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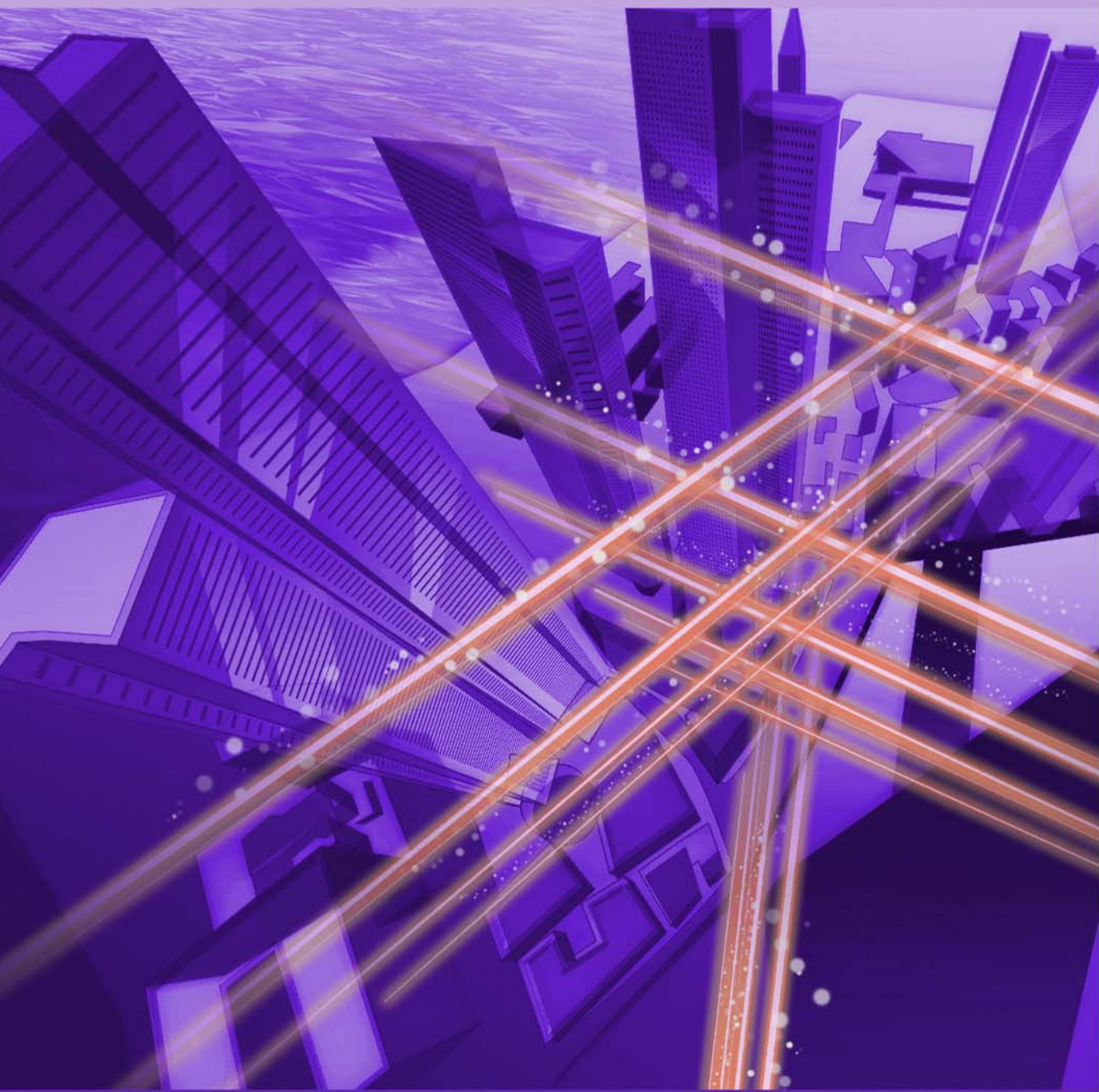

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Creating Extra Value with a New Medium-term Plan toward 2020—Refining Intuition through Experience, Feeling, and Belief

Hiroyasu Asami, Senior Executive Vice President, NTT DOCOMO

Overview

Feature phones and smartphones have become an indispensable part of our lives. How can NTT DOCOMO, a company that has a strong connection with its customers, seize the opportunities to leap forward into the society of the future? We sat down with Hiroyasu Asami, Senior Executive Vice President, to learn about the present role of NTT DOCOMO and its strategies for business expansion, and to hear about a work philosophy that is essential for making predictions about the future.

Keywords: co-creation, 5G, artificial intelligence

Formulating a new medium-term plan toward 2020 after assessing the limits of business growth

—Mr. Asami, in light of the initiatives you have personally been involved with to date, please tell us about the current business conditions surrounding NTT DOCOMO.

After moving to NTT DOCOMO from the NTT holding company in 2003, I oversaw the planning and development of services and content for over ten years. This is a very rare background for vice presidents of technical operations at NTT DOCOMO.

I was always attracted to the unique characteristics of NTT DOCOMO from my vantage point in the NTT holding company. While the target of fixed-line (landline) telephone services is households and businesses, the target of mobile phone services is even finer, that is, the individual. Since coming to NTT DOCOMO, I have placed importance on this feature of having a direct channel to each and every customer, and I have strived to make it a strength in our business operations.

Actually, I came to NTT DOCOMO during the rapid growth period of the i-mode mobile Internet service. It was a time when the company was expanding its business model of delivering the content provided by content providers (other companies) to our customers and generating revenue through commissions. However, with the coming of smartphones, it was inevitable that this business model would undergo a major change. This is because in the smartphone world, smartphone OS (operating system) makers such as Google were beginning to construct platforms that would provide customers with applications and content in much the same way as the i-mode business

model.

Sensing the limits to our i-mode business model, we at NTT DOCOMO thought we needed to take up a new business challenge. The decision was made that NTT DOCOMO itself would provide services and content, and we launched "dmarket" in 2011. The NTT DOCOMO dmarket provides a variety of services such as dvideo (now called dTV), dhits, and dmagazine, all of which are presently being enjoyed by about 15 million customers, reflecting genuine growth.

To digress a bit, in 1980 when I was a new employee, I was involved in the development of a video service in which we attempted to use what was then the latest technology for a mechanism for video on demand. This was a truly analog mechanism consisting of 12 video players and featuring remote operation of a mechanical arm for inserting videotapes with movies and other content into these players. Up to 12 people could simultaneously view whatever they wanted to watch. This mechanism has since evolved into a digital and software-based platform, thanks to technological advances, and it has grown into a DOCOMO service with about 5 million subscribers. To see this cherished idea of video services come to fruition after 30 years of being in the company is truly gratifying for me.

About five years have passed since NTT DOCOMO set out to provide dmarket services. However, as General Manager of the Corporate Strategy and Planning Department, a few years ago I was beginning to think that the things we could accomplish on our own were approaching a limit. With this in mind, last year we took up a variety of important themes such as how to leverage research and development (R&D) results, how to approach corporate sales business, and how to create services for the mass market. As a result, we hammered out a new vision under the keywords *co-creation* and *+d* (plus d) in which NTT DOCOMO would partner with other enterprises and leverage our own business assets with the aim of creating new services. Since then, we have begun +d initiatives with over 150 partners including Lawson (convenient store), McDonald's Japan, and Takashimaya (department store), and we have begun to see results (**Fig. 1**).

—Please tell us about the company's medium-term initiatives and the centerpiece of business expansion toward 2020.

We endeavored to change our business model to keep up with the times, but we suffered a significant drop in revenue with the introduction of a new billing plan in 2014. Consequently, we announced three-year medium-term targets for the period from fiscal year (FY) 2015 to 2017 (April 1, 2015 to March 31, 2018) toward profit recovery at the time of the release of the FY2014 first-half results. We succeeded in reducing the costs by improving efficiency and making our dmarket strategy work, and as a result, we will meet our targets at the two-year point in FY2016.

We are now in the process of drawing up a new medium-term plan for the period FY2017 to 2020. We consider this plan to be the centerpiece of NTT DOCOMO's new management team under Kazuhiro Yoshizawa, our new president, who took office in June 2016. This is a plan that everyone can look forward to.

Two important keywords in the new medium-term plan are "2020" and "5G," which refer to what we want to do for the major international event to be held in 2020 and how we will provide services as a carrier via 5th generation mobile communications (5G), scheduled to be launched around that time. Here, our aim is not to create services for 2020 but rather to have them already in use by 2020.

I would also like to change the image that customers have of NTT DOCOMO. The business of NTT DOCOMO has traditionally been centered on the provision of mobile phone network services, but we are now providing "docomo Hikari" as our own fixed-line broadband service made possible through wholesale purchasing of FTTH (fiber to the home) services from NTT EAST and NTT WEST. We are also providing dmarket services such as dTV to customers who are not using NTT DOCOMO mobile phones. Similarly, customers can use NTT

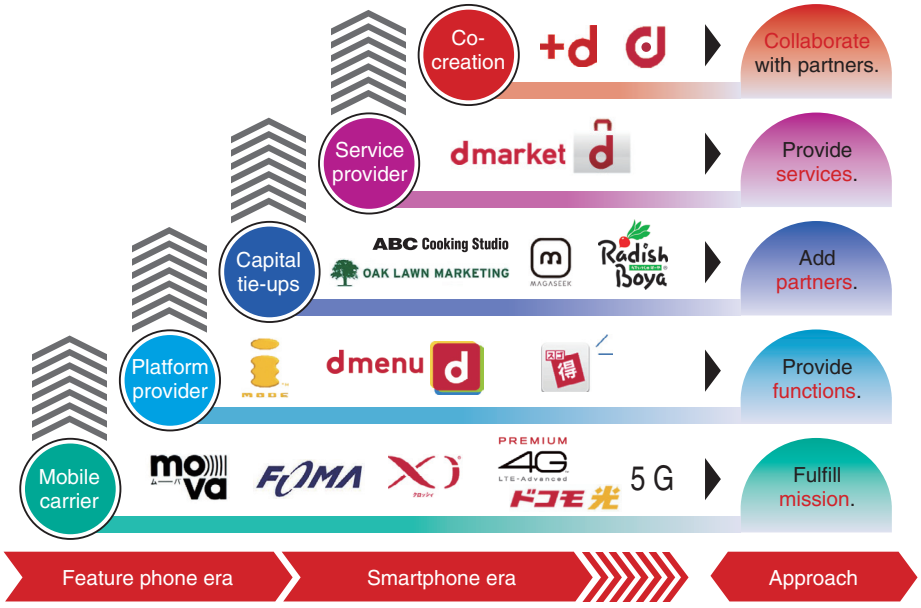

Fig. 1. Business model evolution.

DOCOMO's "d point" loyalty program regardless of whether they have an NTT DOCOMO service contract. The traditional customer management method based on mobile phone subscriptions is reaching its limits.

Capturing the opportunities brought by this change, we would like to treat all customers of the variety of services provided by NTT DOCOMO as members who are tied to a unified system of d point, regardless of whether they have a mobile phone contract with us. In other words, when we carry out our medium-term plan, I want to change the awareness internally to redefine customers as "members" using DOCOMO services, who in the past were just "subscribers." As a member, a person can continue to be an NTT DOCOMO customer even if he or she no longer has a mobile phone contract. Even those residing abroad can use NTT DOCOMO services as long as they are members. This is one example of global expansion. In short, I would like to stress the benefits of DOCOMO so people will say, "Wow, becoming a DOCOMO member is really convenient and brings good value."

Meanwhile, an important element of implementing our medium-term plan is R&D. We are focusing our efforts on artificial intelligence (AI) and 5G. For example, DOCOMO services are used by a very large number of people, so we envision the use of DOCOMO AI technology to analyze the big data generated and thereby deliver more value to customers to enrich their lives. In addition, as 2020 is expected to coincide with a large number of foreign visitors to Japan, we can envision the use of our AI technology to achieve various types of language processing such as automatic translation, speech recognition, and speech synthesis to help overcome language barriers. The term "5G" indicates evolution of the network, which is the core technology of DOCOMO, and initiatives are needed that leverage its features such as large capacity, high speed, and low latency.

People have smartphones with them 24/7, and we can expect them to become more important in the years to come. Compared with feature phones of the

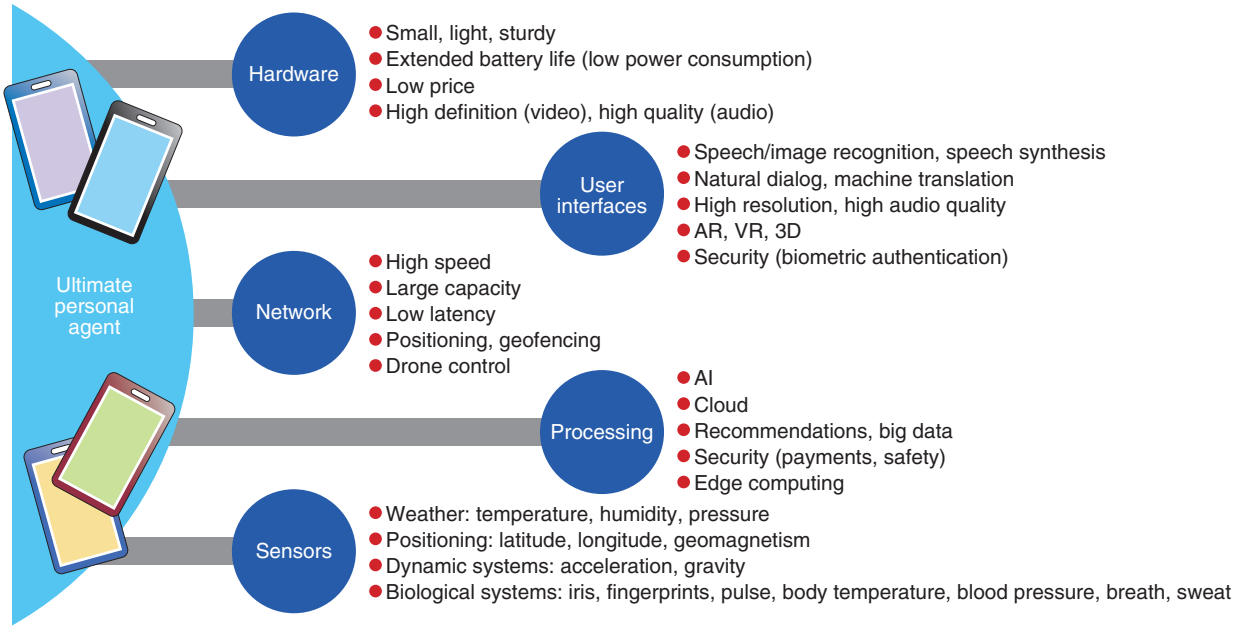

Fig. 2. Making the smartphone into the ultimate personal agent.

past, today's smartphones are much like a supercomputer in the palm of your hand, but if they evolve even further, we can expect the service domain to broaden even more. This, however, will require the development of various types of technology. First, from a hardware perspective, handsets must be lighter, battery capacity must be greater, and displays must be high definition. There will also be a need for virtual reality (VR), augmented reality (AR), and speech recognition in user interfaces as well as support for a high-speed network, built-in AI capabilities, and advanced sensors. I believe that this sort of evolution will turn the smartphone into a "personal agent." Of course, this means the ultimate personal agent that can be used not only in the home, but outside wherever the user goes as well (**Fig. 2**).

For future initiatives, we cannot forget the importance of making social contributions using information and communication technology (ICT) in response to all sorts of issues. For example, ICT could be used to improve Japan's competitiveness at the national level, revitalize local communities and deal with the issues of the low-birth rate and the aging society at the regional level, make operations more efficient at the corporate level, and add value to everyday life at the personal level. As we work to fulfill the +d concept, we won't be smug; we intend to maximize the use of DOCOMO's business assets and co-create new services with a diverse range of partners. Initiatives making use of R&D results and collaborative activities with local governments are already underway (**Fig. 3**).

"Intuition" is the sum total of experience. The "right answer" is found from experience.

—Using new technologies and mechanisms to create the future sounds exciting. What kind of approach is important in uncovering these technologies and mechanisms?

Experience, *feeling*, and *belief* are important. For example, when a new service is launched, it is not enough to just study a comparison chart. It is also important to have a "hands-on" experience. And while it would be time-consuming and unrealistic to try out all aspects of the new service, trying out at least its key points would enable one to exchange opinions and make a sound decision. I myself recently tried out Pokémon Go on my own. By actually playing the game myself, I was able to get a feel for the idea behind it and sense the merits of the service and points where it could be improved. I was able to get the information necessary for making a decision

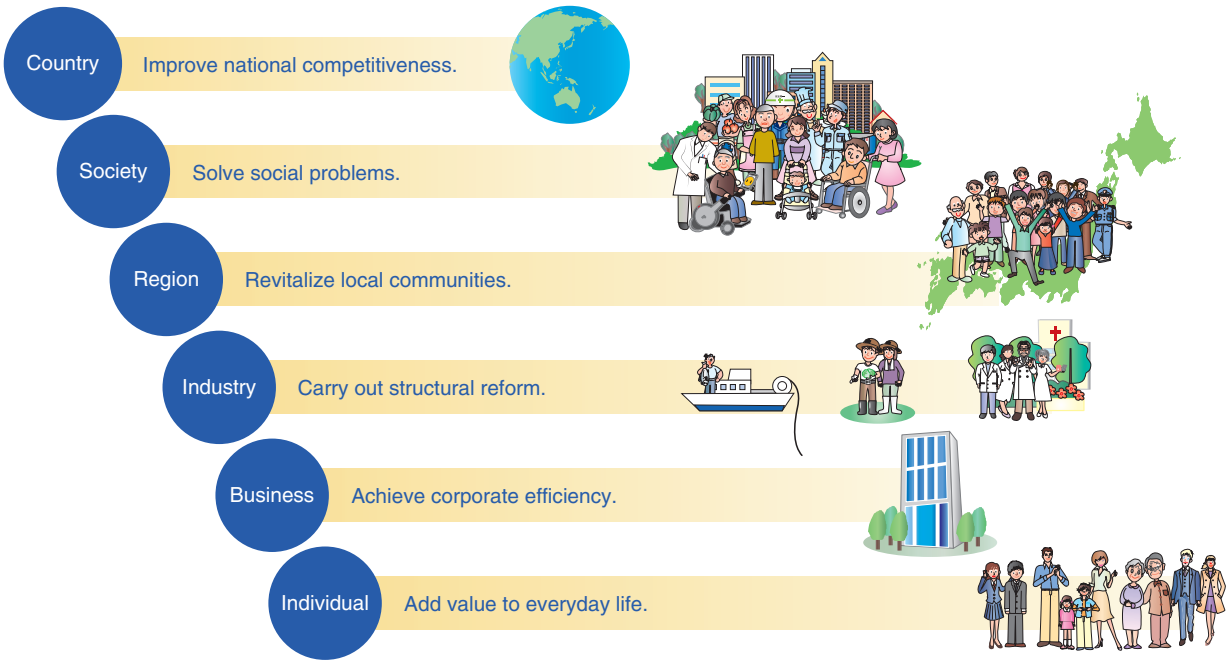

Fig. 3. Expectations of ICT.

by myself.

Looking for the right answer alone will simply lead to a dead end. And no one knows what things will be like in five years' time. Making a judgment solely on what you heard from others is also dangerous. That's why I try to interact with as many people as possible. Through communication, one can get hints for creating new ideas and build up a storehouse of knowledge, which in turn will have the effect of improving decision-making skills. In contrast, a book can only include material on what has occurred up to the time of its writing. For this reason, I only use it to confirm what has already occurred.

When I was involved in service development in the past, I made it a point to communicate with partners who had no direct relationship with a potentially new service. They had an understanding of the way the world works from their own perspective. Of course, their forecasts were sometimes off, but they had information far more accurate than what we had, and they were able to make predictions. From these experiences, I believe that interacting with other people will naturally help me see the right answers, so it is important to have a network in which we can consider what the right answer is.

In this way, we assessed the limits of i-mode-based growth and made a major decision to go in the direction of a smartphone-based business within a new framework called "dmarket." For NTT DOCOMO, a carrier that had not traditionally provided content services on its own, that decision was a major turning point. Furthermore, by providing these services even to customers without DOCOMO subscriptions, there was a need to redefine the "customer." For this reason, and with future business expansion in mind, we made a major decision to shift from the concept of "subscriber" to "member" as a new definition of customer. To put it briefly, the key is to make a sound judgment on what you are thinking about based on your *experience*, *feeling*, and *belief*. And make sure you execute actions appropriately. However, making such a major transformation requires power.

Learning something about "people" through *experience*, *feeling*, and *belief*

—What would you like to say to everyone in R&D?

Please learn about "people." I say this because people do not necessarily behave in a logical manner. For example, when in public, people's actions do not always match their thinking. Also, when presented with a service menu having three pricing levels, people tend to choose the level in the middle. In this way,

please pursue R&D themes based on the assumption that people are not always logical in their actions, and strive to create services and supporting technologies for people who can be somewhat ambiguous in their behavior.

—Mr. Asami, please leave us with a message for all NTT DOCOMO employees.

For our younger employees, always think in first-person terms; what is it that makes you happy and content? Apply this to daily work. Furthermore, do not hesitate to voice what you yourself would like to do. In addition, keep in mind the importance of *experience*, *feeling*, and *belief*, and practice it in your daily life. As I touched upon earlier, pursuing a major transformation might mean coming up against a wall. In this regard, I would like to end by introducing to everyone one of my favorite sayings: "Ryu-kan Go-dou," meaning if you hit a wall, work hard and sweat it out; the way will be revealed.

Interviewee profile

■ Career highlights

Hiroyasu Asami entered Nippon Telegraph and Telephone Public Corporation (now NTT) in 1980 and moved to NTT DOCOMO in 2003. He has served as Senior Vice President, General Manager of the Smart Communication Service Department; Executive Vice President, Executive General Manager of the Smart-life Business Division; and Member of the Board of Directors, Executive Vice President, General Manager of the Corporate Strategy and Planning Department. He took up his current post as Senior Executive Vice President, Chief Information Officer, Chief Information Security Officer, Chief Privacy Officer, and Member of the Board of Directors in June 2016.

2020 Showcase—Providing Japan and the Rest of the World with State-of-the-art Technology for 2020

Ryuji Kubozono

Abstract

The international sporting events that will be held in Tokyo in the year 2020 will be seen as a great opportunity to showcase our new innovations to Japan and the rest of the world. The Feature Articles in this issue focus on the 2020 Showcase—a trial held by NTT Service Evolution Laboratories to introduce the new technologies we are developing in preparation for 2020 and to accelerate the introduction of these technologies into society. We will also introduce some of the business aspects of this initiative.

Keywords: 2020 Showcase, epoch-making service, social innovation

1. Introduction

The major sporting events to be held in Tokyo in 2020 are expected to provide a major boost to Japan's economic recovery. These events will give us a chance to showcase Japan's information and communication technology (ICT) to the rest of the world, and by enhancing our ICT services and infrastructure, we hope to impress visitors from around the world with our technological prowess. They will also create a diverse legacy including an improved social infrastructure and the creation of new business, which will continue to create new opportunities in the future. The Cabinet Office is also actively involved in preparations for the games and is undertaking various studies by creating a task force concerned with science and technology innovation [1].

At NTT's laboratories, we are researching and developing a wide range of technologies for 2020, including new information display technology based on innovative user interface and media technology, and stress-free mobility assistance technology based on the analysis of big data. In particular, at NTT Service Evolution Laboratories, we are conducting research and development (R&D) to promote themes such as shared excitement, optimal navigation, supported growth, and user-friendly service design with the aim of providing visitors to Japan in 2020 with an unparalleled level of hospitality and service [2].

In addition to our R&D efforts, we are also working to verify the results of our R&D and promote the spread of this technology by collaborating with businesses in other fields to create and develop new value. The Feature Articles in this issue introduce the 2020 Showcase, an initiative aimed at holding public demonstrations where people can experience this new technology for themselves in venues such as airports, railway stations, stadiums, museums, art galleries, and exhibition halls. Some of the current business trends are also discussed.

2. 2020 Showcase

For the 2020 Showcase, we aim to hold practical field tests with potential business partners, and we also aim to construct case and role models. The fields in which we will conduct demonstration tests are being strategically chosen based on a consideration of the flow of tourists visiting Japan, their preferences/interests, and their consumption habits (**Fig. 1**). This article discusses the characteristics of each field and the technologies that will be needed for 2020 and introduces the work that we are doing to address these needs.

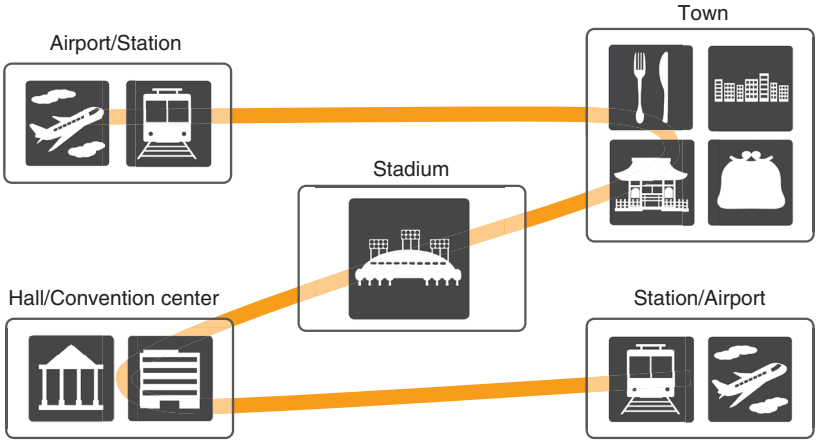

Fig. 1. 2020 Showcase demonstration test fields.

2.1 Airports and stations

The first place people see when visiting Japan is the airport. They may also frequent train stations during their travels. As gateways to Japan, airports and train stations require technology that makes it easy for foreigners to access information despite the language barrier and the cultural differences associated with activities in unfamiliar places such as traveling and eating out.

To address these issues, we are developing technology that can provide information via an augmented reality interface by using technology that can recognize images and other objects and technology that can present information such as maps and routes clearly and concisely, both indoors and outdoors, with clear voice guidance and signs to guide the flow of crowds. We are also conducting demonstration tests at key locations in Japan, including Haneda Airport and Tokyo Station. For further details, including details of a test we are conducting in collaboration with NTT DATA at Namba Station, see the article "2020 Airport/Station—Hospitality for Foreign Visitors at Airports and Train Stations" [3] in this issue.

2.2 Towns

Eating Japanese cuisine, sightseeing, and shopping are some of the top activities that foreign visitors want to experience in Japan. Food and drink outlets in urban areas need to be able to display information in a way that is accessible not only to a growing number of foreign tourists but also to Japanese people with particular needs such as the elderly. There is consequently a need for technology that can transform existing content into a representation that can be easily understood by customers, not only according to the aims of these services but also to the age and other personal attributes of their customers.

To address these issues, we are developing technology that automatically transforms the designs of existing web content according to the attributes of customers, and technology that automatically creates supplemental information. Further details can be found in the article "2020 Town—Web Design Converter for Providing Guidance Assistance to Individuals in Cities" [4].

To develop stronger customer interaction in tourist areas and local shopping malls, there is a need for technologies and systems that can stimulate communication and provide support for suitable guidance and customer actions after an ad hoc appraisal of the customer's situation and requirements. To address these issues, we are developing technologies that facilitate collaboration via the cloud between various devices such as sensors and communication robots. We are also promoting demonstration tests in cities and other places where people gather in large numbers. Further details, including a discussion of the tests we are conducting jointly with NTT Communications and NTT EAST, can be found in the article "2020 Town—Developing MACHINAKA Service, a Device Integration Service that Utilizes Artificial Intelligence Technology" [5].

2.3 Stadiums

At international sporting events, large numbers of visitors including foreign visitors and first-time spectators make their way to a stadium. There is therefore a need for technology that can help people move

around efficiently and safely even at crowded, large-scale events. Also, for spectators in remote locations, it is important to convey the atmosphere inside the stadium and to bring a sense of excitement and unity to them that is similar to what the spectators at the stadium are experiencing. This calls for the development of ultra-realistic services that allow people in different locations to feel as if they were actually present in the stadium.

We have been developing techniques for predicting and guiding the flow of crowds of people, and immersive telepresence technology for the realization of real-time ultra-realistic broadcasting. We are also conducting experiments to demonstrate how the flow of crowds at event venues can be predicted and controlled [6] and immersive telepresence experiments that simulate live broadcasts. Details of our immersive telepresence technology can be found in the article "2020 Public Viewing—*Kirari!* Immersive Telepresence Technology" [7] in this issue.

2.4 Halls and convention centers

Since foreign visitors to Japan will want to make the most of their time in this country, it is assumed that they will also make their way to event halls and conference centers in order to participate in various cultural events and exhibitions. At the venues of events and exhibitions, there is a need for technologies and systems to support trouble-free viewings and visits, and technologies to enliven the events themselves with various types of stagecraft. There will also be a need for technologies and systems that support event operators such as displaying in real time the usage status of networks and applications.

With these issues in mind, we have worked at expanding the enjoyment of kabuki theater and providing completely new kinds of kabuki performances by fusing the latest ICT with traditional performing arts. We have also worked to enable people to experience the latest technology through official applications at NTT R&D Forum 2016 held in February 2016. Further details can be found in the article "2020 Entertainment—A New Form of Hospitality Achieved with Entertainment × ICT" [8], and "2020 MICE—New Hospitality through Exhibitions × ICT" [9].

3. Future development

A key point in promoting the 2020 Showcase has been collaborating with other businesses in different fields. For more details, see the article "Promotion of Co-innovation through Collaboration with Different Business Sectors" [10].

To create epoch-making services to support the events of 2020, the NTT Group will continue with R&D in new collaborations with different industries, promote the incorporation of these services in society in general, and create a legacy that will continue into the future.

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Ryuji Kubozono
Vice President, NTT Service Evolution Laboratories.

He received a B.S. and M.S. in physics from Kagoshima University in 1987 and 1989. He joined NTT Human Interface Laboratories in 1989. He was with NTT WEST from 1999 to 2003 and from 2006 to 2008, and with NTT Smartconnect from 2012 to 2016.

2020 Airport/Station—Hospitality for Foreign Visitors at Airports and Train Stations

Yusuke Ichikawa, Yukihiro Nakamura, Taiji Nakamura, Hirohisa Tezuka, Hitoshi Seshimo, Satoshi Fukada, and Hideki Mitsui

Abstract

The number of foreign visitors to Japan is rapidly increasing, and determining how to provide information adapted to the needs of various nationalities in various languages has therefore become a critical issue. Accordingly, airports—the gateways of Japan—and train stations—key points along visitors' transit routes—will not only require technologies that enable easy access to information for foreign visitors but will also become places that showcase Japan's cutting-edge technologies around the world. In this article, we describe our collaborative efforts with various businesses to conduct demonstration tests in order to improve the way information is provided at airports and train stations.

Keywords: airport, station, showcase

1. Introduction

For visitors to Japan, differences in language and culture in matters such as eating and traveling in unfamiliar places cause a great deal of stress. Visitors may also have difficulty with transit routes, including the airports at which they just arrived and the connecting train stations to their target destinations, and thus, many problems remain to be solved. For example, the guidance information on most signs is limited to major languages such as Japanese and English. In addition, visitors cannot quickly think of their next means of transport and find out how to use it.

At NTT, we are targeting the year 2020 as we aim to solve the problems experienced by visitors at airports, train stations, sports stadiums, and other facilities. Namely, we hope to accommodate differences in cultures and achieve multilingualization of guidance information. We also hope to optimize guidance methods to ensure that visitors can transit smoothly in recognition of the fact that not only physical measures such as conventional human responses and signboard but also measures that utilize ICT (information and communication technology) are required. Moreover, we aim to provide innovative hospitality through user interface/user experience (UI/UX) design by utilizing cutting-edge technologies such as image analysis and big-data analysis. We are thus actively researching and developing such technologies in collaboration with various transport-terminal facility operators, related agencies of government ministries, and equipment manufacturers.

With airports, train stations, and their surrounding environments as target areas, demonstration tests were done in 2015 and 2016 in three locations: Haneda Airport International Passenger Terminal, the area around Tokyo Station, and commercial facilities around Namba Station in Osaka. The effectiveness of the technologies was evaluated, and problems involved in introducing the technologies were clarified.

Point-and-search guidance　　Projection signage　　Intelligent sound sign

Fig. 1. Collaborative tests at Haneda Airport International Passenger Terminal.

2. Demonstration tests at Haneda Airport

We carried out demonstrations of an upgraded universal design for providing information at Haneda Airport. We describe the tests and their results here.

2.1 Overview of collaborative tests

Haneda Airport International Passenger Terminal (international flights terminal) is based on the concept of universal design that involves user participation from the design stage. The airport combines *hard* features such as buildings and facilities and *soft* features such as human services and is one of the world's leading airports that achieves universal design with high dimensionality.

However, the environment is rapidly changing and exceeding expectations; examples of this include the recent rapid increase in visitors to Japan and the huge increase in the number of international flights in and out of Haneda Airport. Consequently, it is forecast that the existing hard and soft facilities will become insufficient in the near future, and new efforts aimed at reducing congestion and further accommodating multilingualization will be needed. It is difficult to address these issues with conventional fixed guidance signs and face-to-face guidance, so new methods of computerization that will help further improve accessibility and the customer experience of various airport users will be required.

In view of the above-described circumstances, NTT has been collaborating with Tokyo International Air Terminal Corporation to upgrade the airport's *information universal design*. In December 2015, NTT started demonstration tests [1] of the upgraded information universal design of the terminal with the following three services: (1) information provision in multiple languages by utilizing *point-and-search UI*; (2) congestion reduction by inducing people-flow through utilization of dynamic signs; and (3) clarification of audio guidance using speech processing technology (**Fig. 1**).

2.2 Technical points

(1) Information provision in multiple languages by utilizing point-and-search UI

This information-provision service utilizes angle-free object search technology developed by NTT. This service is based on a UI that acquires appropriate and useful information by enabling the user to intuitively point their smartphone's camera at advertising signs and guidance signs in the arrival lobby, at retail buildings in shopping areas, and at food samples and products in order to access information in situations where suitable keywords or inquiry methods cannot be thought of quickly. In these demonstration tests, actual feedback from the test targets—namely, foreign nationals—was evaluated, and challenges to be addressed in the future—that is, clarification of required information services—were identified.

(2) Congestion reduction by inducing people-flow through utilization of dynamic signs

This service helps people avoid congestion within facilities and induces the optimum flow of people by foreseeing the ever-changing state of congestion and dynamically varying guidance signs accordingly. Demonstration tests were carried out in 2015 in places where people tend to accumulate, for example, arrival lobbies and departure gates. In these tests, dynamic guidance signs utilizing projection mapping were provided, and their effectiveness was evaluated, knowledge about the most-appropriate presentation (e.g., signage, color, and timing) was acquired, and the effects of inducing people-flow were measured in terms of quantitative values.

(3) Clarification of audio guidance using speech processing technology

For visually impaired people who cannot easily gather information visually, sound plays an important

role in helping them understand their surrounding environment. Accordingly, intelligent sound signs* were developed with the aim of supporting smooth transit of visually impaired people and utilizing a speech intelligibility enhancement technique developed by NTT. These signs provide guidance using a voice that can be heard easily even in noisy environments. They take their environment into account so that the sounds of the sign itself do not become unwanted noise in that environment. The effectiveness of these signs was demonstrated by measuring the hearing and movement of actual visually impaired people.

2.3 Future development

NTT aims to expand the above-described services as a case model for Haneda Airport and therefore collaborated with Panasonic Corporation, Tokyo International Air Terminal Corporation, and Japan Airport Terminal Co., Ltd. in establishing the Information UD Exploratory Committee for Airports (chairperson: Professor Tetsuo Akiyama of Chuo University) in November 2015. From now onwards, we plan to improve the individual technologies that were shown to be effective through the collaborative tests as well as to upgrade the visuospatial and audio designs across the entire airport and appeal to other businesses to join us as partners in collaborative testing.

3. Demonstration tests of seamless navigation near Tokyo Station

We describe here demonstration tests done at Tokyo Station to evaluate technologies designed to achieve seamless navigation.

3.1 Overview of demonstration tests

By the year 2020, thanks to advances such as the four-satellite-set of the Quasi-Zenith Satellite System (with the fourth satellite scheduled to be launched in 2018) and indoor positioning technology, the so-called high-accuracy positioning society will be realized. The Ministry of Land, Infrastructure, Transport and Tourism launched a project called the High-Accuracy Positioning Society Project. This project is involved in carrying out studies and demonstration tests on spatial-information infrastructure in order to produce various services by utilizing indoor and outdoor positioning technologies and mapping information, as well as the methods and systems for efficiently and effectively maintaining that infrastructure. The NTT Group aims to meet the demands of such a society and has therefore been part of this project since its inception and has been participating in the demonstration tests since 2014. NTT Service Evolution Laboratories is playing a key role in those tests [2].

At the Seamless Indoor/Outdoor Navigation Feasibility Tests near Tokyo Station, which were supported by the High-Accuracy Positioning Society Project, a pedestrian-movement support concept was proposed and demonstrated. In this concept, pedestrians acquire navigation information by using natural gestures rather than menus and buttons by simply pointing their smartphone at a target of interest while walking and holding their smartphone in the usual way [3]. Consequently, precise map information and the status of the positioning environment are applied to seamlessly connect indoor and outdoor environments.

3.2 Technical points

In these demonstration tests, two distinctive functions were created by applying NTT's parametric map platform technology and angle-free object search technology. These functions were a 2.5-dimensional (2.5D) map (flat plane + multiple floor levels), which presents indoor and outdoor maps and routes in a concise and unobstructed manner, and point-and-search guidance, which pinpoints the standing position of the user taking a photo and presents information related to the location of the sign or landmark that they photographed (**Fig. 2**). Moreover, when we applied actual map information to these functions and measured an on-site positioning environment, we gained a lot of knowledge and know-how through collaboration with external business vendors familiar with the indoor spaces and facilities of Tokyo Station and its environs and also familiar with the creation of map information.

3.3 Future development

Through these demonstration tests, the feasibility of these two functions (i.e., 2.5D-map display and point-and-search guidance) in an actual environment was verified. However, many issues—such as the need for a scheme for improving the instinctive understanding by 2.5D-map representation and measures for volatile positioning measurement and the

* Sound signs: To aid the transit of visually impaired people, guidance is given by providing information concerning toilet facilities, escalators, and other details in the form of sound (voice and audio).

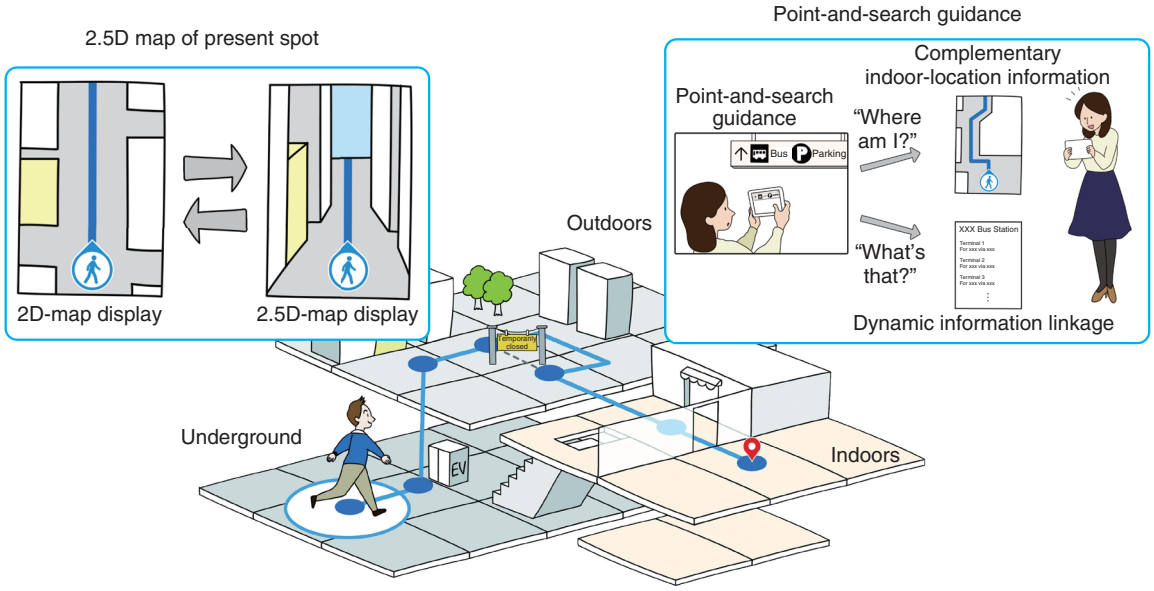

Fig. 2. Image of demonstration test of seamless indoor and outdoor navigation technology.

effects of noise—became apparent as a consequence of the actual environment. We will address these issues in technical developments as we continue our efforts in projects initiated in 2016.

4. Demonstration tests of O2O2O transmit-to-customer service

Here, we describe demonstration tests carried out on our transmit-to-customer service in the Namba area.

4.1 Overview of demonstration tests

Aiming towards 2020, NTT is continuing demonstration tests under a wide range of application scenarios ranging from transit guidance in airports, train stations, towns, and stadiums to drinking and eating, shopping, sightseeing, watching sports, going to the theatre, and appreciating art.

As a first step, in collaboration with Nankai Electric Railway Co., Ltd. and Takashimaya Company, Limited, NTT and NTT DATA conducted demonstration tests of O2O2O services in June 2016. Abbreviated as O2O2O, *out-of-home to online to offline* refers to a system for providing information (*online*) to users via signs outside of the home (OOH signs) and guiding them to their destinations (*offline*) based on that information. In these tests, when the users read an OOH sign via their smartphone with the downloaded app, they were able to receive information about nearby shopping facilities and to be guided to their destinations (**Fig. 3**).

4.2 Technical points

A universal object-recognition platform developed by NTT is utilized for reading OOH signs (**Fig. 4**). In conjunction with an application programming interface, the universal object-recognition platform jointly controls various recognition tools, and it can be called up from various client apps. Its key features are summarized as follows.

- It is possible to widen the coverage of recognition targets (i.e., the number of targets can be increased).
- It is possible to increase the recognition rate compared to when each individual recognition tool is used individually.
- Multiple recognition targets can be processed in parallel simultaneously, so recognition results can be acquired instantaneously, achieving fast recognition speed.

In the demonstration tests, electronic-watermarking technology and angle-free object search technology were applied to make it possible to recognize real logos, posters, and other images, to link to online content, and to acquire helpful information via a simple, instinctive operation.

OOH signs (**Fig. 5**) were prepared for the demonstration tests and set up in 12 locations around Namba Station and nearby shopping facilities in Osaka City,

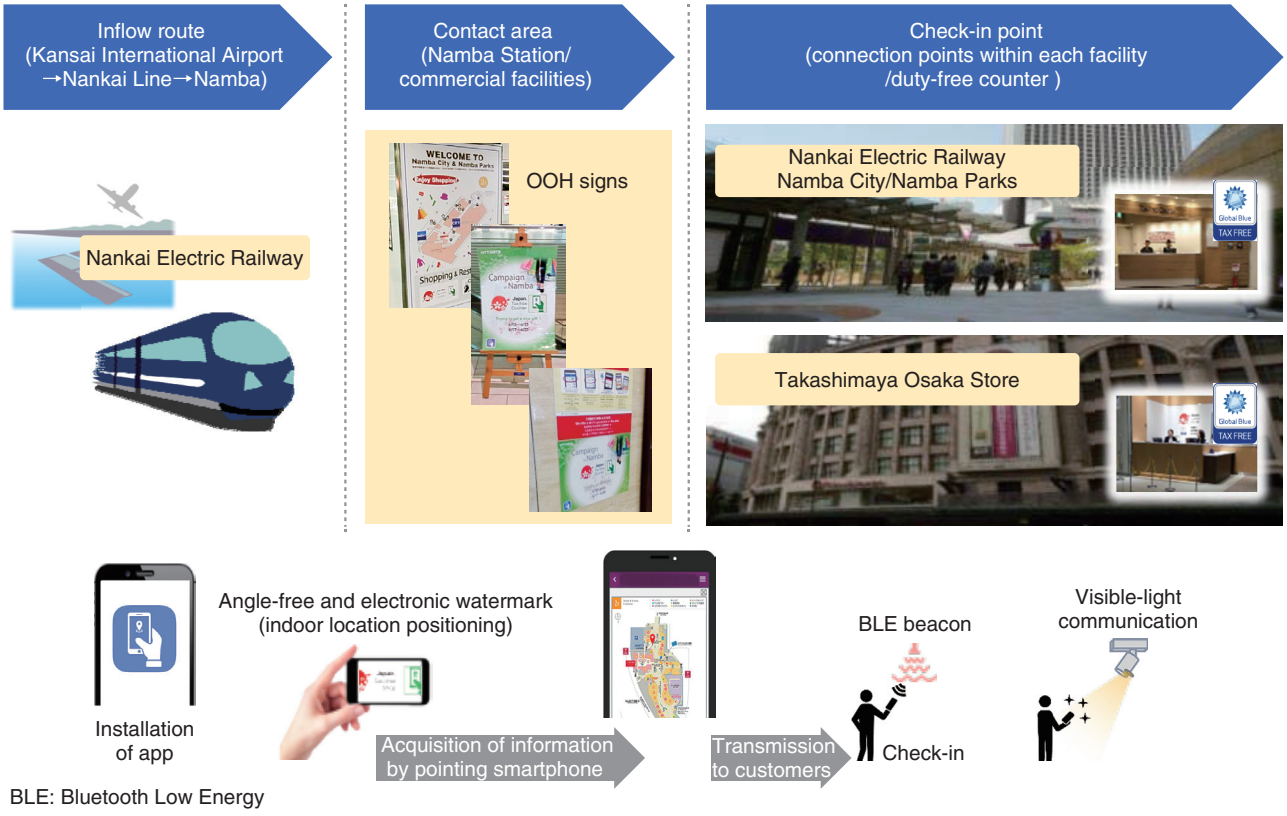

Fig. 3. Image of demonstration tests performed in the Namba area.

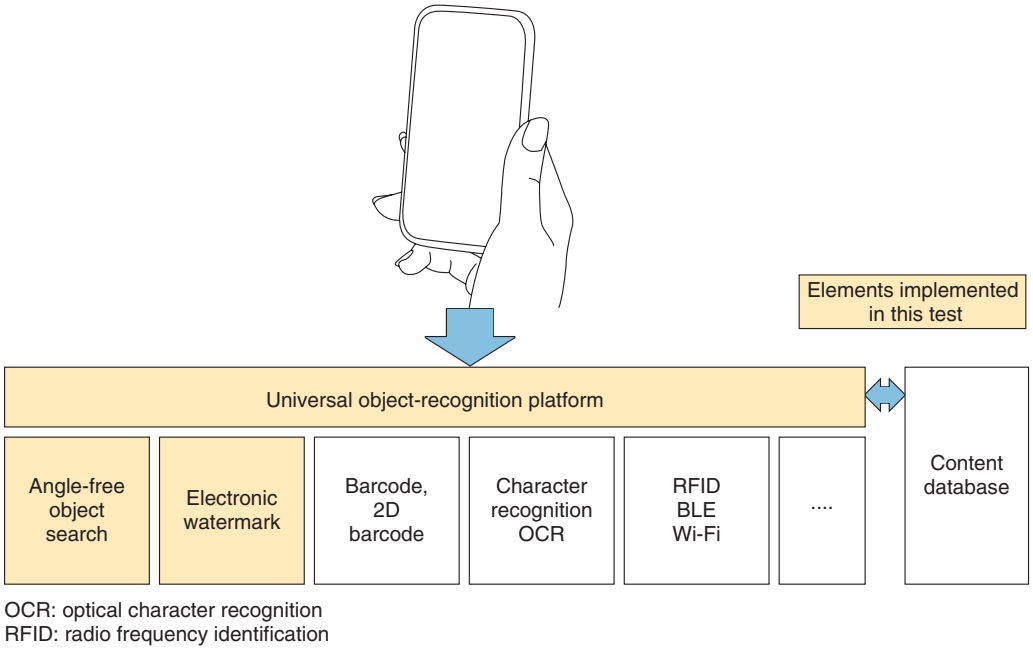

Fig. 4. Universal object-recognition platform.

Installed poster

Attachment of stickers to existing signboards

Fig. 5. OOH signs used in demonstration tests.

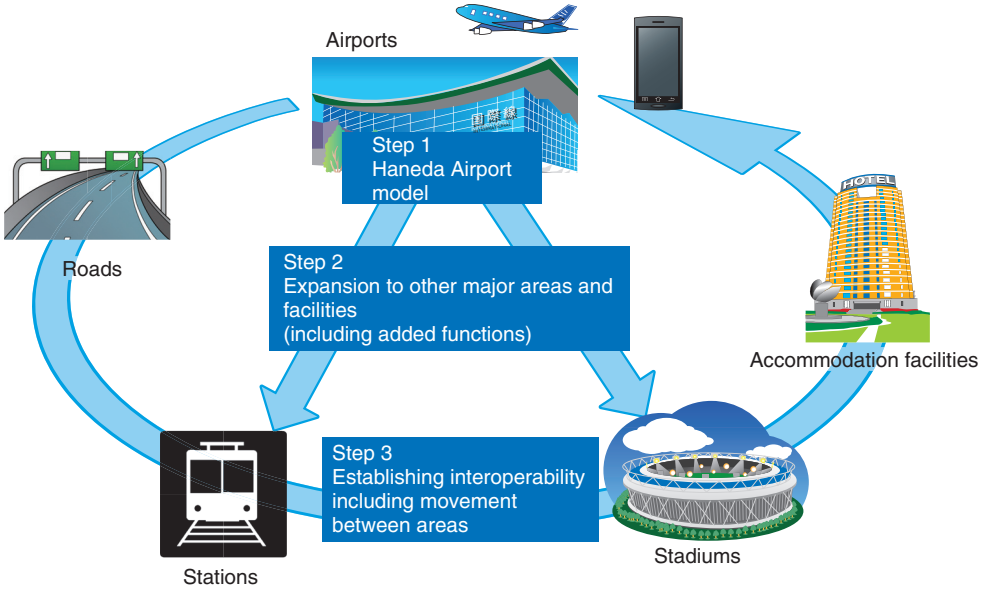

Fig. 6. Three steps involved in expanding hospitality services.

Japan. This service can be introduced by attaching a translucent sticker to existing promotional media such as posters and wall advertising; accordingly, it is possible to start operations without damaging existing designs. Among foreign visitors to Japan who had downloaded the app for events, about 60% acquired information from OOH signs, and it was confirmed that about 20% of them actually visited the place they received guidance to.

4.3 Future development

The NTT Group is planning to carry out new technical development and demonstration tests aiming toward 2020. It is also focusing on commercializing and introducing point-and-search UI using universal object-recognition technology while calling for new business partners to collaborate in experimental trials.

5. Goals targeting 2020

Goals have been set to commercialize services for providing transit guidance and information to foreign visitors to Japan. Three steps are involved in achieving these goals (**Fig. 6**). The first step consisted of conducting demonstration tests at airports, as

described earlier. The second step involved carrying out demonstration tests at train stations and their surrounding facilities. For visitors in the future, however, it is unrealistic to require all tourists to master each app and the UI/UX design for different sites.

In the third and future step, through co-innovation involving various stakeholders, we will establish interoperability, including movement between areas, and provide hospitality services with a sense of uniformity in order to achieve total information support covering sequential travel actions—from arrival at the airport to returning to the airport.

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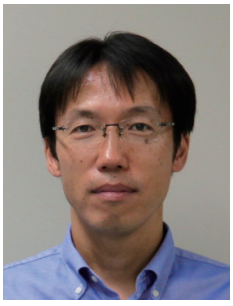

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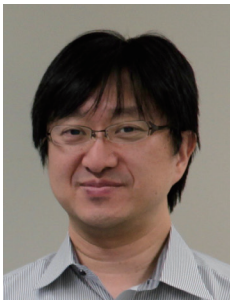

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2020 Town—Web Design Converter for Providing Guidance Assistance to Individuals in Cities

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Abstract

To prepare for the year 2020, NTT Service Evolution Laboratories is striving to develop a system to provide city guidance to individuals such as senior citizens and foreign visitors to Japan. The system takes the characteristics of individuals into account. In this article, we introduce our Web Design Converter system, which presents information tailored to individual user characteristics on signage screens and personal terminals.

Keywords: signage, web, conversion

1. Introduction

Digital signage systems that transmit information using display screens and other display processes are in wide use today. The efficient way in which they display information by effectively using moving images and space makes them a useful means of providing information about cities.

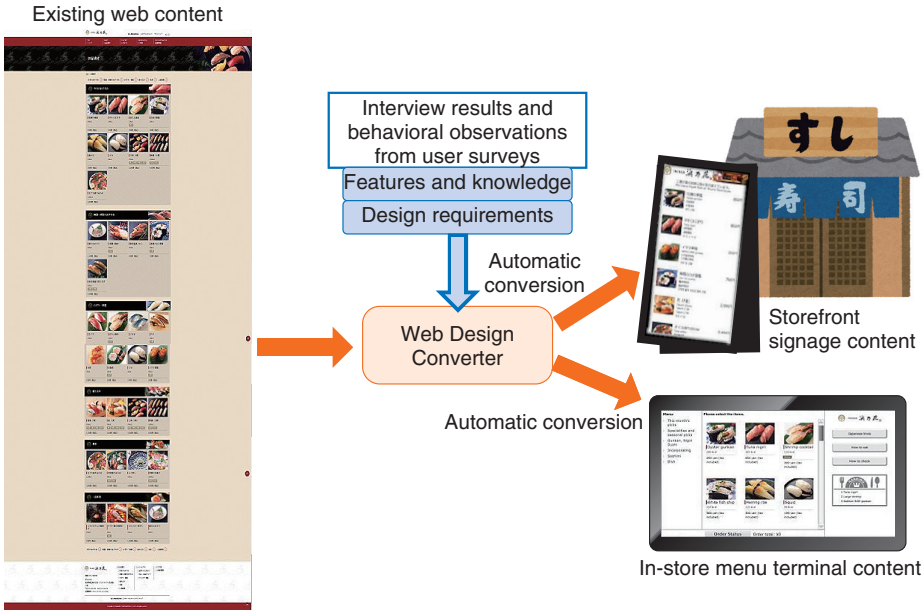
However, two important issues must be taken into account in developing such systems. First, with the international sporting events scheduled to be held in Tokyo in 2020, the number of foreign visitors to Japan is expected to increase greatly during the next few years. Second, Japan faces the problem of a rapidly aging population. To address these issues, it has become essential to develop systems that meet the needs of a greater variety of users. This, however, makes it necessary to create content on an individual basis, which brings added costs.

Accordingly, we at NTT Service Evolution Laboratories are working to develop web design/conversion technology with which content can be converted to make it easier to understand. This will enable us to provide content that will meet service aims and that will match the characteristics of individuals such as their age group and the language they speak. We call the product that utilizes this technology the Web Design Converter, and we have demonstrated a prototype of it at various exhibitions [1, 2].

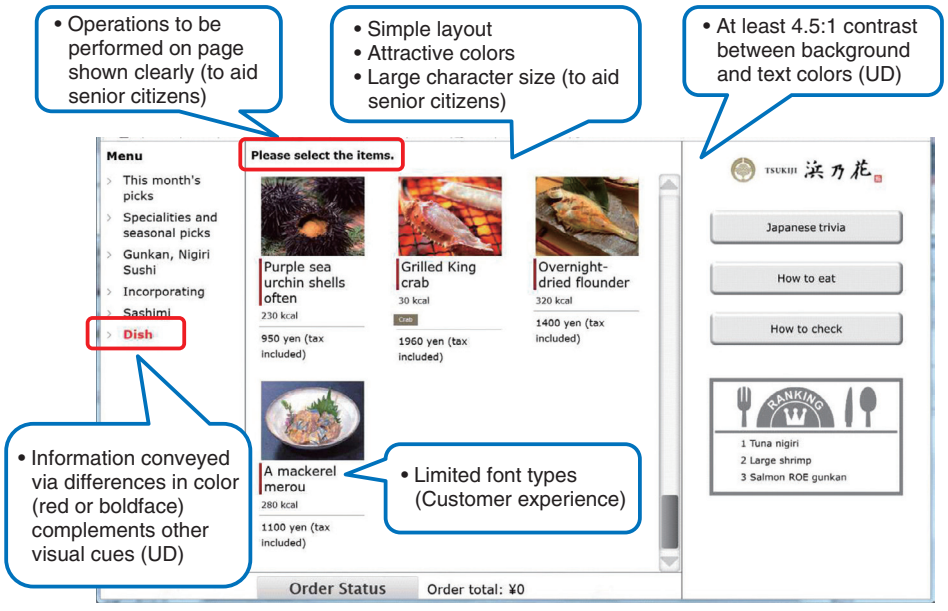
By using this technology to create digital signage content, we expect to be able to not only reduce content creation costs but also to provide content such as information about local events in a timely manner. We believe that the Web Design Converter digital signage system is a useful tool for providing city guidance to individuals according to their personal characteristics, and that by making it available to users worldwide we can achieve a world in which a *universal town* development approach is emphasized.

2. Overview of Web Design Converter

Web Design Converter comprises an automatic design conversion function and a function for automatically generating supplementary information. The automatic design conversion function is used for providing translated information for foreign visitors. In addition, it presents information in an easy-to-understand way in accordance with user and service aims by converting the information structure, fonts, and



(a)



(b)

Fig. 1. Example features of automatic design conversion function.

colors. It does so by applying the information and communication technology service design principles NTT Service Evolution Laboratories has developed and fostered based on user characteristic surveys. This function makes it easy to provide UI (user interface) design applications that take usability into account (**Fig. 1**).

The function for automatically generating

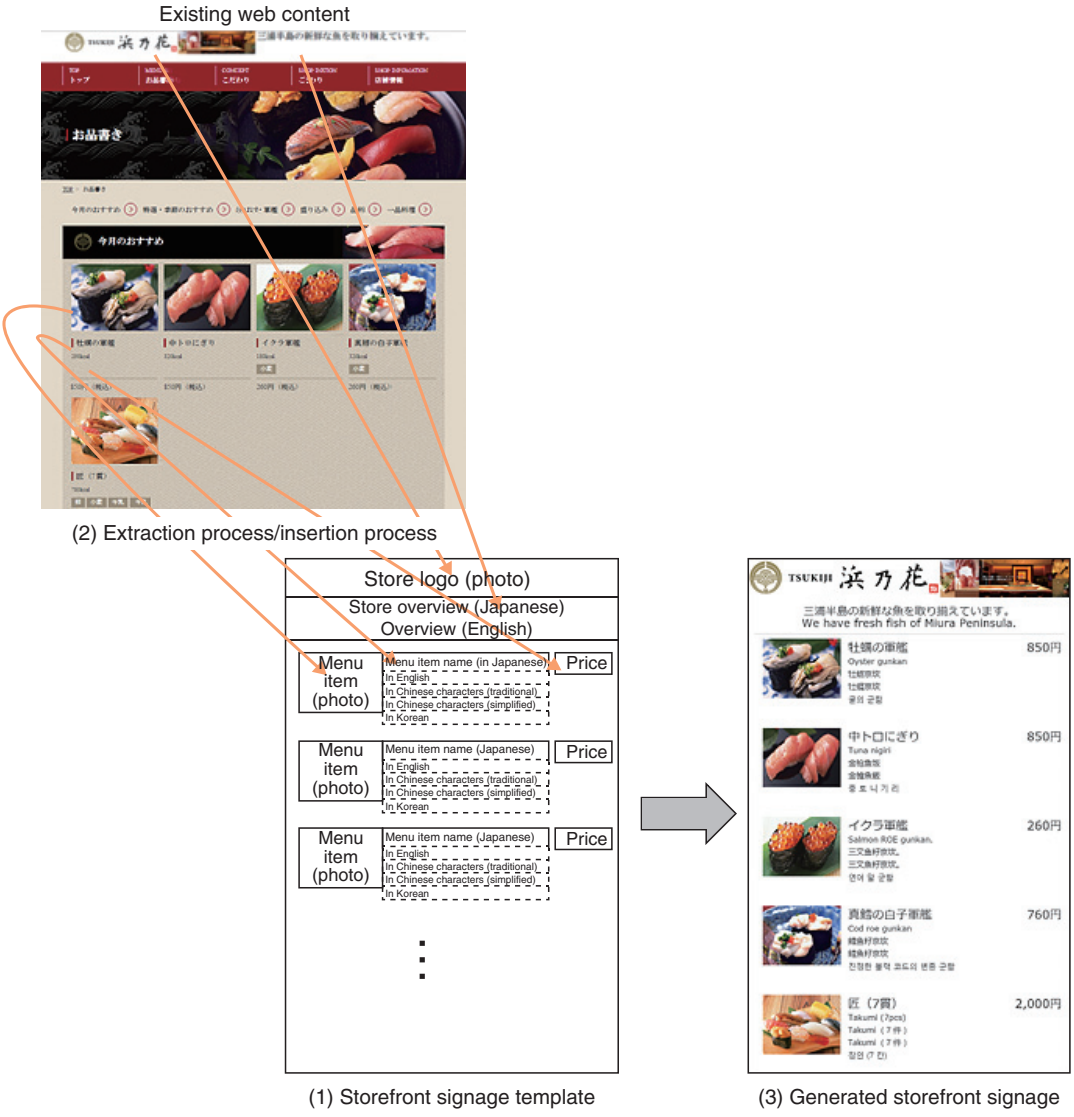


Fig. 2. Process for generating storefront signage content.

supplementary information uses information on the Internet to automatically generate supplementary information about commercial products and the like [3]. For example, if the signage for foreign visitors in a restaurant simply translates a dish as "A mackerel merou" [namerou], they will likely not be able to clearly understand what sort of dish it is. This function can help them by adding further information such as, "A traditional food of Chiba Prefecture." It may also further their understanding by making comparisons to things they are familiar with, such as, "It's like 'tartar for appetizers.'" The translations are provided by machine learning, and as research in this field advances, the resulting translations are expected to improve in accuracy.

3. Example implementation of restaurant service

Applying the Web Design Converter technology to websites that introduce the type of food a restaurant serves enables users to automatically generate content such as that in the storefront signage and the in-store menu terminal.

3.1 Storefront signage

Users first select the display for the storefront signage template (**Fig. 2(1)**). This template includes an

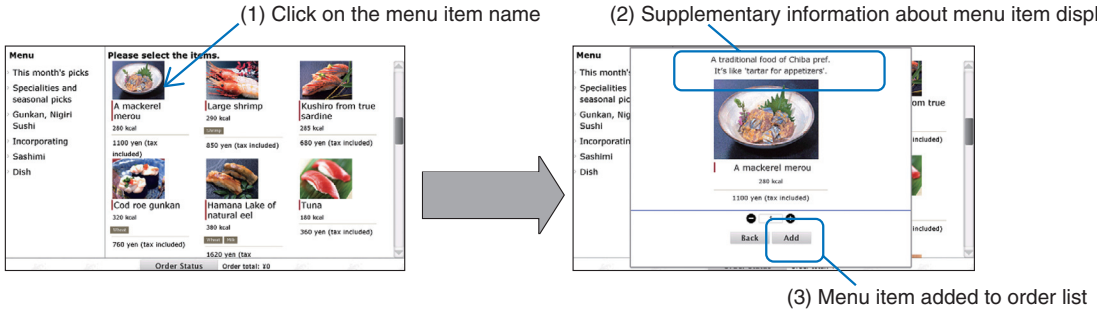


Fig. 3. Interactive menu terminal generating supplemental information.

overview of the store (restaurant), its logo, and a view of the menu items (with photos, names, and prices of dishes). Users then extract the information they want from the existing web content of the store and insert it into the template (**Fig. 2(2)**). If they need to have characters translated during the insertion process, they can use a machine translation function to convert the information into the desired language (**Fig. 2(3)**).

Currently, it is necessary to specify the location of the content to be extracted through the service provider operation when constructing the initial template. However, we are doing further studies with the aim of fully automating the extraction process in the future.

3.2 In-store menu terminal

In the same way as the storefront signage, the in-store menu terminal generates content by extracting a view of the menu items on the menu terminal template. In addition, there is a function (**Fig. 3(2)**) for displaying supplementary information about menu items when they are clicked (**Fig. 3(1)**). It is also possible to use an interaction function (**Fig. 3(3)**) to select or deselect additional items to be ordered.

4. Future development

In the future, we plan to expand the template so that it will be able to handle a wide variety of signage display devices, including smartphones and tablets. We also plan to carry out field trials on how to use the technology, for example, how to use it to provide details on store information or events being held within the city. We aim to use the feedback results to achieve early practical applications of the system. We anticipate that appropriate information will be provided by various contributors such as citizens and local governments, so we will strive to develop a universal town that can be understood by all.

We encourage anyone who is interested in this technology to contact us.

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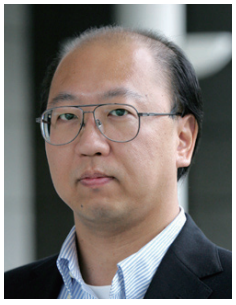

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2020 Town—Developing MACHINAKA Service, a Device Integration Service that Utilizes Artificial Intelligence Technology

Takayoshi Mochizuki, Manabu Norota, and Kousuke Suga

Abstract

At NTT Service Evolution Laboratories, we are working to develop device integration services that can accurately understand the situation a person is in and provide guidance to the person in accordance with the situation. We are working with partner companies and NTT operating companies in this effort and are applying the results of joint experiments to develop services for settings such as long-term care facilities, financial institutions, museums, and outdoor parks that exist within cities. We use the term *MACHINAKA* (*in the city*) services to refer to such services. In this article, we introduce our current efforts and future prospects.

Keywords: communication robots, multi-modal interaction, device integration service

1. Introduction

Currently, most MACHINAKA (*in the city*) services are provided with human labor. However, with the progress of artificial intelligence (AI) technology, the need for human intervention is gradually decreasing. Amazon.com, Inc., a well-known example of a logistics company in the US, has already automated part of its operations using AI and robots, from management of its logistic services to product delivery [1]. The increased use of robots in place of humans has also been seen in the customer service industry recently with the growth of AI [2, 3, 4]. The communication robot "Pepper" of SoftBank Corporation is a typical example of a robot replacing humans in a MACHINAKA service industry. It is an example of leveraging communication robots that can interact intelligently with humans through words and actions using AI. The use of communication robots is expected to lead to a reduction in the cost of human labor as well as greater effectiveness of advertising presented using such robots.

As mentioned, we are starting to see communication robots interacting with people and replacing humans in the customer service field. However, it can be said that most of these interactions are still very limited and are centered on routine one-to-one dialogues with customers, for example, to explain goods and services at a reception counter or provide guidance at facilities. This limited use is presumably because the main feature of communication robots is interacting with people using voice and gestures.

At the NTT laboratories, however, we believe that it is possible to expand the scope of applications for communication robots beyond one-to-one customer service situations by combining communication robots with a number of other devices and systems to constitute a device integration service. We describe here the advances that can be achieved when a device integration service centered around communication

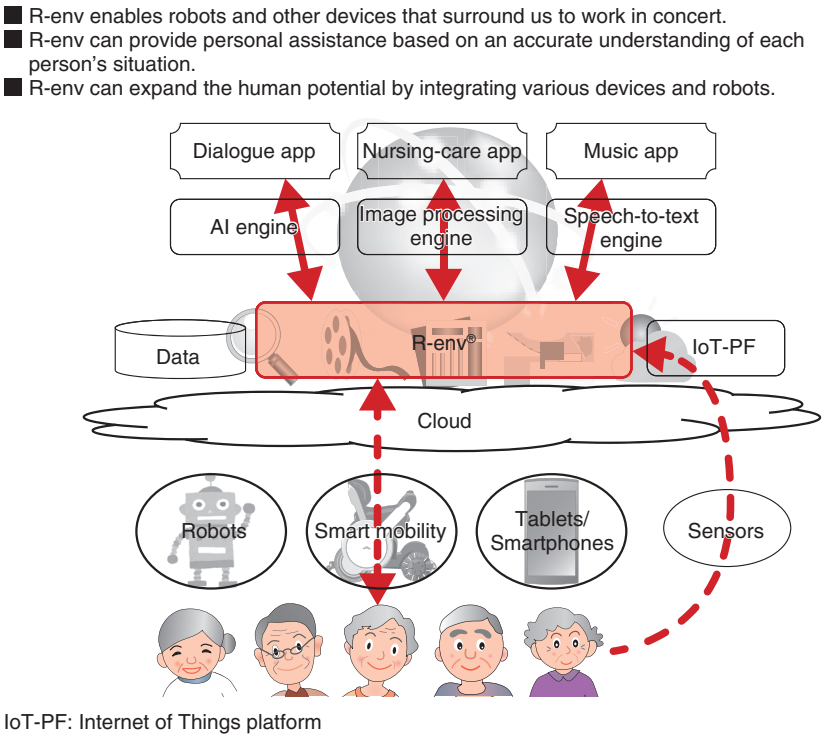

Fig. 1. Overview of R-env®, a platform for expanding the human potential through integration of devices and robots.

robots is realized.

As previously mentioned, the customer service industry is increasingly using communication robots to provide guidance or explain facilities or services using voice. This is occurring more and more frequently in the hospitality industry such as at hotels and reception centers, as well as in the banking and retail industry to provide information to customers. However, combining communication robots with images or videos shown on a display will greatly increase the clarity of information that can be conveyed. Also, connecting communication robots with health monitoring devices such as blood pressure monitors opens up the possibility of providing health advice to users [5].

It is also possible for moderators of recreational activities to use a communication robot as a support device by connecting it with a karaoke system. Furthermore, the use of communication robots in cooperation with various devices placed inside a facility or outdoors within a target area makes it possible to not only provide information and guidance to customers, but also to improve the convenience of getting around in the city and to increase the number of visitors and facilitate visitor movements as well.

In this way, we believe that we can assist peoples' understanding and encourage their behavior and thus stimulate numerous activities within the city by linking various devices to communication robots. In the following sections, we introduce R-env®, the key technology to make all this happen.

2. R-env, technology supporting device and service integration

For more than 40 years, NTT has carried out research and development (R&D) on speech and audio processing technologies and natural language processing technology. NTT is also a world leader in image processing technology, knowledge processing technology, and various other media processing technologies. Efforts are underway to achieve a natural dialogue between communication robots and humans by making use of these technologies. To expand the role of communication robots and increase their existential value, we started R&D on R-env in 2015. R-env enables robots to be easily connected with other external devices and systems (**Fig. 1**).

R-env was developed as a part of ongoing research on interaction technology aimed at expanding the

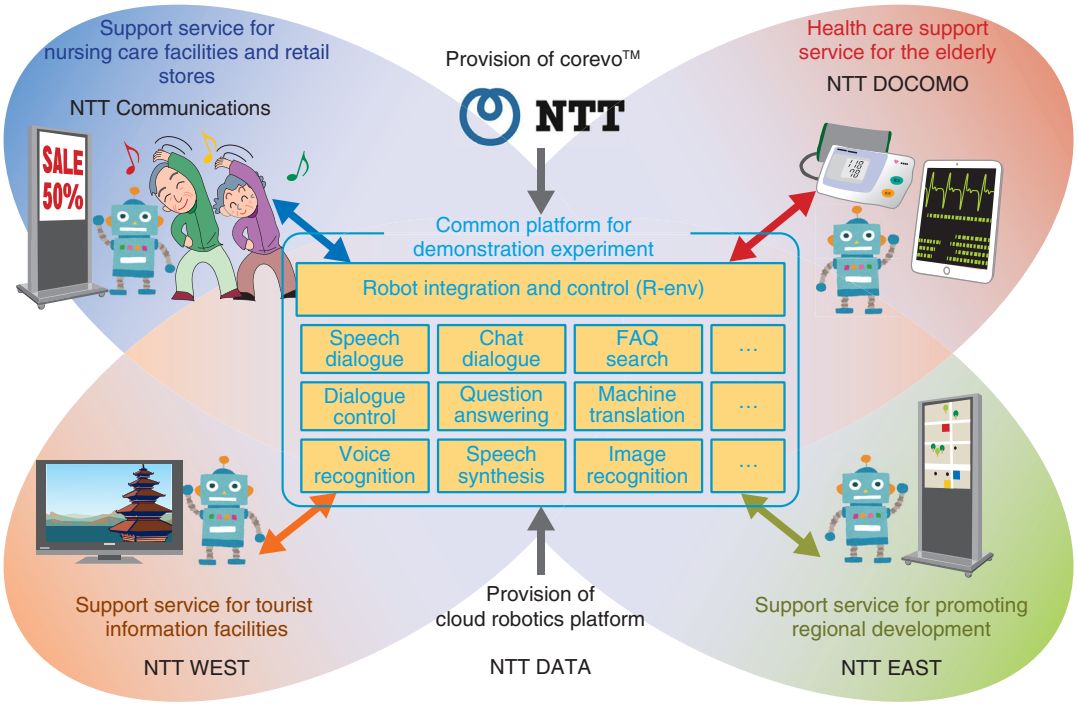

Fig. 2. Examples of device integration services by NTT Group companies.

possibilities of humans. This technology enables easy connection and integration of various devices such as communication robots. By linking these devices, this technology will make it possible for communication robots to accurately understand the situation in which a person is placed, provide guidance to the person in accordance with the situation, and prompt the person to adopt a specific behavior or level of awareness.

With R-env, anyone can develop a device integration service using graphical user interface (GUI) screens on a browser. This is done by creating a state transition diagram, or in other words, by combining actions specified for each device connected to R-env, and the condition for the transition to the next action. R-env can also be used to easily create a complex device integration service by reusing and operating multiple state transition diagrams in parallel. Also, services developed on the GUI can be instructed to continue on with their operation even after closing the browser by keeping it on hold in its execution state. Furthermore, when a new device is added, it can be easily recognized, registered, and prepared for use in the R-env service by simply transmitting the predefined JSON (JavaScript Object Notation) format using WebSocket before use.

3. Device integration service using R-env in MACHINAKA (trial case)

We have been conducting trials with NTT Group companies and their external partners to extract the needs and identify any technical problems of device integration services that utilize R-env [5, 6]. In particular, at the end of July 2016, we initiated a joint demonstration experiment in collaboration with five major NTT operating companies. The purpose of the experiment is to evaluate the effectiveness and acceptability of device integration services in a variety of fields and industries in the city (**Fig. 2**) [7]. In the following section, we introduce a trial case staged in the Shinjuku area.

4. Trial in Shinjuku

The number of tourists visiting Japan from abroad has increased rapidly. This is evident from the increase in the government's target number of foreign tourists to Japan, which was raised from 20 million per year to 40 million per year by 2020 at a tourism related meeting chaired by Prime Minister Shinzo Abe on March 30, 2016 [8].

The driving force behind this is the dramatic

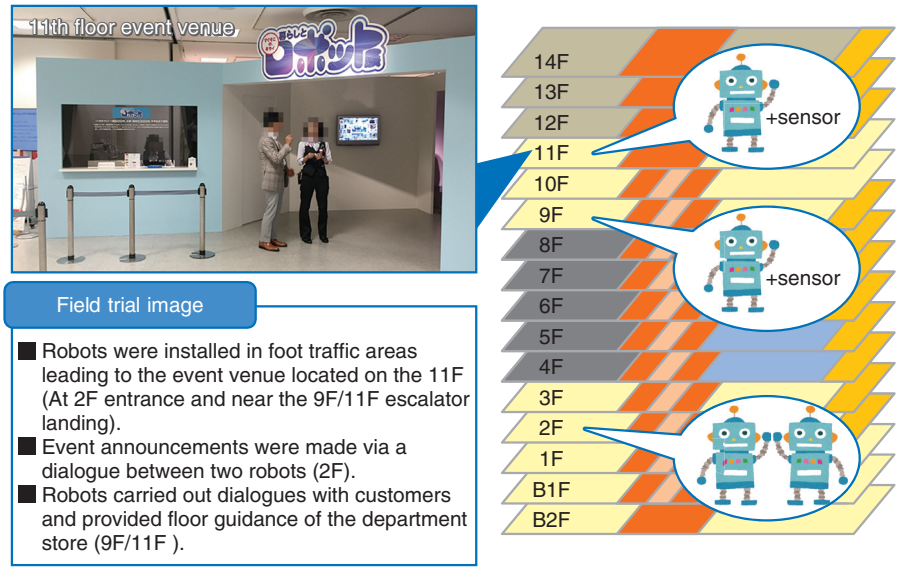

Fig. 3. Service image in Shinjuku Takashimaya.

increase in the number of tourists from China, which doubled in 2015 compared to the previous year. Tourists from China now account for the largest number of foreign tourists to Japan and greatly exceed the number from Taiwan, the second-largest group [9]. Their primary purpose for visiting Japan is shopping, as symbolized by the expression *baku-gai*, or shopping spree.

Popular areas for Chinese tourists, in addition to well-known tourist destinations, are Ginza and Shinjuku, where there are many shops [10]. Places such as Shinjuku Golden Gai and the Kabukicho neighborhood are also favored by foreign tourists in Shinjuku [11]. Therefore, from the viewpoint of regional development, services in Shinjuku are required not only for local residents but also for people coming from outside Shinjuku, including tourists.

We carried out two joint demonstration experiments utilizing a device integration service targeting the Shinjuku area. The first one was a joint experiment conducted by three groups: Takashimaya Company, Ltd., which is engaged in the retail business, NTT Communications, and the NTT laboratories. In the experiment, we used a device integration service to inform and guide customers to event venues using multiple robots placed in a commercial facility (department store) from August 3 to August 14, 2016. In particular, robots were placed in the following locations based on the flow of pedestrian traffic.

1) The location with the largest amount of pedestrian traffic, which was the area near the second floor (2F) entrance leading to JR Shinjuku Station;
2) The 9F escalator landing, where the main target customers (families with children) of the event are likely to gather;
3) In the vicinity of the 11F escalator landing in which the event venue was located.

At each location, a device integration service composed of an external sensor linked to a communication robot provided smooth induction to the venue by arousing customer interest in the event through dialogue with customers and by providing floor guidance of the department store (**Fig. 3**).

The second case is an effort targeting the broad outdoors and is not limited to the indoor space of a facility. It is a joint trial being conducted by the Shinjuku branch of the Tokyo Chamber of Commerce and Industry, the Shinjuku Tourism Promotion Association, NTT EAST, and the NTT laboratories. The trial provides a device integration service consisting of robots and digital signage at multiple locations within a radius of approximately 1 km from Shinjuku Station. In particular, communication robots installed in shops and in tourist facilities in the area provide access information about the respective shops and facilities by utilizing the public wireless local area network service Shinjuku Free Wi-Fi provided by Shinjuku ward.

Communication robots are also playing an important

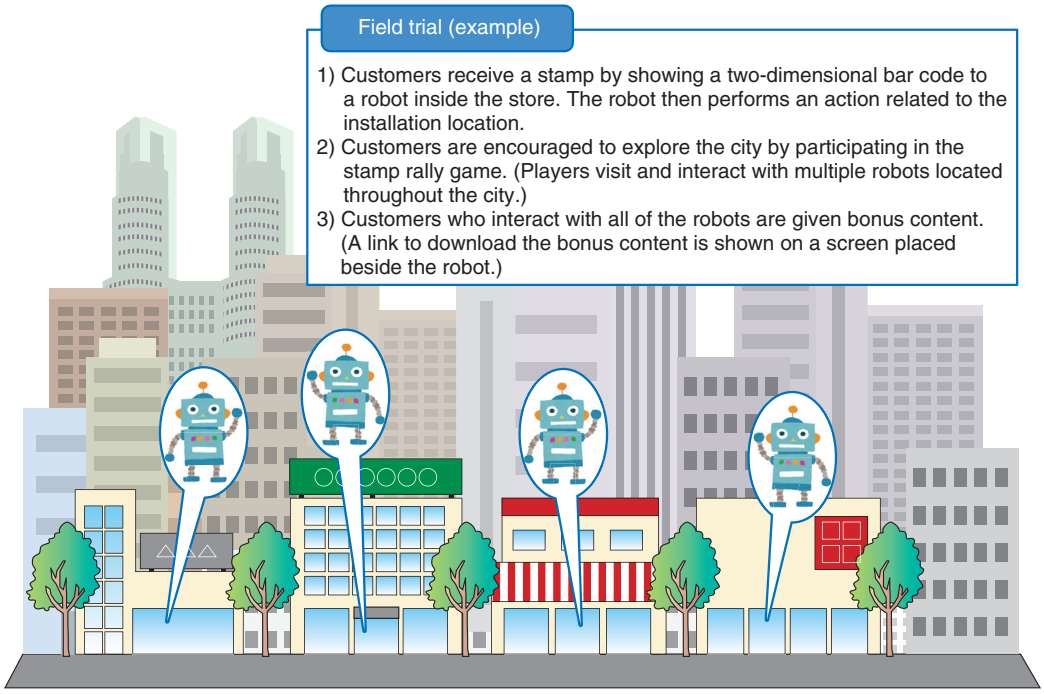

Fig. 4. Service image in Shinjuku area.

role to increase the number of visitors to the area by providing attractive services such as a robot stamp rally that utilizes multiple robots in different places that cooperate with one another. We are in the process of validating how these services help to increase the number of visitors and facilitate visitor movements (**Fig. 4**).

5. Future development

We are promoting trials to apply device integration services to a wide variety of fields and industries in addition to the cases introduced here; some examples of where these services may be beneficial include long-term care facilities and tourist facilities. Furthermore, in parallel with the joint demonstration experiment, we are also working to expand the application of R-env by broadening cooperation and promoting joint events with hardware manufacturers and service developers [12].

We are also working to spread and improve the device integration service by expanding four initiatives:

1) Conducting hands-on events of the latest devices, including robots;
2) Regularly holding a hackathon event targeted for individual developers and service developers with no programming experience;
3) Holding field trials in cooperation with service providers;
4) Conducting business trials.

We aim to create new business opportunities using robots by enhancing and promoting the value of our MACHINAKA service using device integration services, and by improving the performance of the associated element technology based on the verification results obtained from the joint demonstration experiment.

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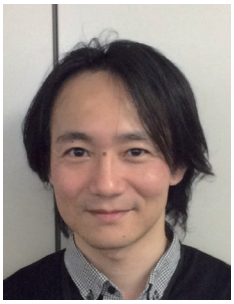

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2020 Public Viewing—*Kirari!* Immersive Telepresence Technology

Akihito Akutsu, Akira Ono, Hideaki Takada, Yoshihide Tonomura, and Maiko Imoto

Abstract

NTT Service Evolution Laboratories is conducting research and development on an immersive telepresence technology called *Kirari!* in order to achieve ultra-realistic services that provide an experience akin to actually being at a sporting or live venue to off-site viewers in remote locations. This article gives an overview of technologies supporting Kirari!, including advanced media streaming and synchronization (Advanced MMT (MPEG Media Transport)), real-time image segmentation for any background, ultra-realistic presence design (virtual loudspeakers), and super high-definition video stitching. Initiatives using these technologies are also introduced.

Keywords: ultra-realistic, immersive telepresence, media processing/synchronization technology

1. Introduction

Diverse ways of viewing sporting events beyond conventional television coverage have been introduced recently for international competitions and popular domestic sports such as baseball and soccer. These include live distribution over the Internet and public viewings at off-site venues. Further, with the spread of 4K and 8K broadcasts, people around the world are expected to share in the excitement of sporting events in the year 2020 through television and public viewings.

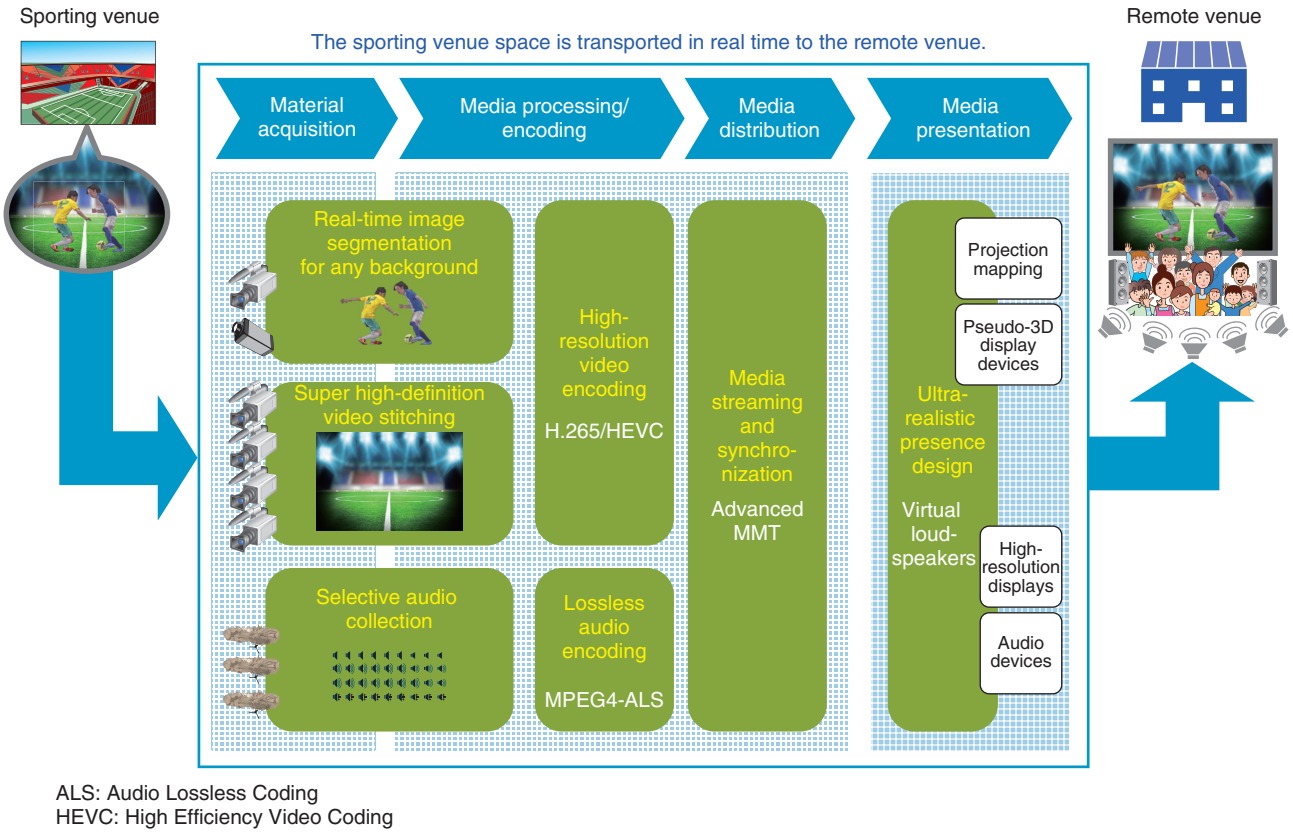
To tackle this world-wide diversification in viewing styles, NTT Service Evolution Laboratories announced our concept of *Kirari!* immersive telepresence technology in February 2015 [1]. Kirari! will implement high resolution and ultra-realistic presence technologies to deliver the sporting venue space in real time throughout Japan and the world. The goal of Kirari! is to enable viewers to experience sporting events as though they were actually at the venue from anywhere in the world.

2. Technologies supporting ultra-realistic services

Two main technical issues arose in implementing ultra-realistic real-time transportation of the video space with Kirari! (**Fig. 1**):

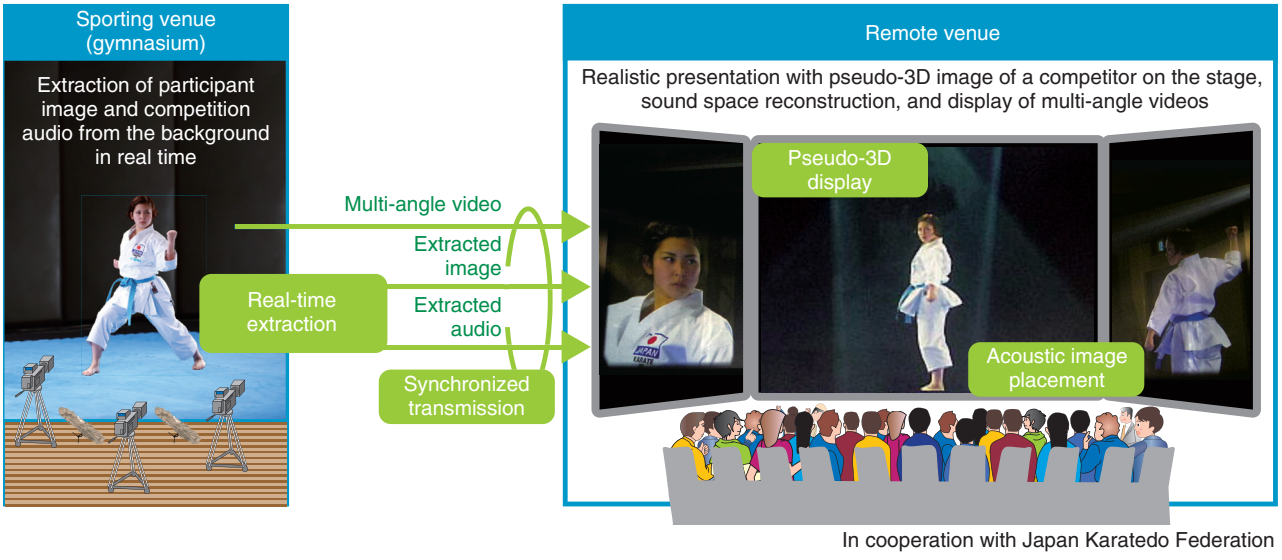
- Improving the accuracy when separating the image of a participant and the sound of the competition from the overall situation at the venue in real time
- Synchronizing the transportation of the extracted participant image and competition audio as well as stitching the overall competition background image and audio data and achieving highly realistic reproduction at the remote venue

We analyzed the technical elements needed to resolve these technical difficulties and carried out research and development (R&D) on each of them. As a result of this R&D, we were able to present real-time pseudo-three-dimensional (3D) video transmission of athletes giving a karate demonstration at the NTT R&D Forum held in February 2016, successfully achieving an ultra-realistic viewing experience (**Fig. 2**). An overview of the technical elements developed and comments on the results are given below.



ALS: Audio Lossless Coding
HEVC: High Efficiency Video Coding

Fig. 1. Kirari! technical elements.



In cooperation with Japan Karatedo Federation

Fig. 2. Live demonstration with Kirari!

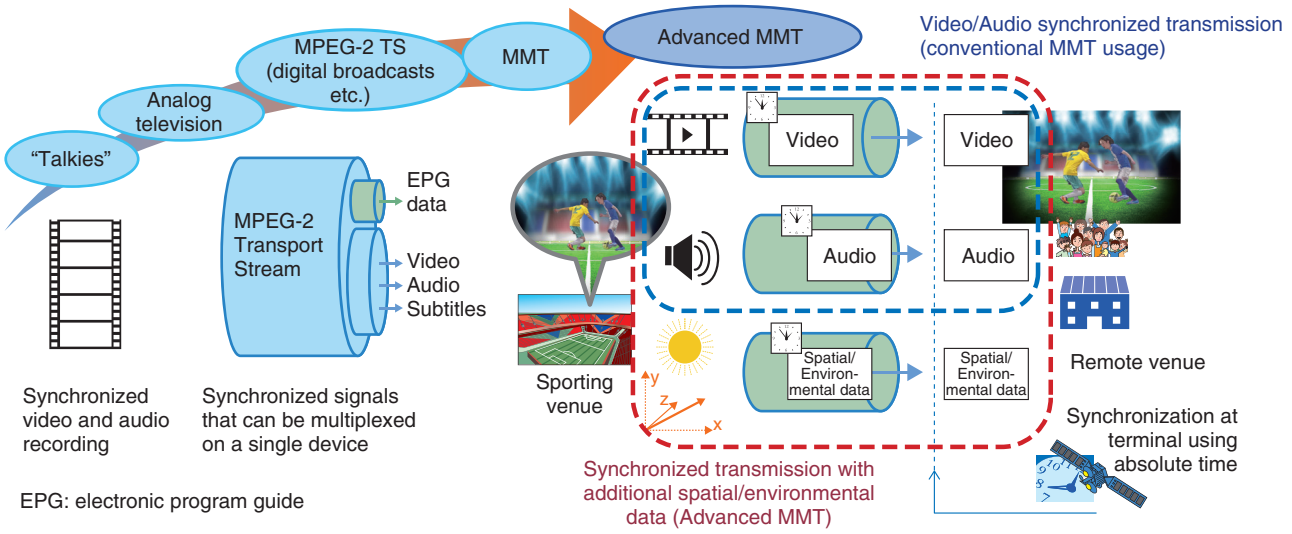


Fig. 3. Media synchronization for realistic sensation (Advanced MMT).

3. Advanced media streaming and synchronization (Advanced MMT)

We developed technology to synchronize and transport video and audio, combined with spatial information, by extending MPEG (Moving Picture Experts Group) Media Transport (MMT), which is an optimized protocol for media synchronization. We added definitions for MMT signaling to describe 3D information such as the size, position, and direction of MMT assets (**Fig. 3**). This technology makes it possible to correlate physical spatial parameters such as the size and position of the display device with asset data (frame pixel data) so that the space can be reconstructed with high realism at the destination at the intended size. Also, transmission of the DMX (Digital Multiplex) signals commonly used in production to control stage lighting and audio devices together with the MMT assets enables realistic presentations that accurately synchronize remote stage equipment with the media.

4. Real-time image segmentation for any background

To implement Kirari!, it was necessary to extract the desired subject from the captured video and display it in a way that resembled the real thing. We developed a technology for extracting the desired subject from any background; this technology can be used in situations such as sporting events, plays, and lectures where it is difficult to use a green screen or other special background (**Fig. 4**). The first step involves extracting an approximate range of the subject using sensor data (trimap generation). The second step is to extract the subject in real time. The technology we developed to achieve this uses a framework that identifies the boundary between the subject and the background and accurately separates them using nearest neighbor search in the color space. It also uses clustering, with constraints to ensure that foreground and background colors do not overlap.

5. Ultra-realistic presence design (virtual loudspeakers)

We developed a highly realistic acoustic image placement technology that uses diffuse ultrasonic reflections to position acoustic images within the video image, where speakers cannot be placed. It can position virtual sound sources realistically using fewer speakers and producing a larger listening area than with earlier surround-sound speaker systems (**Fig. 5**). Degradation of ultrasonic characteristics is handled by using electrodynamic speakers to complement low frequencies. This technology enables virtual sound sources to be generated at any location on large, full-size images displayed on a large screen, so that realistic effects can be generated using a simple configuration such as having voices or competition sounds originate from their source on the screen.

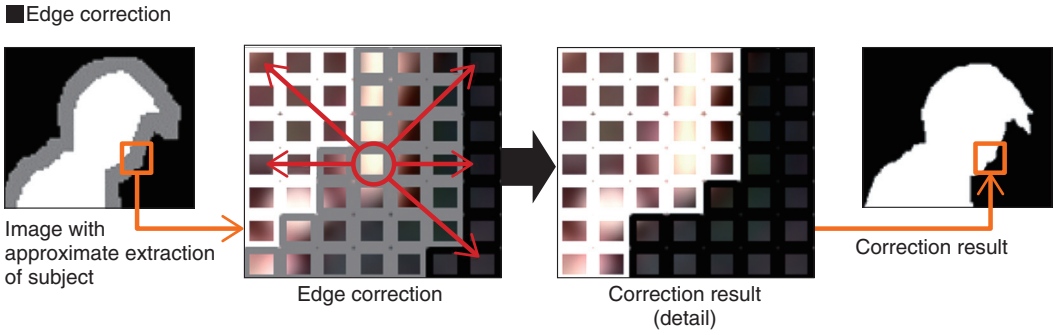
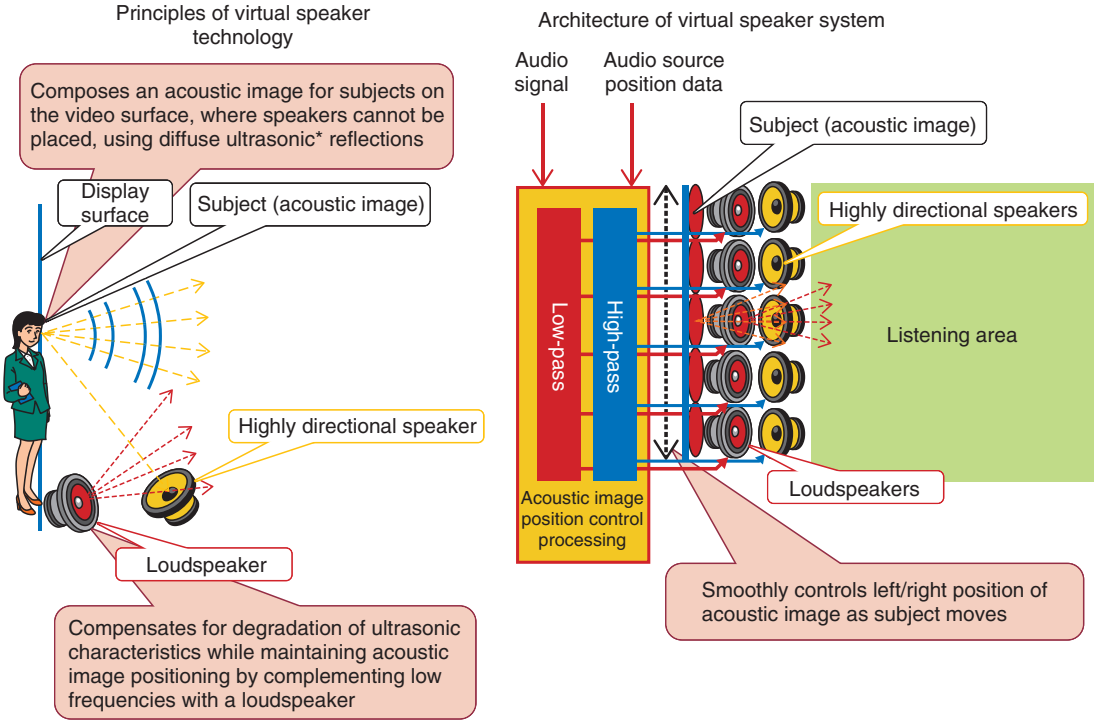


Fig. 4. Real-time image segmentation for any background.



* Uses sound waves in frequencies not audible to the human ear, emitted by highly directional speakers, to transport audible sound from a linear array

Fig. 5. Ultra-realistic presence design (virtual loudspeaker).

6. Super high-definition video stitching

As a first step toward achieving a highly realistic service with ultra-wide video not possible with ordinary 16:9 television video, we established algorithms and a system architecture to capture video using five 4K cameras arranged horizontally, and to compose them in real time (**Fig. 6**). To process the large amount of 4K image data at high speed in real time, the data are partitioned and a mechanism is used that enables successive frames to be processed without waiting for positioning from the previous frame, which is necessary to suppress flicker. These innovations made real-time (4K60p) processing possible.

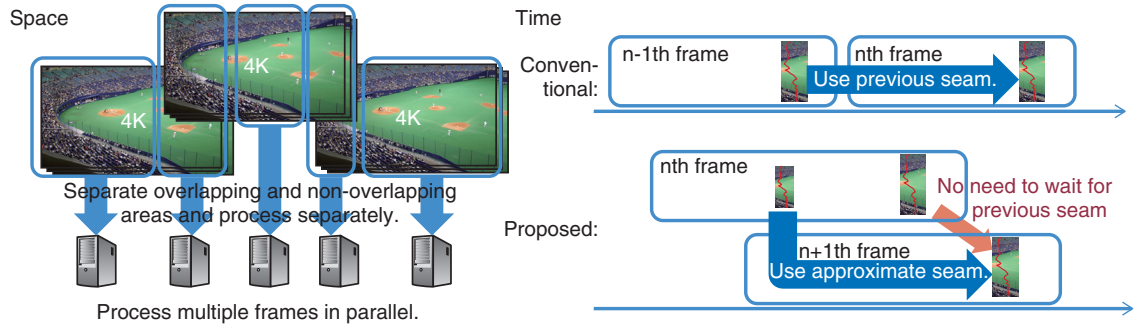


Fig. 6. Ultra-wide image composition.

7. Future development

We plan to conduct real-time transportation trials on these technologies, focusing mainly on individual sports. Beyond sporting events, we also intend to expand our horizons to other types of event that have been difficult for many people to appreciate remotely. This will include public viewings of traditional performances, regional festivals, intangible cultural assets, music concerts, and live coverage of lectures.

In further R&D, we plan to expand the scope of Kirari! to support competition with multiple athletes (competitions with large overlapping subjects) so that in the future, large numbers of competitors, or multiple subjects moving over a wide area, can be presented. This will be applied to sports such as judo and soccer that are currently difficult to present in this way.

We are conducting R&D on elemental technologies needed to provide ultra-realistic services with the goal of making viewing experiences close to actually being at a sporting venue available anywhere in the world by the year 2020.

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2020 Entertainment—A New Form of Hospitality Achieved with Entertainment × ICT

Tomohiro Nishitani, Akira Ono, Tomoyuki Kanekiyo, Takahiro Yamaguchi, Akio Kameda, Shin'ya Nishida, Junichi Nakagawa, and Motohiro Makiguchi

Abstract

This article introduces new applications of information and communication technology (ICT) in the entertainment field. Specifically, we describe two events involving the collaborative creation of new forms of kabuki using ICT: Dwango Co., Ltd.'s Cho Kabuki event held at Niconico Chokaigi (29–30 April 2016, Makuhari Messe, Chiba Prefecture, Japan) and Shochiku Company Limited's KABUKI LION SHI-SHI-O held at the Japan KABUKI Festival (3–7 May 2016, Las Vegas, USA).

Keywords: Kabuki, ICT, hospitality

1. A new way to enjoy kabuki

Until now, kabuki has mostly been enjoyed live on stage. However, NTT Service Evolution Laboratories has used information and communication technology (ICT) to create new ways to enjoy kabuki in each of the pre-performance, mid-performance, and post-performance periods.

1.1 Pre-performance

First, for the pre-performance period, we created an interactive exhibit called *Henshin Kabuki* (transformation kabuki). This non-theater kabuki performance was held at the KABUKI LION Interactive Showcase in front of a Las Vegas theater. The exhibit features the unique make-up methods characteristic of kabuki and uses the *henshin* (transformations) of kabuki actors to showcase the culture and technology prowess that Japan prides itself on, creating a wondrous experience. Participants chose a *kumadori* (stage makeup worn by kabuki actors) mask of their choice and stood in front of the large-screen monitors. The angle-free object search technology automatically detected the type of mask chosen regardless of the mask's angle or tilt and superimposed the *kumadori* patterns onto the faces of the participants using augmented reality (AR) (**Photo 1**). The AR superimposition was made possible due to edge computing technology, which allows servers in distant locations to process images at high speed, allowing for clear, non-blurry images to be placed even if the subjects are moving around at a high speed.

In addition, projection mapping was done on a three-dimensional (3D) face object. All dynamic performance aspects of kabuki such as timing and facial expressions were maintained and combined with the concept of an amplified experience that extracts the key performance points and makes them stand out in a larger-than-life way.

Moreover, fifty *kumadori* masks were hung on a wall. The masks, which ordinarily should not move at all, made use of the same HenGenTou (deformation lamp) light projection technology that was used in the main performance to freely take on a diverse variety of facial expressions such as laughter and anger.

Of the 1018 participants from many different age

Photo 1. Kabuki actor Somegoro Ichikawa experienced the interactive exhibit.

groups, nationalities, and genders, approximately 90% reacted positively to the new interactive experience. The mask-recognition technology that used angle-free object search had an accurate identification rate of 99.2%. However, some challenges for the future also became apparent such as finding a way to provide guest guidance in an exhibit that contains multiple aspects and optimizing the angle-free object search lexicon tuning.

1.2 Mid-performance

The mid-performance period introduced the Cho Kabuki performance and a highly realistic remote rendition of KABUKI LION SHI-SHI-O (**Photos 2** and **3**).

1.2.1 KABUKI LION SHI-SHI-O

Four initiatives were carried out to achieve the highly realistic remote rendition of the KABUKI LION SHI-SHI-O main performance held in Las Vegas.

(1) Room reproduction using 4K multi-screens (**Photo 4**)

Footage from nine 4K-resolution cameras was encoded using high-compression HEVC (High Efficiency Video Coding). MMT (MPEG* Media Transport), which enables multiple videos and voices to be flexibly synchronized in real time, was then used to create the first international 4K multi-screen relay. The Haneda (Japan) venue's omnidirectional screens on the front stage (three 180-inch screens), stage passage (one lower screen, three rear screens), and ceiling (two upper screens) all simultaneously showed 4K video footage. The display received an energetic response from over 80% of the 198 participants that consisted of media personnel and invitees. Over 70% responded in a highly favorable manner, stating that they would like to visit again. On the system side, the synchronization and latency both produced positive results as expected, and various parameters were confirmed for future use. However, problems arose with the linkages between the multiple screens.

(2) Remote greeting using pseudo-3D images generated by Kirari! (**Photo 5**)

Subject abstraction technology was used to finely extract live footage of the performers from their backgrounds. Synchronization of audio with the pseudo-3D video display at the remote stage enabled Somegoro Ichikawa, who was present at the live event in Las Vegas, to greet those viewing the remote stage at the Haneda venue as if he were there in person. This was a world-first for this technology. Despite a lack of prior preparation and confirmation of lighting and camera locations for the actual performance, on the system side, the subject extraction and shadow generation was done well and with high precision. Over

* MPEG: Moving Picture Experts Group

Photo 2. Poster of KABUKI LION SHI-SHI-O.

Photo 3. Poster of Cho Kabuki.

Photo 4. Highly realistic remote rendition with omnidirectional screens.

70% of viewers replied that the experience felt as if Somegoro Ichikawa was really standing on the stage in front of them.

(3) 4K omnidirectional live footage broadcast for mobile devices (**Photo 6**)

By compressing video and transmitting high-definition footage solely in the direction that the user is looking, we were able to create a system that controlled bandwidth while maintaining a high-quality viewing experience (**Fig. 1**). On the technical side of things, the construction and stable operation of a live transmission were achieved, which reduced bandwidth

Photo 5. Somegoro Ichikawa in Las Vegas greeting the audience in Haneda, Japan.

Photo 6. 4K omnidirectional live viewing with mobile device.

by approximately 80% when compared to transmissions of the entire 4K omnidirectional video. In addition, many users replied that they felt they were actually at the theater. We confirmed that we were able to meet the needs of omnidirectional live viewing. However, certain problems arose with image quality.

(4) HenGenTou performance (**Photo 7**)

HenGenTou (deformation lamp) technology was used to create the appearance of a city in the middle of the ocean at the top half of the stage background (15 m high x 4.5 m wide). This technology was also used to present rippling of the water in the ocean.

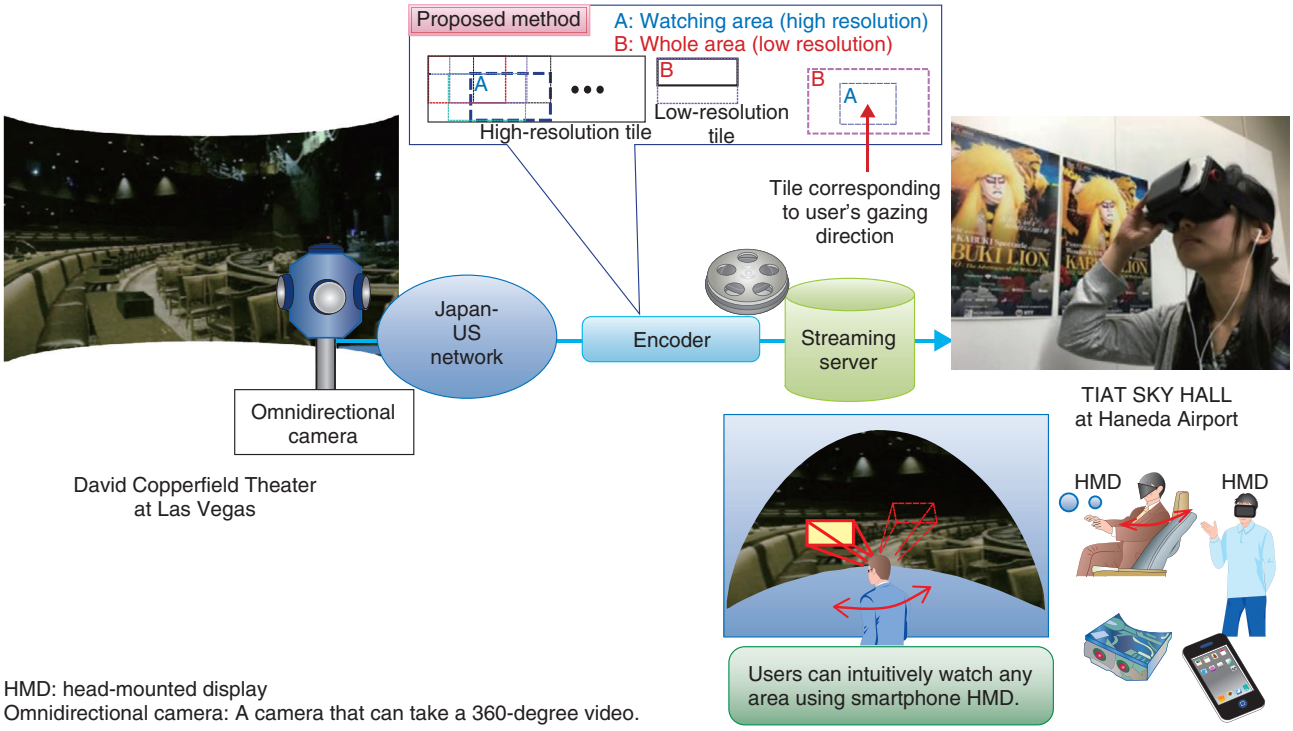

Fig. 1. A system of 4K omnidirectional live footage broadcast for mobile devices.

Photo 7. Rippling of the water in the ocean was presented on stage using HenGenTou.

Several problems were discovered with the characteristics of the stage, though. For example, when spotlights were shown on actors, the stage setting and movements at the top half of the background did not

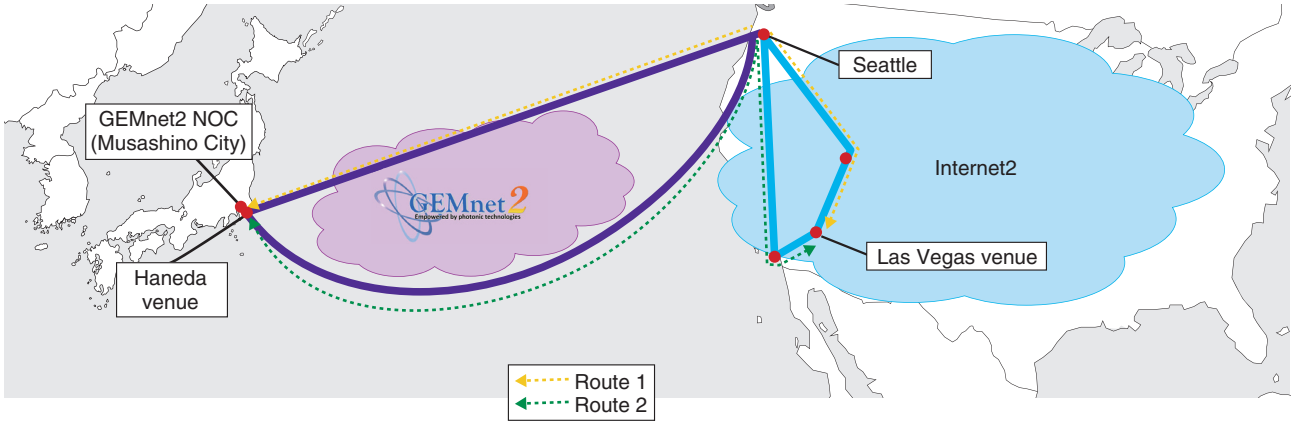

Fig. 2. Outline of Japan-US network for video transmission.

stand out very much. Also, we recognized the importance of having a script in line with the performance.

We constructed a video transmission network linking the Las Vegas and Haneda venues for the remote live viewing (**Fig. 2**). Although the period of time was limited, we were able to construct two paths, which were guaranteed for a 1-Gbit/s bandwidth, by combining a line from Internet2, the US research consortium, and GEMnet2, the network testbed owned and operated by NTT Service Evolution Laboratories. During the performance, packet losses were small enough for the error correction function to handle. Future challenges include monitoring micro-burst traffic, reducing costs, and further reducing construction times.

1.2.2 Cho Kabuki

The Cho Kabuki event consisted of five performances of the kabuki play *Hanakurabe Senbonzakura*. Subject extraction and virtual speaker technologies were used to create highly realistic performances by extracting the figure of the samurai Sato Tadanobu (played by Shido Nakamura) and making it feel as if voices were coming directly from Hatsune Miku's mouth. The performance received high acclaim as a new form of kabuki performance, with many mentions from television and Internet media sources.

1.3 Post-performance

For the post-performance period, we created an experience that used a cardboard craft box combined with a smartphone to provide a simple 3D video display. Looking inside the box would reveal a palm-sized Hatsune Miku rising up in 3D fashion. This allowed users to experience the vibe of Cho Kabuki.

2. Future development

This project was the first step for kabuki × ICT. In preparation for the next generation of kabuki, we will pursue even more realistic forms of expression and create new kabuki space experiences (installations). We also plan to continue these stage performances and live remote performances in more trials with general users from all over the world to obtain their feedback. In addition to pursuing the development of practical-use services with business potential, we plan to take the knowledge gained from ventures in the field of entertainment and make use of it in hospitality, offering new and emotional experiences with our eyes on 2020.

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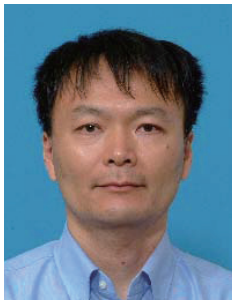

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2020 MICE—New Hospitality through Exhibitions × ICT

Manabu Motegi, Kyoko Hashiguchi, Haruno Kataoka, Takahiro Kusabuka, Yusuke Tanaka, Ushio Shibusawa, Tetsurou Yamazaki, and Tomoaki Ogawa

Abstract

NTT Service Evolution Laboratories is now verifying technologies on site in preparation for 2020 Showcase. In line with this verification, the R&D Forum Showcase was exhibited at NTT R&D Forum 2016 held in February 2016 as an example application in the MICE (meetings, incentives, conventions, exhibitions) field. This article introduces research technologies that visitors were able to experience through the exhibits and through the official application of this event.

Keywords: showcase, MICE, NTT R&D Forum

1. Introduction

At NTT Service Evolution Laboratories, we are striving to create cutting-edge ubiquitous broadband service technologies and promoting research and development (R&D) of service-provision platform configuration technologies. In particular, as we prepare for 2020 Showcase and target visitors to international conferences and events, we are performing verification tests focused on the MICE (meetings, incentives, conventions, exhibitions) [1] field. In this article, we describe R&D Forum Showcase, which was exhibited at NTT R&D Forum 2016, as an example of the above-described efforts.

2. R&D Forum Showcase exhibition

At NTT Service Evolution Laboratories, we are expanding demonstration systems that we have developed and performing verification tests focused on the MICE field. We aim to not only introduce new business and services based on these technologies and apply them by 2020 at certain events, but also to continuously expand them after the events. To achieve this aim, we are continuing R&D and systemization aimed at providing an epoch-making hospitality user interface/user experience (UI/UX) by using the most advanced technologies [2–4].

Held every year in February, the NTT R&D Forum is an exhibition for introducing cutting-edge technologies developed at NTT laboratories. It is an important event for exhibiting the results of research performed with our business partners. The main elements of the R&D Forum Showcase are described here.

(1) NTT R&D Forum 2016 Official App

The NTT R&D Forum 2016 Official App (hereafter, official app) was developed as a MICE-support application with the goal of displaying information in a manner that allows visitors to effortlessly tour the NTT R&D Forum as well as experiencing on the app itself the latest technologies developed at the laboratories (**Fig. 1**). These technologies are explained in detail in section 3.

(2) Digital signage

Digital signage (**Fig. 2**) helped visitors to efficiently tour the Forum by displaying guidance information via projection mapping and LED (light emitting diode) panels as well as projecting a congestion map indicating the state of congestion at each exhibit at the Forum (as explained later). In contrast to conventional signboards in which information is fixed and

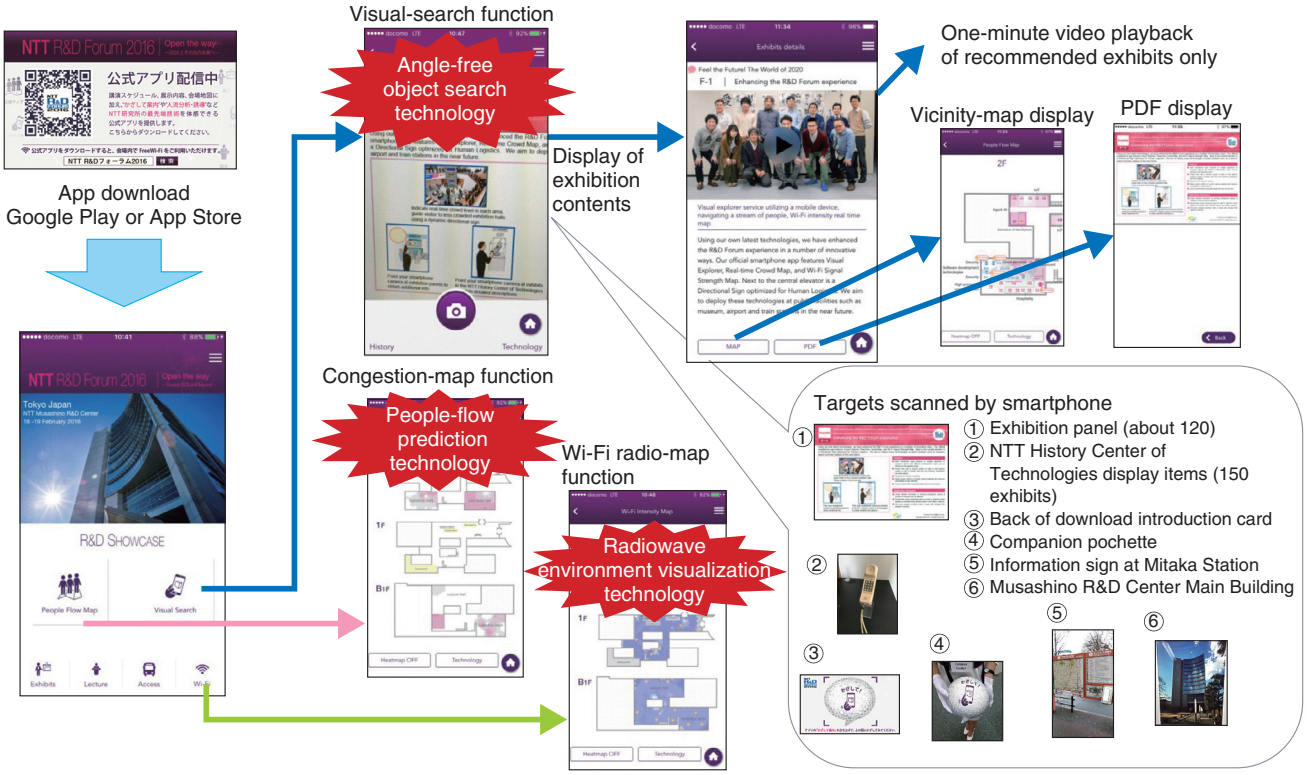

Fig. 1. NTT R&D Forum 2016 Official App.

Fig. 2. Digital signage at NTT R&D Forum.

remains static, digital signage can present information in a manner that is instinctively easy to understand by changing the content flexibly according to the state of congestion and by utilizing moving animation.

(3) Showcase Cockpit

The Showcase Cockpit was configured with the aim of enabling visitors to the Forum to imagine how the event was operating (**Fig. 3**). This was done by displaying in real time the state of the venue (i.e.,

Cockpit: To visualize operations (e.g., unnecessary compatibility adjustment and possible data collection/analysis on the system-environment side), the following content was displayed in real time on the multi-console.

Displayed content: status of the R&D Forum 2016 site (congestion map for operators, Wi-Fi radio map, etc.); status of network utilization; utilization status of application (visual-search function)

XFARM: A system environment for supporting the official app and digital signage was provided.

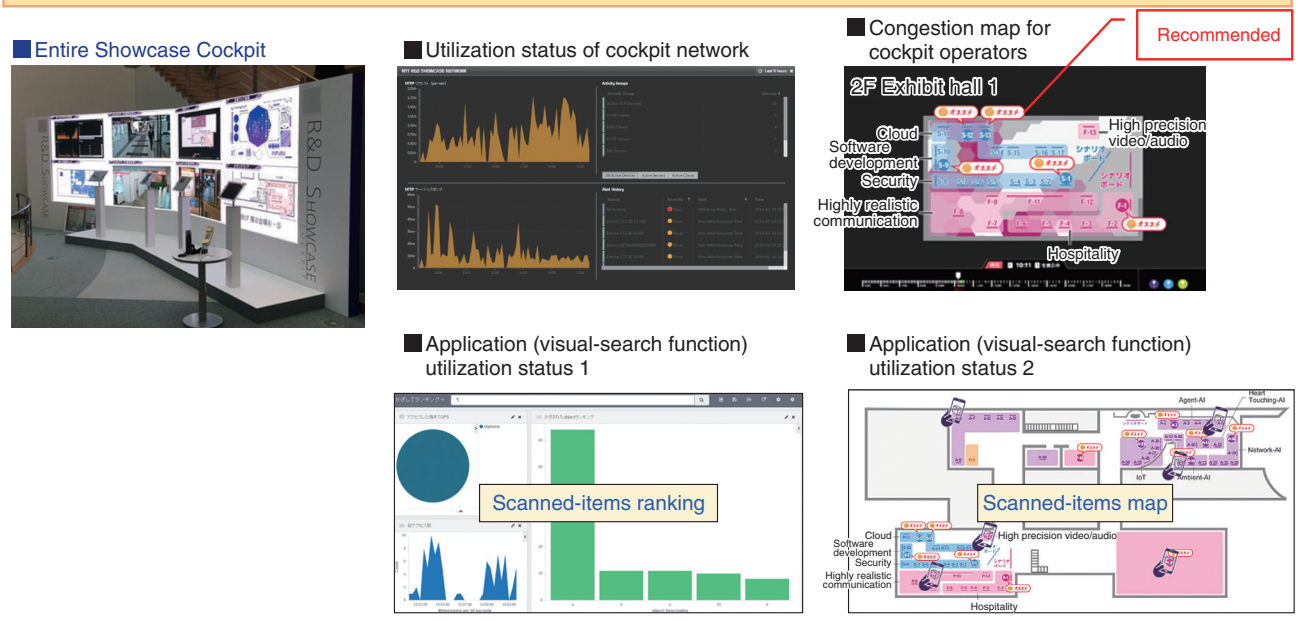

Fig. 3. Showcase Cockpit.

degree of congestion) via a congestion map and Wi-Fi radio map at each exhibition (explained in the following sections), and the state of utilization of the network and various applications on a multi-console. In fact, the information presented on the Showcase Cockpit is in essence a real-time monitoring of the utilization state of the official app. For example, when the visual-search function (explained below) was used at the venue, its utilization state was displayed on the map in real time. This made it possible to find out whether a particular booth was drawing attention. XFARM [5]—a cloud platform of NTT laboratories for service creation—was applied under this implementation setting. The use of XFARM makes it possible to smoothly promote activities ranging from service visualization to development and operation trials in the manner we achieved for the R&D Forum Showcase.

3. NTT R&D Forum 2016 Official App

The official app was developed as a MICE-support application for Android[*1] smartphones and iPhones[*2]. It was made available via the respective app stores for each type of phone (until August 2016) so that visitors could use it on whichever smartphone they possessed. At NTT R&D Forums held in past years, no MICE-supported application was developed, so the 2016 Forum marks the first time such an app was tried. Of the approximately 10,000 visitors to the Forum (over the four days it was held), about 4600 downloaded the official app, more than 40% of the total number of visitors. The number of downloads was about 20% of the number of visitors with standard MICE-support apps, and the official app was rated highly by those who downloaded it.

The official app provides the functions of standard MICE-support apps (namely, displaying the content of each exhibit, lecture schedules, access information, and providing connection to free Wi-Fi services) and also provides the following functions to showcase technologies developed at the laboratories:

*1 Android is a registered trademark of Google Inc.
*2 iPhone is a trademark of Apple Inc., registered in the U.S. and other countries.

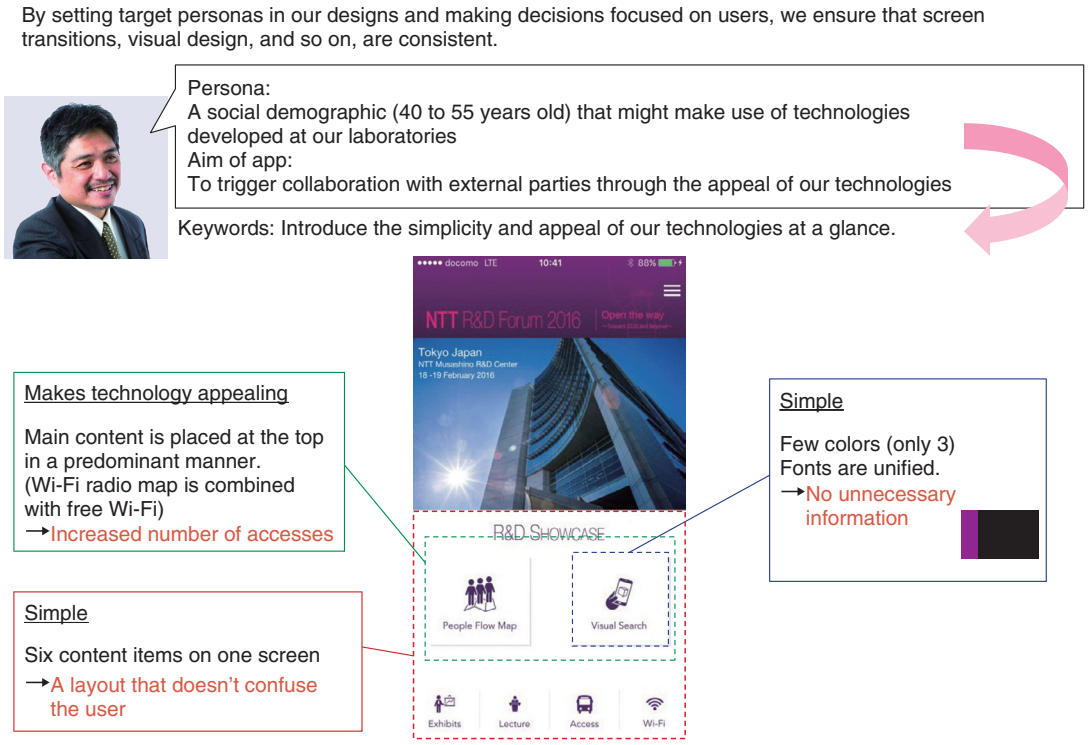

Fig. 4. Human-centered design.

(1) Visual-search function
(2) Congestion-map function
(3) Wi-Fi radio-map function

Moreover, to improve the UX of each visitor, we applied human-centered service design [6] at the design stage of the UI of the official app (including the functions listed above). An example of this human-centered service design is shown in **Fig. 4**. In concrete terms, we studied visitor-application scenarios of the official app, determined the social demographic of the target users, and designed the app on the basis of the persona (i.e., virtual character) of that social demographic. In developing the app, we set the persona as a character (namely, a person 40 to 55 years of age in a management position) who has the power to influence decisions on business collaborations with outside organizations, and on the basis of that persona, we put the required specifications for creating the official app into writing. We focused on three key points regarding screen transitions and visual design—namely, making the technology appealing, maintaining simplicity, and introducing the simplicity and appeal of our technologies at a glance—and we integrated these points into the design of the official app's UI.

For example, displayed content was narrowed down to six items and placed on the top screen of the official app to maintain simplicity, and a function to appeal to the user via a showcase was located boldly in the upper part of the screen as the main content. The content (including the function to appeal to the user) was displayed in purple to give the whole UI a calm look. Furthermore, the official app was configured so that technology introduction pages could be individually introduced in a simple manner and technological points could be understood easily while the app was operated.

3.1 Visual-search function

The visual-search function applies angle-free object search technology developed by NTT Media Intelligence Laboratories. When the visitor photographs an exhibit panel, the function displays detailed information concerning the photographed object. This technology can distinguish unwanted things included in the target object even if the image is captured from various angles, and it makes it possible to determine the content of an exhibit even from a distance by photographing the exhibit panel with a smartphone camera. In this way, even if the writing

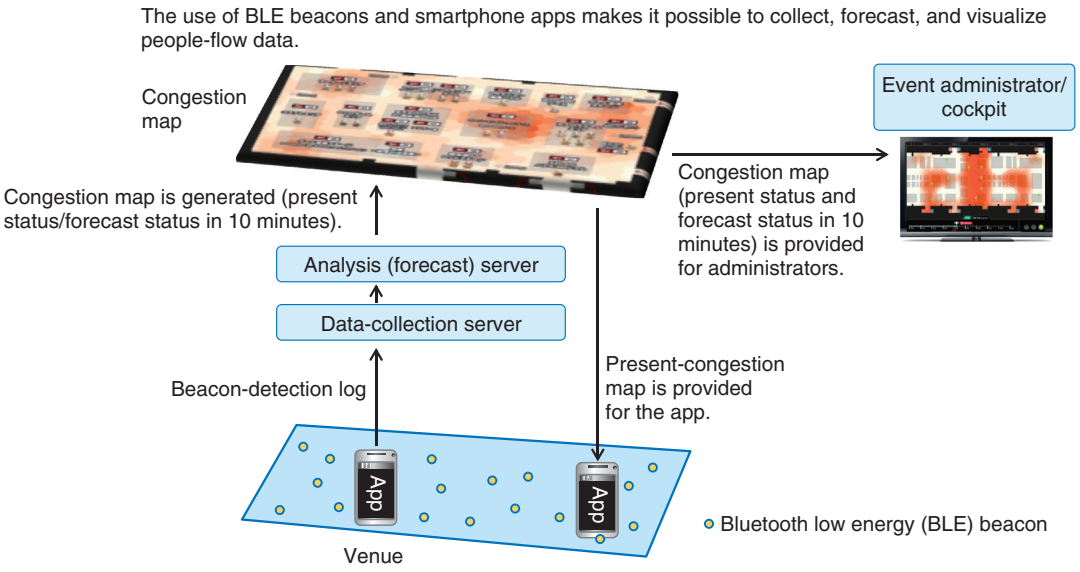

Fig. 5. Overview of congestion-map function.

on a panel at a booth cannot be deciphered, it is possible for visitors to confirm the details about the booth and decide whether to walk around a little and come back to the exhibit at another time if the exhibit is congested.

The objects photographed using the visual-search function are shown at the bottom right of Fig. 1. When about 150 exhibited objects from the NTT History Center of Technologies (set up at the exhibition venue) and about 120 display panels were photographed, detailed information about the exhibited objects was presented to the user. Then, when visual-search marks (displayed on introduction cards distributed outside the exhibition venue, posters inside the venue, companion pochettes (small bags), etc.) are photographed, special content is presented to the user.

Moreover, when information boards at Mitaka Station are photographed with the app-loaded smartphone, bus timetables to the exhibition venue are displayed on the smartphone, and when the NTT Musashino Main Building is photographed, original content is provided. This enabled visitors to experience a visual-search function in correspondence with various physical objects. Furthermore, when we analyzed the recognition results concerning the images taken by the visitors, it became clear that the captured objects were accurately recognized even when the target was far away or at a difficult-to-capture angle. In other words, we confirmed that the app-service can be utilized even when the target objects and their environment are constrained.

In combination with an advanced transparent display device (developed by Panasonic Corporation) [7], the visual-search function successfully demonstrated a futuristic kind of information navigation. Using such a transparent display device makes it possible to display information superimposed onto the target object, for example, with a sentence informing the user that the tall nearby structure is Tokyo Tower. This manner of providing information can be targeted at foreign visitors to Japan (whose number is forecast to increase over the next few years), and detailed information navigation can be provided in accordance with the attributes and movements of each and every visitor.

3.2 Congestion-map function

The congestion-map function utilizes people-flow forecasting and induction technology developed by NTT Service Evolution Laboratories to tell visitors which areas of the exhibition venue are crowded or not. An overview of the congestion-map function is shown in **Fig. 5**.

The congestion-map function consisted of Bluetooth[*3] low energy (BLE) beacons installed at more than 150 locations around the exhibition venue. When visitors carrying an official-app-installed

*3 Bluetooth is a registered trademark of Bluetooth SIG, Inc.

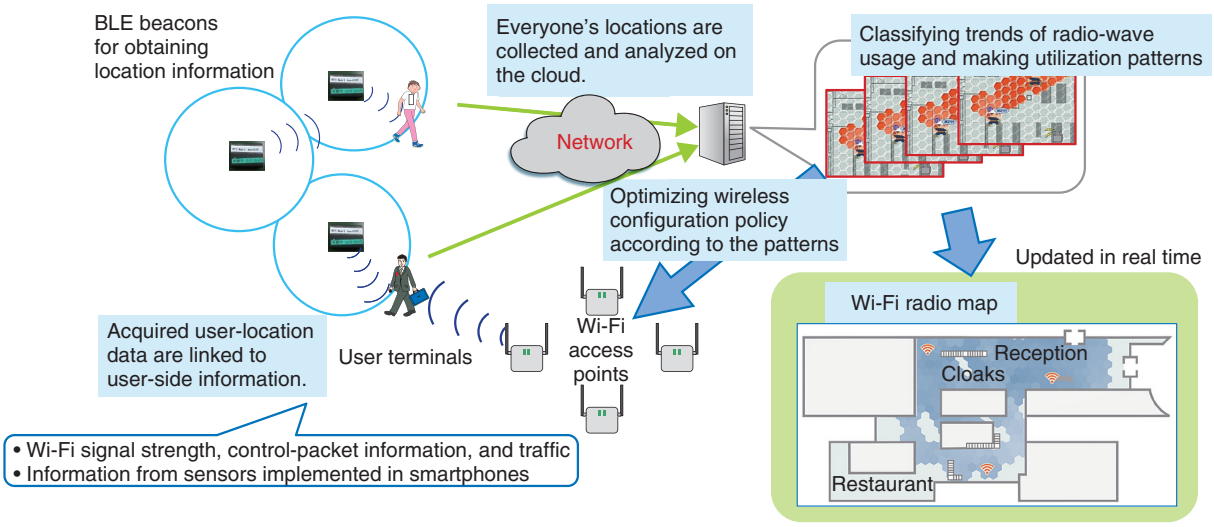

Fig. 6. Eco-cycle of radiowave environment visualization and Wi-Fi radio-map function.

smartphone entered the venue, the identification of the BLE beacon with the highest received power was transmitted to the cloud. On the cloud, the numbers of such beacons were counted, and a congestion map (indicating present congestion and forecasted congestion in 10 minutes) was formulated in the form of a heat map. A characteristic feature of this people-flow forecasting technology is that even if measurement data are not accumulated from this physical environment over a long period of time, it is possible to forecast congestion in 10 minutes from the most recent data (i.e., data collected in the preceding 30 minutes). Accordingly, an advantage of this technology is that it can also be used at temporary sites in addition to permanent ones such as that of the R&D Forum. Although the official app currently only displays the congestion map, the visualized and forecasted (10 minutes in the future) people flow (calculated from data collected in the past 30 minutes) can be displayed on digital signage (as shown in Fig. 2). In this way, presenting the degree of congestion in each exhibition area to the visitors makes it possible for them to experience people-flow forecasting and induction technology for themselves.

3.3 Wi-Fi radio-map function

The Wi-Fi radio-map function utilizes radiowave-environment visualization technology developed by NTT Access Network Service Systems Laboratories to display the signal strength of free Wi-Fi access points. An overview of the radiowave-environment visualization technology and the Wi-Fi radio-map function is shown in **Fig. 6**.

Information related to radio waves is gathered using an approach called collective intelligence. Namely, Wi-Fi signal strength is measured and collected using the terminals of all visitors on which the application is installed. Thereby, the current radio map can be formed without dedicated measuring instruments. When the signal strength is gathered, the data are combined with the position information obtained by the location function from the BLE beacons (which are also used by the congestion-map function described above).

When the Forum was held, free Wi-Fi areas were set up around the venue so that official-app-installed smartphones could access free Wi-Fi. Accordingly, by indicating areas with easy connection to free Wi-Fi to visitors, we enabled visitors to experience the radiowave-environment visualization technology for themselves.

4. Future development

This article introduced the R&D Forum Showcase—which was exhibited at the NTT R&D Forum—as an example of verification tests in the MICE field. In particular, three functions provided by the NTT R&D Forum 2016 Official App—namely, a visual-search function, congestion-map function, and Wi-Fi radio-map function—were described as showcase technologies developed at NTT laboratories.

At NTT Service Evolution Laboratories, we will continue working to improve these technologies in time for the year 2020 through collaborations with partners in different industries. Moreover, we will continue to promote R&D aimed at applying these technologies in MICE fields such as exhibitions, museums, art galleries, airports, and train stations.

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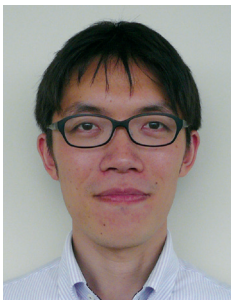

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Promotion of Co-innovation through Collaboration with Different Business Sectors

Tsuguhiro Ohashi and Shinkuro Honda

Abstract

NTT aims to create new services by working with different business sectors as value partners, while shifting its business model from B2C (business-to-consumer) to B2B2X (business-to-business-to-consumer, government, or company). NTT Service Evolution Laboratories is also promoting co-innovation with partners in different business sectors. In this article, we describe some examples of the latest efforts to implement co-innovation activities of the NTT Group.

Keywords: co-innovation, collaboration, value creation

1. Introduction

With the objective of revitalizing the information and communication technology (ICT) market through new-value creation, NTT EAST and NTT WEST have shifted their business models to a Hikari Collaboration Model, under which their business partners are allowed to re-sell NTT's optical access services. To accelerate this switch in business model from the conventional B2C (business-to-consumer) to B2B2X (business-to-business-to-consumer, government, or company), the NTT Group is involved in ongoing co-innovation activities with partners from a variety of different business sectors.

For example, in collaboration with four major companies, NTT WEST began efforts [1] in April 2015 to further accelerate co-innovation aimed at creating new business through facilitating cooperation between large and established businesses and start-ups. In July 2016, in collaboration with McLaren Racing Limited and Honda Motor Co., Ltd., NTT Communications initiated efforts [2] to establish an optimum ICT platform to support Formula 1 racing teams.

Over the last three or four years, NTT has maintained business alliances with Dwango Co., Ltd. [3] and Mitsubishi Heavy Industries, Ltd. [4] and is continuing efforts aimed at creating new value by utilizing research results in the ICT field. The co-innovation effort with Dwango is targeted at upgrading video and social networking services, so we have been jointly developing interactive streaming technology for omnidirectional video, which can deliver immersive video even when bandwidth is limited. This technology was implemented as a virtual-reality live streaming service [5].

The co-innovation project with Mitsubishi Heavy Industries involves the commercialization of a high-noise-reduction head-set type intelligent microphone, which can collect sound clearly even in noisy environments (i.e., at a noise level close to 100 dB) such as factories and building sites, through our combined research and development (R&D) efforts [6].

In addition, we are involved in several other co-innovation activities. For example, in collaboration with Daiichi Kosho Co., Ltd., we are carrying out joint investigations using NTT's speech processing technology [7]. We believe that the significant results of implementing the above-described co-innovation activities by utilizing NTT's own technologies will help to solve problems in society and create value through new markets.

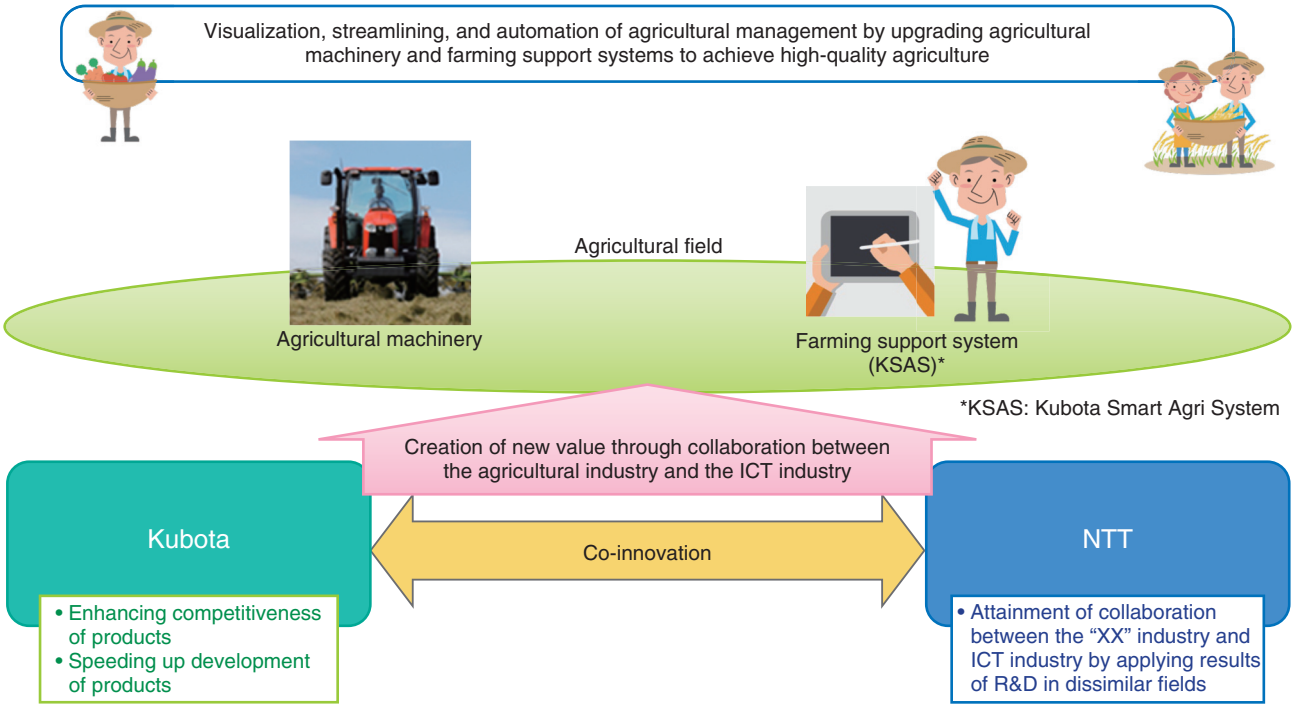

Fig. 1. Agricultural-centered co-innovation with Kubota Corporation.

2. Solutions to social problems and creation of value in new markets

The NTT Group aims to support sustainable development in society and is therefore working on solving various social problems. However, many social problems—such as Japan's decreasing birthrate and aging population as well as sluggish employment generation—can neither be solved single-handedly nor by ICT alone. Nevertheless, we can expect to open up completely new markets by applying ICT. Under these circumstances, we aim to solve social problems and create value in new markets by utilizing NTT technology. We describe in this section some of our ongoing efforts.

2.1 Agricultural-centered co-innovation with Kubota Corporation

The field of agriculture is facing serious problems. For example, Japan's farmers are aging and dwindling in number since fewer people are entering the field. In June 2016, NTT signed a comprehensive partnership agreement with Kubota Corporation, a major agricultural machinery manufacturer [8]. By focusing on the agricultural-solutions field, which Kubota is trying to expand, and combining ICT services provided by various NTT Group companies, we are coming up with ground-breaking innovations that tackle problems such as rejuvenation of farming communities (focusing on the lack of replacement farm workers and improvement of the international competiveness of Japan's farms) (**Fig. 1**).

In particular, we are utilizing global services provided by NTT Communications (such as cloud and security services), cutting-edge ICT services provided by NTT Group companies (such as wireless technology, weather information, and map information), and fault-detection and IoT (Internet of Things) technologies based on artificial intelligence [9] (mainly being researched and developed at NTT laboratories), in order to upgrade agricultural machinery and farming support systems provided by Kubota. Through these upgrading efforts, we plan to promote R&D and provide services leading to value creation in the agricultural field by improving international competitiveness (by volume production of high-quality farm produce) and by visualizing and automating farming to improve its operational efficiency.

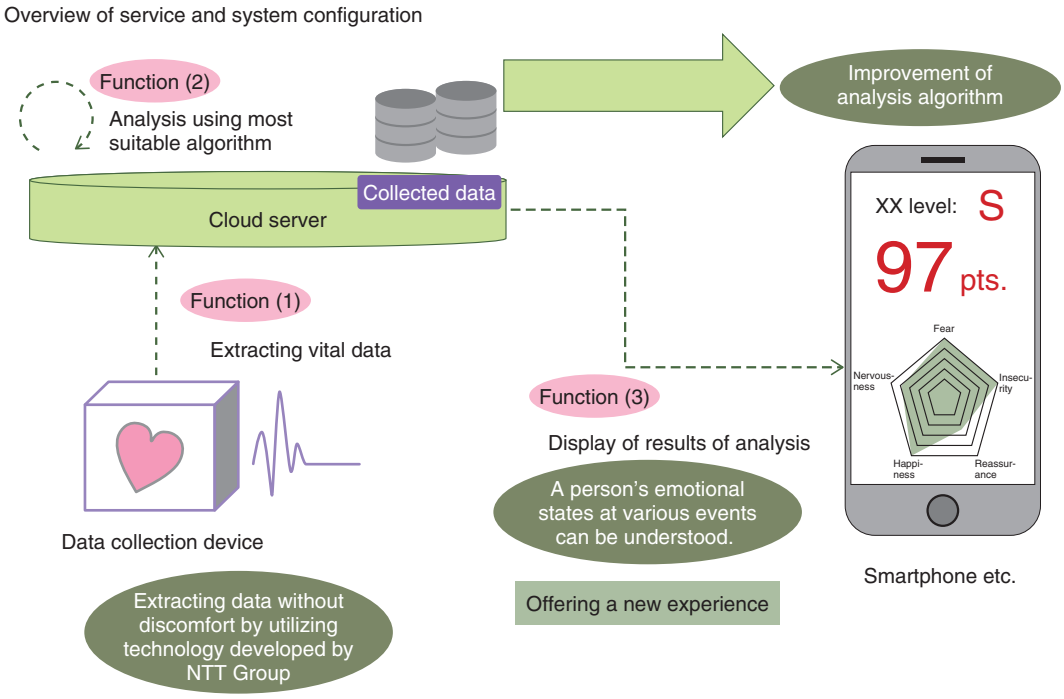

Fig. 2. A service for *visualizing the heart.*

2.2 Development of a service aimed at creating new markets: *visualizing the heart* by utilizing vital data

In 2015, NTT WEST—in collaboration with NTT Smart Connect, Aichi Prefectural University, and NTT—launched a service called *visualizing the heart* [10]. This cloud-type service can analyze people's emotions by analyzing a person's pulse-wave data (measured by surface-type pulse-wave sensing technology developed by NTT laboratories) and applying an algorithm for deducing changes in a person's emotional state (developed by NTT WEST in collaboration with Aichi Prefectural University) (**Fig. 2**).

This service is intended to open up a new market that provides new value by utilizing vital data. At the Umeda Haunted House 2015 event (sponsored by Mainichi Broadcasting System, Inc., and held from July 10 to September 6, 2015), the fear people were experiencing was *visualized* by applying the visualizing the heart service. This service was also utilized at Smart Hikari Futsal (jointly sponsored by Tokyu Sports Oasis, Inc., Goldwin Inc., and NTT WEST, and held from January 24 to March 27, 2016) to visualize the amount of exercise of volunteer subjects. Furthermore, on the Smart Hikari Comedy Theatre show (jointly hosted with Yoshimoto Kogyo Co., Ltd. and performed from February 3 to March 28, 2016), peoples' laughter was visualized (with a laughometer) by utilizing this service. To visualize laughter in this manner, the service applies an analysis algorithm developed by NTT laboratories.

3. Future development

In this article, examples of our latest efforts concerning co-innovation activities were described. NTT Service Evolution Laboratories will continue to promote co-innovation in cutting-edge R&D under the aim of creating value in collaboration with NTT Group companies and partners in various fields.

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Milagro Multi-Factor Authentication

Masahiro Matsui, Hiroaki Ohtsuka, Tetsutaro Kobayashi, Hironobu Okuyama, Akira Nagai, and Go Yamamoto

Abstract

Apache Milagro (incubating) is an open source project to establish open source software (OSS) for cloud computing. A system designer can choose the M-Pin Authentication Protocol (M-PIN) or the extended M-Pin Authentication Protocol (e-M-PIN) in Milagro Multi-Factor Authentication (Milagro-MFA), which is an authentication system in Apache Milagro (incubating). Additionally, e-M-PIN is a non-interactive protocol and is compatible with password-based Hypertext Transfer Protocol (HTTP) authentication methods such as Basic and Digest Access Authentication since password-based HTTP authentication is also non-interactive. Thus, an authentication system that uses password-based HTTP authentication can be easily migrated to e-M-PIN. We presented e-M-PIN at ApacheCon North America held in May 2016 as a contribution for the OSS community.

Keywords: identity-based authentication, M-PIN, Apache Milagro

1. Introduction

Apache Milagro (incubating) [1] is an open source project focused on new authentication technology and was developed by MIRACL, NTT Innovation Institute, Inc. (NTT i^3), and NTT [2]. One of the authentication systems in Apache Milagro (incubating) is Milagro Multi-Factor Authentication (Milagro-MFA). When using Milagro-MFA, the system designer can choose the M-Pin Authentication Protocol (M-PIN) [3] or the extended M-Pin Authentication Protocol (e-M-PIN). We introduce in this article e-M-PIN, an improved M-PIN authentication protocol that the authors developed.

The common features of M-PIN and e-M-PIN are as follows.

(1) ID-based cryptosystem

M-PIN and e-M-PIN are identity (ID)-based authentication methods that are powered by pairing-based cryptography. A user has his own ID and a secret key, which is related to the ID. The server authenticates the user with the ID, the user secret key, and server secret key.

(2) Multi-Factor Authentication

M-PIN and e-M-PIN are user authentication methods based on the user (client) - web server model. Each user has two secrets; one is a secret key stored in the user's computer, and the other is a PIN (personal identification number) code that the user must remember. Even if one of the secrets is leaked, the security of both protocols is still secure.

(3) No need for specific hardware

The user can login using a web browser. Thus, the server does not need to prepare specific secure hardware such as a hardware token for the user. Each user only needs his own computer or smartphone.

(4) No stored user hashed passwords

The server does not have to store a user's hashed password in order to authenticate the user. Therefore, if the server is compromised, the user's hashed password is not leaked. In contrast, password-based Hypertext Transfer Protocol (HTTP) authentication methods such as Basic and Digest Access Authentication need to store the user's hashed password to authenticate the user. Consequently, leakage of the user's hashed password occurs frequently when the server is compromised.

The difference between M-PIN and e-M-PIN is in the amount of communication.

(5) Interactive or non-interactive protocol

M-PIN is an interactive protocol, and e-M-PIN is a non-interactive protocol. In M-PIN, the server and

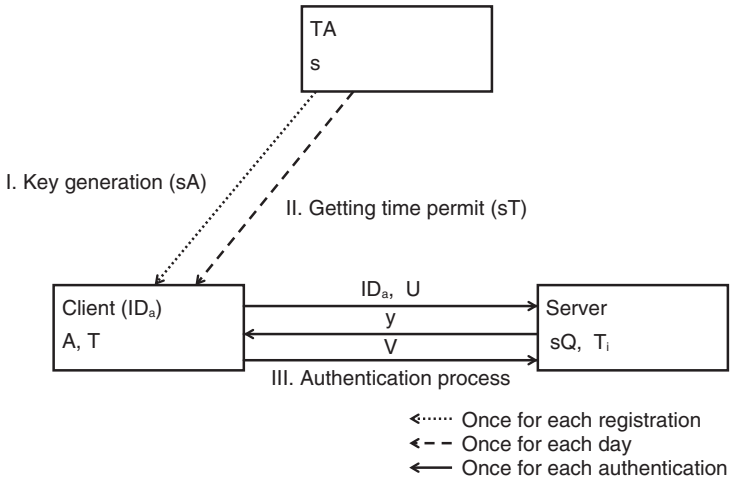

Fig. 1. Entities and processes in M-PIN.

the user have to send data to each other. However, this kind of interactive protocol is not compatible with password-based HTTP authentication, which is non-interactive. Therefore, e-M-PIN is designed as a non-interactive protocol in order to easily migrate from password-based HTTP authentication to e-M-PIN.

To achieve this, we modified M-PIN without reducing its security. We explain the details of M-PIN in section 3 and the points that were improved in section 4.

2. Notations

We define here the notations used in the following sections. The entities are Client, Server, and Trusted Authority (TA). Three functions are discussed: a pairing function (e), which is on an elliptic curve over finite field IF_p, a one-way function (H_q), and a one-way function on a map to a point on the elliptic curve (H_1, H_2). The parameters of these functions are based on the security of cryptography. Therefore, system designers must set the parameters of the functions securely. Recommended parameters can be found in publications of the National Institute of Standards and Technology (NIST) [4], Standards for Efficient Cryptography (SECG) [5], and the Elliptic Curve Cryptography (ECC) Brainpool [6]. Secure parameters have already been implemented in the repository of Apache Milagro (incubating) [7].

- Entities: Client, Server, TA
- q is prime.
- G_1 and G_2 are the q-torsion points on the elliptic curve.
- Z_q is the q-order subgroup of the finite field.
- Pairing e: $G_1 \times G_2 \rightarrow Z_q$
- H_q: $\{0,1\}^* \rightarrow Z_q$
- H_1: $\{0,1\}^* \rightarrow G_1$
- H_2: $\{0,1\}^* \rightarrow G_2$
- P and Q are the respective generators of G_1 and G_2.

3. M-PIN

In this section, we provide the details of the M-PIN protocol (**Fig. 1**). M-PIN comprises three steps: Key generation, Getting a time permit, and an Authentication process.

As a preliminary, the server gets a server secret key (sQ) and a today's date (T_i) in advance. Then, the client processes the Key generation and Getting a time permit steps. In the Key generation part, the client gets a client secret key (sA). Key generation is done only once for each user. In Getting a time permit, the client gets today's time permit (sT), which is generated from today's date (T_i). Thus, the Getting a time permit step has to be done once a day for each user as the first step to authenticate the user.

I. Key generation:

1) The client calculates a point (A) on the ellipse curve by using his ID (ID_a) and sends it to TA in order to generate a client secret key (sA).
2) The client calculates the token ((s–α)A) using his own PIN (α) and stores the token in local storage.

An image of the M-PIN user registration page is

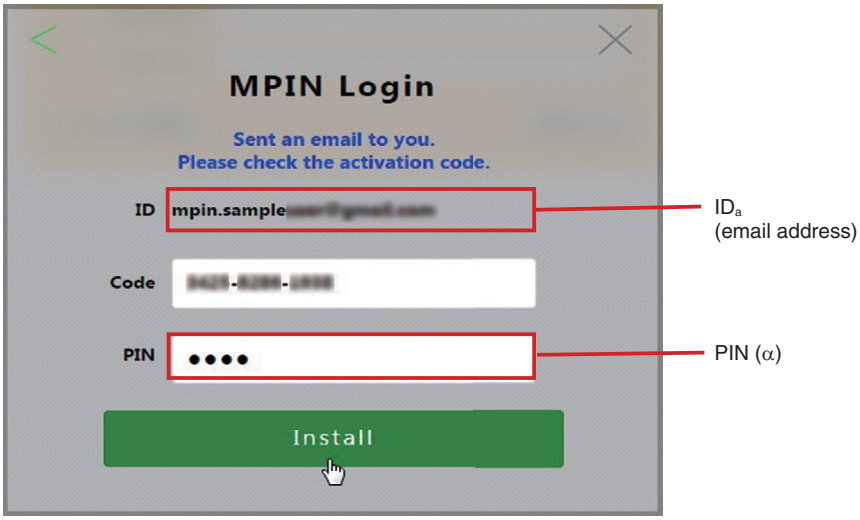

Fig. 2. Image of user registration page of M-PIN.

shown in **Fig. 2**. The user enters his PIN (α), and the browser calculates the token ((s–α)A).

II. Getting a time permit:

1) The first time the client logs in to the server each day, the client sets $T \leftarrow H_1(T_i \| ID_a)$ according to today's date (T_i).
2) The client gets a time permit (sT) by sending T to TA and stores it in local storage.

After completing these steps, the client has his own ID (ID_a) and a client secret key (sA) and a time permit (sT). The client generates a one-time signature (V) with the above information and sends this one-time signature to the server. The server verifies the client with the one-time signature and the server secret key (sQ).

III. Authentication process:

1) The client inputs the PIN (α).
2) The client generates random numbers (x) in Z_q.
3) The client computes $D \leftarrow A+T$ from $A \leftarrow H_1(ID_a)$ and $T \leftarrow H_1(T_i \| ID_a)$.
4) The client computes $U \leftarrow xD$ from D and x.
5) The client sends $\{ID_a, U\}$ to the server.
6) The server generates a random number (y) in Z_q.
7) The server sends y to the client.
8) The client computes $V \leftarrow -(x+y)((s-\alpha)A+\alpha A+sT)$.
9) The client sends {V} to the server.
10) The server computes $D \leftarrow H_1(ID_a)+H_1(T_i \| ID_a)$.
11) The server computes $g \leftarrow e(V,Q) \cdot e(U+yD,sQ)$.
12) If g = 1, return true; otherwise, return false.

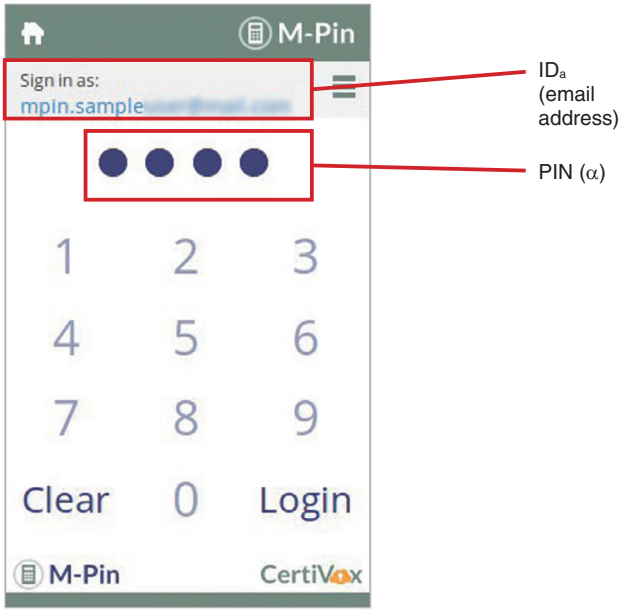

Fig. 3. Image of M-PIN login page.

An image of the login page of M-PIN and the M-PIN authentication protocol are respectively shown in **Figs. 3** and **4**.

3.1 Advantages of M-PIN

M-PIN has some advantages over password-based HTTP authentication. One advantage is that it uses two-factor authentication. Another is that the server does not have to store a user's hashed password. The

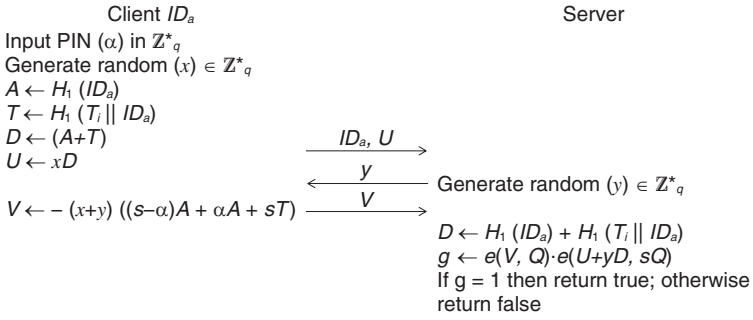

Fig. 4. M-PIN authentication protocol.

client calculates αA with the user's PIN (α) and adds it to the token ((s–α)A) stored in local storage. With the result of this calculation, the client can create a client secret key (sA). Even if an adversary gets one piece of secret data (PIN (α) or token ((s–α)A)), he cannot calculate the secret key (sA) without having the other piece of secret data. In addition, the server only has to keep the server secret key (sQ) secure. This means that the server does not have to have the user's hashed password. Hence, there is no risk of leakage of the user's hashed password.

3.2 Problem in M-PIN

In M-PIN, the client sends his data (ID_a, U) to the server. Then the server sends a random number (y) to the client, and the client makes a one-time signature (V) that includes y. This means the communication between the client and server requires three passes. However, password-based HTTP authentication, which is one of the most popular forms of authentication, is only one pass. The client sends his password or his hashed password to the server only one time. If the server wants to use both password-based HTTP authentication and M-PIN, the server has to change the communication protocol of the system in order to carry out three-pass communications. This is a major obstacle to be overcome in order to migrate M-PIN.

4. e-M-PIN

In this section, we present the details of the non-interactive authentication protocol e-M-PIN and discuss its advantages and security. This proposed protocol uses one-pass communication between the client and server. This is the same as password-based HTTP authentication. Therefore, the server can use both password-based HTTP authentication and e-M-PIN without any modification of the communication protocol in servers.

However, it is necessary to change the challenge and response method between the client and server, which brings the risk of a replay attack. To maintain the same level of security as M-PIN, e-M-PIN uses some additional information in the authentication process. The proposed protocol can prevent a replay attack by using the current time (CCT: Current Client Time, SCT: Current Server Time) and a nonce (an arbitrary number that can be used only once).

While the Key generation and the Getting time permit processes are the same as that for M-PIN, the preliminary process is slightly different. In addition to getting a private key and a time permit, the server has to set an expiration time (t), which is a time range to accept or not accept a one-time signature. Entities and processes in e-M-PIN are shown in **Fig. 5**.

The authentication process is as below (**Fig. 6**).

III. Authentication process:

1) The client inputs the PIN (α).
2) The client generates random numbers (x) and a nonce in Z_q and gets the current time (CCT) from the client device.
3) The client computes D←A+T from A← H_1 (ID_a) and T← H_1 (T_i||ID_a).
4) The client computes U←xD and W←xA from D, A and x.
5) The client computes y← H_q (ID_a || U || W || nonce || CCT).
6) The client computes V← −(x+y)((s−α)A +αA+sT).
7) The client sends {ID_a,U,W,V,nonce,CCT} to the server.
8) The server gets the current time (SCT).
9) If a nonce exists in the database (DB) that the server has, or the time-gap between SCT and CCT is not in t, the authentication fails.

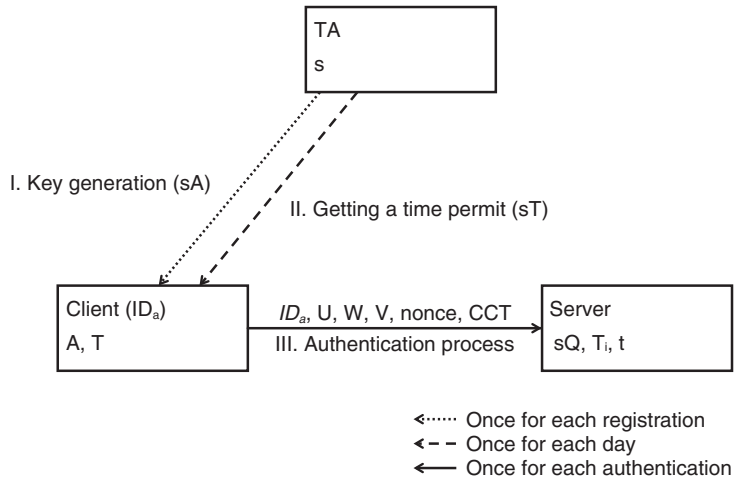

Fig. 5. Entities and processes in e-M-PIN.

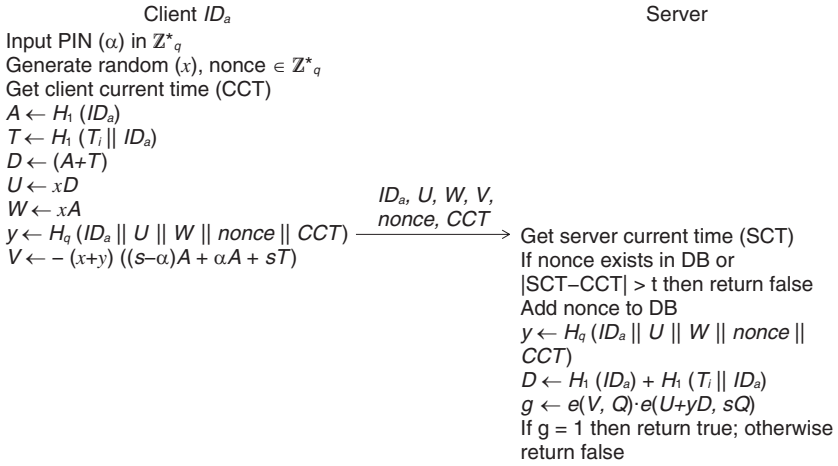

Fig. 6. e-M-PIN authentication protocol.

10) The server adds the nonce to its own DB.
11) The server computes $y \leftarrow H_q(ID_a \| U \| W \| nonce \| CCT)$.
12) The server computes $D \leftarrow H_1(ID_a) + H_1(T_i \| ID_a)$.
13) The server computes $g \leftarrow e(V,Q) \cdot e(U+yD,sQ)$.
14) If g = 1, return true; otherwise, return false.

In the challenge and response method, the server first sends a challenge, which is a random number. After receiving the challenge from the server, the client issues a signature with the challenge. Then, the server verifies the signature. If the signature is issued with the server's challenge, the verification is accepted.

In the proposed method (e-M-PIN), the client sends a signature first, without receiving the server's challenge. If the client issues the signature without the challenge, an adversary can initiate a replay attack because the signature becomes a deterministic value. To solve this problem, we use a nonce and the current time.

The nonce works as the server's challenge. The client uses a nonce when he issues a one-time signature (V), and the server checks that the same nonce was never used before. Then, the adversary cannot implement a replay attack.

However, in this protocol, the server has to keep all nonce log data in his DB, which can place a big load

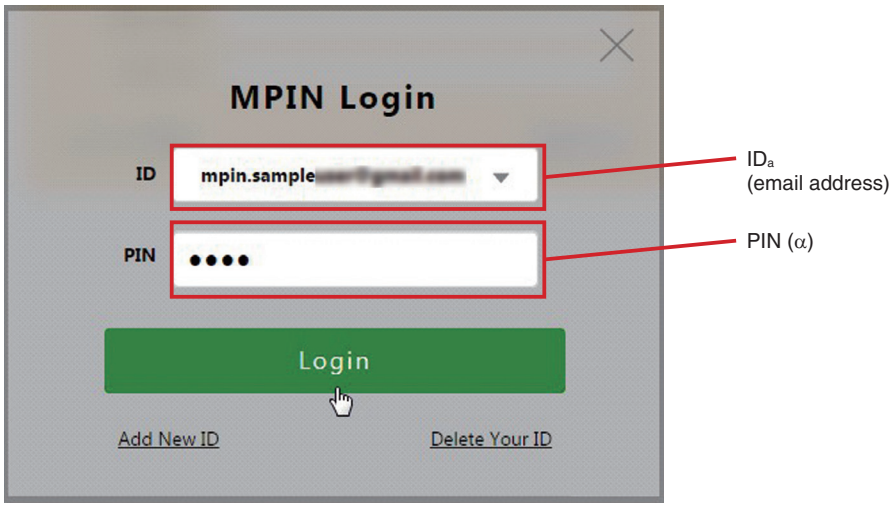

Fig. 7. Login page image of e-M-PIN.

on the server. Therefore, the server sets an expiration time (t) for a one-time signature. The server can then reject an old one-time signature which is |CCT-SCT|<t. With the setting of an expiration time, the server does not have to keep large nonce data for longer than the expiration time. These steps of using a nonce and the current time mean that e-M-PIN can achieve the same level of safety as M-PIN.

The client login page in the authentication process is shown in **Fig. 7**. An ID and PIN are input on the login page. This design is similar to that of the password login page.

4.1 Advantages of e-M-PIN

The advantages of e-M-PIN over M-PIN are as follows; some points have been improved, and there is no reduction in security.

e-M-PIN has almost the same level of security as the previous one. As same as M-PIN, the user splits his secret key into PINα and Token (s–α)A. So, the adversary cannot attack with one factor. Also, the server does not have to store a user's hashed password in the server's storage.

In the e-M-PIN, the communication between client and server is only one time. The client just sends his one-time signature (V) which includes nonce and is made within expiration time (t). So, e-M-PIN can migrate easily from an existing one-pass authentication protocol such as password-based HTTP authentication.

5. Conclusion

We have developed e-M-PIN, an authentication protocol that improves upon M-PIN. e-M-PIN is a non-interactive protocol, which means it is compatible with the traditional password-based HTTP authentication protocol, while the security is equivalent to that of M-PIN. Thus, e-M-PIN is easier to migrate to than M-PIN. e-M-PIN has already been published as open source software in the Apache Milagro (incubating) repository. We presented e-M-PIN at ApacheCon North America held in May 2016 in Vancouver [8]. The demonstration of e-M-PIN showing the ease of migration to it received a positive reaction from visitors. We will continue working to improve Milagro-MFA in order to expand its use in the future.

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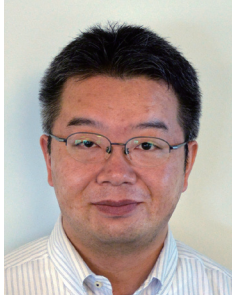

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Path Loss Models for Wireless Access Network Systems Using High Frequency Bands

Motoharu Sasaki, Minoru Inomata, Wataru Yamada, and Takeshi Onizawa

Abstract

To design coverage areas for wireless communication systems and evaluate the performance of the systems, it is necessary to develop a path loss model that can be used for the systems' frequency bands. The fifth-generation mobile communication system (5G) is expected to use high frequency bands above 6 GHz. Therefore, developing a path loss model for wireless access communication systems using high frequency bands has become a pressing issue. NTT Access Network Service Systems Laboratories has developed path loss models for the 20–40 GHz bands that are suitable for use scenarios of mobile phones and wireless local area networks. This article introduces the developed models.

Keywords: propagation, 5G, high frequency band

1. Introduction

In developing wireless communication systems, it is necessary to design their coverage areas and evaluate their performance such as the system throughput, the transmission capacity, and the system capacity. The system performance and the size of the area depend on the degree of propagation attenuation (path loss), as seen in **Fig. 1**. The propagation characteristics, including path loss, vary greatly depending on the frequency band. Therefore, it is necessary to develop a path loss model that can be used for the frequency band of the system.

Although it is assumed that the fifth-generation mobile communication system (5G) will use high frequency bands above 6 GHz, it is known that the propagation characteristics in high frequency bands differ from those for frequency bands below 6 GHz, which have long been used for conventional mobile communication systems. For example, the path loss increases as the frequency increases, and radio waves in high frequency bands do not reach shielded areas such as the areas behind buildings.

The frequency allocation of the high frequency bands for 5G will be discussed at the World Radiocommunication Conference in 2019. The propagation characteristics of the high frequency bands will be the basis of the discussion and should thus be studied in order to discuss appropriate allocation. Therefore, modeling the propagation characteristics of the high frequency bands has become a pressing issue.

At NTT Access Network Service Systems Laboratories, we are carrying out propagation modeling of a wide range of frequency bands in order to develop a variety of wireless communication systems. In this article, we introduce path loss models for the 20–40 GHz bands that can be useful for wireless communication systems in high frequency bands.

2. Path loss models

We clarified a propagation mechanism by measuring and simulating propagation, focusing on urban and residential environments. These environments are important use case scenarios of future wireless communication systems. They include mobile

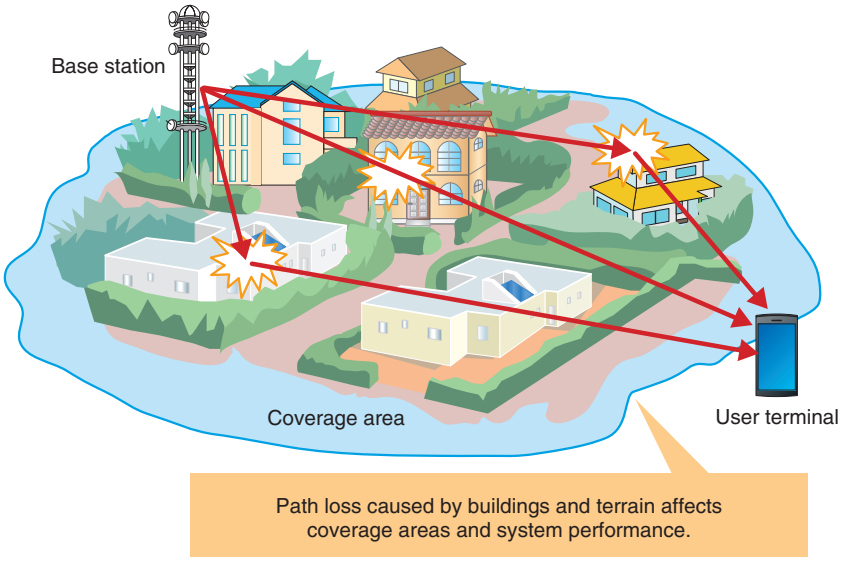


Fig. 1. Path loss model for designing wireless communication systems.

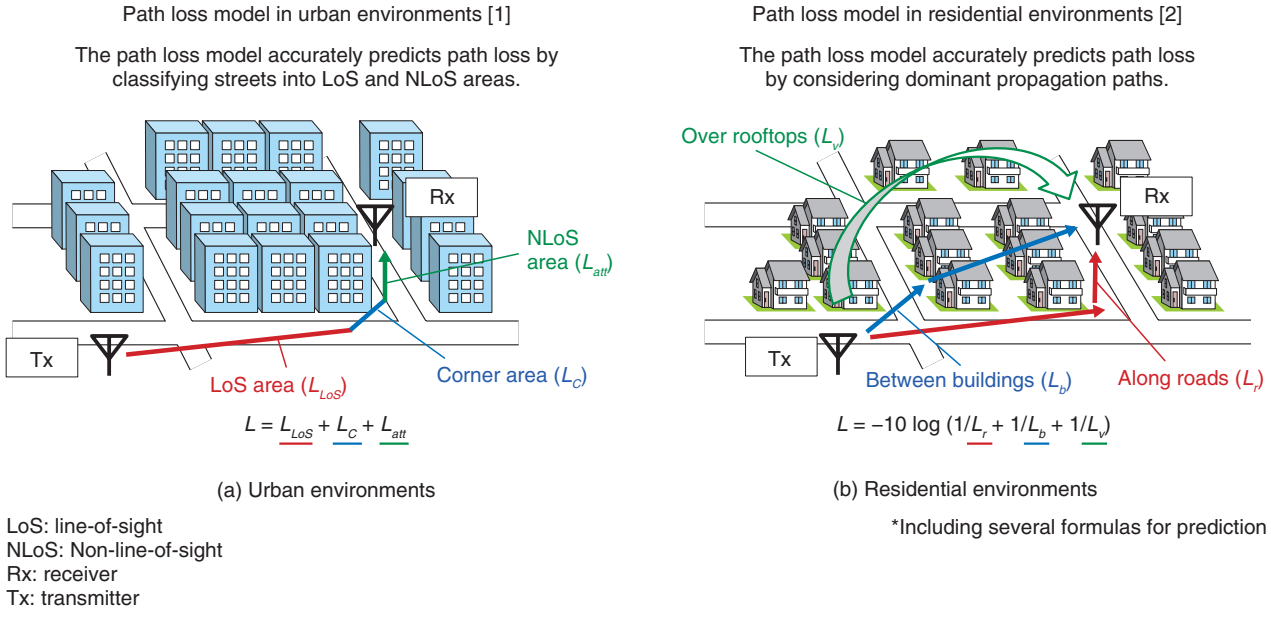
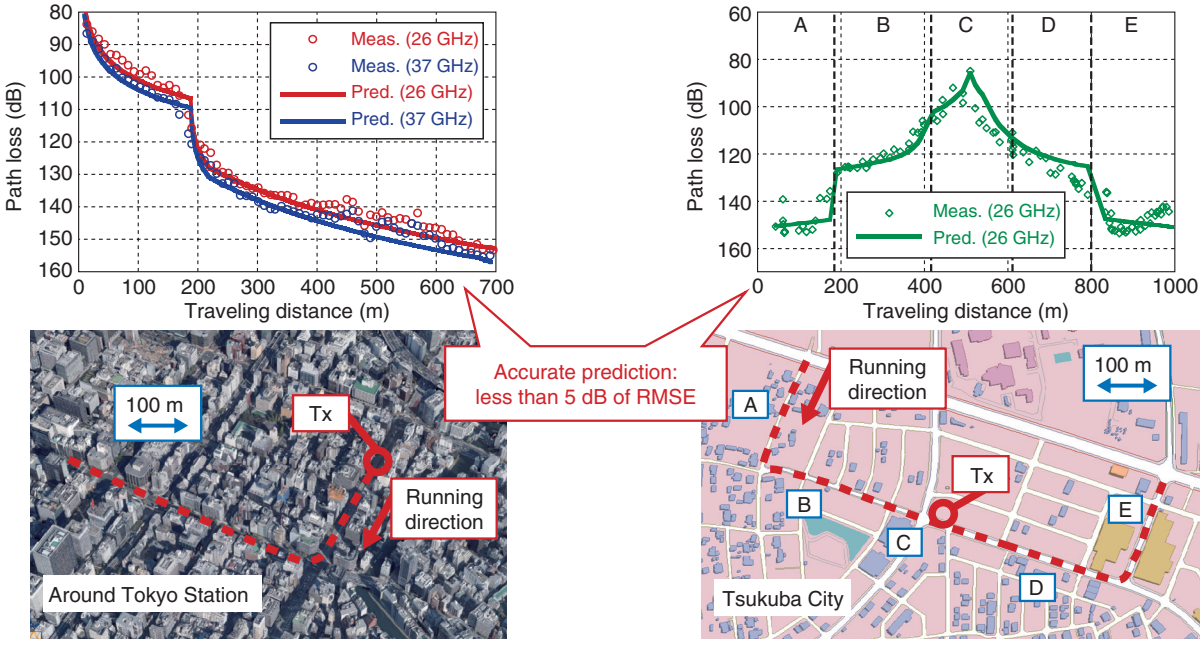


Fig. 2. Path loss models developed for urban and residential environments.

communication systems and wireless local area network systems. We obtained dominant paths from invisible propagation phenomena. The results enabled us to develop path loss models for high frequency bands that had been unclear except for the bands below 6 GHz. These models are depicted in **Fig. 2**.

For urban environments, we developed a model by deriving dominant path loss characteristics for three areas in which waves sent from a transmitter (Tx) to a receiver (Rx) are either visible or invisible: a line-of-sight (LoS) area, a non-line-of-sight (NLoS) area, and a corner (i.e., an intersection) area that is a transition area between LoS and NLoS areas [1]. The



(a) Urban environment

(b) Residential environment

RMSE: root mean square error

Fig. 3. Results of predicting and measuring path loss in urban and residential areas.

respective path losses in these areas are indicated as L_{LoS}, L_{att}, and L_C, as seen in Fig. 2(a). The radio waves transmitted from the Tx propagate to the Rx through these areas, with the three path losses added. We modeled the total path loss by using the frequency, the distance along a road between the Tx and the Rx, and the distance along a road between the Tx and the corner as parameters.

For residential environments, we developed a model by deriving three dominant paths: a path along a road, a path between buildings, and a path above a rooftop. The respective losses for these paths are indicated as L_r, L_b, and L_v, as seen in Fig. 2(b) [2]. We modeled these path losses using parameters including the distance along a road between the Tx and the Rx, building density, and building height. In our study, the equation for the residential environment model differs from that for the urban environment model because the received power at the Rx in a residential environment depends on which of the three paths has the least path loss.

In this way, we were able to develop models from the dominant paths that can easily predict actual path loss with high accuracy using simple parameters. These models have the potential to play a major role on the world stage in studies on the propagation characteristics of high frequency bands.

3. Prediction results obtained with developed path loss models

The results of predicting path loss using the models are plotted in **Fig. 3**. We verified the models' validity by comparing the prediction results and the measurement results obtained using 26 GHz and 37 GHz frequencies in an urban and residential environments.

In the urban environment, as shown in Fig. 3(a), the Rx moves along the road about 180 m and then turns the corner. The path loss increases sharply at the corner because the Rx moves from a LoS area to a NLoS area.

In the residential environment on the other hand, as shown in Fig. 3(b), the path loss shows significant variation when the Rx moves from area A to area E. This is caused by situational variations such as the number of corners between the Tx and the Rx and the degree of building shielding.

In both environments, the developed models accurately predicted the actual path losses. The root mean square error (RMSE) values are less than 5 dB. These

results indicate that the models provide sufficient prediction accuracy for designing future wireless communication systems.

4. Future overview

This article presented path loss models that can accurately predict actual path losses using simple parameters. The derived models are suitable for designing coverage areas and evaluating the performance of various future wireless communication systems using high frequency bands. The models are expected to be utilized for the 5G system, which has been the focus of much research and development in the wireless communication field worldwide.

To contribute to the construction of various wireless communication systems, we intend to actively engage in the modeling of propagation phenomena for a wider range of frequencies and environments.

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Report on Apache Big Data North America 2016 and Spark Summit 2016

Takeshi Yamamuro and Tsuyoshi Ozawa

Abstract

Two key conferences were held this year on open source projects concerning big data processing systems: Apache Big Data North America 2016 and Spark Summit 2016. This article reports on some of the topics discussed at the conferences.

Keywords: distributed processing, Apache Hadoop, Apache Spark

1. Apache Big Data North America

Apache Big Data North America is one of the largest conferences related to open source projects on big data processing and is supported by the Apache Software Foundation. The conference features interesting presentations given by users and developers on various big data processing systems using Apache open source software (OSS) products such as Hadoop [1], Spark [2], Kafka [3], and Cassandra [4]. This is a key conference for OSS developers and typically has higher numbers of developers than other events. Lively discussions were held at the conference that continued even during the coffee breaks.

1.1 Conference summary

Apache Big Data North America 2016 [5] was held in Vancouver, Canada from May 9 to 12. Many people attended the conference from hardware vendors to content providers, including representatives from Intel Corporation, Netflix, Inc., eBay Inc., Yahoo Japan Corporation, and Recruit Holdings Co., Ltd. These companies are active users of OSS products.

1.2 Business use cases

The notable keywords appearing in the titles of the presentations at the conference were Spark, Hadoop, Kafka, and Cassandra. Of the total presentations, 55 of them, or more than 40%, were related to these keywords.

In a keynote speech entitled, "How Netflix Leverages Big Data," Brian Sullivan, Director of Streaming Analytics at Netflix, talked about how open source products are being used in Netflix's services. Netflix is a worldwide video streaming service used by 81 million subscribers. A huge amount of video content—more than 125 million hours—is uploaded and distributed per day. Surprisingly, Netflix's communication traffic occupies more than one-third of all the Internet traffic in North America. Netflix creates and improves its services by using big data. By analyzing over 3 petabytes of data each day, Netflix can create, deliver, and provide excellent content. They utilize OSS developed in community supported by the Apache Software Foundation such as Hadoop, Spark, Kafka, and Cassandra.

2. Spark Summit

The Spark Summit conference was first held in 2013. Since 2015, it has been held three times a year on the east and west coasts of North America and in the EU. Developers present the latest features of Spark, an open source cluster computing framework, and users share Spark use cases and know-how on using it.

Spark was developed by the AMPLab team at the University of California, Berkeley. Developers at

Databricks are now taking the lead in this community. In addition to the underlying mechanisms necessary for distributed processing, Spark includes easy-to-use libraries for SQL queries, machine learning, streaming, and graph data processing. A report on a 2015 questionnaire survey [6] on Spark indicated that the Spark community continues to grow year by year and that Spark is one of the most popular OSS products worldwide. The development community is highly active, and version 2.0 was officially released at the end of July 2016.

2.1 Conference summary

The 7th Spark Summit 2016 [7] was held from June 6 to 8 in San Francisco. It was supported by many companies including IBM Corporation, Microsoft Corporation, Intel, and EMC Corporation. The conference was attended by more than 2500 people from over 720 companies.

2.2 Development community trends

At the conference, the main developers talked about the upcoming features in version 2.0, which is characterized by continuousness and structuralization. The new features provide effective processing of stream data such as sensor log data. Spark version 1.6 has a feature called DataFrame/Dataset for processing static data with schema. Version 2.0 has a new feature for stream data called Structured Streaming. This Structured Streaming feature is intended for users who need to process log data in near-real time. Another session at the conference focused on memory and query management. All indications are that Spark has great potential to grow because of the increasing number of developers and users.

2.3 Business use cases

Spark includes numerous libraries necessary for analytical processing in various use cases. In particular, many use cases concerned Spark Streaming. This function was implemented in version 0.7. Spark Streaming is similar to Structured Streaming, which is currently under development, as it deals with dynamic data. Spark Streaming has certain limitations, however, so it is expected to be replaced over the long term by the sophisticated functions of Structured Streaming.

Presentations were also given at the conference on the analysis of user logs generated daily for Microsoft's search engine Bing and on the behavior analysis of the popular Airbnb, a rental service for lodgings and guest houses. The common point of these two cases is that they use Kafka, a distributed message processing infrastructure. Kafka is used to store generated data, and Spark fetches the data from Kafka. Because Kafka and Spark both use the programming language Scala, they mesh well. Consequently, Kafka is becoming the de-facto standard to input into Spark Streaming.

In the case of the Weather Company, a weather forecasting company purchased by IBM in January 2016, petabytes of data are generated every day, and Spark is used for data processing. Thus, in recent years, the number of large-scale examples has gradually been increasing, so it is expected that the scale of applications will continue to grow even more.

3. Activities of NTT Software Innovation Center

NTT Software Innovation Center performs research and development on big data processing infrastructures, which is the common theme between the two conferences reported in this article. Therefore, we would like to introduce one of our efforts related to these conferences.

We gave a presentation at Apache Big Data North America 2016 on Hadoop's function to manage computer resource allocation, which we developed with other OSS developers [8]. At the conference, we discussed various issues with OSS developers. For example, we discussed how to use various devices on the Hadoop framework with researchers from the University of Toronto. Devices such as a GPGPU*1 and FPGA*2 are the most important accelerators for processing big data. Hadoop's current resource manager does not control these accelerators because it is not clear how they should be allocated to various tasks.

However, two main bottlenecks can occur with the accelerators. One is a CPU*3 intensive bottleneck that can occur with, for example, scientific computing and machine learning. The other is a network I/O*4 intensive bottleneck, which can occur when extracting a specific pattern from a large amount of data. A separate solution must be found for these bottlenecks. Unfortunately, the problem is that both bottlenecks can occur in one use case. This means we must solve the problems under these constraints, which involves a trade-off.

*1 GPGPU: general-purpose graphics processing unit
*2 FPGA: field-programmable gate array
*3 CPU: central processing unit
*4 I/O: input/output

It is difficult to inject accelerator management into the Hadoop framework in terms of interchangeability. However, as the use cases of Hadoop are extended, it will be necessary to solve the problem of the utilization of accelerators in Hadoop.

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[6] Spark Survey 2015 Results, https://databricks.com/blog/2015/09/24/spark-survey-2015-results-are-now-available.html
[7] Spark Summit 2016, https://spark-summit.org/2016/
[8] Apache Big Data 2016, https://apachebigdata2016.sched.org/event/6M0N/yarn-a-resource-manager-for-analytic-platform-tsuyoshi-ozawa-ntt

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Deployment of NTT's Open Source Software GoBGP in INTERNET MULTIFEED's JPNAP Service Achieves Automation of Operation and Vast Improvement in Efficiency

1. Introduction

NTT and INTERNET MULTIFEED CO. have partnered to apply GoBGP [1], an open source Internet routing control software provided by NTT, to JPNAP, an Internet exchange (IX) point provided by INTERNET MULTIFEED. They have achieved commercial deployment. GoBGP enables INTERNET MULTIFEED to automate the operation of JPNAP's RouteFEED service* and reduce the lead time under the new RouteFEED service contract to 1/10th the time required previously. The time needed to process customers' existing configuration change orders is reduced to 1/30th of that previously. Automating the operation means that problems due to human errors in previous manual configuration changes can be prevented. Operational loads are also reduced to 1/10th of their previous amounts. JPNAP is the world's first IX point to introduce the commercial deployment of GoBGP for IX providers.

2. Background

IX services are becoming more and more important for stable operation of the Internet. An IX is an Internet exchange connection point between Internet service providers (ISPs) and content providers. More than 600 IX points are in operation around the world. JPNAP is one of the largest IX points in Asia in terms of exchange traffic volume. As the amount of Internet traffic and the number of routes continue to increase annually, operational efficiency and costs are becoming serious issues.

NTT has engaged in open source software (OSS) projects such as the development of the Ryu SDN (software-defined networking) Framework, which was released as open source in 2012, and OpenStack. Through this participation, NTT has gained technological expertise in network software and OSS development know-how. INTERNET MULTIFEED operates one of the largest IX points in Asia, and has gained advanced knowledge in Internet routing control technologies and operational experience. By working together closely to advance OSS development, NTT and INTERNET MULTIFEED have succeeded in achieving the deployment described above.

3. Features of the technology

GoBGP efficiently leverages the features of modern-day hardware architecture such as a multicore CPU (central processing unit), enabling it to achieve the scalability necessary for processing the current number of Internet routes and connection points required by IX services (**Fig. 1**).

GoBGP uses a design premised on software control instead of conventional manual operation. GoBGP provides application programming interfaces (APIs)

* RouteFEED service: Service provided for JPNAP users that automatically carries out routing exchanges with numerous connection points.

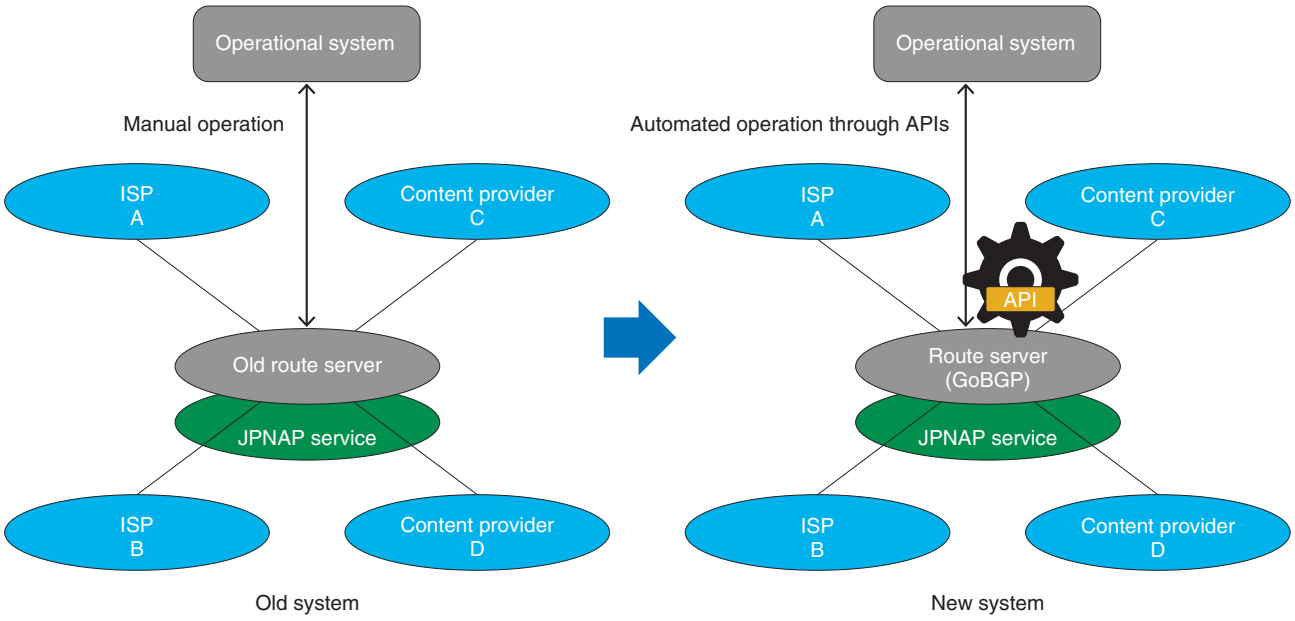

Fig. 1. Overview of RouteFEED Architecture.

and software for configuration changes and other purposes, resulting in a design that can rapidly handle frequent API requests and that makes it easy to automate operational processes. Connections to processes such as data analysis and event notification to external systems can also be easily realized by utilizing these APIs.

4. Future plans

Going forward, NTT is seeking to not only expand the GoBGP open source community and promote the spread of the technology, but also to apply GoBGP to use cases beyond IX services such as datacenter networks and commodity network hardware. It is also seeking to further accelerate the expansion of GoBGP's functions and performance. Furthermore, NTT is seeking to expand the business market with OSS and energize the business and technological development of software networking infrastructure. INTERNET MULTIFED is engaged in providing pioneering IX services that contribute to improving the reliability of IX points as social infrastructure. It seeks to increase its operational knowledge of GoBGP's RouteFEED service and provide feedback to other IX providers in order to continue to expand the Internet quickly and soundly.

Reference

[1] GoBGP, http://osrg.github.io/gobgp/

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New NTT Colleagues
—We welcome our newcomers to the NTT Group

This is a corner of the NTT Technical Review where we introduce our new affiliate companies.

Nefos
Salesforce consulting partner; established in 2007; headquartered in Zurich, Switzerland

Headquartered in Zurich, Nefos AG specializes in delivering tailor-made Salesforce solutions to German-speaking markets via its offices in Germany, Austria, and Switzerland, as well as through its near-shore cloud development center in Croatia. Since it was established in 2007, Nefos has implemented over 500 Salesforce projects across the manufacturing, automotive, telecommunications, and service sectors.

In September 2016, NTT DATA EMEA Ltd, a London-based NTT DATA subsidiary, and Nefos announced that they had entered into a definitive agreement for NTT DATA to acquire Nefos, one of the leading Salesforce consulting partners in Germany, Austria, and Switzerland.

The agreement strengthens NTT DATA's world-class Salesforce consulting and implementation practice and reflects the company's continued focus on expanding its leadership position in customer management/customer experience solutions, key elements of both digital business and digital transformation solutions. For further information about Nefos, please visit: http://www.nefos.com/?lang=en

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http://www.nttdata.com/global/en/news-center/pressrelease/2016/092800.html

External Awards

The Honorable Mention Paper
Winner: Hidetomo Sakaino, NTT Network Technology Laboratories
Date: June 1, 2016
Organization: The Institute of Electrical and Electronics Engineers (IEEE) Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm) 2016 committee

For "A Dynamic Stochastic Optimization Control Model for Data Centers Based on Numerical Modeling."
Published as: H. Sakaino, "A Dynamic Stochastic Optimization Control Model for Data Centers Based on Numerical Modeling," Proc. of ITherm 2016, pp. 675–684, Las Vegas, NV, USA, May/June 2016.

Young Scientist Award
Winner: Hiroshi Hamada, Toshihiko Kosugi, Ho-Jin Song, Hideaki Matsuzaki, Amin El Moutaouakil, Hiroki Sugiyama, Makoto Yaita, Takuro Tajima, Hideyuki Nosaka, and Osamu Kagami, NTT Device Technology Laboratories; Yoichi Kawano, Tsuyoshi Takahashi, Yasuhiro Nakasha, and Naoki Hara, Fujitsu Limited; Katsumi Fujii, Issei Watanabe, and Akifumi Kasamatsu, National Institute of Information and Communications Technology (NICT)
Date: August 24, 2016
Organization: International Union of Radio Science (URSI)

For "20-Gbit/s ASK Wireless System in 300-GHz-band and Front-ends with InP MMICs."
Published as: H. Hamada, T. Kosugi, H. Song, H. Matsuzaki, A. Moutaouakil, H. Sugiyama, M. Yaita, T. Tajima, H. Nosaka, O. Kagami, Y. Kawano, T. Takahashi, Y. Nakasha, N. Hara, K. Fujii, I. Watanabe, and A. Kasamatsu, "20-Gbit/s ASK Wireless System in 300-GHz-band and Front-ends with InP MMICs," Proc. of URSI Asia-Pacific Radio Science Conference, Seoul, Korea, Aug. 2016.

JSAP Fellow
Winner: Tetsuomi Sogawa, NTT Basic Research Laboratories
Date: September 13, 2016
Organization: The Japan Society of Applied Physics (JSAP)

For his research on control of photonic and spin-related properties in semiconductor quantum structures by surface acoustic waves.

JSAP Young Scientist Award
Winner: Pierre-Alix Carles, NTT Basic Research Laboratories
Date: September 13, 2016
Organization: JSAP

For "Deviation from the Law of Energy Equipartition in a Small Dynamic-random-access Memory."
Published as: P. Carles, K. Nishiguchi, and A. Fujiwara, "Deviation from the Law of Energy Equipartition in a Small Dynamic-random-access Memory," Jpn. J. Appl. Phys., Vol. 54, 06FG03, 2015.

Paper Award
Winner: Takeshi Mishima and Yasuhiro Fujiwara, NTT Software Innovation Center
Date: September 14, 2016
Organization: WebDB Forum 2016 committee

For "Database Live Migration Middleware in Cloud Environment."
Published as: T. Mishima and Y. Fujiwara, "Database Live Migration Middleware in Cloud Environment," IPSJ TOD, Vol. 9, No. 1, 2016.

CollabTech Best Paper Award
Winner: Xun Cao, Kyoto University; Naomi Yamashita, NTT Communication Science Laboratories; Toru Ishida, Kyoto University
Date: September 16, 2016
Organization: Information Processing Society of Japan (IPSJ) Special Interest Groups on Groupware and Network Services

For "How Non-native Speakers Perceive Real-time Listening Comprehension Problems: Implications for Adaptive Support Technologies."
Published as: X. Cao, N. Yamashita, and T. Ishida, "How Non-native Speakers Perceive Real-time Listening Comprehension Problems: Implications for Adaptive Support Technologies," Proc. of CollabTech 2016 (the Eighth International Conference on Collaboration Technologies), Kanazawa, Ishikawa, Japan, Sept. 2016.

Duke's Choice Award (Tool Award)
Winner: Yuji Kubota and Shinji Takao, NTT Software Innovation Center; Yasumasa Suenaga, NTT Comware
Date: September 20, 2016
Organization: Java Community/Oracle

For development of HeapStats.
HeapStats is a lightweight Java troubleshooting analysis tool that uses JVMTI (Java Virtual Machine Tool Interface) and SIMD (single instruction multiple data) instructions in x86 and ARM for optimization.

Communications Society: Distinguished Contributions Award
Winner: Kazuhide Nakajima, NTT Access Network Service Systems Laboratories
Date: September 21, 2016
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE) Communications Society

For his contribution as a manager of the IEICE Ad Hoc Technical Committee on Extremely Advanced Optical Transmission Technologies (EXAT).

Communications Society: Distinguished Contributions Award
Winner: Jun Mashino, NTT Network Innovation Laboratories
Date: September 21, 2016
Organization: IEICE Communications Society

For his contribution as a secretary assistant of the IEICE Technical Committee on Radio Communication Systems (RCS).

Communications Society: Distinguished Contributions Award
Winner: Tadao Nakagawa, NTT Network Innovation Laboratories
Date: September 21, 2016
Organization: IEICE Communications Society

For his contribution to the management and invigoration of the executive committee of the IEICE Communications Society.

Communications Society: Distinguished Contributions Award

Winner: Takeshi Kinoshita, NTT Network Innovation Laboratories
Date: September 21, 2016
Organization: IEICE Communications Society

For his contribution to the operation of international symposia hosted by the IEICE Technical Committee on Network Virtualization.

Technical Director Award (Interactive Category) of the 2016 56th ACC CM Festival

Winner: Hidenobu Nagata, NTT Service Evolution Laboratories
Date: September 28, 2016
Organization: All Japan Radio & Television Commercial Confederation (ACC)

For "Cho Kabuki Supported by NTT."
Highly realistic and new forms of kabuki viewing experience are provided using the immersive telepresence technology "Kirari!".

APSIPA Industrial Distinguished Leader

Winner: Takehiro Moriya, NTT Communication Science Laboratories
Date: October 7, 2016
Organization: Asia-Pacific Signal and Information Processing Association (APSIPA)

For his extraordinary accomplishments in the field related to APSIPA scope.

Papers Published in Technical Journals and Conference Proceedings

Lightness and Brightness Match under Colored Illuminants with Special Illuminant Gradients

H. Kawamura, M. Date, T. Yamakawa, T. Kojima, M. Miyao, and A. Kojima

Proc. of AIC (International Colour Association) 2016 Interim Meeting, pp. 417–420, Santiago, Chile, October 2016.

This paper reports an investigation of perceived colors under colored illuminants with spatial illuminant gradients. In performed experiments, two types of illuminant distribution were used; in one the illuminant strength changes suddenly at the center of an image and in the other the strength changes linearly throughout the right and left side of the image. Subjects were asked to match the test patch area to identify the same luminance as the reference one (called the brightness match) or to match the area to be cut from the same piece of paper as the reference one (called the lightness match) under white illuminant or reddish illuminant. The results showed that the response of the subjects in the brightness match is affected by the luminance of the test patch area; however, with the lightness match the response is slightly more stable than the brightness match. This tendency occurred in both illuminant distribution patterns. When using a reddish illuminant, the response of the subjects was lower than that for the white illuminant.

Collapse of the Hierarchy of Constant-depth Exact Quantum Circuits

Y. Takahashi and S. Tani

Computational Complexity, Vol. 25, No. 4, pp. 849–881, December 2016.

We show that there exists a constant-depth polynomial-size quantum circuit for the OR function. We apply this circuit to constructing a constant-depth quantum circuit for the threshold function. Moreover, we show that there exists a classically hard problem that can be solved by a constant-depth quantum circuit with gates for the quantum Fourier transform.
