received text. The text returned from COTOHA is conveyed to the visitor as a response in voice and text in the designated language acquired using the Google Translate API and the Google Cloud Speech API again. The transition of AI Concierge's screen is shown in **Fig. 2**.

AI Concierge also has other functions. For example, one function can change the app's response according to the information about the visitors themselves. The system acquires information about the visitor by capturing an image of the face of the visitor by the internal camera when they are selecting their preferred language and analyzing that image information using the face-analysis function of Microsoft Azure. With that information, AI Concierge can change the image displayed on the reception screen and modify the voice used to communicate with the visitor. It is also possible to change the scenario by, for example, including the name of the visitor in the response, based on the visiting history of the visitor acquired by facial analysis. The groupware feature of Microsoft Office 365 and Twilio[*2] are used to check the schedule of the person in charge of the visit so that AI Concierge can call that person by telephone.

AI Concierge is currently installed in the reception area at NTT Com Thailand, and the reception service is up and running. Commercial services of AI Concierge are expected to begin throughout Thailand in the near future. In addition, since AI Concierge is multilingual, its expansion to other countries is being actively pursued.

2.4 Introduction at events

AI Concierge was exhibited at Digital Thailand Big-Bang 2017[*3] held in Thailand from 21 to 24 September 2017 (**Fig. 3**). At that event, a wide range of customers, including researchers, businesspersons, and students participated and exchanged opinions.

*2 Twilio: A service that makes it easy to incorporate various means of communication such as voice calls, messaging (short messaging service/chat), and video phone calls in applications and businesses.

*3 Digital Thailand Big-Bang 2017: An event held in Thailand based on the concept "Digital Transformation Thailand."

Fig. 3. Exhibition at an event in Thailand.

Many visitors were interested in the possibility of talking in the Thai language, and that fact reconfirmed the need for including local languages in information and communication technology services, which give precedence to handling the major languages such as English and Chinese. Additionally, in the second half of 2017, AI Concierge was exhibited at NTT Com Forum (Japan), a private event of NTT Com, and at an event in India.

3. Future development

This article introduced the AI Concierge service in Thailand as an example of service development outside Japan. AI Concierge has been implemented as a reception service at NTT Com Thailand, and in the near future, a full-scale commercial service across Thailand will start. Furthermore, since AI Concierge is compatible with multiple languages, its use is expected to expand to other countries. NTT Com will continue to actively develop advanced services such as AI Concierge that utilize various state-of-the-art technologies for deployment around the world.

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Dimension Data: Enabling Our Clients' Digital Transformation Journey

Nadeem Ahmad

Abstract

There are emerging and disruptive technology domains that are driving the formation of the next generation of digital enterprises. The Group CTO Office at Dimension Data (part of the NTT family since 2010) investigates and tracks these emerging technology trends to assist our business units in developing client solution strategies to address the impact these technology domains will have on our clients' digital enterprise strategy. This article explores the opportunities around artificial intelligence and machine learning, Internet of Things, and blockchain, and highlights Dimension Data's capability to provide the full stack and underlying infrastructure to truly enable these disruptive technologies for our clients.

Keywords: AI, IoT, blockchain

1. Introduction: dawn of the digital transformation economy

We are seeing the dawn of the digital transformation economy. This is characterized by enterprises utilizing next-generation platforms to create value and more importantly, gain competitive advantage in the market via new offerings and business models. Generically, *digital business* is an overarching theme that covers how the blurring of the physical and virtual worlds is transforming business designs, industry markets, and organizations. What is occurring now is that the continuing digital business evolution is exploiting new digital models to align the physical and digital worlds more closely for employees, partners, and customers. This digital transformation is happening on a macro-economic scale as all types of industries act to deliver digitally enhanced products, services, and experiences to their end-customers. Rich digital services will be delivered, and the development of those services will all happen at a faster rate and to a larger scale when it comes to reaching end-customers and/or consumers, and intelligence will be embedded in everything behind the scenes.

There are various economic and social changes and models that are shaping how businesses are investing in digital transformation. Let us call them the drivers of digital transformation. One economic driver is the fact that there are new funding models that are affecting both the demand and the supply side, especially when we witness a shift in focus from CAPEX (capital expenditure) to OPEX (operational expenditure) as technology software solutions are delivered to the market.

Another key driver is the rise of computer-based intelligence and the fact that all of us are holding computers in our hands today. This changes how we interact with the world around us, with the technology around us, or with the endpoints around us, whether in our work lives or personal lives. Data is rapidly becoming a form of digital capital. Data has real value and has become a way of exchanging information but also exchanging value between organizations or between individuals. The more we can apply data to business processes and decision making, the more value our clients are going to get out of their business, and their ability to digitally transform their business will increase.

Finally, there is the platform economy driver. Whether it is a cloud platform we are talking about,

social platforms, or device platforms, we need these platforms to be able to scale, leading to more effective business operations resulting in increased revenue and better profit margins.

Those drivers lead us to some pretty disruptive trends that are having an impact on, and will evolve, the digital enterprise. They are evolving the end user experience to be more engaging, more robust, and more immersive. These innovations will also enable businesses to engage directly with customers through merging digital forms and to operate their business more efficiently by enabling employees to perform their business functions with the speed and scale that the new digital transformation economy demands.

You could say an intelligent digital mesh of technology is emerging to support the future of digital business and its underlying technology platforms and information technology (IT) practices. The mesh focuses on people and the Internet of Things (IoT) endpoints, as well as the information and services that these endpoints access. Artificial intelligence (AI) and machine learning are the means of injecting intelligence into new and existing applications (apps) and things to form the intelligent digital mesh. Capabilities such as blockchain will bring the physical and digital realms ever closer to supporting digital business initiatives. I highlight these three specific trends, as we believe they are now starting to break out and have an impact on organizations as the organizations look to transform their enterprise into a *digital* enterprise.

2. Key emerging technology domains to impact enterprise strategy

A number of technology domains are driving organizations' digital transformation and are having an impact on their operational strategies. Three key domains are introduced in this section.

2.1 AI & machine learning

AI already seems to be all around us. As we see today in countries like the United States, there are millions of consumer devices with embedded intelligent assistants such as Google Home and Amazon Echo. Intelligent things are also appearing in industries such as healthcare, for example, intelligent MRI (magnetic resonance imaging) image analysis for unique types of cancer that are difficult for human doctors to identify. We will see more AI use cases and investment in industries such as healthcare or manufacturing over the next few years. As we move forward, AI will be applied in a focused manner, and implementations will be for well-scoped purposes. Furthermore, underlying this trend is having systems that adapt or learn to act in ways that were not explicitly programmed. It is more of an implicit programming model with feedback loops so the system can act autonomously.

This point is critical; these are model driven systems. Typically, we explicitly program software or a machine to act based on rules we give it. In these advanced systems, however, instead of an explicit rule-based method, you would build a model to understand some purpose and feed the system data (with content acting as code), and the system would learn from that data and eventually operate with little or no human input or guidance. This is what makes the smart machines appear *intelligent*. Instead of explicitly defining the rules, you define how it is going to interpret the data. An interesting concept to realize is that if a system makes a mistake, it is not actually a bug; the system just has not learned it yet. AI and machine learning will drive the development of both intelligent things and apps.

2.1.1 Intelligent things

One implementation of intelligent things is in the field of robotics. From retail robots in hardware stores that help customers find items in the aisles to hospitality robots in hotels that take reservations or deliver room service, they are already here. Also, robots in healthcare will deliver medications and supplies to doctors and nurses in the hospital.

Another example of intelligent things, with the notion of leveraging AI, is in autonomous vehicles for specialized environments, since the digital enterprise extends beyond office buildings. Mature implementations exist within farming, mining, and warehousing. Companies are saving hundreds of millions of dollars by using autonomous trucks and autonomous drilling mechanisms for mining ore. Farm tractors operate in a coordinated fashion on farms. These are specialized and controlled environments—the low hanging fruit for these types of intelligent things.

These are specific use cases, but they will drive AI forward to permeate in more general scenarios. The question is how this innovation will affect our clients' digital strategy—regardless of where their operations are focused, whether in a warehouse or hospital or in a carpeted office.

2.1.2 Intelligent apps

Organizations are applying AI and machine learning

to create new app categories. Intelligent apps have the potential to transform the nature of operations within a digital enterprise. Some types of intelligent apps focus specifically on operational efficiency. One example is from McDonalds, which is driving greater efficiency over human or manual processes by moving to automated inspection of burger bun production to ensure and improve quality. The system uses a photo-analyzer to autonomously inspect over 1000 buns per minute for color, shape, and seed distribution, and it continually adjusts the oven processes automatically. This has resulted in the elimination of thousands of pounds of wasted product per year, a higher speed of production, and a reduction in manual labor costs.

Another category of intelligent apps is the virtual personal advisor such as the oncologist advisor at Memorial Sloan Kettering Cancer Center in New York City. This advisor uses IBM Watson on the backend. The premise is that doctors cannot keep up with all of the oncology trial information that is constantly being published. When a group of doctors gets together to discuss new treatments for a cancer patient, they try to pull research from various sources, and the oncologist advisor is another feed into that committee that can provide unique insights that the doctors could not have seen within their own human capabilities. This is therefore a high-value use case—the treatment of a potentially lethal disease of a patient. A complex problem with a lot of data such as this—the results of research from oncology trials from around the world—is that much of it is scattered, and the amount is overwhelming. In this use case example, the final result is a high-impact treatment plan (hopefully).

An important example of operational initiatives to support next-generation digital enterprises involves collaboration analytics. Dimension Data is writing analytics around collaboration including voice and video conferencing and messaging. As part of the next generation of digital enterprises, it is important from an operational efficiency perspective to know that these tools are being used and by whom and how often. How do companies know that they are really getting a return on their investment? Through Dimension Data's collaboration analytics, companies will achieve license optimization and cost savings, and will get a truer sense of the adoption patterns and use of collaboration technology in the business. This valuable information will ensure that organizations are in a better position to make decisions on investments around these tools to support better operational execution in their digital enterprise.

2.2 IoT

IoT is not just about things. It is also about building an experience for a user, designed to support a business function. IoT is much more complicated than deploying technology at the edge or platform or an application layer. Some of the complexities are explored below, and in the interest of brevity, focus is placed on edge-related technology considerations.

2.2.1 IoT cuts across several Dimension Data practices

Endpoint management is a critical component of IoT. Our enterprise mobility teams consider IoT device (or thing) management every day and how traditional mobile device management or enterprise mobility management systems fit in. Long-lived nontrivial *things* will require management and monitoring. This includes device monitoring (e.g., are devices still alive, are they connected, what is their battery status). They will need firmware updates, diagnostics and crash analysis, as well as physical management (e.g., installation, retirement, and relocation of things). This must include remote security management, of course (as edge endpoints will be vulnerable to security threats). IoT also brings new problems of scale to the management task, as tools must be capable of managing and monitoring thousands of devices.

Connectivity via low power wide area networks (WANs) is an area our networking practice is considering for our clients. They will be of critical importance in terms of data rates, the battery life of devices, cost, and density support. These types of advances will also have an impact on any organization deploying low-bandwidth IoT devices over wide areas. Some example applications include smart cities, utility meters, environmental monitoring, equipment tracking, and telemetry. Challenges to overcome include a lack of global standards and quality of service.

Our collaboration teams consider how IoT will affect the experience of employees and end-customers in the digital enterprise. As IoT emerges, there will be significantly more interfaces to the building or space, leading to collaboration smartspaces. A basic example here is a smart meeting room; if you walk into such a room, the lights will turn on, and the room will detect people in the room and perhaps adjust the environmental controls accordingly. It may also be able to detect and reconcile the number of attendees versus the number of people who said they would

attend the meeting and feed that information into backend managerial reporting systems. Connected assets such as temperature sensors, lighting, audio/visual equipment (speakers, microphones) will enable these use cases.

2.2.2 Opportunities & use cases

Dimension Data operates in about 47 countries globally, and we are seeing opportunities for IoT across all regions. Manufacturing and transportation seem to be the top industries spending on IoT in the Americas. Body-worn cameras and passenger traffic flow are two rapidly emerging use cases funded by increasing government security budgets. Manufacturing and transportation are also top spending industries in Asia-Pacific and Europe, as is utilities, with enterprise use cases centered around construction machinery management and environmental monitoring. Worldwide, momentum is building in the healthcare industry, as patient monitoring/experience becomes a growth area as a use case.

In addition to smart appliances, system automation and emergency services sit atop the highest-growth IoT use cases. Two specific uses cases are worth mentioning:

a. Securing and monitoring high-value assets is a critical use case, especially in the construction and healthcare industries. Assets are constantly being lost or stolen, and the installation of sensors to track location and measurement metrics such as fuel consumption or temperature tolerance has resulted in a reduction in loss and downtime of assets.
b. Implementing the Connected Workers solution has improved safety for employees in hazardous work areas (e.g., mines) by being able to track locations and to operate/monitor intelligent ventilation systems to alert radio frequency tags worn by workers. This helps to evacuate workers faster in case of emergency.

2.2.3 Dimension Data projects

Dimension Data's client experience in the realm of IoT is across many industries and regions. From connected cities (Barcelona) to connected healthcare (Australia and the United States), we are assisting many clients as they embark on their digital transformation journeys using emerging and innovative technologies. Two projects where IoT, data intelligence and analytics, and connected intelligent devices and sensors are utilized to address two very different use cases are described here.

To remain relevant in the sports industry and cater for existing fans and younger, more tech-savvy audiences, Amaury Sports Organisation (A.S.O.) needed to revolutionize the viewing experience of the Tour de France and other professional cycling races. They recognized that digital transformation is changing the way the world consumes sports media. Partnering with Dimension Data as an Official Technology Partner, A.S.O. used live tracking and data analytics to bring a second-screen viewing experience to pro cycling. This involved publishing real-time tracking data online through social media and on television (TV) during the race. Dimension Data helped A.S.O. build a live-tracking and data analytics solution connecting tracking devices on each bike to a fully mobile datacenter, and then to Dimension Data's cloud. Data are then analyzed and served up on TV and Internet screens around the world.

Dimension Data's Connected Conservation solution is another example of looking at digital transformation to mitigate the escalating crisis around unlawful rhino poaching in South Africa. The solution looked to provide better data and analytics by digitizing and analyzing the entry and exit information of people visiting the game park. Data are collected (e.g., fingerprints, identification scans, video captures) to create an electronic record of everyone coming into the park, with expectations of when they will be leaving the park. The data collected are analyzed on a continuous basis to enable better decision-making in terms of determining whether poaching is occurring, and the situation is escalated to the authorities when necessary. Multi-screen communication and wireless network connectivity keep rangers connected across multiple devices in all areas so that when it is time to act, there is little delay. This solution has been designed to provide a secure network and data flow, eliminating the risk of information falling into the wrong hands or criminals hacking into the system to falsify visitor records to gain access to the park.

2.3 Blockchain

Blockchain is a decentralized and distributed ledger for recording and validating transactions that enables trust to be placed in a heretofore untrustworthy environment. Verification of transactions or events is done without a central intermediary to slow things down or increase the cost of transactions and is therefore consistent with the speed and agility demands of a digital economy.

Think of the blockchain as a simple public ledger in

the cloud, and why the space is also referred to as distributed ledger technology (DLT) in some enterprise circles. This ledger is populated (append only) via a decentralized network of nodes that record transactions with a digital signature in the header. A group of transactions that are approved at the same time and added to the ledger is called a block, and such blocks are continuously and sequentially added to the chain. Each successive block contains a hash, which is an encryption algorithm that provides a unique result of each block. Tampering with any record in the block will cause the hash to change and show attempted fraud. Therefore, cryptography (via these hash codes) is used to secure the authenticity of the transaction, which removes the need for a central intermediary to verify or settle the transaction record. The excitement here comes in looking at how to use the same authenticated, distributed, and decentralized protocol to rethink transaction processing or recordkeeping in a more efficient and less costly manner.

SmartContracts, a sort of killer app of blockchain, offers a lot of promise to create intelligent systems with self-enforcing contracts to enable business processes to execute independently. This could change how patient medical recordkeeping is done, how healthcare institutions track medications, how we keep track of car ownership or shipping records, or even how we track utility usage in a city.

Blockchain and DLT will bring about a huge transformation in the operating model for many companies because we are going from a centralized transaction model to a decentralized one. Two important metrics to look at here are speed and cost. In a traditional centralized model, a transfer can take days, and the efficiency varies by country/institution. Moreover, there are high costs due to the number of intermediaries that need to provide the services necessary to settle payments. In the decentralized model, settlement is near real time, and there are lower direct transaction costs because processing is distributed across the network. For the long term, the increase in speed and reduction of costs will mean that everyone using traditional centralized systems will be disrupted.

2.3.1 Opportunity & use cases

When looking at the opportunities from a sector perspective, we can see that it is the financial services industry (FSI) that has been most active in embracing blockchain. After FSI, the top sectors that are starting to explore this area and invest financial resources in various use cases and proofs of concept are manufacturing and resources, as well as distribution and logistics. We feel there is a great opportunity for growth in the public and government sector, as there are several use cases that make sense for a technology that establishes provenance and an immutable record. Enterprises in Europe and the Middle East and Africa are spending money on use cases around regulatory compliance, which is driven by new legislation. In these regions as well as in Asia-Pacific, energy settlement in the utilities industry is experiencing growth driven by peer-to-peer trading to facilitate direct sales of power. Much of the money spent in the Americas is in the areas of banking and process manufacturing.

However, there are two top (and one emerging) use cases that are leading worldwide:

a. Cross-border payments/settlements across multiple industries is a key area that needs improvements in efficiency, trust, visibility, and traceability. This use case involves tracking, tracing, and managing cross-border/international payments and settlements and creating alternate payment and settlement rails (i.e., platform or network) for immediate payment and settlement.
b. Lineage/provenance is critical across many industries and regions across the globe. The ability to verify the origin and authenticity of a product as it moves throughout the value chain is invaluable whether the product is food or diamonds. This use case captures information about all inputs of a product, enabling accurate visibility and traceability into the history of that product.
c. Identity management is rapidly gaining traction as one of the most important use cases blockchain can address. The ability to accurately authenticate identities is part of the issue, but so is managing personal and financial data, as that will be critical in the new world of legislation around data privacy in many countries that is designed to address fraud prevention and data protection.

2.3.2 Dimension Data's role in blockchain and DLT ecosystem

In addressing the opportunity and blockchain use cases in the market, Dimension Data will look to enable DLT platform vendor solutions by providing the full stack around the digital infrastructure necessary for these platforms to operate. Leveraging our networking, security, and datacenter/cloud expertise in our role as an infrastructure and technology partner will be most effective in the ecosystem, and leveraging

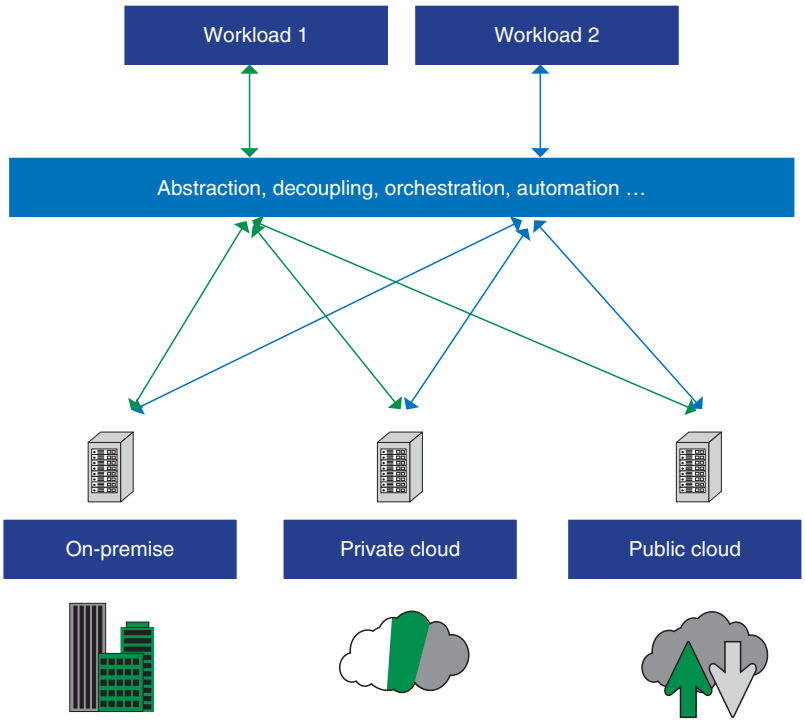

Fig. 1. Hybrid IT enabled through the Service Layer.

our system integration experience in interoperability among different blockchain networks and legacy systems will be critical to this emerging technology domain's success. We anticipate continued engagement with leading DLT platform vendors and application development and consultancy houses such as everis, an NTT Group company.

3. Service Layer: key component of platform-delivered managed services

Support for innovation across the emerging technology domains discussed above must be enabled via a platform to deliver operational and managed services. Dimension Data is well suited to help our clients in their digital transformation journey by providing a foundational Managed Services Platform (MSP) and its key enabling component—the Service Layer.

3.1 What is Service Layer?

Dimension Data's approach to our MSP covers several layers, from the presentation and application layers to the infrastructure layer. One key component or layer within the MSP is called the Service Layer. This layer provides a common service abstraction (via reusable components and services) for rapid integration, automation, and analytics. This layer is our approach to integration architecture.

The Service Layer retains some key features (**Fig. 1**) designed to truly enable Hybrid IT:

- Abstraction of common services required by all workloads. This is where we deal with identity, metadata, integration, analytics, development and operations (DevOps) and portal frameworks.
- Decoupling of the workload from the underlying infrastructure. This effectively removes the close coupling of the reference architecture to the underlying physical or virtual infrastructure.
- Automated readiness discovery and remediation. As we deploy projects, we encounter recurring challenges in trying to get existing environments ready to move to new architectures and platforms. We can now address automation at the workload level.

3.2 Service Layer overview

In terms of architecture, the Service Layer is an API (application programming interface) driven microservices architecture with a pluggable framework to

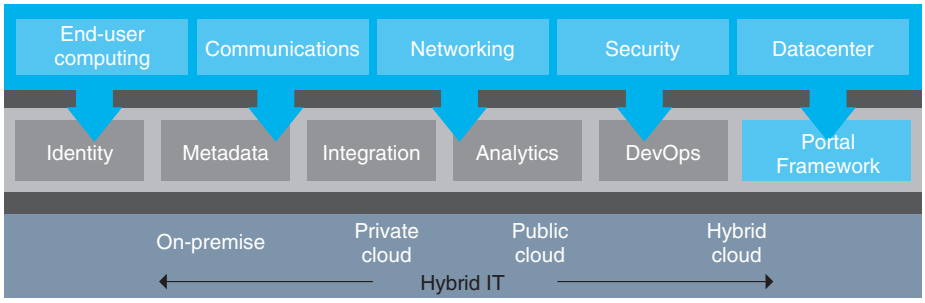

Fig. 2. Service Layer components.

support multi-service orchestration containing 100+ fully extendable micro-services. The Service Layer has a global footprint with availability in 20 datacenters distributed throughout 10 countries servicing 180+ enterprise clients globally cutting across major sectors including government and education, manufacturing, logistics, telecommunications, and banking. To put it in perspective, the Service Layer supports over 300,000 end users and facilitates over 1,000,000 transactions per day.

Currently the popular workloads the Service Layer supports include Compute as a Service, Managed Cloud Services for Microsoft Exchange (includes Skype for Business and SharePoint), Unified Communications, and Managed Backup. Common features of these products include automated onboarding, automated provisioning, and simpler management and monitoring.

The Service Layer has several components (**Fig. 2**) that address common challenges:

- *Identity*: Identity management capabilities to integrate with the client's Active Directory environment—ensures mailboxes & Microsoft Office accounts are tied to each user's corporate identity.
- *Metadata*: Key information about services that a client has deployed, users that have been provisioned, and top-level configuration information are stored in the MSP's metadata system.
- *Integration*: Integration capabilities exist to synchronize users between the on-premises Active Directory and the cloud-hosted Active Directory. Furthermore, it uses the MSP's asynchronous messaging capabilities to enable the automatic provisioning of accounts for new users.
- *Analytics*: Analytics capabilities are present to audit system access by administrators, generate usage reports, and meter resource usage per client so they can be billed appropriately.
- *DevOps*: Addresses deployment, multi-cloud libraries, and cloud portals as well as integration to common DevOps tools such as Terraform and Chef. Shared code is in GitHub.
- *Portal Framework*: A web-based management interface leverages the Portal Framework to share branding and navigation with other Dimension Data cloud services and to provides users with a single sign-on experience using their corporate credentials.

3.3 Case studies

Several clients have already benefited from the use of our Service Layer as part of our MSP offering across several industries. A couple of example case studies are from the government sector.

A large government in the Oceania region struggled with high costs around small mailboxes on older exchange infrastructure as well as difficulty in adding new services such as archiving or Skype for Business (S4B) and was looking for a managed service to facilitate seamless migration from a previous provider. Our Service Layer provided integration capabilities for S4B, email archiving, backup, and other services. These services are used by 80,000 users, and they are integrated among systems across 26 agencies. The government effectively reduced the cost of ownership of their email and collaboration solution while also adhering to government data sovereignty and regulatory security requirements.

A large government institution in Europe identified the need for a single unified communication and collaboration platform as well as a desire to have a dedicated centralized S4B service platform for all federal institutions. The Service Layer provided such a platform designed based on a private cloud architecture with integration into third-party contact center

solutions and included metering based on federal institutions. This solution helped reduce the total cost of ownership of their unified communication solution, which was compliant with security and data sovereignty requirements and also designed to scale for 80,000+ users.

4. Summary: co-innovation with NTT operating units

As we continue to engage in the emerging technology domains discussed above, there will be plenty of opportunities for Dimension Data to collaborate and extend our proposition through engagement with other NTT operating units. There has already been plenty of activity in this regard.

We have engaged in co-innovation within the IoT domain with the NTT laboratories and have used "hitoe" technology [1] in the Deakin FLAIM Trainer project. This was a collaboration with our client, Deakin University in Australia, that involved a solution to train future fire fighters without exposing them to dangerous life-threatening conditions. The solution consisted of a head-mounted virtual reality display to visualize various realistic training scenarios, protective "hitoe" clothing with heat generation components so the user could feel the conditions of the simulation, and Dimension Data's analytics platform to analyze performance data and present results in a supervisor dashboard. This solution was demonstrated at the 2018 NTT R&D Forum.

Dimension Data's Networking practice has engaged NTT Communications around a full stack hybrid WAN offering utilizing Virtela. The solution will offer global bandwidth to our clients as well as focus on software-defined WAN & MPLS (multiprotocol label switching). Our clients will be able to leverage the benefits of points-of-presence in 160 countries.

Hybrid Cloud is a key go-to-market area for Dimension Data's Next Generation Data Centre practice, and the team at this practice has engaged with NTT Communications in offering private, public, and hyperscale solutions including elements such as advanced managed hosting, co-location, datacenter relocation utilizing NTT Communications' facilities, and leveraging of global datacenter interconnects.

Dimension Data's Cybersecurity is working with NTT Security to offer full suite cybersecurity to our clients by leveraging ten security operation centers to deliver services over a global threat platform with managed security services in tow. Together we can offer cyber advisory services such as vulnerability assessments and pen testing focused on the infrastructure, users, and applications.

Dimension Data's Digital Business Solutions practice looks to achieve ERP (enterprise resources planning) scalability by working with NTT DATA around offerings such as SAP and Oracle migration as well as cloud services for SAP HANA Enterprise Cloud.

Full suite collaboration is the goal as Dimension Data's collaboration teams engage with other NTT Group companies such as NTT Communications and Arkadin. Our joint approach is to address a multi-vendor asset footprint whether implemented on-premises or via the cloud. Together we can achieve full collaboration as a service on a global basis in a hybrid IT model that includes Microsoft Office 365. This is all supported with system integration and managed services, as well as telecom expense management and analytics to deliver an end-to-end solution to clients.

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Nadeem Ahmad
Group Vice President, Group CTO Office, Dimension Data.

Nadeem Ahmad is a technology professional with over 20 years of experience in the software consulting and infrastructure services industry with an Internet application development background. He has been working within the specialist IT services area for the past 15 years with recent experience across cloud services, and a current focus within the IoT and blockchain domains. He has built technology delivery organizations in terms of people, capability and processes as well as led multi-disciplinary teams during technical delivery projects across several client industries including financial services, higher education, healthcare, and consumer goods.

Nadeem is currently involved with business innovation projects and defining strategic technology direction, as well as solution development and execution, across several technology areas that will impact enterprise clients in the near future. This involves looking at current trends in the enterprise markets and evolving certain trends from concept to revenue generating solution strategies. Nadeem's recent areas of focus include IoT, containers, microservices and blockchain, with a previous focus on end-user computing and cloud, enterprise mobility, wireless LAN solutions, and mobile Internet strategies.

Nadeem was born in Zambia, Africa, grew up in New York City, lived in London, UK, and now resides in Austin, Texas, with his wife and five-year-old daughter, Aaliyah.

SuSI (Supported Smart Innovation) Leads Strategic Innovation by everis

Carlos Galve

Abstract

Headquartered in Spain and a member of the NTT DATA Group since 2014, everis is a multinational firm dedicated to consulting and outsourcing in all sectors, with 19,000 professionals in 16 countries across Europe, the USA, and Latin America. This article introduces SuSI (Supported Smart Innovation), a corporate unit that leads the company's innovation strategies.

Keywords: global, innovation, R&D

1. Introduction

SuSI (Supported Smart Innovation) was created in 2014 as a strategy to offer new value to our clients. The mission of the department is to promote, industrialize, and facilitate the company's innovation processes transversally in the business units (BUs), business sectors, and cross areas* (**Fig. 1**). We are also very committed to taking part in innovative research and development (R&D) activities such as Innovation Hub with NTT DATA, and we work closely with Japan and other EMEA (Europe, the Middle East and Africa) operating companies in the NTT Group.

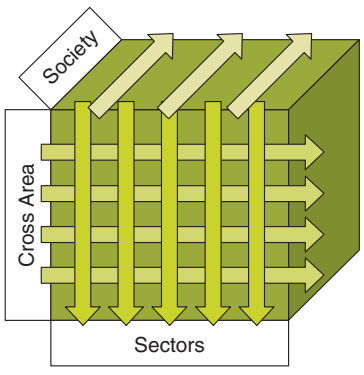


Fig. 1. everis is a matrix organization.

2. Innovation horizons at everis

everis [1] is following an innovation strategy that covers three *innovation horizons*. In horizon 1, our business sectors and cross areas lead the production evolution of existing technology and markets through improvements, extensions, and operational cost reductions. In horizon 2, which is the one led by SuSI, we explore existing markets and technology, but unlike in horizon 1, our activities are centered on next-generation products for core markets as well as asset development. Horizon 3 is focused on disruptive innovation led by the everis nextGen unit (**Fig. 2**).

In summary, we can say that horizon 1 identifies new needs and improves current business practices, horizon 2 works on meeting mid-term innovation business needs, and horizon 3 looks for disruptive innovation for the long term. However, once horizon 3 has reached a mature level, we go back to horizon 2 to develop new innovation use cases. Finally, this innovation will enrich the portfolio of the business sectors in horizon 1 and increase the value they offer.

The knowledge acquired is transferred continuously between the different horizons, and those involved provide the corresponding feedback to each other.

* Cross areas: An everis term referring to Business (business consultancy), SAP & Enterprise Solutions, Outsourcing, Business Process Outsourcing, Technology, and Enterprise & Cloud Solutions.

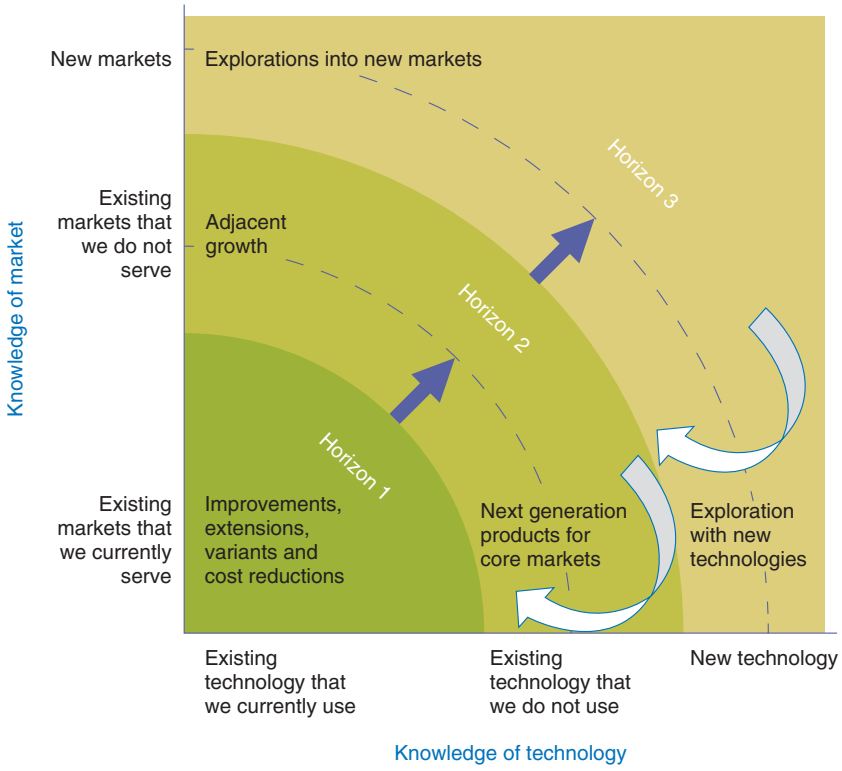


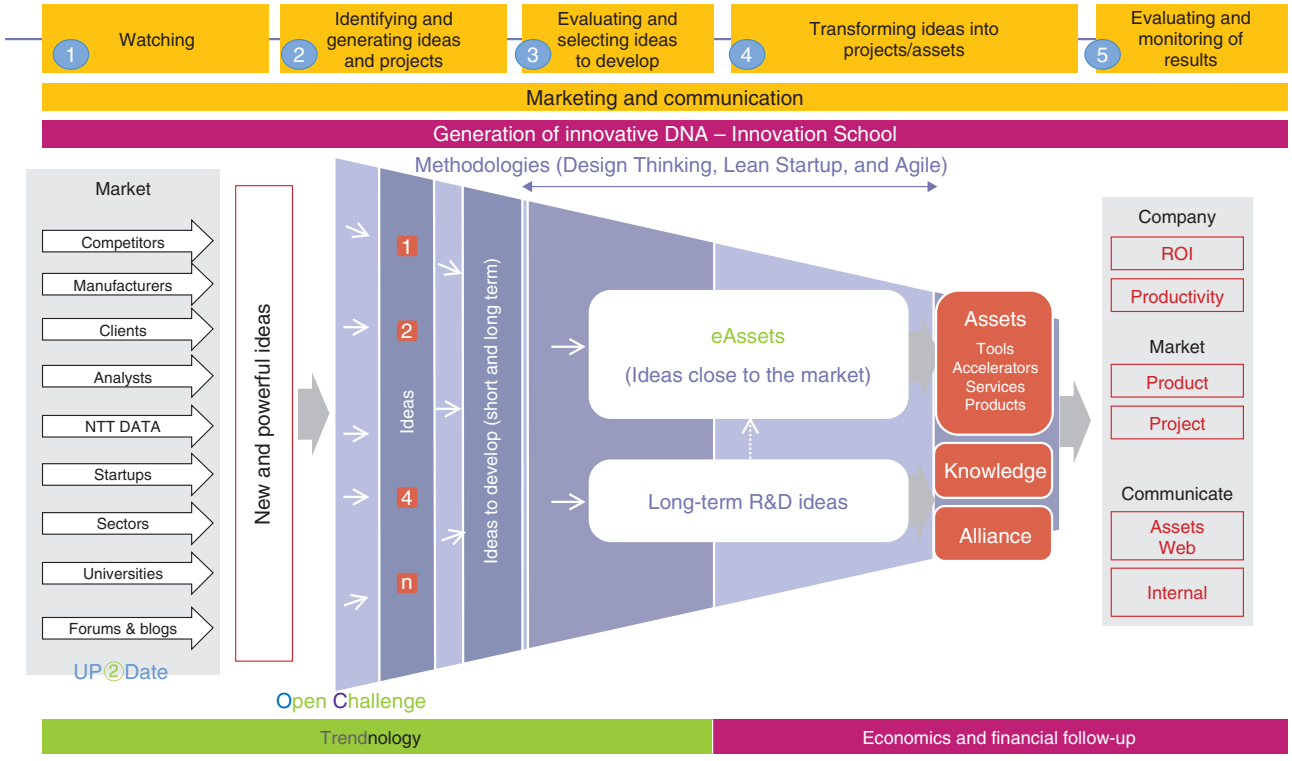
Fig. 2. Innovation horizons.

3. Activities of SuSI: strategic innovation

As a strategy, we have established a strategic innovative framework. The activities carried out by SuSI are focused on three main areas. The first is strategic innovation, in which the objective is to introduce a systematic process of innovation and the creation of *innovative DNA* in the company. The second one, funding, provides support in obtaining competitive funding by offering information about external funding and assistance in accessing it. The third is monetization, which supports BUs in obtaining tax deductions related to research, development, and investment (R+D+I) and controls the investment in assets and the generation of intellectual property (IP). The funding and monetization efforts are extremely important for our innovation strategy.

The strategic innovation effort establishes an innovation process that starts with market research, generation and evaluation of ideas, transformation of the ideas into projects and the seeds of the future product portfolio, through to evaluation and monitoring of the results (**Fig. 3**).

Concretely, the first stage (Watching) consists of the complementary initiatives *Research Services* (providing specific information for BUs from the best insights and reports from analysts such as Gartner, Ovum, etc.), *Up2Date*, and *Trendnology*. Up2Date is a tool that scans hundreds of sources and detects future trends in order to provide the most relevant and updated short-term information on technologies and innovations that can affect or be used by the business sectors and cross units. It is one of the initiatives we are collaborating with NTT DATA on as part of the NTT DATA Technology Foresight annual report (NDTF) [2] (**Fig. 4**) in order to identify new trends in their early stage. Trendnology is the other initiative, a tool to gather informed opinions by taking advantage of the best sources (Up2Date, researchers, scientific articles) and internal and external experts in a three-axis matrix: technology, business impact, and social challenges our company is facing. Trendnology will connect and reduce the gap in a natural way between short-term innovation and long-term research, which is the focus of the NDTF. The combination of all these initiatives could also be used as a validation tool for internal decision making on investments and to align technology and business dimensions.



ROI: return on investment

Fig. 3. Strategic innovation.

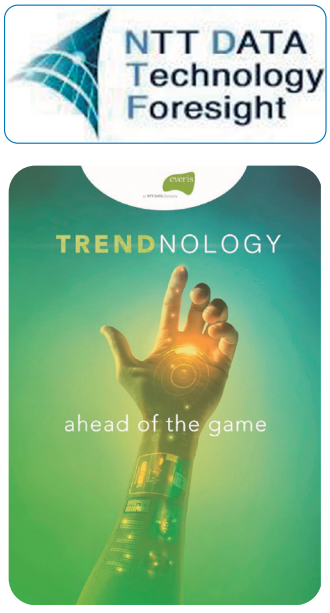


Fig. 4. NTT DATA Technology Foresight.

For the second and third stages (Identifying and generating ideas for projects and Evaluating those ideas), SuSI proposes initiatives such as Hackathon (with the first NTT DATA Global Hackathon taking place last November in Barcelona) and Open Challenges along with the BUs to help them gather and select the best ideas suited for the next sector's challenges. These ideas will be some of the seeds for developing assets.

In the next stage (Transforming ideas into projects) the coaching/mentoring starts for the teams working on the selected ideas to help them develop the ideas using world-class innovative methodologies such as Design Thinking, Value Proposition, and Business Model Canvas, and then starting Agile development with the Lean Startup approach to gain their first insights.

In the final stage, once the BUs have confirmed their commitment with the Open Challenges results, the ideas go into a new level of technological incubator called *everis assets (eASSETS)* (**Fig. 5**). This asset incubator was created for the purpose of facilitating all of the company's initiatives in asset development

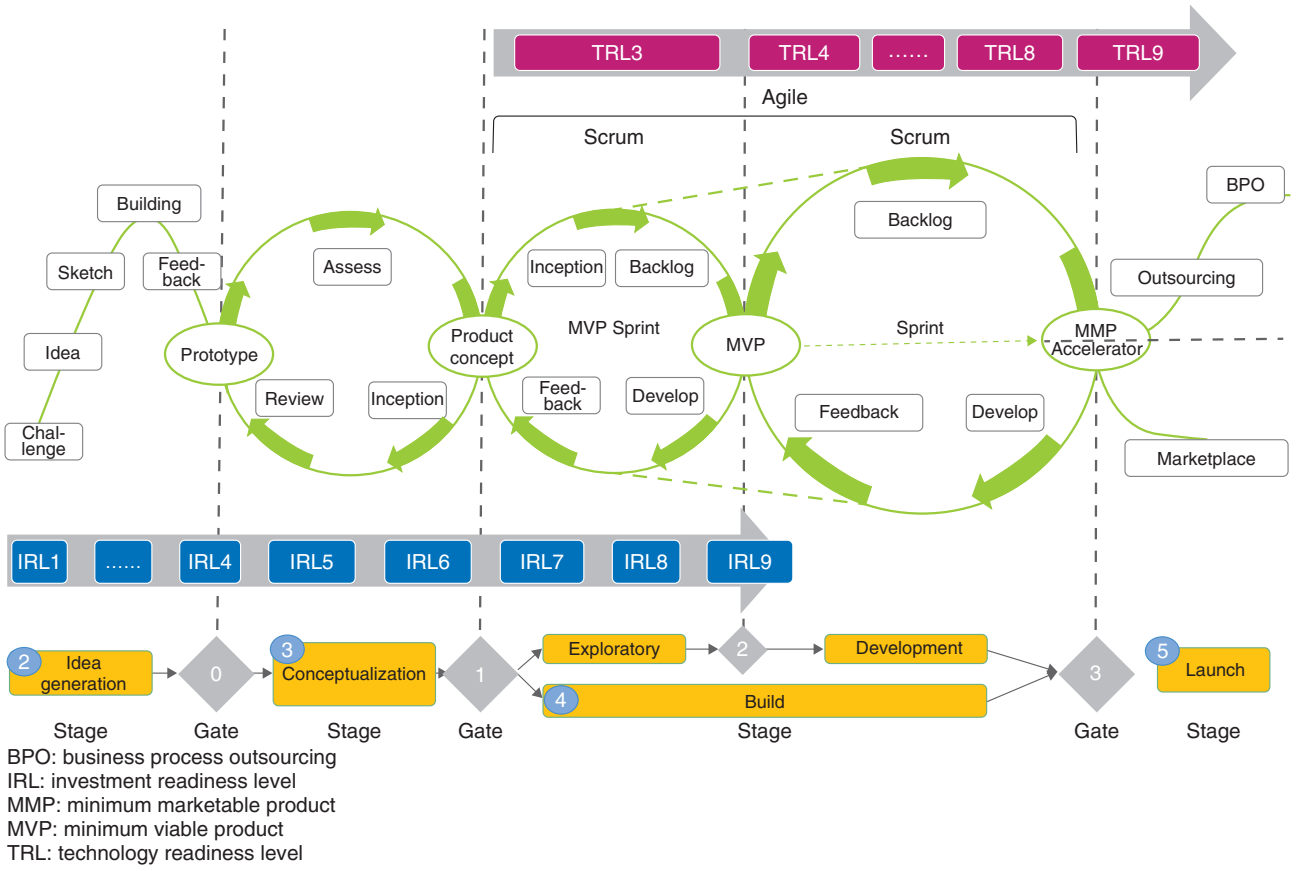


Fig. 5. everis assets (eASSETS).

and tackling the asset life cycle management so that the created asset is a readily marketable product. This process, which starts with idea assessment, is supported by four important pillars: a specific methodology that addresses the entire asset life cycle, specific tools to carry out the development (such as Altemista or Cognitive Assisted Development (CAD), whose details are presented in section 4), technical teams specialized in asset development, and a cultural management process within the company that encourages people to innovate and change from *thinking about projects to thinking about products*.

In this process, the technical team as well as client managers, the outsourcing team, BPO (business process outsourcing), and the Agile and Idea teams are involved. The methodology is very effective, and the results are impressive, especially thanks to the specialized eASSETS professionals, who support the entire asset maturation and incubation process, and also thanks to the company commitment that encourages encapsulating the everis knowledge in attractive products to customers and markets.

Other cross initiatives such as *Innovation School - InnCub3* or *The Wall* focus on generating innovative DNA and supporting a vibrant community of innovators. InnCub3 offers training in practical innovation skills in coordination with everis University (internal educational programs). These activities are also supported by our innovation ambassadors within the BUs.

The Wall is the monthly newsletter sent to the innCub3rs community (people identified as having an innovative profile in the company) that reports on innovation and creativity aspects: news, invitations to workshops, courses, talks, recommendations of videos, and articles.

Finally, I will explain the support of the Funding and Monetization teams. The Funding team provides assistance in getting competitive funding by offering information and support to BUs and sectors in accessing external funding. We focus mainly on public R&D funding opportunities provided by the European

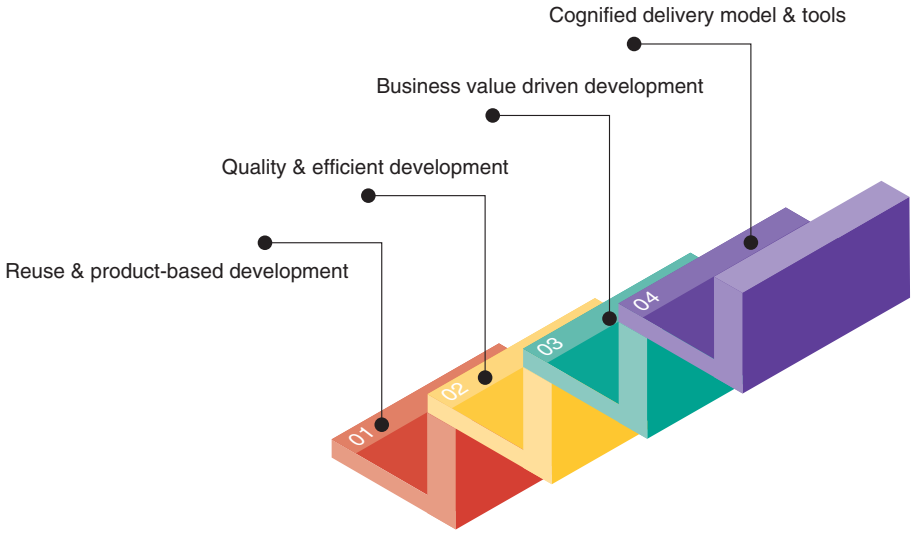


Fig. 6. CAD initiative.

Commission. The requirements are very strict, and it is a very difficult competition. Nevertheless, we have succeeded in obtaining more than 1.5 million euros per year. For example, we have recently won two projects: one about blockchain applied to avoid fake news, and the other about artificial intelligence applied to medical images in order to detect and predict illness (e.g. cancer).

The Monetization team leads the process of obtaining tax deductions related to R+D+I for the created assets. This effort helped the company reduce its taxes by about half a million euros in fiscal year (FY) 2017. The team also helps the BUs draft business plans and observes their commercial achievements. In this way, we manage asset investment and IP generation.

4. Asset creation of SuSI

When we identify assets that will be part of the core transverse strategy of the company, SuSI is also in charge of their development. In addition to Up2Date, Trendnology, and eASSETS already mentioned, we have developed everisKnowler and CAD.

4.1 everisKnowler

At everis, we consider that employee knowledge is one of our most valuable assets. Sharing knowledge about projects or human skills improves numerous aspects in the company such as the project management capacity, human resource allocation, and quality of solutions, and it reduces the time to produce related documents. However, sharing knowledge between different sectors or offices has been a challenging task.

The everisKnowler system was initiated in 2017 in order to deliver the right knowledge to the right people at the right moment without asking. In this system, structured and unstructured information from all company documents is extracted by text to knowledge processes, and relevant information is stored in triplets (a format consisting of subject, verb, and object elements), which enables semantic searches to be done in natural languages (multilingual) and connects all the information (knowledge) in the company. Furthermore, everisKnowler has the capacity to analyze the research history of each user (for example, the activity, projects participated in, colleague relationships, email, and documents), which enables it to suggest useful information to the user without the user asking. Pilot testing of everisKnowler will be done this year in some sectors at everis, and in the near future, it will be deployed as the general intranet of the company. We are also working together with the NTT DATA Knowledge Management team in this initiative to study the feasibility of implementing everisKnowler in Japan.

4.2 CAD

This is a very innovative and critical initiative that was developed in order to respond to the huge social demand for fast software development (**Fig. 6**). Until

2021, the market demand for application development is predicted to grow at least five times faster than the information technology (IT) capacity to deliver it. Recruiting IT professionals has become a difficult task, so to reduce IT backlog, new stakeholders without IT skills have emerged—citizen developers—who create new business applications for consumption by others using development and runtime environments sanctioned by corporate IT.

To support this scenario, a set of platforms, known as low-code platforms, has been developed.

They are defined as products and/or cloud services for application development that employ visual and declarative techniques instead of programming. They are available to customers at little or no cost in terms of money and training time, with any costs involved rising in proportion to the business value of the platforms. Business demands continuous value delivery that requires solutions that are: 1) rapidly built; 2) seamlessly and continuously deployed; 3) easily changed; and 4) that require no bug fixes. If IT corporations do not offer this bimodal IT approach, customers will apply shadow IT (solutions developed by non-IT departments) and will acquire devices, software, and services outside the ownership or control of IT organizations.

In this context, the main motivation in developing the CAD initiative is to avoid shadow IT from our customers, with the aim of leading a software development transformation process oriented to achieve a high productivity, continuous business value delivery model. CAD will promote an IT methodological approach, supported by cognitive tools, supporting the full E2E (end to end) development life cycle to improve the development of cloud-native solutions. This year we have already started to work with the Product Engineering team of NTT DATA to study a possible collaboration to develop this asset.

5. Conclusion

SuSI is based at everis Aragón (Zaragoza), where I have been the director since its establishment in 2009. It is the central office for SuSI's asset development. It is also the base for other units such as the Center of Excellence of AI, where the artificial intelligence platform everisMoriarty is being developed, the DevOps team, which is working on Altemista, and other specialized centers for digital experience and architecture. The operation scale of everis Aragón is getting larger each year, and FY 2017 closed with a turnover of 10 million euros thanks to our innovation, an increase of 30–40% compared with the previous year. The forecast for FY 2018's turnover is 12 million euros. Our team consists of 265 professionals, and we plan to add about 80 more people this year. It makes us feel very proud to lead the innovation of everis and to coordinate all the relationships regarding innovation with NTT DATA. We hope to boost our group collaboration even more in the future.

References

[1] M. Alba, "everis and the Next Generation of Digital," NTT Technical Review, Vol. 14, No. 10, 2016. https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201610ga1.html

[2] NTT DATA Technology Foresight, https://www.nttdata.com/global/en/foresight/trend-listing/trend-archive

Carlos Galve

Partner, everis; Director, everis Aragón; Head of SuSI, Assets Strategy; also a member of the Global Steering Committee at everis.

He obtained an MBA-PDD from IESE Business School, University of Navarra, Spain, and has certification as a Computing Engineer and in Pedagogic Adaptation. In his 25 years of experience in digital transformation and technology, he has led several innovative companies as chief executive officer and/or chief technology officer. He also has 10 years of experience in venture capital, in which he led digital and technology investments. He is a founder shareholder of several innovative companies and is also working as an external expert of innovation for the European Union.

Open Innovation Strategy Pursued by NTT DATA Italy

Giorgio Scarpelli

Abstract

NTT DATA Italy is adopting an open innovation strategy and pursuing collaboration with clients, universities, and startups. The company is focusing particularly on innovation with clients and utilizing an idea management platform called IdeaHUB, where employees with good ideas can post their ideas and gain feedback on them. This article introduces these research and development activities.

Keywords: global, innovation, R&D

1. NTT DATA Italy open innovation model

NTT DATA Italy is pursuing an open innovation strategy aiming to master the big shift we are experiencing nowadays, characterized by several revolutions—all driven by technology—that are happening together at the same time.

Innovation is not just related to ideas, as ideas that just stay in labs or universities are not innovation, they are just ideas. Innovation is more complex. It is the way we bring ideas to reality, turning ideas into something real and useful, failing and retrying, starting from a need and finding an answer. The capability to turn creativity into reality is the key to make the most from innovation, but everything starts from ideas, and in a hyper-connected world, both ideas and capabilities are everywhere. For this reason, we are committed to finding ideas and niche capabilities to turn into reality and bring to the market.

Therefore, innovation is the capability to transform ambitious ideas into tomorrow's solutions. It involves technology and research and development (R&D), of course, but includes much more: intuition, vision, ability to execute, all supported by passion and courage. All of this is expressed in an ecosystem that values perspectives and approaches outside our comfort zone.

This capability is substantiated by the network of relationships, collaborations, and shared efforts that produce the ideal context to imagine new things and find the support to realize them. Such a network of relations is what we call *open innovation*, a kind of distributed collective genius in which several stakeholders, including customers, are part of. By offering our customers the possibility to actively enter the ecosystem and to enable direct and indirect collaboration with universities and startups, in addition to our internal capabilities and labs, we make our open innovation model a key business enabler. We call this the Innovation Empowerment Model (**Fig. 1**).

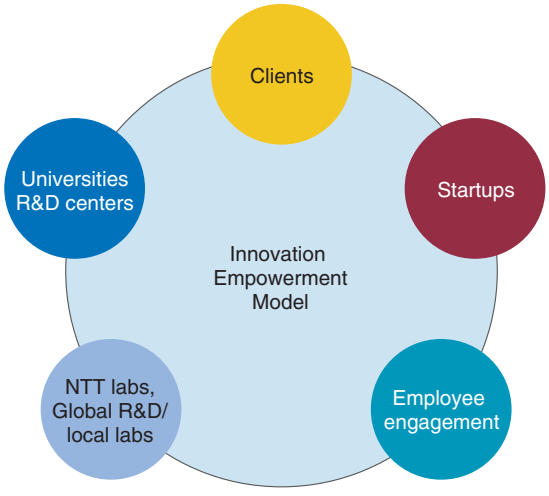


Fig. 1. Innovation Empowerment Model.

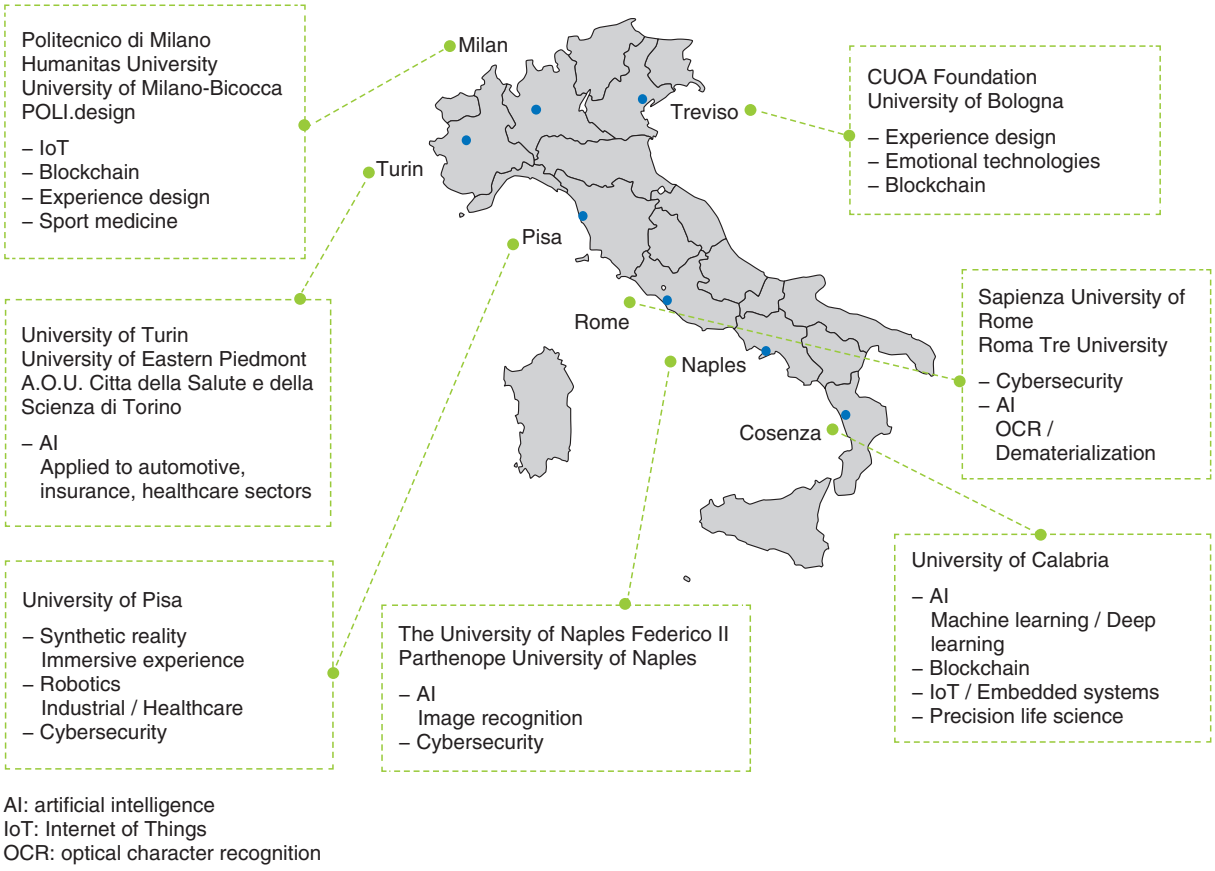


Fig. 2. Collaboration with universities in Italy.

2. Collaboration with universities

Universities represent one of the main actors in the open innovation ecosystem. Maintaining relations with them is one of the most relevant success factors in our strategy, for several reasons:

- Being connected with talented resources
- Accessing cutting edge research
- Receiving information on future technology scenarios
- Being in contact with spin-off and startup incubators that are often based close to the university context

We have experimented with several modalities to collaborate with universities, each characterized by a different level of complexity, such as:

- Degree thesis and internships in domains of interest for NTT DATA
- Ph.D. studies in relevant industry fields
- Open Labs using NTT DATA technologies
- Public funding partnerships
- Post-graduate master's degrees

We are leveraging the presence we have in the entire Italian territory to strengthen collaborations with the local university ecosystem, focusing each area on a peculiar innovation domain (**Fig. 2**).

3. Collaboration with startups

The network of relations that enables the open innovation model gains great value from the startup ecosystem, whose effervescence fuels our capacity to grow while leveraging innovation. The *startuppers* have dreams on which they bet their lives, which are rooted in their passions, which stimulate their ambitions, on which they feel and want to become number one. This is why ideas coming from the startup ecosystem are often the most brilliant and most visionary. However, the startuppers need a travel companion who shares the same spirit who can help them to direct their energy, in order to examine all the aspects necessary to compete in the market. This travel

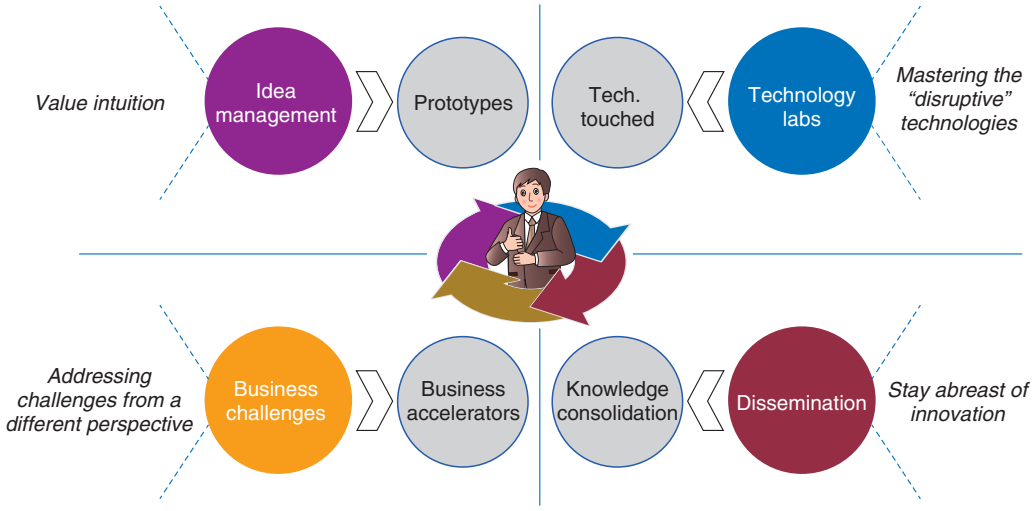


Fig. 3. Co-innovation with clients.

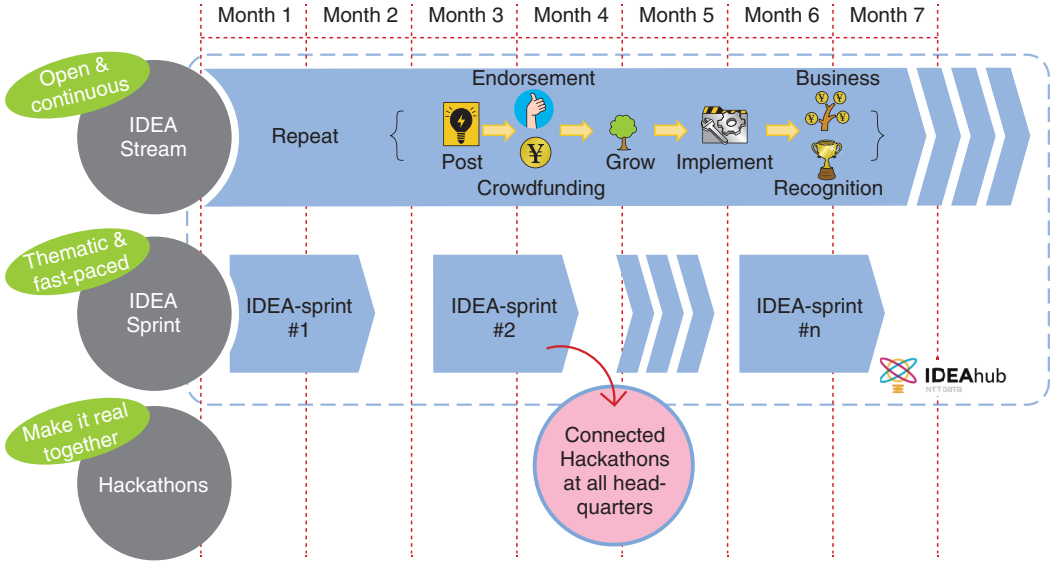


Fig. 4. IdeaHUB.

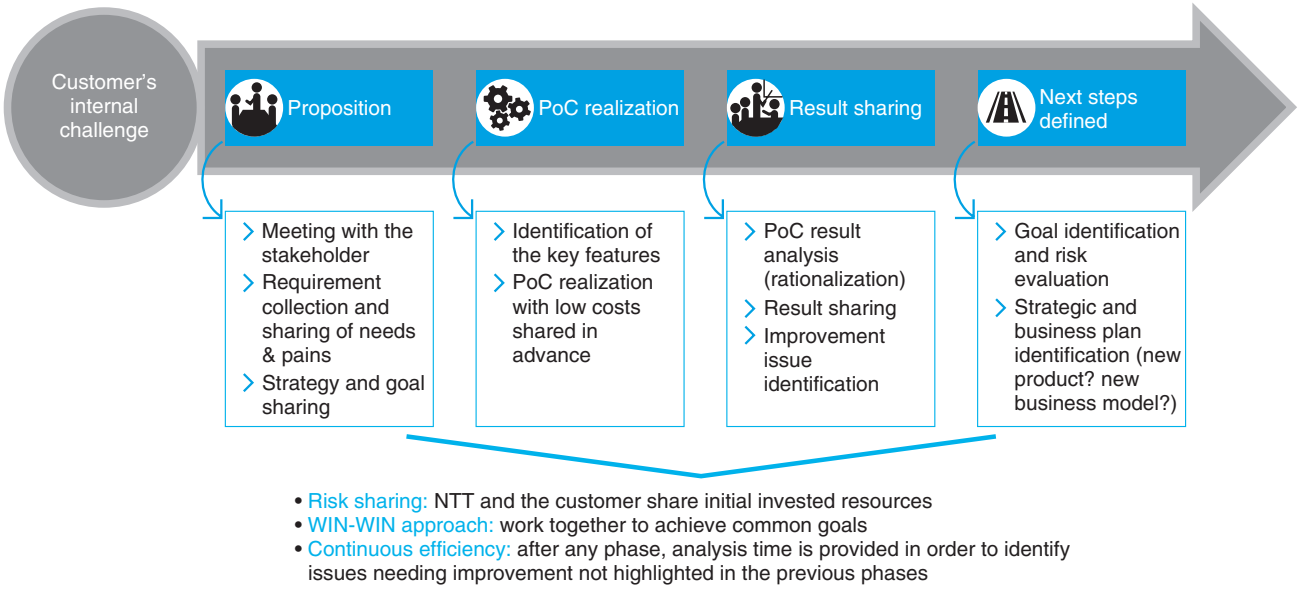
companion will also complement the strength of the startupper's enthusiasm with experience and maturity and look at projects with the realism of one who is familiar with the dynamics of the market.

We are interested in startups for the ideas they can generate, which are enhanced with a long-term project that creates value because it has value in the market. In the last year, we started several collaborations with about 15 startups to explore concrete business opportunities, including some outside Italy, in Europe and Japan.

4. Co-generating innovation with clients

We export the open innovation model to our clients, providing them with a way to respond to their needs for innovation, for whatever reason they have (**Fig. 3**).

To give value to our intuitions, we utilize an idea management platform called IdeaHUB (**Fig. 4**) that permits anyone who has a good idea to post it and



PoC: proof of concept

Fig. 5. Design thinking and quick prototyping methodology.

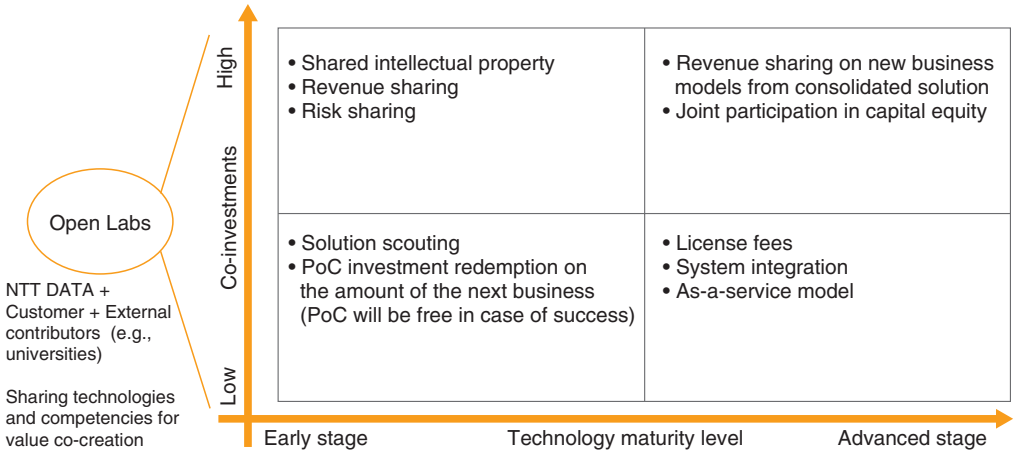


Fig. 6. Open Technological Labs and collaboration model.

gather opinions on it. IdeaHUB is utilized both for fueling internal idea generation and as a service to support our clients with their external challenges. IdeaHUB can also be used to manage *ideackathon* (idea + hackathon) initiatives and special challenges and competitions.

When our customers ask us to help them solve their challenges, we propose a methodology based on a *design thinking* approach to understand the problem and a *quick prototyping* approach that gives the possibility to actually touch the technologies while limiting the costs of trials (**Fig. 5**).

Technologies that have the potential to solve a business challenge or disrupt the business posture of our customers can be jointly experimented on within Open Technological Labs, which are physical/virtual spaces where we can touch technologies with our hands. We propose a collaboration model characterized by a level of co-investment that depends on the maturity level of the involved technologies (**Fig. 6**).

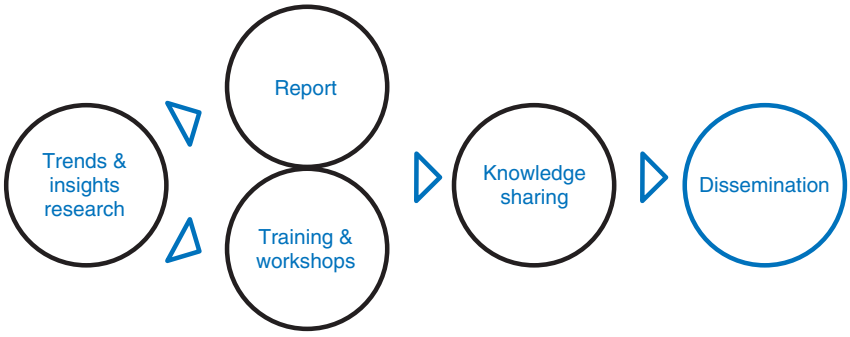


Fig. 7. Consolidating knowledge and making it accessible.

As part of the co-innovation model, we provide services for consolidating knowledge and making it accessible (**Fig. 7**). Such services are centered on analyzing market trends and providing a vision of technology trends while maintaining a specific focus on the business concerns of our customers.

As a member of a large multinational company with a presence in over 50 countries, NTT DATA Italy can guarantee the support of the most valuable initiatives thanks to the value of our brand and the credibility that we can provide to our partners, even beyond Italian borders.

Giorgio Scarpelli
Senior Vice President, Head of Innovation, NTT DATA Italy.

Giorgio Scarpelli holds a degree in mathematics from the University of Calabria. His current position is Chief Technology Officer and Head of Innovation at NTT DATA Italy. Among his goals are to promote innovation trends in the Italian market and to contribute to NTT DATA's global R&D strategy by collaborating with NTT DATA Corporation in Japan.

He is the scientific director of the R&D project concerning End-User Protection within the Cyber Security technological district, one of the biggest initiatives on this topic in Europe. He has also worked for companies in the IT field such as Bull and Value Team. In 2001, he was one of the founding members of VP Technologies, a Value Partner Group's specialized brand in security. Before that, he was the head of the South Europe technical support team for security products at Bull/Evidian Company. His main areas of interest are innovation, network and information security, and leading-edge technologies.

CLOUDWAN: NTT i^3 Software-defined Wide Area Network Solution for Edge Computing

Takeshi Motohashi

Abstract

Since its establishment in 2013, NTT Innovation Institute, Inc. (NTT i^3) has been developing technologies in the fields of cloud computing and security. Today, technology trends are entering a new stage with the advent of software-defined networking, Internet of Things, and artificial intelligence. This article introduces CLOUDWAN as a software-defined wide area network solution developed by NTT i^3. CLOUDWAN provides functions for not only virtual private networks and network functions virtualization but also an edge computing solution through an application delivery function targeting CLOUDWAN's terminal devices at customer premises.

Keywords: edge computing, SD-WAN, IoT

1. Introduction

NTT Innovation Institute, Inc. (NTT i^3) was established in 2013 as a sister company to the research laboratories of NTT (holding company). Located in Silicon Valley on the west coast of the United States, it is an applied research and development (R&D) center that aims to contribute to the creation of new business for the NTT Group's global operation companies. Since its founding, NTT i^3 has been targeting cloud computing and security as fields for technology development, and it has been developing products in those fields using in-house or Silicon Valley-developed technologies as well as contributing to open source communities. It has also been introducing NTT Group efforts in innovation to customers (global firms) at its Customer Experience Center (CXC) and providing proof of concept (PoC) activities geared to solving customer problems.

Today, five years after its establishment, NTT i^3 has come to focus its efforts on new technology fields including software-defined networking, machine learning, artificial intelligence (AI), the Internet of Things (IoT), and edge computing. Moreover, wireless access technology is progressing rapidly toward the fifth-generation (5G) mobile communications. Thus, technology development in the fields targeted by NTT i^3 must correspond to this trend.

In addition to technology and product development, NTT i^3 is providing PoC solutions in human monitoring for the sports field and manufacturing sector such as the automotive industry. These solutions are being presented as PoC activities using R&D technologies such as "hitoe" (functional wearable material) and machine learning analysis. NTT i^3 has also been introducing R&D technologies as its R&D Showcase to visitors since 2017 to obtain feedback from customers in order to improve the future technology development of the NTT laboratories and NTT operating companies (**Table 1**).

This article introduces CLOUDWAN, a state-of-the-art software-defined wide area network (SD-WAN) solution launched by NTT i^3 as the result of its technology and product development. SD-WAN is a field that has recently attracted attention as a new trend in network services, and this commercial SD-WAN solution was launched in South Africa and Japan in 2017. One of CLOUDWAN's advantages is its proprietary edge computing platform that can add functions by delivering applications to terminal

Table 1. Current NTT i³ activities.

Technology domain	NTT i³ activities
SD-WAN Edge computing	CLOUDWAN Global commercialization
IoT Artificial intelligence / Machine learning	Human health monitoring with "hitoe" PoC solutions
Virtual reality, speech recognition, etc.	CXC R&D Showcase Demonstration for CXC visitors

SD-WAN: software-defined wide area network

devices. We are proposing this innovative solution to operating companies and customers under today's strong market competition.

2. Background to edge computing technology in IoT environment

Edge computing is a form of cloud computing technology that enables information processing, data storage, and other functions conventionally carried out closer to the place where users or sensors are, rather than in central datacenters [1, 2]. With edge computing, applications run close to the end users, creating faster responses. Edge computing technology can be expected to enable the provision of a variety of new services such as augmented reality, virtual reality, industrial IoT, smart healthcare, connected cars, and smart cities. In particular, the IoT environment requires processing of streaming data from massive IoT devices, but if such a massive amount of data were to be sent to the cloud side, a large communication bandwidth would be needed, or network delays would occur. In contrast, processing on an edge computing infrastructure close to IoT devices can be expected to reduce such data-capacity and delay issues.

3. CLOUDWAN: from SD-WAN to edge computing

From early on, NTT i³ has been developing and commercializing software-defined networking (SDN) and network functions virtualization (NFV) technologies. In 2015, we announced Elastic Service Infrastructure (ESI), an NFV-based infrastructure for enterprise networking, and began to deploy it at datacenters. Then, building upon this achievement, we released CLOUDWAN [3] in 2017 as an SD-WAN solution. Internet Solutions in South Africa and NTT PC Communications in Japan have begun to provide CLOUDWAN as their commercial services, and Hitachi, Ltd. is one of the major customers of CLOUDWAN [4] as well. The number of customer premises using CLOUDWAN continues to increase steadily.

In addition to offering virtual private network (VPN) and NFV as standard functions by SD-WAN, CLOUDWAN features an application delivery function for its terminal devices. This means that CLOUDWAN can also be an edge-computing infrastructure in the IoT/AI environment.

4. Issues in service delivery and operations in IoT environment

Edge computing is the new horizon for IT (information technology) convergence. The network, services, and functions converge into a single capability that can be delivered anytime and anywhere, and can be instantly updated, removed or modified.

Delivering services to distributed areas and offices has always been a challenge. As business enterprises have expanded, the network has exploded as well. However, the way to operate the network has not changed. The existing approach of making the manual task of operating and managing such infrastructure is nearly impossible, as locations and services remain distant and remote.

CLOUDWAN is a single solution delivering all the components needed for the journey to edge computing:

- The speed and agility of overlay networks
- The delivery, management, integration and control of NFV and network orchestration
- Applications and DevOps (development and operations) at the edge of a network

These functions provide uniform management of networks, services, and applications, making it possible to deploy them anytime and anywhere and to perform updates and deletions quickly.

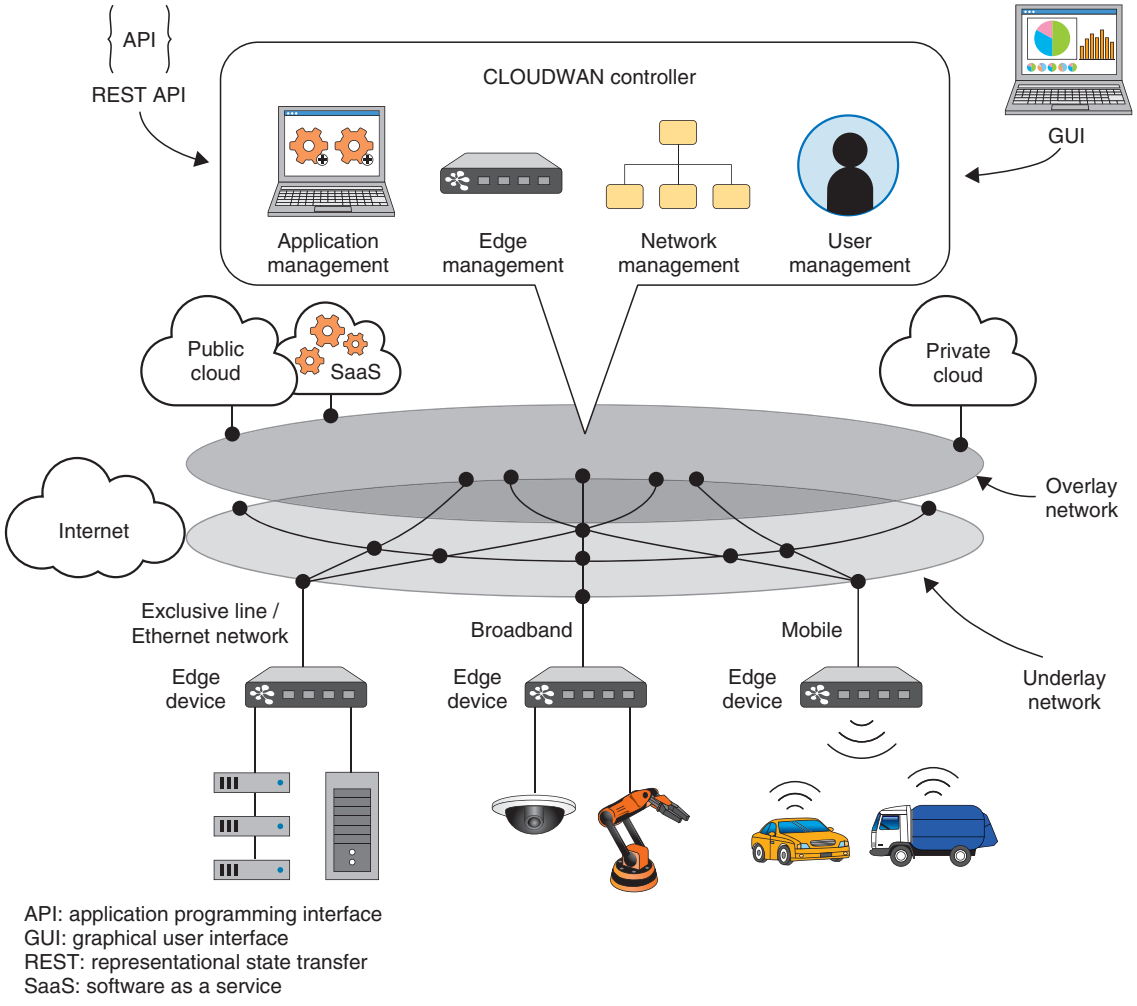


Fig. 1. CLOUDWAN features.

5. Overview of CLOUDWAN functions

The CLOUDWAN functions are summarized below (**Fig. 1**).

(1) Edge device

Terminal equipment installed on the customer's premises. The hardware of a terminal under CLOUDWAN is also called a *white box*, which is hardware equivalent to an ordinary computer server. Loading an edge device with CLOUDWAN operating software gives the terminal a variety of functions.

(2) Underlay network

The existing legacy network (physical network) for performing simple transmission operations. Here, edge-device networks are set up according to the hardware implemented on edge devices. Physically, this includes Ethernet, LTE (Long-Term Evolution), and Wi-Fi networks with connections made via MPLS (multiprotocol label switching), the Internet, mobile communications, and other means.

(3) Overlay network

A single, unified network that performs integrated virtual management of the underlay network. Various processes and functions can be performed on this network, which can also be used to connect private and public clouds, and software as a service (SaaS) functions.

(4) CLOUDWAN controller

An integrated management function on the cloud providing uniform management of users, networks, devices, and applications. It provides a GUI (graphical user interface) in the form of a single dashboard and simplifies operations management by providing REST APIs (representational state transfer application

programming interfaces).

The above functions are used to set up VPNs and apply NFV, as well as to enable the delivery of applications as elements of edge computing. They can place both communication functions and applications on individual edge devices. To deliver applications, CLOUDWAN adopts the Docker system, a well-known type of containerization software, and this function enables practically anyone to create applications and provide them through the controller.

6. Use case of CLOUDWAN edge computing

A variety of use cases can be envisioned for edge computing such as smart cities, smart homes, and automobile-related mobility. NTT i^3 presented an edge computing use case demonstration with CLOUDWAN at NTT R&D Forum 2018 (Japan) and at the Mobile World Congress 2018 (Spain) held in February and March 2018, respectively (**Fig. 2**).

The scenario of this demonstration was a safe intersection in a smart city. In the demonstration, a CLOUDWAN terminal device installed near an intersection was connected to a camera used for monitoring the intersection. An obstacle detection application that is delivered to the device enables it to determine the presence and position of an obstacle in the intersection. If detected, it informs cars entering the intersection of the position of the obstacle and instructs the cars to avoid it. Such a safety solution requires prompt action, so a short delay is directly related to ensuring safety. Consequently, if data processing here were to rely on a public cloud on the Internet, the delay would be longer, and notification of the obstacle might arrive too late for the car to take appropriate action. The edge computing solution is desirable in such a case.

Fig. 2. A CLOUDWAN use case demonstration of edge computing.

7. Future development

NTT i^3 is working on a global rollout of CLOUDWAN, an SD-WAN solution for the IoT and edge computing environment. Going forward, NTT i^3 will continue to target cutting-edge technologies with the aim of fostering innovation in NTT Group global operation companies and global firms.

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Overview of 5G Field Trials toward Social Implementation, and Experimental Trials of 5G in the Entertainment Area

Yukihiko Okumura, Satoshi Suyama, and Jun Mashino

Abstract

The Ministry of Internal Affairs and Communications of Japan began field trials of fifth-generation mobile communications systems (5G) in fiscal year 2017. This effort is aimed at developing a new market through social implementation of 5G. These Feature Articles explain the results of experimental trials conducted by NTT DOCOMO and NTT Communications. In this article, a brief overview of the project is outlined, and some experimental examples concerning applications of 5G in the entertainment area are introduced.

Keywords: 5G, experimental trials, entertainment

1. Introduction

Fifth-generation mobile communications systems (5G) provide not only large capacity and ultrahigh throughput but also new capabilities and features such as massive connectivity, low latency, and high reliability. Early realization of 5G is desired as an information and communication technology (ICT) infrastructure in the Internet of Things (IoT) era, which is essential for economic growth.

To ensure that Japan leads the world in social implementation of 5G while strengthening collaboration with the United States, Europe, and other Asian countries, the Ministry of Internal Affairs and Communications (MIC) of Japan initiated a research and development (R&D) project in fiscal year 2015 to achieve a 5G system, and NTT DOCOMO and NTT have been entrusted with two projects related to that R&D. Additionally, in October 2016, MIC took steps to study the technical requirements of 5G by consulting with the Information and Communications Council and by conducting studies on securing radio frequencies for 5G. MIC began comprehensive demonstration testing of 5G (5G Field Trials [1]) in fiscal year 2017.

These Feature Articles introduce the experimental trials conducted by NTT DOCOMO and NTT Communications and explain their results [2, 3]. In this article, we describe the trial conducted by NTT DOCOMO under a project commissioned by MIC to examine the technical specifications for 5G that can achieve a data communication speed exceeding 10 Gbit/s in densely populated areas (study group GI) as part of the 5G Field Trials, and introduce examples of experimental trials carried out in the entertainment area.

2. Overview of 5G Field Trials

The 5G Field Trials are led by Japan's MIC and are being carried out in various application areas. The trial project involves six study groups, as listed in **Table 1**. The trials have started in Tokyo and other metropolitan areas as well as in rural areas. We aim to lead the world in social implementation of 5G in Japan by establishing an open environment in which

Table 1. Study groups conducting the 5G Field Trials initiated by MIC.

Study group	GI	GII	GIII	GIV	GV	GVI
Outline of trials	• Ultrahigh-resolution video streaming • Advanced city security • Remote medical services	• Entertainment for high mobility transportation	Remote operation for construction machinery	• Entertainment in stadiums • Ultrahigh-resolution video streaming	Platooning vehicles and remote operation for trucks	• Logistics • Smart office
Technological target	eMBB (enhanced mobile broadband) • 5 Gbit/s/UE; over 10 Gbit/s/BS	eMBB • 2 Gbit/s in high mobility environments	URLLC (ultra reliable and low latency communication) • Low latency communication within 1 ms (radio frame)	eMBB • 5 Gbit/s/UE; over 10 Gbit/s/BS	URLLC • Low latency communication within 1 ms (radio frame)	mMTC (massive machine type communication) • 1 million UE/km^2
Mobile velocity	Up to 30 km/h	More than 90 km/h	Up to 60 km/h		Up to 90 km/h	
Experimental environment	Densely populated urban environment	Urban or rural environment	Urban or rural environment	Indoor/closed-space environment	Urban or rural environment	Indoor/closed-space environment
Radio frequency	• 3.7-GHz band etc. • 28-GHz band	• 28-GHz band	• 3.7-GHz band etc. • 28-GHz band	• 28-GHz band	• 3.7-GHz band etc. • 28-GHz band	• 3.7-GHz band, etc., 28-GHz band, less than 1-GHz band, and unlicensed band (920-MHz and 2.4-GHz bands, etc.)

BS: base station
UE: user equipment

companies and universities around the world can participate and by contributing to international standardization activities.

NTT DOCOMO is undertaking the implementation of study group GI as part of the 5G Field Trials. We are carrying out 5G performance evaluations in densely populated urban environments with user equipment (UE) that moves at speeds up to 30 km/h to elucidate radiowave propagation characteristics in the frequency bands of 3.6–4.2 GHz and 4.4–4.9 GHz (3.7-GHz band etc.), and 27.5–29.5 GHz (28-GHz band) in Japan, and evaluating ultrahigh-speed communication using these frequency bands with the aim of introducing 5G in these bands.

Specifically, while utilizing various 5G wireless platforms, which is the result of the R&D project to realize the 5G system, we efficiently prepared an environment for the field trials that combine services and applications for the 5G era. By providing such opportunities for vertical players from the viewpoint of telecommunications carriers, we are facilitating the creation of new industries based on 5G and strengthening the competitiveness of Japanese companies, as well as encouraging collaboration between service providers, wireless platform vendors, and carriers.

Study group GI is conducting various investigations and analyses. Technical aspects such as evaluation of radiowave propagation characteristics and simulation-based evaluations on radio transmission characteristics are being evaluated by the study group, while the feasibility of services and applications using 5G (**Table 2**) are being evaluated in cooperation with various partner companies in three application areas (namely, entertainment, smart city/smart area, and medical).

3. Examples of experimental trials in the entertainment area

We conducted various experimental trials related to the entertainment area by using high-presence, high-resolution video transmission using the features of 5G ultrahigh-speed and large-capacity communication (**Fig. 1**).

Table 2. Companies participating in GI and their roles.

Companies participating in GI	Role
NTT DOCOMO	• Overall implementation and supervision of the field trials • Provision of test environment (5G Trial Site)
Fujitsu	• Experimental trial of high-resolution video transmission in densely populated indoor environments such as shopping malls • Provision of 5G wireless devices (in the entertainment area)
Huawei	• Experimental trial of communication system that projects MR images through a holographic lens • Provision of 5G wireless devices (in the entertainment area)
Ericsson	• Experimental trial of 5G transmission in densely populated environments • Provision of 5G wireless devices
Nokia	• Experimental trial of 5G transmission in populated environments and sports stadiums • Provision of 5G wireless devices (in the entertainment area)
Tobu Railway, Tobu Tower Skytree	• Promotion of experimental trial in the entertainment area • Preparation and installation of experimental environment at 5G Trial Site at Tokyo Skytree Town®
Panasonic	• Experimental trial of VR entertainment with 4K 360° live camera • Provision of wide-viewing-angle (220°) head-mounted display (in the entertainment area) and 4K close-up camera (in the medical area)
Sharp	• Experimental trial of 8K multichannel MMT transmission • Provision of 8K decoder supporting forward error correction in the application layer
Japan Display	• Experimental trial of outdoor digital signage with low-power-consumption display • Provision of 4K reflective display
NTT	• Experimental trial of high-resolution relay-camera video transmission at sports events • Provision of cooperative wireless LAN system
INFOCITY	• Experimental trial of high-resolution live-viewing service at sports events • Provision of high-resolution camera, 4K live encoder, and image switcher

LAN: local area network
MMT: MPEG (Moving Picture Experts Group) Media Transport
MR: mixed reality
VR: virtual reality

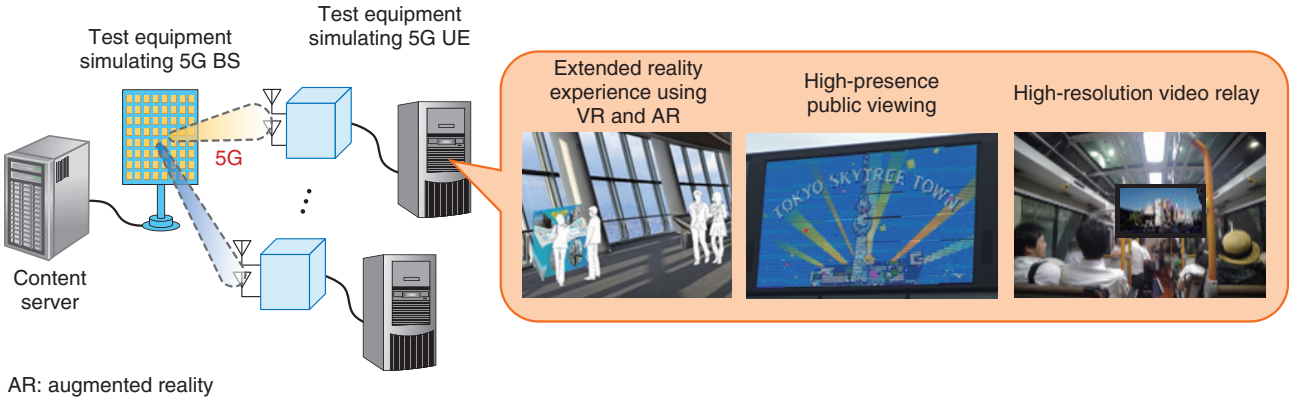

Fig. 1. Overview of experimental trial in the entertainment field.

3.1 Virtual reality (VR) entertainment system

In cooperation with Tobu Railway Co., Ltd., Tobu Tower Skytree Co., Ltd., and Panasonic Corporation, we conducted an experimental trial of a VR entertainment system (**Fig. 2**) that transmitted 5G video images at Tokyo Skytree Town® Space 634 from December 8 to 10, 2017. The 5G VR images were taken with a 4K high-resolution 360-degree live camera for viewing on a wide-viewing-angle (220°) head-mounted display. A maximum transmission bandwidth

Fig. 2. VR entertainment system.

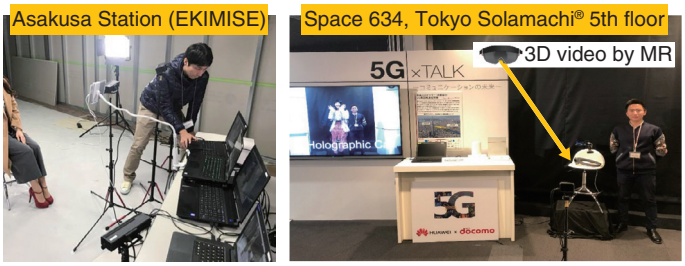

Fig. 3. New communication system utilizing MR.

of about 70 Mbit/s is required for transmission of live concert video with high presence; even so, it was possible to deliver images to multiple users in real time via 5G wireless transmission. In addition, the image transmission was kept stable by compressing the video according to the ever-changing wireless transmission condition of each user by means of a variable-rate video encoder.

It is assumed that this system will be used as a new form of entertainment by which viewers can experience the realistic feeling of being in a sports stadium or at a concert venue. About 70% of the general public who experienced the system evaluated it favorably and commented that they would like to experience live concerts remotely via the system.

3.2 New communication system utilizing mixed reality (MR)

During the same period as the demonstration described in the preceding section, in cooperation with Tobu Railway, Tobu Tower Skytree, and Huawei Technologies Japan K.K., we connected the indoor observation deck (Tembo Deck; 340 m above) of Tokyo Skytree® to the rooftop of EKIMISE of Asakusa Station via 5G, and we experimentally demonstrated a new communication style, namely, reproducing the image of a person in an area further away in three-dimensional (3D) images on a head-mounted display by using MR technology (**Fig. 3**). Although the wireless transmission conditions were challenging, (such as a long transmission distance of 1.2 km and insertion loss due to the glass covering of the Tembo Deck), a maximum transmission rate of 4.5 Gbit/s was achieved, and a 3D image of the person was successfully reproduced on the holographic display at a remote location. Real-time conversations with realistic sensations via this system are expected to be utilized for services such as bidirectional 3D

Experimental trial of 8K video multichannel MMT transmission

Experimental trial of digital signage with 4K reflective display

Construction of 5G communication environment at Sky Arena on 4th floor of Tokyo Skytree Town

Experimental trial of high-resolution video transmission using ultrahigh-density distributed antennas

Fig. 4. Experimental trials at Tokyo Skytree Town.

video transmission in anticipation of relaying sports events in the future.

3.3 Experimental trials at Tokyo Skytree Town

From March 5 to 8, 2018, we constructed experimental environments indoors and outdoors at Tokyo Skytree Town and used them to verify the feasibility of services using 5G in densely populated commercial facilities (**Fig. 4**).

In cooperation with Sharp Corporation, we conducted an experimental trial of multichannel MMT (MPEG Media Transport) transmission of 8K video via 5G, and we confirmed that stable video quality can be obtained by forward-error-correction processing in both the wireless (physical) layer and the video (application) layer. In the preliminary indoor experiments, we successfully transmitted 8K video, which requires an average transmission rate of 80 Mbit/s, on 12 channels via 5G by H.265/HEVC (High Efficiency Video Coding). This technology is expected to be applied, for example, to temporary public viewing at various events.

In cooperation with Japan Display Inc., we installed a low power consumption reflective display outdoors and used it to experimentally demonstrate digital signage in a commercial area. In this test, 4K resolution was achieved by tiling four displays, and high-resolution video content—assumed to consist of advertisements—was transmitted from the base station (BS) and sequentially displayed. Consequently, we confirmed that it was possible to display sufficient contrast and color reproducibility without degrading image quality under outdoor light. Through a questionnaire targeting general tourists, we obtained positive feedback on the natural appearance peculiar to a reflective display. In the future, it is expected that combining such a device with 5G UE will enable flexible installation of digital signage without the need for cables (i.e., an AC (alternating current) power supply).

In cooperation with Fujitsu Limited, we deployed 5G ultrahigh-density antennas in an indoor model of a commercial facility, and we conducted a test to transmit 4K high-resolution video to UE assumed to be displaying product information at shopping malls. We experimentally demonstrated simultaneous high-resolution video transmission to multiple UE devices in motion (i.e., devices held by numerous pedestrians

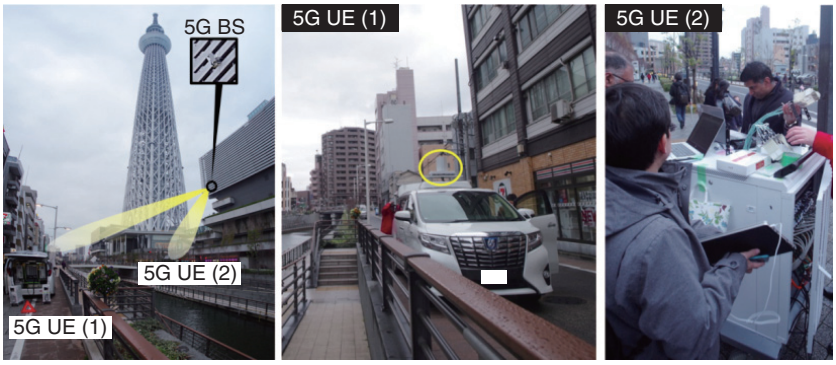

Fig. 5. Radio transmission test at 5G Trial Site.

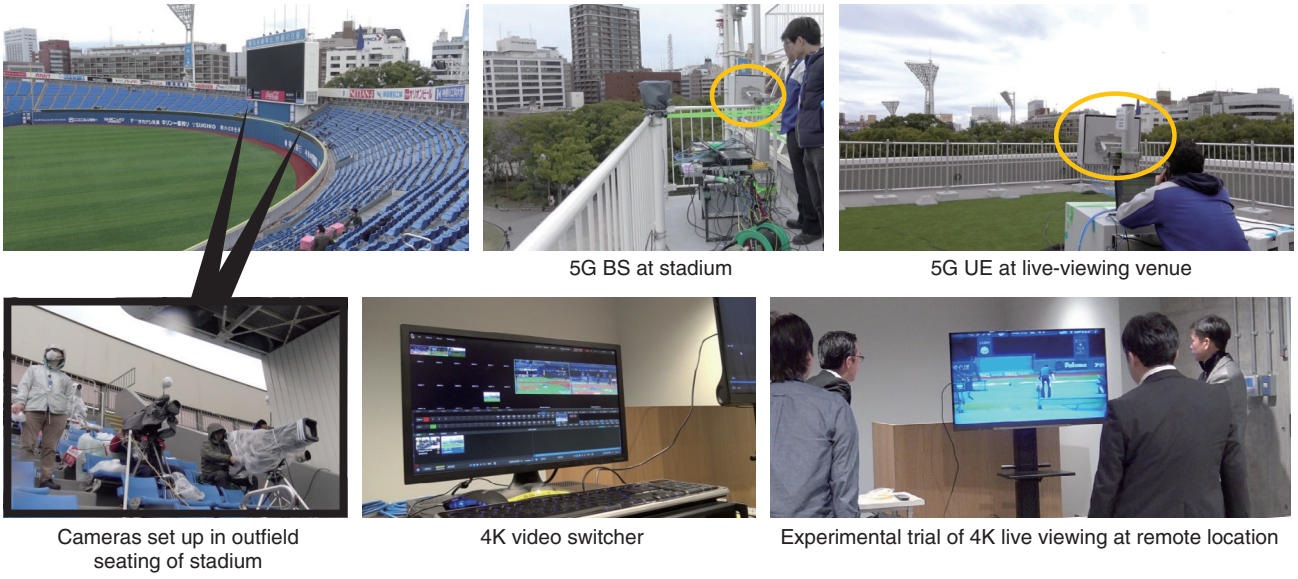

Fig. 6. Experimental trial of live viewing of sports events.

walking around), and we confirmed that it was possible to stably transmit video by employing dynamic virtual cell technology using cooperative control of the distributed antennas even in complex structures with uneven shapes.

3.4 Wireless transmission test at 5G Trial Site

From March 19 to 20, 2018, a 5G wireless transmission test was conducted at a 5G Trial Site constructed at Tokyo Skytree Town by NTT DOCOMO (**Fig. 5**). The major specifications of the radio devices were as follows: the center frequency was 27.9 GHz, the bandwidth was 730.5 MHz, and there were two units of 128 antenna elements for BSs and 8 antenna elements for UE.

We measured a maximum throughput of 10.2 Gbit/s when two users in outdoor environments were simultaneously connected, and we confirmed that ultrahigh-speed and large-capacity communication was possible in the actual field.

3.5 Experimental trial of live viewing of sports events

On March 19, 2018, we conducted an experimental trial of a 4K high-resolution live-viewing service of a sports event at a stadium (**Fig. 6**).

In this trial, large data of high-resolution videos captured by cameras installed in the stadium were

transmitted to a remote area in real time with low latency using 5G, and we demonstrated the prospect of providing entertainment services that enable viewers to experience watching events with a feeling of being there at the same time not only within the stadium facilities but also in the space outside them.

More specifically, images captured by three 4K high-resolution relay cameras installed in the outfield seats of the stadium were transmitted to a 5G BS installed near the stadium's centerfield screen via a cooperative wireless LAN (local area network) system and passive optical network provided by NTT Access Network Service Systems Laboratories and then retransmitted from there to the facilities outside the stadium via 5G.

Moreover, in cooperation with INFOCITY, INC., we constructed a 4K live-viewing system by which the multiple high-resolution videos transmitted by 5G were converted by a 4K video switcher for viewing on a large monitor at the live-viewing site. We confirmed that even outside the facility in places located far from the stadium, viewers were able to experience watching an event in real time just as it was being experienced in the stadium itself, and that it was possible to greatly reduce the time needed for setting up the service by using wireless transmission, as compared to that needed by a conventional system.

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5G Field Trials in the Smart City and Medical Service Areas toward Social Implementation of 5G

Yukihiko Okumura, Satoshi Suyama, and Jun Mashino

Abstract

In this article, we describe two examples of field trials contracted by the Ministry of Internal Affairs and Communications of Japan concerning application of fifth-generation mobile communications systems (5G). The first example was in the area of smart city/smart area and was focused on providing a safe and secure society. The results of experimental trials confirmed that the transmission and aggregation of high-resolution video to a monitoring center enabled facility monitoring and wide-area monitoring in places where many people gather such as public facilities and sports events. The second example was in the medical area and involved the provision of remote medical services. Video interviews conducted via a high-resolution television conference system and multiple high-resolution videos obtained for diagnosis were simultaneously transmitted between a general hospital in a city and a rural clinic.

Keywords: 5G, security, medical care

1. Introduction

NTT DOCOMO was contracted by the Ministry of Internal Affairs and Communications as the main implementing entity for a fiscal year 2017 project to examine the technical specifications for fifth-generation mobile communications systems (5G) that can achieve a data communication speed exceeding 10 Gbit/s in densely populated areas (study group GI). This article introduces examples of experimental trials conducted in the areas of smart city/smart area and medical services. The organizations participating in the experimental trials in these application areas are listed in **Table 1**.

2. Experimental trial in smart city area

With the aim of establishing the advanced security services required for smart cities, namely, services for addressing premeditated crimes (e.g., terrorism, random attacks, and child kidnappings) that cannot be prevented by existing deterrence measures alone, we carried out experimental trials on a new security model for detecting and predicting signs of crime by utilizing high-resolution images and artificial intelligence (AI) via 5G in cooperation with Sohgo Security Services Co., Ltd. and NEC Corporation (**Fig. 1**).

This initiative is based on the concept of modern-day fire watchtowers, with the ultimate goal being to achieve an urban-space security system that monitors an entire urban space by analyzing various camera images corresponding to the three eyes described below (**Fig. 2**).

(1) *Insect eyes* for detecting suspicious persons and people in trouble from camera images captured at facilities
(2) *Fish eyes* for analyzing field video in real time from images captured by cameras worn by guards and attached to drones
(3) *Bird eyes* for promptly detecting fire and damaged and/or impassable roads as well as vehicle attacks by terrorists from images captured by high-elevation cameras

In fiscal year 2017, we carried out experimental trials on two monitoring services, namely, facility monitoring and wide-area monitoring.

Table 1. Organizations participating in experimental trials in areas of smart city/smart area and medical services and their roles.

GI-participating organization	Role
NTT DOCOMO	• Promotion and supervision of all experimental trials in GI • Provision of experimental environment (5G Trial Site)
Sohgo Security Services (ALSOK)	• Experimental trial of security operations concerning in-facility monitoring and wide-area monitoring • Provision of high-resolution camera system for wide-area monitoring
NEC	• Experimental trial of security systems such as face-authentication gate for in-facility monitoring • Provision of 5G wireless devices (for smart city/smart area, and medical area)
Wakayama Prefecture Wakayama Medical University	• Experimental trial of remote medical service utilizing high-resolution video transmission • Provision of experimental environment (at medical university and clinic)
NTT Communications	• Experimental trial of high-resolution television conference system for interviews via remote medical service • Provision of 4K television conference system

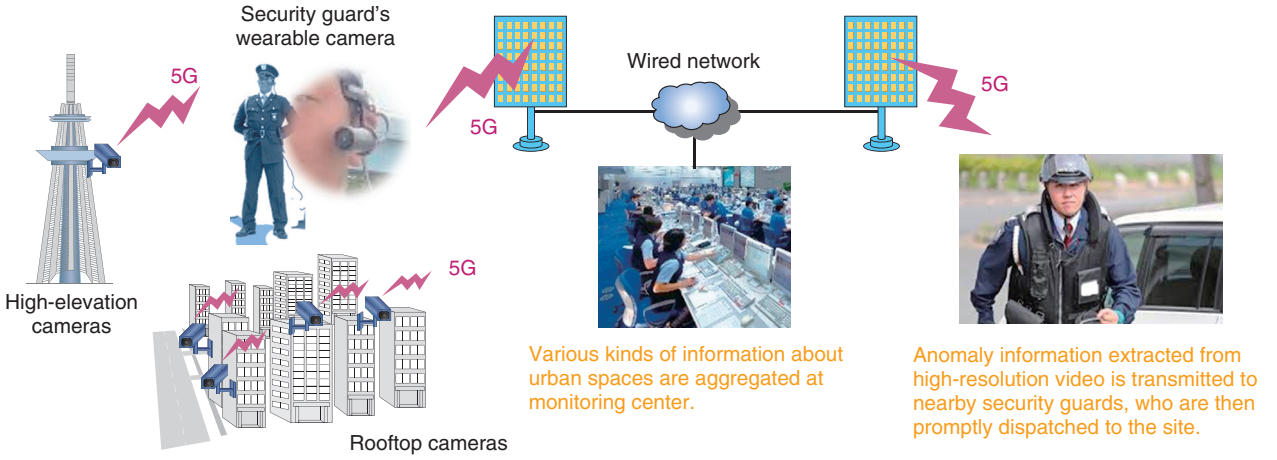


Fig. 1. Overview of experimental trial in smart city area.

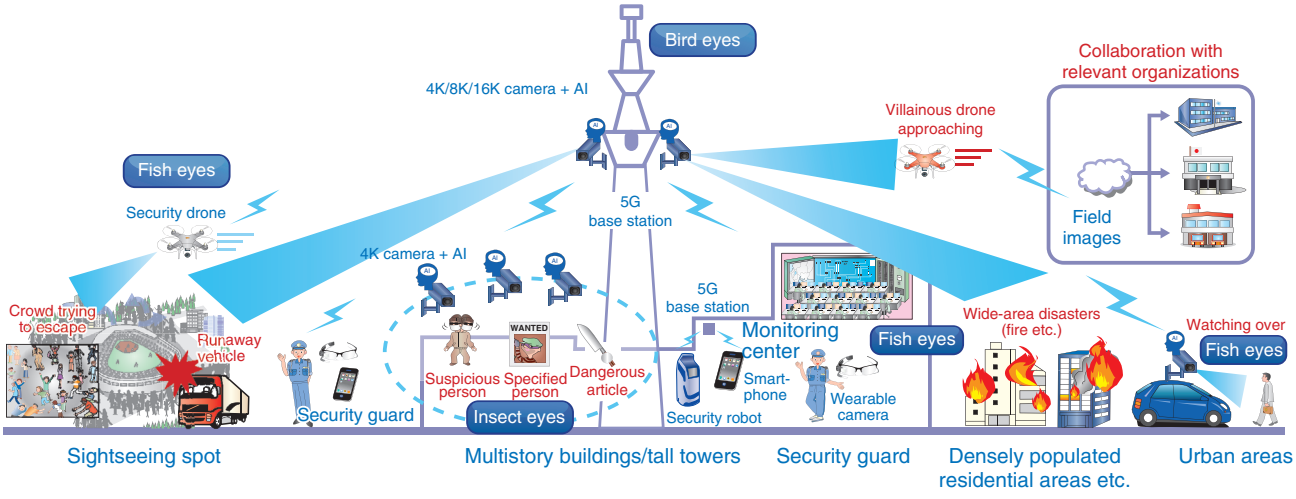


Fig. 2. Modern-day fire watchtower concept.

Experimental trial of facility monitoring using face authentication

Experimental trial of high-resolution video transmission for security guards

Fig. 3. Experimental trial of facility monitoring.

- Facility monitoring (insect eyes and fish eyes): The goal here was to understand actual site conditions by transmitting high-resolution video and identifying dangerous persons by facial detection by inputting high-resolution images to AI recognition systems.
- Wide-area monitoring (bird eyes): The goal was to detect wide-area disasters and understand traffic conditions by utilizing AI and high-resolution cameras mounted high above the ground.

2.1 Facility monitoring (insect eyes and fish eyes)

At the National Museum of Emerging Science and Innovation (Tokyo) from November 9 to 11, 2017, we experimentally demonstrated a new in-facility security system utilizing high-resolution images captured by surveillance cameras and a face-authentication gate (**Fig. 3**). This demonstration featured the utilization of face-recognition and image-recognition technology based on AI and recognition of necessary information in real time from images captured by surveillance cameras to achieve primary security in a specific space.

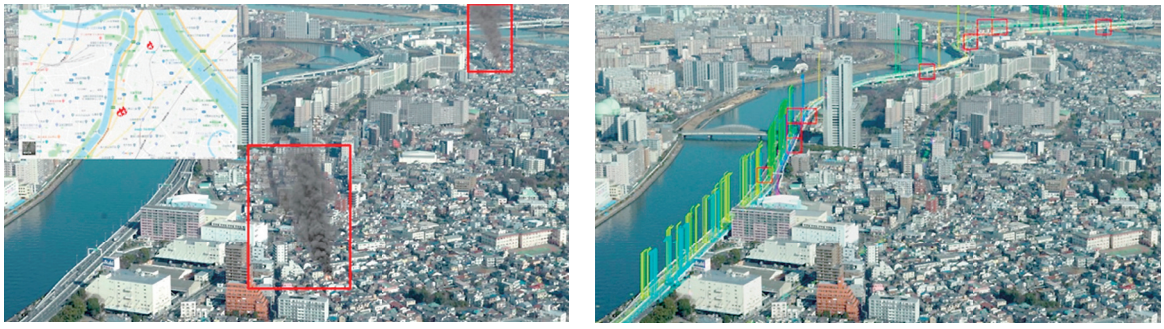
We confirmed that increasing the video frame rate by utilizing the ultrahigh-speed and large-capacity communication of 5G made it possible to increase face-collation frequency by up to six times in comparison with that of a system assumed to utilize 4G that uses the same face-collation algorithm. This system is expected to easily enable the construction of a security area for events. Visitors evaluated the system favorably with comments such as "Although I normally feel nervous in places where security guards are concentrated, I didn't experience that feeling at all with this new system."

Moreover, from February 13 to 16, 2018, in the vicinity of Yasukuni Avenue, Tokyo (Shinjuku Ward), we conducted an experimental trial on transmission of high-resolution video under the assumption that security guards will share security and warning information. We confirmed that even with 5G transmission, performance (throughput and response time) comparable to that achieved in an indoor test using a wired LAN (local area network) was obtained, and transmission was quicker and more stable than that of a conventional wireless transmission system.

2.2 Wide-area monitoring (bird eyes)

Since March 15, 2018, we have been conducting experimental trials on wide-area monitoring using 4K high-resolution cameras installed on the Tembo Deck (340 m high) of Tokyo Skytree® and an AI processing server (**Fig. 4**). The final goal of this trial is to achieve high-precision monitoring and real-time information sharing by transmitting on-site video captured by wearable cameras worn by security guards and by surveillance cameras via 5G. The assumed use case was monitoring the observation area for fires and traffic accidents, and this trial verified the effectiveness of this technology for detecting anomalies.

In particular, we tested 720p video transmission by 4G and 2160p (4K) video transmission by 5G in order to evaluate the network bandwidth capacity. With image analysis by AI, for example, for detection of fires by using images captured from the Tembo Deck, recognition of vehicles traveling on expressways, and recognition of locations of traffic jams where traffic accidents are expected, this test confirmed that the ability to discriminate distant objects greatly depends on the resolution of the image and also confirmed that 5G is clearly superior in terms of that ability to distinguish distant objects. The large-capacity data



Analysis of fire (fire synthesized by computer graphics)　　Monitoring of traffic conditions

Fig. 4.　Experimental trial of wide-area monitoring.

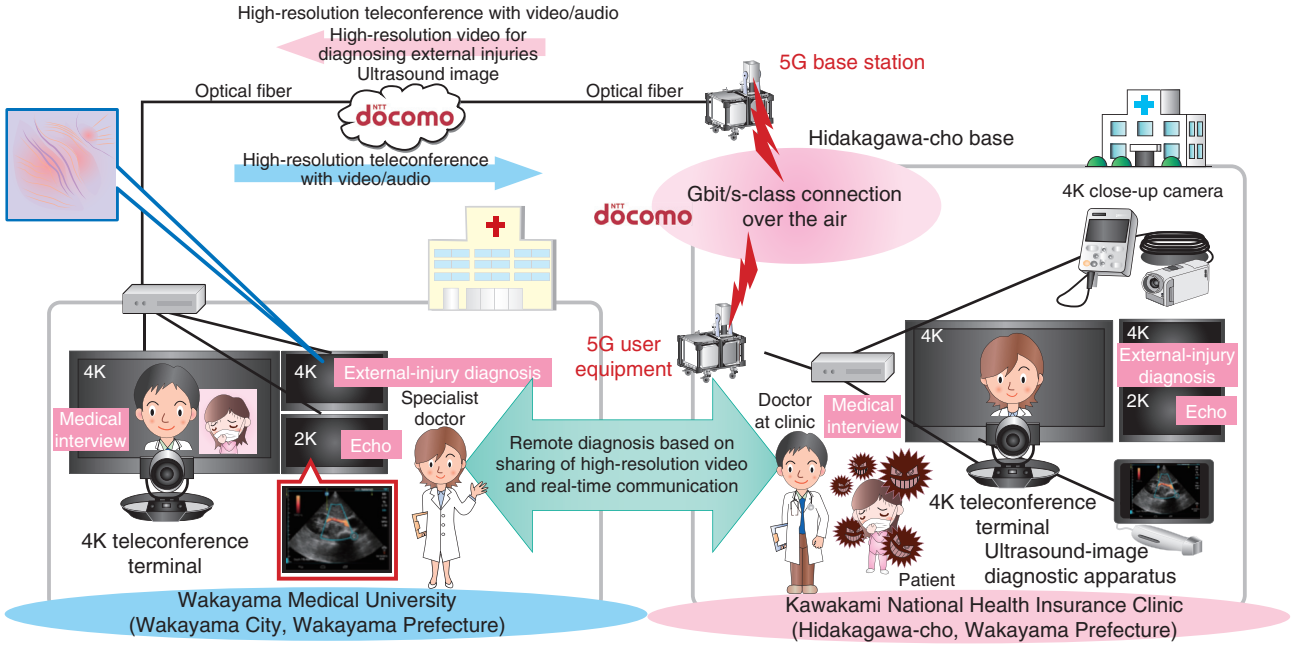


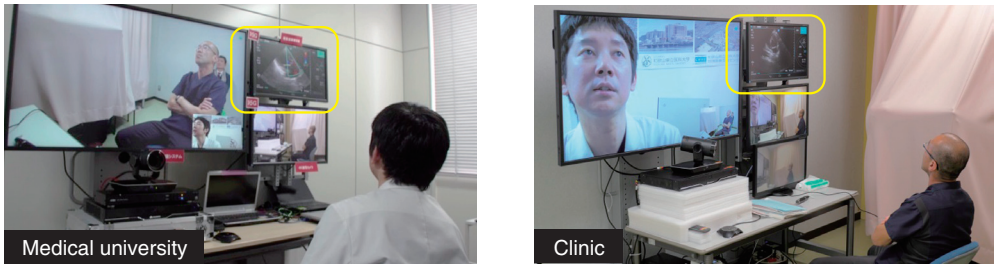
Fig. 5.　Overview of experimental trial by study group GI in the medical area.

communication made possible by 5G enables wide-area monitoring and thereby contributes to creating safe and secure cities. It is also expected to contribute to early detection and prevention of crimes and disasters and to reduce work flows for security operation.

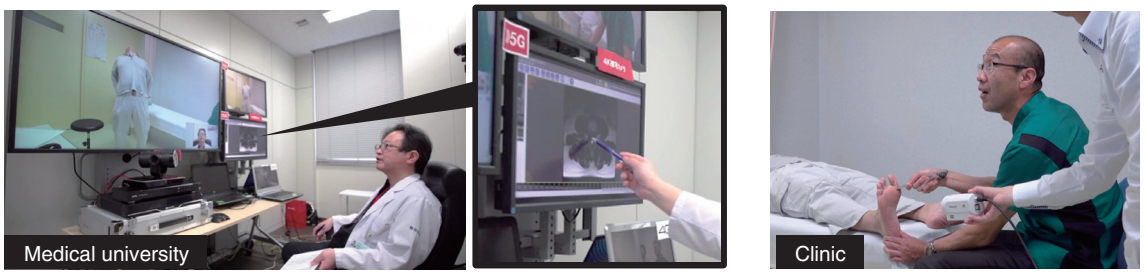
3. Experimental trial in medical area

In collaboration with Wakayama Prefecture and Wakayama Medical University, we conducted an experimental trial of advanced telemedicine services utilizing high-resolution video transmission via 5G (**Fig. 5**). The objective of this test was to evaluate the effectiveness of the video transmission system in medical consultations. The goal is to develop a system for providing advanced medical treatment equivalent to that available at urban general hospitals, in rural areas such as mountainous areas, and to eliminate medical disparities between urban and rural areas.

A large portion of Wakayama Prefecture is taken up by mountains, and in many areas, it takes a long time to get to a secondary medical institution. Large hospitals with more than 500 beds are only available in



Real-time transmission of echo images from clinic to medical university to confirm internal disease



Examination of patient is instructed by physician via 4K teleconference system.

MRI image is transmitted in real time.

The doctor at the clinic conducts the response-confirmation test according to the instructions of the doctor at the university.

Fig. 6. Experimental trial of telemedicine.

Wakayama City. The Regional Medical Support Center of Wakayama Medical University (Wakayama City, Wakayama Prefecture) has already introduced a remote medical support system that enables various kinds of support for remote medical institutions. This system connects remote medical institutions with the university via television conferences (teleconferences) using an Internet connection to support local medical care services throughout Wakayama Prefecture. However, in the case of rural clinics, where FTTH (fiber-to-the-home) services are not available, the xDSL (x digital subscriber line) service provided by cable television operators and 4G (LTE: Long-Term Evolution) services are the current means of Internet access, so the video quality of the teleconferences has been restricted.

In this experimental trial, a network was configured connecting the Regional Medical Support Center of Wakayama Medical University and the neighborhood of the Kawakami National Health Insurance Clinic (Hidakagawa-cho, Wakayama Prefecture) by optical fiber and the last-mile communication to the clinic by using 5G. This test confirmed that through the ultra-high-speed communication enabled by 5G, it was possible to correctly comprehend symptoms such as skin diseases by transmitting high-resolution video. It also confirmed that doctors at Wakayama Medical University and doctors at the Kawakami National Health Insurance Clinic can cooperate and smoothly diagnose patients while communicating via the high-resolution teleconference system.

In concrete terms, as diagnostic equipment for the imaging system, a 4K high-resolution close-up camera (used for diagnosis of skin diseases and injuries as well as intraoral diagnosis), an ultrasound-image diagnostic apparatus (echo) (used for diagnosis of internal diseases etc.), and video output from an MRI (magnetic resonance imaging) device were set up in a manner enabling communication between the university and the clinic. In addition, a 4K high-resolution video conference system was implemented to enable doctors to exchange opinions and interview patients.

In this experimental trial, which was conducted from February 20 to March 6, 2018, we utilized the framework of the remote outpatient service provided by Wakayama Prefectural Medical University to conduct examinations according to medical practice and a demonstration for media in a total of five cases (three cases of dermatology, one case of orthopedic surgery, and one case of cardiovascular internal medicine) (**Fig. 6**). Utilizing 5G made it possible to share high-resolution video, which requires a data rate over 100 times faster than past rates, between the two sites. Listed below are the impressions of doctors

and patients who participated in this experimental trial.

Doctors' impressions

- "With the current remote outpatient system, signs of external injury could not be seen well; however, with the 4K camera, I could see the examination with the feeling that I was seeing the patient up close. That was quite incredible!" (dermatology)
- "Although it was my first experience of telemedicine, I was able to smoothly interact with patients, thanks to the realistic teleconference system, so I think the findings we obtained were appropriate." (orthopedics)
- "The clarity of the 4K image is excellent, and I felt that the quality of the echo image was in no way inferior to that of the image at hand. I expect this system to enhance regional medical care." (cardiovascular medicine)
- "I felt relieved with the sense that a specialist is 'nearby,' and I felt it was very effective as a tool for upgrading clinics and training young doctors." (a doctor at the clinic)

Patients' impressions

- "By seeing the medical professor on a big screen, I think I received medical treatment in exactly the same way as if I had gone to the outpatient clinic of the medical university. The system works for me because it is troublesome for the elderly like myself to take over one hour getting to the medical university."
- "I tried the remote diagnosis for a second opinion. Although I answered the doctor's questions via a screen, which still gave me a realistic feeling, as expected, the explanation of my symptoms and a new treatment policy appeared to be the considerations of a university-hospital specialist, so I was awakened to the truth about the severity of my condition."

Through the above-described tests, we clarified that at actual remote medical practices, it was possible to achieve increased presence, improve the accuracy of diagnosis, and reduce medical treatment time by utilizing the high-resolution video transmission provided by 5G. As a result, these achievements helped to reduce the burden on doctors at the medical university and also helped patients access the highest quality medical care without having to undertake a long and inconvenient journey. We also confirmed that this 5G system contributes to raising the level of local medical care and nurturing young doctors at remote clinics.

Trademark notes

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Field Trials of Use Cases in High Mobility Environment toward Social Implementation of 5G

Yukihiko Okumura, Satoshi Suyama, and Jun Mashino

Abstract

Experimental trials of use cases of fifth-generation mobile communications systems (5G) in high mobility environments exceeding 90 km/h were carried out as part of the 5G Field Trials initiated by the Ministry of Internal Affairs and Communications of Japan. These trials were conducted to evaluate the transmission and distribution of high-presence, high-resolution video and audio content of sightseeing information, news, advertisements, and entertainment content by 5G for passengers in cars traveling on highways and in trains traveling on a conventional line.

Keywords: 5G, field trials, high mobility environment

1. Introduction

Experimental trials were conducted as part of a project to examine the technical specifications for fifth-generation mobile communications systems (5G) that can achieve a data communication speed exceeding 2 Gbit/s in high mobility environments (study group GII). The trials were contracted to NTT Communications by the Ministry of Internal Affairs and Communications (MIC) as the main implementing entity and conducted in cooperation with NTT DOCOMO (**Table 1**). In this article, we describe an overview of the trials and introduce some experiments to transmit entertainment content for vehicle passengers as a potential application area. The roles of the organizations participating in the experimental trials are listed in **Table 2**.

2. 5G wireless transmission tests in high mobility environment exceeding 90 km/h

Two transmission tests were conducted to evaluate the transmission characteristics of 5G radio access in mobile environments consisting of a bus or private car traveling on a highway and a high-speed train traveling on a railway line. One test was conducted with a car at Fuji Speedway and one was done with a train on the Tobu Railway Nikko Line.

2.1 Transmission test with car at Fuji Speedway

At Fuji Speedway (Shizuoka Prefecture) from February 7 to 9, 2018, a 5G communication area was constructed near the grandstand, and an experimental trial—assuming 5G radio transmission to a car moving at high speed—was conducted (**Fig. 1**).

The base station (BS) was installed near the grandstand of the home straight, set at an azimuth angle of 45° to the track, and the user equipment (UE) was mounted on the roof of the measurement car. The specifications of the transmission equipment consisted of a center frequency of 27.9 GHz, bandwidth of 700 MHz, and 96 (BS) and 64 (UE) antenna elements. A maximum throughput of 2.24 Gbit/s was obtained as the result when the car was traveling at a speed of 90 km/h.

2.2 Transmission test with a train on Tobu Railway Nikko Line

From February 19 to 23, 2018, in cooperation with Tobu Railway Co., Ltd., 5G communication areas were set up near Ienaka Station and Niregi Station (Tochigi Prefecture) on the Tobu Railway Nikko

Table 1. Study groups conducting the 5G Field Trials initiated by MIC.

Study group	GI	GII	GIII	GIV	GV	GVI
Outline of trials	• Ultrahigh-resolution video streaming • Advanced city security • Remote medical services	• Entertainment for high mobility transportation	Remote operation for construction machinery	• Entertainment in stadiums • Ultrahigh-resolution video streaming	Platooning vehicles and remote operation for trucks	• Logistics • Smart office
Technological target	eMBB (enhanced mobile broadband) • 5 Gbit/s/UE; over 10 Gbit/s/BS	eMBB • 2 Gbit/s in high mobility environments	URLLC (ultra reliable and low latency communication) • Low latency communication within 1 ms (radio frame)	eMBB • 5 Gbit/s/UE; over 10 Gbit/s/BS	URLLC • Low latency communication within 1 ms (radio frame)	mMTC (massive machine type communication) • 1 million UE/km^2
Mobile velocity	Up to 30 km/h	More than 90 km/h	Up to 60 km/h		Up to 90 km/h	
Experimental environment	Densely populated urban environment	Urban or rural environment	Urban or rural environment	Indoor/closed-space environment	Urban or rural environment	Indoor/closed-space environment
Radio frequency	• 3.7-GHz band etc. • 28-GHz band	• 28-GHz band	• 3.7-GHz band etc. • 28-GHz band	• 28-GHz band	• 3.7-GHz band etc. • 28-GHz band	• 3.7-GHz band, etc., 28-GHz band, less than 1-GHz band, and unlicensed band (920-MHz and 2.4-GHz bands, etc.)

Table 2. Companies participating in GII and their roles.

Company participating in GII	Role
NTT Communications	• Supervision of experimental trials in GII
NTT DOCOMO	• Overall implementation of experimental trials • Provision of test environment in advance (DOCOMO R&D Center) and test measurement vehicles
NEC	• Transmission test of high-speed mobile communication at Fuji Speedway and on Tobu Railway Nikko Line • Provision of 5G wireless devices
Ericsson	• Transmission test of high-speed mobile communication on Tobu Railway Nikko Line • Provision of 5G wireless devices
Tobu Railway	• Promotion of experimental trial on Tobu Railway Nikko Line • Operation of Skytree Train for test and site adjustment of test environment
Japan Display	• Experimental trial of 8K high-resolution display in train cars • Provision of 17-inch 8K display
INFOCITY	• Experimental trial of high-quality video distribution service for high-speed moving vehicles • Provision of video distribution server, vehicle-mounted application server, and 4K display equipment
Dandelion	• Management of experimental trial at Fuji Speedway

R&D: research and development

Line. Experimental trials in those areas were conducted with a 634-series Skytree Train running at high speed under the assumption of 5G wireless transmission for a high-speed railway (**Fig. 2**).

The BS baseband equipment #1 (subordinate to the core-network equipment) was installed at the northern end of the platform of Ienaka Station, and the BS baseband equipment #2 was installed on vacant land on the south side of the station building. This equipment configuration enabled handover testing across the BS. Two antenna units (for transmission diversity) were connected to BS baseband equipment #1 and

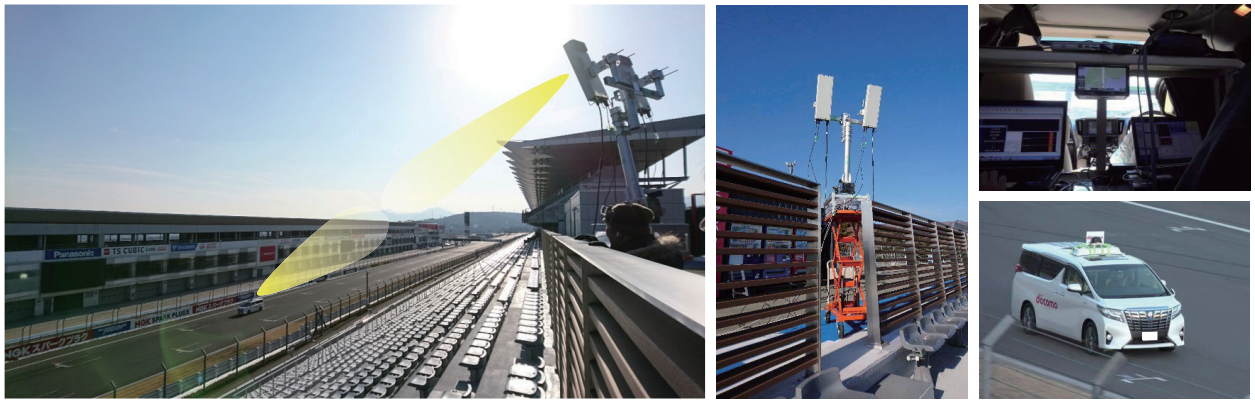


Fig. 1. Wireless transmission test on high-speed mobile communication conducted at Fuji Speedway.

(a) 5G BS near Ienaka Station

(b) 5G BS near Niregi Station

(c) 5G UE onboard 634-series Skytree Train

Fig. 2. Wireless transmission test of high-speed mobile communication on Tobu Railway Nikko Line.

#2. The antenna unit of the UE was fixed in the crew cabin of the Skytree Train to ensure line-of-sight (LOS) between the BSs and UE. The major specifications of the transmission equipment included a center frequency of 27.9 GHz, bandwidth of 700 MHz, and 96 (BS) and 64 (UE) antenna elements. The test result indicated that when the train was traveling at a speed of 90 km/h, a maximum throughput of 2.08 Gbit/s was obtained, and handover between BSs was successful.

Near Niregi Station, the BS was configured as distributed antennas. The major specifications were as follows: the center frequency was 27.9 GHz, bandwidth was 730.5 MHz, and there were 128×2 units (BS) and 8 (UE) antenna elements. The UE was installed inside the train, and its antenna was attached to the front window of the driver's seat (via an acrylic panel) to ensure the best-possible LOS. The test result

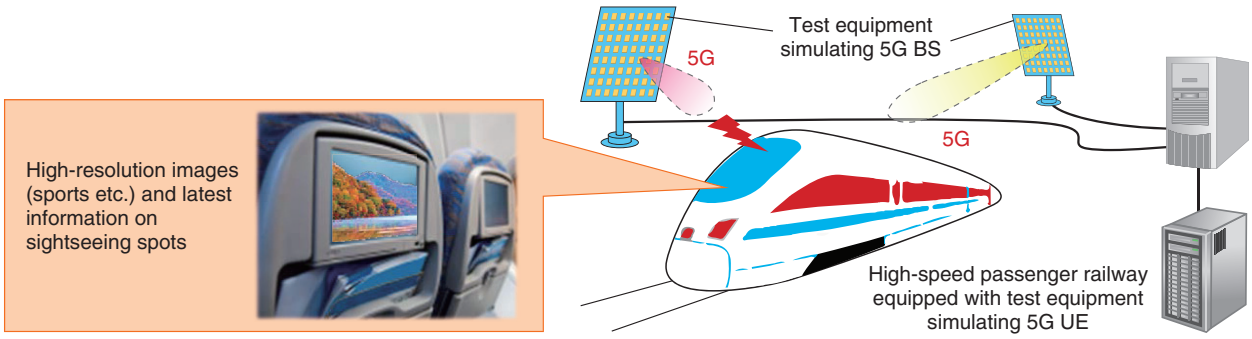


Fig. 3. Experimental trial of high-speed transmission of entertainment content.

revealed that a maximum throughput of 2.90 Gbit/s was obtained when the train was traveling at a speed of 90 km/h.

3. Experimental trial to transmit entertainment content

With public transport, the longer the distance traveled, the more time is taken traveling, and high mobility is required. Under those circumstances, it is important for passengers spending time traveling at high speed to have entertainment, and it should be provided with high quality such as having high-resolution images. Therefore, to evaluate a service utilizing 5G during high-speed transit, an experimental trial was conducted of a high-resolution video service for passengers carried by passenger transport operators such as railways, buses, and taxis at speeds of over 90 km/h (**Fig. 3**).

One of the main forms of usage of 5G services by passengers traveling in trains or passenger cars (traveling vehicles) is expected to be Internet-connected services, and it is assumed that such services will be included as a basic feature. This trial was carried out in order to visualize and evaluate 5G-specific services, specifically, a high-resolution video service providing information and entertainment content for passengers traveling at high speed. For a 5G video delivery service for passengers in vehicles, it is anticipated that information-provision services with higher-resolution video information, more channels, and better timeliness (such as live distribution of video) will be possible thanks to the large capacity of 5G services compared to services using conventional transmission methods.

Video distribution services are roughly categorized as either linear-delivery type (programming type) services or on-demand distribution type services. In this experimental trial, only a limited number of BSs could be prepared, so the time to communicate in the high mobility environment was also limited. Consequently, our aim was to obtain the advantages of both the linear-delivery service (timeliness) and the on-demand delivery service (convenience), so a hybrid delivery service was implemented and experimentally verified (**Fig. 4**).

In cooperation with INFOCITY, INC., a cache server was installed between a video distribution server (master server) installed on the BS side and the UE devices in the train, and the network was separated into two networks: a server-to-server network (from the master server to the cache server) and an end-user network (from the cache server to the UE devices). The server-to-server synchronization function enables the service operator to add content of the master server, and even if the cache server cannot use 5G communication at the time of the updating, the content of the cache server can be appropriately updated at a later time when 5G communication becomes available, and users can be provided with instantaneous services similar to live distribution.

From February 19 to 23, 2018, this hybrid-type video delivery system was used to conduct an experimental trial to download multiple 4K and 8K video files simultaneously in the 5G area set up near Tobu Railway's Ienaka Station (**Fig. 5**).

During the 21-s period in which the train passes through the 5G area, a 4K and 8K video file with a total size of 1.2 GB was transferred, and video images were displayed on a 4K display and a 17-inch 8K display (provided by Japan Display Inc.) installed in the train.

Achieving Gbit/s-grade ultrahigh-speed communication in high mobility environments will make it

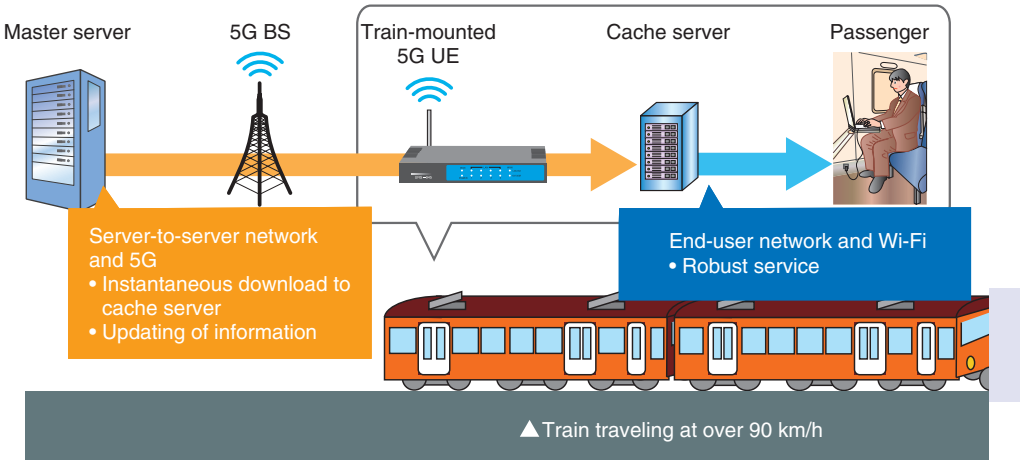
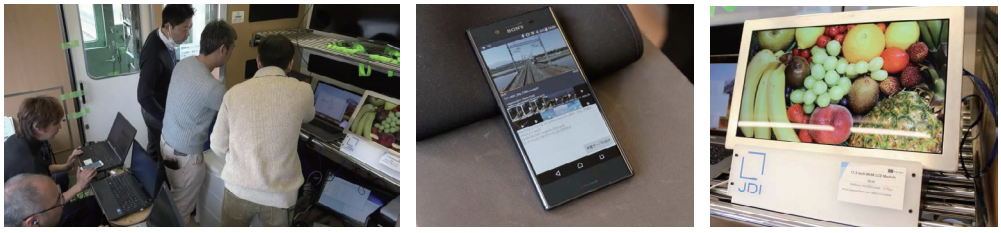


Fig. 4. Hybrid-type video delivery system.



(a) Video server and display devices are installed in the train.

(b) 4K images are transmitted to smartphones.

(c) 8K images are transmitted to 17-inch 8K display.

Fig. 5. High-resolution video transmission test for high mobility environment on Tobu Railway Nikko Line.

possible to deliver high-resolution video clips (such as the latest news) to passengers of high-speed rail services in a timely manner.

Trademark notes

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He received a B.S. and M.S. in electrical engineering from Tokyo University of Science in 1989 and 1991, and a Ph.D. in engineering from Tohoku University, Miyagi, in 2006. In 1991, he joined NTT Radio Communication Systems Laboratories. Since 1992, he has been engaged in the research, standardization, and development of wideband/broadband mobile radio communication technologies, terminals, and systems at NTT Mobile Communications Network, Inc. (now NTT DOCOMO, INC.). He is currently involved in researching 5G system technologies. He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE).

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High-accuracy SS-OCT Thickness Measurement Using Refractive Index Dispersion Adaptation

Masahiro Ueno, Takashi Sakamoto, Seiji Toyoda, Yuzo Sasaki, Tadashi Sakamoto, and Masatoshi Fujimoto

Abstract

Swept-source optical coherence tomography (SS-OCT) is a technique to capture tomographic images of moving samples at high speed with high resolution at the level of several tens of micrometers. We have developed highly precise thickness measuring instruments used in factory automation by using the SS-OCT technique based on a $KTa_{1-x}Nb_xO_3$ (potassium tantalate niobate) deflector, which is an optical switch device used for optical communication. However, since the principle of SS-OCT is to measure the time the light reciprocates in the sample (by converting it to the frequency of the beat signal between the reference light and the sample reciprocating light), there is a problem in that the thickness measurement value of the sample varies depending on the wavelength of light due to the refractive index wavelength dispersion of the sample. To solve this problem, we modified the beat signal according to the dispersion of the sample by signal processing. As a result, we confirmed that fluctuation of the thickness measurement value was suppressed even when using light of different wavelengths.

Keywords: SS-OCT, thickness measurement, refractive index dispersion

1. Introduction

In factory automation, measuring in real time whether products meet specifications is important for efficient product manufacturing. We have developed a high-speed thickness measuring instrument for this purpose using optical coherence tomography (OCT) [1, 2] by applying optical communication technology, specifically, high-speed optical switching using a potassium tantalate niobate ($KTa_{1-x}Nb_xO_3$, or KTN) light deflector [3, 4].

OCT is a technique for producing tomographic images with a resolution of several tens of micrometers. The technique is useful for cell-level diagnosis and has been put to practical use as a biological tomographic imaging apparatus for medical use. There are two types of OCT: time domain OCT (TD-OCT) and Fourier domain OCT (FD-OCT). In addition, swept-source OCT (SS-OCT) has been attracting attention. It is a variation of FD-OCT, which is advantageous in that it enables the acquisition of tomographic images in real time.

SS-OCT uses a wavelength swept laser as a light source, which is a laser that continuously varies (sweeps) in wavelength with time. SS-OCT operates in two steps. First, the SS-OCT apparatus produces interference between two light waves—reflected light (sample light) obtained by irradiating light to the sample to be measured (measurement sample) and light (reference light) that passes through a fixed length optical path. Next, frequency analysis is performed on the intensity signal (interference signal) of the interfered light to obtain depth information on the sample. Since the frequency of the interference signal is proportional to the optical path difference between the optical paths through which the sample and the reference light pass, it is possible to measure the position of the reflection point in the sample by analyzing

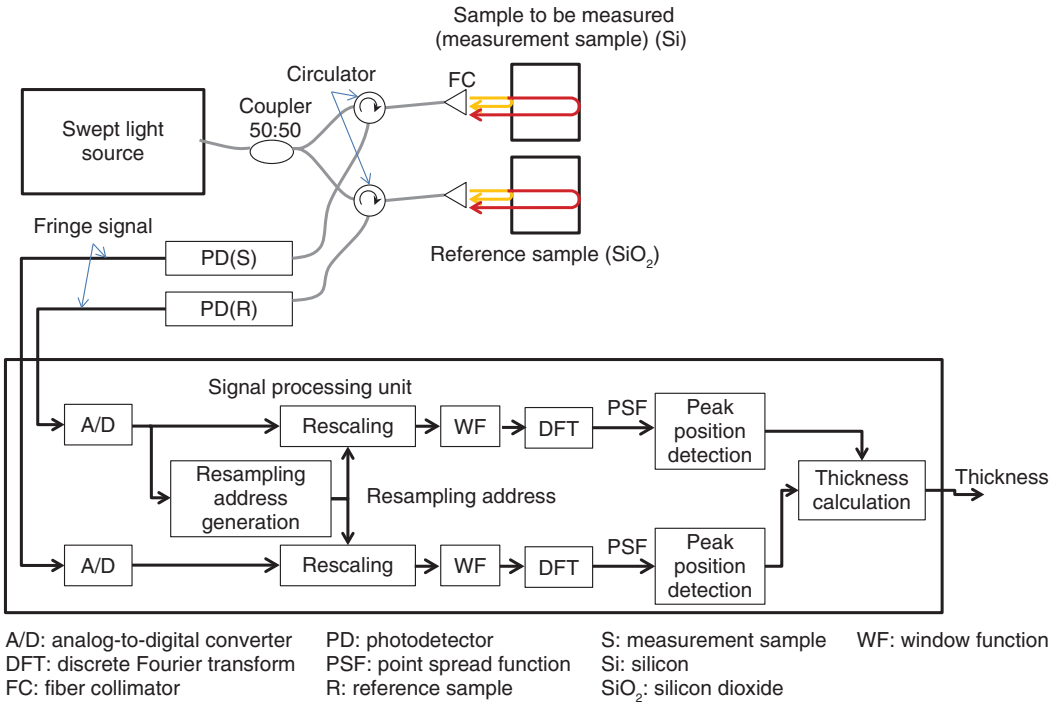

Fig. 1. Thickness measurement instrument using SS-OCT technique. Copyright©2018 IEICE [5].

the frequency.

In our thickness measuring instrument, reflected light beams from both the back and front sides of the measurement sample are respectively used as sample and reference light beams. (That is, the sample itself functions as a Fabry-Perot interferometer.) At this time, since the combining of the sample and the reference light is performed on the sample front side surface, the optical path length difference is twice the product of the thickness and the refractive index of the sample. Therefore, since the refractive index varies depending on the wavelength due to the refractive index wavelength dispersion of the sample, there is a problem in that the thickness measurement value differs accordingly, if the central wavelength is different.

To solve this problem, we use the characteristic of the refractive index wavelength dispersion of the sample to correct the interfered light signal according to the difference in the center wavelength. As a result, we confirmed that the fluctuation of the thickness measurement value was suppressed [5].

2. SS-OCT thickness measurement instrument

The basic construction of our thickness measurement instrument using the SS-OCT technique is shown in **Fig. 1**. The thickness of a reference sample is already known, and the thickness value is used as a reference value for thickness measurement.

The light wave of the swept light source is divided into two light waves by a coupler and irradiated to the measurement sample and the reference sample via the circulator (C) and the fiber collimator (FC), respectively. As described above, each sample functions as a Fabry-Perot interferometer, and the light wave irradiated to each sample is reflected on the front surface and the back surface of each sample, and light waves from the front and back surface are multiplexed on the front surface of each sample to become the interfered light wave.

The interfered light of the measurement sample and the reference sample is input to the photodetectors PD(S) and PD(R) via the FC and the circulator and photoelectrically converted. The signal obtained by converting the interfered light into an electrical signal is called an interference signal. The interference signal generated by the measurement sample is referred to as a measurement interference signal, and the reference sample is referred to as a reference interference signal.

The interference signal s(t) is generally expressed

by the following equation [6],

$$s(t) = a(k(t))\cos(2zk(t)), \quad (1)$$

where t is time, $k(.)$ is the wave number of the light, z is the optical thickness of the sample, and $a(.)$ is the amplitude. If the refractive index of the sample is n and the thickness of the sample is L, then $z = nL$. In this way, the interference signal has a form in which the cosine function is AM (amplitude modulation)-modulated with the amplitude $a(.)$. This means that the envelope curve of the cosine function is $a(.)$.

The instantaneous frequency $f(.)$ at time t of the interference signal is expressed by the following equation,

$$f(t) = \frac{z}{\pi}\frac{dk}{dt}\bigg|_t = \frac{z}{\pi}k'(t), \quad (2)$$

where $k'(.)$ is a function obtained by differentiating k with time t.

If $k(.)$ is linear with respect to time t (referred to as wavenumber linear), since $k'(.)$ is constant with respect to time t, the interference signal frequency $f(.)$ becomes constant. Therefore, the Fourier transform result S(.) of the interference signal s(.) is as follows,

$$\begin{aligned} S(\nu) &= A(\nu) * F(\cos(2zk(t)))\big|_\nu \\ &= A(\nu) * \delta\left(\nu + \frac{z}{\pi}k'\right) + A(\nu) * \delta\left(\nu - \frac{z}{\pi}k'\right), \end{aligned} \quad (3)$$

where $A(.)$ is the result of Fourier transformation of $a(.)$, '$*$' is a convolution integral, $F(.)\big|_\nu$ is Fourier transformation, and $\delta(.)$ is a δ function.

According to Eq. (3), the Fourier transform result of the interference signal is a signal in which the $A(.)$ signal centered on zk'/π and the inverted $A(.)$ centered on $-zk'/\pi$ are arranged symmetrically around the frequency zero. Therefore, when we extract only the signal of the positive frequency and detect its center frequency ν_c, we can calculate the optical thickness z by $z = \pi\nu_c z/k'$.

Here, the signal centered on ν_c is called a point spread function (PSF). Its shape is indicated by $A(.)$ as shown in Eq. (3). Normally, PSF is a function expressing the blurring degree of a point in an image, but in the OCT image, it represents the blurring degree of the signal representing the reflection point in the measurement sample.

Incidentally, if $k(t)$ is nonlinear with respect to time t, $f(t)$ fluctuates over time, and $F(\cos(2zk(t)))\big|_\nu$ is not a linear combination of the two δ functions. Therefore, the width of the PSF increases, and the signal representing the reflection point becomes blurred. In other words, the resolution of the OCT image deteriorates.

Rescaling is one method of narrowing the width of the PSF [6]. This involves shaping the waveform of the interference signal to be linear with respect to time by sampling (hereafter, expressed as 'resampling') the interference signal $s(t)$ at a specific timing to equally divide phase $\theta = 2zk(t)$, which is the argument of the cosine function of Eq. (1). Rescaling is described in detail later in the article.

The sampling timing data (denoted as 'resampling address' in Fig. 1) in the resampling process are generated from the reference interference signal. Resampling (rescaling) is performed on both the sample interference signal and the reference interference signal using the resampling address. Each rescaled interference signal is Fourier transformed after being windowed.

PSF signals are respectively obtained from the sample and reference interference signals, and their peak positions are calculated. The peak position corresponds to the aforementioned $\nu_c = zk'/\pi$. In the thickness measurement, the thickness z_S of the optical path length is measured by calculating $z_S = z_R$ (ν_{cS}/ν_{cR}) using $\nu_{cS} = z_S k'/\pi$ corresponding to the measurement sample and $\nu_{cR} = z_R k'/\pi$ corresponding to the reference sample. The advantage of this method is that it is unlikely to be affected by the time variance of the wavelength.

3. Rescaling signal processing

An outline of the rescaling process is shown in **Fig. 2**. Rescaling is a process of converting an interference signal whose frequency varies with time into a signal whose frequency is constant with respect to time.

The basic mechanism of rescaling is described below. The fact that $\theta = 2zk(t)$, which is the argument of the cosine function of the interference signal in Eq. (1), does not linearly change with time is problematic in that $F(\cos(2zk(t)))\big|_\nu$ in Eq. (3) is not a sum of two δ functions. One method to effectively solve this is to resample the interference signal so that $\theta = 2zk(t)$ changes linearly with time.

Let us assume that an inverse function $t(k)$ of $k(t)$ is obtained. (The method of obtaining $t(k)$ is described later.) With $t(k)$, the interference signal $s(t)$ of Eq. (1) is resampled at times (resampling address) $t_n = t(\delta k \cdot n + k_0)$ such that the sampling point interval becomes δk (constant), and at the timing $t' = n\delta t$ (δt is constant), the sample signal $s(t_n)$ is rearranged. As a result, the rearranged signal $s'(t')$ is equivalent to the

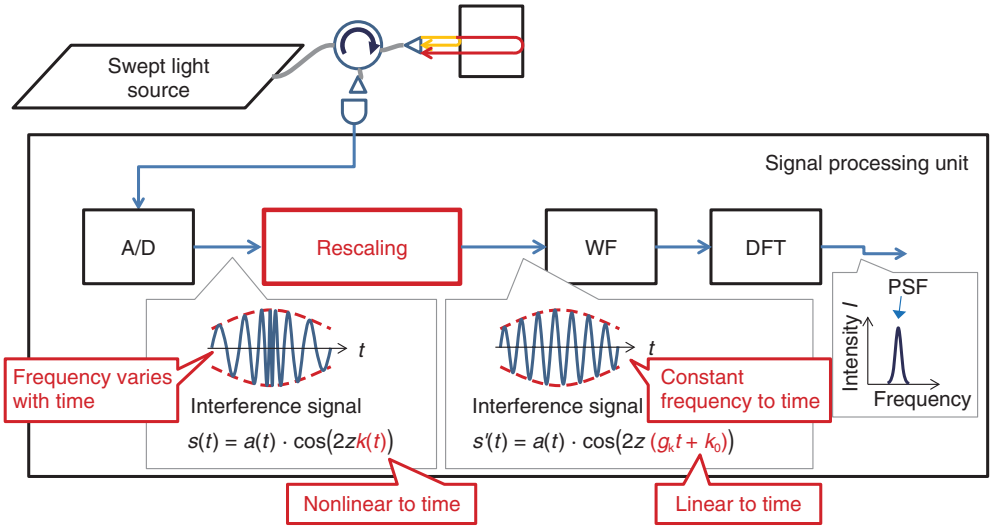

Fig. 2. Outline of signal processing for PSF generation. Although the frequency of the interference signal fluctuates with respect to time, it is unified by the rescaling process. Copyright©2018 IEICE [5].

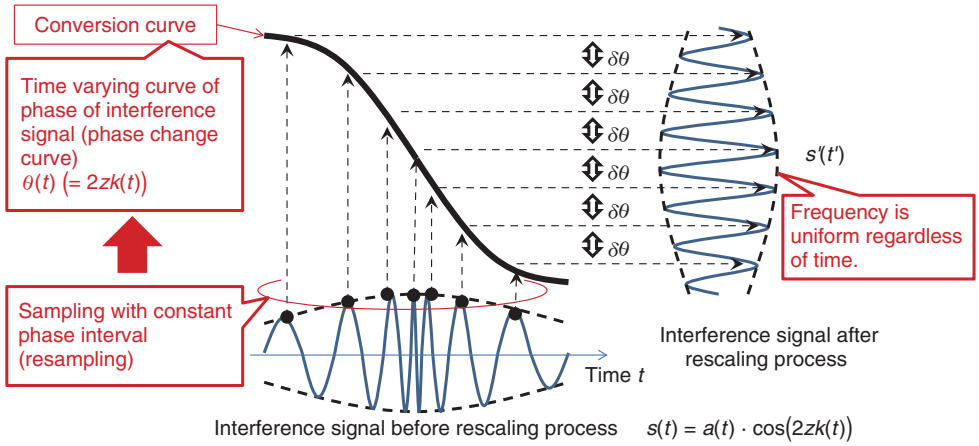

Fig. 3. Concept of rescaling process. Rescaling involves expanding and contracting the interference signal as appropriate so that the frequency becomes uniform at any time. Copyright©2018 IEICE [5].

case where the wave number linearly changes to time t'. That is, $k(t_n) = g_k t_n + k_0$, where $g_k = \delta k/\delta t$. As described above, the frequency of the interference signal subjected to rescaling processing is constant with respect to time.

In the above description, the method of acquiring the resampling address using wavenumber k of light is shown, but the address can be similarly obtained even by using the phase $\theta = 2zk(t)$. In the actual processing, phase $\theta(t)$ can be directly calculated as described later, so the resampling address is calculated using phase $\theta(t)$. A diagram of the concept of rescaling is shown in **Fig. 3**.

When the interference signal s(t) is resampled with sample points (resampling address) having equal phase intervals with respect to the phase change curve, s(t) is converted into an interference signal s′(t') whose frequency is constant regardless of time. Hereinafter, the phase change curve is referred to as the conversion curve.

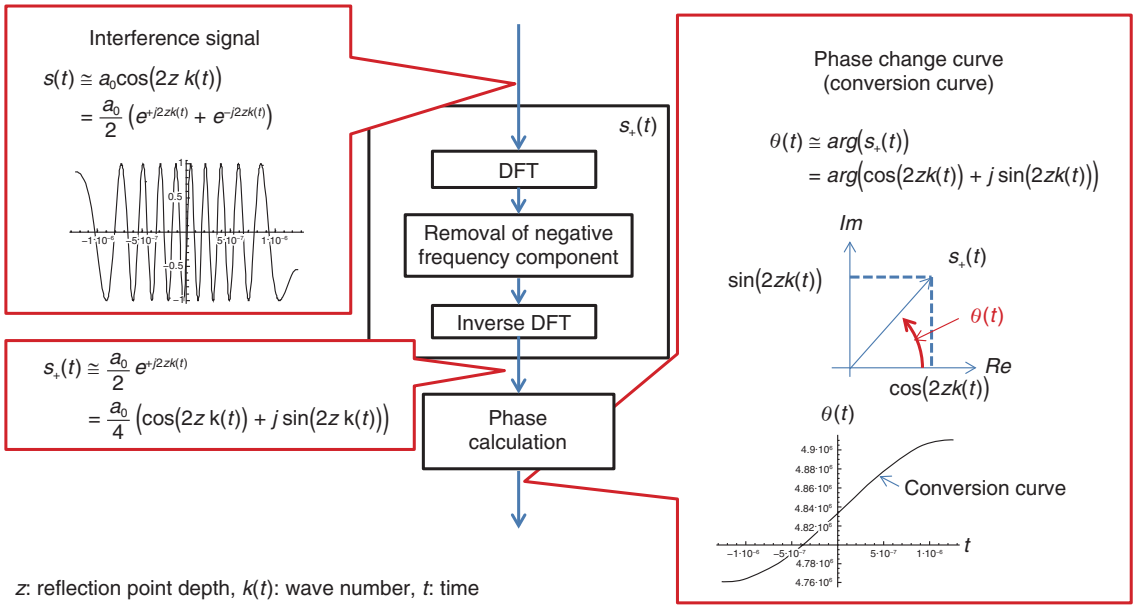

Fig. 4. Conversion curve calculation method. A conversion curve to carry out rescaling is calculated from a typical interference signal before taking a tomographic image and then used during imaging. Copyright©2018 IEICE [5].

For rescaling, $t(\theta)$ needs to be known before rescaling. For this purpose, it is necessary to find $\theta(t)$. Therefore, a specific method for obtaining $\theta(t)$ is described below. When the optical distance of the thickness of the measurement sample shown in Fig. 1 is z, the interference signal output from the PD is expressed by Eq. (1). To simplify the explanation, the interference signal s(t) is simplified as follows by assuming $a(k(t))$ is constant over time,

$$\mathrm{s}(t) = a_0 \cos(2zk(t)), \tag{4}$$

where a_0 is a constant. The method of obtaining phase $\theta(t)(= 2zk(t))$ is described below. Equation (4) is transformed as follows,

$$\mathrm{s}(t) = \frac{1}{2} a_0 \left(e^{j2zk(t)} + e^{-j2zk(t)}\right), \tag{5}$$

where j stands for the imaginary unit. The component $s_+(t)$ obtained by removing the negative frequency component from $s(t)$ is as follows,

$$\begin{aligned} \mathrm{s}_+(t) &= \frac{1}{2} a_0 e^{j2zk(t)} \\ &= \frac{1}{2} a_0 \left(cos(2zk(t)) + j\, sin(2zk(t))\right). \end{aligned} \tag{6}$$

According to Eq. (6), $s_+(t)$ is a complex number, and using the real part and the imaginary part enables us to obtain $\theta(t)$ as follows.

$$\theta(t) = arg\left(\Re(s_+(t)) + j\,\Im(s_+(t))\right)$$

$$= arg\left(cos(2zk(t)) + j\, sin(2zk(t))\right), \tag{7}$$

where $arg(.)$ stands for argument, and $\Re(.)$ and $\Im(.)$ respectively represent the real and imaginary parts.

An example of the signal processing procedure for obtaining the conversion curve $\theta(t)$ from the interference signal s(t) is shown in **Fig. 4**. To obtain $s_+(t)$ from s(t), s(t) is Fourier-transformed, the negative frequency component is removed, and inverse Fourier transform is performed. Then, $\theta(t)$ is obtained by calculating the argument of $s_+(t)$. By obtaining $t(\theta)$ from $\theta(t)$, obtaining the sampling address having the constant interval $\delta\theta$ from $t(\theta)$, and sampling the interference signal using the sampling address, we can obtain an interference s′(t') equivalent to that obtained when a wavenumber linear swept light source is used. Since $\theta(t)$ and $k(t)$ can be used in the same way to obtain the sampling address, $k(t)$ may be used instead of $\theta(t)$. If z is known, $k(t)$ is obtained from $\theta(t)$ as follows,

$$k(t) = \frac{\theta(t)}{2z}. \tag{8}$$

4. Problem of rescaling signal processing

In our thickness measurement instrument as shown in Fig. 1, the reference sample to acquire the resampling address and the measurement sample (sample

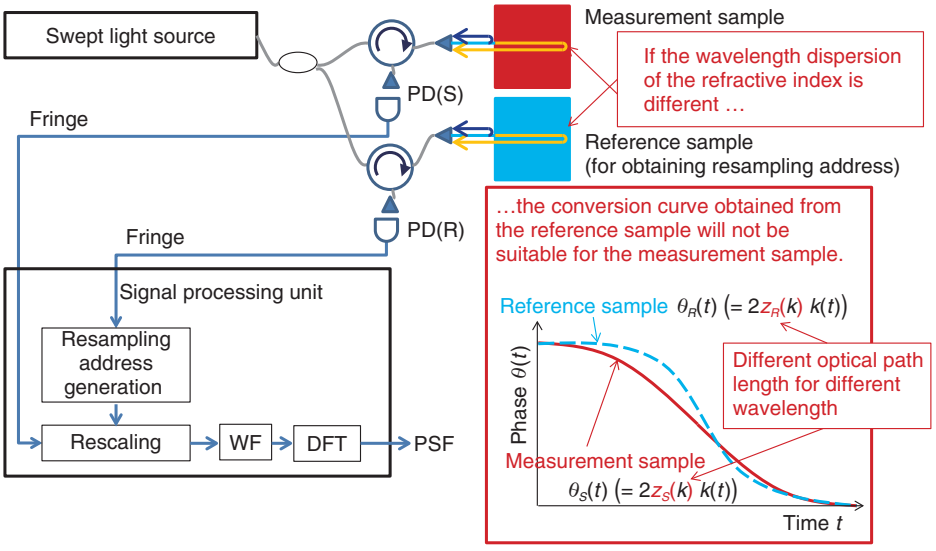

Fig. 5. Process to calculate PSF of measurement sample. If the refractive index wavelength dispersion values of the reference sample and the measurement sample are different, the conversion curve obtained from the reference sample will not match the measurement sample. Copyright©2018 IEICE [5].

to be measured) are different. From the viewpoint of wavelength dispersion, it is desirable that the measurement sample and the reference sample are made of the same material. However, in order to acquire a highly accurate resampling address from a signal with a high signal-to-noise ratio, since the measurement sample and the reference sample cannot be made of the same material when the light transmittance of the measurement sample is low, the reference sample material should have high transmittance, unlike the measurement sample.

We show in **Fig. 5** a diagram extracted from Fig. 1 of the process to obtain the PSF of the measurement sample of the thickness measurement instrument. If the wavelength dispersion of the refractive index of the measurement sample and that of the reference sample are different, the ratio $z_S(\lambda)/z_R(\lambda)$ of the optical path lengths in two samples will differ with wavelength. Therefore, the conversion curve $\theta_R(t)$ $(= 2z_R k(t))$ obtained from the reference sample will not have a similar shape to the conversion curve $\theta_S(t)$ $(= 2z_S k(t))$ adapted to the dispersion of the measurement sample.

The effect on the PSF position when the conversion curve is not appropriate is shown in **Fig. 6**. When the conversion curve used for generating the resampling address is not suitable for the measurement sample, even if the rescaling is performed, the frequency of the interference signal will not become uniform with respect to time. For this reason, the peak position of the PSF will vary depending on the area of the interference signal on which Fourier transform is performed. Similarly, when the sweeping wavelength band of the swept light source is shifted, the peak position of the PSF shifts.

5. Correction method of conversion curve

Since the shift in the PSF peak position described above is caused by the fact that the conversion curve generated in the reference sample does not match the measurement sample, it is necessary to correct the conversion curve generated using the reference sample so that it fits the measurement sample.

An outline of the conversion curve correction is shown in **Fig. 7**. The phases $\theta_R(t)$ and $\theta_S(t)$ of the interference signals of the reference sample and the measurement sample are given below,

$$\theta_R(t) = 2z_R k(t) = 2n_R(\lambda)L_R k(t), \quad (9)$$
$$\theta_S(t) = 2z_S k(t) = 2n_S(\lambda)L_S k(t), \quad (10)$$

where z_R and z_S are the optical path lengths of the thicknesses of the reference sample and the measurement sample, $n_R(.)$ and $n_S(.)$ are the refractive indices of the reference sample and the measurement sample, λ is a wavelength, and L_R and L_S are the thicknesses of the reference sample and the measurement sample. By rewriting Eqs. (9) and (10) using the refractive

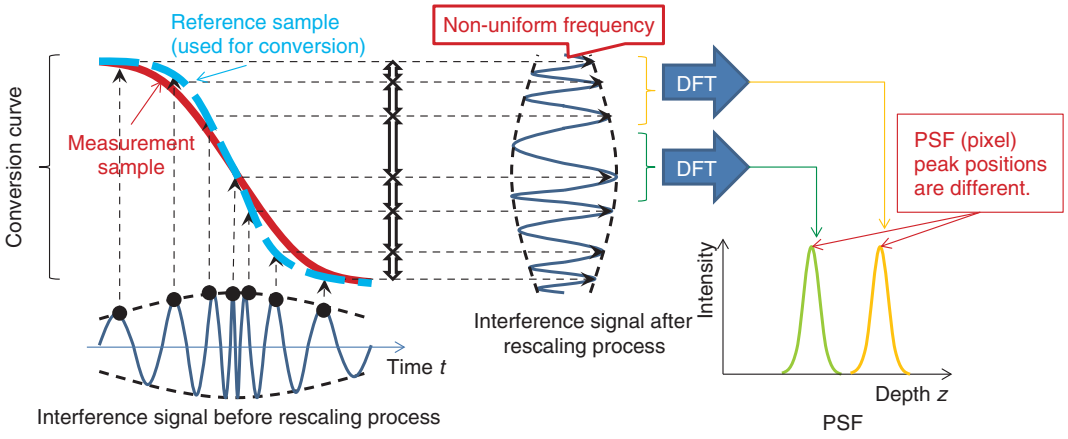

Fig. 6. Effect on PSF position when conversion curves are different. When the refractive index wavelength dispersion values of the reference sample and the measurement sample are different, the frequency of the interference signal becomes non-uniform even after rescaling. Therefore, since the frequency of the interference signal varies depending on the acquisition time of the interference signal, the PSF peak position also differs according to the acquisition time zone. Copyright©2018 IEICE [5].

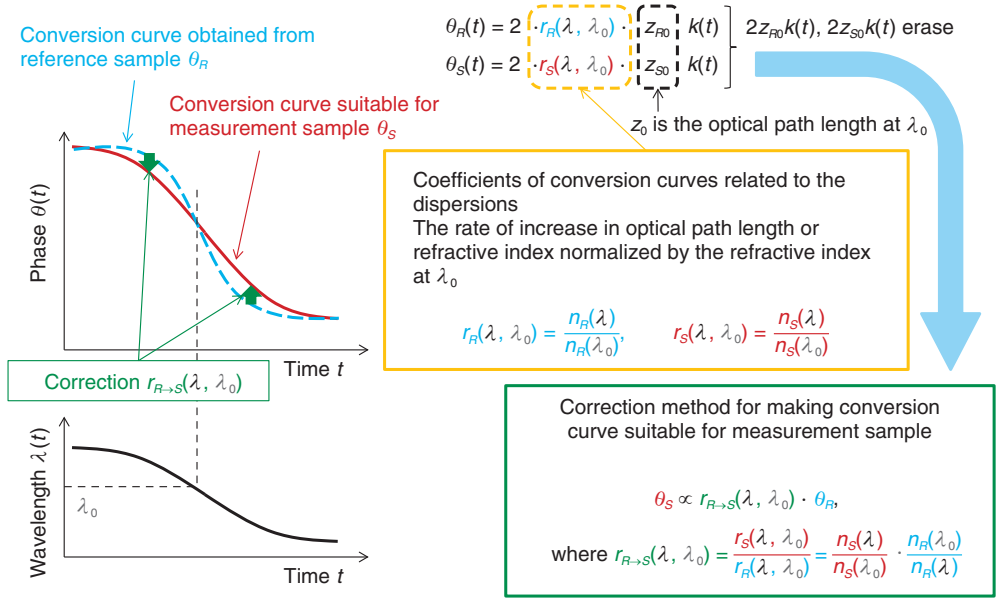

Fig. 7. Conversion curve correction. If the refractive index wavelength dispersion is known, the conversion curve for the measurement sample can be obtained. Copyright©2018 IEICE [5].

index ratios $r_R(\lambda, \lambda_0) = n_R(\lambda)/(n_R(\lambda_0)$ and $r_S(\lambda, \lambda_0) = n_S(\lambda)/n_S(\lambda_0)$ based on the refractive index $n_R(\lambda_0)$, $n_S(\lambda_0)$ when the wavelength is λ_0, we obtain the following,

$$\theta_R(t) = 2r_R(\lambda, \lambda_0)n_R(\lambda_0)L_R k(t), \quad (11)$$
$$\theta_S(t) = 2r_S(\lambda, \lambda_0)n_S(\lambda_0)L_S k(t). \quad (12)$$

To convert the conversion curve $\theta_R(t)$ obtained from the reference sample into a conversion curve suitable for the measurement sample, we use the method described below to make $\theta_R(t)$ similar to $\theta_S(t)$ by multiplying $\theta_R(t)$ by the correction coefficient (expressed as $r_{R\to S}(\lambda, \lambda_0)$). At this time, $\theta_R(t)$ and $\theta_S(t)$ have the following relationship,

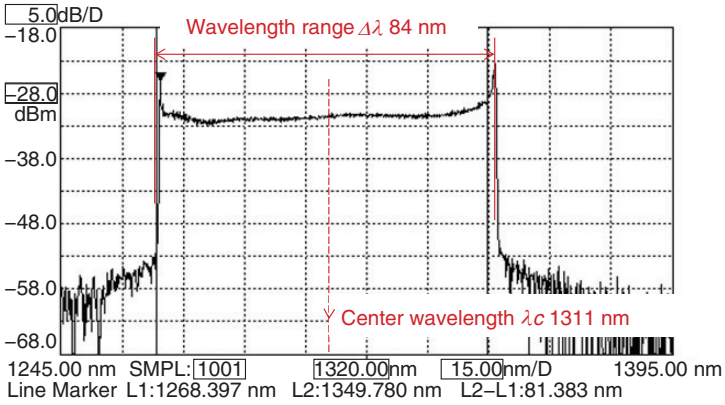

Fig. 8. Spectrum of swept light source. Copyright©2018 IEICE [5].

$$\theta_S(t) \propto r_{R\to S}(\lambda, \lambda_0)\theta_R(t). \quad (13)$$

Substituting Eqs. (11) and (12) into Eq. (13) yields the following,

$$r_S(\lambda, \lambda_0)n_S(\lambda_0)L_S k(t) \propto r_{R\to S}(\lambda, \lambda_0)r_R(\lambda, \lambda_0) n_R(\lambda_0)L_R k(t). \quad (14)$$

If we consider that $n_S(\lambda_0)L_S$ and $n_R(\lambda_0)L_R$ are constant, the correction coefficient $r_{R\to S}(\lambda, \lambda_0)$ must be as follows,

$$r_{R\to S}(\lambda, \lambda_0) = \frac{r_S(\lambda, \lambda_0)}{r_R(\lambda, \lambda_0)} = \frac{n_S(\lambda)}{n_S(\lambda_0)} \frac{n_R(\lambda_0)}{n_R(\lambda)}. \quad (15)$$

By multiplying the conversion curve $\theta_R(t)$ obtained from the reference interference signal by the correction coefficient $r_{R\to S}(\lambda, \lambda_0)$, we can obtain the conversion curve $\theta_R'(t)\big(= r_{R\to S}(\lambda, \lambda_0) \cdot \theta_R(t)\big)$. Then, the resampling address is obtained from the conversion curve $\theta_R'(t)$ and used for rescaling.

Incidentally, before calculating $\theta_R'(t)$, it is necessary to obtain $\lambda(t)$ in order to calculate the product of $r_{R\to S}(\lambda, \lambda_0)$ and $\theta_R(t)$. It is likely to be calculated as $\lambda(t) = 4\pi z/\theta(t)$ in consideration of Eq. (8), but since z is a function of wavelength λ because of the effect of the refractive index wavelength dispersion, it is difficult to obtain $\lambda(t)$ analytically from the following formula with z in Eq. (8) as a function of λ,

$$\lambda(t) = \frac{4\pi \cdot z\big(\lambda(t)\big)}{\theta(t)} = \frac{4\pi \cdot n\big(\lambda(t)\big) \cdot L}{\theta(t)}. \quad (16)$$

Therefore, $\lambda(t)$s that satisfies Eq. (16) is calculated for each time t using the Newton-Raphson method. The initial values of $\lambda(t)$ are obtained by calculating $\lambda(t) = 4\pi \cdot n_R(\lambda_0) \cdot L_R/\theta_R(t)$ using $\theta_R(t)$ obtained from the reference interference signal using the method shown in Fig. 4.

6. Experimental results and discussion

In the experiment, silicon (Si) was used as a measurement sample, and fused quartz glass (silicon dioxide: SiO_2) was used as a reference sample. As shown in **Fig. 8**, the spectrum of the swept light source used in the experiment had a center wavelength of 1311 nm and a wavelength range of 84 nm.

The refractive index wavelength dispersions of Si and SiO_2 are shown in **Fig. 9**. They were approximated by the Sellmeier equation [7] using the coefficients given in **Table 1**. According to Fig. 9, since the rates of change of the refractive index with respect to the wavelengths of Si and SiO_2 are different, these phase change curves are not similar.

We show in **Fig. 10** the correction coefficients $r_S(\lambda, \lambda_0)$, $r_R(\lambda, \lambda_0)$, and $r_{R\to S}(\lambda, \lambda_0)$ when λ_0 = 1310 nm (1.310 μm). Further, conversion curves before and after correction are plotted in **Fig. 11**. The one-dotted chain line represents the ratio between them, and we can see that the conversion curve is corrected with reference to 1310 nm.

The relationship between the center wavelength and the thickness of the measurement sample was investigated to confirm whether the deviation of the thickness measurement value due to the wavelength shift improves by correcting the wavelength dispersion. Specifically, the wavelength region was divided into five regions, and then the PSF was calculated and the silicon thickness was measured for each region. The center wavelength and region for each of the five regions are listed in **Table 2**. To clearly observe the suppression of fluctuation in the thickness measurement value with respect to wavelength fluctuation, the difference between the center wavelengths of

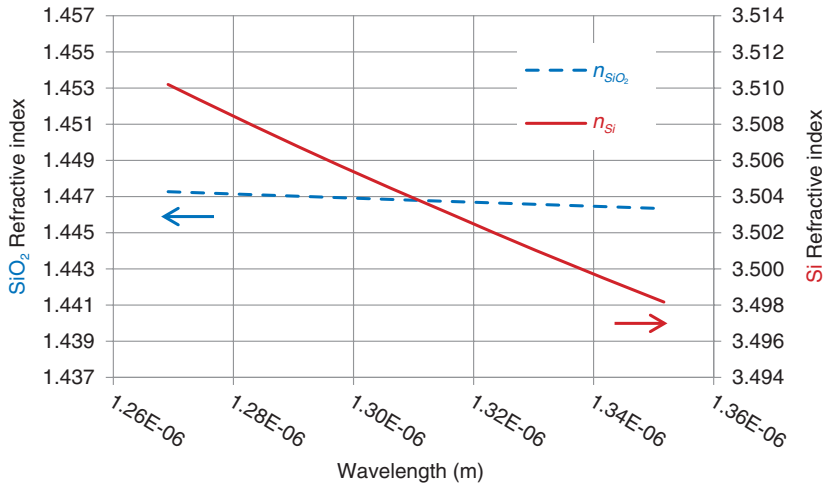

Fig. 9. Refractive index wavelength dispersion of Si and SiO_2. Copyright©2018 IEICE [5].

Table 1. Sellmeier equation and coefficients. Copyright©2018 IEICE [5].

Silicon (Si)	Fused quartz glass (SiO_2)
$B_{1si} = 10.6890595128$ $B_{2si} = 0.0029996985$ $B_{3si} = 1.5413105256$ $C_{1si} = 0.0882073723$ $C_{2si} = 128777194$	$B_{1sio_2} = 0.6961663$ $B_{2sio_2} = 0.4079426$ $B_{3sio_2} = 0.8974794$ $C_{1sio_2} = 0.00467914826$ $C_{2sio_2} = 0.0135120631$
$(n(\lambda))^2 = 1 + \frac{B_1\lambda^2}{\lambda^2 - C_1} + \frac{B_2\lambda^2}{\lambda^2 - C_2} + \frac{B_3\lambda^2}{\lambda^2 - C_1}$	

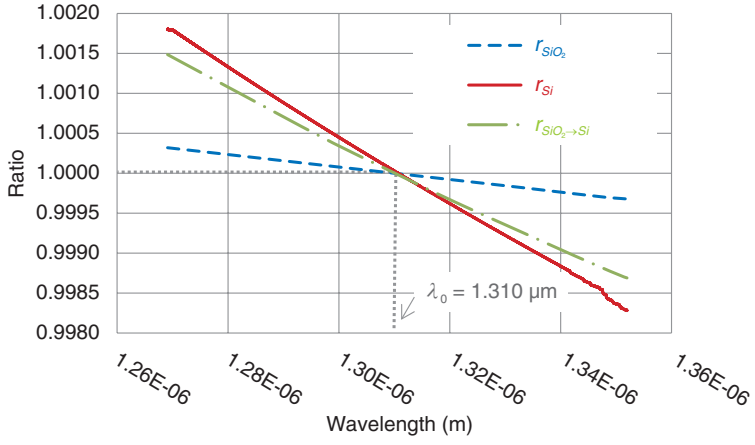

Fig. 10. Correction coefficient of conversion curve. Copyright©2018 IEICE [5].

regions (1) and (5) is relatively large at about 50 nm.

The results of measuring the thickness of Si as the measurement sample are shown in **Fig. 12**. Before the correction of the conversion curve (wavelength dispersion non-adaptive), the measured value shifted by 24.7 µm with respect to the deviation of the central

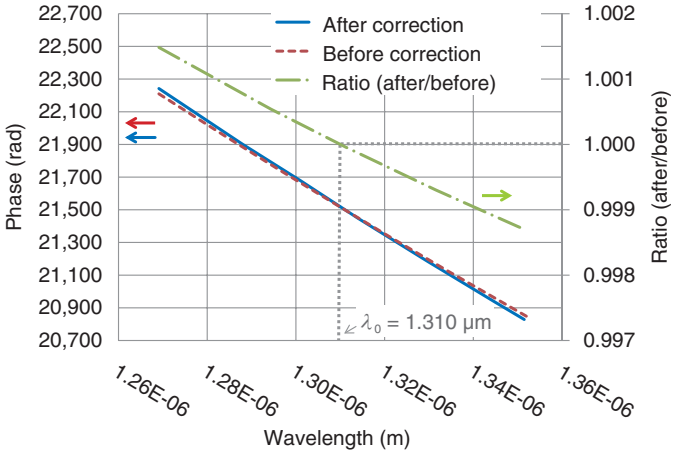

Fig. 11. Conversion curves before and after correction, and their ratio. Copyright©2018 IEICE [5].

Table 2. Wavelength regions used for measurement. Copyright©2018 IEICE [5].

Region number	Center wavelength (nm)	Range (nm)
(1)	1283.0	7.0
(2)	1292.7	11.4
(3)	1305.5	13.8
(4)	1320.0	14.6
(5)	1333.8	12.3

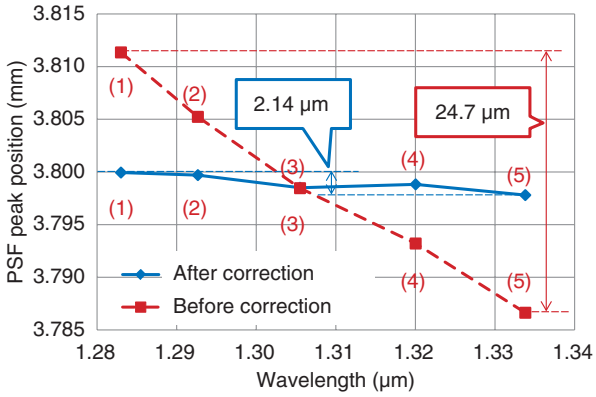

Fig. 12. Results of measuring Si thickness (optical path length). Thickness values were measured at five points arranged at intervals of wavenumber width of about 47,000 rad/m, which corresponds to a wavelength width of 12 nm. The deviation width of the thickness measurement value was improved to a width that was about one-tenth of that before correction. Copyright©2018 IEICE [5].

wavelength of 50 nm. After the correction (wavelength dispersion adaptation), however, it only shifted by 2.14 μm. This result indicates that the deviation width of the thickness measurement value was improved to a width that was about one-tenth of that before correction.

7. Summary

With the SS-OCT thickness measuring instrument, if the refractive index wavelength dispersion of the sample to be measured is not taken into account, a deviation will occur in the thickness measurement value due to deviation of the central wavelength of the light source. To solve this problem, we adapted the rescaling process to the wavelength dispersion of the sample to be measured and confirmed that the deviation of the thickness measurement value improved to about one-tenth of the value before adaptation.

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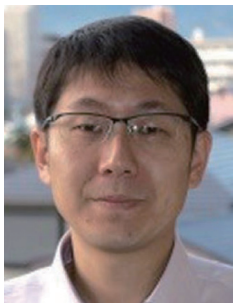

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QoE Visualization and Prediction Model for QoE Improvement

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Abstract

The use of smartphones continues to spread, and smartphone services are becoming increasingly diverse. In response to these trends, NTT Network Technology Laboratories is researching quality of experience (QoE)-centric operation, which takes into consideration the effect of network quality on the QoE of services. In this article, we summarize a QoE visualization and prediction model, which is one of the components of QoE-centric operation. We also explain how the concept of co-created quality enables all actors in a network to contribute to QoE improvement by providing service providers or users with visualized information that is the output of this model.

Keywords: QoE visualization, QoE prediction, network operation

1. Introduction

The advancing functionality of smartphones and the continued progress in cloud services have led to the provision of numerous types of communication services through telecommunications networks. However, the necessary network quality for each service is different, and the effect of network quality degradation on each service is also different. Therefore, it is difficult to determine whether users can use each service comfortably only by monitoring network quality. Thus, the impact of network quality degradation must be understood from the viewpoint of quality of experience (QoE), and this will enable service quality to be optimized from the user's perspective.

To improve QoE, we aim to develop QoE-centric operation: an operation cycle that includes QoE quantification and optimization based on QoE-related information (network, terminal, or user information that affects QoE) obtained from in-service monitoring. To realize this cycle, NTT Network Technology Laboratories is researching four component technologies: (1) QoE quantification, (2) QoE measurement and collection, (3) QoE analysis and prediction, and (4) QoE control (**Fig. 1**).

QoE quantification derives relationships between QoE and QoE-related information. QoE measurement and collection measures QoE-related information and stores it in a database. QoE analysis and prediction visualizes the impact range of QoE degradation by QoE quantification or analysis of QoE-related information in the database and supports network operation by predictive detection or cause analysis for QoE degradation. QoE control optimizes QoE through optimal network resource allocation, policy control, or video delivery control.

In this article, we introduce a QoE visualization and prediction model, which is one of the technologies in QoE analysis and prediction.

2. Technologies composing QoE visualization and prediction model

The QoE visualization and prediction model visualizes the QoE status and time-series changes on a map by analyzing QoE-related information collected from user terminals or network devices, for example,

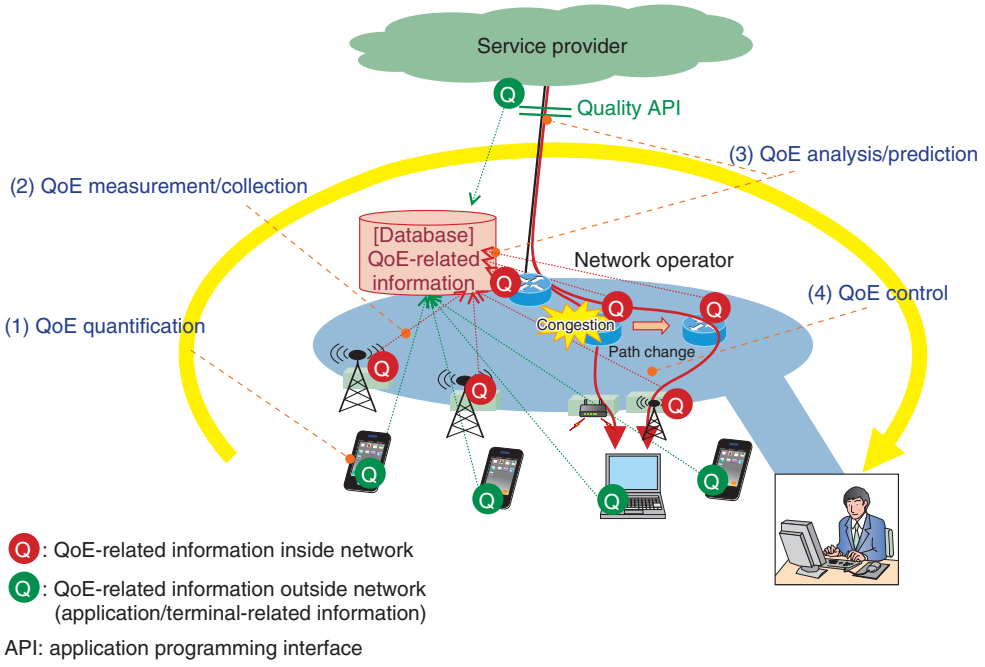

Fig. 1. Cycle of QoE-centric operation.

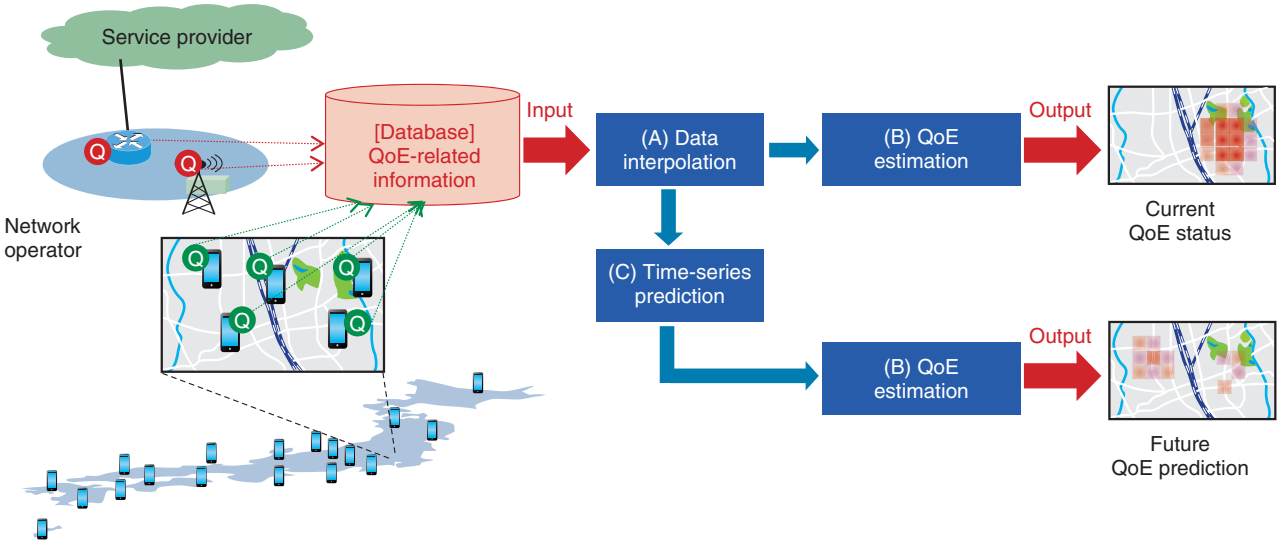

Fig. 2. QoE visualization and prediction model.

terminal information, signal reception quality, and network quality. Furthermore, this model predicts future QoE based on predicted QoE-related information that changes in a time-series.

We are studying three network artificial intelligence (AI) techniques: (A) data interpolation, (B) QoE estimation, and (C) time-series prediction (**Fig. 2**). First, QoE-related information collected and measured using a crowdsourcing approach is used as the input of this model. However, it is difficult to collect QoE-related information for all periods of time and all areas. Thus, we apply data interpolation to

Fig. 3. Data interpolation.

interpolate the value of QoE-related information based on the relationships among these values in the surrounding area.

Next, QoE estimation is used to derive relationships between QoE and QoE-related information by analyzing these values and to compute the QoE from input values that are collected or interpolated from QoE-related information for each period of time or each area. Thus, QoE is visualized on the map for each time period, making it possible to visually identify the area that should be preferentially handled in terms of QoE.

We apply time-series prediction to predict future values for QoE-related information changes in time-series data based on their past values. These predicted values are used as inputs for QoE estimation, and the outputs are used for future QoE visualization and risk detection.

2.1 Data interpolation

In data interpolation, the characteristics of QoE-related information and/or its similarity to the surrounding area are considered.

If the values of QoE-related information vary in accordance with the effect of congestion caused by increasing traffic, all terminals that received a radio signal from the same sector of the base station are affected by the congestion. Since traffic varies with time, the values representing the features of a specific period and specific area must be calculated from several QoE-related parameters measured in this period and this area. If the volume of measured data is not sufficient for a certain area and time, the data interpolation technique interpolates the values in that area and time, factoring in the variation tendencies in some directions (**Fig. 3**). Here, data interpolation using graph Fourier transform is applied as one method to achieve the data interpolation.

2.2 QoE estimation

QoE estimation is based on the relationships between QoE and QoE-related parameters. We derive these relationships using two steps (**Fig. 4**).

The first step is to derive the relationships between collected QoE-related information and application quality, which means the factors in the application layer that affect the QoE of the service. For example, the waiting time until a web page displays is the application quality of a web browsing service, and the video/audio bitrate and duration of a stalling event are the application quality of an audiovisual streaming service. When application quality is degraded in a terminal, many causes (e.g., weak radio received power, large interference or noise, traffic congestion, server or terminal in a high load state, or transmission characteristics of the terminal model) can be given as the reason for this degradation. To derive the relationships among them, we extract the parameters that can represent this effect quantitatively from collected QoE-related information, and we generate an input-output model by using machine learning.

The second is to derive the relationships between application quality and QoE. We define this relationship by elucidating people's perceptions or cognitive features. A subjective test or questionnaire is used to obtain data representing this relationship, and we generate a conversion model to analyze these data.

2.3 Time-series prediction

Time-series prediction clarifies the characteristics of time-series variances in QoE-related information, the value of which varies over time. If crowdsourcing is used to collect QoE-related information, this information includes discrete data obtained from various user terminals, and time-series variances for each user terminal cannot be obtained. Thus, we quantify macro properties based on the value distribution for a

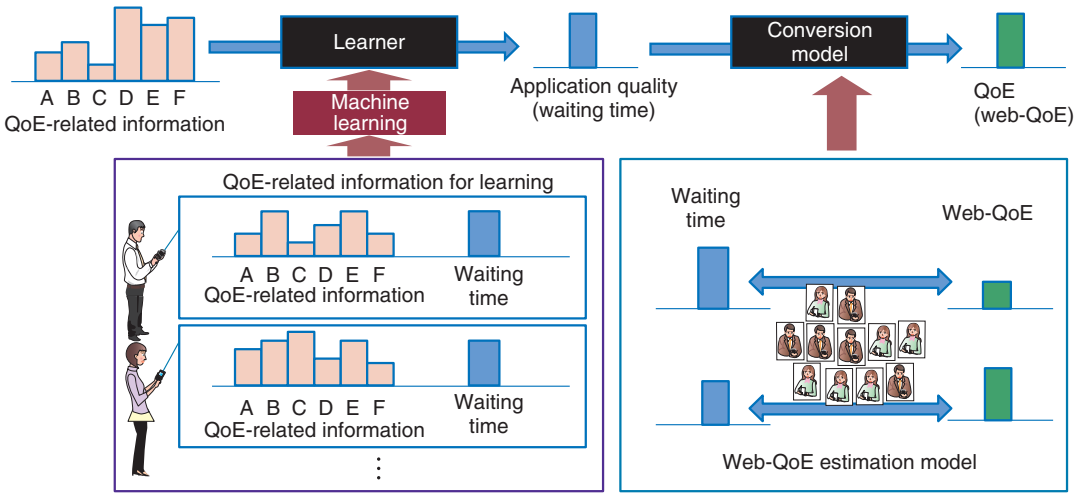

Fig. 4. QoE estimation for web browsing service.

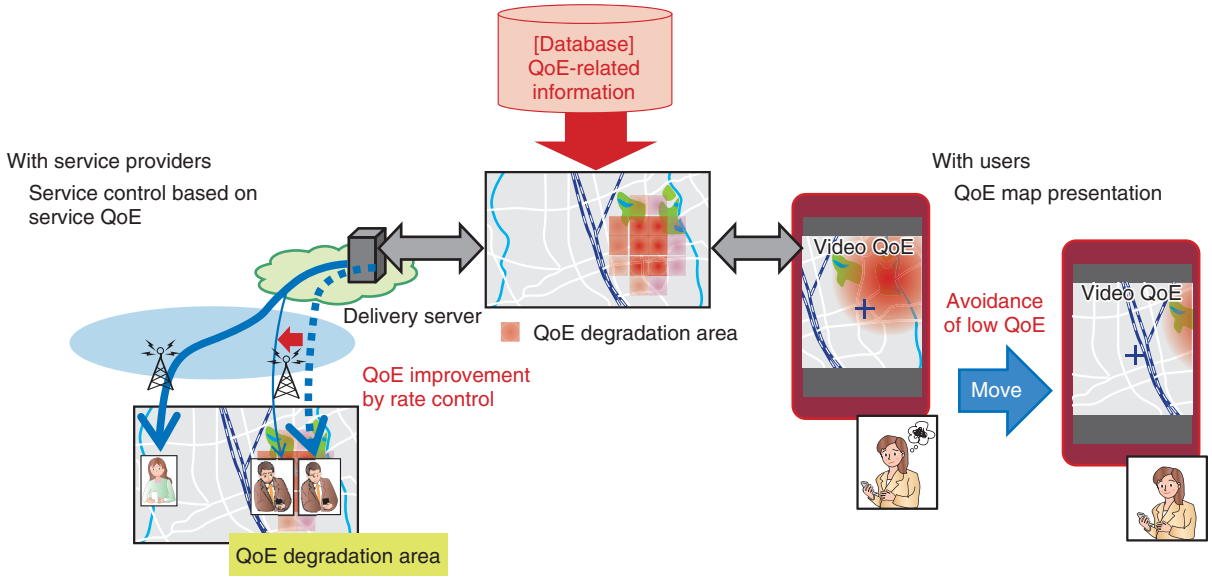

Fig. 5. Collaboration with service providers and users.

specific period and specific area and clarify the characteristics of time-series variances based on these macro properties.

3. Utilization examples of QoE visualization and prediction model

QoE visualization on a map enables network operators to visually detect degraded areas on the basis of QoE and to identify preferential areas to focus on to optimize QoE when resources are limited.

We are studying ways to utilize this information not only for network operation but also for achieving co-created quality (**Fig. 5**). Co-created quality is a concept in which a network operator cooperates with service providers or service users through a network to improve QoE. Utilization of QoE-related information provided from service providers or service users improves the accuracy of visualized QoE information, and this information is provided to service

providers or service users. Service providers improve the value of their service by optimizing service parameters or notifying users in advance based on the visualized QoE information. Service users then take the optimal action (movement to high QoE area, selection of application) based on the visualized QoE information. Thus, we aim to create an environment in which every actor related to a network can improve QoE.

4. Future development

We introduced the concept of a QoE visualization and prediction model and its component technologies. We aim to construct a network that enables win-win relationships to be established among all players related to the network. We will continue working on ways to more efficiently utilize the output of the QoE visualization and prediction model in cooperation with service providers and service users to achieve optimum service provision.

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ICT Standardization Trends for Disaster Relief, Network Resilience, and Recovery by ITU-T

Noriyuki Araki

Abstract

The Great East Japan Earthquake in March 2011 led to standardization of resilient information and communication technology (ICT) such as disaster relief systems, network resilience, and recovery measures by the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T). Additionally, use cases of resilient ICT services/systems in several countries have been summarized and reported in ITU-D (ITU Telecommunication Development Sector). This article reports on the recent progress in standardization related to resilient ICT in the ITU.

Keywords: ITU-T, disaster relief, network resilience

1. Introduction

Over seven years have passed since the Great East Japan Earthquake struck in March 2011, and since then, various natural disasters have occurred in Japan and around the world, including the Kumamoto earthquake in April 2016. Since the Great East Japan Earthquake, research and development of disaster-response information and communication technology (ICT) has been promoted in collaboration with academia and industry, and a disaster-resistant ICT research center was established in Japan by the National Institute of Information and Communications Technology.

In line with the proposal by Japan in 2012, the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) established a time-limited investigation group called the Focus Group on Disaster Relief Systems, Network Resilience and Recovery (FG-DR&NRR) that studies standardization of disaster relief systems and ways to achieve resilient ICT during disasters.

The focus group created eight deliverables between 2012 and 2014 [1]. The deliverables include many research and development results on disaster-tolerant ICT from Japan. Disaster relief services and disaster tolerant ICT and their requirements that need to be newly standardized are indicated in the deliverables, and some of them are discussed in the ITU-T Study Groups (SGs) that result in new ITU-T Recommendations. In addition, a use case document was produced, in which case examples from Japan and around the world were collected, and the information was also shared with the ITU Telecommunication Development Sector (ITU-D), which is highly relevant for developing countries, and is utilized as a technical report [2].

This article reports on the recent progress in standardization related to ICT for disaster relief systems, network resilience, and recovery by the ITU.

2. Progress in relevant Recommendations by ITU-T SG2

ITU-T SG2 (operation aspects and numbering) is a lead study group on disaster relief systems, network resilience, and recovery in ITU-T, and it approved the following Recommendations based on the deliverables transferred from FG-DR&NRR.

- E.108: Requirements for disaster relief mobile message service
- E.119: Requirements for safety confirmation and

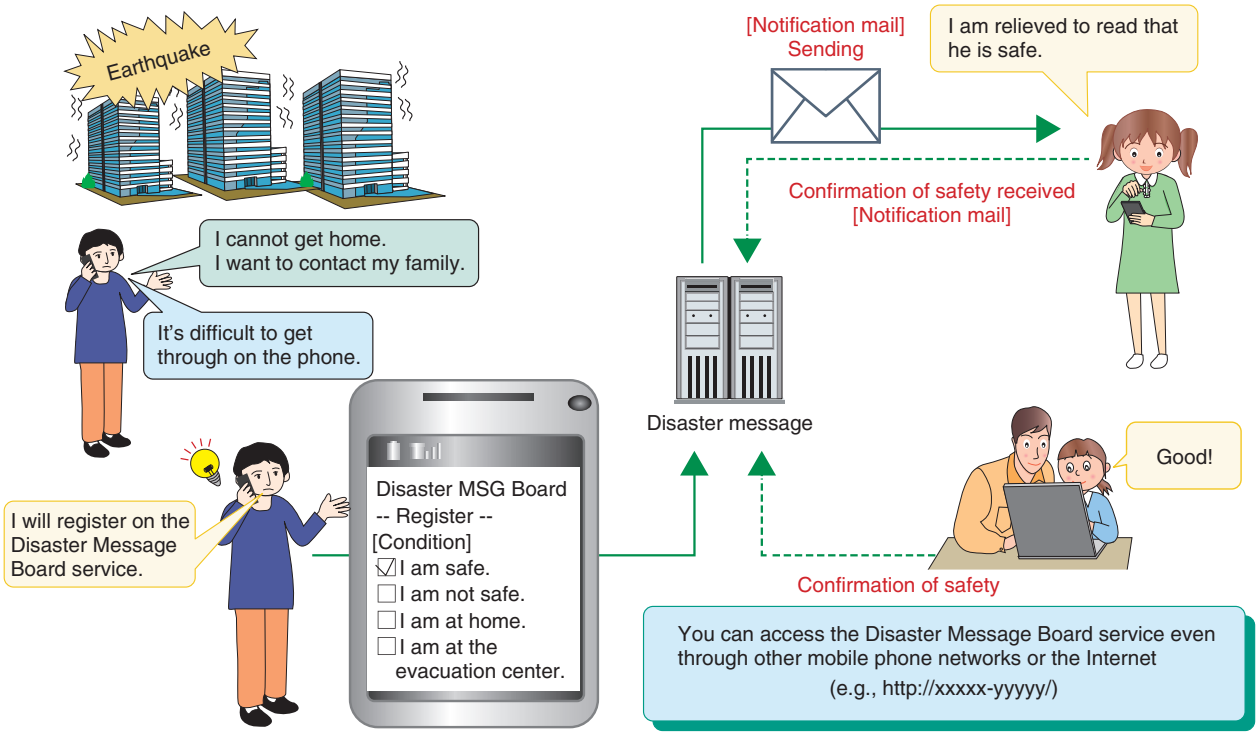

Fig. 1. Outline of disaster relief mobile message service.

broadcast message service for disaster relief

A new draft Recommendation on terms and definitions for DR&NRR and the supplementary document on framework of disaster management for disaster relief systems are also being studied.

2.1 Disaster relief mobile message service

The new Recommendation ITU-T E.108, which was proposed by Japan, was approved in January 2016. The functions described in this Recommendation are already being offered by NTT DOCOMO in the Disaster Message Board service, which can be used to check on the safety of family and friends via mobile phones and smartphones in the event of a disaster [3]. An outline of this service is shown in **Fig. 1**. In the event of a large-scale disaster, users in the affected areas can register their own situations and check the registered safety information through the Internet. It is possible to send notifications by email to predesignated family members and friends, or to request users in a disaster area to register their safety information.

Recommendation E.108 provides requirements for safety information required for disaster message board services, requirements for search and display functions, and requirements for mutual provision of services by different mobile phone operators. It also describes the interface requirements of the voice message board service that can be used by foreigners and people with disabilities.

2.2 Safety confirmation and broadcast message service for disaster relief

The new Recommendation ITU-T E.119, which was also proposed by Japan, was approved in April 2017. This Recommendation describes services that support the business continuity plan of important organizations such as local governments, public institutions such as police and fire departments, telecommunications carriers, medical facilities, and other organizations at the time a disaster occurs as well as after the disaster. It is very important for the full implementation of disaster relief activities.

This service is mainly divided into two functions: safety confirmation and message delivery. Outlines of the safety confirmation service and the message delivery service are respectively shown in **Fig. 2** and **Fig. 3**. Safety confirmation is carried out automatically by optimal means such as email, fax, mobile phone, and the Internet so that information about staff

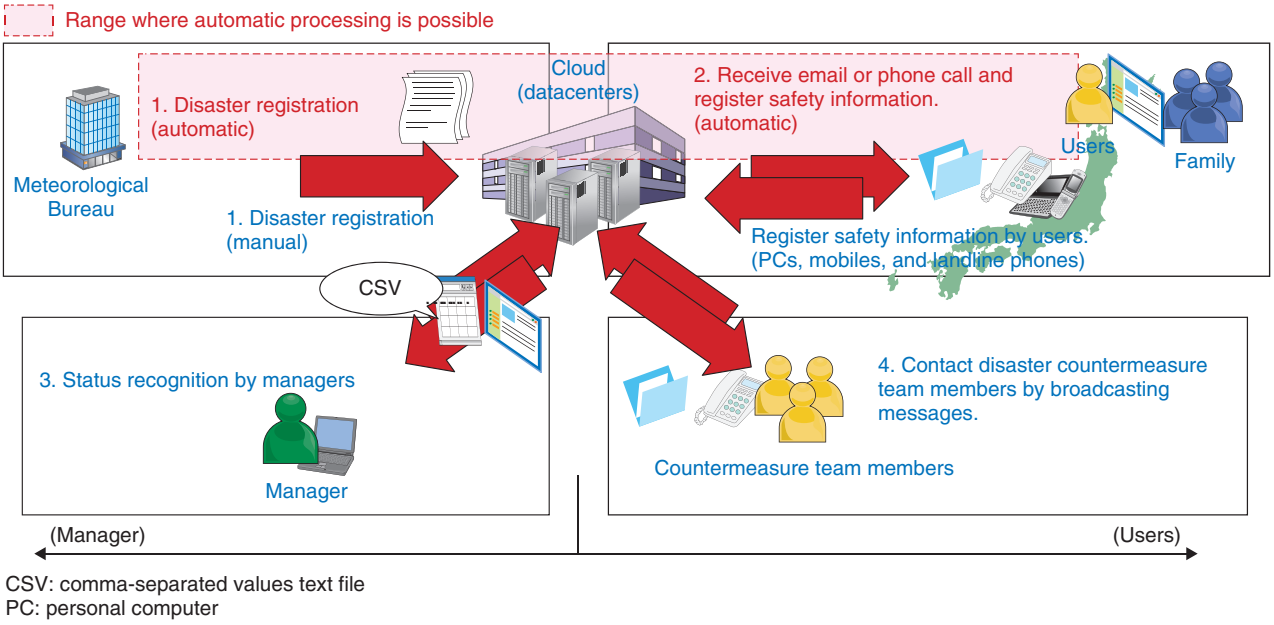

Fig. 2. Outline of safety confirmation service.

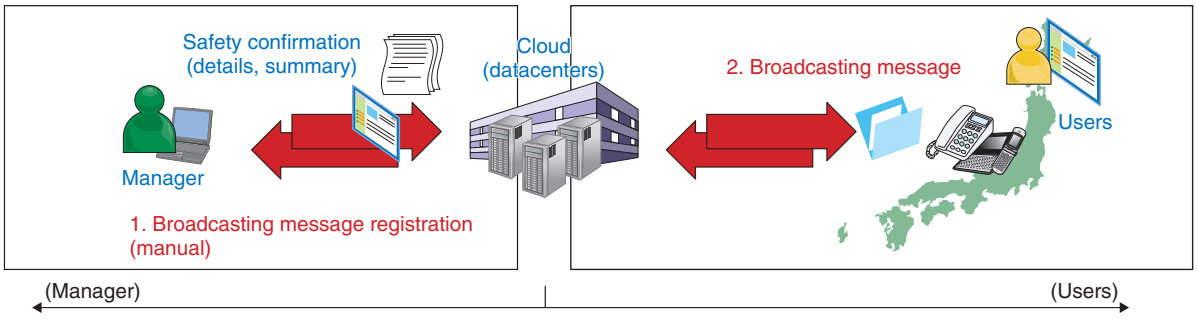

Fig. 3. Outline of message delivery service.

members can be exchanged in the event of a disaster. Then messages to the designated team members and/or employees are broadcast so that they can be dispatched to the appropriate workplaces and work sites. This Recommendation states requirements related to system reliability, security, language, and operability.

3. Progress in relevant Recommendations by ITU-T SG15

In ITU-T SG15 (transport, access and home networks), the following Recommendation and a Supplement have been respectively approved and agreed, based on the deliverables transferred from FG-DR&NRR via ITU-T SG2.

- L.392: Disaster management for improving network resilience and recovery with movable and deployable information and communication technology (ICT) resource units
- L.sup.35: Framework of disaster management for network resilience and recovery

3.1 Disaster management with movable and deployable ICT resource units

The new Recommendation ITU-T L.392, which was proposed by Japan, was approved in April 2016. L.392 proposes a means of early recovery of communication facilities and provides application

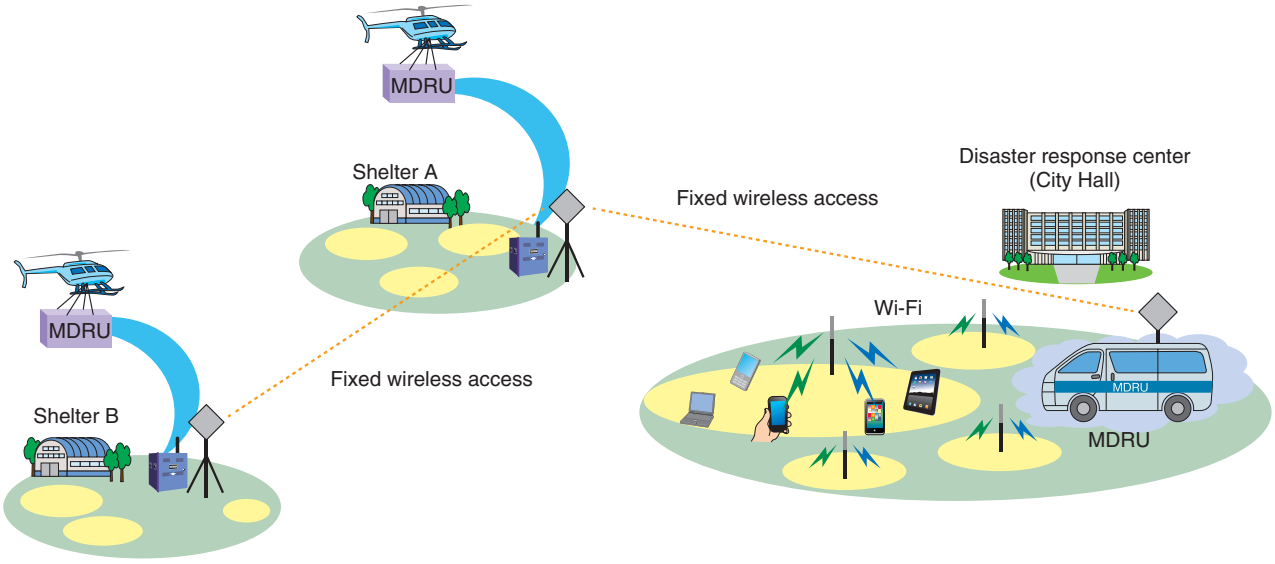

Fig. 4. Example of MDRU implementation.

guidelines to enable the immediate provision of ICT services by transporting, installing, and setting up movable and deployable ICT resource units (MDRUs) [4] to disaster areas. An example of MDRU implementation is shown in **Fig. 4**.

The MDRU is a portable unit that houses equipment necessary for providing ICT services. In the event of a disaster, the MDRU is transported to the affected area and quickly installed. It is possible to construct a local Wi-Fi network in a short period of time and to immediately provide minimum necessary ICT services in the affected area. Also, by using the remaining optical fiber cable and satellite communication line, the MDRU can connect to the wide area network and function as a network hub in the disaster area. The Appendix to this Recommendation introduces as an example information on ITU demonstration experiments using an MDRU conducted in the Philippines, which suffered tremendous damage caused by high waves in November 2013.

This technology was used as a communication tool in some affected areas after the Kumamoto earthquake in Japan in April 2016 and was utilized to support restoration work. Also, in cooperation with the Ministry of Internal Affairs and Communications of Japan in 2017, the ITU decided to introduce the MDRU as a disaster emergency communication system in disaster areas around the world for the purpose of promptly restoring communication services during a disaster [5].

3.2 Framework of disaster management for network resilience and recovery

The new Supplement ITU-T L.sup.35, which was proposed by Japan, was agreed in June 2017 and gives countermeasures and guidelines for each phase of disaster occurrence, that is, preparation before disaster occurrence, response/relief immediately after the disaster strikes, and restoration/reconstruction in the short and long term after the disaster.

This document recommends network redundancy and congestion control and application of alternative networks specialized for disasters as countermeasures against disasters (**Fig. 5**). The MDRU mentioned above is also cited as an alternative network at the time of a disaster. Also, effective technologies and network forms/functions for disaster response are listed in the Appendix.

4. Progress in ITU-D

ITU-D is a development sector within the ITU and has issued a technical report on the utilization of telecommunications/ICT for disaster preparedness, mitigation, and response in various countries including information described in the FG-DR&NRR deliverables [2]. This report describes the fundamental approaches to disaster risk management using ICT, the formulation of a disaster countermeasure strategy, and country use cases that are not standardized but are considered to be useful for disaster relief, and also

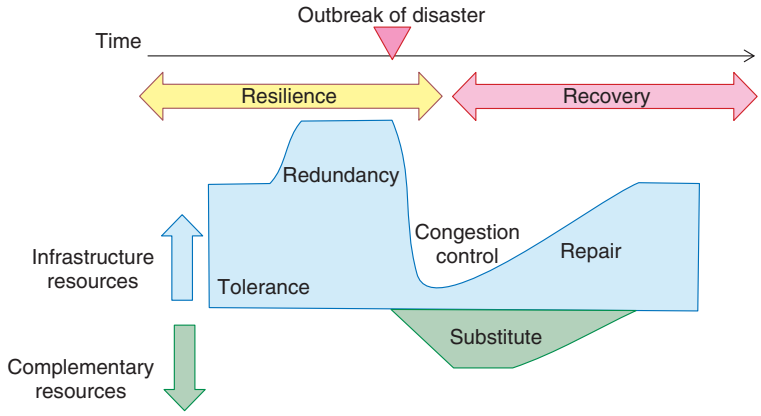

Fig. 5. Disaster phases and relevant approaches for network resilience and recovery.

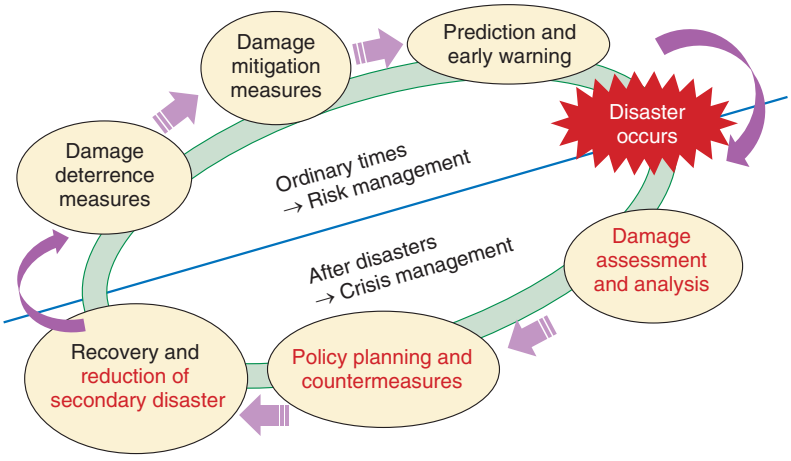

Fig. 6. Disaster risk management flow.

useful for improving the tolerance (resilience) of communication facilities and reducing damage in the event of a disaster (**Fig. 6**). The report also provides as an example Japan's use of MDRUs after the Kumamoto earthquake in April 2016. This report is a document on disaster response guidelines mainly for developing countries and is considered useful for devising disaster countermeasures.

5. Future activities

The ITU continues to make progress in standardizing ICT for disaster response. Disaster countermeasures vary depending on the kind of disaster, the infrastructure situation of the country/region, and the environmental conditions due to the topography and climate, and the technical field is very wide. Nevertheless, we believe that the Recommendations and the Supplement, which summarized the common requirements for disaster response ICT, will be useful in the future to minimize the damage caused by disasters.

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Snow-stopper Pole as a Countermeasure for Preventing Snow Damage to Utility Poles

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Abstract

NTT works diligently to inspect and maintain equipment to ensure that information and communication services can be provided to customers. Utility poles also require maintenance, as they can incur damage caused by the outdoor environment, including the effects of heavy snowfall. This article presents a countermeasure to reduce the amount of damage that occurs due to snow loading. This is the forty-eighth article in a series on telecommunication technologies.

Keywords: utility pole, snow damage, snow-stopper pole

1. Introduction

Utility (i.e., telephone) poles are located throughout the country to deliver ICT (information and communication technology) services provided by NTT. The utility poles installed along the slopes of mountains in regions with heavy snowfall may suffer from damage (*snow damage* hereafter) such as cracks and breaks in the concrete due to the effect of snow loading by snow cover.

We conducted a survey on snow damage in regions with heavy snowfall and studied countermeasures against such damage. In this article, an example of snow damage to utility poles is given, a countermeasure to prevent such damage is proposed, and the results of an on-site verification of the proposed method are presented.

2. Example of snow damage to utility pole

An example of breakage of a concrete utility pole located in a mountainous region that experiences heavy snowfall is shown in **Fig. 1**. In this example, breaks in the concrete of a utility pole affected by snow damage occurred near the ground. The concrete was crushed, and the rebar inside the utility pole was exposed. Moreover, at the site shown in Fig. 1, there are no trees on the slope of the hillside above the utility pole, and Japanese pampas grass (*Miscanthus sinensis*) grows wild. Therefore, it is conceivable that lumps of snow on the hillside combine with each other to become a massive deposit of snow with heavy snow pressure that piles up on the dry grass with lower frictional resistance. Thus, snow damage can easily occur at this site.

A common countermeasure for reducing the impact of snow damage is to plant trees on mountain slopes and install snow fences or avalanche bridges; however, such countermeasures require large-scale civil engineering work on slopes. Therefore, we focused on protecting utility poles from the pressure of large deposits of snow and proposed a snow-stopper pole as a low-cost and simple measure to prevent snow damage.

Fig. 1. Site of snow damage and state of broken concrete utility pole.

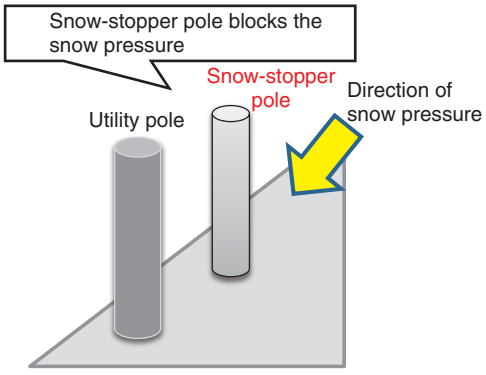

Fig. 2. Placement of snow-stopper pole.

3. Measure to prevent snow damage: snow-stopper pole

As a countermeasure against snow damage, the snow-stopper pole (about 6 to 7 m in length and 40 to 50 cm in diameter) was set up close to the utility pole (on the upper side of the slope) about 1 m from the utility pole (**Fig. 2**). The snow-stopper pole will alleviate the snow pressure applied to the utility pole positioned below the snow-stopper pole by receiving the snow pressure. The snow-stopper poles are set to be about 40 to 50 cm in diameter, approximately the same size as the utility pole, which enables NTT construction contractors to install the poles themselves without having to undertake large-scale civil engineering work. Since the maximum snow depth in the area where a field trial with the pole was carried out is about 4 m, and the pole should be embedded 2 to 3 m deep, the total length of the snow-stopper pole was set to 6 to 7 m. The separation distance between the snow-stopper pole and the utility pole was set to about 1 m. The effect of the snow-stopper pole was verified by both computer simulation and actual measurements in the field.

4. Verification of effectiveness of snow-stopper pole (simulation of flow mechanism of snow)

The snow-stopper pole is not a structure that supports the snow with its width in the manner of snow fences or avalanche bridges. Accordingly, the fact that snow can go around the snow-stopper pole down to the utility-pole side—and possibly negate the effect of reducing snow pressure on the utility pole—was a major concern. To clarify that effect, a computer simulation was conducted to evaluate the way snow flows around the snow-stopper pole. In the simulation, it was assumed that snow is a viscous body, and the simulation parameters related to snow refer to snow quality in the area where the field trial was carried out.

The simulation results shown in **Fig. 3** are represented as a top view of the slope on which the snow-stopper pole and utility pole are installed. The direction in which snow flows is indicated by the arrows, and the amount of snow movement on the slope is shown as a color distribution. The simulation results confirmed that snow largely flows in the downward direction of the slope. In the vicinity of the snow-stopper pole, the flow vectors in the downward direction slightly wrap around the snow-stopper pole and utility pole; even so, no increase due to the effect of the wraparound vectors can be seen in the amount of snow movement between the snow-stopper pole and

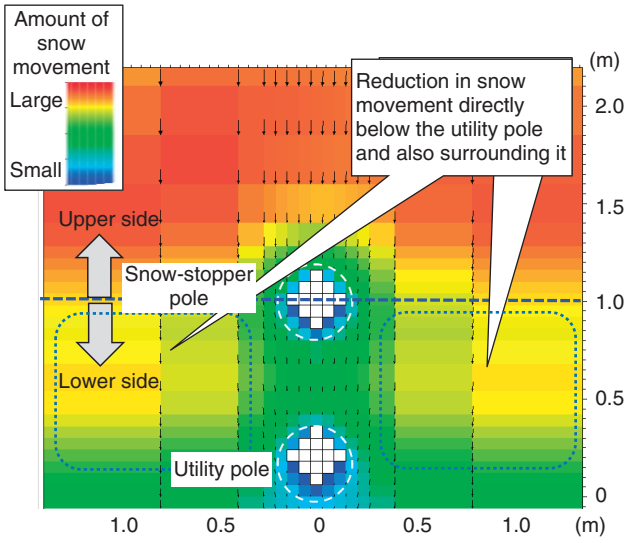

Fig. 3. Simulation result of direction of flow and amount of snow movement.

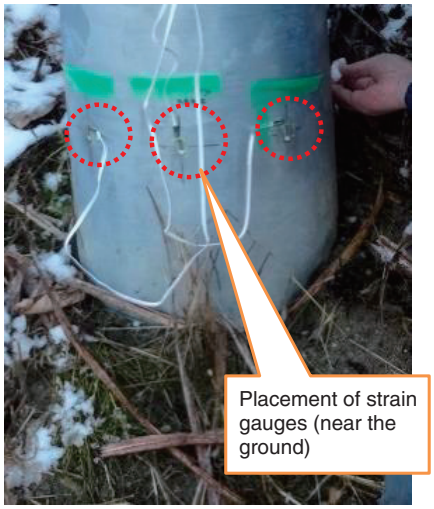

Fig. 4. Setup for evaluating applied stress due to snow pressure.

the utility pole.

This result suggests that the effect of the wrap-around snow is small when the separation between the snow-stopper pole and the utility pole is about 1 m. The simulated distribution of snow movement also shows that the amount of snow movement on the lower side of the snow-stopper pole is reduced not only just below the snow-stopper pole but also in the areas to the lower left and right of the pole. This result indicates that the snow around the upper side of the snow-stopper pole is supported by the snow-stopper pole as a mass with a certain width.

5. Verification of effectiveness of snow-stopper pole (in-field measurement of stress due to snow pressure)

Installing snow-stopper poles as a countermeasure against snow damage is expected to be effective based on the results of the computer simulation described in the last section. Nevertheless, to verify the effectiveness more concretely and quantitatively, the snow pressure applied to the snow-stopper pole and utility pole was evaluated in the field. Stress on the snow-stopper pole and utility pole caused by snow pressure was evaluated by installing strain gauges on the base part of a utility pole and a snow-stopper pole installed exclusively for this test (near the ground, as shown in **Fig. 4**). Both the snow-stopper pole and utility pole for this test were made of steel and had the same specifications (9.5 m/16 kN/STK490) with no overhead equipment attached. This test was performed from December 2016 to March 2017. The amount of snowfall during this period was less than usual for the area, and the maximum snow depth was about 2 m.

The results of evaluating applied stress due to snow pressure on the snow-stopper pole and utility pole by using strain gauges (**Fig. 5**) confirmed that the stress received by the utility pole was greatly reduced compared with that received by the snow-stopper pole. For example, the measurements taken on January 24 indicate that the magnitude of the stress received by the utility pole was reduced to about one-eighth of that received by the snow-stopper pole. Moreover, the stress received by the snow-stopper pole changes significantly with time, but the stress received by the utility pole was fairly constant. The snow-stopper pole receives the snow pressure directly from the snow on the slope above it, so the applied stress changes according to the fluctuation in the amount and depth of snow on the slope. In contrast, the utility pole receives snow pressure due to snow between itself and the snow-stopper pole as well as snow in the surrounding area. It is thus inferred that the snow on the slope does not move much, so the applied stress maintains a constant value to some extent.

6. Concluding remarks

An example of snow damage to a utility pole was

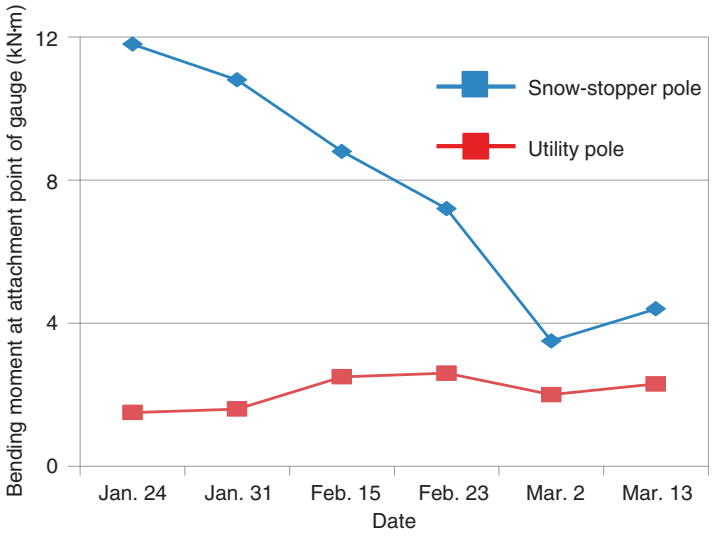

Fig. 5. Results of evaluating applied stress using strain gauges.

described, and the results of verifying the effectiveness of a countermeasure against such damage using a snow-stopper pole were presented. The verification results confirm the effectiveness of the snow-stopper pole in significantly reducing the snow pressure applied to the utility pole. In consideration of that result, snow-stopper poles have been installed at sites of utility poles in current use on a trial basis, and these trial installations have confirmed that as of the present time, no new cracks due to snow pressure have occurred in the utility poles (**Fig. 6**). The plan is to continue such trials in the future.

Fig. 6. Trial of snow-stopper poles with in-use utility poles.

External Awards

IEEE Signal Processing Society (SPS) Japan Best Paper Award

Winner: Takuya Higuchi, Nobutaka Ito, Shoko Araki, Takuya Yoshioka, Marc Delcroix, and Tomohiro Nakatani, NTT Communication Science Laboratories
Date: November 14, 2017
Organization: The Institute of Electrical and Electronics Engineers (IEEE) Signal Processing Society, Tokyo Joint Chapter

For "Online MVDR Beamformer Based on Complex Gaussian Mixture Model with Spatial Prior for Noise Robust ASR."
Published as: T. Higuchi, N. Ito, S. Araki, T. Yoshioka, M. Delcroix, and T. Nakatani, "Online MVDR Beamformer Based on Complex Gaussian Mixture Model with Spatial Prior for Noise Robust ASR," IEEE/ACM Trans. Audio Speech Lang. Process., Vol. 25, No. 4, pp. 780–793, Apr. 2017.

IEEE Signal Processing Society (SPS) Japan Best Paper Award

Winner: Daichi Kitamura, The University of Tokyo; Nobutaka Ono, Tokyo Metropolitan University; Hiroshi Sawada and Hirokazu Kameoka, NTT Communication Science Laboratories; Hiroshi Saruwatari, The University of Tokyo
Date: November 14, 2017
Organization: IEEE Signal Processing Society, Tokyo Joint Chapter

For "Determined Blind Source Separation Unifying Independent Vector Analysis and Nonnegative Matrix Factorization."
Published as: D. Kitamura, N. Ono, H. Sawada, H. Kameoka, and H. Saruwatari, "Determined Blind Source Separation Unifying Independent Vector Analysis and Nonnegative Matrix Factorization," IEEE/ACM Trans. Audio Speech Lang. Process., Vol. 24, No. 9, pp. 1626–1641, Sept. 2016.

Prize for Science and Technology (Research Category), the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology

Winner: Naonori Ueda, NTT Communication Science Laboratories
Date: April 17, 2018
Organization: Ministry of Education, Culture, Sports, Science and Technology

For his research on a machine learning technique for analyzing complex and diverse data.

The Young Scientists' Prize, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology

Winner: Hirokazu Kameoka, NTT Communication Science Laboratories
Date: April 17, 2018
Organization: Ministry of Education, Culture, Sports, Science and Technology

For his research on audio signal decomposition and auditory scene analysis.

The Young Scientists' Prize, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology

Winner: Takahiro Kawabe, NTT Communication Science Laboratories
Date: April 17, 2018
Organization: Ministry of Education, Culture, Sports, Science and Technology

For his research on human recognition systems and their applications.

JSAI Best Paper Award

Winner: Sho Takase, NTT Communication Science Laboratories; Naoaki Okazaki, Tokyo Institute of Technology; Kentaro Inui, Tohoku University
Date: June 27, 2018
Organization: The Japanese Society for Artificial Intelligence (JSAI)

For "Learning to Compose Distributed Representations of Relational Patterns."
Published as: S. Takase, N. Okazaki, and K. Inui, "Learning to Compose Distributed Representations of Relational Patterns," Trans. Japanese Society for Artificial Intelligence, Vol. 32, No. 4, p. D-G96_1–11, 2017.

Certificate of Appreciation

Winner: Yoshitaka Shimizu, Yasuo Suzuki, Satoshi Kotabe, and Atsushi Yamamoto, NTT Network Innovation Laboratories
Date: July 13, 2018
Organization: Budhanilkantha Municipality, Nepal

For successfully conducting the MDRU (movable and deployable ICT resource unit) field testing and training program in Nepal.

Technical Committee on Communication Quality Research Encouragement Award

Winner: Takuto Kimura, Arifumi Matsumoto, Takafumi Okuyama, and Jun Okamoto, NTT Network Technology Laboratories
Date: July 19, 2018
Organization: Technical Committee on Communication Quality, the Institute of Electronics, Information and Communication Engineers (IEICE) Communications Society

For "A Video Bitrate Selection Method to Reduce the Traffic Volume While Maintaining QoE."
Published as: T. Kimura, A. Matsumoto, T. Okuyama, and J. Okamoto, "A Video Bitrate Selection Method to Reduce the Traffic Volume While Maintaining QoE," IEICE Tech. Rep., Vol. 117, No. 159, CQ2017-49, pp. 111–116, July 2017.

Technical Committee on Communication Quality Best Research Award

Winner: Hideaki Kinsho, Osaka University; Rie Tagyo and Daisuke Ikegami, NTT Network Technology Laboratories; Takahiro Matsuda, Osaka University; Jun Okamoto, NTT Network Technology Laboratories; Tetsuya Takine, Osaka University
Date: July 19, 2018

Organization: Technical Committee on Communication Quality, IEICE Communications Society

For "Graph Construction for Mobile Delay Tomography Based on Graph Fourier Transform."
Published as: H. Kinsho, R. Tagyo, D. Ikegami, T. Matsuda, J. Okamoto, and T. Takine, "Graph Construction for Mobile Delay Tomography Based on Graph Fourier Transform," IEICE Tech. Rep., Vol. 117, No. 486, CQ2017-121, pp. 105–110, Mar. 2018.

Technical Committee on Communication Quality Volunteer Service Award

Winner: Kimiko Kawashima, NTT Network Technology Laboratories
Date: July 19, 2018
Organization: Technical Committee on Communication Quality, IEICE Communications Society

For her contribution to the planning and management of the workshop on cross-sector collaboration for IoT utilization.

1906 Award

Winner: Yoshiharu Akiyama, NTT Network Technology Laboratories
Date: July 20, 2018
Organization: The International Electrotechnical Commission (IEC)

For proposing a new method for measuring conducted electromagnetic interference at wired network ports and for his technical contributions to developing a method for measuring electromagnetic interference of wireless power transmission.

Certificate of Appreciation

Winner: Michiharu Takemoto, NTT Network Innovation Laboratories
Date: July 25, 2018
Organization: IEEE Computer Society

In appreciation for his service as Fast Abstract Chair and his continued support over many years.

Best Paper Award

Winner: Jun Shimamura, NTT Media Intelligence Laboratories; Taiga Yoshida, NTT Communications; Yukinobu Taniguchi, Tokyo University of Science; Hiroko Yabushita, NTT Media Intelligence Laboratories; Kyoko Sudo, Toho University; and Kazuhiro Murasaki, NTT Media Intelligence Laboratories
Date: June 22, 2018
Organization: The Institute of Image Electronics Engineers of Japan (IIEEJ)

For "View-directional Consistency Constraints for Robust 3D Object Recognition."
Published as: J. Shimamura, T. Yoshida, Y. Taniguchi, H. Yabushita, K. Sudo, and K. Murasaki, "View-directional Consistency Constraints for Robust 3D Object Recognition," IIEEJ Trans. Image Electronics and Visual Computing, Vol. 3, No. 2, pp. 164–173, 2015 (in Japanese).

Excellent Paper Award

Winner: Atsushi Otsuka, Kyosuke Nishida, Itsumi Saito, Hisako Asano, and Junji Tomita, NTT Media Intelligence Laboratories
Date: June 22, 2018
Organization: The 10th Forum on Data Engineering and Information Management (DEIM2018)

For "Neural Network Based Question Generation Model for Identifying Question Intention" (in Japanese).
Published as: A. Otsuka, K. Nishida, I. Saito, H. Asano, and J. Tomita, "Neural Network Based Question Generation Model for Identifying Question Intention," DEIM2018, F1-4, Fukui, Japan, Mar. 2018.

IEICE-ISS Distinguished Achievement and Contributions Award

Winner: Yukihiro Bandoh, NTT Media Intelligence Laboratories
Date: June 25, 2018
Organization: IEICE Information and Systems Society (ISS)

For his contributions as secretary of the IEICE Technical Committee on Image Engineering.

IE Award

Winner: Shota Orihashi, Shinobu Kudo, Masaki Kitahara, and Atsushi Shimizu, NTT Media Intelligence Laboratories
Date: July 9, 2018
Organization: IEICE Technical Committee on Image Engineering

For "Image Coding Based on Completion Using Generative Adversarial Networks."
Published as: S. Orihashi, S. Kudo, M. Kitahara, and A. Shimizu, "Image Coding Based on Completion Using Generative Adversarial Networks," IEICE Tech. Rep., Vol. 118, No. 113, IE2018-27, pp. 33–38, June 2018.

Papers Published in Technical Journals and Conference Proceedings

Analyzing Generation and Cognition of Emotional Congruence Using Empathizing-systemizing Quotient

L. C. Antaket, M. Matsuda, K. Otsuka, and S. Kumano

International Journal of Affective Engineering, Vol. 17, No. 3, pp. 183–192, July 2018.

Emotional congruence is a definition of emotional empathy. However, little is known about what types of people are more likely to be emotionally matched with others, and how they perceive emotional congruence. This paper proposes a cognitive model of emotional congruence assuming that people judge their emotional congruence with others based on interpersonal distance by putting the self and the other in emotional dimensions. We asked participants to engage in discussion with each other, and to rate their emotional congruence level in addition to their own emotional states in a valence-arousal space. We observed that i) participants with lower Empathizing Quotient scores exhibited a shorter emotional Euclidean distance from others, ii) when combined together, the overall results for all participants showed significant goodness of fit to the proposed model, and iii) those with higher Systemizing Quotient scores showed stronger goodness of fit.

Reachability Analysis of Multi-hop D2D Communications at Disaster

N. Kamiyama, K. Ishibashi, and Y. Hoshiai

IEICE Transactions on Communications, Vol. E101-B, No. 8, pp. 1833–1844, August 2018.

During a disaster, users will not be able to communicate with their families and friends using mobile terminals, e.g., smartphones, in many cases due to failures of base stations and the backhaul of cellular networks. Even when cellular networks normally operate without failure, they will become seriously congested due to dramatically increased traffic demand. To solve these problems, device-to-device (D2D) communications, in which mobile terminals directly communicate without cellular networks, have been investigated. Multi-hop D2D communication using multiple mobile terminals as relay nodes will be effective in maintaining connectivity during a disaster. It is preferable to estimate the success probability of multi-hop D2D communication by using a simple method that offers optimal parameter control, e.g., the ratio of mobile terminals using D2D communications and the maximum hop length. Moreover, when evaluating the reachability of multi-hop D2D communication, we need to consider the evacuation behavior during a disaster because success probability depends on the geographical distribution of mobile terminals. Therefore, in this paper, we derive a formula for estimating the success probability of multi-hop D2D communication in a simple manner and analyze its reachability using a multi-agent simulation that reproduces the evacuation behavior expected during an earthquake in Tokyo's Shinjuku Ward.

Neural Mechanisms Underlying the Impact of Speech Sound Naturalness during Transformed Auditory Feedback

S. Hiroya and T. Mochida

Proc. of the 10th Annual Meeting of the Society for the Neurobiology of Language, p. 146, Quebec City, Canada, August 2018.

Articulatory compensations in response to formant perturbation in vowels have shown that auditory feedback plays an important role in speech production. Although most conventional perturbation studies have used linear predictive coding (LPC) for estimating formants, LPC would result in degradation of sound naturalness of transformed speech due to misestimating of formants. To improve sound quality, we have developed a real-time robust formant tracking system using the phase equalization-based autoregressive exogenous (PEAR) model. In this study, to investigate the neural mechanisms underlying the impact of speech sound naturalness, we performed fMRI (functional magnetic resonance imaging) scans during transformed auditory feedback in which formant frequencies estimated by LPC or PEAR were perturbed. Results showed that the impact of speech sound naturalness in transformed auditory feedback emerged in the bilateral superior temporal gyrus.
