NTT Technical Review

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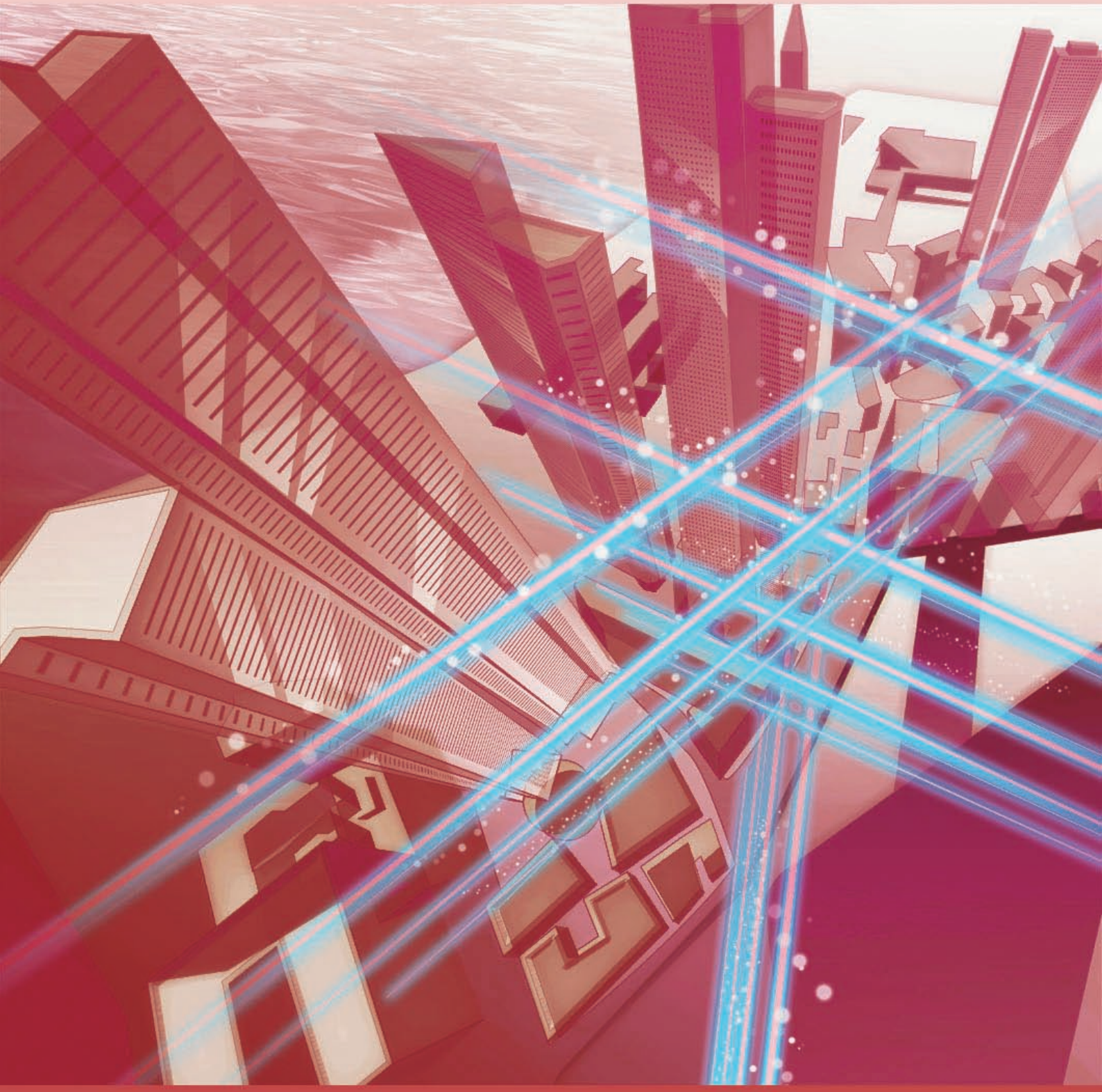

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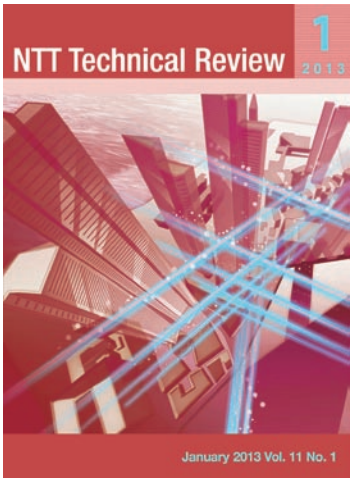

Separating Playful Exploration from Waste in R&D and Thinking while Running —2013: Toward the Next Stage—

Yasuyoshi Katayama,
Senior Executive Vice President, NTT

Overview

NTT Group's three main business domains—fixed communications, mobile communications, and cloud services—are undergoing a variety of changes, and the communications industry itself is in a period of transition. What is the mission of the NTT Group, which has the goal of being the *value partner* that customers continue to select? We asked Yasuyoshi Katayama, NTT Senior Executive Vice President, to tell us about NTT's targets for 2013.

Addressing problems now—not later—to gain a new perspective

—Mr. Katayama, it appears that your duties have expanded significantly since you became vice president. Please tell us about your aspirations as a person holding enormous responsibility.

I am actually in charge of two major areas. The first is the entire network, which I originally became involved with as director of the Technology Planning Department. I will continue in this role as we move forward.

The other area is research and development (R&D), which is, of course, very broad. For example, just in terms of technology, there are fields that I have never been involved in or had any experience in, so learning about fields I know very little about is very interesting and productive. When visiting NTT's laboratories, I have had the opportunity to attend half-day lectures given by managers and researchers. I can't say that I've always come away having a clear-cut understanding of the content covered, but that is exactly why I find new technology so interesting. As the person in charge, hearing about these new fields keeps me sharply aware of the scale of work that I must keep my eye on.

In addition, time allocation has become more important for me since taking on the duties of vice president. For example, as I meet more and more people with all sorts of viewpoints, I want to absorb as much as possible at every encounter. Regardless of how basic a matter may seem, I make it a point to ask questions without hesitation on any unclear points and to understand the situation there and then. In such a limited time, my aim is to acquire new knowledge and insights without leaving any unanswered questions.

2013: Towards the Next Stage

—As the New Year begins, what can you tell us about 2013?

NTT's Medium-term Management Strategy announced in November last year was given the title

Towards the Next Stage.

Our business domains are fixed communications, mobile communications, and cloud services. These three large domains are undergoing various changes that differ for each domain.

This new strategy points out that dealing with these changes on the basis of present-stage policies has not provided NTT with a path to future growth. It also states that these last few years have been a period of transition, and that NTT is now set to move on to the next stage.

But what specifically must we do to move on to the next stage? Up to now, our relationship with our customers has been one of a service provider in our capacity as a telecommunications carrier. From here on, however, we would like to give more attention to whether the services we provide are truly useful and appropriate for our customers.

We also need to keep in mind that those who we would like to see using our services are not just individuals but corporate entities too. We therefore need to provide services that, of course, connect the customer and NTT, but that also connect the customer with its customers and that even provide a platform for service-to-service connections. In this way, I look to grow the NTT Group by becoming that necessary partner to a company that is expanding its business.

From a provider to a value partner

—What is NTT's specific strategy for making these changes?

First and foremost, the customer must see value in choosing NTT as a partner. Needless to say, cloud and big-data technologies are going to have a big impact on society. And I believe that the smartphone gives users the feeling of being able to do something that they could not do in the past. At present, we are moving into a stage of trying to figure out how we can use such technologies and tools in an organic, systematic way.

NTT is promoting this trend making best use of its extensive experience and the know-how it has accumulated over many years. At the same time, NTT Group companies are pursuing how best to approach the creation of new networks and services. I would like to leverage this forward-looking mindset to become the company that customers seek out as a partner and to drive the change from being a provider to a value partner.

To give you an example of specific actions in this

regard, we are working to enhance our R&D efforts by setting up R&D bases in North America, where much information and R&D in relation to communications technologies are concentrated, and by building open relationships with others in this field.

In trying to produce things that could not be given form in the past or to simply create new and novel things, problems surrounding a particular R&D location can have a serious impact on results.

In North America, companies that are performing cutting-edge tests are concentrated in areas such as Silicon Valley. Since problems related to cultures and regulations can hamper the R&D process, a location that provides researchers with creative stimuli gives them the freedom to pursue the next stage as they see fit.

I myself am endeavoring to set up more channels of communication with people both inside and outside the company and inside and outside Japan. If it initially seems that no relationship is forthcoming, I have found that looking at the situation from a different angle will give me a valuable hint about how to proceed. For this reason, I think it is important that I place myself amidst the chaos and associate with as many people as possible.

Incidentally, some companies that we have acquired through mergers and acquisitions have bases in North America, and I would like to make the best use of those bases in establishing productive relationships.

Separating playful exploration and waste in R&D

—What expectations do you have of R&D?

I would like to bring together the R&D efforts of the NTT Group to provide useful services that can

have a true impact on society. Just last year we introduced new and compelling services such as Shabette Concier, a voice-agent application, and we also began to set up an infrastructure involving the network, smartphones, and other elements to further enhance our service lineup. I would like to point out that these new services that we are providing may not necessarily be the final, fixed form, but if we don't put them on the market now, we will never be able to understand our customers' response to them. With a view to receiving input from others in developing and enhancing services, I would at times like to actively pursue open innovation to make good use of wisdom from the outside.

Additionally, I truly feel that a new type of development cycle is appearing within R&D at NTT. In this cycle, someone takes an idea that someone else has talked about in passing and launches a service based on that idea even if it's still incomplete. Then, while the service is being monitored, further research is conducted to enhance it. I would like to promote further use of this effective cycle.

However, it seems that people aren't yet able to fully utilize smartphones and other advanced mobile devices. I would like to see NTT create a society in which these devices can be used in a stress-free manner through a variety of services.

We should also help to create a society that enables the elderly and physically challenged to use services without worry. This, I believe, is the mission of any company involved in the information and communications technology (ICT) industry.

For example, we are researching ways of moving a wheelchair using brain waves and detecting danger by means of a camera mounted in a person's eyeglasses. The idea here is to create conditions in which a person can easily receive a desired service by simply thinking about it.

At one time, futuristic services such as a translating telephone were things that you would see only in movies. But today, such services are entering a practical stage. The Shabette Concier phone app that I mentioned will return a spoken reply when asked a question. Services like these were just a fantasy only a few years ago, but they are now becoming a reality. Looking forward, I would like to open up even more possibilities in communication services. I believe that there is much that can be done with the R&D expertise of the NTT Group.

Of course, it goes without saying that providing the network with full support is important given the huge impact that the smartphone is having on society. Moreover, as it can no longer be said that doubling traffic doubles revenues as in the past, we must make an effort to lower network costs. For example, we are continuously researching and developing ways of increasing the capacity of a single optical fiber.

I can say that this year will be a time of many and varied trials that will help to give direction to such R&D efforts. In some cases, they will provide a basis for continuing or terminating certain R&D projects. In this regard, it is also necessary to check carefully for any duplication in R&D caused by a lack of communication between researchers and to eliminate waste when found. In particular, we have established a global R&D committee to steer R&D in North America and to investigate the presence of any waste in our globalization efforts.

However, there is a fine line between playful exploration and waste in research. Basically, I would like to see researchers include a playful spirit in their work and to be open to unexpected discoveries within the research objective given to them. Either an individual or an organization can adopt this approach. Within the larger research theme, however, I would ask each researcher to remember the role that he or she is being asked to carry out.

While an open mind and the free testing of ideas are essential to basic research, duplication in R&D that has a set direction can possibly lead to waste. I'd like to keep a close eye on that to prevent this kind of

waste.

—Could you tell us something about NTT's energy strategy?

In terms of our Green ICT activities, the planned power outages and power-saving measures that followed the Great East Japan Earthquake placed us in a very severe environment. Of course, telecommunications is an industry in which nothing can be done without energy, so it is imperative that we adopt power-saving measures on our own and reduce our energy consumption to fulfill our company mission. I am taking up the challenge of deploying telecommunications equipment and air conditioning systems with good energy efficiency and would like to propose energy-saving mechanisms that can be used outside the NTT Group by society as a whole. We are entering an era in which solar power generators will be installed in every home and school and elsewhere to provide energy for individual use as well as to provide surplus energy for sale. If the use of electric cars continues to expand, the places that produce energy and use energy will ultimately cover a wider range than ever before. Here, ICT is the best way of controlling this energy infrastructure in real time, and I would like to demonstrate technology for that purpose.

A year of trials: thinking while running

—Mr. Katayama, could you leave us with a few words for all employees of the NTT Group?

It is vitally important that we face the future with a sense of urgency. NTT DOCOMO promotes a "70% is OK at first" mindset to emphasize the importance of speed in R&D, and more and more NTT Group companies are establishing systems that recognize the need for speed and an approach that pursues R&D while on the run. I plan to promote the adoption of such a system throughout the NTT Group. Of course, this assumes that any such system will have to be refined to obtain a 100% adoption rate.

I would also like to see NTT Group employees communicate better with each other by clearly recognizing their own value while respecting the value of others. In the end, it is individuals that carry the NTT signboard on their back.

Additionally, when faced with a major problem in your work, keep cool and don't despair—seek the advice of those around you to overcome the problem.

Talking to lots of people at such a time will help you stop for a moment and assess the situation before making a decision. It might be especially helpful here if you listen to people who have been down the same road before and had the same worries.

The NTT Group is off to a good start in making the transition to the next stage. Please keep in mind what it is that you want to accomplish in that stage and what it is that you should do to achieve that. Let's combine the abilities and talents of everyone in the NTT Group to form an even greater force in moving forward.

Interviewee profile

■ Career highlights

Yasuyoshi Katayama joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1976. He became Senior Vice President and the Executive Manager of the Fundamental Services Department and Executive Manager of the Plant Planning Department of NTT WEST in 2004, Senior Vice President and General Manager of Networks of NTT WEST in 2006, and NTT Senior Vice President and Director of the Technology Planning Department in 2008. After serving as NTT Director and Executive Vice President and as Director of NTT's Technology Planning Department from 2009, he took up his present position in June 2012.

Energy and Environmental Technologies Toward a Sustainable Society

Yuji Uenishi

Abstract

The Feature Articles in this issue focus on NTT's efforts to introduce environmentally friendly and energy-efficient technology in line with objectives to establish effective business continuity planning and, ultimately, to achieve a sustainable society. The Great East Japan Earthquake in March 2011 was a forceful reminder of the importance of both of these areas. This article presents an overview of NTT's energy management technologies that are bringing us closer to a sustainable society and reviews green infrastructure technologies that help conserve natural resources.

1. Introduction

As environmental degradation due to global warming, depletion of natural resources, and loss of biodiversity (**Fig. 1**) becomes more severe, the task of solving global environmental problems is one that companies must address as part of their corporate social responsibility.

Providing information and communications technology (ICT) services to the public requires a huge amount of electric power for routers, servers, and other network equipment, as well as for air-conditioning and power-supply systems. Moreover, the ongoing deployment of optical fiber lines, the surging use of smartphones, and the sharp increases in Internet traffic to deliver large-volume and video content has further driven up power use and caused CO_2 emissions to rise as a result.

To help bring about an environmentally friendly sustainable society*, NTT Energy and Environment Systems Laboratories conducts research and development (R&D) in areas related to the NTT Group's core business activities in order to reduce CO_2 emissions that are the main cause of global warming and conserve resources as a way of contributing to a sustainable society.

* Sustainable society: A society that meets the needs of the present without compromising the ability of future generations to meet their own needs.

2. Migration to a sustainable society

NTT Energy and Environment Systems Laboratories has committed itself to creating new technologies that will reduce the CO_2 emissions and waste generated by the NTT Group's activities to zero by the year 2050, and as illustrated in **Fig. 2**, is pursuing R&D in two broad classes of technologies to help achieve this ambitious vision: *energy management technologies* that reduce CO_2 emissions and *green infrastructure technologies* that conserve natural resources.

In the aftermath of the devastating Great East Japan

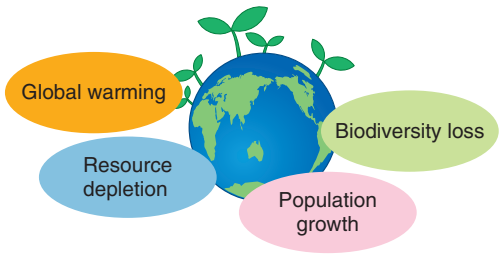

Fig. 1. Global environmental issues.

Earthquake in 2011, we learned that certain technologies are critically important: namely, energy-saving technologies that reduce energy consumption and technologies that enable a stable energy supply to ensure that ICT services—which are a critical social infrastructure—remain up and running 24 hours a day, 365 days a year through normal times as well as during disastrous events.

A schematic of a robust sustainable infrastructure that supports ICT services is shown in **Fig. 3**. The rest of this article takes a closer look at the energy management technologies and green infrastructure technologies needed to achieve a sustainable society.

2.1 Energy management technologies

An energy management system scheme that leverages and controls energy-saving, energy-storing, and energy-creating technologies to ensure that ICT services are kept up and running and available 24 hours a day, 365 days a year is under development.

2.1.1 Energy-saving technologies

The power consumed by telecom buildings and datacenters continues to increase, and it has been reported that by 2016 these facilities will require some 1.3 times the power they used in 2011 [1]. Clearly, this calls for aggressive efforts to reduce energy consumed by ICT equipment itself as well as to streamline the energy supply, air conditioning, and other functions. Some of the energy-saving technologies now being developed by the NTT Group include new energy-smart ICT equipment and ways to improve the energy efficiency of communications networks [2], as well as direct current (DC) power supply technology that supports DC power feeding in telecom buildings and datacenters [3].

We can also anticipate substantial temperature and power load fluctuations in ICT equipment now that virtual servers and networks have become so commonplace. To coordinate and harmonize the power supplies for ICT equipment with the air conditioning used to cool exhaust from that equipment, we must be able to track CPU (central processing unit) utilization, traffic loads, and other process load fluctuations and to control the amount of power consumed. A datacenter energy management system (DEMS) that will minimize these problems by coordinating and implementing optimum control between air conditioners and ICT equipment is currently under development [4].

2.1.2 Energy-storage technologies

ICT services must remain up and running not only during normal times, but also in the event of a disaster. Indeed, ICT services are even more critical when a disaster strikes. The NTT Group maintains robust backup power sources to ensure that ICT services are not interrupted by power outages. R&D work continues to focus on cost-effective high-energy-density storage batteries for telecommunications that provide

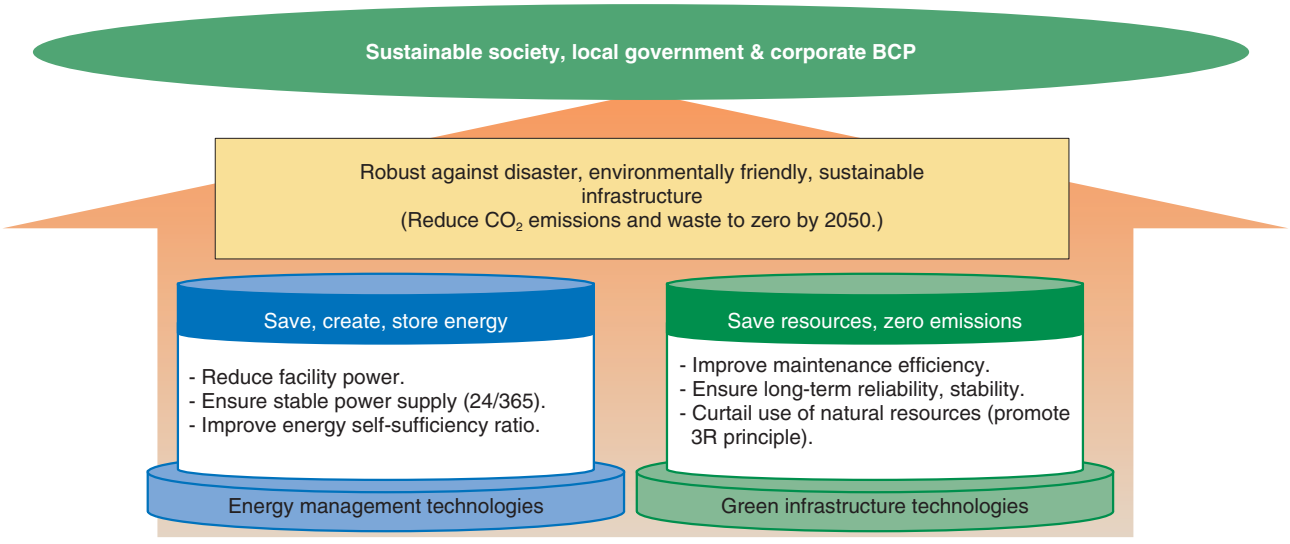

Fig. 2. R&D policy of NTT Energy and Environment Systems Laboratories.

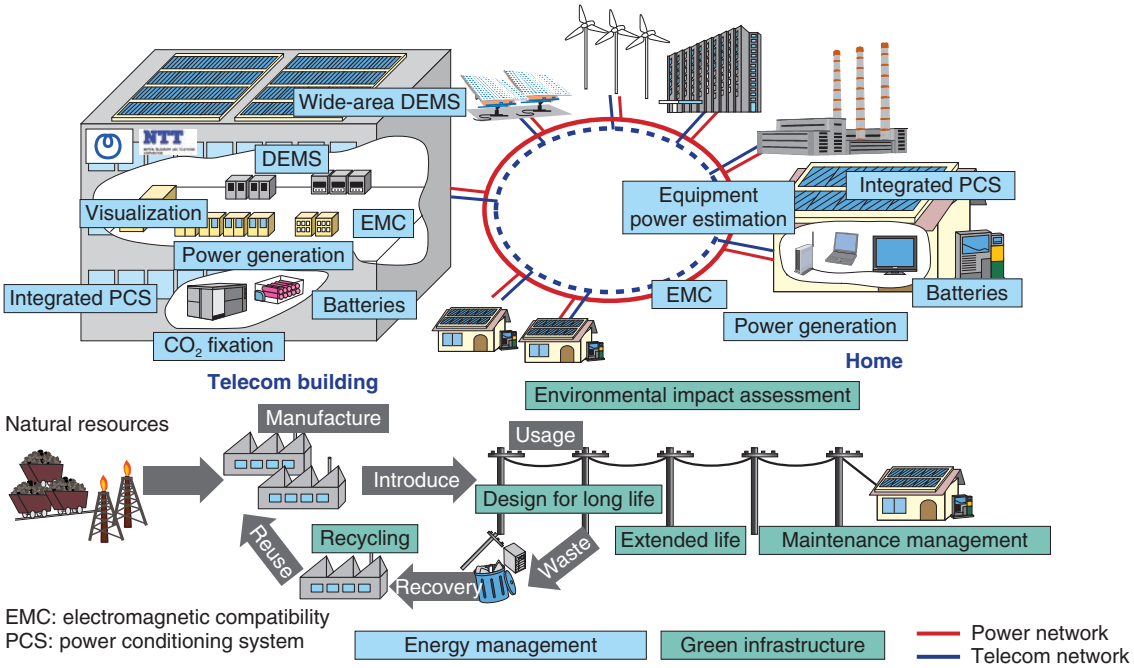

Fig. 3. Schematic of sustainable infrastructure.

the compactness and long battery life required of backup power systems.

2.1.3 Energy-creating technologies

The importance of creating low-carbon clean energy and not simply relying on commercial power became apparent in the aftermath of the Great East Japan Earthquake of March 2011. One such energy-creating technology under development at NTT Energy and Environment Systems Laboratories is the high-efficiency solid oxide fuel cell [5].

In addition, the recent implementation of a renewable energy buyback program in Japan in July 2012 is expected to accelerate the adoption of solar, wind, and other sources of renewable energy. However, the electricity-creating capacity of solar and wind power varies tremendously depending on climate and weather conditions. For the telecom sector to effectively exploit renewables, we must be able to accurately estimate and optimally control electricity generated from renewables on the supply side and energy consumed by telecom buildings and datacenters on the demand side. NTT Energy and Environment Systems Laboratories is working on an integrated PCS (power conditioning system). It provides stable centralized control that ensures a highly reliable power supply required for critical telecom loads.

A projection of energy management advances for telecom facilities that illustrates how these technologies will continue to evolve is shown in **Fig. 4**. Currently, we are seeing rapid expansion of the visualization capabilities that enable us to observe electrical power, temperature, and other pertinent data for entire buildings and for individual pieces of equipment. NTT Energy and Environment Systems Laboratories is also developing a way to visualize energy demand situations and to implement demand-side optimum control using DEMSs, DC power supply, and other tools, while seeking to improve energy efficiency. Finally, through a combination of storage batteries and solar power generation, we are working on a two-way (supply and demand) optimum energy control scheme covering a wide area that implements a robust sustainable infrastructure 24 hours a day, 365 days a year.

2.2 Green infrastructure technologies

As Japan's flagship provider of ICT services, the NTT Group owns a vast amount of equipment and resources including ICT equipment, telephone poles, and communication cabling. All of this equipment is eventually taken out of service when it reaches the end of its useful life or when equipment is overhauled to accommodate new systems. The NTT Group discards close to 800,000 tons of waste every year but

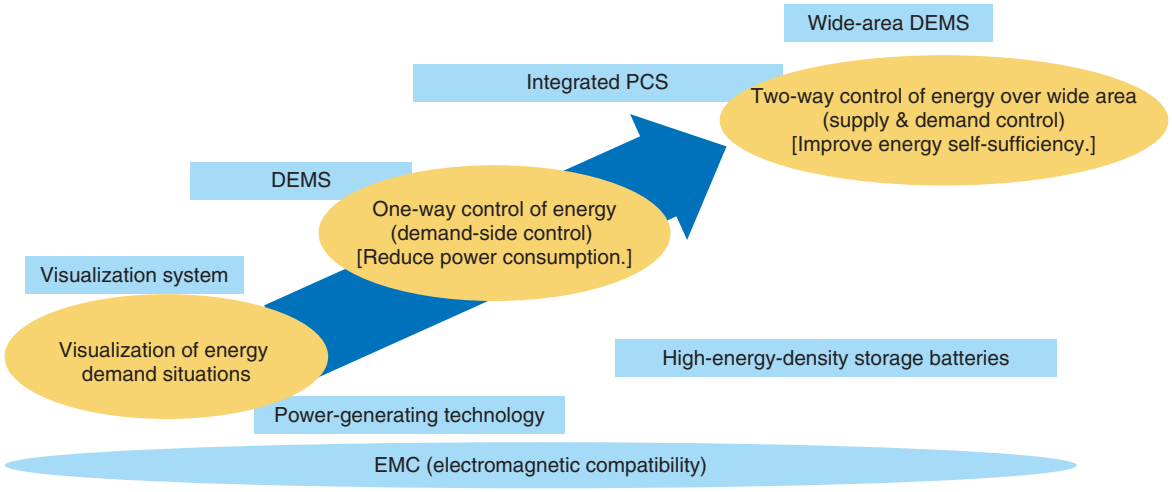

Fig. 4. Projected upgrade of energy management.

is now pursuing an ambitious program to slash company-generated waste to zero emission by reusing and recycling obsolete equipment and other materials. NTT Energy and Environment Systems Laboratories has stepped up resource-saving R&D initiatives by focusing on: (1) life-prolonging technologies that extend the useful service life of resources for as long as possible and (2) recycling technologies that promote reuse of value added materials. Specific initiatives include analyzing the breakdown mechanisms of materials, introducing technologies to extend the life of materials, developing diagnostic tools for visualizing the vulnerability to salt damage and other risks [6], designing equipment for long life and durability that minimizes the amount of resources going into telecom equipment from the time it is manufactured until it reaches the end of its useful life and is taken out of service, and finally, using recycling-friendly technologies to facilitate disassembly of equipment and easy salvage of rare metals and other useful components.

3. ICT utilization to reduce environmental impact on society

We are doing everything possible to reduce the amount of energy needed to deliver ICT services, but ICT utilization by its very nature provides a number of other energy-saving benefits. For example, by streamlining industrial activities and by reducing the need to physically travel (e.g., through videoconferencing) and transport goods, an enormous amount of energy is saved, and the associated CO_2 emissions are eliminated. To objectively quantify and assess the impact of these various factors, we created an ICT Service Environmental Impact Assessment model that we have proposed as an international standard [7]. Used in conjunction with a *Solution Eco Label* system [8], this model is helping to support and promote the NTT Group's environmental initiatives and policies.

4. Conclusion

This article offered a broad overview of NTT Energy and Environment Systems Laboratories' R&D objectives and initiatives. We recognize the importance of business continuity planning and a sustainable society, so we have redoubled our commitment to these objectives in line with our corporate responsibility to society. We are also committed to the development and deployment of a robust sustainable telecom infrastructure that remains up and running through good times and disasters alike 24 hours a day, 365 days a year.

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Yuji Uenishi

Director of NTT Energy and Environment Systems Laboratories.

He received the B.E., M.S., and Ph.D. degrees in applied physics from Osaka University in 1982, 1984, and 1997, respectively. In 1984, he joined the Musashino Electrical Communication Laboratories of Nippon Telegraph and Telephone Public Corporation (now NTT), where he was engaged in R&D of micro-optical integrated devices. He served as Branch Manager of the Aomori branch office in 2009 and moved to NTT Energy and Environment Systems Laboratories in 2012. He has mainly been studying the technology for integrated MEMS (microelectromechanical systems) and environmental technology. He is a senior member of IEEE and a member of the Japan Society of Applied Physics.

Reducing Datacenter Energy Consumption Using Coordinated ICT-cooling Control Technology of Datacenter Energy Management System

Masayuki Nakamura, Akira Takeuchi, and Hiroyuki Enomoto

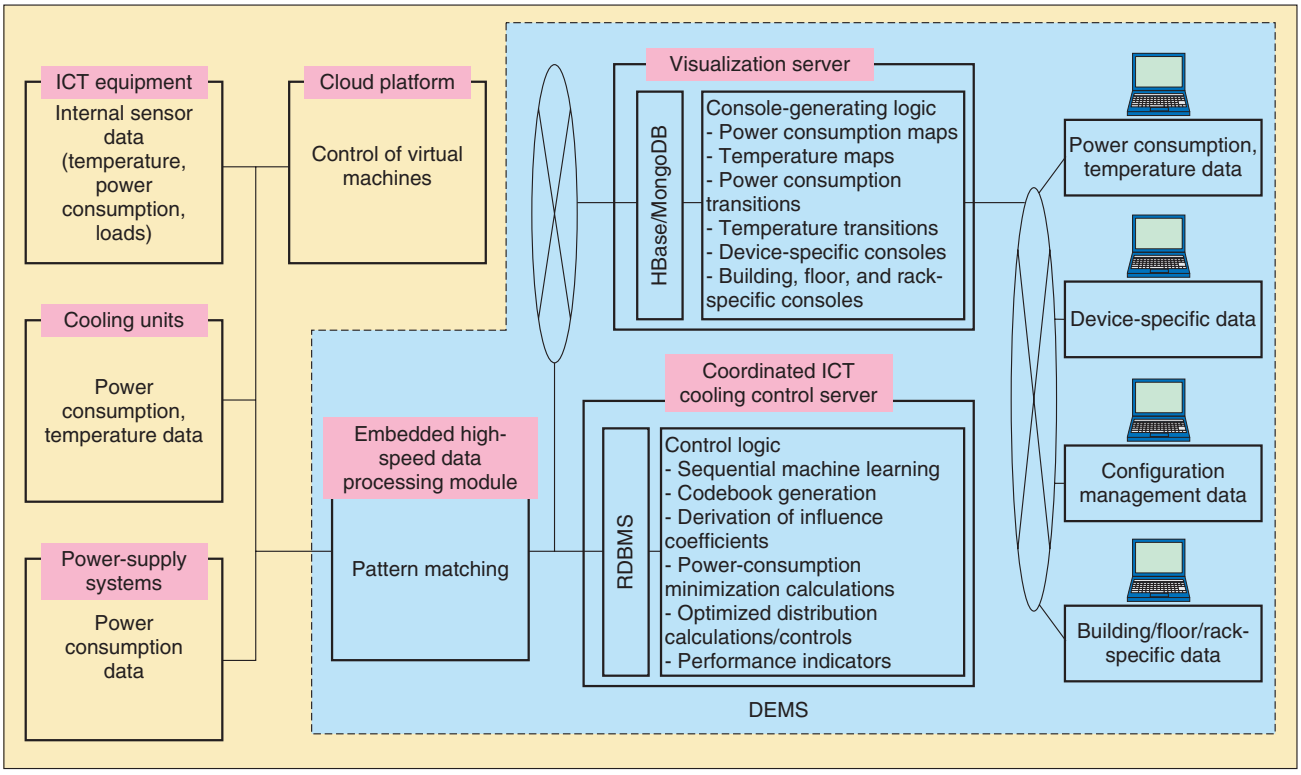
Abstract

This article describes research efforts underway in NTT Energy and Environment Systems Laboratories in the area of datacenter energy management systems (DEMSs), which are systems designed to reduce energy consumption in datacenters and other telecommunication buildings. We present a new energy-saving system that comprises coordinated control of multiple cooling systems to minimize cooling power consumption, integration with information and communications technology (ICT) equipment to extend the benefits of the cooling-system controls, and high-speed data processing that can be adapted to large-scale datacenters.

1. Introduction

Energy consumption in datacenters has been increasing annually in recent years, driven by the rapid growth of cloud services. Information and communications technology (ICT) equipment, cooling units, and power supply systems account for the majority of energy consumed in datacenters. The energy use breakdown in one example revealed that 45% of the total energy was consumed by ICT equipment, 30% by cooling units, and 18% by power supply systems [1]. NTT has been researching and developing datacenter energy management systems (DEMSs) as a technology to cut energy consumption in datacenters and telecommunication buildings [2]. Our research has led to advances in coordinated ICT-cooling control technology that links multiple cooling units and regulates load distributions among ICT equipment to lower the total energy costs of ICT equipment, power supply systems, and cooling units. We have also examined high-speed data processing technology designed to process the large amounts of device information within a datacenter.

A block diagram of the DEMS-coordinated ICT-cooling control architecture is shown in **Fig. 1**. The DEMS consists of a visualization server that enables operators to view temperatures and power consumption within the datacenter, a coordinated ICT-cooling control server, and an embedded high-speed data processing module. The visualization server collects temperature, power consumption, and load data using sensors inside ICT equipment rather than external sensors. It then provides fine distributions of the temperatures and power consumption of all the devices within the datacenter. The coordinated ICT-cooling control server takes the visualization server's sensor data and calculates the optimal cooling settings and ICT equipment load distributions to minimize the power consumption of cooling units and ICT equipment. The server then accordingly adjusts the cooling



RDBMS: relational database management system [3]

Fig. 1. Block diagram of DEMS-coordinated ICT-cooling control architecture.

controls and controls the ICT equipment's virtual machines and power supply systems via a cloud platform. The embedded high-speed data processing module quickly implements the optimized cooling settings and load distributions. It does this not by recalculating optimized values but by implementing pattern matching of sensor data using a codebook of optimal cooling settings and optimal load distributions calculated by the coordinated ICT-cooling control server.

2. Coordinated ICT-cooling control technology

Cooling unit assets located in datacenters and telecommunication buildings have conventionally been operated independently of other control systems. NTT Energy and Environment Systems Laboratories in partnership with NTT Facilities, Inc., has been working to raise cooling efficiency by unifying the controls that manage ICT equipment and multiple cooling units. An optimization problem can be formulated to find the combination of cooling settings that 1) ensure ICT equipment does not exceed its upper temperature limits and 2) minimize the overall power consumption. A flowchart governing the coordinated control of multiple cooling units is shown in **Fig. 2**.

The first step necessary in implementing such controls is to develop a technique to estimate ICT equipment temperatures in response to changes in cooling unit settings. A temperature estimation equation can be found by analyzing data obtained during actual datacenter operation for the correlation between cooling-unit temperature changes and ICT equipment temperature changes.

A model of power consumption by cooling units is also necessary. The problem is the difficulty and calculation cost of deriving an accurate model, since cooling-unit power consumption is affected by multiple parameters.

To test and demonstrate the savings in cooling energy using the control flowchart mentioned above, we decided to use as our test case a linear model of cooling temperature settings for temperature estimates and cooling-unit power consumption. An automatic control system using prototype software

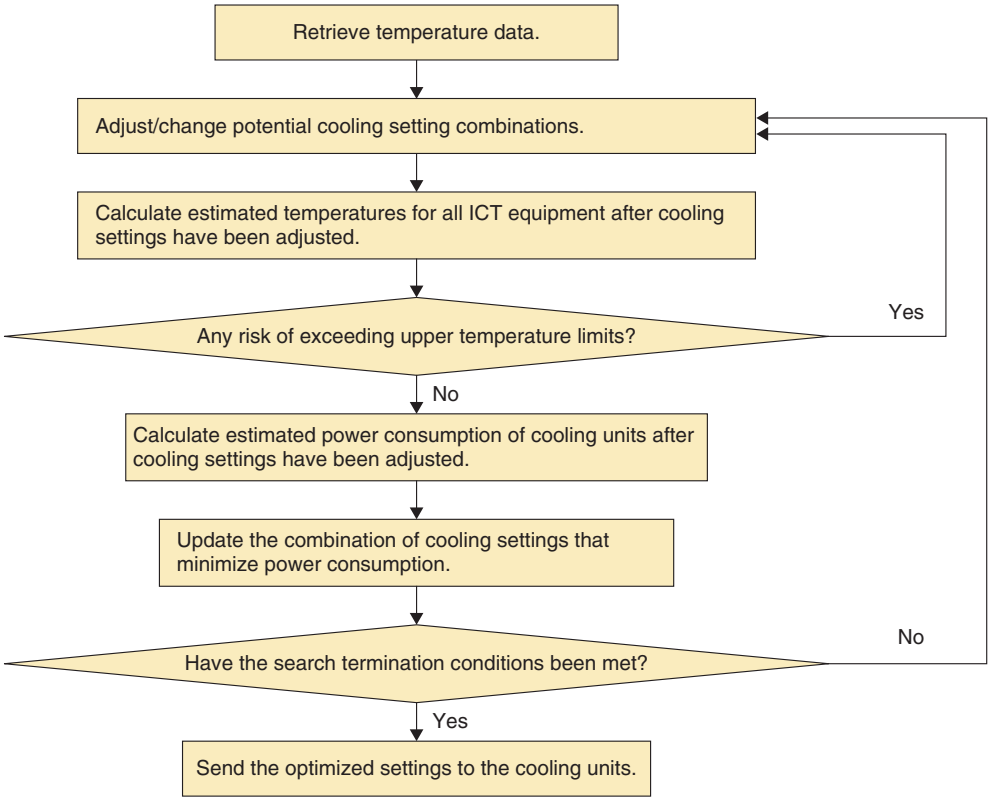


Fig. 2. Flowchart of coordinated control over multiple cooling units.

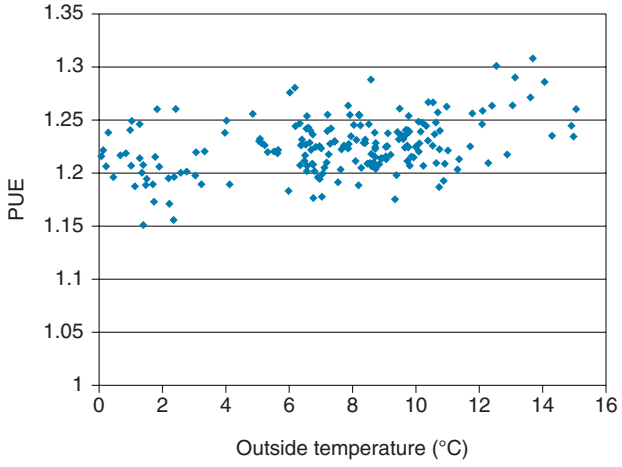


Fig. 3. Hourly correlations between PUE and outside temperature.

was constructed in a server room containing 9 cooling units and over 1000 operating servers. The test results are shown in **Figs. 3** and **4**. The test system obtained an average power usage effectiveness (PUE) [4] of 1.225 while maintaining ICT equipment temperatures at proper levels (at or under 27°C). Although the trials were done in an environment conducive to favorable PUE values, as aisle capping* was

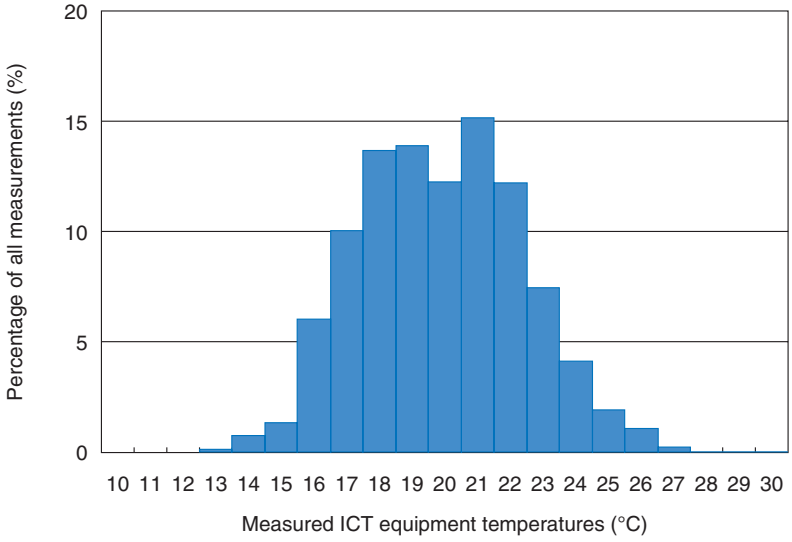


Fig. 4. Distribution of measured temperatures.

implemented in a season with low external temperatures, the system did demonstrate that practical results could be achieved even with a linear model for temperature estimates and power consumption.

We believe that in addition to balanced control of multiple cooling units, coordinated ICT-cooling controls that regulate ICT equipment loads can further reduce datacenter energy consumption. Controlling ICT equipment via cloud platforms can reduce the number of pieces of equipment in operation and consequently reduce the load on the cooling system. Additionally, further controls of the loads placed on working ICT equipment can be added to raise the cooling system's efficiency. In this way, coordinated ICT-cooling control technology can cut the overall power consumption of ICT equipment while simultaneously reducing the cooling system's energy costs. This leads to the problem of determining which ICT equipment to run and how to distribute the load. At a typical datacenter, warm exhaust air of ICT equipment is recirculated with the cold supply air to other ICT equipment, and this lowers the cooling system's efficiency. Thus, governing loads in such a way as to minimize the recirculation of exhaust air is an effective means of reducing cooling power consumption.

The DEMS uses a temperature estimation model that includes the temperature relationship between cooling and ICT equipment to forecast ICT equipment temperatures for a given load situation. Next, the DEMS sets limiting conditions on load distributions to implement the required cloud services with an ICT information model. This model, provided from a cloud platform, describes the relationship between cloud services and the ICT equipment necessary to deliver the cloud services. The DEMS finds a power consumption model for the ICT equipment, power supply systems, and cooling units and calculates cooling settings and load distributions that will minimize power consumption while meeting temperature conditions and load distribution constraints derived from the temperature estimation model and the ICT information model. The calculated load distribution is sent to a cloud platform, which adjusts the ICT equipment and the power supply systems. Cooling units are controlled following the calculated cooling settings (**Fig. 5**).

In datacenters that have areas with high and low volumes of recirculated heat from ICT equipment, hot spots—where ICT equipment near high recirculation areas runs hotter than that near low recirculation areas—will form if loads are distributed uniformly. In these cases, the cooling system works to eliminate the hot spots so that no ICT equipment operates above their upper temperature limits. Unfortunately, this results in overcooling of ICT equipment near low-recirculation areas. Without proper load distribution controls, the existence of excessively cooled ICT equipment means the cooling system is

* Aisle capping: an airflow control method that divides cool supply air and warm exhaust air by compartmentalizing the aisles between racks with walls or ceilings.

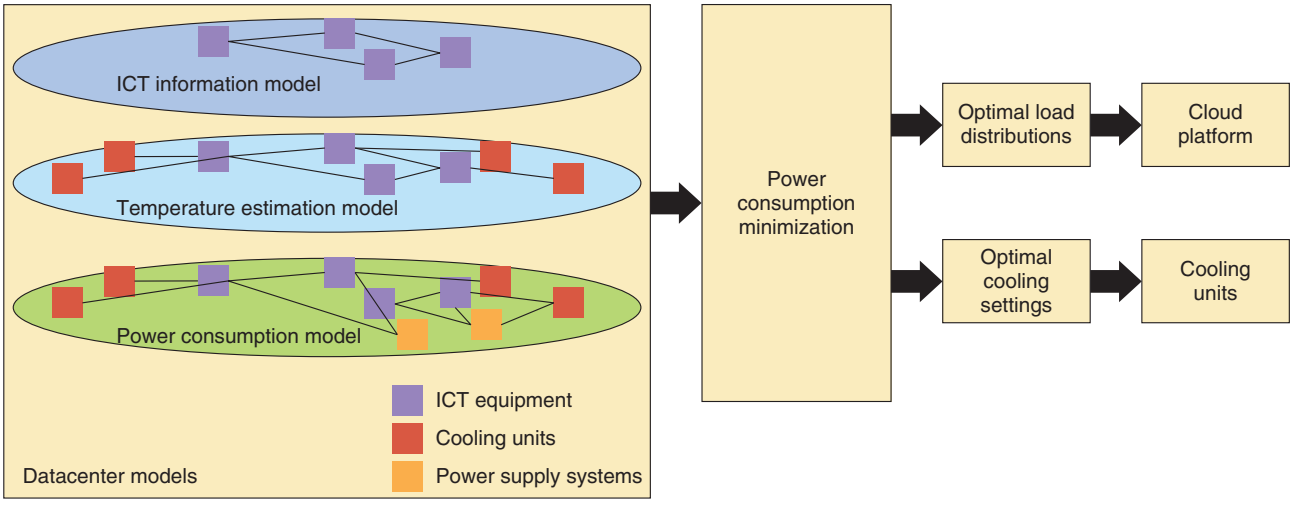


Fig. 5. Optimization of cooling settings and load distributions using coordinated ICT-cooling controls.

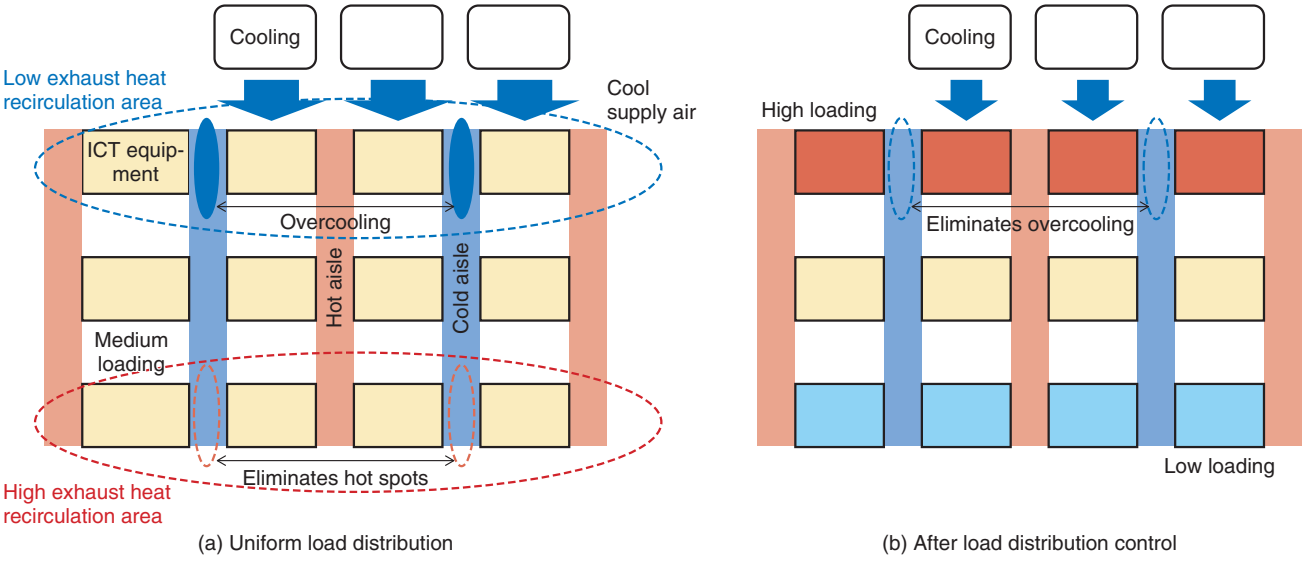
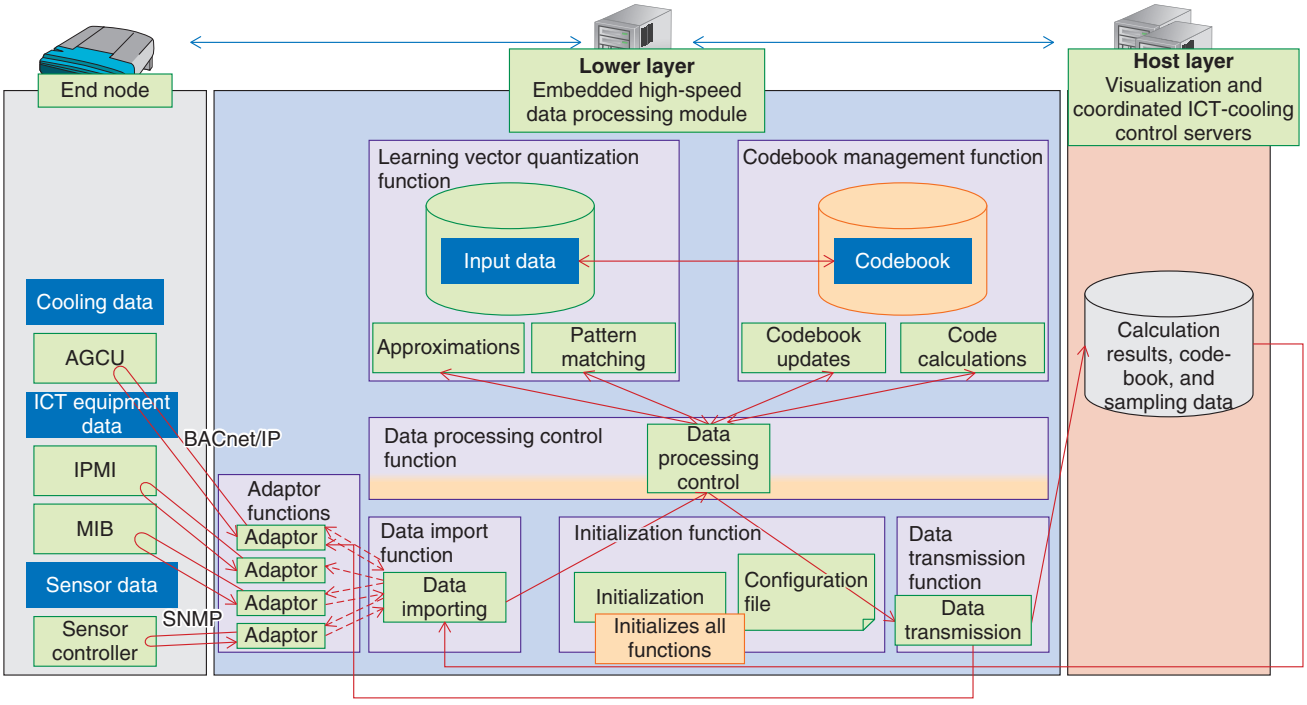


Fig. 6. Effect of load distribution control (overhead view of datacenter room).

using more energy than necessary. The DEMS, however, implements load distribution controls to allocate larger loads to ICT equipment near low-recirculation areas and lighter loads to that near high-recirculation areas and, thus, equalizes temperatures between devices. The DEMS combines load controls with coordinated cooling unit controls to calculate optimal cooling settings and eliminate overcooling conditions (**Fig. 6**). In the actual system, the relative amount of heat recirculation is accounted for in the temperature estimation model that describes the temperature relationship between cooling and ICT equipment. In the model, the ICT equipment temperature is given as a function of the cooling settings and the load distribution. The DEMS then calculates the combination of cooling settings and load distributions that both meets ICT equipment maximum temperature limits and minimizes cooling power consumption. This optimization uses mathematical programming and other techniques.



BACnet/IP: building automation and control network, Internet protocol

Fig. 7. Block diagram of functions from high-speed processing technology for time-series numeric data.

3. High-speed processing technology for time-series numerical data

When the DEMS must collect data from thousands of pieces of ICT equipment in a datacenter or telecommunication building, and thousands of external sensors are installed to collect temperature and power consumption data, the sensor maintenance operations become exceedingly complex, and the cost is prohibitive. To overcome these problems, we investigated the possibility of collecting temperature, power consumption, and other data of ICT equipment using standard protocols, for example, the simple network management protocol (SNMP) or the Intelligent Platform Management Interface (IPMI), to construct a highly reliable, inexpensive, sensor-less system. Another issue we faced was how to process data inexpensively and energy-efficiently when calculating the optimal settings for multiple cooling units and the optimal load distribution among hundreds of pieces of ICT equipment from large data sets. Ordinary hardware solutions that scale up to meet increased calculation costs (i.e., distributing the processing load over additional servers) result in greater power consumption and higher costs.

Our solution was to focus on a scalable architecture that contributes to reducing power consumption. In the DEMS data collection layer (lower layer), we implemented a high-speed processing module specialized for time-series numeric data that has interfaces to collect data from SNMP management information bases (MIBs) and from IPMIs. This module makes rapid adjustments to cooling unit controls and ICT equipment load distributions based on the collected data to minimize overall power consumption (**Fig. 7**).

The module collects cooling data, ICT equipment data, and other external sensor data through interface adaptors with air-conditioner group control units (AGCUs), MIBs, and IPMIs. The module manages a codebook generated from optimization calculations run by the host server and from input data in order to effect cooling controls and ICT equipment load distributions. Learning vector quantization is used for codebook pattern matching with sensor data as the input. In this way, quasi-optimal cooling settings and load distributions are found without redoing the optimization calculations, which would require significant

calculation costs. The quasi-optimal settings are sent to the cooling system and cloud platforms via interface adaptors to control the actual cooling units and ICT equipment. The module is capable of very high-speed processing because it is done in memory without any database access. We also believe the module can be implemented with inexpensive hardware because the approach uses quasi-optimal solutions instead of combinatorial computing and other costly optimization calculations.

4. Future research directions

NTT is moving ahead with energy-efficient datacenter trials in which the cooling and ICT control technology discussed in this article will be linked with cloud platforms.

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Secondary Batteries and Fuel Cells for Telecommunication Facilities with Improved Tolerance to Power Outages

Ryuichi Kobayashi, Katsuya Hayashi, and Satoshi Sugita

Abstract

The long-lasting commercial power outage caused by the catastrophic earthquake in eastern Japan in 2011 demonstrated the importance of the power supply in providing continuous telecommunication services. This article introduces an approach to power supply to ensure that telecommunication services operate normally in all situations and describes the development of high energy density secondary batteries and highly efficient fuel cells to achieve energy storage and generation for that purpose.

1. Introduction

The NTT Group uses about 1% of the total electrical power produced in Japan (8.9 trillion kWh per year) to provide telecommunication services, so reducing that figure is important from environmental and energy viewpoints. Furthermore, the damage to NTT's telecommunication facilities caused by the Great East Japan Earthquake in March 2011 amounted to over 100 trillion yen [1]. The role of telecommunication services in the event of disasters such as earthquakes, floods, and typhoons is increasing in importance, and it is therefore necessary to ensure that services are provided continuously at all times. One requirement in achieving continuous service is to maintain the supply of power to telecommunication facilities.

Many telecommunication facilities operate on commercial power and so are equipped with lead-acid batteries for a backup power supply in the event of power outages. However, the outages caused by the catastrophic earthquake in 2011 exceeded all possible backup times. Thus, service continuation in such circumstances requires a reduced dependence on commercial power and an extended backup time.

Three strategies can be considered to address issues concerning the power supply to telecommunication facilities (**Fig. 1**). One is to extend the backup time to cope with power outages. Another is to implement a cut or shift in peak usage to deal with power supply shortages. The third strategy is to reduce the dependence on commercial power by generating power locally and to ensure that important installations receive a certain minimum amount of power. In order to give telecommunication facilities improved tolerance to power outages, NTT Energy and Environment Systems Laboratories has been conducting research and development (R&D) of secondary battery and fuel cell technologies for implementing these strategies.

2. High-energy-density secondary batteries

2.1 Trends in secondary battery R&D

Coping with long-term power outages requires higher storage capacity in order to increase the backup time. For example, if backup time is extended from 3 hours to 24 hours, eight times as much storage is required. Current power supply backup systems mainly use lead-acid batteries. However, it is often not possible to provide the space needed for an eightfold increase in the number of batteries. In other

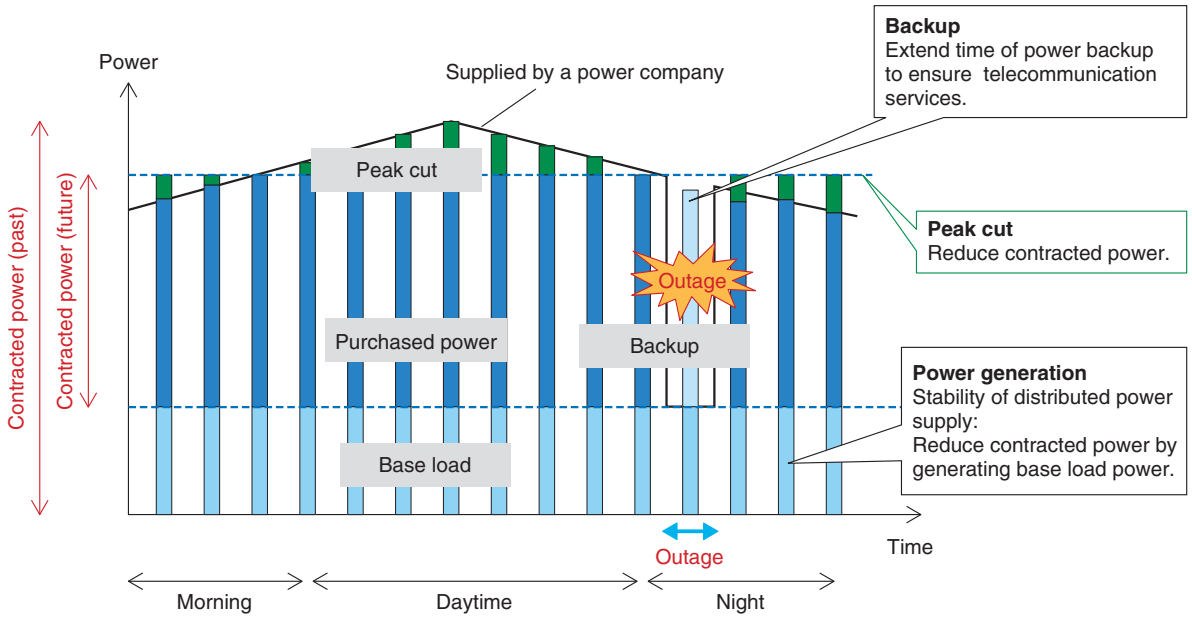


Fig.1. Measures to improve telecommunication facility tolerance to outages.

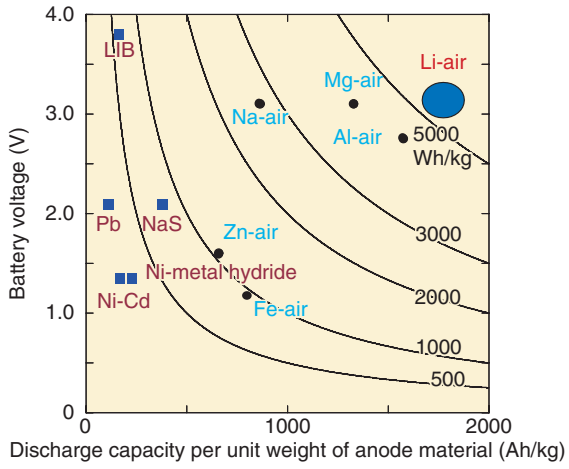


Fig. 2. Limiting energy density for various batteries.

words, it is desirable to install batteries that have eight times the capacity (eight times the energy density) of lead-acid batteries in the same installation space.

Currently, the leading high-energy-density batteries are the lithium-ion batteries (LIBs) that are used in notebook computers, cell phones, smartphones, and even electric vehicles (EVs). LIBs have been commercially available since 1991. However, current EVs are limited to a short driving range of about 100 km to 200 km on a single charge. To extend the range to 500 km per charge, next-generation batteries that have higher energy density (post-LIBs) are currently being developed. Extending telecommunication facility power backup to 24 hours also requires high-energy-density post-LIB battery technology.

Post-LIBs include air batteries that use the oxygen in air. These batteries have been attracting attention for their potential use in achieving long-term electricity backup [2]. The calculated limiting energy densities for various air batteries are shown in **Fig. 2**, and that of LIB is indicated for comparison. Here, the limiting energy density is calculated under the assumption that the battery contains only the anode and cathode materials, which are directly related to the battery reaction. Of course, all actual batteries contain materials that are not directly related to the reaction, for example, electrolytes, separators, and current collectors. Thus, the limiting energy density is not available in practice; the effective capacity of real batteries is only about 25–50% of that value.

As we can see in Fig. 2, each of the air batteries has a higher limiting energy density than the LIB. This is because air batteries obtain the anode material, which is oxygen, from the air, so the entire battery consists only of the cathode material. Accordingly, the usable capacity is near the limiting energy density. In

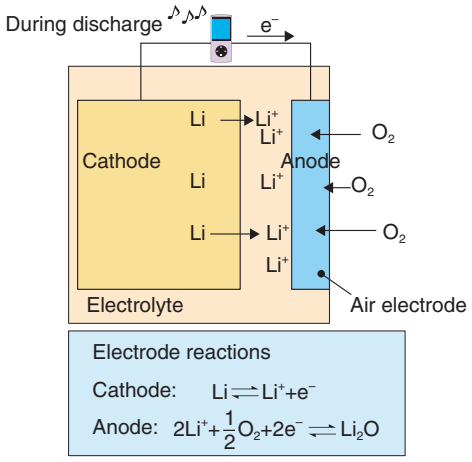


Fig. 3. Operating principle of lithium-air battery (discharge).

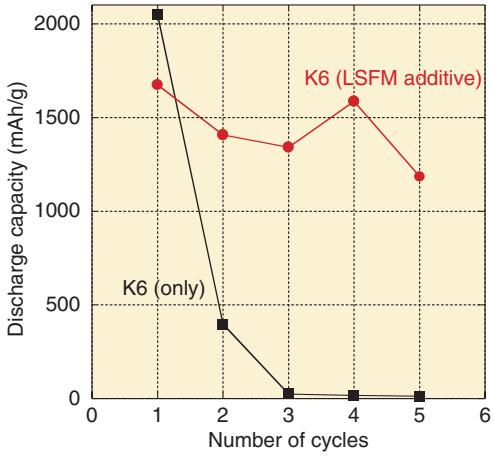


Fig. 5. Charge-discharge cycle characteristics with $La_{0.6}Sr_{0.4}Fe_{0.6}Mn_{0.4}O_3$ (LSFM) catalyst.

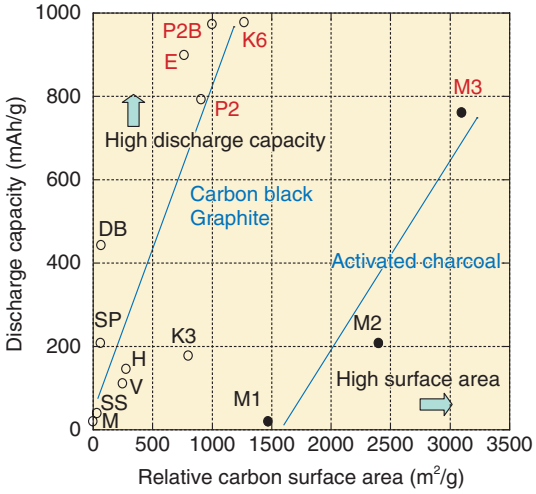


Fig. 4. Carbon surface area and discharge capacity.

particular, the lithium-air battery has the highest limiting energy density, over ten times that of the LIB.

2.2 Lithium-air batteries

When a lithium-air battery is discharging (**Fig. 3**), oxygen is taken from the air at the anode, which is also called the air electrode. At the same time, lithium ions from the lithium cathode dissolve into the electrolyte at the cathode. The lithium ions from the electrolyte react with oxygen at the anode to form lithium oxide. The reverse reaction occurs when the battery is charging. This operation is expressed by the following chemical reactions.

Anode reaction: $(x/2)O_2 + Li^+ + e^- \Leftrightarrow LiO_x$
Cathode reaction: $Li \Leftrightarrow Li^+ + e^-$
Overall battery reaction: $(x/2)O_2 + Li \rightarrow LiO_x$

Lithium can be used for the cathode of a lithium-air battery, and the same technology for lithium ion batteries can most likely be applied for the electrolyte, separator, etc. Therefore, the key factors for implementing rechargeable air batteries are the air electrode and the technologies related to it.

The discharge characteristics of the various forms of carbon materials used in the development of the air electrode have been studied and compared. The relationship of capacity to relative surface area and unit weight for various carbon materials (**Fig. 4**) shows that the capacity tends to increase with the relative surface areas of the different forms of carbon; it increases in the order: carbon black, graphite, and activated charcoal. Among those, K6 (a form of carbon black) has the highest capacity.

Although K6 features high capacity, the capacity decreases to almost zero after charging and discharging (i.e., one charge/discharge cycle) about three times (**Fig. 5**). That effect is believed to result from educed lithium compounds on the carbon remaining on the electrode without being decomposed.

Therefore, catalysts for promoting the decomposition of the chemical products of cell discharge and thus, for retaining greater capacity over more charge/discharge cycles have been studied [3]. The result of that work led to the use of the oxide $La_{0.6}Sr_{0.4}Fe_{0.6}Mn_{0.4}O_3$ as an additive to the anode carbon. Although

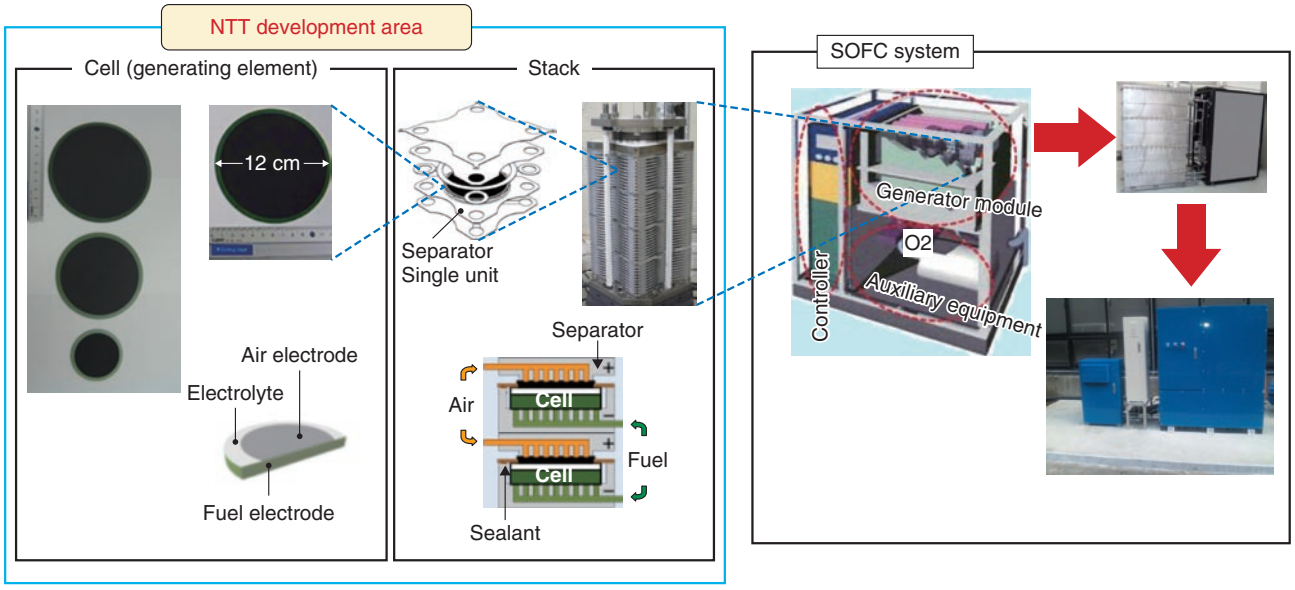


Fig. 6. Solid oxide fuel cell.

this additive reduced the original capacity by about 20%, that capacity was retained over repeated charge/discharge cycles.

In the future, we will aim for even higher capacity and good charge/discharge cycle characteristics in order to achieve practical lithium-air batteries.

3. Fuel cells

3.1 Trends in fuel cell technology and R&D

Fuel cells generate electrical power cleanly and with high efficiency by extracting electrical energy from the process of forming water from hydrogen and oxygen. Fuel cell co-generation systems for home use have been sold under the name Ene-Farm since 2009. In the beginning, only polymer electrolyte fuel cells (PEFCs) were available, but later, highly efficient solid oxide fuel cells (SOFCs) became commercially available, and their use is spreading.

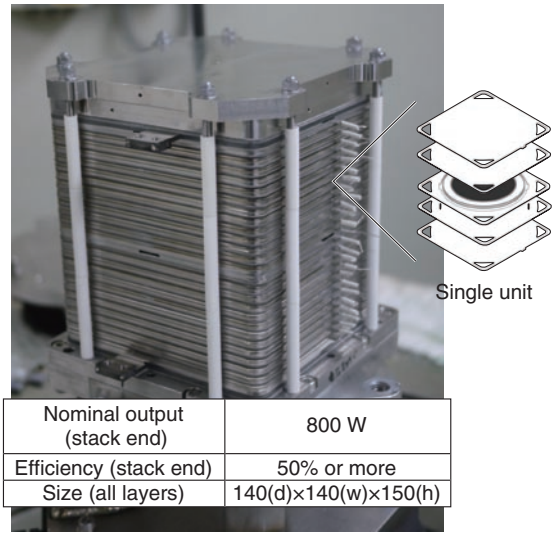
SOFCs have an operating temperature range from 700°C to 1000°C and high power generation efficiency relative to other fuel cells. They are therefore suitable for providing stable electrical power to facilities that have no thermal demand, such as telecommunication facilities. NTT Environment and Energy Systems Laboratories has focused on that point to conduct R&D on SOFCs [4]–[6]. This R&D is focused on the cell and stack technologies that make up the power generating component and the core of a fuel cell system (**Fig. 6**). We have formed an alliance with outside vendors to collaborate in developing a system that is practical in terms of a lower cost, longer life, and smaller size.

3.2 SOFC cell and stacks

An anode support structure shaped like a round plate (Fig. 6) was chosen for the cell because it can provide high output density. For the air electrode, $LaNi_{0.6}Fe_{0.4}O_3$ is used, and zirconium stabilized with scandia and alumina serves as the electrolyte. Both are proprietary materials developed by NTT. These materials have very low internal resistance, and consequently, the cell has excellent output characteristics and exhibits little degradation [4].

The stack consists of single-cell units that have independent gas flow paths. They comprise multiple heat-resistant alloy separators and the abovementioned cells. The required output can be obtained by stacking the appropriate number of cell units. The 40-unit stack shown in Fig. 6 attains an output of about 1.5 kW with an efficiency of over 60% [5], [6].

We are currently investigating ways to reduce the stack size in order to improve the output power density per unit stack volume. The more compact stack is shown in **Fig. 7**. This stack has 30% less volume per unit output compared with the stack shown in Fig. 6, even though its performance for a single unit is the same. Characteristics for the minimized stack that is



Nominal output (stack end)	800 W
Efficiency (stack end)	50% or more
Size (all layers)	140(d)×140(w)×150(h)

Fig. 7. Compact cell stack.

constructed with 12 single units are presented in **Fig. 8**. The cell units are numbered from the bottom up on the horizontal axis. The generated voltage per single unit and for various fuel consumption rates (labeled UF for utilization factor) is shown on the vertical axis. We can see from the figure that there is low variance in the voltage of each single unit, and the power generation characteristics are stable, even when the fuel consumption rate varies. Long-term continuous generation tests are currently underway, and the results obtained so far indicate a degradation rate from about 0.2–0.25% per 1000 hours during stable generation, which represents good lifetime characteristics of from four to five years of continuous use.

In the future, we will focus our efforts on reducing the size of SOFCs, extending their lifetime, and developing applications for inexpensive materials and processes in order to achieve a practical SOFC.

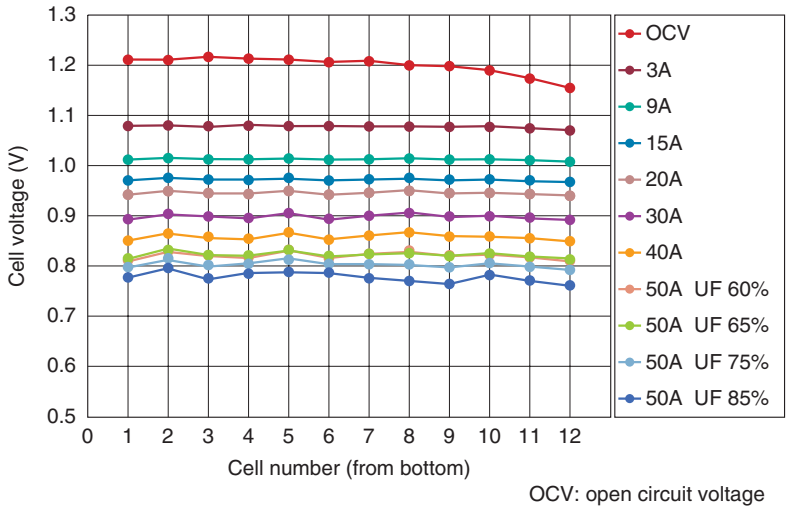


Fig. 8. Power generation characteristics of stacked cells.

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Increasing the Lifetime and Reliability of Telecommunication Plant Materials

Yukitoshi Takeshita, Zhang Xiaoxi, Akira Sugiyama, and Takashi Sawada

Abstract

We are researching and developing techniques to strengthen the reliability and environmental adaptation of telecommunication facilities in order to increase their lifetime. This article introduces examples of techniques to determine the degradation of coatings on telecommunication steel towers. An application to lightning damage prediction is also introduced as a risk-based facility maintenance strategy to evaluate the need for maintenance depending on the degree of risk.

1. Overview of telecommunication facilities

An enormous quantity of telecommunication plant materials is required to provide information and communications technology (ICT) services to communities. An example of some of the materials composing the outdoor infrastructure in the telecommunication field is shown in **Fig. 1**. NTT owns around 700,000 km of optical fiber cable, more than 1,100,000 km of long metal cable, approximately 12,000,000 telephone poles, and nearly 620,000 km of long cable conduits throughout Japan. Consequently, it is crucial to reduce the impact of these materials on the environment and to increase maintenance efficiency [1], [2]. We have investigated this issue focusing on the areas of materials science and a risk management system. In this article, we describe examples of techniques to determine the degradation of coatings on steel towers used for wireless telecommunications, and we introduce a risk-based facility maintenance application to predict lightning damage.

2. Technique to determine degradation of coatings

Steel towers and cable conduits under bridges are examples of outdoor equipment that are protected by organic coatings [3]. Steel towers have been installed at various NTT locations, and the maintenance of these huge structures includes periodical repainting.

2.1 Objective of degradation determination

Visual observation and adhesion testing are normally performed before NTT's steel towers are repainted. A practical cross-cut test (JIS K 5600-6-6) is used to evaluate adhesion. This involves cutting a section of the coating film into nine squares, placing adhesive tape over them, and then peeling off the tape. The number of remaining squares corresponds to the adhesion force. This is a simple evaluation method, although it is not very precise for detecting the onset of degradation. If the degradation goes undetected, corrosion will proceed, and this often results in the need to replace steel parts, which increases the maintenance cost. Therefore, we are developing new techniques to evaluate degradation.

2.2 Evaluation of film performance and material properties

We have introduced various coatings at NTT such as solvent-type coatings that are applied to steel towers and cable conduits used on bridges as well as powder coatings that are coated on steel telephone poles.

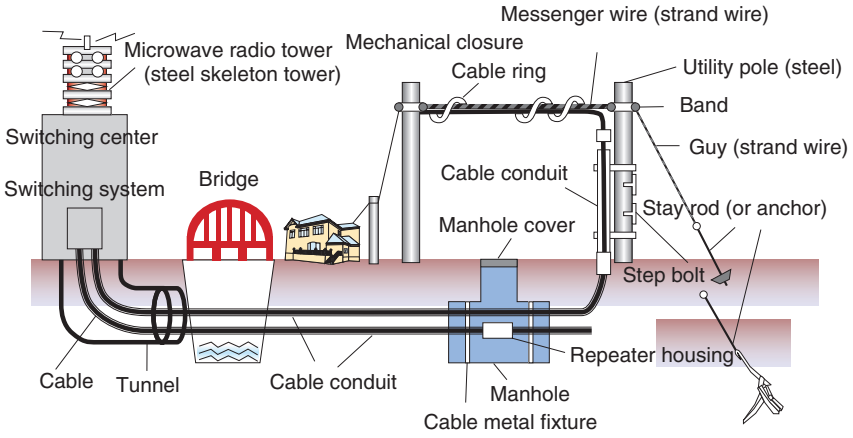

Fig. 1. Outdoor components of telecommunication equipment.

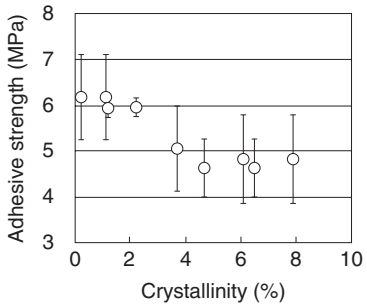

Fig. 2. Relationship between adhesive strength and crystallinity.

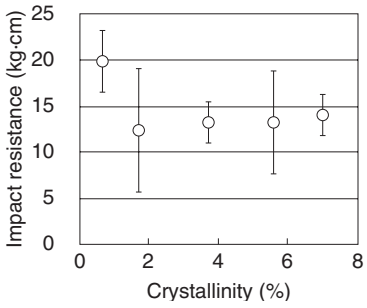

Fig. 3. Relationship between impact resistance and crystallinity.

It is possible to efficiently determine the film degradation by clarifying the relationship between film performance, that is, the film's adhesive strength and impact resistance, and the material properties. We have focused on the material properties, which are measurable and useful for determining the appropriate time to repaint and replace components.

The relationship between the adhesive strength and crystallinity, one of the material properties [4], is shown in **Fig. 2** for powder coatings. The crystallinity is the ratio of crystalline parts in a crystalline and non-crystalline mixture of polymer material. Polyester powder is a crystalline polymer, so the film performance varies depending on the degree of crystallinity. Good performance, which is higher adhesive strength here, was obtained with up to 3% crystallinity, as shown in Fig. 2.

The relationship between the impact resistance and crystallinity [4] is shown in **Fig. 3**. As with adhesive strength, it is observed that higher impact resistance is obtained in the lower crystallinity region.

We were able to clarify practical film performance by understanding one of the basic material properties (crystallinity in this case).

2.3 Study of new material indicator

We are developing new criteria to determine coating degradation and are focusing on viscoelasticity to quantify the degree of degradation of solvent-type anti-corrosion organic coating films. Viscoelasticity, as the name suggests, is the combination of viscous and elastic properties. It is generally known that most of the energy necessary to peel a film is consumed by deformation of the bulk material, and thus, the adhesive performance strongly depends on the viscoelasticity. Also, we previously reported that the viscoelasticity of solvent-type anticorrosion organic coating film varies depending on the degradation [5]. Thus, we believe that it is possible to precisely evaluate the degree of degradation by measuring viscoelasticity as

the material property of the coating film. Furthermore, because this measurement is very sensitive to even a small variation of the property and because the measurement distribution is small, this technique is expected to indicate the onset of degradation.

3. Risk-based maintenance

Risk-based maintenance is a new methodology for maintaining infrastructure that involves assessing the risk for each component of the infrastructure and preparing an appropriate maintenance plan for each component on the basis of the risk assessment. This method makes it possible to balance the need to control maintenance costs with the requirement to ensure the reliability of the infrastructure. This method was developed with the intended use of maintaining chemical plants in western countries and is also being applied in chemical plants in Japan [6]. Telecommunication industries have not yet applied this method. The risk for a component is determined by the expected likelihood and consequences of a specific failure of the component. One of the first research tasks is to establish a method of estimating the likelihood and consequences using some particular data, such as information on facility features, inspection results, and weather information. Here, we introduce a method of estimating the risk of lightning damage.

3.1 Aim of method to evaluate risk of lightning damage

For many years, damage to telecommunication infrastructure caused by lightning surges has been a serious issue [7]. The cost associated with such damage has been increasing year on year as low-voltage LSIs (large-scale integrated circuits) and electrical devices connected to the network become more prevalent in the ever-expanding information technology (IT) society. Furthermore, our study of long-term trends in the number of annual days with lightning [8] indicates that lightning damage will become more serious because of the increased occurrence of lightning in Japan in conjunction with future global warming.

Although lightning damage can be reduced by introducing lightning protection countermeasures, it is difficult to introduce countermeasures uniformly throughout the country because of the high cost. An advanced method is needed to classify areas by the cost-effectiveness of introducing countermeasures. We have been researching a method to evaluate the risk of lightning damage; it involves estimating the potential number of equipment failures and the subsequent economic loss. The estimation of the potential number of equipment failures corresponds to likelihood estimation in the risk-based maintenance, and the economic loss estimation corresponds to the consequence estimation.

3.2 Model for estimating degree of lightning damage

We analyzed the relationship between the number of equipment failures, the number of lightning strikes, i.e., the cause of the damage, and the amount of equipment, i.e., the location of the damage. A scatter plot graph of the logarithmic values of these three variables, where the resident population is substituted for the amount of equipment, is shown in **Fig. 4**. As this graph indicates, the number of equipment failures is proportional to both the number of lightning strikes and the resident population. Thus, we defined the lightning damage estimation model [9] as:

$$1\log(Y)=\log(a)+ b_1 1\log(L)+b_2 1\log(P).$$

Here, Y is the number of equipment failures; L is the number of lightning strikes; P is the resident population; and a, b_1, and b_2 are coefficients of regression. We conducted a case study of three prefectures in Japan to validate the accuracy of the model using past data, and we confirmed that the correlation coefficient between the values estimated using our estimation model and the actual values was more than 0.8. These correlations can be considered statistically significant.

3.3 Prediction of future lightning damage and equipment failures

The potential number of equipment failures can be estimated using the estimation model from the predicted number of lightning strikes [8] and population in the future. The average numbers of lightning strikes and equipment failures between 2006 and 2010 in Gunma prefecture, where the density of lightning strikes is among the highest in Japan, are shown in **Fig. 5**. The average predicted numbers of lightning strikes and equipment failures between 2026 and 2030 are shown in **Fig. 6**. The predicted results show that the number of equipment failures in the late 2020s will increase owing to the remarkable increase in the number of subscribers of optical fiber broadband services and the increase in the number of lightning strikes.

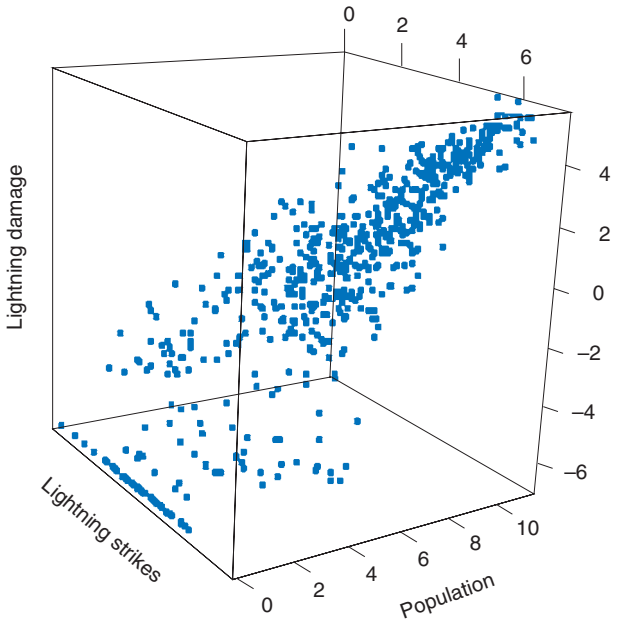

Fig. 4. Relationship between number of lightning strikes, lightning damage, and population.

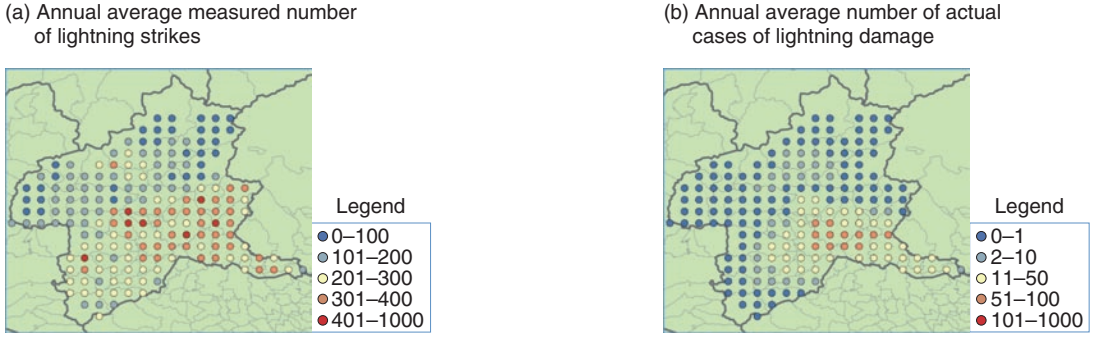

Fig. 5. Annual average measured number of lightning strikes and actual number of cases of lightning damage from 2006 to 2010.

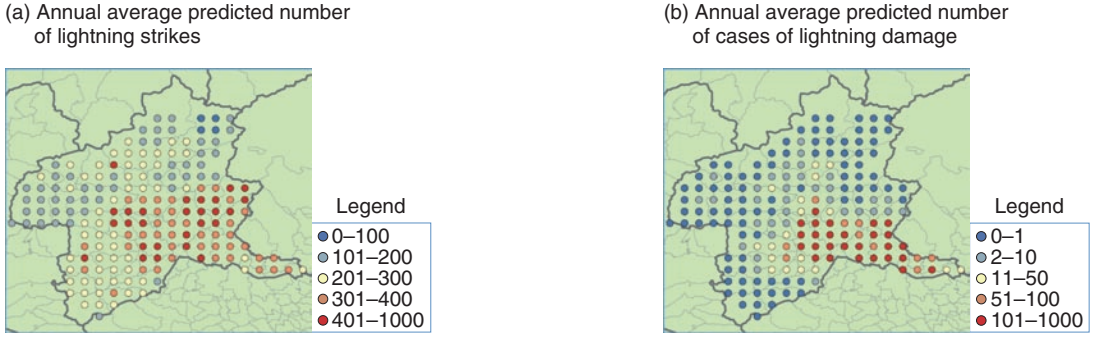

Fig. 6. Annual average predicted number of lightning strikes and predicted number of cases of lightning damage from 2026 to 2030.

3.4 Identification of high-priority areas for countermeasures

We are using the results of our study to analyze the potential economic loss and the cost-benefit of implementing lightning countermeasures in nearly every region of Japan. Our method makes it possible to identify the areas where countermeasures should be implemented first and is thus expected to be useful to ensure the reliability of telecommunications services and to optimize maintenance costs by reducing lightning damage and maintenance work.

4. Future prospects

NTT will continue to develop techniques to assess degradation by focusing on coating properties and risk-based maintenance and will also continue working to reduce both environmental load and maintenance costs in the future.

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Environmental Impact Assessment System

Shinsuke Hannoe, Yuichiro Takei, and Hiroto Kitabayashi

Abstract

We describe an environmental impact assessment system that was developed by the NTT Energy and Environment Systems Laboratories in response to a call for contributions to suggest ways of reducing the environmental load of information and communications technology (ICT) services provided by the NTT Group. We explain an approach to evaluating the effects of ICT services on the environment, the NTT Group Solution Environmental Label System, and the positioning of the system in attaining the objectives of THE GREEN VISION 2020.

1. Introduction

The NTT Group has drawn up THE GREEN VISION 2020 as a new vision to guide its environmental efforts in information and communications technology (ICT) through the year 2020 [1]. This vision involves three targets: Green of ICT, Green by ICT, and Green with Team NTT. The goal of Green by ICT is to reduce CO_2 emissions by at least 20 million tons by the year 2020 through the use of ICT solutions as a step toward becoming a low-carbon society.

To achieve this target, it is necessary to quantitatively evaluate the effectiveness of individual ICT solutions in reducing CO_2 emissions. The NTT Energy and Environment Systems Laboratories have developed an environmental impact assessment system as a tool for evaluation.

2. Evaluation of environmental effects of ICT solutions

The energy efficiency of new devices such as home electronics products, light-emitting diode (LED) light bulbs, etc. has been increasing, and the energy-saving effects can be measured quantitatively by comparing the power consumption of new products with that of earlier products.

ICT solutions generally lead to greater work efficiency and a reduction in the use of paper through digital storage of information. Although it is assumed that these benefits also reduce the environmental load, it is difficult to quantitatively measure the amount of energy saved, as can be done with home electronic equipment, LED light bulbs, etc.

To overcome this difficulty, we categorized the features of ICT solutions into eight activities (**Fig. 1**), and for each of the activities, we converted the amount of energy and goods used into a quantitative value for CO_2 emissions. The individual values were totaled to obtain the amount of CO_2 emitted when the ICT solutions were applied. We also calculated the CO_2 emissions for a reference product system (conventional) services that have the same functions as the ICT solutions in order to compare the CO_2 emission reduction effects of ICT and conventional services.

By preparing the factors for the conversion of CO_2 emissions (basic units of emission sources) for the respective activities, we can obtain the amount of CO_2 emitted from the quantities of the eight activities. The emission quantities are calculated based on a life-cycle assessment (LCA). LCA is a method of quantitatively assessing the effects of a product or service on the environment at each stage of the product's or service's life cycle, from obtaining the raw materials to manufacture, use, and disposal (**Fig. 2**).

This kind of assessment makes it possible to quan-

	Items (eight activities)	Description
(1)	ICT hardware	CO_2 emissions produced in life cycle of IT equipment
(2)	ICT software	CO_2 emissions produced in the stages of software design, development, and use
(3)	Consumable goods and other support products	CO_2 emissions from production of CDs, books, etc.
(4)	Site infrastructure	CO_2 emissions produced in life cycle of facilities that constitute the network infrastructure
(5)	Transport (movement of goods)	CO_2 emissions produced in the movement of freight by truck, train, etc.
(6)	Travel (movement of people)	CO_2 emissions produced in the movement of people on aircraft, electric trains, and other vehicles
(7)	Storage of goods	CO_2 emissions produced by warehouses, etc.
(8)	Human work environments	CO_2 emissions produced by workplaces such as offices

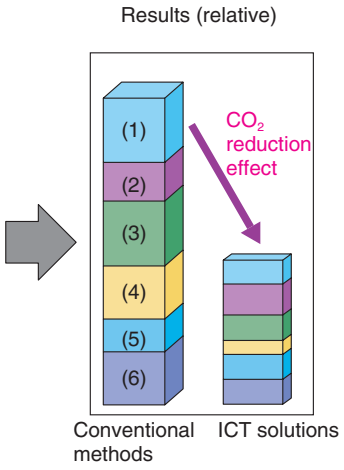

Fig. 1. Descriptions of items evaluated for their environmental load (left) and relative results of applying ICT solutions (right).

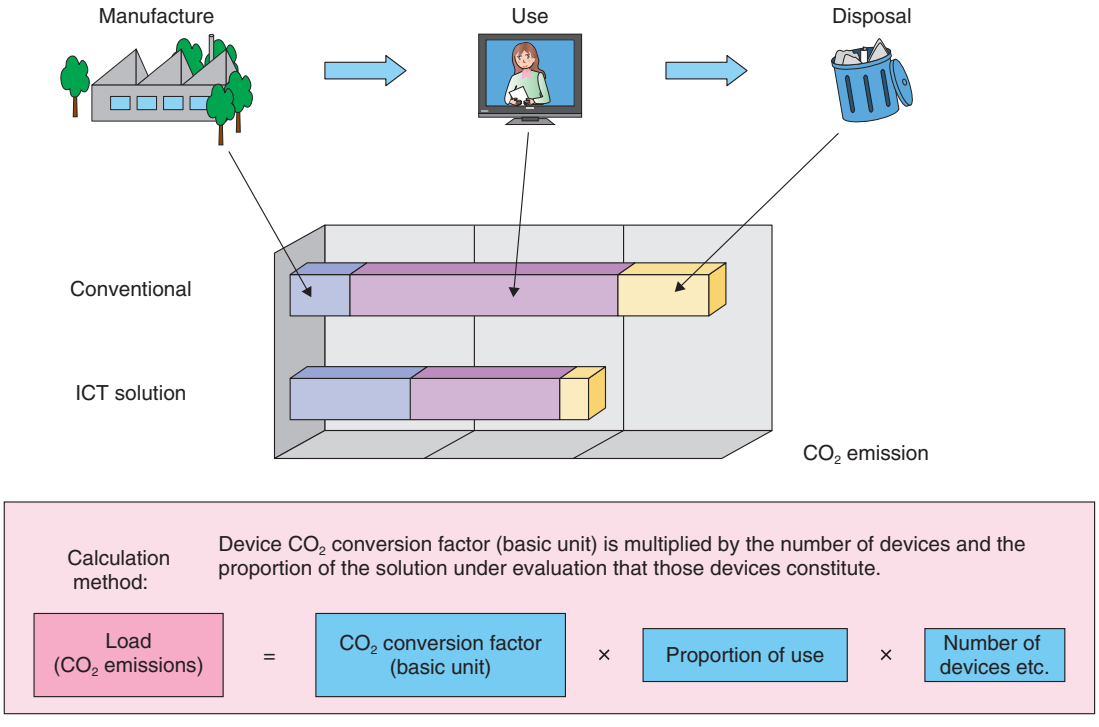

Fig. 2. Calculation of environmental load.

titatively calculate the CO_2 emissions associated with diverse ICT solutions.

This evaluation method is described in the Environmental Efficiency Evaluation Guidelines of the Japan Environmental Efficiency Forum [2]. NTT has been conducting advanced research on evaluating the

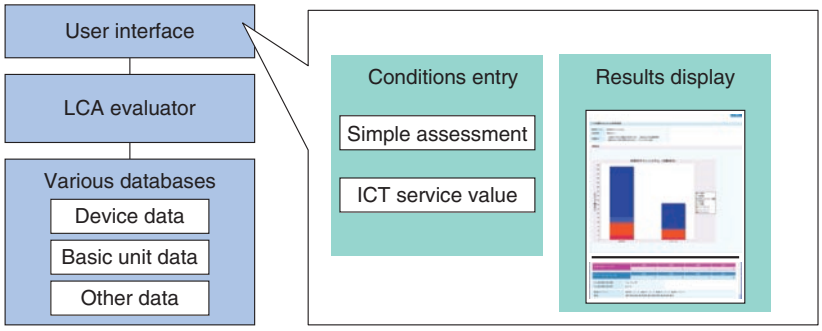

Fig. 3. Configuration of common assessment system.

effects of ICT solutions on the environment and has played a leading role in the development of these guidelines.

The environmental impact assessment system consists of a database of evaluation techniques and the basic units required for evaluation. The user selects the ICT equipment that constitutes the ICT solution to be evaluated and selects how the equipment is used. Then, the user enters the respective quantities (e.g., the number of ICT devices and the duration of use) to evaluate the environmental load.

3. Overview of environmental impact assessment system

The configuration of the environmental impact assessment system is shown in **Fig. 3**. The system comprises an LCA evaluation unit for calculating the environmental load as well as various databases. An algorithm is implemented in the evaluation unit to calculate the environmental load. The information required for the calculations is stored in the databases. This information includes the models of terminal devices, communication cables, and other components of the communication facilities, as well as the environmental load at the stage of disposal and the power consumption during use. The user enters the evaluation conditions on the screen and the evaluation is performed.

This assessment system has two evaluation functions. One is a simple evaluation function that presents the evaluation items on a single screen; the other is an ICT service evaluation function that allows the evaluation items to be customized according to the purpose of the evaluation. The simple evaluation function is provided for broad general use (described in more detail below), whereas the ICT service evaluation function defines models that are specialized for the solution being evaluated to enable a stricter evaluation. The screen for entering the evaluation conditions for the simple evaluation function (**Fig. 4**) has forms for entering data for the eight activities described in Fig. 1. To allow comparison, the conventional means are presented on the left half of the screen and the ICT solutions are shown on the right. The user enters the values, and the evaluation is then performed.

4. Evaluation examples

Example applications of the environmental impact assessment system are shown in **Fig. 5**. The use of a videoconferencing system to hold meetings is compared to the conventional means of traveling by train to attend meetings. The videoconferencing system connects distant locations via a network and makes it possible to conduct meetings with far less movement of people.

Evaluation results are presented for cases involving meetings held between participants from Tokyo and Yokohama and from Tokyo and Nagoya under the same conditions (48 meetings per year, 2 hours per meeting, two people).The videoconferencing option places a load on the environment from the use of the ICT equipment, but it is substantially lower than the load resulting from the conventional means of traveling by train to attend meetings in person. We can therefore easily see which option will have the greater effect on reducing the environmental load.

In these examples, the travel distance was greater for the Tokyo and Nagoya meeting participants than it was for the Tokyo and Yokohama participants (conventional means), so the environmental load was larger, and the reduction effect of using videoconfer-

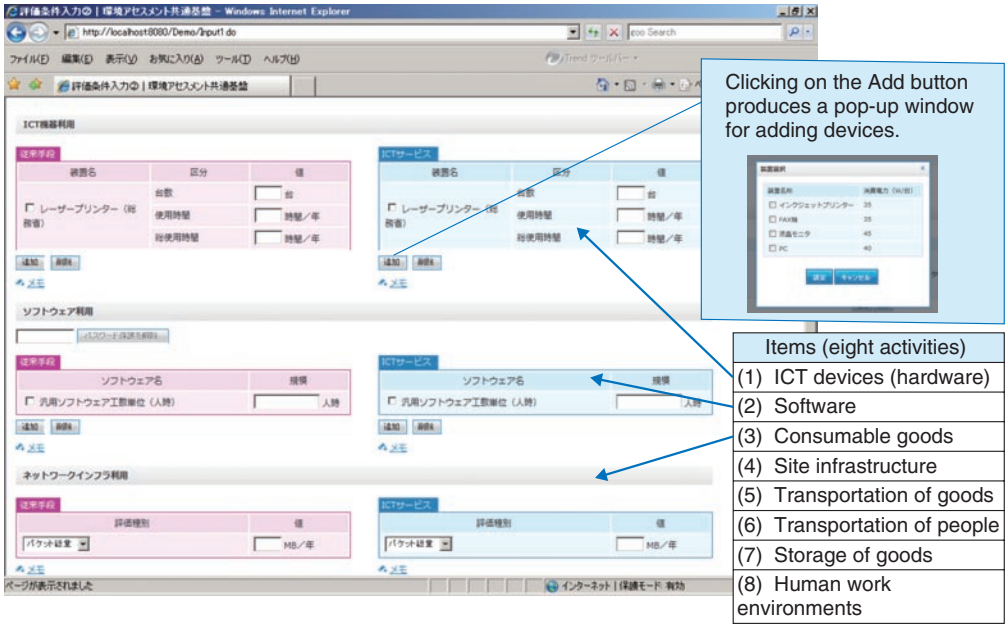

Fig. 4. Screen to enter evaluation conditions.

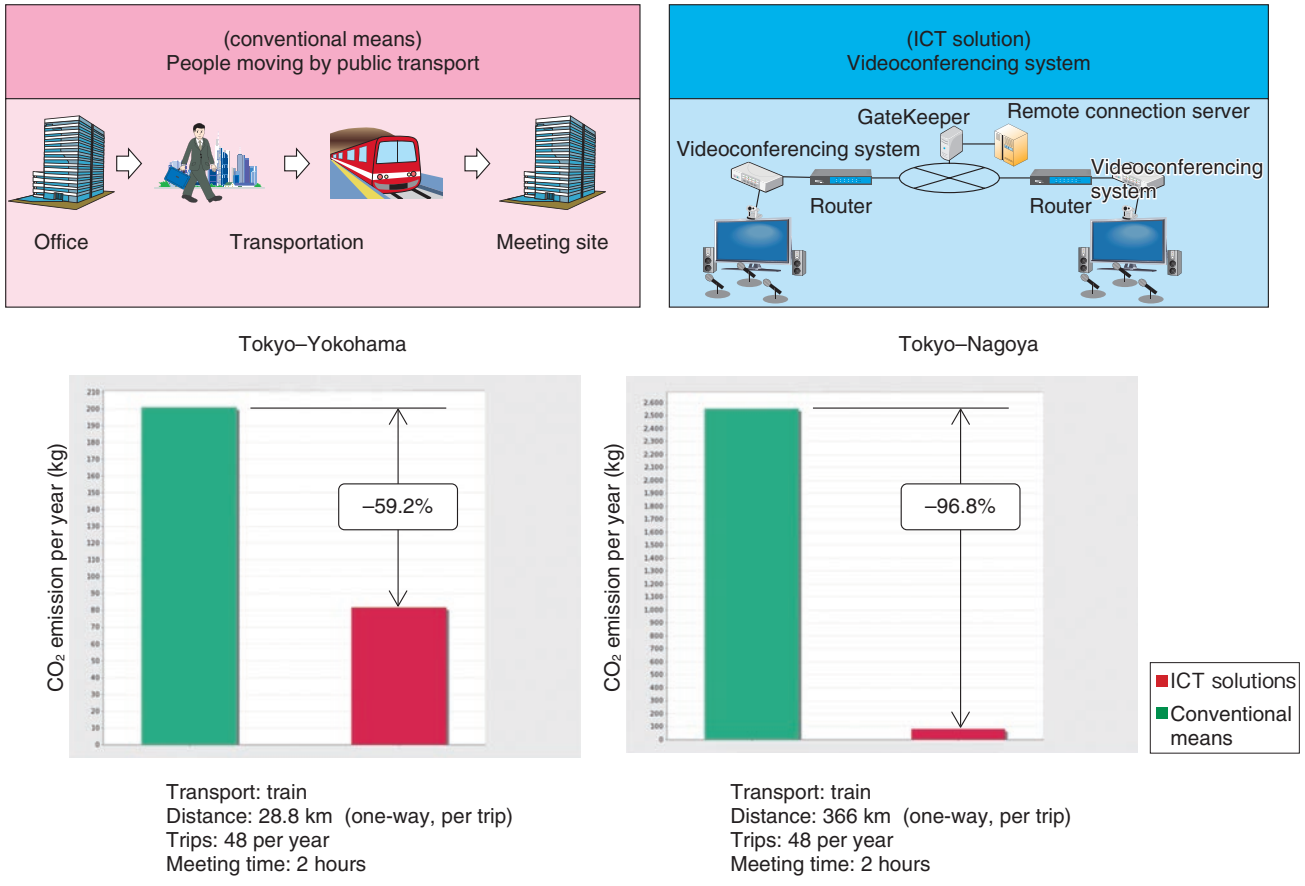

Fig. 5. Evaluation of videoconferencing system.

Fig. 6. NTT Group environmental label.

encing was also larger. The environmental load varies with the meeting duration and the number of meetings as well as with the travel distance. The amount of environmental-load reduction through the use of ICT services varies with the evaluation method used. This assessment system can also be used effectively to check the variation in reduction effects due to differences in the evaluation method by changing the evaluation parameters.

This assessment system allows results to be saved in a Microsoft Excel file for wide use.

5. NTT Group Environmental Labeling System for Solutions

Results from this assessment system can also be used to certify use of the NTT Group environmental labeling system for ICT solutions.

In this labeling system, solutions that reduce the environmental load by at least 15% are certified as being environmentally friendly with a symbol that we call the environmental label (**Fig. 6**). The label can be displayed in pamphlets or on websites to inform customers at a glance that a solution is environmentally friendly. Certified solutions and the environmental impact evaluations in which the certifications are grounded are also displayed on the NTT Group websites to further promote this idea to customers [3]. From 2009, when this system was initiated, to 2011, 19 solutions were certified. The environmental labeling system itself was standardized in the ISO 14020 series, so this labeling system is also administered according to that standard.

6. Future development

To measure the attainability of THE GREEN VISION 2020, we need a total value for the load reduction effects of solutions applied at the enterprise level. However, it is difficult to obtain an overall evaluation of all of the solutions offered by the NTT Group and to measure their total value. To solve that problem, we will work on developing technology that can be estimated to a total value for the load reduction effects of all solutions.

We also plan to promote examples of how this assessment system can be used for evaluations and to devise other means of facilitating the use of the system. By doing so, we hope to encourage widespread use of the system in evalua-tion solutions and to contribute to the environmental efforts of the NTT Group.

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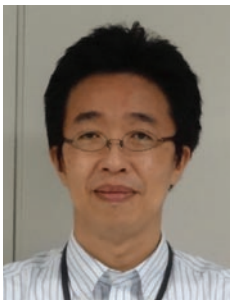

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Subsequence Matching in Data Streams

Machiko Toyoda and Yasushi Sakurai

Abstract

Subsequence matching is a basic problem in the field of data stream mining, and dynamic time warping (DTW) is a powerful similarity measure often used for subsequence matching; however, the straightforward method using DTW incurs a high computation cost. In this article, we describe two subsequence matching problems in data streams—(1) the similarity between a query sequence and a data stream and (2) the similarity between data streams—and we present effective algorithms to solve these problems. We also introduce some applications using these algorithms.

1. Introduction

Data streams have attracted interest in various fields (theory, databases, data mining, and networking) because of their many important applications including financial analysis, sensor network monitoring, moving object trajectories, web click-stream analysis, and network traffic analysis. Efficient monitoring of time-series data streams is a fundamental requirement for these applications, and subsequence matching is an important technique for this. We consider two problems with subsequence matching over data streams: the similarity between a query sequence and data stream and the similarity between data streams. In the former problem, one is a fixed sequence and the other is an evolving sequence. This approach works well if we have already determined the patterns we want to find. By contrast, the latter problem focuses on co-evolving sequences and reveals hidden patterns between them without preliminary knowledge.

Unlike the traditional setting, the sampling rates of streams are often different, and their time period varies in practical situations. Subsequence matching should address asynchronous data and should be robust against noise and provide scaling along the time axis. We focus on dynamic time warping (DTW) as a similarity measure for subsequence matching over data streams. DTW is typically applied to limited situations in an offline manner. Since data streams arrive online at high bit rates and are potentially unbounded in size, the computation time and memory space increase greatly. Ideally, we need a solution that can return correct results without any omissions, even at high speed.

This article presents the streaming algorithms SPRING and CrossMatch for subsequence matching. These are one-pass algorithms that are strictly based on DTW and that guarantee correct results without any omissions. We describe the basic ideas behind each algorithm and show how these algorithms work in relation to data stream processing. Moreover, we focus on sensor network monitoring as an application of subsequence matching and discuss the differences between the two algorithms.

2. Background

2.1 Related work

Similarity search over time-series data has been studied for many years. Most methods focus on similarity queries for static datasets with a query sequence. Specifically, given a query sequence and a distance threshold, a similarity query finds all the sequences or subsequences that are similar to the query sequence. The basic idea is to transform the sequence into the frequency domain using a discrete Fourier transform (DFT) and then to extract the few features from the resultant frequency-domain sequence [1]. Euclidean distance is used as a similarity measure. Other feature

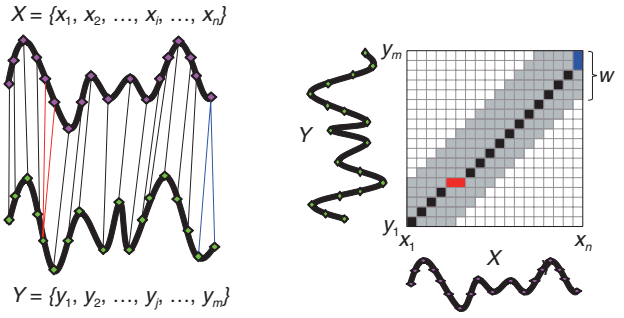

Fig. 1. Illustration of DTW.

extraction functions include discrete wavelet transform (DWT) [2], singular value decomposition (SVD) [3], piecewise aggregate approximation (PAA) [4], and adaptive piecewise constant approximation (APCA) [5]. These functions have been proposed to reduce the number of dimensions of the time-series.

Since the Euclidean distance treats sequence elements independently, it cannot be used to calculate the distance between sequences whose lengths are different. DTW has been adopted to overcome these problems [6]; it is a widely used similarity measure that allows time-axis scaling. The DTW distance can be computed using dynamic programming techniques. Therefore, DTW is typically a much costlier approach than the Euclidean distance. To address the cost issue, several methods have been proposed that use a lower bound to refine the results and envelope techniques to constrain the computation cells [7]–[10].

Similarity search over data streams has recently attracted more research interest. In contrast to a setting where the data sequences are fixed, data streams arrive irregularly and are frequently updated. Therefore, incremental computation techniques that use the previous feature when computing the new feature are required. Several discriminative methods have been proposed for subsequence matching with a query sequence. These include subsequence matching based on prediction [11], approximate subsequence matching with data segmentation and piecewise line representation [12], subsequence matching supporting shifting and scaling in the time and amplitude domains [13], and subsequence matching based on DTW with batch filtering [14].

Another important area is pattern discovery between data streams. Mueen et al. [15] presented the first online motif discovery algorithm to accurately monitor and maintain motifs, which represent repeated subsequences in time-series, in real time. Papadimitriou et al. [16] proposed an algorithm for discovering optimal local patterns, which concisely describe the main trends in data streams.

In summary, there have been many previous studies on similarity search over data streams; however, none of them have addressed effective subsequence matching based on DTW. We formally define two problems for subsequence matching and present efficient and effective algorithms to solve them.

2.2 DTW

DTW is a transformation that allows sequences to be stretched along the time axis to minimize the distance between them. The DTW distance of two sequences is the sum of the tick-to-tick distances after the two sequences have been optimally warped to match each other. An illustration of DTW is shown in **Fig. 1**. The left figure is the alignment by DTW for measuring the DTW distance. To align two sequences, we construct a time warping matrix as shown in the right figure (the warping scope w will be described in section 4.1). The warping path is a set of grid cells in the time warping matrix; this set of grid cells represents the optimal alignment between the sequences. Consider two sequences, $X = (x_1, x_2, ..., x_n)$ of length n and $Y = (y_1, y_2, ..., y_m)$ of length m. Their DTW distance $D(X, Y)$ is defined as

$$D(X, Y) = d(n, m)$$
$$d(i, j) = \|x_i - y_j\| + min \begin{cases} d(i, j-1) \\ d(i-1, j) \\ d(i-1, j-1) \end{cases} \quad (1)$$

$$d(0, 0) = 0, d(i, 0) = d(0, j) = \infty$$

$$(i = 1, ..., n; j = 1, ..., m;).$$

Note that $\|x_i - y_j\| = (x_i - y_j)^2$ is the distance between two numerical values in cell (i, j) of the time warping matrix. Note that other choices (e.g., absolute difference $\|x_i - y_j\| = |x_i - y_j|$) can also be used; the algorithms we present in this article are completely independent of the choice made. Specifically, DTW requires $O(nm)$ time because the time warping matrix consists of nm elements. Note that the space complexity is $O(m)$ because the algorithm needs only two columns (i.e., the current and previous columns) of the time warping matrix to compute the DTW distance.

In the problem of subsequence matching with a

query sequence, given an evolving sequence $X = (x_1, x_2, ..., x_n)$ and a fixed-length query sequence $Y = (y_1, y_2, ..., y_m)$, we want to find the subsequences of X that are similar to Y in the sense of the DTW distance. By contrast, in the problem of subsequence matching between data streams, given two evolving sequences $X = (x_1, x_2, ..., x_n)$ and $Y = (y_1, y_2, ..., y_m)$, we want to find the subsequence pairs, namely the common local patterns over data streams. We will give the exact definitions for these problems later (in sections 3.1 and 4.1). In both settings, naïve ways of subsequence matching require unfeasible computation time and memory consumption in data stream processing. We show that our approaches offer considerable improvement without loss of accuracy.

3. Subsequence matching with a query sequence

3.1 Problem definition

Data stream X is a discrete, semi-infinite sequence of numbers $x_1, x_2, \ldots, x_n, \ldots$, where x_n is the most recent value. Note that n increases with every new time-tick. Let $X[i_s : i_e]$ be the subsequence of X that starts from time-tick i_s and ends at i_e. The subsequence matching problem is to find the subsequence $X[i_s : i_e]$ that is highly similar to a fixed-length query sequence Y (i.e., the subsequence with a small value of $D(X[i_s : i_e], Y)$. However, a subtle point should be noted: whenever the query Y matches a subsequence of X (e.g., $X[i_s : i_e]$), we expect that there will be several other matches with subsequences that heavily overlap the *local minimum* best match. Overlaps provide the user with redundant information and would slow down the algorithm since all useless solutions are tracked and reported. In our solution, we discard all these extra matches. Specifically, the problem we want to solve is as follows:

Problem 1 Given a stream X (that is, an evolving data sequence, which at the time of interest has length n), a query sequence Y of fixed-length m, and a distance threshold ε, report all subsequences $X[i_s : i_e]$ such that

1. the subsequences are close enough to the query sequence: $D(X[i_s : i_e], Y) \leq \varepsilon$, and
2. among several overlapping matches, report only the local minimum; that is, $D(X[i_s : i_e], Y)$ is the smallest value from the set of overlapping subsequences that satisfy the first condition.

Hereafter we use the term *optimal subsequences* to refer to subsequences that satisfy both conditions.

3.2 SPRING

The most straightforward (and slowest) solution to this problem is to consider all possible subsequences $X[i_s : i_e]$ $(1 \leq i_s \leq i_e \leq n)$ and apply the standard DTW dynamic programming algorithm, which requires $O(n^2)$ matrices. The time complexity would be $O(n^3m)$ (or $O(n^2m)$ per time-tick). This method is extremely expensive. Moreover, it cannot be extended to the streaming case. To solve the problem, we therefore proposed SPRING [17], which is an efficient algorithm. SPRING uses only a single matrix and detects optimal subsequences in stream processing.

3.2.1 Basic ideas

Our solution to the problem is based on two ideas. The first idea is *star-padding*, in which sequence Y is prefixed with a special value ("*") that always gives zero distance. This value stands for the *don't care* interval, that is, the interval $(-\infty : +\infty)$.

Definition 1 (Star-padding) Given a query sequence Y, star-padding of Y is defined as follows.

$$Y' = (y_0, y_1, y_2, ..., y_m)$$
$$y_0 = (+\infty : -\infty) \tag{2}$$

We use Y' to compute the DTW distances of Y and subsequences of X, instead of operating on the original sequence of Y.

Given a sequence $Y = (y_1, y_2, ..., y_m)$, we have the star-padding of Y. Let X be a sequence of length n. We can then derive the minimum distance $D(X[i_s : i_e], Y)$ from the matrix of X and Y'.

$$D(X[i_s : i_e], Y) = d(i_e, m) = min(d(i, m))$$

$$d(i, j) = \|x_i - y_j\| + d_{best}$$

$$d_{best} = min \begin{cases} d(i, j-1) \\ d(i-1, j) \\ d(i-1, j-1) \end{cases} \tag{3}$$

$$d(i, 0) = 0, d(0, j) = \infty$$

$$(i = 1, ..., n; j = 1, ..., m).$$

Star-padding dramatically reduces both time and space since we need to update only $O(m)$ numbers per time-tick to derive the minimum distance.

Star-padding is a good first step, and it can tell us (a) where the subsequence match ends and (b) what

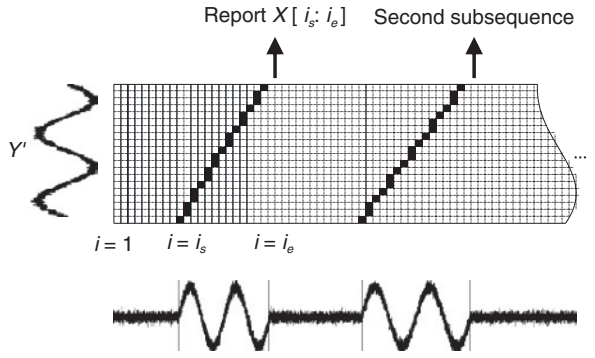

Fig. 2. Illustration of SPRING algorithm, which uses only a single matrix to capture all qualifying subsequences.

the resulting distance is. However, such applications often also need the starting time-tick of the match. Our second idea is to use a *subsequence time warping matrix* (STWM): we augment the time warping matrix and record the starting position of each candidate subsequence.

Definition 2 (STWM) The STWM contains the value $d(i, j)$, which is the best distance to match the prefix of length i from X with the prefix of length j from Y, and the starting position $s(i, j)$ corresponding to $d(i, j)$. The starting position is computed as

$$s(i,j) = \begin{cases} s(i,j-1) & (d(i,j-1) = d_{best}) \\ s(i-1,j) & (d(i-1,j) = d_{best}) \\ s(i-1,j-1) & (d(i-1,j-1) = d_{best}) \end{cases} \quad (4)$$

We obtain the starting position of $D(X[i_s : i_e], Y)$ as

$$i_s = s(i_e, m). \quad (5)$$

We update the starting position accompanied by the distance value as well as the distance value itself. By using the matrix, we can identify which subsequence gave the minimum distance during stream processing.

3.2.2 Algorithm

The way SPRING detects optimal subsequences is shown in **Fig. 2**. SPRING is carefully designed to (a) guarantee no false dismissals for the second condition of Problem 1 and (b) report each match as early as possible (detailed proofs are given in [17]). For each incoming data point x_n, we first incrementally update the m distance values $d(n, j)$ and determine the m starting positions $s(n, j)$. The algorithm reports the subsequence after confirming that the current optimal subsequence cannot be replaced by the upcoming subsequences. That is, we report the subsequence that gives the minimum distance d_{min} when the $d(n, j)$ and $s(n, j)$ arrays satisfy

$$\forall j,\ d(n,j) \geq d_{min}\ V\ s(n,j) > i_e, \quad (6)$$

which means that the captured optimal subsequence cannot be replaced by the upcoming subsequences. Otherwise, the upcoming candidate subsequences would not overlap the captured optimal subsequence. We initialize d_{min} and the $d(n, j)$ arrays after the output.

Example 1 Assume that $\varepsilon = 15$, $X = (5, 12, 6, 10, 6, 5, 13)$, and $Y = (11, 6, 9, 4)$ in **Fig. 3**. The cell (i, j) of the matrix contains $d(i, j)$ and $s(i, j)$. At $i = 3$, we found candidate subsequence $X[2 : 3]$ whose distance $d(3, 4) = 14$ below ε. At $i = 4$, although the distance $d(4, 4) = 38$ is larger than ε, we do not report $X[2 : 3]$ since $d(4, 3) = 2$, which means $X[2 : 3]$ can be replaced by the upcoming subsequences. We then capture the optimal subsequence $X[2 : 5]$ at $i = 5$. $X[2 : 5]$ is reported at $i = 7$ since we now know that none of the upcoming subsequences will be the optimal subsequence. Finally, because subsequences starting from $i = 7$ may be candidates for the next group, we do not initialize $d(7, 1)$.

4. Subsequence matching between data streams

4.1 Problem definition

We have focused on finding subsequences similar to a query sequence. In this section, we address subsequence matching between data streams. That is, both sequences X and Y are co-evolving data streams, and we want to identify common local patterns between them.

Like data stream X, data stream Y is a discrete, semi-infinite sequence of numbers $y_1, y_2, \ldots, y_m, \ldots$, where y_m is the most recent value. Note that m increases with every new time-tick. Let $Y[j_s : j_e]$ be the subsequence of Y that starts from time-tick j_s and ends at j_e. The lengths of $X[i_s : i_e]$ and $Y[j_s : j_e]$ are $l_x = i_e - i_s + 1$ and $l_y = j_e - j_s + 1$, respectively. The goal is to find the common local patterns of sequences by data stream processing based on DTW. That is, we want to detect subsequence pairs that satisfy

$$D(X[i_s : i_e], Y[j_s : j_e]) \leq \varepsilon L(l_x, l_y), \quad (7)$$

$y_4 = 4$		54 (1)	110 (2)	14 (2)	38 (2)	6 (2)	7 (2)	88 (2)
$y_3 = 9$		53 (1)	46 (2)	10 (2)	2 (2)	10 (4)	17 (4)	18 (4)
$y_2 = 6$		37 (1)	37 (2)	1 (2)	17 (4)	1 (4)	2 (4)	51 (4)
$y_1 = 11$		36 (1)	1 (2)	25 (3)	1 (4)	25 (5)	36 (6)	4 (7)
x_i		5	12	6	10	6	5	13
i		1	2	3	4	5	6	7

Fig. 3. Illustration of SPRING. The upper numbers show the distance in each element of the matrix. The numbers in parentheses show the starting position.

where L is a function that sets the length of the subsequence. The DTW distance increases as the subsequence length increases since it is the sum of the distances between elements. Therefore, unlike the problem where sequence Y is fixed, the distance threshold should be proportional to the subsequence length to detect the subsequence pairs without depending on the subsequence length. Accordingly, we set the distance threshold at $\varepsilon L(l_x, l_y)$. In this article, the algorithm uses $L(l_x, l_y) = (l_x + l_y)/2$, which is the average length of the two subsequences, but the user can make any other choice (e.g., $L(l_x, l_y) = max(l_x, l_y)$ or $L(l_x, l_y) = min(l_x, l_y)$).

Equation (7) allows us to detect subsequence pairs without regard to the subsequence length. In practice, however, we might detect shorter and meaningless matching pairs owing to the influence of noise. We introduce the concept of subsequence match length to enable us to discard such meaningless pairs. We formally define the *cross-similarity* between X and Y, which indicates common local patterns.

Definition 3 (Cross-similarity) Given two sequences X and Y, a distance threshold ε, and a threshold of subsequence length l_{min}, $X[i_s : i_e]$ and $Y[j_s : j_e]$ have the property of cross-similarity if this sequence pair satisfies the condition

$$D(X[i_s : i_e], Y[j_s : j_e]) \leq \varepsilon (L(l_x, l_y) - l_{min}). \quad (8)$$

The minimum length l_{min} of subsequence matches should be given by the users. The subsequences that satisfy this equation are guaranteed to have lengths exceeding l_{min}.

In addition to subsequence matching with a query sequence, we need to consider several other matches that strongly overlap the local minimum best match. Specifically, in this setting, an overlap is simply where two subsequence pairs have a common alignment, which is defined as follows:

Definition 4 (Overlap) Given two warping paths for subsequence pairs of X and Y, their overlap is defined as the condition where the paths share at least one element.

Our solution for subsequence matching between data streams is to detect the local best subsequences from the set of overlapping subsequences. Thus, our goal is to find the best match of cross-similarity.

Problem 2 Given two sequences X and Y, thresholds ε, and l_{min}, report all subsequence pairs $X[i_s : i_e]$ and $Y[j_s : j_e]$ that satisfy the following conditions.

1. $X[i_s : i_e]$ and $Y[j_s : j_e]$ have the property of cross-similarity.
2. $D(X[i_s : i_e], Y[j_s : j_e]) - \varepsilon (L(l_x, l_y) - l_{min})$ is the minimum value among the set of overlapping subsequence pairs that satisfies the first condition.

Hereafter we use the term *qualifying* subsequence pairs to refer to pairs that satisfy the first condition, and we use *optimal* subsequence pairs to refer to pairs that satisfy both conditions.

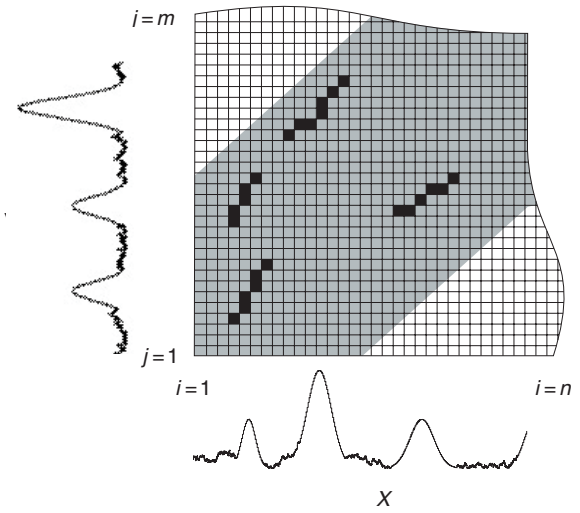

Fig. 4. Illustration of CrossMatch. Black cells indicate the warping paths of the optimal subsequence pairs, and gray cells indicate the warping scope.

Typically, new elements in data streams are usually more significant than those in the distant past. To limit the number of cells in the matrix and focus on recent elements, we utilize a global constraint for DTW, namely the Sakoe-Chiba band [18] that restricts the warping path to the $|i - j| \le w$ range (i.e., the gray cells in Fig. 1), where w is called the warping scope. In data stream processing, we compute the cells from a recent element to an earlier element of the warping scope w. If $m = n$, the warping scope is exactly equal to the Sakoe-Chiba band.

4.2 CrossMatch

To solve the problem of cross-similarity, the most straightforward solution is to consider all possible subsequences of $X[i_s : i_e]$ $(1 \le i_s < i_e \le n)$, and all possible subsequences of $Y[j_s : j_e]$ $(1 \le j_s < j_e \le m)$ in the warping scope and apply the standard DTW dynamic programming algorithm. Let w be the warping scope (the gray cells in the figure). The solution requires $O(nw^2+mw^2)$ time (per update) and space because it has to handle a total of $O(nw+mw)$ matrices to compute the DTW distance. If we prune dissimilar subsequence pairs and reduce the number of matrices, the distance computations become much more efficient. Our method, CrossMatch [19], finds good matches in a single matrix efficiently by pruning the subsequences (see **Fig. 4**).

4.2.1 Basic ideas

To identify the dissimilar subsequences early, we propose computing the DTW distance indirectly by using a *scoring function*. The scoring function computes the maximum cumulative score corresponding to the DTW distance with a score matrix. The score is determined by accumulating the difference between the threshold and the distance between the elements in the score matrix. Thus, we can recognize a dissimilar subsequence pair since the score has a negative value if the subsequence pair does not satisfy the first condition of Problem 2. The scoring function initializes the negative score to zero and then restarts the computation from the cell. This operation allows us to discard unqualifying, non-optimal subsequence pairs.

Definition 5 (Score matrix) Given two sequences, $X = (x_1, x_2, ..., x_n)$ and $Y = (y_1, y_2, ..., y_m)$, and the warping scope w, score $V(X[i_s : i_e], Y[j_s : j_e])$ of $X[i_s : i_e]$ and $Y[j_s : j_e]$ defined as follows:

$$V(X[i_s : i_e], Y[j_s : j_e]) = v(i_e, j_e)$$

$$v(i, j) = max \begin{cases} 0 \\ \varepsilon b_v - \|x_i - y_j\| + v(i, j-1) \\ \varepsilon b_h - \|x_i - y_j\| + v(i-1, j) \\ \varepsilon b_d - \|x_i - y_j\| + v(i-1, j-1) \end{cases} \quad (9)$$

$$v(0, 0) = v(i, 0) = v(0, j) = 0$$
$$(i = 1, ..., n;\ j = 1, ..., m;$$
$$n - w \le i \le n;\ m - w \le j \le m;).$$

Symbols b_v, b_h, and b_d in Eq. (9) indicate a weight function for each direction, which makes transformation between the score and the DTW distance possible. These values are determined as subsequence length L. For example, for $L(l_x, l_y) = (l_x+l_y)/2$, we obtain $b_v = b_h = 1/2$ and $b_d = 1$, respectively. The scoring function is designed so that the sum of the weights on the warping path is equal to subsequence length L. Therefore, it guarantees transformation between the DTW distance and the score, and it finds the qualifying subsequence pairs without any omissions (detailed proofs are given in [19]). The DTW distance of a subsequence pair is computed from the score and the subsequence length as

$$D(X[i_s:i_e], Y[j_s:j_e]) = \varepsilon L(l_x, l_y) - V(X[i_s:i_e], Y[j_s:j_e]) \quad (10)$$
$$\text{s.t. } V(X[i_s:i_e], Y[j_s:j_e]) > 0.$$

6	13			21	0	0	0
5	9		16	22	25	20	0
4	2	11	0	0	27	49	0
3	4	13	0	0	36	42	0
2	9	0	11	26	24	0	
1	11	0	13	19	1		
j	y_j \ x_i	5	12	10	6	3	18
	i	1	2	3	4	5	6

(a) Score matrix

6	13			(1,3)	(4,6)	(5,6)	(6,6)
5	9		(1,3)	(1,3)	(2,1)	(2,1)	(6,5)
4	2	(1,3)	(2,4)	(3,4)	(2,1)	(2,1)	(6,4)
3	4	(1,3)	(2,3)	(3,3)	(2,1)	(2,1)	(6,3)
2	9	(1,2)	(2,1)	(2,1)	(2,1)	(5,2)	
1	11	(1,1)	(2,1)	(2,1)	(2,1)		
j	y_j \ x_i	5	12	10	6	3	18
	i	1	2	3	4	5	6

(b) Position matrix

Fig. 5. Example of cross-similarity detection. The lightly shaded cells signify cross-similarity, and the dark cell in each matrix shows the best match.

Equation (10) holds for the time warping and the score matrices, which have the same starting position (i_s, j_e).

The scoring function tells us the subsequence match ends and the subsequence score. However, we lose the information about the starting position of the subsequence. This is the motivation behind our second idea, a position matrix: we store the starting position to keep track of qualifying subsequence pairs in a streaming fashion.

Definition 6 (Position matrix) The position matrix stores the starting position of each subsequence pair. The starting position $p(i, j)$ corresponding to score $v(i, j)$ is computed as:

$$p(i,j) = \begin{cases} p(i, j-1) & (v(i, j-1) \neq 0 \ \Lambda \ v(i,j) \\ & \quad = \varepsilon b_v - \|x_i - y_j\| + v(i, j-1)) \\ p(i-1, j) & (v(i, j-1) \neq 0 \ \Lambda \ v(i,j) \\ & \quad = \varepsilon b_h - \|x_i - y_j\| + v(i-1, j)) \\ p(i-1, j-1) & (v(i-1, j-1) \neq 0 \ \Lambda \ v(i,j) \\ & \quad = \varepsilon b_d - \|x_i - y_j\| + v(i-1, j-1)) \\ (i, j) & (otherwise) \end{cases} \quad (11)$$

The starting position is described as a coordinate value; $p(i_e, j_e)$ indicates the starting position (i_s, j_s) of the subsequence pair $X\,[i_s : i_e]$ and $Y\,[j_s : j_e]$. We can identify the optimal subsequence that gives the maximum score during stream processing by using the score and position matrices. Moreover, the starting position of the shared cell is maintained through the subsequent alignments because we repeat the operation, which maintains the starting position of the selected previous cell. Thus, we know the overlapping subsequence pairs from the fact that the starting positions match.

4.2.2 Algorithm

We now have all the pieces needed to answer the question: how do we find the optimal subsequence pairs? Every time x_n or y_m is received at time-tick n or m, our CrossMatch algorithm incrementally updates the score and starting position and retains the end position. We use a candidate array to find the optimal subsequence pair, and we store the best pair in a set of overlapping subsequence pairs. CrossMatch reports the optimal subsequence pair after confirming that it cannot be replaced by the upcoming subsequence pairs. The upcoming candidate subsequence pairs do not overlap the captured optimal subsequence pair if the starting positions in the position matrix satisfy the condition:

$$(\forall i, p(i, m) = C_s) \ \Lambda \ (\forall j, p(n, j) \neq C_s). \quad (12)$$

CrossMatch requires only $O(w)$ (i.e., constant) time (per update) and space. This is a great reduction because the straightforward solution requires $O(nw^2+mw^2)$ time (per update) and space.

Example 2 Assume that we have two sequences X = (5, 12, 6, 10, 3, 18) and Y = (11, 9, 4, 2, 9, 13) as well as $\varepsilon = 14$, $l_{min} = 2$, and $w = 3$ in **Fig. 5**. To simplify our example with no loss of generality, we assume that x_i

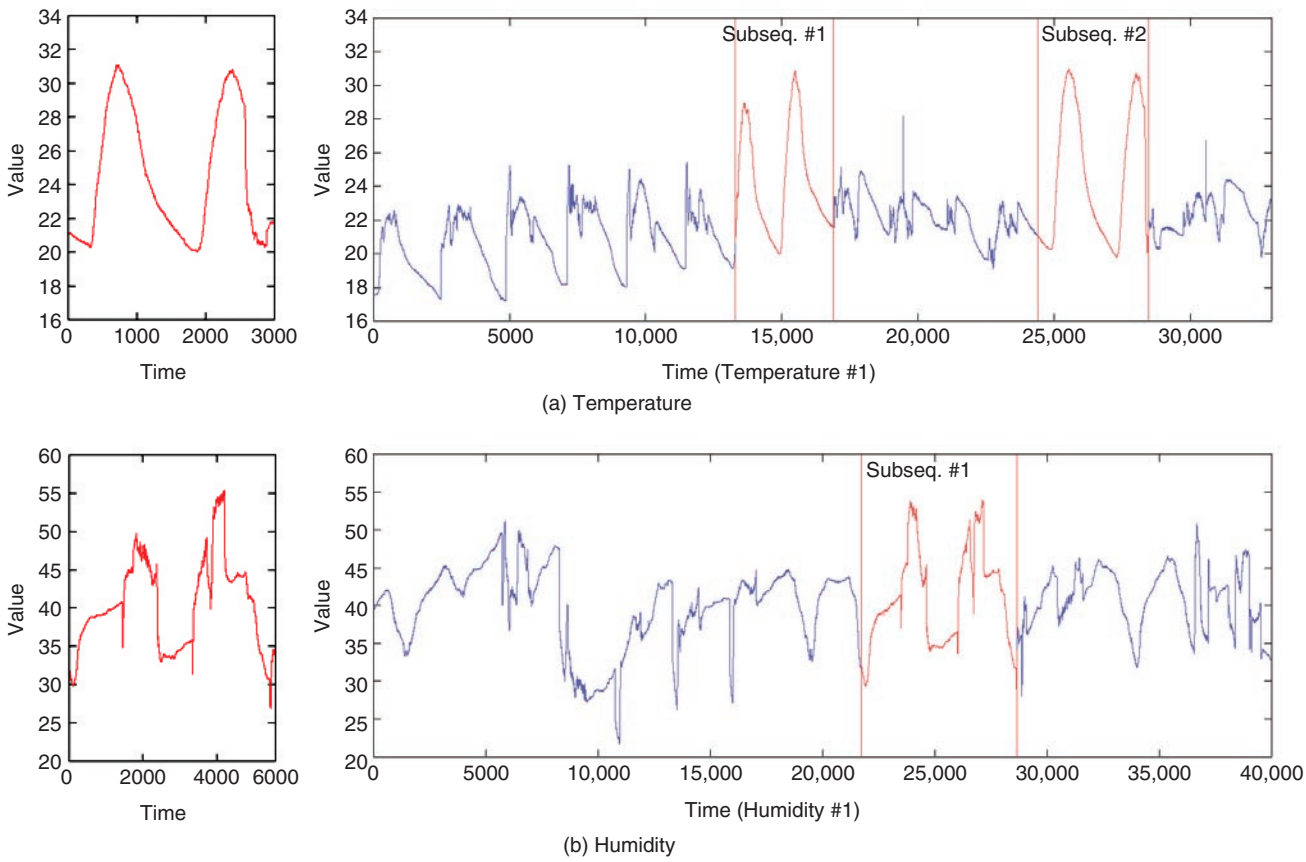

Fig. 6. Discovery of similar subsequences using SPRING. The left and right columns show the query and data sequences, respectively.

and y_j arrive alternately. At each time-tick, the algorithm updates the scores and the starting positions. At $i = 4$, we update the cells from (4, 1) to (4, 3) and identify a candidate subsequence, $X[2 : 4]$ and $Y[1 : 3]$, starting at (2, 1), whose score $v(4, 3) = 36$ is greater than εl_{min}. At $j = 4$, we update the cells from (1, 4) to (4, 4). Although we detect no subsequences satisfying the condition, we do not report the subsequence $X[2 : 4]$ & $Y[1 : 3]$ since this pair might be replaced by upcoming subsequences. We then capture the optimal subsequence pair $X[2 : 5]$ & $Y[1 : 4]$ at $i = 5$. Finally, we report the subsequence as the optimal subsequence at $j = 6$ since we can confirm that none of the upcoming subsequences can be optimal.

5. Applications of SPRING and CrossMatch

One example of subsequence matching application is sensor network monitoring. In sensor networks, sensors send their readings frequently. Each sensor produces a stream of data, and these streams need to be monitored and combined to detect changes in the environment that may be of interest to users. Users are likely to be interested in one or more sensors within a particular spatial region. These interests are expressed as trends and similar patterns.

The optimal subsequences that SPRING detected in temperature and humidity datasets are shown in **Fig. 6**. The problem that SPRING solves is very simple. Users assign the pattern for which they wish to search. The detected subsequences may be normal patterns, abnormal patterns, frequent patterns, or trends depending on the query sequences.

By contrast, CrossMatch focuses on the commonality between data sequences and reveals hidden local patterns. The left graphs in **Fig. 7** show similar subsequence pairs in each dataset (i.e., the left and center graphs) as the optimal warping paths. These pairs can be frequent patterns or trends and may be query

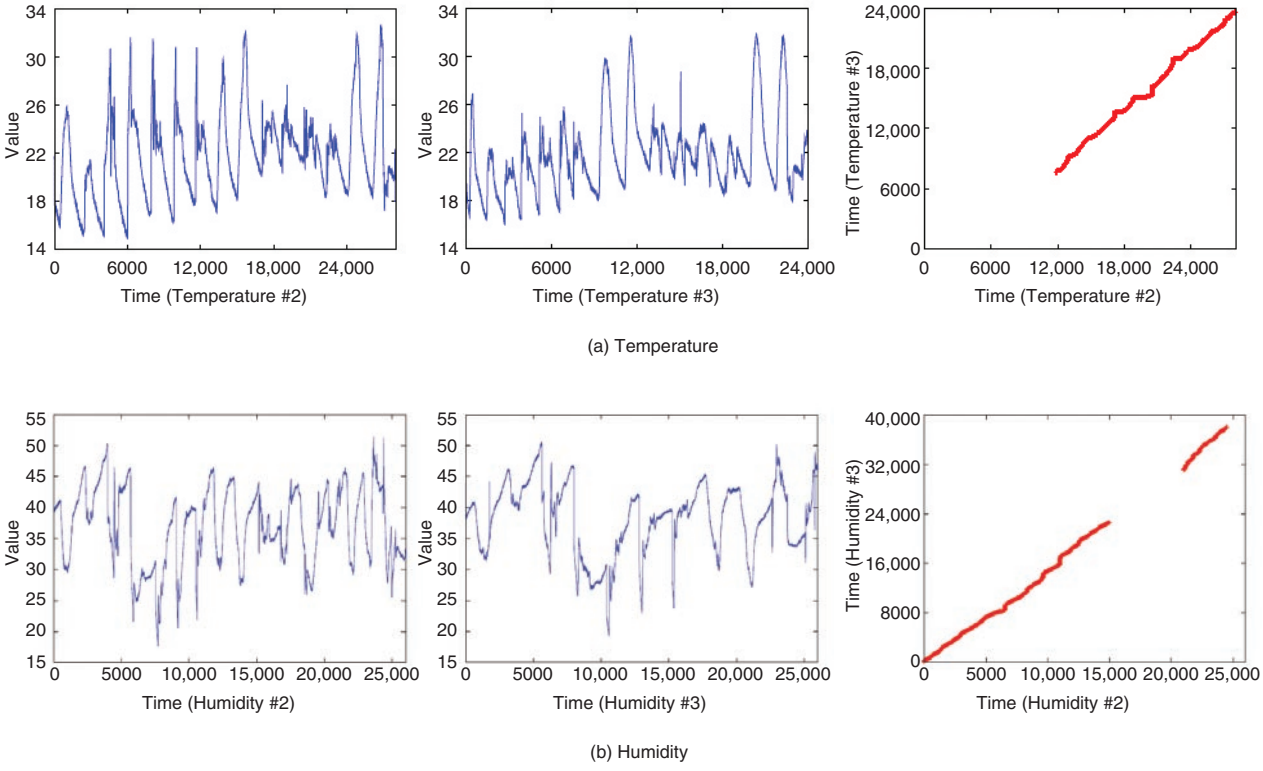

Fig. 7. Discovery of cross-similarity by CrossMatch. The left and center graphs show data sequences, and the right graphs show the warping paths for the optimal subsequence pairs.

sequences that users want to search for in the future. This focuses on the *similarities* of datasets. If we look at the *dissimilarities*, we can see different applications. For example, the result in Fig. 7(b) can be interpreted as showing that two sensors behaving in the same way have dissimilar intervals. In this case, we can assume a sensor failure and an anomaly in the environment.

6. Conclusion

In this article, we summarized subsequence matching and presented two one-pass algorithms, SPRING and CrossMatch, for subsequence matching over data streams. Both algorithms process at high-speed, exhibit constant time and space consumption, and guarantee correct results. Subsequence matching is applied in several domains, and DTW is a powerful similarity measure for subsequence matching. We believe that our algorithms will contribute to the development of many different intelligent applications.

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Evaluation of Earthquake Resistance of Shield-tunnel/vertical-shaft Connections and Countermeasure Technology

Yasushi Yamazaki, NobuhiroSegawa, and Akira Koizumi

Abstract

This article describes a technique developed by NTT for assessing the need for earthquake-proofing measures in shield tunnels and introduces technology for effective and economical seismic-motion countermeasures.

1. Introduction

In the aftermath of the Great Hanshin-Awaji (Kobe) Earthquake of 1995, NTT implemented earthquake-proofing measures for its tunnel facilities consisting of open-cut tunnels and shield tunnels (**Fig. 1**).

In the open-cut tunnels, ground liquefaction caused by the earthquake caused the tunnel section connecting an NTT building or vertical shaft to shift or uplift. To counteract such phenomena, we developed a rubber-based, flexible joint as an earthquake-proofing measure in 1996 and proceeded to implement it.

The earthquake also caused some minor damage to shield tunnels, for example, cracks and water leakage in the tunnel section connecting to a vertical shaft, and in some cases, caused that section to protrude into the shaft (Fig. 1). However, if such damage were to occur under high-water-pressure conditions, the shaft might flood, which, in turn, could affect communication services and prevent safe working conditions from being ensured during restoration work. In light of these concerns, NTT developed technologies to counter earthquake-induced ground movement (seismic-motion countermeasure technologies) in 2002 [1]. Issues arose, however, in the implementation of those technologies, such as the lack of criteria for applying such countermeasure technologies and insufficient working space within the tunnels. As a result, earthquake-proofing measures for shield tunnels in sections connected to a vertical shaft have not sufficiently progressed.

A major inland earthquake in the Tokyo metropolitan area and major earthquakes in the Tokai, Tonankai, and Nankai regions of Japan are expected to occur sometime in the future. The reliability of shield tunnels, which are considered to be critical facilities in the network, must therefore be ensured. To this end, we have been studying a method for evaluating the necessity of earthquake-proofing measures and have been working on effective seismic-motion countermeasures since 2009.

2. Method for evaluating the necessity of earthquake-proofing measures

Our method for evaluating the earthquake-resistance of the connecting section of a shield tunnel consists of judging whether earthquake-proofing measures are needed to prevent an inundation of water into the tunnel. Specifically, we judge whether groundwater will penetrate the tunnel by first performing an evaluation based on the installation environment of the shield tunnel and then performing one based on seismic motion. In the former, we determine whether the position of the shaft mouth is above the groundwater level and whether the soil in the vicinity

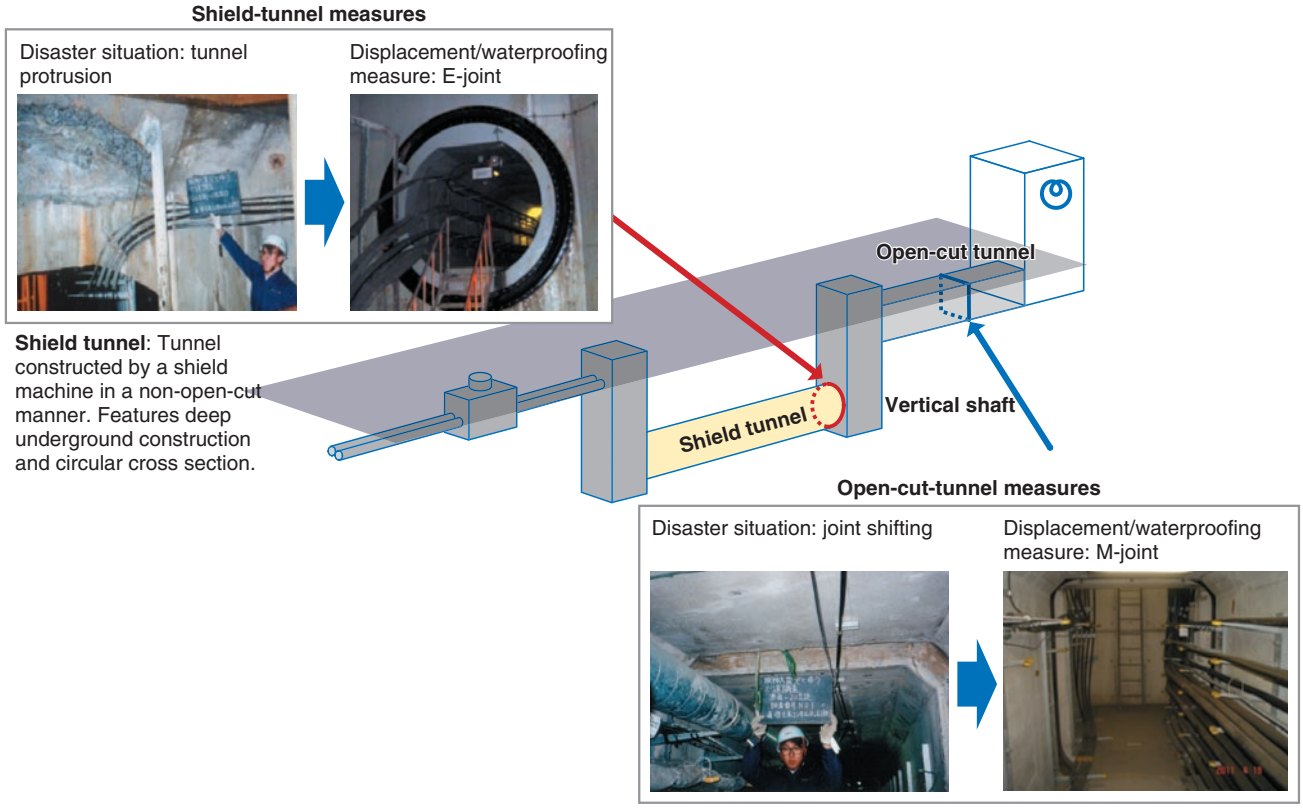

Fig. 1. Implementation of earthquake-proofing measures.

of the shaft mouth is of a type that is easily penetrated by water. In the latter, we determine whether the ground in the vicinity of the shaft mouth is of a type targeted for earthquake-proofing measures and finally investigate whether groundwater will penetrate it on the basis of a characteristic value of the ground in the vicinity of the shaft mouth. We have prepared a decision flowchart to facilitate this evaluation procedure (**Fig. 2**).

The characteristic value of the ground based on seismic motion refers to the ground's natural period as an indicator of its hardness. It is known to have a correlation with ground displacement. In addition, the difference in natural period between two points in subsurface ground[*1] can be used as an index of bedrock[*2] change. The value of this difference and the relative ground displacement would tend to be large for an abruptly changing section of bedrock. This analysis of ground behavior based on seismic motion has been clarified by applying the finite element method (FEM)[*3] (**Fig. 3**).

The most accurate method for evaluating earthquake resistance would be to perform FEM analysis on each and every tunnel, but this would require a high degree of expertise and much labor and expense. A technique that a non-specialist could easily use to evaluate the necessity of earthquake-proofing measures was therefore required. We consequently proposed a technique for determining the likelihood of shield-tunnel protrusion from the relationship between the driving force of shield-tunnel protrusion into the vertical shaft and the resistive force at the mouth of the vertical shaft [2] (**Fig. 4**). After formulating the effects of relative ground displacement based on the ground's natural period and natural-period difference and comparing them with the results of ground analysis by FEM, we were able to

*1 Subsurface ground: Ground deposited up to the earth's surface in a relatively recent age; a target of earthquake-proofing measures.

*2 Bedrock: Hard ground such as diluvium deposits; not a target of earthquake-proofing measures.

*3 FEM analysis: A technique for approximating the behavior of an object by treating it as an aggregate of small simple elements and subjecting each element to analysis.

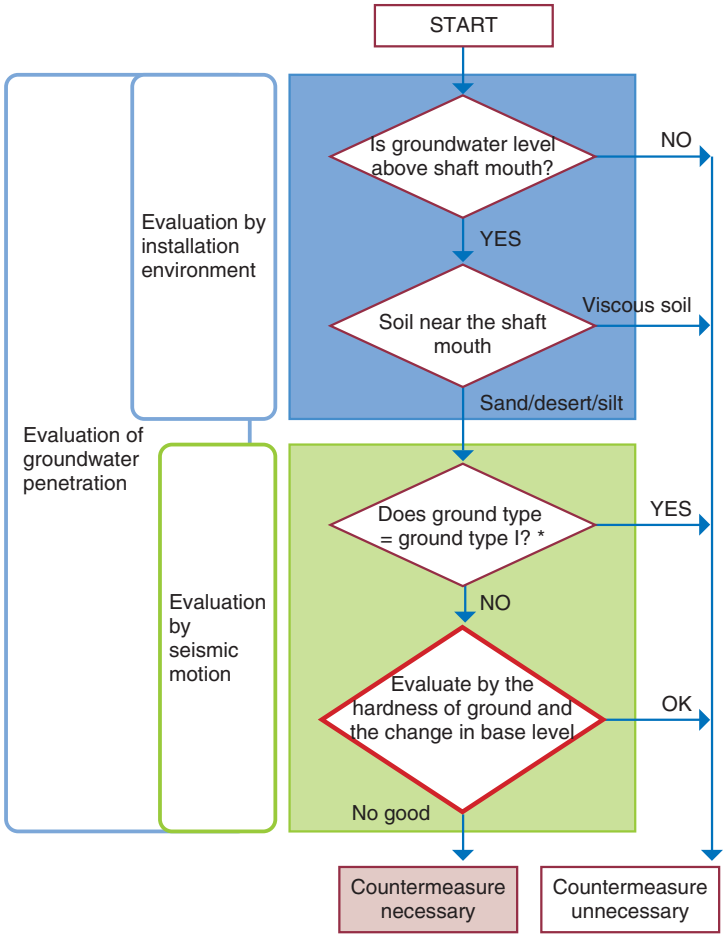

Fig. 2. Decision flowchart.

improve reliability by taking the following three items into consideration: (1) dynamic effects, (2) effects in the depth direction, and (3) the drop in rigidity of ground affected by seismic motion.

We also prepared a graphic chart to make it easier for users to apply the technique when determining whether earthquake-proofing measures are needed (**Fig. 5**).This decision chart aids the user in judging the necessity of an earthquake-proofing measure on the basis of the ground's natural period and natural-period difference. Furthermore, since the results of ground analysis by FEM indicate that the distance between the shield tunnel and bedrock can affect this decision, this chart includes two lines separating the necessary and unnecessary regions. These two lines show that the natural period and the natural-period difference of the ground in question become larger as the distance between the tunnel and bedrock increases; consequently, the region in which countermeasures are deemed necessary becomes larger. Additionally, ground-related information such as hardness, soil type, and depths of various soil layers can be obtained from boring data if such data are available. Such information can be used to manually calculate the natural period and natural-period difference, thereby making it relatively easy to judge the need for earthquake-proofing. This decision chart has been found to be valid by comparing its predictions with actual examples of damage caused by the Great Hanshin-Awaji (Kobe) Earthquake and the Great East Japan Earthquake.

A key feature of this decision technique is a decision flowchart that provides a simple procedure for judging the need for earthquake-proofing in the field. In this way, sites requiring earthquake-proofing measures can be narrowed down and examined in detail.

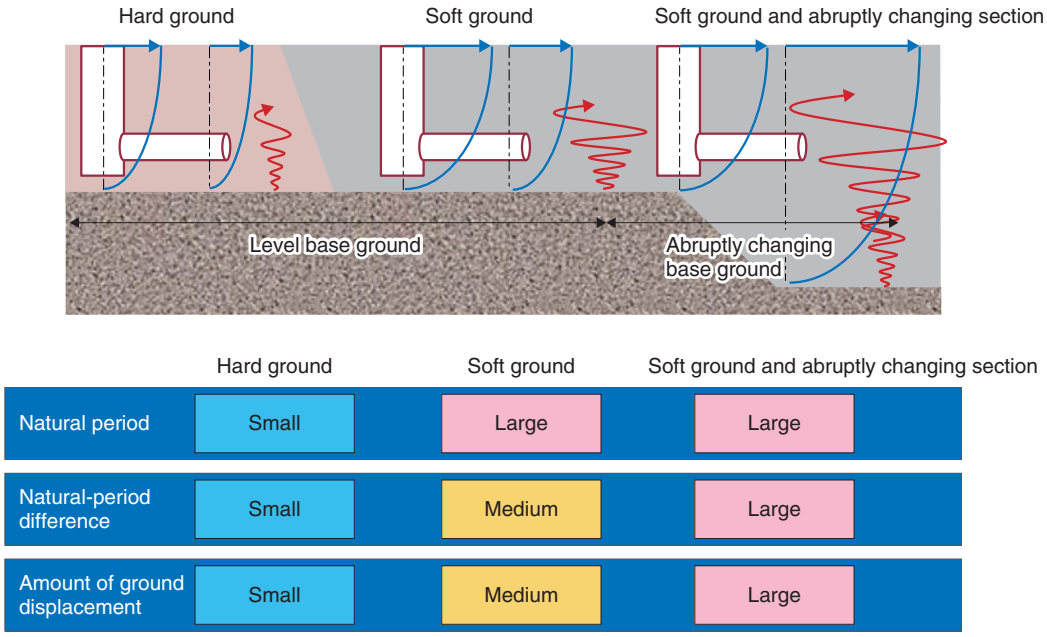

Fig. 3. Concept of natural period and natural-period difference of ground based on seismic motion.

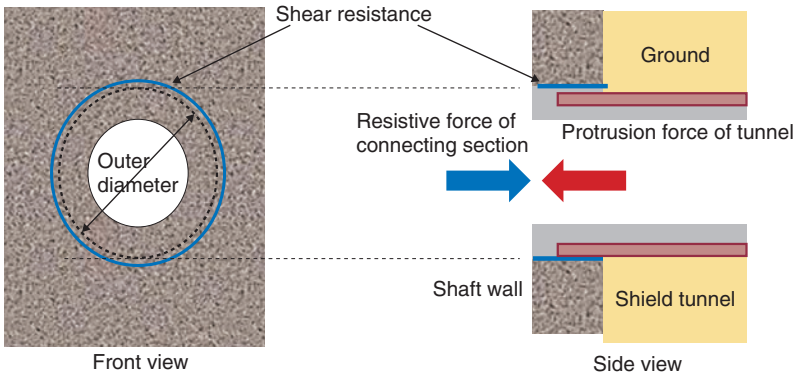

Fig. 4. Relationship between force of protrusion caused by seismic motion and resistive force of connecting section.

This makes for more efficient collection and use of boring data to compute the natural period and natural-period difference that are used with the decision chart to make a final decision.

This decision chart focuses on the hardness of the surrounding ground and sudden changes in the nature of that ground. Comparisons of the results produced using the chart with those of FEM-based ground analysis have shown it to be a reliable means of evaluating the need for earthquake-proofing. Moreover, it requires less specialized knowledge, labor, and expense than the application of FEM analysis to each and every shield tunnel. It is also easy to apply in the field if boring data are available, which makes it an advanced technique that cannot be found in other lifeline infrastructure design policies.

3. Economical countermeasure technology

The existing countermeasure involves installing a rubber joint where the shield tunnel connects with the vertical shaft to accommodate any protrusion of the

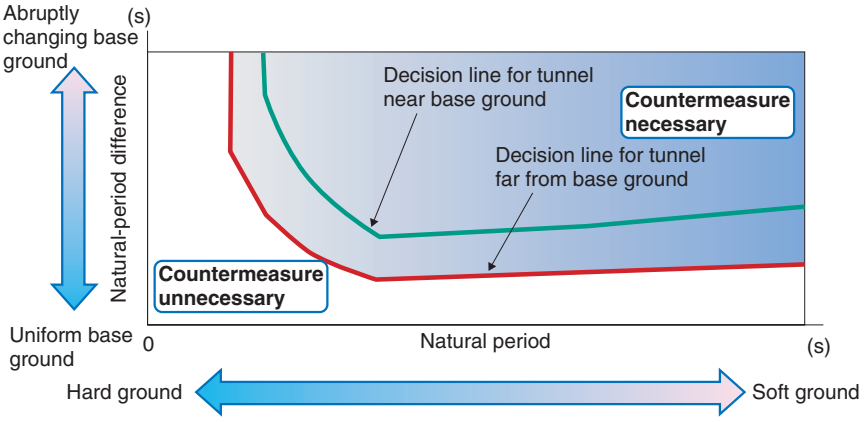

Fig. 5. Decision chart.

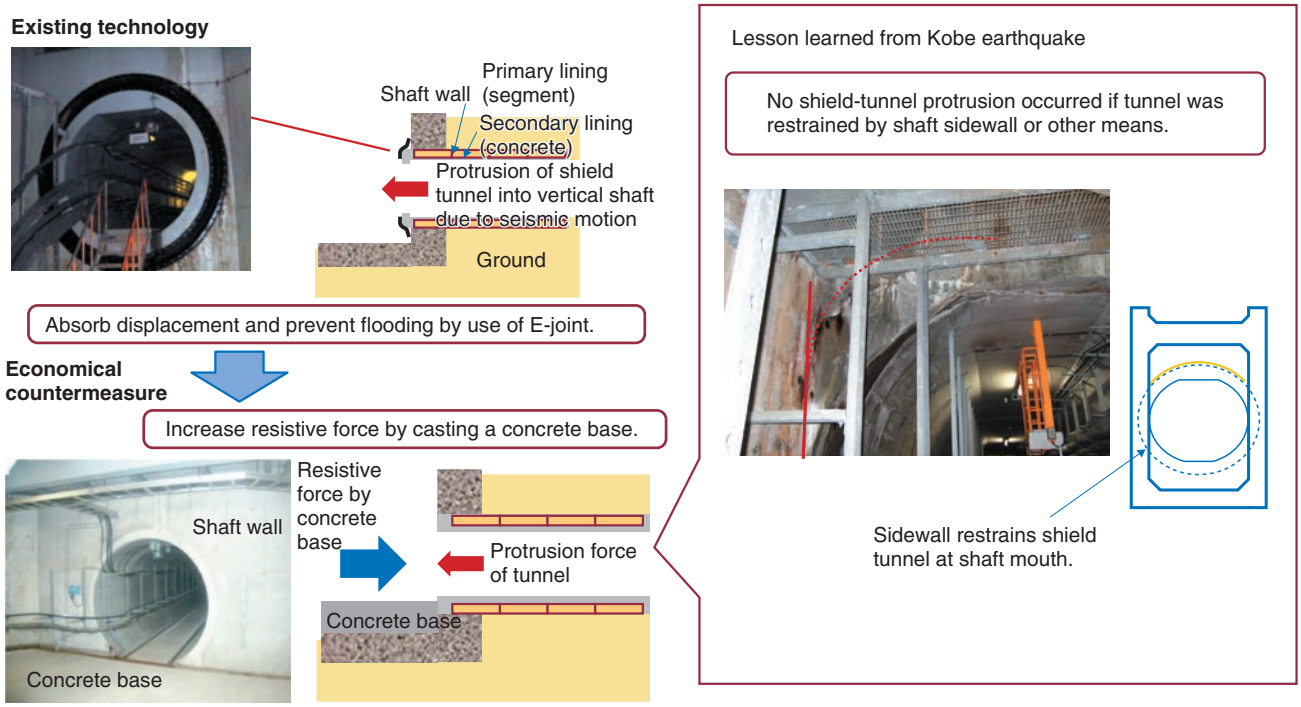

Fig. 6. Countermeasure technologies.

shield tunnel due to seismic motion and to prevent water from penetrating the tunnel. However, the presence of obstacles in addition to the expense of construction work can make it difficult to install a rubber joint and consequently to apply this method. Surveys on actual damage in shield tunnels caused by the Great Hanshin-Awaji (Kobe) Earthquake revealed that no tunnel protrusion occurred if the tunnel was restrained by the sidewall of the vertical shaft. We used the results of these surveys to devise a method for preventing the protrusion of a shield tunnel by casting a concrete base to increase the resistive force [3]. This significantly reduces the cost of construction when implementing countermeasures and can be applied even if obstacles are present in the area (**Fig. 6**).

4. Future plans

We plan to prepare operation manuals and conduct briefings in order to promote the implementation of this technology in actual operations.

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Highly Reliable 8K Video Transmission Technologies and Experiments over Global IP Networks

Masanori Ogawara, Naohiro Kimura, and Tatsuya Fujii

Abstract

NTT Network Innovation Laboratories has developed transmission equipment that uses high-efficiency forward error correction and multipath transmission technology to achieve highly reliable Internet Protocol (IP) transmission. We conducted joint experiments with NHK Science & Technology Research Laboratories on Super Hi-Vision (8K) transmission between the UK and Japan using the international research and education IP networks. The experimental results confirmed the feasibility of video transmission under the large burst losses in shared IP networks.

1. Video delivery service

Video delivery services such as those enabling public viewing have become popular recently. They are often used to temporarily show theatrical performances, concerts, and sports events in theaters. Video content in such services is often played using storage media such as digital video disks (DVDs). However, a realtime delivery service has attracted much attention in the business world and is becoming the primary service because it offers simultaneous experiences and interactivity.

To operate a service that is commercially successful, it is necessary to achieve stable and secure transmission. In addition, high-speed transmission is required for high-definition video transmission to increase its popularity.

NTT Network Innovation Laboratories has been studying a 4K video, low-latency transmission system. We have developed Internet protocol (IP) packet compensation technology using forward error correction (FEC) that achieves highly reliable IP transmission.

In addition, in the R&D Forum held in February 2011, we demonstrated live IP transmission of 8K video (Super Hi-vision) [1] between Japan and the UK. In this demonstration, we compensated for 500 burst packet losses and confirmed the reliable IP transmission using our developed transmission equipment without depending on codecs. In September 2011, we also demonstrated 8K video IP transmission between the Netherlands and the UK at IBC 2011 (International Broadcast Conference 2011) [2] using an improved FEC function (see **Fig. 1**).

Fig. 1. Display of 8K video IP transmission at IBC 2011.

2. Highly reliable IP transmission technology

In video delivery, packet losses and jitter that occur in transmission significantly affect the video quality; consequently, functions to suppress them are necessary for the video IP transmission service. We have been studying output packet control to handle several IP streams and have also investigated ways of achieving secure IP transmission. For transmission with greater reliability, we developed highly efficient error correction technology and multipath transmission technology. These technologies are achieved with software that runs on a small personal computer.

2.1 Highly efficient error correction technology

The most effective way to achieve reliable IP transmission is to compensate for packet loss. We have adopted the low-density generator matrix (LDGM) code FEC, which is able to encode large data. The LDGM FEC can theoretically encode and decode at high speed. It is therefore suitable for the large-size of 8K video transmissions.

In previous international IP transmissions of 8K video, as many as 15,000 burst packet losses occurred. We assume these were caused by changing the transmission line. It is important to reduce such packet losses. However, providing a carrier-grade dedicated line is not possible for public viewing of a temporary event, so it is difficult to secure adequate communication quality in global IP networks.

In general, an error correcting code can achieve better error reduction performance if the block length is chosen to be large, but this causes a delay. On the basis of the experimental results, we designed the block length and redundancy to compensate for a burst loss of approximately 15,000 packets. Our well-designed parity matrix enables the compensation performance for burst packet loss to be comparable to that for random packet loss.

2.2 Multipath transmission technology

We implemented a multipath transmission function to enhance the reliability. Multipath transmission is a method to distribute the IP traffic as multiple transmission paths on a network, as shown in **Fig. 2**.

For example, when the IP traffic is distributed on two paths having equal quality, the total number of lost packets occurring in multipath transmission may in principle be twice the number that occurs in normal transmission. The transmission rate is half, though, so the number of lost packets caused by the change in the transmission line is reduced to half. In addition, multipath transmission can reduce the network load by lowering the transmission rate. Therefore, it improves transmission reliability by dispersing the risk of packet losses during transmission.

In multipath transmission, when the quality of a network declines, the IP stream can gradually be shifted to a network with better quality to improve the transmission rate. For example, we can select a bandwidth-guaranteed service called the Dynamic Circuit Network (DCN) [3], which served Internet2 and

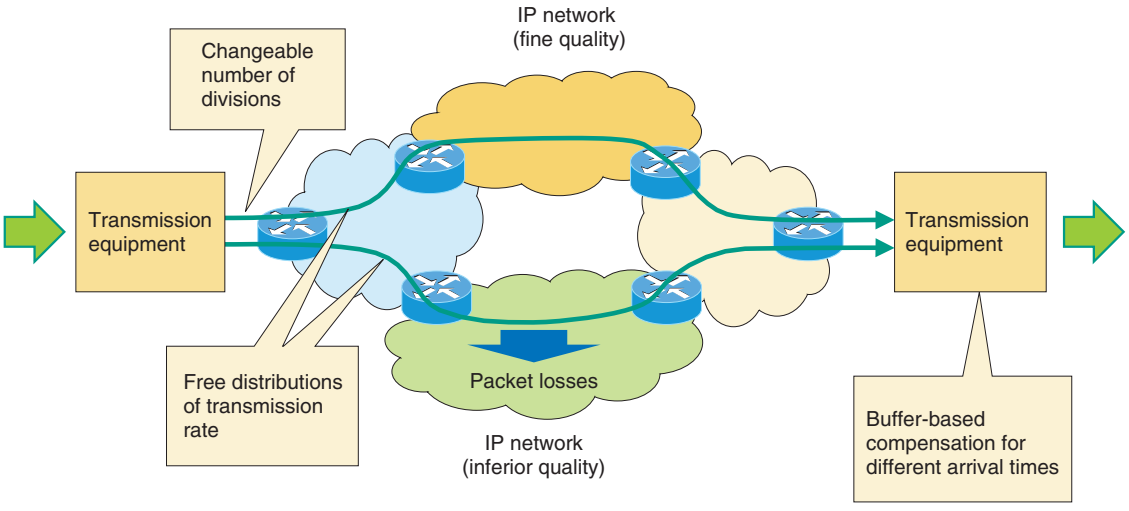

Fig. 2. Multipath transmission.

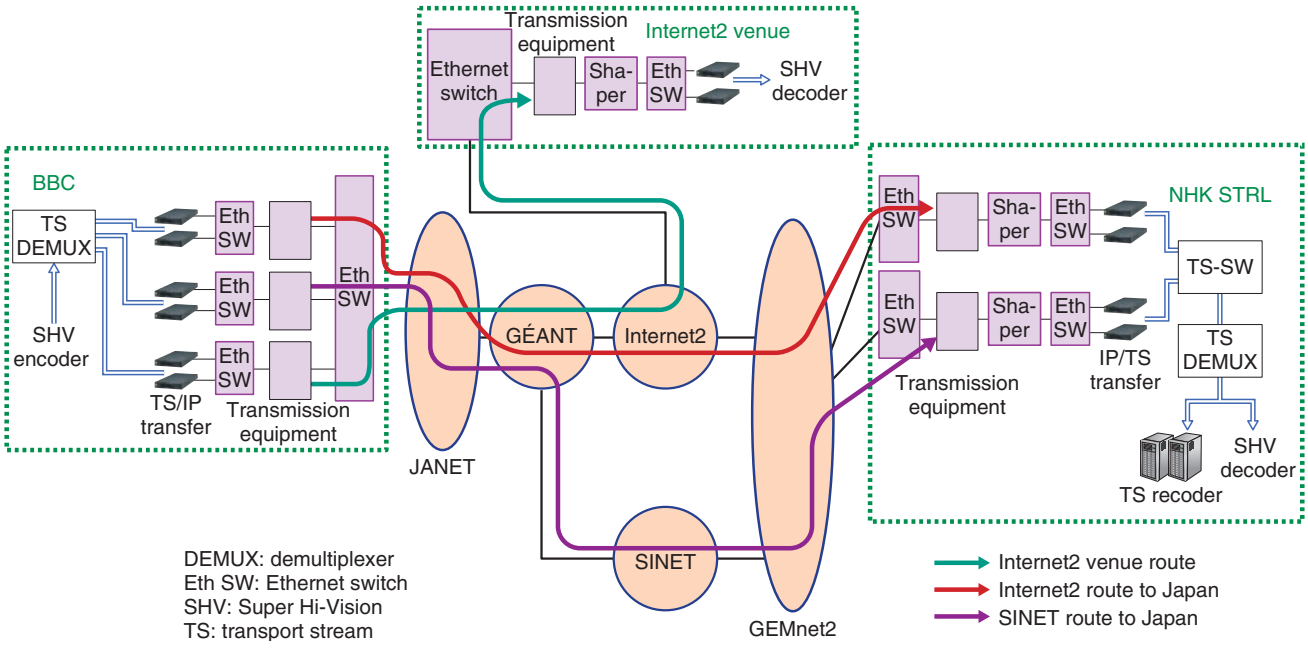

Fig. 3. Transmission system and network used in experiment.

GÉANT, as a candidate for the better quality network.

It is difficult to prepare multiple transmission paths in normal IP transmission, but we can achieve multipath transmission when using multiple access lines simultaneously or using research and education IP networks. The multipath transmission can change the transmission rate freely to each path.

When the transmission bandwidth is inadequate, multipath transmission can secure the required bandwidth by using multiple paths and gathering the IP streams at the reception side. The arrival times of IP streams are different when multipath transmission is used. Therefore, we designed a transmission system that permits 100-ms time differences. We also designed a function to duplicate IP streams. Therefore, if we cannot transmit by IP multicast, this function makes it possible to transmit the same IP stream to multiple places.

3. Experiment

NTT Network Innovation Laboratories conducted an IP transmission experiment of 8K video between the UK and USA and also between the UK and Japan at the Internet2 Member Meeting 2012 (Internet2 meeting), in April 2012. The network and the transmission system in the experiment are shown in **Fig. 3**. The BBC in London was the transmitting side, and the Internet2 meeting venue in the USA and NHK Science & Technology Research Laboratories (NHK STRL) in Japan were the receiving sides. In the Internet2 meeting demonstration, we applied the FEC technologies and multipath transmission technologies to the 8K video IP transmission.

In the experiments, we utilized international research and education IP networks (JANET, GÉANT2, INTERNET2, SINET, and GEMnet2). The 8K video was transmitted in two IP streams via Internet2 and SINET. Between BBC and NHK STRL, the delay was about 264 ms, and 20 routers were used.

The IP stream rate of 8K video was originally 300 Mbit/s. We added 20% redundancy with FEC at the transmission equipment, so the total IP stream rate was 360 Mbit/s. The block length was set to 150,000. The total delay was approximately 14 s, which was based on FEC using such a large block length.

The state of packet loss occurrence via Internet2 is plotted in **Fig. 4**. In the measurements at approximately 12 hours, packet loss did not occur most of the time. However, a burst loss of 17,246 packets occurred once, and packet losses of fewer than 1000 packets occurred about 20 times. In the experiments, the transmission system was able to compensate for all the packet losses including the burst loss of 17,246 packets.

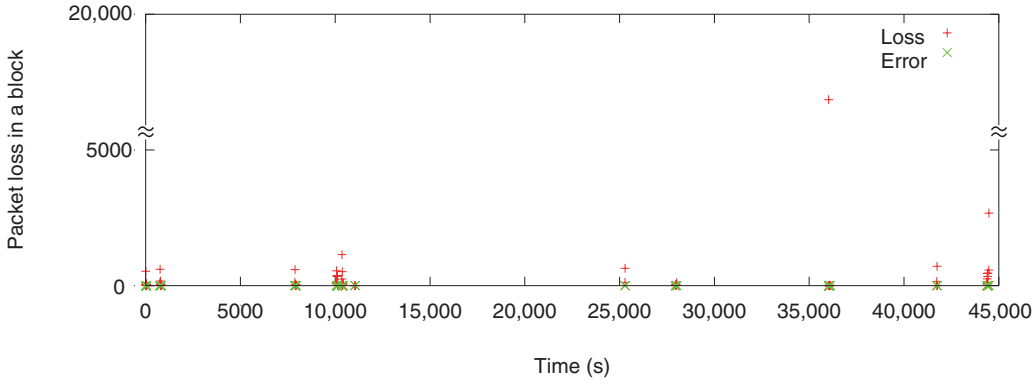

Fig. 4. State of packet loss occurrence via Internet2.

In the multipath transmission, we examined the use of two paths via Internet2 and SINET. The FEC setting was the same as in the normal transmission. The difference in network delay between two paths was only 7 ms, but in 6-day experiments, we observed a 414-ms delay via Internet2 and a 370-ms delay via SINET. Through the experiments, we confirmed that the multipath transmission was equivalent to normal transmission. We also verified the expected transmission results when the ratio of transmission via Internet2 and SINET was set to 80:20 and 20:80.

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GEMnet2 R&D Testbed Network

Michio Shimomura, Akeo Masuda, Hisao Uose, Noriaki Inoue, and Naho Nakayama

Abstract

GEMnet2 is a testbed network for research and development that is operated by the NTT Service Evolution Laboratories. The network is connected to other research and education networks in Japan and other countries and is used in large-scale joint experiments being conducted with various research organizations. Here, we describe the configuration of the GEMnet2 network, explain the services provided and how they are being used, and introduce some of the main support experiments that are being conducted, including Super Hi-Vision video transmission experiments and high-quality virtual network construction technology verification experiments.

1. Introduction

GEMnet2 (Global Enhanced Multifunctional Network 2) is operated to provide a testing environment for NTT's research and development (R&D) of network technology. It is connected to research and education (R&E) networks and other research organizations in Japan and other countries to form networks that enable the testing of ultrahigh-speed applications and other such experiments. The network has been used for over 40 experiments in the past few years (including joint research projects with other research institutes) that cover a wide range of research on technology ranging from optical transmission to networks, middleware, and applications. An overview of GEMnet2 was presented in the February 2009 issue of the NTT Technical Review [1]. Here, we focus on the services provided and the experiments that are being conducted.

2. GEMnet2

2.1 Structure

The GEMnet2 network configuration is illustrated in **Fig. 1**. The Musashino, Yokosuka, and Atsugi R&D centers are connected by optical fibers via the NTT Communications Otemachi Building and the Yokohama Yamashita Building. Each office is equipped with a dense wavelength division multiplexing (DWDM) system reconfigurable optical add-drop multiplexer (ROADM) and WDM Caster II, which constitute a trunk network that has a capacity of several tens of gigabits per second. A redundant physical layer configuration is set up using two pairs of dark fibers between Musashino and Otemachi. Connections other than between Musashino and Otemachi use a single pair of dark fibers, but in those cases, the ROADM and WDM Caster II use different wavelengths to form a redundant configuration.

GEMnet2 is also optically connected to the National Institute of Informatics (NII), the National Institute of Information and Communications Technology (NICT), and the NHK Science & Technology Research Laboratories (STRL) for high-capacity connections. Those links are used for interconnection with SINET4 (Science Information NETwork 4), which is operated by NII, and JGN-X (Japan Gigabit Network eXtreme), which is operated by NICT, to facilitate high-speed network experiments conducted with the universities and research organizations that belong to those networks.

There is also a GEMnet2 facility in Seattle in the USA. The line between Japan and the USA uses the NTT Communications V-Link service. Additionally, there is an interconnection with the U.S. Internet2 research and education network via the Pacific Northwest Gigapop (PNWGP) operated by the University of Washington in Seattle. Many joint experiments are also being conducted via the European GÉANT and British JANET research and education networks.

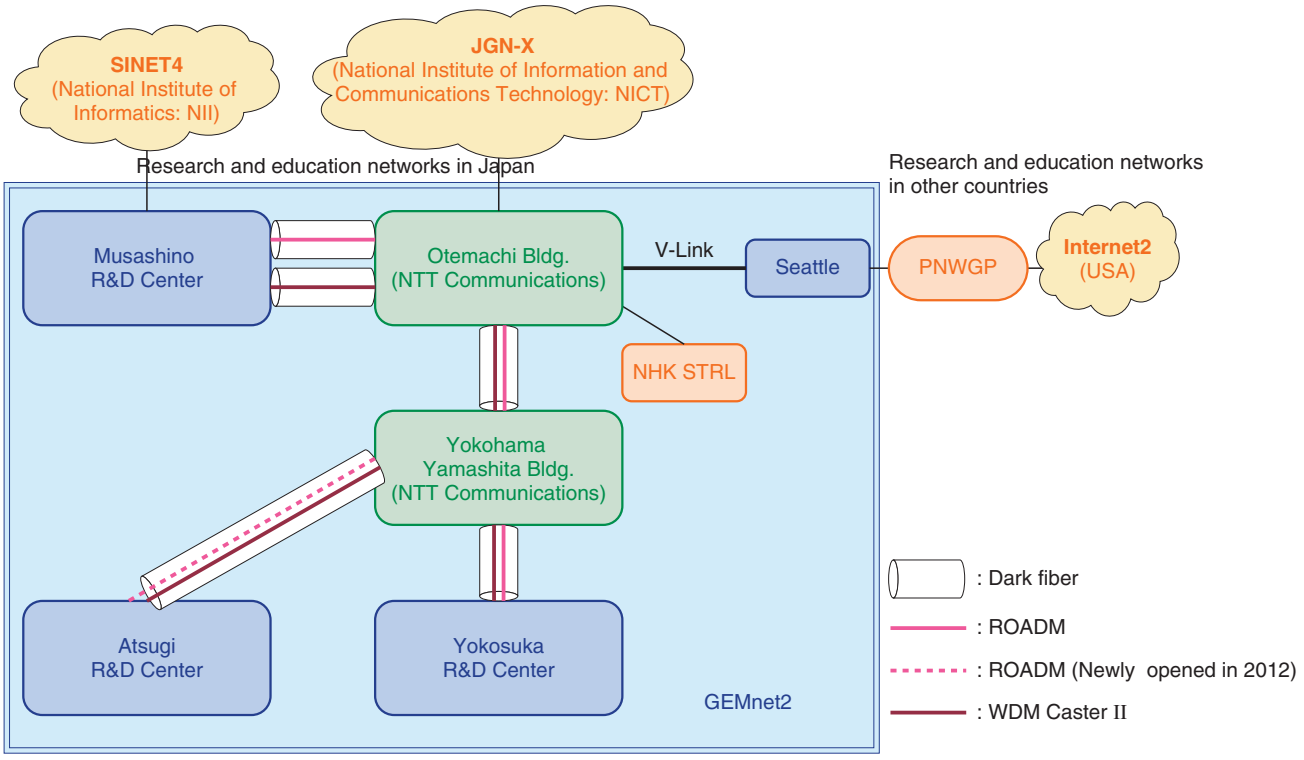

Fig. 1. GEMnet2 network configuration.

2.2 Services

GEMnet2 provides L1, L2, and L3 services, which are used according to the nature of the experiments. The L1 service guarantees a dedicated wavelength path for each user experiment. The L2 service, which has the most users, provides a virtual local area network (VLAN) between locations. The L3 service provides IPv4 and IPv6 (Internet protocol versions 4 and 6) routing services to offer a communication environment with the global R&E networks.

In addition to providing communication lines, we also actively support user experiments. The network emulation service provides a diverse network environment by using a network emulator to add delay, packet loss, and jitter to emulate various kinds of actual circuits having different characteristics. Measuring instruments and support for their operation are also provided.

2.3 Usage

Operation of the GEMnet experimental network began in 1998 and was integrated with the network on which NTT was conducting ultrahigh-speed information and communication network experiments at that time. In 2003, the current GEMnet2 began operation. The trend in the number of experiments conducted using GEMnet2 is shown in **Fig. 2**. Over 40 experiments have been conducted in the last few years. The proportion of joint research and experiments conducted with outside organizations has also increased.

3. Current experiments

GEMnet2 resources are frequently provided to researchers at domestic and international events such as the NTT R&D Forum, Interop exhibitions, and Super Computing (SC) to improve the presence of NTT and raise awareness of NTT's research achievements. In the next section, we introduce four recent experiments that have been conducted with GEMnet2 support.

3.1 Super Hi-Vision video transmission experiments

The objective of the Super Hi-Vision (SHV) video transmission experiments is to enable public viewing of sports and other popular events. NHK STRL and the NTT Network Innovation Laboratories, NTT

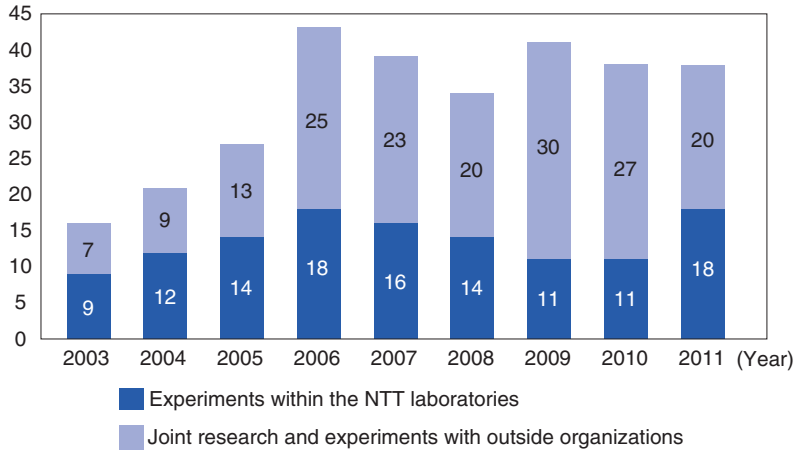

Fig. 2. Trend in number of experiments.

Service Evolution Laboratories, and NTT Network Service Systems Laboratories are conducting international SHV video transmission verification experiments using the R&E networks of Japan, the USA, and Europe.

For those experiments, GEMnet2 network connections were provided between Japan and the USA and to NHK STRL. Also, to provide end-to-end connections using the R&E networks of Japan, the USA, and Europe, we have coordinated connections with network organizations in other countries (including Pacific Wave, Internet2, DANTE, and JANET). We are also conducting detailed network monitoring to evaluate network quality and facilitate trouble shooting.

We provided support for exhibits at the IBC (International Broadcast Conference) 2011 event. We also supported multipoint transmission experiments in Japan and other countries (**Fig. 3**) for public viewing of a large-scale sports event in 2012 and provided support for SHV video transmission experiments from the BBC (British Broadcasting Corporation) to three venues in Japan (Shibuya, Akihabara, and Osaka) and to NBC (National Broadcasting Company) in the USA.

We coordinated the SHV demonstration exhibits at the Internet2 Member Meeting in April 2012 and made network-related arrangements among relevant R&E networks as well as provided on-site support. At the Internet2 meeting, we exhibited a diverse range of technology related to the SHV transmission experiments, including technology from NTT laboratories. In parallel with the Internet2 Meeting, we also conducted comprehensive tests that assumed actual public viewing (simultaneous multipoint transmission) and failure procedure testing.

3.2 R&D cloud experiments

The R&D cloud is a service provided by the NTT Software Innovation Center to enable shared development and verification environments. Its objectives are to establish technology for flexible facility configuration and business continuity planning (BCP) technology in order to promote the sharing of facilities and ultimately the realization of a social cloud infrastructure. In addition to providing one L1 line and one L2 line (IEEE 802.1QinQ: extended tagged VLAN) between the Musashino and Atsugi R&D centers, GEMnet2 serves as an access line to the R&D cloud.

The number of users connected to the R&D cloud has increased since 2011, which has raised the importance of the GEMnet2 as an R&D infrastructure within NTT laboratories.

3.3 International high-precision, high-resolution network measurement experiments

Experiments to measure international high-precision and high-resolution networks are part of the R&D efforts underway at the NTT Network Innovation Laboratories on high-precision measurement and control technology for high-speed streaming traffic. These experiments use the PRESTA 10G network interface card, which is equipped with very precise quality measurement functions. These experiments target broadband transmission applications on high-speed broadband IP networks and show the effectiveness of NTT technology through demonstrations both

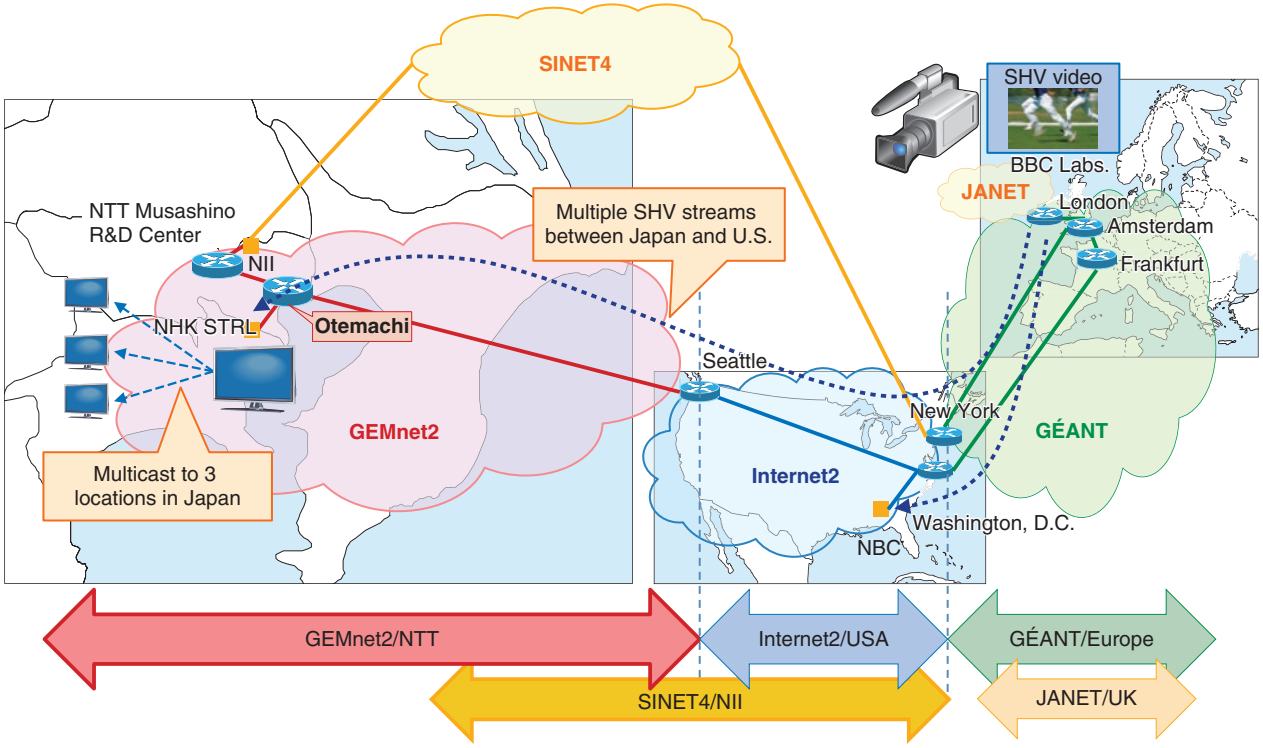

Fig. 3. Experiments on SHV video transmission.

within and outside the company. They also empirically verify the high-precision network measurement results. The measurement instruments are installed in various sites including the GEMnet2 Seattle facility, NHK STRL, the Internet2 New York facility, and the BBC Television Centre in the UK. The highly precise packet jitter measurements can also be used for the SHV video transmission experiments.

3.4 Experiments on global-scale virtual networks

The verification experiments for global-scale virtual networks are conducted in collaboration with the NTT Network Service Systems Laboratories, NTT Network Innovation Laboratories, and NICT. GEMnet2 provided support for demonstration exhibitions of the verification experiments at SC11, the world's largest conference and exhibition on high-performance computing and network technology.

Negotiations between the operators of GEMnet2 and operators of R&E networks in other parts of the world (Pacific Wave, DANTE, JANET, etc.) were carried out in order to provide an L2 path to the SC11 venue. Verification experiments and demonstrations were conducted on technology for achieving the dynamic creation and switchover of high-quality global-scale virtual networks on which communication quality can be controlled [2], [3]. In the past several years, NTT Network Service Systems Laboratories has been working on IP-optical networking technologies such as the operation of multiple virtual network topologies upon a shared physical infrastructure, and their dynamic optimization in response to fluctuations in traffic demand. Recently, notable functionality that provides an interface to enable users to request dedicated circuits on-demand has been under development for national R&E testbeds throughout the world. We have recently enhanced our network virtualization technology by making it possible to quickly form a global-scale network by connecting the circuits that are provisioned in multiple domains through the on-demand circuit request interface. Since the set of circuits is organized as a single managed network with multiple path alternatives, the global-scale network can provide sufficient quality and reliability to applications through control mechanisms such as optimal path selection by taking into account the QoS requirements, path-level redundancy, and dynamic switchover based on a prediction of performance degradation.

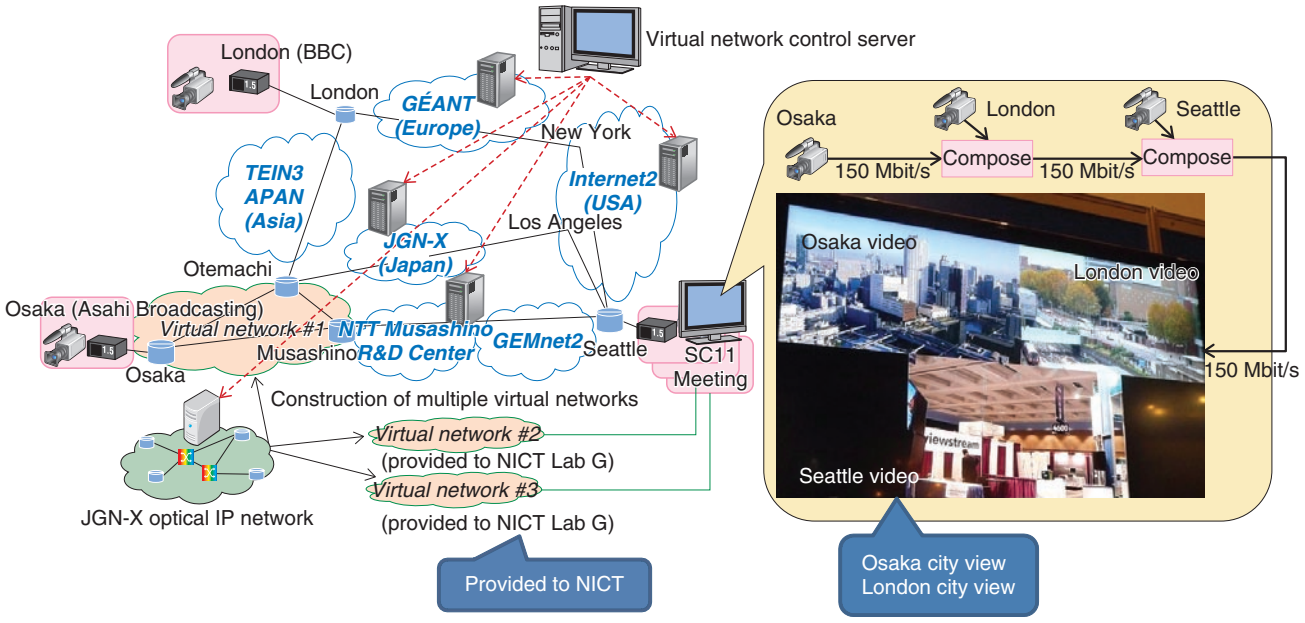

Fig. 4. Experiments on global-scale virtual networks.

To evaluate the feasibility of our networking technologies, we conducted an experiment to actually compose a global-scale virtual network that connects Osaka, London, and Seattle (**Fig. 4**). The virtual network in the experiment was formed by circuits provided by testbeds in Japan, Europe, and the USA. We examined the path selection for high-definition television (HDTV) transmission through actual performance measurements. The demonstration at SC11 produced excellent results in the sense that the audience was able to view high-resolution video of Osaka and London city views transmitted over a network that was actually provisioned throughout the world. Moreover, we succeeded in verifying the usefulness of flexible path selection with which we were able to use the trans-Pacific route when we faced problems with the trans-Atlantic route.

4. Future development

To further expand the user base of GEMnet2, we intend to improve service stability and provide a highly reliable network to support user experimentation. We will continue to strengthen facilities and change the configuration in response to user needs and to appropriately renovate aging facilities and promote network use.

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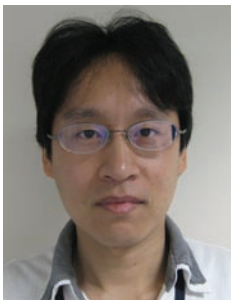

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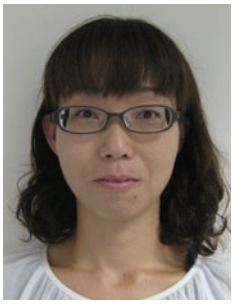

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Koemiru: ICT Tool for Special Needs Schools

Yuichi Muto, Kenta Tetsuzaki, Takako Sato, Masayuki Sugizaki, and Yumiko Matsuura

Abstract

This article introduces Koemiru, our ICT (information and communications technology) system developed for special needs schools. Koemiru, which literally means "see the voice" in Japanese, uses speech recognition technology to support hearing-impaired elementary school pupils. Our system converts utterances into text and displays them on an interactive whiteboard and portable game terminals. Validation experiments were conducted in Okinawa and Tottori to identify the strengths and weaknesses of Koemiru.

1. Introduction

1.1 Challenges in using ICT in the education field

The NTT Group is implementing the Education Square × ICT project with the aim of leveraging information and communications technology (ICT) to develop new learning methods. Through this project, we found that there was a compelling need to use ICT to support the teachers and pupils of special needs schools, but that existing solutions were unable to meet their requirements.

1.2 Our solution for special needs schools

We surveyed special needs schools and consulted with NTT CLARUTY Corporation and found there was a desire for ICT to be applied to meet the fundamental needs of their pupils. These needs include a *visible voice* for hearing-impaired pupils, a *hearing character* for sight-impaired pupils, and *easier conversation* for developmentally disabled pupils. Our market research activities clarified the importance of using ICT technologies for conversation support and for providing information for people with disabilities by alternative methods. We also noticed that pupils wanted to use devices that were already popular at home and in their daily life at school as well. NTT has been researching free conversation speech recognition technology [1]–[3] and has already developed a speech auto-answer system that is used over the telephone. In addition, because schools for the deaf are much quieter than conventional schools, their environment is appropriate for the use of speech recognition technology. Accordingly, we decided to create a conversation support system for hearing-impaired pupils by applying speech recognition technology (**Fig. 1**). We focused on the three key goals of visualization of the teacher's voice, utterance training, and conversation support in everyday life.

2. Koemiru

2.1 Overview

We developed Koemiru (see the voice) to support hearing-impaired pupils in special needs schools [4]. The system consists of various servers and terminals. A speech recognition server and administration server are cloud services (**Fig. 2**). The teachers use a personal computer (PC) or smartphone as a terminal, the pupils use Nintendo DS portable game players as terminals, and the classroom has an interactive whiteboard. We chose the game terminal for three reasons. First of all, it is highly popular with pupils, and they can use it easily. Second, it is a familiar device in the community and does not look out of place when the pupils use it outside school. Third, it is very durable and easy to reboot.

2.2 Main functions

Koemiru has three functions: classroom mode,

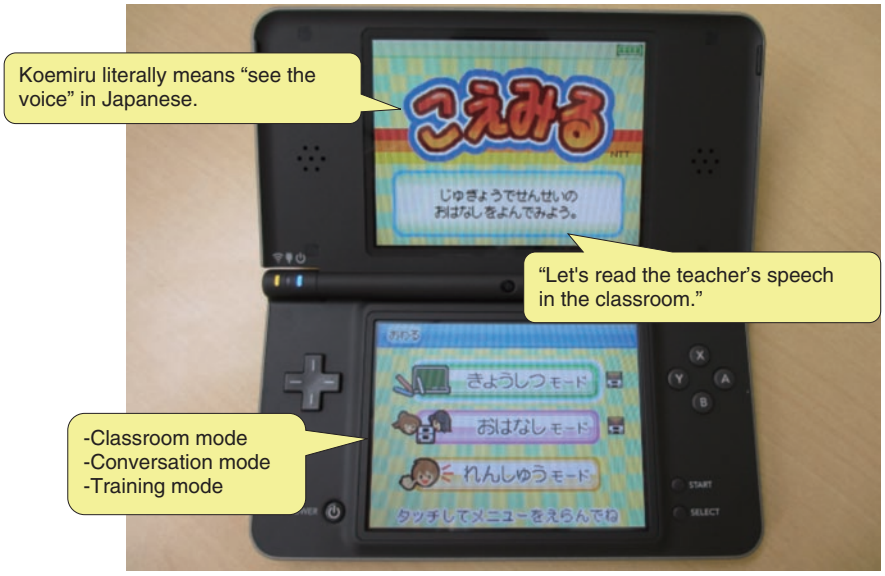

Fig.1. Welcome screen of Koemiru on a game terminal.

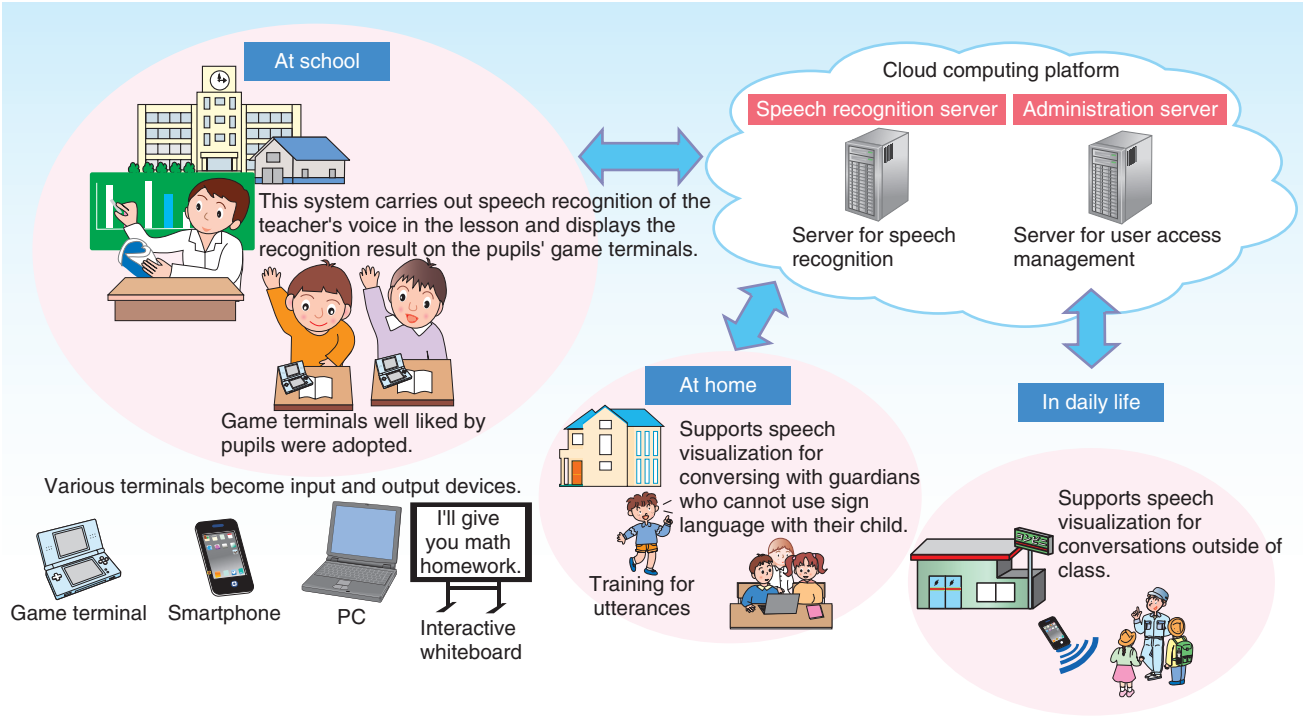

Fig. 2. Overview of Koemiru.

training mode, and conversation mode.

Classroom mode is used in school lessons. When the teacher speaks into the wireless microphone, his or her voice is sent to the speech recognition server on the cloud computing platform and is recognized and output as text. The text output is displayed on the

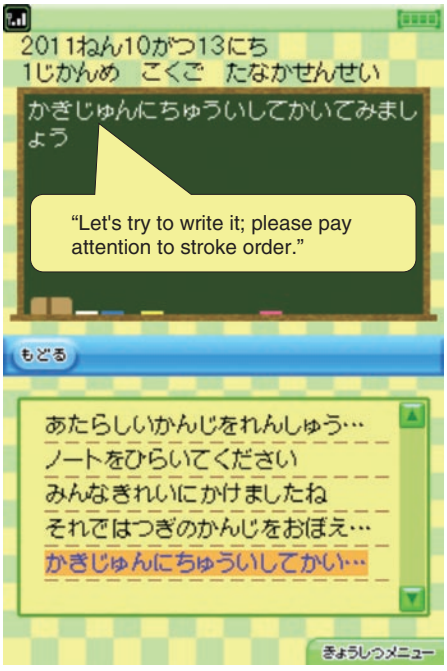

Fig. 3. Example of classroom mode on a game terminal.

interactive whiteboard and on the portable game terminals of authorized pupils. Japanese uses both kanji and kana (hiragana and katakana). Because the pupils can read only kana, teachers can choose either kana alone or both kanji and kana when outputting the recognition results (**Fig. 3**). This selection is managed by the administration server; the recognition results are displayed only to authorized teachers and pupils. Additionally, the teacher can correct any mistakes in the recognition results via this server.

When hearing-impaired pupils perform voice training, they access the training mode on the Nintendo DS, as shown in **Fig. 4**. If a pupil utters something, the recognition results are displayed on the DS. Voice-volume training is supported by the visualized volume bar.

When pupils are at home or outside of school, they can use the conversation mode to communicate with other people. They can pose questions on the Nintendo DS using stored questions or by entering the text themselves. When the respondents speak into the Nintendo DS to reply to the hearing-impaired pupils,

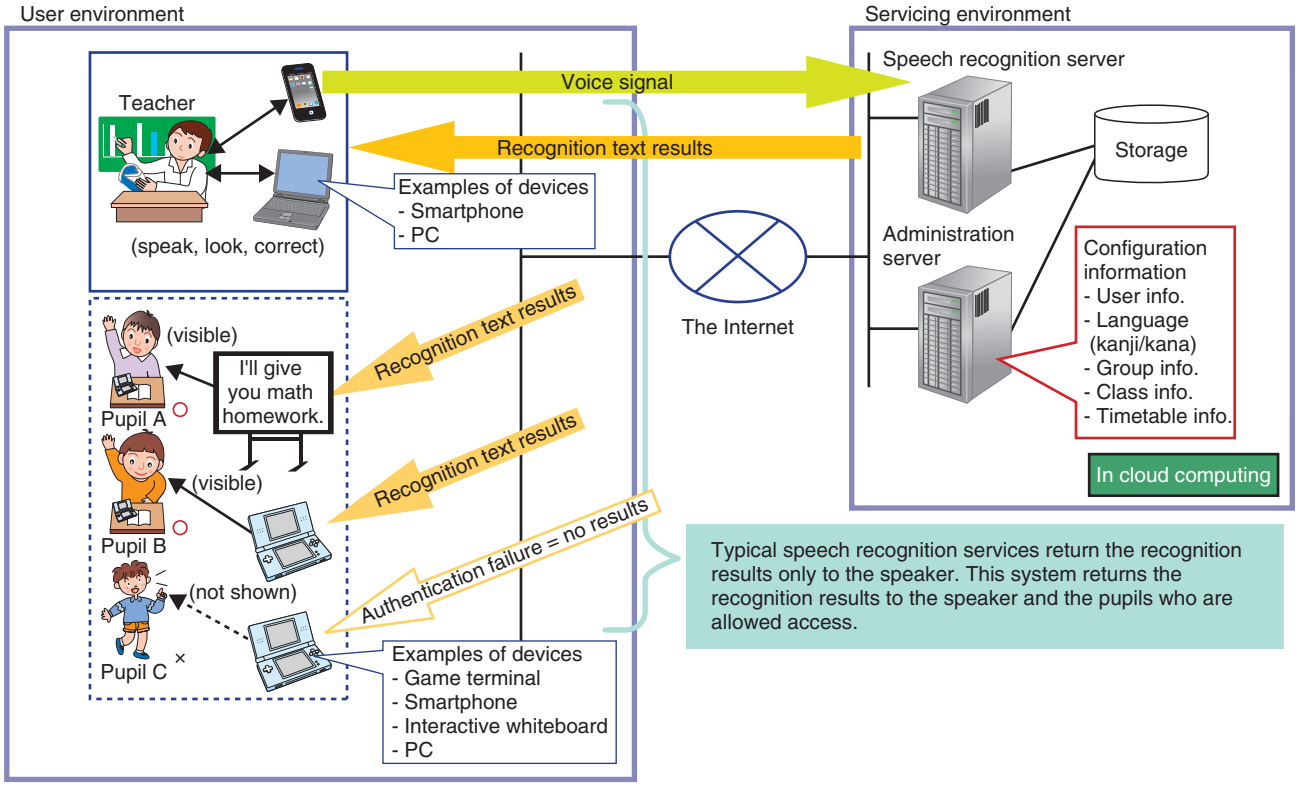

Fig. 4. System configuration.

the recognized text appears on the display of the Nintendo DS.

3. Demonstration experiment

3.1 Overview

We conducted trials to evaluate the effectiveness of Koemiru. These trials were held from the end of January to early March 2012 in a fifth-grade class at Tottori Prefectural School for the Deaf, Himawari campus, and in a first-grade class at Okinawa Prefectural School for the Deaf. We prepared broadband connections by establishing Wi-Fi links from each terminal to a Wi-Fi router in the classroom, which was linked via optical fiber to the Internet. We optimized the acoustic model of the speech recognition server by using speech samples recorded by the actual teacher in the classroom. We also added the words in the textbooks used in the classroom to the speech recognition dictionary, so the server could accurately recognize the speech of the teacher. The teachers requested that all recognition results be output in hiragana because they wanted to teach the pupils how to read kanji (**Fig. 5**). We also conducted free-form interviews with the teachers using a prepared questionnaire to determine service acceptability.

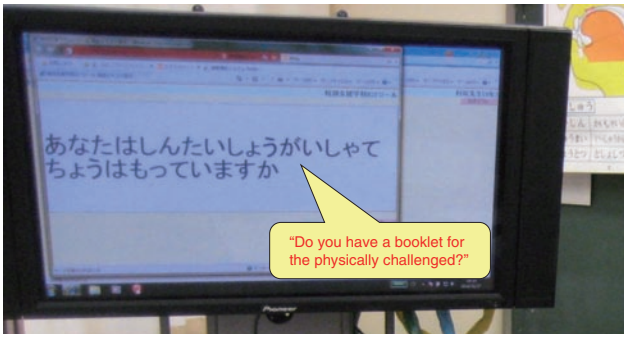

Fig. 5. Recognized speech displayed on interactive whiteboard.

3.2 Results

The results of the trials (**Fig. 6**) are summarized as follows.

(1) This system is effective in teaching new words to pupils, since physical objects can be imagined from the words.
(2) This system stores all the speech recognition results of the teacher. Thus, teachers and pupils can review what was said at the end of the class.
(3) All devices are very user-friendly for both teachers and pupils. In particular, the Nintendo DS, one of the most popular portable game terminals, was well received by the pupils because no special instruction is needed to use it. Moreover, the pupils do not need to hold it when using it; they can simply put it on their desks.
(4) This system provided a very easy-to-use way for the teacher to edit the recognized text. The teachers used this function often, even though recognition accuracy was extremely high, to improve the content of their messages.

The results also highlighted the following challenges.

Good points

- This system is effective in teaching new words to pupils: objects imagined from the words.
- Teachers and pupils can review what was spoken at the end of the class.
- All devices for teachers and pupils are very user-friendly.
- The teachers liked the correction function and wanted to use it even when recognition accuracy was high.

Challenges

- Response time should be shorter for short speech.
- Teachers would like to be able to modify the recognition result and voice input operation on the interactive whiteboard rather than going to a PC.
- Teachers should be able to add unrecognized words to the dictionary.
- It is impractical for teachers to use smartphones. They must have their hands free to use sign language for pupils, so they cannot hold a smartphone at the same time.

Fig. 6. Experimental results.

- The response time should be reduced to improve the service acceptability, particularly with short sentences. The teachers found that with short sentences, the current version did not start to return the text until the teacher had finished speaking the sentence, and they felt the waiting time was annoying.
- Output correction required that the teacher access his or her PC. However, because the teacher is often in front of the classroom's blackboard or whiteboard, it is desirable to enable output correction at the interactive whiteboard.
- It is preferable for teachers to be able to add words to the dictionary by themselves.
- The teachers had difficulty in using the smartphone as the interface. Because they must be able to use sign language for the pupils, they cannot simultaneously hold the phones.

4. Future plans

We developed the Koemiru system based on speech recognition technology to support conversations with and among pupils with hearing disabilities. The results of trials indicated that Koemiru is effective in providing support to pupils in special needs schools. We plan to work on eliminating the aforementioned problems so that we can introduce this system into the market at the earliest possible date.

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Standardization Trends in Proximity Contactless Communication Technology

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Abstract

Services using proximity contactless communication such as NFC-enabled smartphones and contactless IC cards have been widely used in recent years (NFC: near field communication, IC: integrated circuit). We introduce the trends in proximity contactless communication technology from the viewpoint of international standardization.

1. Introduction

1.1 Short-range communication

Proximity contactless communication is defined as interactive communication technology in which the maximum communication distance is approximately 10 cm when using a magnetic field of 13.56 MHz. This technology has become prevalent in systems used for such services as access control, railway ticketing, and electronic payment.

In recent years, the use of near field communication (NFC) has expanded, particularly in applications using mobile phones. NFC is an interactive communications technology whose operating principle is based on the proximity contactless communication described above. It has three different modes, which are selected according to their use cases:

- card emulation mode (behaving like an IC card (IC: integrated circuit))
- reader/writer mode (behaving like a reader/writer)
- P2P (peer-to-peer) mode (behaving like transceivers between terminals)

1.2 Potential applications of proximity contactless communication

Proximity contactless communication has a unique feature as a human interface device. By passing a card over a reader/writer, the user is able to access the card's services. Conventionally, the use cases of proximity contactless communication have consisted of using a contactless card and a reader/writer. Recently, however, smartphones and tablet terminals have come equipped with proximity contactless technology that enables them to be used to access a wide variety of services.

New applications will follow these conventional applications (i.e., authentication and payment using contactless IC cards). For example, access to websites related to IC card data and configuration of wireless local area networks and Bluetooth are expected to become easier by passing a terminal in close proximity to an object (such as an IC card and a printer).

2. Overview of standardization organizations

An outline of standardization organizations focusing on proximity contactless communication is shown in **Fig. 1**. Specifications regarding proximity contactless communication have been standardized by many organizations. These standardization organizations cooperate with one another by referencing the standards of other organizations and proposing the standards of one organization to other organizations. Organizations that have had an inter-industrial influence on proximity contactless communication are

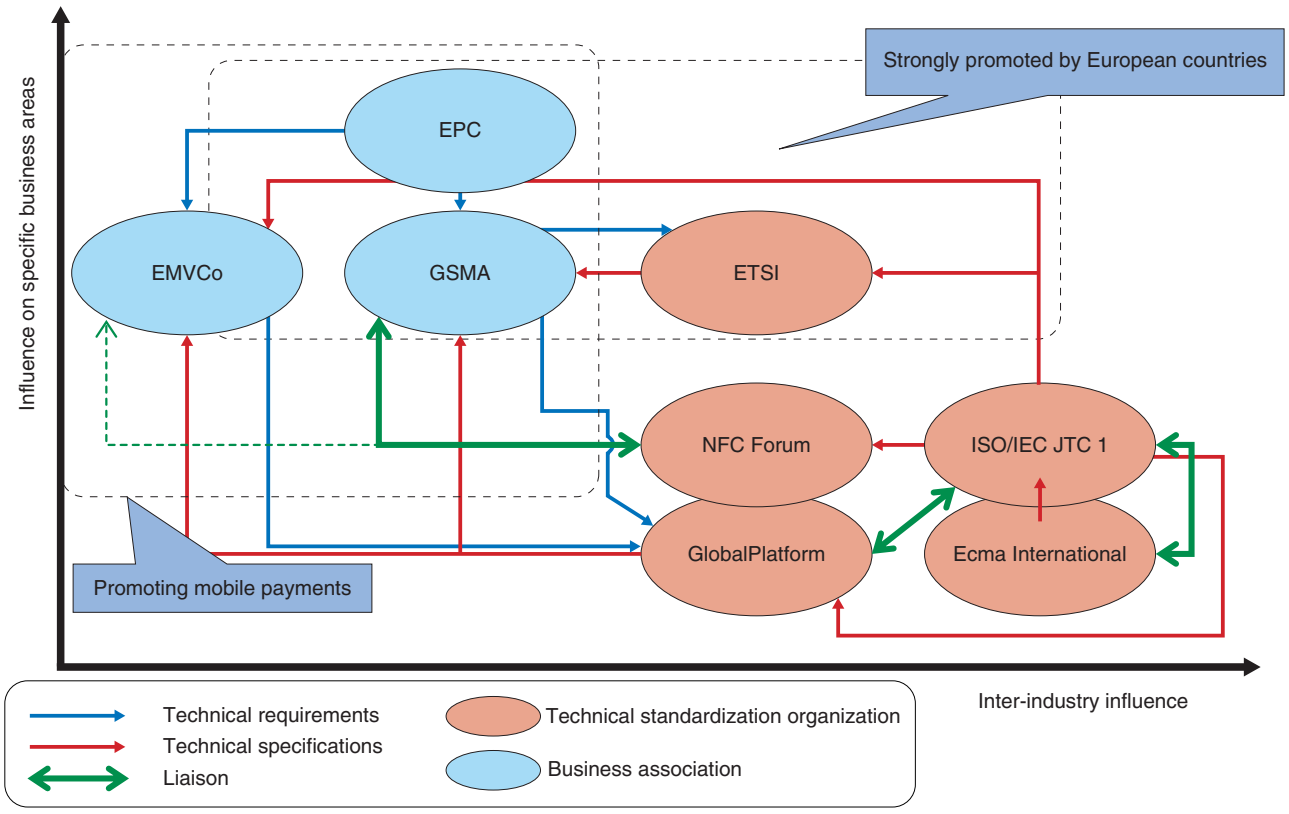

Fig. 1. Overview of standardization organizations.

ISO/IEC JTC 1 (International Organization for Standardization, International Electrotechnical Commission Joint Technical Committee 1), NFC Forum, and GlobalPlatform. Organizations that have had an inter-business influence on proximity contactless communication are GSMA, EMVCo, and EPC. These organizations liaise with other relevant organizations by proposing standards and exchanging information.

The specifications represented at a lower layer (e.g., RF (radio frequency) interface) are mainly standardized by ISO/IEC JTC1, and those at a higher layer (e.g., platforms and applications) are mainly standardized by GlobalPlatform and NFC Forum.

The group of organizations categorized as business associations (e.g., payment and mobile phone services) establish their standards by referencing existing standards from other organizations and their own specifications.

To develop a system using proximity contactless communication, it is necessary to review the standards established by each organization and to integrate the entire system consistently from the lower to upper layers. Brief descriptions of the organizations are given below. The activities of three of them that are influential to the inter-industry of proximity contactless communication are explained in section 3.

(1) ISO/IEC JTC 1

Extends across ISO and IEC and deliberates on information technology [1], [2].

(2) Ecma International

Deliberates on information and communications technology (ICT) and is a substantial developer of NFC technology [3].

(3) GlobalPlatform

Deliberates on multi-application IC card systems based on open platform technology [4], [5].

(4) NFC Forum

Focuses on NFC technology and products compliant to its specifications [6].

(5) ETSI (European Telecommunications Standards Institute)

Table 1. Standards on contactless interface communication deliberated in ISO/IEC JTC1.

(as of Dec. 2012)

	Title	Version (publication)
Proximity contactless IC card	ISO/IEC 14443-1 Physical Characteristics	2 (June 2008)
	ISO/IEC 14443-2 Radio Frequency Power and Signal Interface	2 (Sep. 2010)
	ISO/IEC 14443-3 Initialization and Anticollision	2 (Apr. 2011)
	ISO/IEC 14443-4 Transmission Protocol	2 (July 2008)
	ISO/IEC 10373-6 Test Methods –Proximity cards	2 (Mar. 2011)
NFC	ISO/IEC 18092 Interface and Protocol (NFCIP-1)	1 (Apr. 2004)
	ISO/IEC 21481 Interface and Protocol -2 (NFCIP-2)	2 (July 2012)
	ISO/IEC 22536 NFCIP-1 RF Interface Test Method	1 (July 2005)
	ISO/IEC 23917 NFCIP-1 Protocol Test Methods	1 (Nov. 2005)
	ISO/IEC 28361 Near Field Communication Wired Interface	1 (Oct. 2007)
	ISO/IEC 13157-1 NFC-SEC: NFCIP-1 Security Services and Protocol	1 (Apr. 2010)
	ISO/IEC 13157-2 NFC-SEC cryptography standard using ECDH and AES	1 (Apr. 2010)

-NFCIP-1: Standard based on the contactless interface of ISO/IEC14443 Type-A and FeliCa (technology developed by Sony)
-NFCIP-2: Standard based on the contactless interface of ISO/IEC 14443 Type-B and ISO/IEC 15693 (Vicinity contactless interface) on top of NFCIP-1
-Wired interface: Digital interface with wired connection between NFC transceiver and NFC front-end
-ECDH: Method of key distribution using elliptic curve cryptography
-AES: New generation cryptography standardized by US National Institute of Standards and Technology

Operates within the EU region focusing on the ICT field [7].

(6) GSMA (Global System for Mobile Communications Association)

Consists of carriers adopting GSM (Global System for Mobile Communications), which presently includes the 3G (third-generation) system [8].

(7) EPC (European Payments Council)

Deliberates on settlement infrastructure [9].

(8) EMVCo

Deliberates on the interoperability of financial services using IC cards and mobile phones; founded by four credit card companies [10].

3. Activities of standardization groups

3.1 ISO/IEC

The technology of contactless IC cards and NFC is categorized as information technology, so JTC1 leads the international standardization in that field [11].

Within ISO/IEC JTC1, 18 subcommittees (SCs) have been formed. Matters related to IC cards and to NFC are respectively handled by SC17 and SC6. Their international standard specifications are listed in **Table 1**.

The first editions of ISO standards for proximity contactless IC cards (ISO/IEC 14443 series) were enacted in 2001. The first edition of ISO standards for NFC (ISO/IEC 18092) was enacted in 2004 and was based on the communication methods used in both Europe and Japan. The coexistence and selection of ISO/IEC 18092 and ISO/IEC 14443 were then standardized as ISO/IEC 21481.

Table 2. Standards deliberated in NFC Forum.

(as of Dec. 2012)

	Title	Outline	Version (publication)
Application layer	NFC Data Exchange Format (NDEF)	Data format for NFC application	1.0 (July 2006)
	NFC Record Type Definition (RTD)	Record used in NDEF	1.0 (July 2006)
	Text Record Type Definition	Record used for displaying text message	1.0 (July 2006)
	URI Record Type Definition	Record used for Web-to services	1.0 (July 2006)
	Signature Record Type Definition	Record for signature	1.0 (Oct. 2009)
	Smart Poster Record Type Definition	Record for smart poster	1.0 (July 2006)
	Generic Control Record Type Definition	Record of implementing multiple functions	1.0 (Mar. 2008)
	Type 1 Tag Operation Specification	Access to NDEF data using TOPAZ	1.1 (Apr. 2011)
	Type 2 Tag Operation Specification	Access to NDEF data using MIFARE Ultralight	1.1 (May 2011)
	Type 3 Tag Operation Specification	Access to NDEF data using FeliCa	1.1 (June 2011)
	Type 4 Tag Operation Specification	Access to NDEF data using products compliant ISO/IEC 14443-4(transmission protocol) and ISO/IEC 7816-4(APDU)	2.0 (Nov. 2010)
Handover	Connection Handover	Selection on wireless interface	1.2 (July 2010)
	Bluetooth Secure Simple Pairing Using NFC	Handover NFC to Bluetooth	1.0 (Oct. 2011)
P2P	Logical Link Control Protocol (LLCP)	NFC Forum specific protocol	1.1 (June 2011)
	Simple NDEF Exchange Protocol	Transmission protocol over LLCP	1.0 (Aug. 2011)
Subset of ISO	NFC Digital Protocol	Subset of ISO/IEC 14443 series and NFC relevant standard	1.0 (Apr. 2009)
Others	NFC Activity Specification	API of NFC firmware	1.0 (Nov. 2010)
	NFC Analog Specification	Analog interface of NFC devices	1.0 (July 2012)

-TOPAZ: Product of Innovision Research & Technology, compliant with ISO/IEC 14443 Type-A
-MIFARE Ultralight: Product of NXP semiconductors, compliant with ISO/IEC 14443 Type-A
-FeliCa: Product of Sony, compliant with ISO/IEC 18092
-APDU: application data unit

ISO/IEC periodically reviews the established international standards. The conventional international standards of proximity contactless IC cards and NFC are currently undergoing revision. The relevant technologies are described below.

(1) Very high bit rate (VHBR)

It is important to implement high-speed data communication in systems that use IC cards containing large amounts of data. The bitrates specified in the ISO/IEC 14443 series are from 106 kbit/s to 848 kbit/s. Specifications for bitrates from 1.70 Mbit/s to 6.78 Mbit/s have been established as amendments for the ISO/IEC14443 series and were enacted in 2012.

(2) Proximity extended device (PXD)

At the time of enactment of the first edition of the ISO/IEC 14443 series, there was an assumption that the functions of contactless IC cards and their reader/writer were separated. Innovations in electronic device technology have enabled portable terminals to implement the functions of contactless IC cards and their reader/writer within them. The need to use both functions with a single portable device has been increasing, and the method of switching between these functions is under development as an amendment to the ISO/IEC14443 series.

3.2 NFC Forum

NFC Forum mainly specifies application layers and their implementation, which are not specified in ISO/IEC. The public specifications of NFC Forum are listed in **Table 2**. NFC Forum defines the functions of the three modes mentioned previously in combination with the three kinds of contactless interfaces (ISO/IEC14443 Type-A, Type-B, and FeliCa), which is called *mode switching*.

Since 2010, the program called N-Mark has been underway, where the devices are certified for NFC Forum compliance.

NDEF (NFC Data Exchange Format) and RTD (NFC Record Type Definition) are the key formats

Table 3. Standards on contactless interface communication deliberated in GlobalPlatform.

(as of Dec. 2012)

	Title	Outline	Version (publication)
Card	Card Specification	Command and security specification in GP compliant multi-application card	2.2.1 (Jan. 2011)
	Amendment C-Contactless Services	Service specification in GP compliant multi-application card	1.0.1(Feb. 2012)
Device	Secure Element Access Control	Method for upper device to access secure element	1.0 (May 2012)
System	System Messaging Specification for Management of Mobile-NFC Services	Message and profile in mobile-NFC services	1.0 (Feb. 2011)

Secure element: Semiconductor designated as tamper-proof that is equipped with secured memory and cryptography. It is implemented using a SIM card embedded in the device.

specified in NFC Forum. NDEF is a data format for NFC applications. RTD is the format for NDEF records specified for each type of application. These specifications enable access to websites, NFC smartphone displays, electronic signatures, and other capabilities, which makes it possible to achieve a variety of services using NFC-enabled smartphones.

3.3 GlobalPlatform

GlobalPlatform (GP) is developing and deploying standards with a focus on the management of IC card applications for various fields from an industry-neutral standpoint.

Card specifications developed by GP have been adopted for SIM (subscriber identity module) cards and are a de facto standard of application management in the field of mobile communication. Furthermore, the test specifications are defined through a conformance testing certification process that exists at GP.

In recent years, GP has been working on standardization for the management of devices with a proximity contactless interface. The GP standards related to the proximity contactless interface are listed in **Table 3**. GP standards will have a stronger influence on the services using proximity contactless cards and NFC-enabled smartphones.

NTT has greatly contributed to GP activities through its staff serving on GP's board of directors and by hosting GP conferences and seminars.

One of the most remarkable specifications recently deliberated at GP concerned multi-secure elements (SEs). This is a method for managing multiple SEs installed in mobile phones from remote servers. This enables services involving the collaboration of multiple applications in the mobile phone (e.g., e-money charging with the user's ID (identity) in the SIM and an e-money application in the embedded device in the phone).

4. Future trends and NTT's involvement

With the spread of mobile devices represented by NFC-enabled smartphones, the use cases of proximity contactless devices will be expanded. Furthermore, SIMs, which are conventionally used only for subscriber identification, are expected to be used for new services in which an application program is downloaded into the vacant memory in a SIM. Thus, it is assumed that the standardization for the upper layer will be accelerated, which will lead to greater utilization of the established contactless proximity communication technology and secure devices.

Through participation in these kinds of standardization activities, NTT is working to achieve an information infrastructure that is both open and interoperable to allow anyone the carefree, secure, and easy use of ICT services anywhere in the world.

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External Awards

ICIN2012 Best Paper Award

Winners: Haruno Kataoka, Daichi Namikawa, Hiroya Minami, Michio Shimomura, and Naoki Uchida, NTT Service Evolution Laboratories

Date: October 11, 2012

Organization: ICIN (16th International Conference on Intelligence in Next Generation Networks)

For "SightFinder: Enhanced Videophone Service Utilizing Media Processing".

The purpose of this study is to construct a framework for enhancing the network services of telecommunications operators. To achieve this framework, we propose "SightFinder," an enhanced videophone service in which media such as video images are processed on the network by multiple pattern recognition engines working in parallel. This service sends alerts to users on local information when they cannot see it (e.g., visually impaired users) and provides explanations to users who have difficulty understanding it (e.g., foreigners).

Published as: H. Kataoka, D. Namikawa, H. Minami, M. Shimomura, and N. Uchida, "SightFinder: Enhanced Videophone Service Utilizing Media Processing," Proc. of the 16th International Conference on Intelligence in Next Generation Networks (ICIN 2012), pp. 114–120, Berlin, Germany.

Best Student Paper Award

Winners: Susumu Kiyoshima[†1], Yoshifumi Manabe[†1, †2], and Tatsuaki Okamoto[†1, †3]

†1 Graduate School of Informatics, Kyoto University
†2 NTT Communication Science Laboratories
†3 NTT Secure Platform Laboratories

Date: November 8, 2012

Organization: IWSEC 2012 (7th International Workshop on Security)

For "Efficient Concurrent Oblivious Transfer in Super-Polynomial-Simulation Security."

In this paper, we show a concurrent oblivious transfer protocol in super-polynomial-simulation (SPS) security. Our protocol does not require any setup and does not assume any independence among the inputs. In addition, it is efficient since it does not use any inefficient primitives such as general zero-knowledge proofs for any NP (nondeterministic polynomial time) statements. This is the first concurrent oblivious transfer protocol that achieves both of these properties simultaneously. The security of our protocol is based on the decisional Diffie-Hellman (DDH) assumption.

Published as: S. Kiyoshima, Y. Manabe, and T. Okamoto, "Efficient Concurrent Oblivious Transfer in Super-Polynomial-Simulation Security," Proc. of the 7th International Workshop on Security (IWSEC2012), Springer, Vol. 7631, pp. 216–232, Fukuoka, Japan.